

ACOUSTIC MEASUREMENT OF EMOTION EXPRESSION OF WOMEN WITH  
CHRONIC KNEE PAIN

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## ABSTRACT

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Acoustic Measurement of Emotion Expression of Women with Chronic Knee Pain  
(Under the direction of Dr. Jo Ann Dalton)

The purpose of this study was to determine if change in acoustic parameters of sustained vowel vocalization occurred in women with and without chronic knee pain when asked to rise from sitting to standing and if changes could be associated with occurrence of an emotion. Scherer's component process model of emotion and sequential check theory of emotion differentiation provided the framework for the study. Acoustic parameters evaluated were mean fundamental frequency, highest fundamental frequency, lowest fundamental frequency, range of fundamental frequency, jitter, shimmer, amplitude perturbation quotient, and three formant frequencies. Depression, anxiety and anger were measured and entered as interactions in mixed models to determine the influence of mood-related measures on acoustic parameters with non-pain and pain samples and with two levels of pain intensity.

The sample consisted of 62 women 45 years of age or older: 32 women with knee pain of longer than 6 months' duration and 30 women with no musculoskeletal pain for comparison. Significant differences in range of fundamental frequency and jitter were observed between the non-pain and pain groups with stand tasks. Differences in shimmer, amplitude perturbation quotient and  $F_2$  were demonstrated between two pain intensity groups. Differences in range of  $F_0$  and jitter were associated with interactions of anxiety and anger.

To those whose pain remains unrecognized.

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## LIST OF ABBREVIATIONS AND SYMBOLS

<u>Abbreviation</u>	<u>Meaning</u>
$\alpha$	Level of significance
ANOVA	Analysis of Variance
ANS	Autonomic nervous system
ASES	Arthritis Self-Efficacy Scale
BBL	Biobehavioral Laboratory
BDI-II	Beck Depression Inventory-II
BPI	Brief Pain Inventory
CNP	Chronic non-malignant pain
CSL	Computerized Speech Laboratory
dB	Decibel
DFT	Discrete Fourier Transform
ə	IPA symbol for sound “ah”
e	IPA symbol for sound “ay”
eɪ	IPA symbol for sound “ay - ē”
Est. M	Estimated mean
$F^1$	Folded F statistic
$F_0$	Fundamental frequency

<u>Abbreviation</u>	<u>Meaning</u>
F <sub>1</sub>	First formant
F <sub>2</sub>	Second formant
F <sub>3</sub>	Third formant
FFT	Fast Fourier Transform
fMRI	Functional Magnetic Resonance Imaging
FSE	Self-Efficacy for Physical Function Scale
Hz	Hertz
kHz	KiloHertz
LIC	Low Intensity (Pain) Class
MDVP	Multi-Dimension Voice Program
M est.	Estimated Mean
MC est.	Monte Carlo estimate
MIC	Moderate Intensity (Pain) Class
NRS	Numerical Rating Scale
OA	Osteoarthritis
Ω	Ohm
PET	Positron Emission Tomography
RMANOVA	Repeated Measures Analysis of Variance
SE	Standard Error
SEC	Sequential Evaluation Checks
SOPA	Survey of Pain Attitudes

<u>Abbreviation</u>	<u>Meaning</u>
SpO2	Saturation of oxyhemoglobin
SPL	Sound Pressure Level
STAI	Spielberger State-Trait Anxiety Inventory
STAXI	Spielberger State-Trait Anger Expression Inventory
UNC	University of North Carolina at Chapel Hill
VAS	Visual Analogue Scale
VAS-PI	Visual Analogue Scale of Pain Intensity
VAS-UNP	Visual Analogue Scale of Pain Unpleasantness
VRP	Verbal Rating of Pain

## CHAPTER ONE

### INTRODUCTION

Nearly one-third of the general population reports chronic pain symptoms (M. Clark, 2005). About half of patients when asked if pain management was adequate reported it was not (Joint Commission on Accreditation of Healthcare Organizations, 2003). In addition, chronic non-malignant pain is associated with limitation of activities of daily living, anxiety, and depression (O'Reilly & Doherty, 2003). Limitation of activity increases with age with 13.1% reporting limitations between 45-54 years of age, 20.7% between 55 and 64 years of age, and 34.4% at 65 years of age and older (Centers for Disease Control and Prevention & National Center for Chronic Disease Prevention and Health Promotion(U.S.), 2004; Centers for Disease Control and Prevention & National Center for Health Statistics (U.S.), 2005).

Of 46 million Americans with self-reported and diagnosed arthritis, 19 million indicate they have activity limitation due to arthritis (Hootman, Bolen, Helmick, & Langmaid, 2006). Arthritis pain contributes to this functional disability (Creamer, Lethbridge-Cejku, & Hochberg, 2000; Snizek, 2004) as well as anxiety and depression. The need to prevent disability secondary to chronic pain and loss of function requires prompt recognition and action to prevent disability in this growing segment of the population (Elders, 2000). Because statistics indicate that osteoarthritis is self-managed for long periods before health care is sought, prompt detection of changes in pain and the emotional reaction

to it could reduce functional disability and, ultimately, promote better pain management (Creamer et al., 1999; Lin et al., 2003).

While pain is recognized as having a psychological component in addition to the protective physiological reflex (Melzack & Wall, 1965; Price, Riley, & Wade, 2001; Sherrington, 1906), acceptance of a biopsychosocial model of medicine (Engel, 1977) and of pain (Blackwell, Galbraith, & Dahl, 1984) is fairly recent. In 1994, the International Association for the Study of Pain defined pain as “...an unpleasant sensory and emotional experience associated with actual and potential tissue damage, or described in terms of such damage” (Merskey, Bogduk, & International Association for the Study of Pain. Task Force on Taxonomy, 1994) reflecting the inclusion of emotional influence on pain. Emphasizing reaction to pain, Price (1999) proposed that pain is “a somatic perception containing (1) a bodily sensation with qualities like those reported during tissue-damaging stimulation, (2) an experienced threat associated with this sensation, and (3) a feeling of unpleasantness or other negative emotion based on this experienced threat (pp. 1-2). Although recent research suggests that pain be considered a “homeostatic emotion” (A. D. Craig, 2003a, 2003b), most research has focused on the sensory component of pain (Price, 2000).

Although a patient’s self-report of pain is described as the most reliable indicator of pain (Keefe, 2000; McCaffery, 1972), self-report has been labeled “contaminated” (Pennebaker, 2000) by some clinicians and researchers who consider self-report of pain to be influenced by physiological, cognitive, emotional, cultural and environmental factors (Jensen & Karoly, 2001). Attention continues to focus on the assessment and management of pain by adhering to standards that focus on single-item numerical measurements of pain intensity (Joint Commission on Accreditation of Healthcare Organizations, 2001) used in research

settings and drug effectiveness studies (Ozyuvaci, Yanmaz Alnigenis, & Altan, 2004; Price, McGrath, Raffi, & Buckingham, 1983; Schwartz, Turturro, Istvan, & Larkin, 2000) such as the visual analogue scale (VAS; (Price et al., 1983) and the numerical rating scale (NRS; (Daut, Cleeland, & Flanery, 1983 ).

The VAS and NRS provide measures of sensory intensity useful in acute and chronic pain assessment (Ferraz et al., 1990; Paice & Cohen, 1997). Both of these single-item scales require cognitive evaluation, or appraisal, of the sensory experience and quantification of the sensation with an abstract number. The VAS was designed to measure attitudes or characteristics thought to exist along a continuum rather than in distinct categories like mild, moderate, and severe (Gould, Kelly, Goldstone, & Gammon, 2001). In order to capture the person's perception of pain, the VAS requires the person to indicate the level of pain by marking a point that describes the pain experienced on a 10-centimeter line with verbal anchors of "no pain" and "pain as bad as you can imagine" at opposite ends of the line. The score on the VAS is the distance in millimeters from the "no pain" end to the patient's mark.

In contrast to the VAS, the NRS requires patients to use discrete categories to rate their pain "on a scale of 0 to 10 with 0 meaning no pain and 10 meaning pain as bad as you can imagine (or the worst you have had)" (Daut et al., 1983). Variations in the printed form of the VAS and NRS exist. In print, the NRS may appear with a line with the 100 points from 0 to 100 indicated (Jensen, Karoly, & Braver, 1986). In clinical areas, patients may be asked to verbally rate pain intensity with the verbal rating scale (VRS), an adaptation of the NRS that requires the patient to verbally assign a number to the intensity of pain experienced (Paice & Cohen, 1997). Problems occur when scales with different rating ranges, (e.g., 0-5, 0-10, or 0-100) are used by different providers and misinterpretation of the patient rating

occurs (Dalton & McNaull, 1998; Lund et al., 2005) or when the patient has misinterpreted what the task is meant to measure (de C. Williams, Davies, & Chadury, 2000).

### The Problem

Sources indicate that despite the use of intensity rating in the management of acute and chronic pain, patients' reports indicate pain management continues to be inadequate (J. Brody, 2005; Collins et al., 2000; Teno, Weitzen, Wetle, & Mor, 2001). While thorough pain assessment should include the emotional component of pain (Gonzales, Martelli, & Baker, 2000), single-item rating scales do not capture pain affect, or emotional reaction to painful stimuli, a significant component of chronic pain experience (Price et al., 2001). Assessment of affective response has used self-report using a single-item (Wade, Price, Hamer, Schwartz, & Hart, 1990), more lengthy written instruments, observation, and psychophysiological measures. However, psychological instruments used to measure emotional state in pain research tap into more enduring patterns of temperament and, thus, do not capture the short-term emotional reaction to pain. In addition, such instruments often increase subject burden because they require cognitive skills persons in pain may not be able to use at the time of testing (Fernandez, Clark, & Rudick-Davis, 1999). Completion of standard psychological instruments, therefore, may not provide a real-time indication of emotional state.

Because emotion precedes the occurrence of pain behaviors and verbal self-report of pain (Damasio, 1999), reliable measurement of emotional reaction probably would be less influenced by social constraints if verbalization and cognition were removed. Supporting Buck's (1984) findings, Hadjistavropoulos and Craig (2002) note that observed behavior tends to be automatic and involuntary while self-report is controlled by cognitive centers and

is subject to purposeful re-shaping. Emotional expression can be observed in automatic facial expressions (Dalton, Brown, Carlson, McNutt, & Greer, 1999; Ekman, 2003; Ekman & Friesen, 1978), body postures and movements (Darwin, 1872/1955). Because of rapid emotional changes and the effect of masking and social constraints, cues to the presence of emotions have been studied via visual and auditory channels since they are less subject to social constraint than self-report (Juslin & Scherer, 2005 ). While facial expression is a readily observable reaction to a situation or person, the vocal channel of expression has been found to “leak,” or be less influenced by display rules of appropriate behavior associated with emotion expression, providing more affective information than face (Hochschild, 1979; Kemper, 2000; Planalp, 1999).

### The Purpose

Because emotion can be carried in the vocal signal (van Bezoooyen, 1984) and paralinguistic content is less subject to voluntary control by the speaker (Hadjistavropoulos & Craig, 2002), acoustic analysis of vocalization during increased pain could provide information about emotional state as well as indicate the meaning the pain has for the person with pain. Although emotion research has used acoustic analysis of voice, little information is available on patterns of vocalization associated with chronic non-cancer pain and its emotional component. The purpose of this investigation is to determine whether acoustic parameters change in vocalizations associated with chronic pain induction and if patterns of the signal indicate a type of emotional reaction to chronic pain.



## CHAPTER TWO

### CONCEPTUAL FRAMEWORK

Cannon (1915, 1928, 1929) and Selye (1956, 1973, 1985) both noted the influence of emotional reaction to internal and external environmental stressors. Although appraisal was first suggested by Aristotle (Solomon, 2000) and later by Darwin (1872/1955), it was Arnold's effort to reintroduce appraisal (Arnold, 1960) at the height of behaviorism that probably is responsible for the beginnings of appraisal theory development. Lazarus' focus on the cognitive aspects of psychological stress (Lazarus, 1966) and, later, (Lazarus & Folkman, 1984) on adaptation to stressors and coping provided the foundation for cognitive psychological study of emotion (Laukka, 2004). Cognitive theories of emotion assume that an individual's cognitive ability to process contextual information and to recall experiences will facilitate coping, adaptation, and survival from situations or objects perceived as threatening, dangerous, or challenging (Lazarus, Averill, & Opton, 1970 ). In contrast to other theories of emotion based on undifferentiated activation or arousal (Duffy, 1934; Schacter & Singer, 1962), appraisal theories claim emotions follow an individual's evaluations of events or situations (Arnold, 1969; Frijda, 1994; Roseman & Smith, 2001; K. Scherer, 1984). Mandler (1975) proposed cognitive appraisal of the event and arousal as being essential for emotion and that appraisal alone could generate the level of arousal. Lazarus and Folkman (1984) recognized the individual arrives at each event with values,

beliefs, and goals that influence appraisal and lead to specific patterns of arousal rather than the diffuse, generalized arousal proposed by earlier theories. Previous experience coping with a stressor influences how well a new event is managed and choice of activities used to regulate emotion. Assumptions of appraisal theory include the following:

1. Emotion is a system that is organized to provide primarily adaptive capability.
2. Emotions are generated and differentiated by appraisals.
3. Differences in appraisal can account for individual and temporal differences in emotional response.
4. All situations to which the same appraisal pattern is assigned will evoke the same emotions.
5. Appraisals precede and elicit emotions.
6. The appraisal process makes it likely that the emotions will be appropriate responses to the situations in which they occur.
7. The appraisal system has evolved to process information that predicts when particular emotional responses are likely to provide effective coping.
8. Conflicting, involuntary, or inappropriate appraisal may account for irrational aspects of emotions.
9. Changes in appraisal may account for developmentally and clinically induced changes in emotion.

(Planalp, 1999; Roseman & Smith, 2001).

While emotion theorists like Lazarus (1966), Frijda (1986), Smith and Ellsworth (1985) agree that emotion has different components (like antecedent event, appraisal, feeling, activation, behavior), theorists disagree on which components are essential and the order in

which the components appear. Level of cognition has sparked the largest controversy with Zajonc (1984) arguing for minimal cognition and Lazarus et al. (Lazarus, 1984; Lazarus et al., 1970 ) arguing for increasing level of cognition with appraisals. Componential theories of emotion argue that emotion causes cognitive activity along with other characteristics of physiological arousal, action tendencies, motor expression, and feeling states (K. Scherer & Ellgring, 2007a). To more precisely define the phenomenon of emotion elicitation and patterns of response, componential theories have developed detailed predictions of changes that occur in response to specific appraisals (K. Scherer & Ellgring, 2007b; C. Smith & Ellsworth, 1985). These theories also propose that a larger number of well-defined emotions exist in contrast to the limited number proposed in discrete emotion theories(K. Scherer & Ellgring, 2007a).

#### Scherer's Component Process Model and Theory of Sequential Evaluation Checks

The theoretical framework selected for this study is the component process model of emotion and the sequential check theory (SECs) of emotion differentiation developed by Klaus Scherer (1984, 1986, 2001a). Scherer, a social psychologist, first studied nonverbal communication with studies related to personality and expression of stress (Giles, Scherer, & Taylor, 1979; K. Scherer, 1981; K. Scherer & Giles, 1979). Using a process model view of stress and appraisal, Scherer provided a cognitive psychological approach to emotion that builds on work describing the expression of emotion and evolution (Darwin, 1872/1955; Wilson, 2006); work on psychological aspects of stress, appraisal, adaptation, and coping (Arnold, 1960; Bombardier, D'Amico, & Jordan, 1990; Frijda, 1986; Lazarus, 1966; Lazarus & Folkman, 1984 ); and work on emotion (Arnold, 1969; Damasio, 1999; Ekman, Levenson,

& Friesen, 1983; Frijda, 1986, 1994; Porges, 2001; K. Scherer & Ekman, 1984; Zajonc, 1984).

Scherer's theory is based on studies of emotion and emotion portrayal (Ladd, Silverman, Tolkmitt, Bergmann, & Scherer, 1985; K. Scherer, 1978; K. Scherer, Banse, Wallbott, & Goldbeck, 1991; K. Scherer & Ceschi, 1997). As cognitive theory of stress and emotion developed, Scherer incorporated aspects of cognitive (Arnold, 1960; Lazarus et al., 1970 ) and physiological theory (Gellhorn, 1970) with his acoustic studies of vocal expression (Ladd et al., 1985; K. Scherer, 1986; K. Scherer, Ladd, & Silverman, 1984). Dissatisfied with the limitation of discrete and dimensional theories of emotion, Scherer (2001b) proposed a component process model in which an antecedent event causes a series of evaluations in a prescribed order that can lead to a limitless number of emotion combinations. Like Darwin's phylogenetic theory of emotion, Scherer notes that some combinations occur more frequently in daily life and induce consistent reactions as the result of nervous system development (Darwin, 1872/1955). In contrast to Ekman's (1992) support of "basic emotions," Scherer refers to emotions of anger, disgust, fear, happiness, and sadness as "modal" emotions (K. Scherer, 1986) with the possibility of an unlimited number of emotions and emotion blends. According to Scherer, restriction of the number of emotions has contributed to the lack of significant findings in studies since some emotions, like anger, would be expected to be different based on intensity of physiological activation as well as potency of the reaction. Anger that is "cold" results in irritation or less ergotropic, or energy expending, behavior than "hot" anger that leads to rage. Consequently, acoustic parameters would be dissimilar due to physiological differences although participants report "anger."

Most cognitive appraisal theories do not explain the rapid change that occurs with environmental encounters that do not allow time for the cognitive processing necessary for action, like acute injury (Damasio, 1994; Lazarus & Folkman, 1984). Increased somatic nervous system activation expected with heightened emotion increases striated muscle tension that fosters the “fight or flight” phenomenon when an organism is exposed to a threatening adversary (Cannon, 1929) or “freezing “when the organism is alone and escape is not possible (Porges, 2001). Such changes cause characteristic increases in fundamental frequency level and range by increasing tension of muscles that support vocal folds (Gobl & Chasaide, 2003), the so-called “push effect ” of physiological activation (K. Scherer, 1984). Effects of cultural constraints on emotion expression are referred to as “pull effects,” describing the effort to suppress emotional expression.

Scherer’s theory (1986, 2001a) incorporates physiological mechanisms to predict parameters altered with different emotions. Scherer uses Gellhorn’s classification of autonomic nervous system (ANS) activation with ergotropic arousal for sympathetic nervous system dominance causing energy expenditure and trophotropic, or energy restoring, arousal for parasympathetic dominance promoting energy conservation (Gellhorn, 1970).

The effect of the ANS activation on the speech production system cannot be overstated (Juslin & Laukka, 2001). Although the vocal folds do not possess nerve supply, the recurrent laryngeal and superior laryngeal nerves, branches of the vagus nerve, innervate the laryngeal muscles and are primarily parasympathetic in nature (Chagnon, Papagiannis, Mlynarck, & Massie, 2005; Jiang, Lin, & Hanson, 2000). Changes in subglottal pressure due to altered respiration, secretion of mucus and saliva, and tone of facial and supralaryngeal

muscles all contribute to changes in fundamental frequency, intensity and resonance (C. Williams & Stevens, 1981).

Fundamental frequency ( $F_0$ ), the acoustic correlate of pitch, changes with strong emotions like hot anger, fear/panic, and elation. These emotions are associated with intense physiological activation or arousal indicated by changes in respiratory rate and depth, subglottal pressure, and glottal tension.

Intensity changes in the speech signal are perceived as loudness and are reflected in amplitude of the waveform. Increased amplitude is seen with strong positive emotion like elation as well as strong negative emotion like rage/anger (K. Scherer & Ceschi, 1997) that cause physiological activation.

Resonance changes in the speech signal, often referred to as voice quality changes, can be noted in formant changes and distribution of frequencies in the energy spectrum (Laver, 1991). A formant is a frequency at which a particular vocal tract is more efficient than nearby frequencies. Formants are not due to source-spectrum properties but rather to the amplitude and articulators of the vocal tract (Baken & Orlikoff, 2000, p. 258). Formant precision of the first formant ( $F_1$ ) and second formant ( $F_2$ ) can indicate coping strategy of a speaker under cognitive or emotional stress (Tolkmitt & Scherer, 1986).

In his review of studies of vocal cues of emotion, Scherer categorized findings on the basis of the emotions (1986). For purposes of the current investigation's consideration of the emotions of anxiety, sadness, and anger, it is important to note that Scherer's category labels indicate the level of physiological arousal expected to color expression. For example, Scherer differentiates emotions with more qualitative descriptors (e.g., "cold" anger associated with irritation versus "hot" anger associated with rage) to indicate potency. Sadness/dejection is

differentiated from grief/despair, worry/anxiety is differentiated from fear/panic, irritation/cold anger is differentiated from rage/hot anger. The additional descriptors provide clarification about the strength or potency of the emotion being described. Scherer's component process model recognizes that physiological changes occurring in emotional states alter phonation and resonance and suggests acoustic parameters of vocal expression of emotion be used to differentiate emotions (Banse & Scherer, 1996; K. Scherer, 1984, 1986).

The component patterning theory (K. Scherer, 1984, 1986, 2001a), recognizes the interplay of the neuroendocrine system, autonomic nervous system, and somatic nervous system in appraisal. Appraisals of relevance, implications, coping potential, and normative significance result in different subsystem changes (K. Scherer, 1984). Scherer described sequential evaluation checks (Table 1) as a means of explaining the reasons for these differences in emotion. Sequential evaluation checks (SECs) are cognitive evaluations of an event or object that take place in the same order whenever a situation presents itself.

Table 1.

*Scherer's Sequential Evaluation Checks (1986, 2001)*

Check	Level of Awareness	Positive	Negative
Novelty	Change in stimulation	Not novel, expected	Novel, unexpected
Intrinsic Pleasantness	Stimulus event evaluated with innate or learned detectors	Pleasant, Approach tendencies	Unpleasant, Avoidance tendencies
Goal / Need Significance	Stimulus influence on goals, needs, survival	Relevant  Conducive to Goals  Response not required	Relevant  Obstructive to Goals  Urgent response
Coping Potential	Ability to adapt to event and consequences	Did not cause event  Control  High power  Adjustment possible	Caused event  No control  Low power  Adjustment unlikely
Norm/Self Compatibility	Behavior conform to person, social, cultural norms/ expectations of self and others	Internal standards and  External standards surpassed	Internal standards violated  External standards violated



Once it is determined that an antecedent event or situation is judged “relevant” to an individual’s goals or concerns, components of cognition, physiological regulation, motivation, motor expression, and monitoring-feeling respond with adjustments (Banse & Scherer, 1996).

The sequence of the checks incorporates recent neuroscience findings. Dichotomous decisions are predicted to be made almost automatically with the early checks of novelty and pleasantness. This finding is borne out in neuropsychological studies where the amygdala is thought to trigger the somatic response when detecting “novel” or “unexpected” stimuli (Bechara, Damasio, & Damasio, 2003; Phelps & LeDoux, 2005). Unpleasantness has also been associated with rapid evaluation in experimental pain studies (Rainville, Duncan, Price, Carrier, & Bushnell, 1997). For example, as a greater amount of cognition is required, more time is needed to process the evaluation using cortical information regarding past experience and coping strategies. A final check for cultural norms and self-concept requires more cortical activity (Bechara et al., 2003). While the process is open to re-evaluation of the stimulus at any point, closure is required to prevent indecision in the individual and physiological systems (K. Scherer, 2001a).

This component process model of emotion proposes that changes in acoustic parameters occur with each sequential evaluation check and each successive check modifies the evaluation of the previous check so an unlimited combination of evaluation outcomes is possible, leading to more rather than fewer emotional responses. Studies suggest that a recurring event is not appraised as novel and early SECs are passed over to deal with more cognitively (K. Scherer, 1986) demanding evaluation checks (Johnstone, Van Reekum, Hird, Kirsner, & Scherer, 2005; K. Scherer, 2001a). Because some situations present themselves

frequently in normal living, it is expected that some patterns of evaluation and emotional reaction will occur more often (K. Scherer, 1986). Because persons in the transition period from acute to chronic pain are confronted with frequent pain episodes, it is expected that each pain-inducing event may induce frequent appraisals of the pain's significance to well-being or goals that lead to physiological changes and behaviors that reflect emotional reaction. The SECs of goal need/significance and coping potential checks seem to resonate with the stage of extended pain affect suggested by Riley and Wade (2004) where patients evaluate goals and self-image and the need for change. If so, measures of voice might provide information about the emotional status of persons in pain.

## CHAPTER THREE

### REVIEW OF LITERATURE

Because this study incorporates theory related to pain, emotion, and linguistics, literature was reviewed that could provide information on relevant research. A general overview of stress, emotion, emotion expression, acoustic analysis, and chronic pain follows.

#### Stress

Pain sensation, or nociception, is classified as a stressor since it precedes physiological and psychological changes that comprise the acute stress response and disruption of homeostasis (Chrousos, 1992; Chrousos & Gold, 1992; Cousins & Power, 1999). Thus, stimulus – response theories of pain and studies of nociception that include specificity and patterning theories provide the basis for much of the research about pain (Price & Bushnell, 2004). The gate control theory of pain (Melzack & Casey, 1968; Melzack & Wall, 1965) proposes that pain is composed of sensory, affective, and evaluative dimensions. In the years since the theory was first introduced, investigations of experimental and clinical pain have indicated that the emotional component of pain influences the pain intensity experienced (Ochsner et al., 2006; Rainville, Carrier, Hofbauer, Bushnell, & Duncan, 1999). While study of nociception continued and new mechanisms and neurotransmitters were discovered, the gate control theory sparked cognitive psychological research that recognized cortical influences on pain perception and control. Although the

unpleasant or aversive nature of pain diverts attention away from other activities (Grisart & Plaghki, 1999), pain can also be ignored or tolerated at levels that vary from high to low in some contexts (Boston & Sharpe, 2005; Crombez, Eccleston, Baeyens, van Houdenhove, & van den Broeck, 1999; Seminowicz & Davis, 2006).

The definition of stress as the disruption of homeostasis (Chrousos & Gold, 1992) highlights the importance of Cannon's early work on homeostasis (Cannon, 1915, 1929) and the work of Selye describing the effects of chronic stress on the body (Selye, 1955, 1956, 1959). While in early work, Cannon and Selye provide physiological evidence of the connection of stress to tissue pathology (Cannon, 1915; Selye, 1955), later work provides the link of psychological stress to pathology (Selye, 1961, 1985). Stressor is a term used to describe a physiological or psychological stimulus that threatens to alter homeostasis and activate neural, hormonal, or behavioral responses (Chrousos & Gold, 1992).

Painful stimuli may act as a stressor when these responses are activated or when prior experience modifies responses influencing perception of intensity and consequences of the painful stimulus (Melzack, 1999). Because of the aversive nature of pain, emotional reaction to pain is often negative, with the person in pain noticing and trying to avoid having the pain. Because genetic history and learning experiences are unique to an individual, a variety of responses should be possible. However, Darwin (1872/1955) found that responses to environmental stimuli with specific behaviors like freezing, fighting, or fleeing were similar across species and are important to survival of species. Cannon (1929) associated acute pain with an interruption of homeostasis and focused on activation of the sympathetic nervous system with observable features like pupil dilation, increased heart rate, and increased skeletal muscle tension. These changes characterize the energy expenditure needed for the

“fight or flight response” when threat is recognized and indicate level of arousal. Whether arousal occurs prior to the event or following the appraisal is the basis of controversy in psychological theories.

Although chronic pain is a stressor (Dysvik, Natvig, Eikeland, & Lindstrom, 2005; Ruhl, 1999), it does not always demonstrate the distinctive signs of sympathetic nervous system activation. Adaptation to a chronic stressor like pain may result in reduced sympathetic response, possibly related to hypocortisol levels resulting in dominance of parasympathetic input (Glass et al., 2004; Heim, Ehler, & Hellhammer, 2000; Hellhammer, Schlotz, Stone, Pirke, & Hellhammer, 2004). Parasympathetic activation is characterized by efforts to restore homeostasis, counteracting sympathetic activation through decreased heart rate, decreased respiratory rate, and rest or inactivity. While heart rate is often thought to provide an indication of arousal and pain intensity, the possibility of a gender effect also exists (Tousignant-Laflamme, Rainville, & Marchand, 2005). In their study of 39 non-pain subjects using experiment thermal pain, Tousignant-LaFlamme et al. (2005) found that heart rate was highly correlated with pain intensity ( $r = .77$ ) and pain unpleasantness ( $r = .86$ ), and heart rate in men, while correlation was absent in female subjects (intensity,  $r = -0.2$ ; unpleasantness,  $r = 0.001$ ).

Much of the cognitive psychological research of emotion relies on theory related to stress, coping and adaptation introduced by Lazarus and Folkman (Lazarus, 1966; Lazarus & Folkman, 1984). In this particular cognitive theory, an individual experiences a stressor, appraises its significance to his or her well-being or survival and his or her ability to cope with the stressor, experiences a physiological reaction, and undergoes a behavioral response (Lazarus, 1966). It is the appraisal of a stressor – be it an event, an object, or the occurrence

of pain – that sets off a cascade of neurophysiological events that trigger the internal feeling, sometimes referred to as arousal, leading to observable behaviors or emotions that express the feeling state (Damasio, 1994).

## Emotion

The terms affect, feeling, emotion, mood, and temperament are often used interchangeably in the literature (Alpert & Rosen, 1990) to refer to the phenomenological response to an object, person, or situation. Fernandez et al. define affect as the collection of emotions, moods, and temperaments. Feeling refers to the intrapersonal awareness of muscular and endocrine activity and is only recognized by the individual experiencing the feeling (Damasio, 2003; Fernandez et al., 1999) and lasts briefly, i.e., seconds or minutes. Emotion, from the Latin root *e-movere*, “to move out,” (*Oxford English Dictionary Online*, 2005) refers to the extra-personal or observable evidence of this muscular and endocrine activity in expressive behavior. Emotion occurs when specific patterns of varied and complex physiological reactions are touched off by brain systems when an individual is exposed to an image, object or situation external or internal to an individual and lasts from minutes to hours (Damasio, 2000). Mood refers to a prevailing emotional disposition over an extended period of time with little variation in intensity over hours or days (Fernandez et al., 1999). Temperament is used to describe a tendency of an individual to experience specific emotions or mood more frequently for an extended period and provides a basis for future appraisals. Temperament is considered to be the result of learning and inherited traits, and it is temperament that is tapped in psychological inventories of anxiety, depression, and anger (Fernandez et al., 1999). Emotion, the observable evidence of muscular and autonomic

nervous system change, is the focus of this investigation although temperament was measured with psychological inventories.

While pain may not be widely acknowledged as an emotion, pain does evoke emotion (Damasio, 2000) as evidenced by the occurrence of predominately negative emotions of depression, anger, and anxiety associated with chronic pain (Price & Bushnell, 2004). Study of emotion has a long history of study in biological (Darwin, 1872/1955), physiological (Cannon, 1915), psychological (Arnold, 1960; James, 1884), sociological (Kemper, 2000), and cultural (Mesquita & Frijda, 1992; K. Scherer & Wallbott, 1994) disciplines. While there is some consensus that emotion is a process with multiple components, many theories include some combination of cognitive appraisal, subjective feeling, physiological arousal, motor expression, action tendency, and regulation (Laukka, 2004; Planalp, 1999). However, the mechanism of the process from a stimulus or antecedent event, to the feeling generated, and finally to the observable behaviors is not fully understood (Damasio, 1994, 1999; Eich, Kihlstrom, Bower, Forgas, & Niedenthal, 2000; Porges, 1997). Cognitive psychologists propose that emotions result from evaluations or appraisals of events or situations, and emotions may change over short periods of time, i.e., minutes or hours (Arnold, 1960; Lazarus, 1968). However, other prominent researchers do not acknowledge this need for complex cognitive activity, or even consciousness, for emotions to occur (LeDoux, 2002; Zajonc, 1984).

Undifferentiated activation or arousal was thought to cause emotional responses and psychophysiological measures were employed to empirically demonstrate level of arousal and explain the emotional states that occurred. Arousal or activation theories of emotion were developed from these psychophysiological studies (Duffy, 1934; Schacter & Singer, 1962).

Because the relationship of arousal and emotion is prominent, researchers assumed arousal was the primary cause of emotion. However, Schacter and Singer's (1962) experiment of injecting epinephrine to induce emotion did not explain how emotions differ despite similar levels of arousal (Planalp, 1999).

Appraisal theories suggest that emotions follow an individual's evaluations of events or situations and the relation of the evaluation to goals and plans (Arnold, 1969; Frijda, 1994; Roseman & Smith, 2001; K. Scherer, 1984). Disagreement in appraisal theory exists about the number and way that emotions should be described, producing discrete, dimensional, and process theories.

Discrete emotion theories propose that a small number of emotions exist (e.g., anger, fear, sadness, and joy) and that each has its own specific and individualized pattern of components. Because consciousness, not cognition is required, emotions are possible in infants. Because each emotion is thought to have distinguishable facial expressions, Ekman's (1992) work with facial expression supports discrete emotions theory.

Dimensional emotion theories focus on subjective feeling and identify a small number of dimensions to account for emotional states. For example, Wundt (1912/1924) proposed three dimensions – pleasure-displeasure, strain-relaxation, and excitement-calmness. The circumplex model of emotion (Larsen & Diener, 1992; J. Russell, 1980) proposed structuring emotional states using two dimensions – pleasure-displeasure and arousal-sleep – and organizing affect terms in a circle around the two axes with certain states – excitement, distress, depression, sleepiness - methodically positioned based on their relation to the two dimensions (Altarriba, Basnight, & Canary, 2003). Ortony et al. (1988) observed that all emotion terms are valenced leading to good-bad, pleasant-unpleasant



ratings. A two-dimensional model having an activation dimension ranging from sleep to excitement and a valence dimension ranging from displeasure to pleasure has been proposed (Laukka, Juslin, & Bresin, 2005).

In a follow-up study to determine how many dimensions might be involved in vocal expression of emotion, Laukka et al. (2005) asked participants to evaluate portrayals of emotion using four dimensions. While distinct patterns for various emotions were found with only three dimensions – activation, valence, and potency – four dimensions, including emotion intensity, were related to vocal cues (Laukka et al., 2005).

Strength of the emotion has also been suggested as a third dimension that is included in the individual's coping appraisal and differentiation of negative emotions (C. Smith & Ellsworth, 1985). In addition to the previous dimensions, action tendencies or action readiness (Frijda, 1986) may be used to differentiate emotions. Action readiness refers to “involuntary, nonhabitual action control” (Frijda, 2000 p.63) that is separate from cognition and decision-making.

In contrast to discrete and dimensional theories, process theories of emotion identify components that work together to form an emotion and, because subtle differences can occur, an unlimited number of emotions and blends of emotions is possible (Planalp, 1999). Process theories can identify discrete categories of emotions, like fear and anger, by identifying the events, appraisals, action tendencies, behaviors, physiological reactions, and regulation. But these theories can also explain why differences exist in emotions that appear similar, e.g., emotions such as guilt and shame as well as blended emotions like happiness and sadness at a wedding. Because of their ability to incorporate the recurring and the highly individual experiences humans have (Planalp, 1999), process theories are more likely to provide

guidance in emotion assessment of persons with chronic pain since they have varied disease etiologies, experiences, cognitive abilities, and personalities.

The ability to probe the brain non-invasively with functional magnetic resonance imaging (fMRI) and positron emission tomography (PET) have allowed study of brain activity when an emotion is recalled or induced in conscious adults (Kalisch, Wiech, Critchley, & Dolan, 2006; Liotti et al., 2000) and shown the interconnectivity of various brain locations in emotion processing. Among these locations, the amygdala, hippocampus, cingulate and prefrontal cortex play important roles in danger detection, recall of past experience, memory of past coping strategies, and adaptation. All of these skills allow the organism, in this case, the human, to survive in a complicated environment. Communication of emotion provides signals of danger, dominance, submissiveness, and sexual access that allows the species to reproduce and survive (Kemper, 2000). Because humans have evolved to possess large cortices that allow them to learn from past experiences and well-placed larynges that allow them to communicate through language and other means of expression, they have become more social animals. Vocal and facial signals that were more automatic may now be more subject to the constraints of social norms.

### Emotion Expression

Although Darwin's study of emotional expression in man and animals (1872/1955) provides the foundation for much of the work on emotion and its communication (Bachorowski & Owren, 2003; Davidson, 2003), the link of emotion and expression can be seen in the works of Aristotle on rhetoric.

However, expression and communication of emotion are not one and the same. To clarify, expression is defined as that part of emotion that is essential to the experience of emotion; it occurs involuntarily through facial, vocal, and body cues (Buck, 1984). Communication occurs only if the speaker intends for it to occur, requires an individual to step away from feeling the emotion, and is shaped by the environment or perception of the audience (Planalp, 1999). Communication requires a common code or shared language (Akmajian, Demers, Farmer, & Harnish, 1995). Communication, consequently, is heavily influenced by social and cultural norms that can constrain emotional expression (Planalp, 1999). Efforts to determine emotional state from emotional expression through only one channel is difficult. Fortunately, a combination of cues and the multiplicity of cues in different channels provide a recognizable pattern of behavior that signals emotion to an observer (Ekman, 2003; Planalp, DeFrancisco, & Rutherford, 1996).

Because emotion precedes the occurrence of behavior and verbal self-report (Damasio, 1999), reliable measurement of emotional reaction would be less influenced by social constraints if verbalization and the cognitive level it requires were removed. Emotional expression can be observed in automatic facial expressions (Ekman, 2003; Ekman & Friesen, 1978), body postures, and movements (Darwin, 1872/1955) as well as voice. Supporting Buck's (1984) findings, Hadjistavropoulos and Craig (2002) note that observed behavior tends to be automatic and involuntary while self-report is controlled by cognitive centers and is subject to purposeful re-shaping.

Because of the rapid changes possible with emotion and the effects of masking and social constraints, cues to the presence of emotions have been studied via visual and auditory channels because they are less subject to social constraint than self-report (Juslin & Scherer,

2005 ). Much of the research on emotional expression has used facial expressiveness as an indicator of emotion occurrence (K. Craig & Patrick, 1985; Ekman & Friesen, 1978; J. Russell, Bachorowski, & Fernandez-Dols, 2003; Wallbott & Scherer, 1991; Wilson, 2006). While facial expression is readily observable reaction to a situation or person, the vocal channel of expression has been found to “leak” more affective information, or to be less influenced by cultural display rules of appropriate behavior associated with emotion expression (Hochschild, 1979; Kemper, 2000; Planalp, 1999). Voice becomes so important to individual’s identity that family and friends can recognize not only the person, but subtle variation in speech patterns that signal particular emotions even over the telephone where frequencies are reduced.

Although emotion can be carried in the vocal signal (van Bezooeyen, 1984) and one is able to identify current emotional state from acoustic properties of voice like loudness and pitch (Friedhoff, Alpert, & Kurtzberg, 1962), study of emotion in voice has not progressed as rapidly as that of facial expression (K. Scherer, 1986). Because a limited number of encoders and few common acoustic and physiological measures were used, results of many studies cannot be generalized (Laukka, 2004; K. Scherer, 1986). Although many studies of vocal expression of emotion are reported, few theories have been available to foster hypothesis development derived from the synthesis of similar parameters (Banse & Scherer, 1996; K. Scherer, 1986). Few theories predict cues based on physiological changes known to occur in response to emotion and none as complete as Scherer’s theory (Juslin & Laukka, 2001).

Voice carries emotional content detectable by human decoders (Monnot, Orbelo, Riccardo, Sikka, & Rossa, 2003; K. Scherer, 1986; K. Scherer & Zei, 1988). Further, emotions have been more accurately detected by human decoders than the computer systems

designed to perform acoustic analysis of voice, however this difference may be due to the equipment and parameters used. Listeners have achieved accuracy rates four to five times that expected by chance (Monnot et al., 2003; Pittam & Scherer, 1993). The absence of significant findings from computer assisted programs is attributed to the use of few parameters of fundamental frequency (K. Scherer, 1986), only a few emotions (Banse & Scherer, 1996), and few encoders in studies (Juslin & Laukka, 2001).

Emotional expressions are classified by whether they are naturally expressed, induced, and portrayed. Natural expressions of emotion have been studied using recordings of events like a broadcaster's reporting of the crash of the Hindenburg (C. Williams & Stevens, 1972) and cosmonauts' reaction to emergency situation in space (Simonov & Frolov, 1973). These reactions are of high intensity not present in the moment-to-moment changes of natural emotion. Scherer notes the difficulty in capturing natural emotion due to ethical constraints that limit induction of heightened emotional states of fear, grief, depression, and anger. Induction of emotion, often in the form of recalling an event, is reported in a variety of studies, some related to pain (Rainville, Bao, & Chretien, 2005; K. Scherer, 2003; Weisenberg, Raz, & Hener, 1998). Induction of pain, while done in experimental research, has limited generalization to naturally occurring pain since participants are aware that pain is under the control of the experimenter and will stop when they signal. Portrayal of emotion by actors and healthy volunteers (Bachorowski & Owren, 1995; L. Brody & Hall, 2000; K. Scherer, 1986; van Bezoooyen, 1984) has been used and justified as stronger than naturally occurring emotional behaviors and well-differentiated. While use of portrayal is stereotypical, some cues like jitter are not thought to be under

voluntary control and, therefore, would not be evident in acoustic recordings (Bachorowski & Owren, 1995).

Cross-cultural studies of facial and vocal expression of emotion demonstrated similarities in interpretation of facial expression, but also confusion of interpretation of some facial expressions of anger and joy (Ekman & Friesen, 1988; K. Scherer & Wallbott, 1994). While Scherer (K. Scherer, 1986) recognizes that there is the possibility of an unlimited number and blends of emotions, he also notes that certain emotions occur more frequently. In a study of vocal expression across cultures, support for the universality of vocal expression of seven emotions (i.e., joy, anger, fear, sadness, disgust, shame, and guilt) is found in studies encompassing 37 countries (K. Scherer & Wallbott, 1994) .

Paralinguistic content (i.e., content due to intonation, intensity or duration) may provide additional data on which to base clinical assessments. The absence of information about adults' paralinguistic content of pain expression limits its usefulness as an indicator to assist in chronic pain management. Selection of a participant sample with chronic ongoing pain that can be influenced by normal activities of daily living could provide a means of measuring naturally occurring emotional reaction to pain as well as information on the utility of acoustic analysis in emotion.

### Chronic Pain

Response to acute pain is characterized sympathetic nervous system activation and with fear and behaviors that avoid or reduce pain or attempt to get help from others in relieving the pain. When the pain is relieved, the emotional response dissipates. However, chronic non-cancer (CNP) pain tends to be characterized by predominance of an affective-

motivational component with negative affect and sometimes maladaptive pain behaviors (Riley & Wade, 2004). Vicious cycles that promote increased pain, disability, and depression can occur (Bálint, 2002) and the risk of suicide with chronic non-cancer pain is present especially in elders with multiple chronic illnesses (Fishbain, 1999; M. T. Smith, Edwards, Robinson, & Dworkin, 2004). Because effects of pain and the delay for treatment of many chronic conditions that are associated with aging, the impact of emotional as well as sensory aspects of persistent pain needs to be assessed quickly to minimize disability (Elders, 2000).

CNP like the acute phenomenon demonstrates sex differences (Berkley, 1997; Unruh, 1996). Not only is the experience of clinical and experimental pain (Lautenbacher & Rollman, 1993; Morin, Lund, Villarroel, Clokie, & Feine, 2000; Riley, Robinson, Wise, Myers, & Fillingim, 1998) different for males and females, but response to analgesics is different as well (Fillingim & Ness, 2000; Mogil et al., 2005). Sex differences in emotional response to CNP have been demonstrated with frustration and depression associated with usual and high pain unpleasantness while frustration is associated with pain intensity in women. Men, on the other hand, reported frustration with pain unpleasantness and depression and anxiety associated with pain intensity (Riley, Robinson, Wade, Myers, & Price, 2001). Because women are overrepresented in many chronic conditions (Fillingim & Ness, 2000) and have been reported to be more expressive of emotion (Eckert, 1989), selection of women as subjects was done to highlight the change in vocal aspects of pain occurrence.

The progression from acute pain to chronic pain has been described as going from a stage of fear, anxiety, and worry to a stage of increased psychological and behavioral problems related to distress, anger, and depression, and culminating with extensive psychological, physical, and social issues (Gatchel & Epker, 1999). Price et al. (2001) define

pain affect as the end product of many contributing processes that includes pain sensation, arousal, autonomic and somatomotor activation, as well as cognitive appraisals or meanings. Because the experience of CNP is quite different from the acute pain experience, pain processing is thought to be more complex than the more automatic reaction to pain that occurs when touching a hot stove. Psychological stages of pain processing have been suggested that provide an indication of how acute and chronic pain experience could differ and which neuroanatomical sites are likely to be involved (Price & Bushnell, 2004).

Price and Bushnell (2004) note pain unpleasantness has several sources that combine with context appraisal to produce a “felt meaning” that is reliant on the body’s prior pain experience and the level of pain unpleasantness: sources include pain sensory qualities, arousal, as well as visceral and somatomotor responses. This felt meaning leads to immediate pain affect (Price & Bushnell, 2004, p.7). While appraisal of immediate pain affect is centered on the imminent threat to the body, extended pain affect, based on reflective cognitive appraisals, is pain-oriented and the threat to self. Reflective cognitive appraisals include concerns about the effect of pain on well-being, future goals, and ability to live with the pain (Price & Bushnell, 2004). Because of the influence of duration of pain on cognitive, affective and behavioral aspects of pain, researchers (Riley & Wade, 2004) note extended pain affect is influenced by beliefs, meanings, and expectations. Unlike the chronic pain criterion of 6 months duration, this pain processing model identifies the individual’s appraisal as critical and suggests a person with pain of a shorter duration than six months could demonstrate extended pain affect.

Because subjective experience also affects emotions, expectancy of a goal and desire to achieve a goal can be described in positive (approach) or negative (avoidance) terms.



Expectancy refers to “the experienced likelihood of an outcome” (Vase, Price, Verne, & Robinson, 2004, p. 213) while desire refers to “the experiential dimension of wanting something to happen or avoid something happening” (Vase et al., 2004, p. 214). Since persons with CNP have experienced their pain for some time, anticipation of pain influences goals and their achievement. Price (1999) found experience increased intensity of remembered pain and there was a higher correlation of expected pain intensity and remembered pain than of expected pain and actual pain measured concurrently. Rainville et al. (Rainville, 2004; Rainville et al., 2005) found that changes in pain unpleasantness more strongly predicted changes in emotional dimensions of desire, expectation, valence, felt arousal, and dominance than pain intensity. Expectation, however, was also found to contribute to pain intensity supporting Price’s findings of the correlation of expected and remembered pain (Price, 1999).

Pain affect varies widely between persons due to the individual’s appraisal (Lazarus & Folkman, 1984) or cognitive evaluation of the stimulus or situation determined by the individual’s interpretation of reality or beliefs. Appraisal of a threatening situation is more likely to signal the need for coping strategies and greater likelihood that the type of strategies selected will be emotion-focused (Dysvik et al., 2005). Appraisal of a situation as challenging is more likely to result in problem-focused coping strategies. Further, if the individual believes he or she is unable to manage pain, pain unpleasantness is also increased. Cognitive-behavioral interventions for chronic pain aim to reduce emotional reaction to pain that interfere with activity with the assumption that cognition does influence emotional reaction (Dobson & Craig, 1996; Haythornthwaite, Menefee, Heinberg, & Clark, 1998).

Stress and adaptation through coping are key concepts to the management of CNP (Haythornthwaite et al., 1998; Keefe et al., 1997). Researchers consider pain that continues beyond the time of normal healing, disrupts sleep and normal activities, and no longer provides an adaptive function should be classified as chronic (National Pharmaceutical Council Inc., 2001). The gradual decrease in pain with tissue healing and the close correlation of pain to tissue pathology seen with acute pain may be minimal or absent in CNP. Emotional response to CNP is not related solely to tissue damage, but includes the prospect of enduring unrelieved pain for the rest of one's life and the threat to sense of self and long-term goals (Riley & Wade, 2004). Cassell (1999) refers to this reaction of fear to the threat to self as "suffering."

A four-stage model of pain-processing has been outlined that suggests that emotional reaction to acute and chronic pain is differentiated by neural activation (Riley & Wade, 2004; Wade, Dougherty, Archer, & Price, 1996). Extended pain affect, or secondary emotional reaction, occurs when the individual must re-evaluate self concept and goals (Wade et al., 1996). Specifically, CNP is often associated with negative affect, including depression (Dworkin & Gitlin, 1991; Fishbain, 1999; Geisser, Robinson, Keefe, & Weiner, 1994; Katon, 2003; McCracken, Vowles, & Eccleston, 2004; Turk & Okifuji, 1994), anxiety (Dehghani, Sharpe, & Nicholas, 2003; Eccleston, Crombez, Aldrich, & Stannard, 2001; Wade, Dougherty, Hart, & Cook, 1992), and anger (Fernandez & Turk, 1995; Kerns, Rosenberg, & Jacob, 1994). These negative emotions influence chronic pain appraisal (Fernandez & Turk, 1995; Nelson & Novy, 1997) and the transition from acute pain to chronic pain (Linton, 2004). Each of these reactions requires different types of interventions (Dalton, Keefe, Carlson, & Youngblood, 2004; Klaber Moffett, Carr, & Howarth, 2004; McCracken & Turk,

2002). Additionally, clinical studies indicate that timing of interventions employed in CNP plays a role in the prevention of disability as well as return to work (Marhold, Linton, & Melin, 2002; Sharpe et al., 2001) making early assessment of pain appraisal important to the success of interventions. Methods to assess emotional reaction to pain include paper-and-pencil instruments requiring cognitive ability (Beck, Ward, Mendelson, Mock, & Erbaugh, 1961; Spielberger, 1983, 1999; Spielberger, Jacobs, Russell, & Crane, 1983) and imaging technology to identify areas of brain activation associated with specific emotional responses (Duncan, Bushnell, & Lavigne, 1989; Kremer & Atkinson, 1981; Rainville, Feine, Bushnell, & Duncan, 1992; Strigo, Bushnell, Boivin, & Duncan, 2002).

Attempting to measure affective response has led some researchers to consider verbal descriptors requiring cognitive skills (Fernandez & Towery, 1996; Gracely, McGrath, & Dubner, 1978; Melzack, 1975; Melzack & Torgerson, 1971; Tearnan & Cleeland, 1990). Persons who perceive a threatening situation when experiencing experimental pain used more affective than sensory descriptors (Boston & Sharpe, 2005) demonstrating the effect of appraisal. In addition, persons with CNP tend to use more affective descriptors than persons with cancer pain (Dalton & Feuerstein, 1989) or acute postoperative pain (Agnew & Merskey, 1976). Lack of prior life experience with CNP and duration may contribute to increased emotional response as persons attempt to signal distress and obtain assistance of others. The reaction to pain, as in fear of pain with movement, has been related to decreased function (Dehghani, Sharpe, & Nicholas, 2004; Pfingsten et al., 2001), and observation of behaviors has been employed as an indicator of disability (Keefe et al., 1997; Keefe et al., 2000). Self-efficacy, or the confidence that one can continue activities, has been found to be associated with maintenance of activities in spite of pain.

Negative emotions like sadness, anger, or fear commonly observed in chronic pain (Kerns et al., 1994; Riley et al., 2001) have been studied using vocal analysis (K. Scherer & Zei, 1988; Sobin & Alpert, 1999; Wallbott & Scherer, 1986). Because interventions for depression, anger, and anxiety with chronic pain use strategies specific to the particular state (Nicholson, Gramling, Ong, & Buenevar, 2003; Paquet, Kergoat, & Dube, 2005), attention to the acoustic signal could lead to more appropriate and timely management of these emotional problems as well as pain.

### Acoustic Analysis and Voice

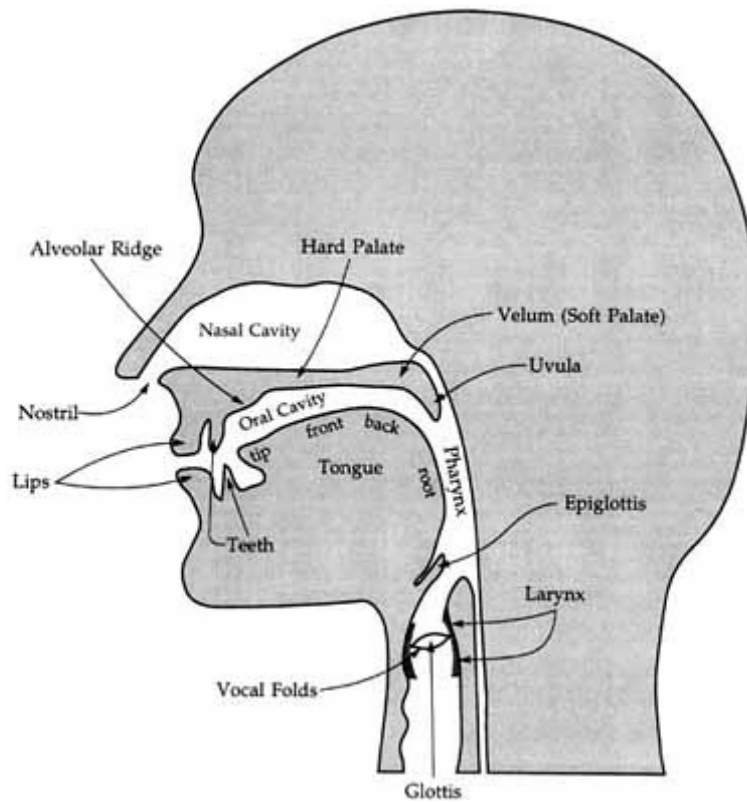
Acoustic analysis of vocalizations provides a measure of an organism's response to internal or external environmental stimuli through an indirect means of observing muscle tension via vocal fold vibration (Johnstone et al., 2007) and resonances since the neck, larynx, and folds are supported by numerous muscle groups (Copstead & Banasik, 2000). Vocal tract resonances are expected to be influenced by tension in the musculature of the face and neck, the faucal and pharyngeal settings (K. Scherer, 1986), and precision of articulation (Johnson, 2003). While acoustic measures have not been found to be as sensitive to emotion detection as the perceptual capabilities of the human ear (Juslin & Laukka, 2001), these measures provide a way of identifying major contributors to emotional speech that can be subjected to perception testing.

Studies of naturally occurring emotion using acoustic analysis have used psychiatric as well as normal populations (Alpert, Pouget, & Silva, 2001; Louth, Williamson, Alpert, Pouget, & Hare, 1998; Sobin & Alpert, 1999). Some of the earliest observations of emotion

in voice were by psychiatrists using tape-recorded sessions of patients (Friedhoff et al., 1962).

Studies of portrayed emotion expression (Pittam & Scherer, 1993; K. Scherer, 1986; K. Scherer, 1997) have demonstrated certain acoustic parameters, like fundamental frequency ( $F_0$ ) and amplitude are associated with emotions. Prosodic (e.g., intonational and rhythm aspects) and acoustic parameters related to voice quality (i.e., jitter and shimmer) are suggested as indicators of emotion in voice (Brenner, Shipp, Doherty, & Morrissey, 1983; K. Scherer, Schorr, & Johnstone, 2001).

Use of acoustic analysis with emotion expression builds on autonomic nervous system activation in response to a stressor and the arousal that produces a feeling and motivates emotional expression (Damasio, 1994; Ekman et al., 1983). Acoustic analysis of voice provides a means of indirectly assessing level of muscle tension via vocal fold vibration as well as alteration in the resonance frequencies in the oropharyngeal tract (Ladefoged, 2001). Although various theories about the physical aspects of speech exist, the source-filter model for speech contends that the complex wave that is produced in speech depends on the source, or glottal wave, and the filter, or those amplification and attenuation features that are made by the vocal tract's frequency response curve (K. Russell, 2005). The vocal tract includes the entire supralaryngeal space through the lips (Figure 1).



*Figure 1.* Schematic of vocal tract.

While hearing is not in the scope of the current study, it is the hearing process that measuring devices attempt to mimic and has implications to data collection. A common oversimplification states speech is composed of sound waves that hit the tympanic membrane making sound leading us to believe tiny curved lines proceed out mouths to ears. In actuality, speech results from alterations in air pressure released from the vocal tract that moves air molecules in a pulse-like wave that moves forward as well as backward (Henderson, 2004). Under normal circumstances, the vocal folds have an opening between them called the glottis that allows breathing. When the glottis is closed and the vocal folds are within close approximation, pressure behind the folds increases and passage of air from the lungs through the larynx causes the folds to vibrate. This vibration, referred to as glottal pulses, disrupts airflow. Fundamental frequency is the lowest rate of repetition of the changes in air pressure at the glottis and is expressed in cycles per second or Hertz (Hz) (Ladefoged, 2001). The measurement of fundamental frequency ( $F_0$ ) indicates the frequency of vibration of vocal folds at the glottis (Johnson, 2003). Air then passes through supralaryngeal structures – pharynx, oral cavity, nasal cavity, tongue, teeth, hard and soft palates, and lips – each of which contributes to alteration in airflow. These alterations cause formation of resonances that are unique to the individual. (National Center for Voice and Speech, 2005).

Recording of a clean, strong vocal signal needed for acoustic analysis requires consideration of microphone, recording device, and environment. Microphone requirements to be considered are (1) sensitivity, (2) impedance, (3) frequency response, and (4) directionality (Baken & Orlikoff, 2000) (Table 2). First, sensitivity refers to the effectiveness of a microphone in converting acoustical to electrical energy with many ranging from -51 to -60 decibels (dB). Decibel is the unit of measurement of amplitude or loudness based on the

bel first developed by Alexander Graham Bell (Johnson, 2003). The range of microphones is so low at the microphone since most systems amplify the signal.

Second, impedance is measured in ohms ( $\Omega$ ), referring to the resistance to current flow to an amplifier, in the case of the microphone, or other circuit. Impedance, usually around 200  $\Omega$ , should match the amplifier input with a mismatch increasing noise and reducing sensitivity.

Thirdly, frequency response refers to the microphone's ability to remain equally sensitive over all frequencies, or have a reasonably flat curve when dB are plotted against frequency. A microphone that has a frequency range (usually 20 Hz to 20 kHz) that includes all frequencies the ear can hear is the standard.

Lastly, directionality refers to the sensitivity of microphone design to sounds coming from different directions and is plotted on polar response graphs of concentric circles spaced 5 dB apart that indicate the angle from which sound comes to the microphone. Omni-directional microphones are sensitive to sound coming from behind and in front of the microphone and would be useful in recording several persons around a table. Unidirectional microphones are sensitive to sound coming in from the direction the microphone is aimed, dampening the input of other sound sources and having a cardioid (or heart-shaped) pattern of response useful in recording for acoustic analysis (Baken & Orlikoff, 2000).



Table 2.

*Microphone Evaluation Criteria*

Microphone Characteristic	Definition	Range
Sensitivity	Effectiveness in conversion of acoustical to electrical energy	-51 to -60 dB
Impedance	Resistance of current flow to amplifier	200 $\Omega$
Frequency Response	Ability to demonstrate equal sensitivity over all frequencies	20 Hz to 20 kHz
Directionality	Sensitivity to sounds coming from different directions to the microphone	
1. Omnidirectional	Sensitivity to sound coming from behind and in front of microphone	Round polar response graph
2. Unidirectional	Sensitivity to sound coming from the where the microphone aimed, dampens other input	Cardioid polar response graph

Microphones are designed to perform like the ear, converting mechanical energy from air pressure waves striking the diaphragm to electrical energy. Various types of microphones have been developed to answer specific needs. Dynamic microphones have a metallic diaphragm placed closely to a coil of wire connected to a magnet that generates a magnetic field around the coil. When the diaphragm moves from air pressure, it displaces the magnetic field generating an electric charge. The speed of the displacement determines the degree of electric charge produced. Although the dynamic microphone is durable, of moderate cost, and has good frequency-response, it can generate internal noise.

To circumvent the internal noise and boost the signal, condenser microphones add a capacitor and require a small battery to maintain a slight charge across the diaphragm and backplate. The amount of charge is proportional to the displacement of the diaphragm and, because displacement is very small, requires amplification. A condenser microphone has a flat response over a wide range of frequencies, or higher sensitivity than the dynamic microphones. Although more expensive and more sensitive to abuse, the condenser microphone is recommended for precision measurement of sound pressure and is recommended for acoustic measurement of voice (Baken & Orlikoff, 2000; Titze & Winholtz, 1993).

Recording systems for voice have been refined and analog recording using magnetic tape has been almost totally replaced by digital recording equipment. Laptop computers offer the ability to record a digital signal using installed or available add-on sound cards. Recordings are digitized immediately so environmental noise must be considered (Deliyski, Evans, & Shaw, 2005). Because sound cards are cheaply mass-produced for computer installation, features like sound-to-noise levels may not be the same for each card and

specifications may change at the computer manufacturer without notice. All of these situations lead to possible introduction of noise by the sound card (Deliyski, Evans et al., 2005). After analyzing various combinations of equipment commonly used in speech labs, a comparison study recommends professional-grade data acquisition systems and high quality microphones to control for extraneous noise (Deliyski, Shaw, & Evans, 2005).

While calculations before the advent of computers were tedious or impossible, the use of Fourier series has revolutionized analysis of speech waveforms and computer programs have made these analyses widely accessible. Fourier, a French mathematician and physicist during the French Revolutionary period, developed Fourier series, a mathematical means of determining the component simple waves in a complex wave composed of periodic sinusoidal waves. Because the speech waveform is relatively periodic (Johnson, 2003; K. N. Stevens, 2000), Fourier series has led to the development of other mathematical methods among them the fast Fourier transform (FFT) and the discrete Fourier transform (DFT).

The FFT is an algorithm used in digital signal processing to calculate the Fourier transform or spectrum of the signal. The FFT algorithm supports four types of windows – Bartlett, Hann (also called Hanning), Hamming, and Blackman - used to minimize end-point mismatch if a waveform is not cut precisely at matching points at each end of the waveform. The Blackman window is favored by some due to its additional cosine calculation that reduces ripple due to truncation required in analysis of segments (Theussl, 1999). The number of data points that are used in the FFT must be equal to a  $2^n$  number since the FFT uses a base 2 logarithm (Dataq Instruments Inc., 2002).

If a more accurately selected part of the waveform is needed than FFT can provide, a discrete Fourier transform can be used by selecting the portion of the waveform and a DFT

will be calculated after the FFT to produce a power spectrum for that selected sample. Time resolution and frequency resolution are important considerations with FFT. Frequency resolution is better when more samples are included or a larger window is used. Time resolution is improved with a smaller window, but too few points may be sampled and frequencies will be missed causing aliasing, a misrepresentation of frequencies present in a waveform (Johnson, 2003). The power spectrum now provides a description of the frequencies within the waveform that previously only provided information on amplitude and time (Dataq Instruments Inc., 2002). However this picture only gives a view of what happened at one point in time.

To observe what changes occur over time in an utterance, a number of spectra are needed. A spectrogram provide a description of waveform based on frequency on the vertical axis, time on the horizontal axis, and amplitude indicated by shades of gray. Using FFT analysis to calculate individual spectra and changing the window size, it is possible to handle time and frequency resolution problems mentioned earlier. With a narrow-band spectrogram, long analysis windows (e.g., 0.05 sec) are used resulting in high frequency resolution but low time resolution and damping resulting in better visualization of the harmonics.

With wide-band spectrogram, a short time window is used (e.g., 0.005 sec) resulting in frequency resolution that is wider than most harmonic spacing so the harmonics are no longer clearly visible. However, high damping leads to smoothing of the spectrum allowing visualization of dark bands indicative of formants used in data collection. In addition, better time resolution demonstrates rapid changes in the waveform (University College London. Department of Phonetics and Linguistics, 2006).

Along with the ability to record higher quality speech samples, detection and measurement of emotion in voice requires analysis of the signal using various acoustic parameters. Scherer's work is among the earliest to address emotion in the voice and continues to guide this area of research. Analyses of the studies of vocal cues in emotion expression find that few acoustic cues have been analyzed (Laukka, 2004; K. Scherer, 1986) despite the advances in analysis programs.

Measures of frequency have often been associated with signaling of emotion since frequency is a strong perceptual cue (Barrett, Pike, & Paus, 2004; Brenner et al., 1983; Monnot et al., 2003; Ohala, 1983). Fundamental frequency ( $F_0$ ), the lowest frequency simple wave, is lower in males than females because the size difference inside the larynx is 60% greater in males than females (Baken & Orlikoff, 2000; National Center for Voice and Speech, 2005; K. N. Stevens, 2000). Since sympathetic activation usually increases striated muscle tension and vocal cords are supported by muscles in the larynx, it is hypothesized that increased muscle tension pulls the vocal folds taut and thinning them resulting in higher pitch.

Parasympathetic influence is observed when sympathetic activation is reduced or with restoration of homeostasis. Parasympathetic activation results in relaxation of the musculature, thickening of the vocal folds, and lower pitch associated with sadness. Although pitch, or its acoustic correlate, fundamental frequency ( $F_0$ ), is the most frequently obtained parameter (Johnstone & Scherer, 2000) and pitch tends to indicate level of arousal (Bänziger & Scherer, 2005; Johnstone et al., 2005), pitch by itself has not been found to differentiate emotional states well (Sobin & Alpert, 1999). Age does influence pitch with older women developing lower  $F_0$  while older men develop an increase in  $F_0$  (Baken, 2005).

Other  $F_0$  parameters as  $F_0$  maximum, minimum, range, variability, and jitter have been considered valuable (Juslin & Laukka, 2003; K. Scherer, 1986).

Perturbation of fundamental frequency, the variability in frequency from period-to-period, is called jitter. Because each period coincides with vocal fold vibration, jitter is used to indirectly assess vibration and voice pathology (Brockmann, Storck, Carding, & Drinnan, 2007). Sources of jitter include neurogenic, aerodynamic, mechanical, stylistic and chaotic oscillation factors (Baken & Orlikoff, 2000). Although jitter has held some promise as an indicator of emotion, it has not been reliable. Because of the sex difference in fundamental frequency (Baken & Orlikoff, 2000; K. N. Stevens, 2000), only women will be studied to increase potential effect size since no estimates of  $F_0$  in chronic pain are available.

Perturbation of amplitude, the variability in intensity from cycle to cycle, is called shimmer. Sources of shimmer are unclear, but shimmer is inversely proportional to mean vocal intensity (Baken & Orlikoff, 2000). Effort to provide a quiet environment and computer system during data collection will aid in providing optimal voice signal in order to eliminate measurement error that results due to noise (Deliyski, Evans et al., 2005; Deliyski, Shaw et al., 2005)

Elements of voice quality (i.e., creaky, breathy, harsh, tense, lax) can be potential sources of emotional information (Murray & Arnott, 1993). While assessment of voice quality has been based on subjective evaluation, Laver's effort to identify and quantify phonetic characteristics of various qualitative evaluations allows increased reliability and comparison of data not possible with subjective labels.

Because the shape of the vocal tract is altered by articulators (i.e., tongue, lips, teeth and nasal passages), musculature of the neck and oropharynx, and the presence of saliva and mucus, different configurations produce a specific pattern of resonance frequencies of vowels called formants. Formants, especially the first and second formants, are thought to carry emotional content of speech (K. Scherer et al.; Tolkmitt, Helfrich, Standke, & Scherer, 1982). Because of its role in articulation, the tongue plays an important role in formant production due to its segmental muscular architecture and very complex innervation (Stone, Epstein, & Iskarous, 2004). Measurement of formants and other acoustic properties of voice can be done non-invasively using special recording equipment and acoustic analysis programs. Related to articulation, speech alternating motor rates requiring coordination of articulatory structures of the jaws, lips, and tongue were observed to be slower in person having higher intensity chronic back pain (Roy, Volinn, Merrill, & Chapman, 2009).

Acoustic measurements have been used to demonstrate the various changes specific to the sequential evaluation checks (SECs) proposed (Johnstone et al., 2005; K. Scherer, 1997; van Reekum et al., 2004). Recent studies have indicated that all sequential evaluation checks in the Scherer theory may not be evident. For example, if the situation or event has been encountered frequently, the checks for novelty and implications may be bypassed (van Reekum et al., 2004). The changes in voice anticipated would be based on the subsequent checks of coping potential and normative significance. In cases where the stimulus has been experienced frequently in similar situations, the stimulus (i.e., pain in this study), may be anticipated and the arousal may precede a stimulus (Landon, 1989; Porro et al., 2002).

Addition of the categorization of anger, fear, and sadness as “cold” /“hot” or “weak”/strong” in terms of emotion intensity has allowed for more careful specification of

changes in parameters for emotions. Juslin and Laukka (2001) investigated encoding of emotion using parameters and predictions of Scherer (K. Scherer, 1986), finding 33% of predictions exactly matched results while 57% of predictions were in the same direction of results. While jitter did not have a significant main effect, it did interact with emotion and emotion intensity to exert a significant interaction effect.

It is anticipated that emotional response to pain would affect physiological arousal due to movement, i.e., increased heart rate, as well as acoustic parameters of voice that are associated with sympathetic nervous system activation.



## CHAPTER FOUR

### METHODS

#### Study Purpose

Because pain is a stressor capable of inducing emotional reaction, voice is thought to carry paralinguistic content related to emotional state that could signal the need for intervention. However, little information is available on patterns of vocalization associated with chronic non-cancer pain and its emotional component. Because research suggests that pain has an emotional component that is not being assessed in clinical settings and voice may carry emotional content that could aid in assessment of and more appropriate intervention for chronic pain, the purpose of this investigation is to determine whether acoustic parameters change in vocalizations associated with chronic pain induction and if patterns of the signal indicate a type of emotional reaction to chronic pain.

#### Research Design

An exploratory, descriptive, longitudinal design was used to describe the effect of chronic pain on repeated measures of the acoustic parameters of voice in women with and without knee pain performing usual activities that might exacerbate chronic knee pain.

Longitudinal method was selected as repeated measures were collected from the same subject over time. Subjects underwent a standard protocol that included administration of written questionnaires and measurement of physical characteristics, followed by

measurement of pulse rate and acoustical measurements when seated and upon standing. Pulse rate and acoustical measurements were completed a two times to acclimate the subject to the equipment and tasks and to reduce anxiety about performance or the possibility of experimental pain induction. Because theory related to emotion indicates that anticipation of an event could cause physiological changes in response to a challenge or threat (Lazarus & Folkman, 1984), continuous pulse rate was obtained to determine if greater change occurred in the pain group prior to movement tasks than the non-pain group. The sit-to-stand activity was also used to determine functional disability in movement from sit-to-stand.

### Research Questions

The specific research questions that were addressed in this exploratory, descriptive, longitudinal study include:

1. How does pulse rate differ between women with and without chronic knee pain:
  - A. While seated at rest?
  - B. When anticipating change of position from sitting to standing?
  - C. After standing?
2. How do various acoustic parameters (i.e., mean fundamental frequency, lowest fundamental frequency, highest fundamental frequency, range of fundamental frequency, jitter, shimmer, amplitude perturbation quotient, and three formant frequencies) extracted from sustained vowel utterances of women with and without chronic knee pain differ with change of position?
3. How do various acoustic parameters (i.e., mean fundamental frequency, lowest fundamental frequency, highest fundamental frequency, range of fundamental

frequency, jitter, shimmer, amplitude perturbation quotient, and three formant frequencies) extracted from sustained vowel utterances of women with chronic knee pain differ with pain intensity?

4. How do various acoustic parameters (i.e., mean fundamental frequency, lowest fundamental frequency, highest fundamental frequency, range of fundamental frequency, jitter, shimmer, amplitude perturbation quotient, and three formant frequencies) extracted from sustained vowel utterances differ in relation to psychological variables (i.e., depression, anxiety, and anger) reported by women with and without chronic knee pain?
5. How does disability influence verbal and written reports of pain intensity reported by women with and without chronic knee pain?

### Setting

Initial testing took place in the Biobehavioral Laboratory (BBL) of the University of North Carolina at Chapel Hill School of Nursing. The BBL is on the ground floor, with kitchen area for simple meal preparation, handicapped accessible rooms and bathrooms.

Parking in the Bell Tower or on Medical Drive was arranged when possible but was a concern for subjects given the construction in the area. Evening and weekend sessions were scheduled to facilitate parking and access to the BBL. The investigator would arrange to reserve a space for the subject and escort her to the BBL. Bus transportation and transportation from retirement communities was available, but limited after 7:00 pm when subjects usually completed testing. More subjects were recruited in the late spring and summer when daylight hours were extended. The location allowed employees to participate

and the late afternoon time did not appear to interfere with recruitment of subjects who could come after work or weekends. Wheelchairs and walkers were available, on loan, from the Clinical Education Resource Center. Handicapped restroom facilities were located in the BBL.

The BBL includes sound attenuated rooms, typically used for cognitive testing, as well as audio-video recording capabilities, fluorescent and incandescent lighting, and temperature controls. More accurate equipment for weight, height, and blood pressure were available than in a community setting. Computer support with a variety of desktop and laptop computers as well as data acquisition and analysis programs were available. Recording of voice and videotaping of the movement task took place in room 310B of the School of Nursing that was found to have much lower noise levels than the BBL rooms (Appendix 1), but did not have temperature control conducive to the extended period of written testing.

Recordings were done in a room in the School of Nursing with lower noise levels than the BBL since the room was not currently connected to the heating and air conditioning system. Although the quieter room required subjects to walk to another location, the noise generated by the ventilation system would have required subjects to increase intensity to 80 dB for the 20 sustained vowels and may have been too difficult for some subjects. Situational issues of scheduling around room availability and parking ensured pain group subjects would come after a day's worth of normal activity, and thus, more prone to have increased pain. While being able to test in the same area where subjects arrived was planned initially, the change for the quiet test room was worth the inconvenience.

## Subjects

In order to obtain a sample with chronic knee pain, potential subjects for the pain group needed to report knee pain of 6 months or longer duration to comply with the definition of chronic by the International Association for the Study of Pain (Merskey et al., 1994). The comparison group was composed of females 45 years of age or older with no musculoskeletal pain. Males, younger females, and children were excluded from this study because different acoustic parameter levels, especially fundamental frequency, are used to establish algorithms and the higher frequencies of children and lower frequencies of males would skew results (K. N. Stevens, 2000) and could reduce the likelihood of detecting a significant change in voice with movement.

Since females 45 years of age and older have a higher incidence osteoarthritis of the knee and of knee pain that could be induced by sit-to-stand movement (Woolf & Pfleger, 2003), and since females are also thought to encode emotion better than males (K. Scherer et al., 1991), female subjects 45 years of age and older were selected in order to increase effect size. Subjects were recruited by flyers and word of mouth. Persons interested called a telephone number and were screened for qualification. Males and children were excluded due to differences in fundamental frequency. Potential subjects were required to have a health care provider. Inclusion and exclusion criteria (Figures 2 and 3) were reviewed in the telephone screening interview and again at enrollment on the consent form. Because the data collection would take place after working hours and on weekends, safety of the subjects was important.

Of the 103 persons who responded to recruitment flyers, seventy-seven women qualified and were enrolled. Fifteen of the enrolled subjects were not included in the final

<u>Inclusion Criteria</u>	<u>Exclusion Criteria</u>
Ambulate and stand independently	Males and children
Competent in English	Respiratory or oral conditions that limit breathing or speaking as cancer of the lung, larynx, mouth, or lip; cleft lip or palate; asthma, COPD, allergies that cause wheezing; and routine use of inhaled corticosteroids (Balter, Adams, & Chapman, 2001).
Speak and understand English	Cognitive impairment due to learning problems or learning disability, illness or surgery that resulted in a decrease in memory or other mental function
Read magazines and newspapers in English	Cardiovascular problems like stroke, transient ischemic attacks, requirement of beta blocker medication, or heart attack in the past three months
Write in English	Metabolic problems like liver disease or kidney disease requiring fluid restriction and/or renal dialysis
Hold a pencil and write	Neurological problems like seizures and Parkinson's Disease
Travel to UNC School of Nursing	Eye, ear, nose and throat problems like vision problems that prevent reading ordinary print even with glasses; difficulty understanding conversations; difficulty with slurring of speech; poorly fitting dentures; and hearing aids required to hear normal conversation.
Consent to audio taping and videotaping of the recording session	

*Figure 2.* Subject inclusion and exclusion criteria reviewed at telephone interview.

Exclusion Criteria

Skin problems like open areas or rash on hands and fingers

Hormonal problems like treatments requiring the use of male hormones

Musculoskeletal problems like difficulty using hands to hold a pencil and difficulty writing; inability to stand unassisted or stand for several minutes; and history of tripping or falling

Joint pain on movement for the non-pain group

Professional singing or acting experience

Inability to say a sustained “ah” for 4 seconds

Knee surgery less than one year ago or amputation

*Figure 3.* Additional exclusion criteria reviewed at telephone interview.

analysis. Among these fifteen subjects, three women were excluded due to presence of conditions not revealed during the screening interview or enrollment; two subjects became ill during the study and could not complete the session; ten subjects had insufficient video, acoustic or pulse rate data for the analysis. Of the twenty-six persons who were not enrolled, fourteen did not meet inclusion criteria and twelve could not be reached for follow-up, were not interested in participation, or had transportation issues.

### Power Analysis

Since difference in acoustic parameters associated with chronic pain was being tested and no effect size has previously been reported, the effect size was an estimate based on pain intensity as low (0.2) to moderate (0.5) size employing Cohen's parameters (Cohen, 1988). Power and Precision software (Borenstein, Rothstein, & Cohen, 1997) was employed, using the convention of adequate statistical power level of 0.80 and beta of 0.20. Because differences in the interval scale data of acoustic parameters of voice before standing and after standing of the non-pain sample and the chronic pain sample would provide outcome data, a paired t-test for between group differences in pain intensity provided a statistical measure appropriate for comparison since there is no such measure available in mixed models. Calculation using Power and Precision (Borenstein et al., 1997) indicated that a sample size of 40 for each group would be sufficient to demonstrate an effect size of .56 at a .80 level and beta of 0.20.



## Variables and Measurement

Because objective measurement of pain is not possible, this study's purpose was to determine whether the impact of pain can be detected in voice. Concepts important to this study included pain, voice quality, emotion, and physical function. Measurement of acoustic parameters of voice, pulse rate, and physical function of a normal activity were used as measures of reaction to self-induced pain in movement tasks. Occurrence of emotion was defined as a physiological response to a stimulus and was indicated by the objective measure pulse rate change and written self-report of felt emotion. Mood is defined as an enduring emotional state. In order to provide validated measures of a subject's usual mood or temperament, psychological inventories measuring anxiety, anger, and depression were included. Specific instrumentation used is described below and listed (Appendix 11).

### Descriptive Variables

Descriptive data were collected that provided information for exclusion and comparisons of groups during the telephone screening interview or after enrollment (Table 3). Because pulse was obtained with different equipment than that used for continuous pulse rate, these data and blood pressure and temperature data were used for descriptive and safety purposes and not included in data analysis.

Table 3.

*Descriptive Variables and Measurement Schedule*

Variable	Measurement	Obtained	Time
Health History	Health Screening Questionnaire	Telephone Interview	T1
Demographic Information	DIDS	BBL	T2
BP	DIDS, Dinamapp	BBL	T2, 3, 4, 10
Temperature	DIDS, Dinamapp	BBL	T2
Pulse	DIDS, Dinamapp	BBL	T2, 3, 4, 10

BBL – Biobehavioral Laboratory

### Independent Variables

Independent variables (Table 4) provided baseline data related to physical characteristics, psychological distress, and pain-specific characteristics or attitudes and were collected prior to the acoustic testing session in the BBL.

Table 4.

*Independent Variables and Measurement Schedule*

Variable	Measurement	Location	Time
Height	DIDS, Stadiometer	BBL	T2
Weight	DIDS, Scale-Tronix 5600 Stand-On Scale	BBL	T2
Body Mass Index	DIDS, CDC Website	BBL	T2
Pain-Specific - Duration	BPI	BBL	T2
Attitudes about Pain-Related Disability	SOPA-35 – Disability Scale	BBL	T2
Pain Intensity	VAS-PI	BBL	T2
Pain Unpleasantness	VAS-UNP	BBL	T2
Pain-Specific -Disability	BPI – Pain Interference Scale	BBL	T2
Depression	Beck Depression Inventory- II	BBL	T2
State and Trait Anxiety	Spielberger State-Trait Anxiety Inventory	BBL	T2
State and Trait Anger	Spielberger State-Trait Anger Expression Inventory	BBL	T2
Emotion Occurrence	Emotion Presence and Rating Scale	BBL	T2
Functional Ability	Arthritis Self-Efficacy Scale – Self-Efficacy for Physical Function Scale	BBL	T2

## Dependent Variables

Pain-specific data, occurrence of an emotion, observation of movement, and acoustic parameters were obtained at intervals (Table 5). Pulse rate was recorded continuously during the acoustic session. Timing of the measures is graphically outlined (Tables 6, 7, and 8).

Table 5.

*Dependent Variables and Measurement Schedule*

Variable	Measurement	Location	Time
Pain Intensity	VAS-PI	310B	T4, 6, 8, 10
Pain Unpleasantness	VAS-UNP	310B	T4, 6, 8, 10
Emotion Occurrence	EPRS	310B	T4, 6, 8, 10
Observed Disability	Sit-to-Stand Time	310B	T5-T6, T9-T10
Acoustic Parameters	Mean Fundamental Frequency	310B	T4, 6, 8, 10
	Range of $F_0$	310B	T4, 6, 8, 10
	Flo	310B	T4, 6, 8, 10
	Fhi	310B	T4, 6, 8, 10
	Jitter	310B	T4, 6, 8, 10
	Shimmer	310B	T4, 6, 8, 10
	Amplitude Perturbation Quotient	310B	T4, 6, 8, 10
	Formant Frequencies ( $F_1, F_2, F_3$ )	310B	T4, 6, 8, 10
Pulse Rate	Pulse Oximeter	310B	Continuous

BBL – Biobehavioral Laboratory; 310B – Acoustics Recording Room

Table 6.

*Time of Descriptive Variable Measurement*

Measure	T1	T2	T3	T4	T5	T6	T7	T8	T9	T10	T11	T12
Location	Call	BBL	BBL	310B	310B	310B	310B	310B	310B	310B	310B	310B
TEMP		X										
PULSE		X	X	X								X
RESP		X	X	X								X
BP		X	X	X								X
HT		X										
WT		X										
HSQ	X											
DIDS		X	X	X								X

BBL – Biobehavioral Laboratory; 310B – Acoustics Recording Room

Table 7.

### Time of Independent Variable Measurement

Measure	T3	T4	T5	T6	T7	T8	T9	T10	T11	T12
Location	BBL	310B	310B	310B	310B	310B	310B	310B	310B	310B
BPI	X									
SOPA-35	X									
BDI- II	X									
STAI	X									
STAXI	X									
ASES	X									

BBL – Biobehavioral Laboratory; 310B – Acoustics Recording Room

Table 8.

*Time of Dependent Variable Measurement*

Measure	T2	T3	T4	T5	T6	T7	T8	T9	T10	T11	T12
Location	BBL	BBL	310B	310B	310B	310B	310B	310B	310B	310B	310B
VAS-PI	X	X	X		X		X		X		
VRP			X		X		X		X		
EPRS	X	X	X		X		X		X		
Mean Pulse Rate			X	X	X		X	X	X		
Acoustic			X		X		X		X		
Measures			sit		stand		sit		stand		

BBL – Biobehavioral Laboratory; 310B – Acoustics Recording Room

## Instruments

### Pain Measures

Measures of pain intensity and unpleasantness and its effect on activities and attitudes were measured at baseline. Intensity and unpleasantness were assessed at intervals during the acoustic measurement session tasks.

#### *Brief Pain Inventory (BPI) (Cleeland, 1991b)*

The BPI is a 32-item, self-report instrument initially designed to provide measures of pain severity and pain interference of cancer pain in a format that was short and unambiguous (Daut & Cleeland, 1982). The instrument has two scales – pain severity and pain interference. The pain severity scale includes four items that rate pain at its “worst” and “least” in the last week, “on the average,” and “right now.” The pain interference scale includes seven items that describe impact of pain on general activity, mood, walking ability, normal work, relations with others, sleep, and enjoyment of life. Item response format is an 11 point numerical rating scale labeled as 0% - 100% for pain severity items and 0 to 10 for pain interference items. No algorithm for scoring is provided, but scale scores can be obtained by using the arithmetic mean of the four pain severity items and the seven interference items.

Validity of the BPI for use with non-cancer pain was first established with a sample of 250 primary care patients with arthritis and low back pain - osteoarthritis (56%), rheumatoid arthritis (44%), low back pain with worker’s compensation (50%), and low back pain without worker’s compensation (50%) (Keller et al., 2004). Internal consistency of BPI pain severity scale ( $\alpha = 0.89$ ) and for the BPI interference ( $\alpha = 0.95$ ) were similar to the



cancer pain results ( $\alpha = 0.77 - 0.91$ ). More recent studies with osteoarthritis samples (Mendoza, Mayne, Rublee, & Cleeland, 2006; V. S. Williams, Smith, & Fehnel, 2006) have supported the initial findings with Cronbach alpha coefficients ranging from 0.86-0.96 on six consecutive days using a modified short form of the BPI (Mendoza et al., 2006). Construct validity of the BPI using factor analysis determined that the best structure was a two-factor solution explaining 67% of the variance in earlier work, but a three factor solution that included eight items describing “pain intensity, impact of pain on mood, and impact of pain on physical activity” accounted for 86% of the variance with an osteoarthritis sample (Mendoza et al., 2006). Two items on the pain interference scale –“sleep” and “enjoyment of life” – did not load on one factor and were dropped from subsequent analyses in the Mendoza et al. (2006) study. Correlation of BPI scale scores with the Health Assessment Questionnaire (HAQ) (Fries, 1978), a condition-specific pain measure for arthritis disability usually considered as a quality of life measure, was moderate with  $r = 0.58$  for severity and was higher with  $r = 0.69$  for interference. High correlation with the generic pain measure, SF-36 (Rand Health Science Program, 1992; Ware & Sherbourne, 1992), and bodily pain scale ( $r = 0.74$  for BPI pain severity and  $r = 0.70$  for BPI interference) indicates that the two instruments measure similar constructs (Keller et al., 2004). Convergent validity of the pain scale was demonstrated by correlations at or above 0.60 with the pain visual analog scale (VAS) and Western Ontario and McMaster Universities Osteoarthritis Index (WOMAC) (Mendoza et al., 2006).

In this study, all items of the BPI pain interference scale were used to provide a scores used in describing self-evaluated effect of pain on function or disability. Inclusion of a body outline that the participant is asked to shade in the location where pain is present can

provide an indicator of pain involvement in other areas and was used in clarifying pain reported in non-pain subjects. Since the BPI provides valid and reliable measures of pain severity and interference with usual activities, has readability compatible with grade-school reading levels, and takes approximately 10-15 minutes to complete, it was selected for this study. Directions to participants noted that while the instrument was developed specifically for persons with cancer pain, it has been used with pain of other types. Changes were written for Item 21 on the BPI to indicate that the primary condition was “arthritis or knee pain” and a medical condition unrelated to the primary condition was “diabetes.”

*Survey of Pain Attitudes-35 (SOPA-35) (Jensen & Karoly, 1989; Jensen, Karoly, & Huger, 1987; Jensen, Turner, & Romano, 2000; Jensen, Turner, Romano, & Lawler, 1994)*

Three versions of the SOPA have been developed. A recent instrument is composed of 57 items and assesses seven pain-related beliefs thought to influence adjustment to chronic pain. These beliefs are defined as follows:

1. “Control – belief in one’s personal control over pain
2. Solicitude – belief in the appropriateness of solicitous responses from one’s family when in pain
3. Medication – belief that medications are appropriate for chronic pain problems
4. Disability – belief in oneself as unable to function because of pain
5. Emotion – belief in the relationship between emotions and pain
6. Medical cure – belief that a medical cure exists for one’s pain problem
7. Harm – belief that pain signifies damage and that exercise should be restricted.”  
(Jensen et al., 1994)

The original instrument had 24 items on five subscales – control, disability, medical cures, solicitude, and medication (Jensen et al., 1987). A second version included the emotion subscale and had 35 items (Jensen & Karoly, 1989). Because the length of the instrument precluded its use in many research and clinical settings, a shorter version based on criteria used to develop the SOPA-57 was developed (Jensen et al., 2000). Items were

retained from the original instrument if they had an absolute value correlation with the parent scale of 0.30 and a difference of greater than 0.10 between the item-parent scale correlation and the correlation between the item and each of the other scale. Five items per scale were selected. Responses were selected on a 5-point rating scale with 0 indicating the statement is “very untrue for me” and 4 indicating the statement is “very true for me.” Some items are reverse-scored. Subscale scores are calculated by adding all the ratings for items in the scale after transforming reverse-scored items and then dividing by the number of items answered in each scale. Higher scores indicate strong beliefs associated with pain behaviors. Internal consistencies of the SOPA-35 range from a moderate to high value of 0.66 for the Harm subscale to an adequate level ( $> 0.70$ ) for four subscales (i.e., Disability, Medical Cure, Pain Control, and Medication) to an excellent level ( $>0.80$ ) for Emotion and Solicitude. Test-retest reliabilities obtained at post-treatment to 2 weeks and 2 weeks to 1 month follow-up were greater than 0.70 for all subscales of the SOPA-35. Correlation of the subscales of the SOPA-35 and the SOPA-57 ranged from 0.91 to 0.98 at the one month follow-up.

Construct validity was established for the SOPA using comparison with criterion measures of pain coping responses with the Chronic Pain Coping Inventory (Jensen, Turner, Romano, & Strom, 1995), disability with the Roland-Morris Disability Scale (Roland & Morris, 1983), depression with the CES-D (Radloff, 1977), and number of physician visits for pain. Significant, moderate ( $r > 0.30$ ) relationships occurred with all subscales of the SOPA-35 and criterion measures except for the Medical Cure subscale. Subscales of any of the versions of the SOPA have strengths and weaknesses (Jensen et al., 2000) and the SOPA-57 is the most reliable with internal consistencies ranging from 0.70 to 0.84.

For this study, the scale score for disability provided a self-report of disability related to pain as well as other pain-specific attitudes. The disability scale demonstrated adequate internal consistency (Cronbach alpha raw = 0.74, standardized 0.75), and the instrument demonstrated similar internal consistency as a whole (Cronbach alpha raw = 0.77, standardized = 0.76 )(Jensen et al., 2000). The SOPA-35 was considered adequate for purposes of this study and chosen over the SOPA-57 due to subject burden of additional items. Format was changed to include 16 font typeface and printed on ivory paper to foster readability for the sample.

*Visual Analogue Scale (VAS) for Pain Intensity (Price et al., 1983)(Appendix 12) and Visual Analogue Scale (VAS) for Unpleasantness (Price et al., 1983) (Appendix 13)*

The visual analogue format used for both of these instruments is customarily a horizontal or vertical 10 cm line anchored at each end by labels that indicate the range under consideration, i.e., “no pain” and “pain as bad as I can imagine.” In addition to pain intensity, use of the VAS has been used to describe pain unpleasantness (Price et al., 2001). Persons are instructed to make a mark across the line that represents level of pain intensity or degree of “bother” with pain unpleasantness. Scoring of the VAS is done by measuring in millimeters the distance from the “no pain” end to the person’s mark; it provides interval level data. Because this scale requires measurement to obtain a score, care is needed to insure that copying of the scales provides a true 100 mm line for participants to mark. Lines were drawn on each instrument to insure accurate length was provided.

Validity of the VAS has been established using experimental and chronic pain (Price et al., 1983) and comparison with the numerical rating scale (Good et al., 2001). Once the participant understands the VAS, the instrument is completed in seconds making it useful

when rapid response is desired. Its use in clinical studies has demonstrated utility in analgesic dose effectiveness (Aubrun, Langeron, Quesnel, Coriat, & Riou, 2003) and studies of cognitive attention to odors and pain (Villemure, Slotnick, & Bushnell, 2003).

The Visual Analogue Scale for Pain Intensity (VAS-PI) requires careful instruction at the time of administration and careful examination of the marking, especially with non-pain subjects. It is important that subjects are instructed to mark across the line only if pain is present.

The Visual Analogue Scale of Pain Unpleasantness (VAS-UNP) requires careful instruction at the time of testing similar to that involved with the VAS-PI.

In this study, the VAS-PI and VAS-UNP were used to obtain real-time self-report of pain intensity and pain unpleasantness. The VAS can be completed while seated and after standing and added supplemental information to the pain intensity measured by verbal report.

#### *Verbal Rating of Pain (VRP) (Appendix 22)*

The Verbal Rating of Pain (VRP) scale asks a person to self-report pain intensity using a numerical rating scale in the sentence, “My pain now is about a \_\_\_\_ (where 0 indicates no pain and 10 indicates the worst pain you can imagine),” leaving the subject to complete the sentence with a number that best describes pain intensity (McDowell & Newell, 1996). Verbal pain ratings have been used in clinical trials of drugs as well experimental pain to provide a subjective measure of intensity (Gursoy et al., 2007; Price, Patel, Robinson, & Staud, 2008; Skovlund, Bretthauer, Grotmol, Larsen, & Hoff, 2005). In addition to a rating of pain intensity, the sentence used to obtain VRP was employed in the acoustic session of this study to capture the vowel /ə/ (i.e., “ah”) in connected speech with “a-bout” and “a.”

## Psychological Measures

Measures related to enduring emotional states, or moods, were collected one time in the BBL along with the baseline pain measures. Measures of emotion occurrence and intensity were assessed during the acoustic measurement session tasks at the same time the pain intensity and unpleasantness ratings were obtained.

### *Beck Depression Inventory - Second Edition (BDI-II) (Beck, Steer, & Brown, 1996)*

Since depression often co-exists with chronic illness and chronic pain, but may not be identified in primary care settings (Blackburn-Munro & Blackburn-Munro, 2001; J. W. Williams, Noel, Cordes, Ramirez, & Pignone, 2002) and potential suicidal risk is present, the Beck Depression Inventory - Second Edition (BDI-II) was used for case-finding capability and current mood. Composed of 21 items, the BDI-II is designed to evaluate levels of depression of adult and adolescents 13 years of age and older. The original BDI (Beck et al., 1961) evaluated depression based on appearance, thought content, vegetative signs, and psychosocial performance observed by psychiatrists. The BDI-II has been revised to assess symptoms listed for depressive disorder in the Diagnostic and Statistical Manual for Mental Disorders – Fourth Edition (American Psychiatric Association, 1994). Internal consistency of the BDI-II was evaluated with coefficient  $\alpha$  ranging from 0.92 to 0.93 provided by samples of psychiatric outpatients and college students, respectively. Test-retest reliability was determined with a small sample of psychiatric outpatients at their first and second therapy sessions. Tests one week apart found a significant correlation of scores ( $r = .93, p < .001$ ).

Construct validity has been tested comparing scores on the BDI-IA to BDI-II ( $r = .93$ ), the Beck Hopelessness Scale ( $r = .68$ ), the Scale for Suicidal Ideation ( $r = .37$ ), the

Beck Anxiety Inventory ( $r = .60$ ), the Hamilton Psychiatric Rating Scale for Depression ( $r = .71$ ), and the Hamilton Rating Scale for Anxiety ( $r = .47$ ) (Beck et al., 1996). Factorial validity of the BDI-II is evident in the intercorrelation of the 21 items; the iterated principal-factor analysis with Promax rotation identified two factors with eigenvalues of 4.61 and 4.41. The first factor is associated with somatic-affective aspect of self-reported depression. The second factor is more reflective of cognitive aspects of self-reported depression.

A person rates statements for the best description of how he or she has been feeling in the past 2 weeks, using a 4-point scale with 0 indicating the symptom listed is not present to 3 indicating symptom is present all the time. According to Williams et al. (2002), the BDI is reported as easy to read and takes from 2-5 minutes to complete. It can also be administered verbally (Beck et al., 1996). Item scores are added to produce interval level data as a depression score ranging from 0-63. Guidelines are provided for cutoff scores that include: 1-13, minimal depression; 14-19, mild depression; 20-28, moderate depression; and 29-63, severe depression. Studies have demonstrated that depressed individuals have altered speech rate and increased pauses (Alpert et al., 2001; Friedhoff et al., 1962). Because a prevailing mood of depression is likely to affect pain as well as voice, the BDI-II may provide a reliable baseline measure for later comparisons and analyses as well as a warning of possible suicidal risk since chronic musculoskeletal pain has a reported attempted suicide rate of 5% (M. T. Smith et al., 2004).

In this study, the BDI-II was used to determine the presence of depression and provide a measure of current depressed or sad mood. Prior to consent, potential participants were informed that if scores were at a level indicative of risk, a letter would be provided that they could take to their physician if they wished. Persons with scores in the mild-severe

range were told of the result and a letter that indicated BDI-II results (Appendix 21) was given to the participant to provide to her personal physician if she chose. Because the type face of the BDI-II was small and printed on a colored background, the format was modified to 16 font typeface on ivory paper to foster readability with this sample.

*Spielberger State-Trait Anxiety Inventory (STAI) (Spielberger, 1983)*

The STAI is a reliable psychological measure of transient or state anxiety. State anxiety is a condition that may fluctuate depending on situations and the individual's proneness to anxiety, or trait anxiety. The two scales of the STAI have a total of 40 items, with each scale's 20 items rating how subjects generally feel (trait) and how they feel at a specific time (state) using a 4- point scale where 1 = "not at all" and 4 = "very much so" providing ordinal level data. The instrument is written at a fifth grade reading level and may take 5 to 10 minutes to complete.

Internal consistency using Cronbach's alpha coefficients is reported to range from 0.83-0.92 for state anxiety and 0.86 to 0.92 for trait anxiety. Test-retest reliability coefficients are reported to range from 0.73-0.86 and 0.86-0.92 for trait anxiety, but somewhat lower for state anxiety with coefficients ranging from 0.16-0.54 and 0.83-0.92 (Soderstrom & Grimm, 2004). Construct validity has been determined in medical patients (Derogatis & Wise, 1989).

There is evidence that women 75 years of age and older score higher on trait anxiety scale of the STAI than men of the same age. Scores on anxiety scales often are significantly correlated with the Beck Depression Inventory as these measures contribute to distress or negative affectivity (D. A. Clark, Steer, & Beck, 1994). Reasons for this correlation may be due to a variety of reasons: (1) anxiety and depression may coexist together, (2) the two



conditions may have the same underlying cause, (3) one condition predisposes the individual to the other condition, and (4) definitional overlap results in similar items on diagnostic instruments (Frances et al., 1992).

In this study, the instrument was used to provide measures of the current (or state) and enduring (or trait) level of anxiety since anxiety was expected to affect vocal measurements. The format was modified to 16 font typeface on ivory paper to foster readability with this sample.

*State-Trait Anger Expression Inventory-2 (STAXI-2) (Spielberger, 1999)*

While the State-Trait Anger Scale (Spielberger et al., 1983) provided information on the frequency and intensity of anger, it became clear to the instrument developers that expression of the anger and the degree to which a person tries to control anger was also important. The tendency to hold angry feelings in, i.e., “anger-in,” was associated with cardiovascular changes like hypertension and coronary heart disease (Julius, Harburg, Cottington, & Johnson, 1986). Expression of anger through aggressive behavior motivated by angry feeling, i.e., “anger-out,” was associated with significantly lower diastolic blood pressure and slightly lower systolic blood pressure. Anger expression and anger control scales were developed by asking the participants to respond with how their anger usually is expressed and how they control anger (Spielberger, 1999). Acoustic measures of vocal expression of emotion have reported characteristics of anger in voice (Johnstone & Scherer, 2000). Anger is associated with chronic pain (Fernandez & Turk, 1995) along with the inability to verbalize negative feelings (Kerns et al., 1994).

In this study, the STAXI-2 scores on state and trait anger scale were used to provide a current (or state) and enduring (or trait) measure of angry or irritated mood. The STAXI-2

was selected to determine if a relationship to acoustic measures existed with this sample. Format was changed to foster readability with this sample using 16 font typeface and printing on ivory paper.

#### *Emotion Presence and Rating Scale (EPRS) (Appendix 14)*

The emotion presence and rating scale was developed by the investigator and has not been validated. The EPRS was intended to provide a self-report measure of the occurrence of three specific emotions. It was introduced at the same time other cognitive evaluations were requested to isolate that activity from the vocalization and physiological measures. The subject was asked to evaluate if she was irritated or angry, sad or depressed, and anxious or fearful by circling “yes” or “no.” If the participant answered “yes,” she was asked to indicate how much she felt that emotion by rating the experience from 1 = slightly to 3 = very much. Scoring consists of 0 for “no” response, 1 for “slightly,” 2 for mid-range selection, and 3 for “very much.” Scores could range from 0 to 9. The EPRS has not been validated and was used only to determine if the subject experienced different emotions during the study. Few subjects reported experiencing emotion during the intervals of the study. In this study, the scale attempted to measure occurrence of short-term intensity of the emotion experienced. The instrument used a 16 font typeface and was printed on ivory paper.

#### *Acoustic Measures*

Acoustic samples were recorded using the Computerized Speech Laboratory and analyzed using software associated with that program as well as the Multi-Dimensional Voice Program.

*Computerized Speech Laboratory (CSL) 4500 (KayPENTAX, 2004)*

Vocal signals were obtained and analyzed using software programs developed by Kay Elemetrics for use with their Computerized Speech Laboratory (CSL) with Multi Dimensional Voice Program (MDVP). Records were saved as .wav files. CSL is a hardware and software speech analysis system that includes acquisition, playback, editing, and analysis capabilities. The Model 4500 has four channel capability, phono and XLR connections, and preamplifier. It has a 24-bit quantization range, and can sample at a total rate of 200 kHz, or 50 kHz per channel. The system can provide pitch, intensity, Fast Fourier Transform series data, digital filtering, and data log features. CSL requires a host desktop computer that incorporates a PCI card interface (KayPENTAX, 2004). The Dell Optiplex Pentium 4 desktop computer with 504 MB of RAM and a 2.8 GB hard-drive and a sound card designed for voice evaluation had been installed by KayPENTAX in the Model 4500. The system provides high quality measurement of speech parameters and avoids some measurement error that environmental noise and regular laptop and desktop sound cards introduce (Deliyski, Evans et al., 2005; Deliyski, Shaw et al., 2005).

Pitch contour, energy contour, formant history, voiced period marks, spectrogram, linear predictive coding and fast Fourier transform analysis settings were configured in advance of subject recruitment (Figure 6 and 7). The configurations were used with every subject.

Time for the investigator to learn the system and analyses was required. Experience with linguistics/phonetics, recording and analysis was necessary. Expert advice on configuration cannot be overstated and was obtained from Dr. David Zajac, Associate

Professor, Craniofacial Research, School of Dentistry, University of North Carolina at Chapel Hill. In addition, customer support at KayPENTAX provided excellent advice.

*Multi-Dimensional Voice Program (MVDV)(KayPENTAX Corporation, 2005)*

MDVP is an optional software program for the CSL system. The advanced level program is capable of calculating 22 different voicing parameters and includes comparison to a database. The program is used primarily in analysis of dysphonic voice but studies have also used MVDV in analysis of normal voices (Bhuta, Patrick, & Garnett, 2004; Nicastrì, Chiarella, Gallo, Catalano, & Cassandro, 2004; Pützer, 2001). It requires the professional hardware associated with CSL for high quality voice acquisition. In addition to the ability to record multiple tokens in succession, MDVP provides a radial graph comparing subject data to normative values. Use of MVDV with CSL is reported to provide more accurate jitter and shimmer measurements in an environment where computer fan noise is present (Carson, Ingrisano, & Eggleston, 2003). Because computer fan noise and other environmental noise were expected, MVDV provided a more reliable method of measurement and analysis than other systems available. This program allows for adjustment of the wide-bandwidth setting to 450 Hz to accommodate high-pitched speakers possible in an all female sample. Configuration is nearly identical to CSL settings (Figures 4 and 5).

Range of  $F_0$  is not directly obtained from CSL or MDVP, but was determined by subtracting  $F_{lo}$  from high fundamental frequencies ( $F_{hi}$ ) measurements provided by MDVP. Range of  $F_0$  indicates the variation in frequencies used by an individual. In this study, range provided information of the frequencies used by a subject when phonating a vowel for four seconds. Because  $F_{lo}$ ,  $F_{hi}$ , and range of  $F_0$  are fundamental frequency derived measures,

these measures may be detected by human hearing and would be important to perception and intervention studies in the future.

Analysis	Setting	CSL	MDVP
Spectrogram	Analysis	75 points	75 points
	Window weighting	Blackman	Blackman
	Pre-Emphasis	0.80	0.80
	Frequency Display	Linear	Linear
	Show % Nyquist	0 -100%	0-100%
Voiced Period Marks	Impulse location	Zero crossings	Zero crossings
	Range	70-300 Hz	70-300 Hz
	Zero offset	0	0
Pitch Contour	Analysis	Pitch Synchronous	Not checked
	Range	70-350 Hz	70-350 Hz
	Smoothing	None	None
	Pitch sensitivity	Default - 100	Default - 100
Energy Contour	Analysis	Pitch synchronous	Pitch synchronous
	Display range	30-80 dB	30-80 dB
Formant History	Analysis	Autocorrelation	Autocorrelation
	Filter Order	24	24
	Window-weighting	Blackman	Blackman
	Pre-Emphasis	0.900	0.900
	Framing	Use VPM	Show only voiced
	Frame size	10 msec unvoiced	25 msec
	Frame advance	Default -10 msec	Default – 10 msec
	Frequency Display	Linear	Linear
	Show % Nyquist	0-100 %	0-100 %
	Show	Formants with	Formants with
		BW< 500 Hz	BW< 500 Hz

*Figure 4.* Configuration of settings for Computerized Speech Laboratory and Multi-Dimensional Voice Program.

Analysis	Setting	CSL	MDVP
Linear Predictive Coding	Analysis	Pitch Synchronous	Pitch Synchronous
	Analysis Method	Autocorrelation	Autocorrelation
	Frame Length	20 msec	20 msec
	Filter Order	24	24
	Window-weighting	Blackman	Blackman
	Pre-Emphasis	0.9	0.9
	Display		
	X-Axis		
	Show % Nyquist	0-100%	0-100%
	Y-Axis	-20 to 30 dB	0-80 dB
	Smoothing Level	-	None
	Frequency Report	Hz	Bark and Hz
FFT Analysis	Analysis		
	Size	1024 points	1024 points
	Frame Size	Match FFT size	Match FFT size
	Window-weighting	Blackman	Blackman
	Pre-Emphasis	0.0	0.0
	Display		
	X-Axis	0-4000 Hz default	
	Show % Nyquist	0-100%	0-100%
	Y-Axis	0-80 dB	0-80 dB
	Smoothing Level	None	None
	Frequency Report	Hz	Bark and Hz

*Figure 5.* Configuration of settings for Computerized Speech Laboratory and Multi-Dimensional Voice Program (Continued).

The timing of the acoustic variables is outlined (Figures 6 and 7). Time 4 readings took place while seated after the movement from the BBL. While effect of movement to the acoustic testing room was acknowledged, Time 4 measurements provide an “at rest” recording and might be considered “baseline.” Written measures of pain intensity, pain unpleasantness, and emotion presence took place after the vocal tasks at the same time point.



Variable Name	Abbreviation	Definition	T4	T6	T8	T10
			First	First	Second	Second
			Seated	Stand	Seated	Stand
Fundamental Frequency	$F_0$	Rate at which a waveform repeats per unit of time expressed in Hz, one cycle per second	X	X	X	X
Mean Fundamental Frequency	$MF_0$	Average of fundamental frequencies during phonation	X	X	X	X
Lowest Fundamental Frequency	$F_{lo}$	Lowest fundamental frequency for all extracted pitch periods in an utterance	X	X	X	X
Highest Fundamental Frequency	$F_{hi}$	Highest fundamental frequency for all extracted pitch periods in an utterance	X	X	X	X
Range of $F_0$ Frequencies	Range	Difference between highest fundamental frequency and lowest fundamental frequency	X	X	X	X

*Figure 6.* Acoustic dependent variables and measurement schedule.

Variable Name	Abbreviation	Definition	T4	T6	T8	T10
			First	First	Second	Second
			Seated	Stand	Seated	Stand
Jitter in Percent	Jitter	Aperiodic irregularity in glottal pulses relative evaluation of period to period variability in pitch within analyzed voice sample	X	X	X	X
Shimmer	Shimmer	Aperiodic irregularity in intensity; perturbation of amplitude	X	X	X	X
Amplitude Perturbation Quotient	APQ	Relative evaluation of period-to-period variability of the peak-to-peak amplitude at smoothing of level of 11 periods	X	X	X	X
Mean Formant Frequencies	F <sub>1</sub>	Mean resonances of the vocal tract or overtones	X	X	X	X
	F <sub>2</sub>					
	F <sub>3</sub>					

Figure 7. Acoustic dependent variables and measurement schedule (Continued).

## Continuous Physiological Measures

### *Datex-Ohmeda 3900 Pulse Oximeter (Datex-Ohmeda, 1998)*

Arterial oxygen saturation and pulse rate was measured by the Datex-Ohmeda 3900 Pulse Oximeter (Datex-Ohmeda, 1998) that is able to transfer current or trend SpO<sub>2</sub> and pulse rate analog data to a computer. Use of heart rate as a physiological measure of arousal has been used in emotion studies (Bazhenova, Plonskaia, & Porges, 2001; Crucian et al., 2000). In order to avoid the need to have participants disrobe and have electrocardiogram leads attached that could restrict movement, and because telemetry was not affordable, pulse oximetry was employed. Pulse rate, not heart rate, is reported. It is unclear that a chronic pain induces arousal before movement, in anticipation of movement, or after movement. Because movement alone causes an increased heart rate, monitoring of pulse rate provides a physiological measure to assess if arousal occurs. Pulse rate was checked before the command to stand, e.g., anticipation of stand task, in order to provide more accurate determination the timing of pulse rate changes.

The default low SpO<sub>2</sub> alarm is set at 85% with the Datex-Ohmeda 3900 pulse oximeter. Pulse rates may range from 20 to 255 beats per minute (bpm), making this monitor capable of use with infants as well as adults. Alarms can be set to signal high pulse rate at 130 bpm and low rate 40 bpm but were silenced for the study. Averaging mode is set for every 12 seconds but can be adjusted to a short interval of 3 seconds and a medium length interval of 6 seconds. Since change in emotional state is reported to be short (Rainville et al., 2005; van Reekum et al., 2004), the 3 second interval was chosen for this study to provide

more accurate pulse rate changes. Synchronization of the pulse oximeter and video camera clock to the computer clock was essential to allow analysis of events and pulse rate.

A finger sensor was attached to the middle finger of the non-dominant hand to allow marking of written instruments. The clip-on sensor designed for adults was found to be loose on many women's fingers requiring tape around the sensor to prevent lost data. Consequently, a pediatric sensor was used and, when taped, was less bulky and more reliable with movement. Use of hypoallergenic tape seemed sufficient to secure the sensor. Nail polish did not affect the signal capture. While nail polish remover packets were available, none was used.

The A-to-D converter was attached between the output of the pulse oximeter and the computer where WinDaq software was used to collect and digitize both SpO<sub>2</sub> and pulse rate data. While SpO<sub>2</sub> data were screened, analysis was not included in this investigation as respiratory disease was an exclusion criterion. Electrical inspection of this equipment was handled by the BBL and UNC Hospital Medical Engineering.

In this study, the average pulse rate of a three second sample was determined at six times: (1) Time 4 while seated before vocal tasks, (2) Time 5 before first command to stand, (3) Time 6 after standing and vocal tasks, (4) Time 8 while seated before vocal tasks, (5) Time 9 before second command to stand, and (6) Time 10 after standing and vocal tasks.

#### Physical Function

##### *Sony Handicam Digital Camera Recorder Model DCR TRV103*

The Handicam video camera was situated on a tripod and was used to capture head-to-toe recording of the sit-to-stand movement tasks. Although the picture quality was not of

high resolution due to lighting, it was adequate and use of two camera set-up would have been difficult for the investigator to manage. Recording on tape required digitization and re-recording to CD. Only the ID number was saved on the recordings. Protocols for equipment set-up included synchronization of the camera time with the computer clock where physiological data is being captured.

In this study, the difference in time of the first indication of intent to stand and time when the subject was standing with weight on both feet and hands at sides was determined as sit-to-stand time for both tasks. Shorter sit-to-stand times were expected to be indicative of physical pain and disability due to osteoarthritis or joint pain. While the plan was to time the sit-to-stand tasks using the time stamp on the recording, it was necessary to have slower, frame-by-frame advancement capability to determine onset of movement as well as completion of stand. Use of Observer XT provided more accurate timing of the responses. The timing format (minutes:seconds.thousandths of a second) reported by Observer could not be directly imported into Excel and then to SAS (minutes:seconds.hundredths of a second). Reconfiguration of the data was required.

*Arthritis Self-Efficacy Scale (ASES) (Lorig, Chastain, Ung, Shoor, & Holman, 1989; Stanford Patient Education Research Center)*

The ASES was developed using rheumatologist and patient focus group participation in item generation. A subject rates certainty of ability, or self-efficacy, to perform a variety of activities on an interval scale ranging from 1 = “very uncertain” to 10 = “very certain,” providing ordinal level data. Internal consistency reported with coefficient  $\alpha$  estimates for the physical function self-efficacy (FSE) scale with 9 items was .89, for the other arthritis symptoms self-efficacy (OSE) scale with 6 items was .87, and for the pain management self-

efficacy (PSE) scale with 5 items was .76. Factorial validity was evaluated and three factors, self-efficacy for physical function (FSE) associated with function or disability, self-efficacy for controlling other arthritis symptoms (OSE) highly related to depression, and pain management self-efficacy (PSE) were identified in a replication study (Lorig et al., 1989). A correlation of .61 between patient perceived performance and actual performance rated by trained, but blinded, observers is moderately high and establishes concurrent validity of the FSE subscale (Lorig et al., 1989; Redman, 1998).

The ASES self-efficacy for physical function scale was used to provide a self-report of physical ability to perform specific activities requiring large and small musculoskeletal movement with higher scores indicating confidence in ability to perform activities and lower score indicating reduced confidence in ability to perform the activities. This score was expected to contrast with the objective measure of disability (i.e., the sit-to-stand times) and the subjective measure of disability (i.e., the BPI pain interference scale score). A difference in acoustic parameters of persons scoring higher on self-efficacy scales and persons with lower self-efficacy scores was anticipated. The downloaded format from the Internet had small font that would be difficult for an older sample to read. Format was changed to 16 font typeface and printed on ivory paper to foster readability of this sample.

## Descriptive Variables

### *Health Screening Questionnaire (HSQ) (Appendix 6)*

The Health Screening Questionnaire was an investigator-designed instrument used to determine the presence of medical conditions that would exclude potential participants from the sample. Because this screening took place prior to written consent, care was taken to

maintain the privacy of the caller by obtaining verbal consent prior to asking about categories of conditions that could interfere with ambulation or respiration.

#### *Demographic Information and Data Sheet (DIDS) (Appendix 10)*

This investigator-designed form was intended to be a guided interview tool used following enrollment to collect information about age, ethnicity, education, and occupational experience not included on other forms but needed to answer the research questions. In addition, the form included space for recording of physical data like height, weight, BMI, and vital signs for later data entry.

### Procedure

#### Recruitment

After obtaining approval from the Nursing Institutional Review Board at the University of North Carolina at Chapel Hill (Appendix 2) and permission from retailers, community groups, and university authorities, flyers, some with cards including telephone number to call for information, (Appendix 3) were provided to senior centers, pharmacies, a wellness center, a public library, a community group, an orthopedic nurse practitioner, two retirement communities, a grocery store, a fitness center, physical therapy centers, and campus buildings. These agencies were contacted and provided approval for posting of the flyers (Appendix 5).

Cards with the name of the study – “Voice and Knee Pain Study” - and the local telephone number to call for more information were included in a pocket on two flyers or as a tear-off strip with study name and telephone number on flyers. Recruitment of the non-pain group required an additional flyer design and broader posting.

Telephone access had recording capability and provided a message notifying callers about the “Voice and Knee Pain Study” requesting the caller to leave a number for a return call between 6:00 and 9:00 PM. The investigator used a telephone script (Appendix 4), asking how the person heard about the study and explaining that the study’s purpose was to determine whether the impact of pain can be detected in voice. The initial screening criteria, e.g., female 45 years of age or older with OA of the knee and pain lasting 6 months or more for the pain sample or female 45 years of age or older without joint pain on movement for the non-pain sample, were reviewed to determine if the caller qualified. The recruitment telephone interviews were held in the evening so privacy was maintained at the investigator telephone. If the volunteer met initial screening criteria, she was told that she might qualify and was asked for verbal consent for the interviewer to ask more detailed questions about age, ethnicity, diagnosis of osteoarthritis, treatment of pain, and health problems included in the Health Screening Questionnaire (HSQ) (Appendix 6) that could affect voice and that the interview would take approximately 15-20 minutes. If the time was not convenient, permission to call later was obtained. If the time was convenient, the Health Screening Questionnaire was administered and provided self-reported information about existence of health conditions. Responses to interview and health screening questions were self-reported by volunteers. After review of the volunteer’s responses to exclusion criteria listed in the health screening questionnaire, determination of status as a study participant was made.

If qualified, the volunteer was asked if she would participate in testing that required travel to UNC School of Nursing and stay for 2-2.5 hours. Afternoon or early evening appointments were preferred to allow for parking and easier building access for persons with



limited mobility as well as to avoid interference with circadian rhythm effects on heart rate variability in persons with chronic conditions (Burger, Charlamb, & Sherman, 1999).

The volunteer was told that during her appointment, she would receive two copies of the Informed Consent that outline the details of participation. If she agreed to participate, she would sign one copy to remain with the study investigator and the unsigned consent would be given to the participant. The study session would begin after the consent was signed.

Timing of subject activities and measurements were described to the volunteer caller (Figure 10). First, she would have her routine vital signs measured including temperature, pulse, respirations and blood pressure - as well as height and weight. Then she would complete several written tests that take approximately 1 hour. She would receive a sandwich snack, beverage and water. She would also be asked to rate her pain and emotions at intervals. During the part of the study where voice and movement were recorded with audio and video equipment, she would be fitted for and wear (1) head-mounted microphone and (2) pulse monitoring device that involves attaching a small device to a finger. After performing three vocal tasks, she would need to rise to a standing position from a seated position and remain standing for about 3 minutes two different times. She would receive 30 dollars in appreciation for her participation, transportation costs, and parking. She was also told she could withdraw at any time.

Permission was requested for mailing address and a telephone number where the volunteer could receive a follow-up letter (Appendix 7) and a call on the day of the appointment to remind her of the date and time of the session as well as directions to the BBL and parking. The volunteer was asked not to eat a large meal before coming to the appointment. Address information and telephone number were obtained and recorded on the

intake form in the log book. The caller was reminded to keep the card with the Voice and Knee Pain telephone number that she called since that number would always be a way to reach the study director. After asking if there were any further questions, the caller was thanked for her interest in participation. A mobile telephone number was provided in the follow-up letter and during the telephone contact on the day of the study in case the participant needed directions.

The interviews usually lasted 15-20 minutes with much of the time spent scheduling, obtaining a mailing address, and snack preferences. Check of the room schedule at the time of scheduling was important. Once the appointment was scheduled, the letter with map and instructions was prepared and mailed.

## Enrollment

The protocol for the enrollment and the consent form is provided (Appendices 8 and 9). Prior to meeting the volunteer, the investigator set-up of equipment required 30 minutes (Appendices 19 and 20). Subjects were called to verify arrival time and time allowed after equipment set-up to hold a parking place for the subject. Volunteers were escorted to the BBL and walking ability was assessed as they walked the sidewalks and hall. Once inside the BBL, the plan for the study was discussed and the consent provided. A timeline of study activities indicates the physical activity required of the subject (Figure 8) and measures that taken at different time-points and in different rooms – the Biobehavioral Laboratory and Room 310B.

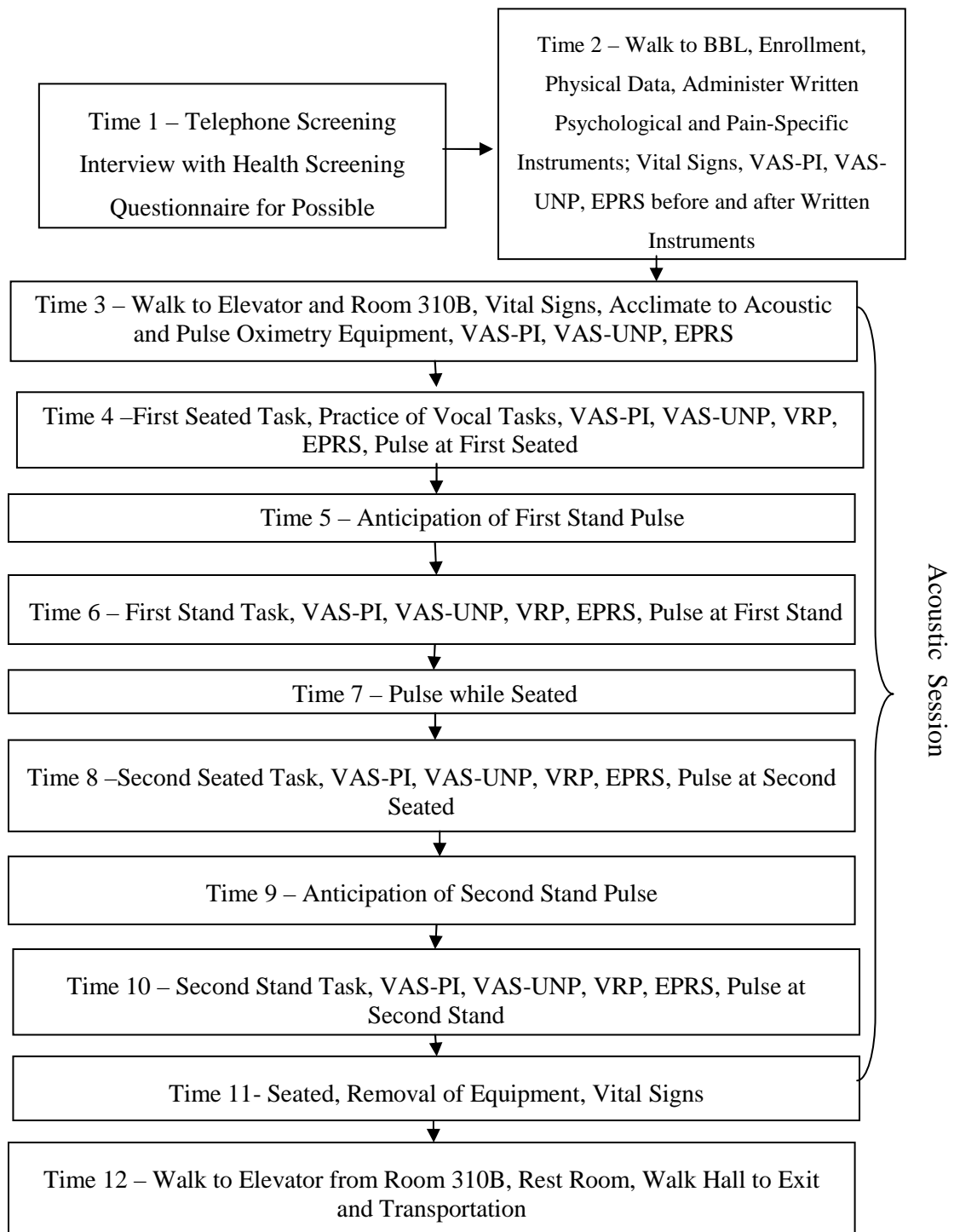


Figure 8. Timeline for subject activities.

## Baseline Data Collection – BBL.

The demographic data and information sheet (DIDS) (Appendix 9) was completed with only the assigned identification number listed (i.e., mmddyy#). Various equipment was used in the collection of physical measurement data (Figure 9). After the baseline vital signs, height, and weight were obtained, the subject began completion of written instruments.

Several printed instruments were used in the study to assess subject temperament, attitudes, pain intensity, and pain unpleasantness that required subject completion. When instruments were first purchased and/or obtained, it became clear that they were not designed for the visual needs of an older population. Several required reprinting to increase readability. Written instruments were printed on ivory paper instead of white to foster readability. In addition, because a font size of 16 is recommended with older adults with visual deficits, instruments were reproduced in a 16 font size. Order of instrument administration was varied by altering the order of the tests in each packet with the BPI given last to encourage focus on pain. Time required for testing was estimated based on reports and confirmed in the feasibility study (Table 9).

Measurement	Equipment
Weight	Scale-Tronix 5600 Portable Stand On Scale
Height	Perspective Enterprise Stadiometer
Temperature	IVAC Electronic Oral Thermometer
Pulse	Dinamap 1846 SX
Blood Pressure	Dinamap 1846 SX
SpO2	Datex-Ohmeda 3900 pulse oximeter

*Figure 9.* Equipment for baseline physical measurements.

Table 9.

*Instrument Completion Times*

Instrument	Time to Complete
BPI	10 minutes
STAI	10-20 minutes
STAXI-2	12 -15 minutes
BDI-II	5-10 minutes
SOPA-35	7-10 minutes
ASES	5-10 minutes
VAS-Pain Intensity	Less than 1 minute
VAS –Pain Unpleasantness	Less than 1 minute
Emotion Presence and Rating Scale	Less than 1 minute
Total	Approx. 1.25 hours

After one-half hour of testing, or if the participant appeared fatigued, a 10-minute break with a beverage was offered and provided. After completing the instruments, the participant was provided a sandwich snack and beverage and a restroom break. Effort was taken to put subjects at ease prior to the acoustic testing to reduce anxiety and stress that could interfere with measurement of the influence of pain on movement that was estimated to be of small effect size. Scoring of the BDI-II was completed during this time to determine if there was a need for referral (Appendix 17). Five women were given letters they could provide to their health care providers.

## Acoustical Data Collection – Room 310B

After completion of the written instruments and a snack, the subject moved to the acoustics session in Room 310B where the recording session began (Appendix 21). While the CSL system was loaded on a pneumatic-wheeled cart to allow transport to the study area and safe storage, this type of transport is not recommended for acoustical instrumentation. The size and nature of equipment makes transport to various clinical sites difficult and not recommended due to the sensitivity of the instrumentation.

Because the quality of acoustic measures relies on high quality acquisition, the AKG C420 head-mounted condenser microphone with 20-20kHz frequency response and a cardioid response pattern (AKG Acoustics) was added to the CSL system. Head-mounting allowed for the movement required in this study. This microphone has been recommended for voice measurement (Titze & Winholtz, 1993) and has been found to introduce very little noise when used with the CSL system (Deliyski, Evans et al., 2005). The CSL system includes a desk-mount microphone that would not be compatible with movement required.

The microphone head was placed 5 cm from the corner of the subject's mouth. Check of the sound transmission by having the participant speak normally was performed to assure quality of the signal and amplitude of at least 60 dB, or 30 dB above the nearly 30 dB level of room noise.

Data were collected and inputs processed by a Dell Optiplex Pentium 4 desktop computer with 504 MB of RAM and a 2.8 GB hard-drive. The Computerized Speech Laboratory (CSL) and Multi-Dimensional Voice Program (MDVP) were configured to use the multiple token protocol with sustained vowels in MDVP and analysis of the connected speech samples in CSL.

Multi-channel physiologic recorders can be connected through A-to-D converters attached to computer and WinDaq data acquisition software (Dataq Instruments Inc., 2002) was installed on the hard drive to collect the recorded data. An event marker and vocal announcement audible on the videotape was included to aid in synchronizing the video data, acoustic analysis, and physiological data for analysis. Pulse rate data were acquired via Datex-Ohmeda 3900 pulse oximeter set that averaged pulse rate every three seconds and transmitted to the A-to-D converter. Video recording used a camcorder camera on a tripod to allow more accurate coding and analysis of the sit-to-stand transitions. The video camera clock and computer clock were synchronized in the equipment set-up. The length of time to rise from a sitting position to a vertical standing position was to provide an indicator of disability.

It was necessary to be aware of a change in pain intensity and occurrence of an emotional change to determine if these measures correlated with the acoustic parameters of voice. Therefore, frequent assessments of pain intensity, pain unpleasantness, and emotion presence were made (**Error! Reference source not found.****Error! Reference source not found.**).



Table 10.

*Dependent Variables Associated with Physical Activity and Measurement Times*

Variable Name	Instrument/Subscale	Time of Administration
Pain severity now	VAS-PI	T 2,3,4,6,8,10
Pain unpleasantness	VAS-UNP	T 2,3,4,6,8,10
Sad Now	0 to 3 rating	T 2,3,4,6,8,10
Angry now	0 to 3 rating	T 2,3,4,6,8,10
Anxious now	0 to 3 rating	T 2,3,4,6,8,10
Mean Pulse Rate	At rest, seated	T4, T8
Mean Pulse Rate	At anticipation of stand	T5, T9
Mean Pulse Rate	End of complete stand	T6, T10

Once in the test room, several activities occurred: vital signs were taken; VAS-PI, VAS-UNP, and EPRS were completed; subject was acclimated to the equipment (i.e., microphone and pulse oximetry); and instruction and practice of the three verbal tasks and the movement tasks were performed (Appendix 21).

The microphone and pulse oximeter were shown to the participant and explained. Persons wearing glasses were asked to take them off while the microphone was situated and then glasses were replaced. Placement of the microphone head was set at 5 cm from the corner of the mouth, but might be able to be moved out farther as cardioid pattern may be able to capture the signal at a greater distance. Once the equipment was in place, the microphone was demonstrated and the participant's recorded voice and heart rate was observed on the computer screen and the pulse oximeter monitor. Observation of pulse rate

and participant comfort was assessed during equipment placement to note signs of increased anxiety that could affect written testing and vocal samples. Time to allow participant training and relaxation was anticipated to take 10-15 minutes, but a reduced time frame was used when comfort was reported by the participant. Practice with the subject phonating to ensure 60-65dB intensity was done prior to the actual recording. All participants were offered and provided water to insure adequate moisture in the oral cavity at the beginning of and during the session. Alarms were silenced to avoid influencing participant and recording. Once activation of the video camera, the WinDaq software, and MDVP program occurred and the subject was instructed, the investigator coordinated recording, signaled the subject, triggered the event marker, and saved sound files.

In order to capture frequencies of voice, a sampling rate of 22.05 kHz (i.e., employing Nyquist frequency, or a frequency greater than half the sampling rate) is usually sufficient to capture frequencies of voice. Aliasing can occur if a "...continuous signal contains frequency components that are higher than half the sampling rate" (Johnson, 2003 p.23). The signal completes more than one cycle between successive samples and the sample appears to be from a lower frequency waveform, totally missing the higher frequency components. In order to avoid aliasing and insure acquisition of the data needed, a sampling rate of 44.1 kHz was selected in the MDVP computer software for recording. Sound files were saved as .wav files on the computer and copied onto a compact disk. Identification numbers were assigned to the participant files, with "a" and "c" indicating the seated recordings and with "b" and "d" indicating the standing recordings. The vocal segment of the study was explained to the participant. All participants were offered water to moisten the oral tract as resonances are affected by lack of moisture. The participant sat comfortably in a chair with arms such that

the participant's back rests against the back of the chair and both feet were flat on the floor. No table was in front of the participant to allow the video camera to capture the movement of the sit-to-stand sequence.

The investigator demonstrated the vowel that the participant would say, holding it for 4 seconds. Because a number of prolonged vowel utterances were recorded, each particular instance is referred to as a token (*Oxford English Dictionary Online*, 2005). In order to obtain a sufficient number of tokens for analysis (R. C. Scherer, Vail, & Guo, 1995), multiple tokens protocol in the MDVP advanced program was used (5 tokens x 2 seated tasks x 2 standing tasks = 20 tokens). The investigator used a hand signal to indicate when the first vowel should be started and when the each succeeding speech token should begin and nodded her head when the screen was filled and vocal production could be stopped. The subject was advised to indicate when she needed to rest or take a drink of water.

When the participant indicated readiness, the signal was given and the participant phonated, or said, the vowel /ə/ and repeat the vowel five different times with approximately 30 seconds between each token. The participant was then asked if she was having pain and asked to say, "My pain now is about a (number from 0-10)" (Appendix 22). Capture of two additional clear /ə/ tokens with "a-bout" and "a" in the sentence, "My pain now is about a \_\_\_\_ (0 – 10)," were planned. Many speech samples were either absent or too short to be used for connected speech analysis. Prompting for the vowel change during the session was ineffective as it often resulted in subjects overemphasizing the vowel intensity or reverting to use their normal, automatic /e/ (i.e., "ay") or /eɪ/ (i.e., "ay-ē") after one or two focused

efforts. The subject then completed the written VAS for pain intensity and unpleasantness and the EPRS.

On completion of the seated recordings, the participant was asked to rise from the chair and stand with weight distributed equally on both legs and feet. The event marker was activated immediately prior to the command to stand was given. Two event marks were activated when participant made her first move to rise – arms or hands move or on armrests or move back forward from chair. When both feet had equal weight distribution, i.e., no leaning to one side, and the back was upright, the event marker was activated three times. Videotape was used to provide audio record of the event marker activation and the sequence in which participants respond and stand in order to determine lag time and estimate disability by time from sit to fully standing with arms at sides. In order to capture the early signs of change due to movement or pain, the participant was asked to begin phonating once fully standing – approximately 30 seconds after standing. The subject provided 5 /v/ tokens as before, and completed the connected speech sample, i.e., “My pain is about a (0-10).” The participant was asked to rate pain intensity and unpleasantness on the VAS scales again and rate emotional presence on numerical rating scales.

The participant was asked to sit and the event marker pressed 4 times when participant was seated. When seated with the back touching the back of the chair, the participant was given the opportunity to take a drink of water. Then the third series of five tokens and the connected speech sample were collected and another set of written ratings of pain intensity, pain unpleasantness, and emotion presence were completed.

Prior to giving the second command to stand one long and one short event mark was made. Movement to rise – e.g., movement of the head, arms or hands to armrests, or back from back of chair – received one long and two short event marks. When the participant completed standing, the event maker was struck one long and three short times. After standing for 15 seconds with weight distributed on both feet, the participant phonated /ə/ five times with approximately 30 seconds between each token and then stated, “My pain is about a (0-10).” After completing the five tokens and the connected speech sample, the participant was again asked to rate pain intensity, pain unpleasantness, and emotion presence. The participant sat down, and once seated, one long and four short event marks were made. After allowing a short period of time while the subject was seated at rest, the WinDaq program was stopped and the pulse oximetry file saved to a separate subject file. The microphone and pulse oximetry sensor were then removed.

Vital signs consisting of pulse, respirations, and blood pressure were obtained and recorded at intervals. Pulse rate below 60 and over 100 beats per minute and blood pressure above the established norm of 140/90 for hypertension (Bickley & Szilagyi, 2007; Chobanian et al., 2003) were considered abnormal. If vital signs were found to be above or below normal, the participant was provided with a card with the readings on it (Appendix 16) and a letter of referral to provide to her physician (Appendix 18). Seventeen women were given letters for increased blood pressure and 2 women were given letters for low blood pressure. If there was no physician of record, the subject should not have been enrolled. However, plans included the possibility of referral to Student Health Action Coalition or the UNC emergency room. No women were referred to these agencies. The participant was provided opportunity

to use the restroom prior to departure and was given \$30 for time, parking, and gas.

Participants were given a comment sheet to provide suggestions about the study along with an addressed, stamped envelope (Appendix 19) that could be anonymously returned by mail to the investigator.

### Data Processing

Following the acoustic session, videotape files were digitized and saved to compact disk with the subject's identification number. Voice samples were saved as raw data and copies of the .wav files were low-pass filtered and down-sampled to 22 kHz to facilitate interpretation. All files were used unless a file was shorter than 3.75 sec. All tokens were analyzed for all the acoustic parameters with the exception of the token used for formant analysis.

In order to obtain a stable segment of sustained vowel for analysis of formant frequencies, the third or middle token of each task's five tokens obtained was used. This token was judged to be more likely to be free of increased amplitude encountered in early tokens of a task or shortened as subject ran out of breath on later tokens in a task. Two seconds of the token at the center of the token were selected to provide a stable vowel nucleus for subsequent analysis.

Data from the inventories and acoustic analysis program were first entered into Excel spreadsheet program (Microsoft, 2003) twice and these files imported into SAS 9.1.3 (SAS Institute Inc., 2002) where PROC COMPARE procedure was used to eliminate typographical entry errors (SAS Institute, 1999). Because longitudinal data analysis was planned, the data was recorded in person-period, also referred to as "long" or multivariate

format, where each subject has multiple records, one for each measurement time point (Singer & Willett, 2003).

Confidentiality was maintained by assignment of an identification number when the participant was enrolled (i.e., mmddyy#), through use of only first name (if participant agreed), and with storage of the log book and data (written instruments, demographic information, audio, and video recordings) in a locked file cabinet in a locked location. All written instruments were de-identified using the identification number instead of name, birth date, or other personal information.

### Data Analysis

Analysis was determined by the unique characteristics of the dataset as well as assumptions of statistical methods. The rationale for the method of analysis is included to address the choice of linear mixed model analysis.

### Overview

Since repeated measurement of continuous data collected on the same subject at different times produced longitudinal data (Verbeke & Molenberghs, 2000; West, Welch, & Galecky, 2007), this study is a longitudinal design. Unlike the broad, or univariate, data entry with one line for each subject and multiple observations listed, data entry for longitudinal data in long form requires long format with a record entered for each observation. While data transformation or re-entry is possible, it is time-consuming. In this study, the additional complexity of formant data nested in person-level at multiple times provided an additional layer of complexity in model development.

The study was designed to include repeated measurement of continuous data on outcome variables of pain intensity, pain unpleasantness, and acoustic parameters in order to describe whether a change exists between the non-pain and pain samples. Repeated measures analysis of variance (RM ANOVA) is used to address the issue of correlation of data from the same subject since this correlation conflicts with the assumption of independence of data of more commonly used statistical tests like analysis of variance (ANOVA). In addition, RM ANOVA is a stronger statistical test than mixed models analysis (Krueger & Tian, 2004). However, RM ANOVA has strong assumptions and requirements for its use. Pertinent to this study is the RM ANOVA assumption of complete data and the requirement that subjects with missing data be excluded from the analysis. Over the year long data collection period, missing data occurred. RM ANOVA would require deletion of several subjects' data, reducing power to demonstrate an effect. Also, RM ANOVA requires that any missing data must be missing completely at random. Because most missing data were vital signs measurement and verbal ratings of pain related to the lack of protocol adherence by the investigator, the data cannot be considered missing completely at random. Lastly, an assumption of RM ANOVA is that variances of the groups are equal. The variance and covariance of the non-pain and pain group were different on many variables and non-normality would need to be addressed. It became clear that another statistical method was needed for analysis of the data and mixed model method was investigated.

Multilevel analysis describes a group of statistical methods using hierarchical linear regression models (Bijleveld & van der Kamp, 1998). Multilevel analysis, also referred to as linear mixed models and general linear mixed models, has its roots in Airy's 1861 formulation of a one-way random-effects model to describe observations of night sky (West et al., 2007),



but, because of complexity of hand calculation, this type of model was not widely used. With the availability of computers and statistical software, calculations necessary to address the covariance parameters with mixed models became possible.

Using regression strategies, the method became more widely used to address the hierarchical nature of agricultural data (Brown & Prescott, 2006), educational research data (Raudenbush, 1988), and repeated measures of longitudinal data (West et al., 2007). A problem encountered in use of traditional regression analyses is that aggregation of the individual level variables to the group level tends to provide regression coefficients unlike those that would result from regression at the individual level. With multilevel analysis, variables can exert different effects at different levels and effects can vary between units or individuals as well as demonstrate interactions between levels or groups (van der Leeden, 1998).

Assumptions of mixed models are more flexible than RM ANOVA in that incomplete data are allowable since there is a weaker missing data assumption of missing at random (Singer, 1998). Specifically, mixed models can be used to estimate parameters as long as the data is missing completely at random, meaning there is no relationship between the cause of the missing data and the dependent variable. Unlike, RM ANOVA, irregularly time longitudinal data and time-varying covariates are also allowed in mixed models. Both RM ANOVA and mixed models assume that the variable, particularly the dependent variable is normally distributed. In general, mixed models are also more robust to violation of this assumption than RM ANOVA but even mixed model are not robust against extreme violations in the normality assumption. Thus, in this analysis, it was believed that the missing data was missing at random and the distributions of all variables were

examined for extreme violations of the normality assumptions. Nonparametric approaches were used to answer the research question that addressed (1) non-pain and pain group pulse rates with weight and BMI and (2) classes based on pain intensity as groups/classes were non-normally distributed on variables of interest and were of small sample size. While large samples and datasets have used mixed models to demonstrate individual and groups effects, small groups have been able to demonstrate group and individual effects as well (Oman, Shapiro, Thoresen, Plante, & Flinders, 2008; Payne, Held, Thorpe, & Shaw, 2008).

Fixed and random effects are evaluated in mixed models. Fixed effects, also called regression coefficients, are based on means of the group and describe the relationship of the dependent variable and predictor variables between individuals (or fixed factors). Random effects are random values associated with random factors, or within subject data, and utilize variance and covariance parameters to incorporate individual data. In order to determine whether acoustic parameters of voice changed with pain or movement, use of a mixed model methodology was considered appropriate given its flexibility in dealing with correlation of data from repeated measures. To summarize, group data provide the fixed effects portion of the model specification, while individual data provide random effects portion of the model. Because this study aimed to describe differences between groups and because of limited sample size, only fixed effects were evaluated. The mixed model method with repeated measures is designed to analyze within-subject factor and between-subject factors estimating the covariance parameters in order to utilize the correlation (West et al., 2007). SAS 9.1.3 (SAS Institute Inc., 2002) and the PROC MIXED procedure was used for analyses.

In studies using repeated measures, groups are considered as the first level and the individual subjects as the second level (Singer & Willett, 2003). In this study, subjects are the

first level and time is the second level. The format of general linear mixed models would take the form:

$$Y_{ijk} = \beta_{0j} + \beta_{1j} X_{ijk} + \varepsilon_{ijk}$$

where  $Y_{ijk}$  is the variable of interest with subject  $i$  in group  $j$  at time  $k$  (Littell, Milliken, Stroup, Wolfinger, & Schabenberger, 2006; van der Leeden, 1998). Imagining the variables are  $Y$  = acoustic variable and  $X$  = a matrix that includes group factor, time factor and independent variables (i.e., VAS-PI, VAS-UNP, ...etc.),  $\beta_{0j}$  indicates the intercept of the linear mixed model.  $\beta_{1j}$  indicates the expected change of  $Y_{ijk}$  for each increase or decrease per unit of  $X_{ijk}$ . The error term,  $\varepsilon_{ijk}$ , represents the error of  $Y_{ijk}$ , and is assumed to follow a normal distribution with a mean of zero and a variance of  $\Sigma^2$ . Different types of coding can be employed for mixed models with reference and cell mean coding most commonly used. Cell mean coding provides results that are “easier to interpret,” (Muller & Fetterman, 2003) and was chosen because of the complexity of the nested formant data and the focus on fixed not random effects. In cell means coding, the intercept effect is shared by the factors and embedded into groups at different levels, not averaged. Reference coding is used to show difference between grand mean and marginal means and would take the form of:

$$E[Y_{ij}] = \mu + a_j.$$

where  $a_j$  refers to marginal mean. With cell mean coding, only the group means are of interest and the formula is:

$$E[Y_{ij}] = \mu_j$$

where  $\mu_j$  is the group mean and is equal to the grand mean plus the cell mean.

The fixed effects model used maximum likelihood method to estimate model parameters. The Kenward-Rogers (KR) correction was used to address issues related to

unbalanced data and repeated measures in order to reduce the likelihood of Type 1 error (Padilla & Algina, 2004). A compound symmetry variance-covariance structure was judged to be the best type of structure based on the limited sample size and the short measurement intervals. Compound symmetry had the highest goodness-of-fit statistics, but when formant frequencies were analyzed a Kronecker product of compound symmetry combined with unstructured provided estimations when compound symmetry alone did not.

Estimates, similar to contrasts in analysis of variance (ANOVA), were developed using covariance parameter estimates. Estimates were used instead of contrasts in order to obtain more precise information about group mean differences. Non-pain or lower pain intensity groups' data were entered into the model first so estimates are based upon difference from the non-pain or lower pain intensity group means. Significance level was set at the .05 level. Several comparisons were performed on the data of the two groups. Dunnett's adjustment, the default in PROC MIXED for multiple comparisons between two groups, was used.

In order to examine the stability of those models that attained significance, further analysis was performed in PROC MIXED and consisted of plots of fitted residuals and influence diagnostics (Littell et al., 2006) as part of perturbation analysis. Perturbation analysis is intended to describe the stability of model output given alterations in input and aid in determination of the need to modify a model. Perturbation analysis includes graphical analysis of fitted residuals, goodness of fit statistics on residuals, collinearity diagnostics, and influence diagnostics (Littell et al., 2006, pp. 413-414). Because only fixed effects were analyzed in this study, those diagnostics related to fixed effects as Cook's *D*, COVRATIO, and graphical evaluations were used in this phase of analysis.

*Student's t-test* was used to demonstrate difference between groups with some variables. When unequal variance was demonstrated, the folded  $F$  ( $F^1$ ) test was used to determine the *t-test* result reported.

Because some sample data was non-normal, scatter plots of residual versus the linear predictor were assessed for tortuous character that could indicate the need for data transformation. Log transformation provided improvement in tortuous character and interpretable results and was chosen for diagnostic analyses. When the log transformation yielded less tortuous plot and Cook's  $D$  less than .05 in the influential subjects than the original model, the log transformation model was selected. It should be noted that  $p$ -values in the log transformation can not be equated to  $p$ -values in the mixed model results. The mean differences of the groups were included to indicate the magnitude of group difference.

Correlation matrices were evaluated to determine linear relationships of variables that warranted inclusion (i.e.,  $r > 0.5$ ). While correlation does not establish causality, a reliable relationship must exist between variables in order to establish a link between observed phenomena and other variables to allow comparison with the conceptual framework. The Pearson product-moment correlation or linear correlation,  $r$ , is used to determine the level of correlation with values ranging from -1.0 to +1.0 with negative values indicative of the degree of a negative relationship of variables and positive values indicative of the degree of a positive relationship of variables. A Pearson product moment correlation coefficient of zero is indicative of no correlation or a non-linear relationship of variables. Assumptions of the Pearson product-moment correlation include bivariate normal distribution of the variables and independence of the consideration of mixed models analysis. Once variables that showed promise ( $r > 0.6$ ) were determined, it was possible to develop models of the data.

## Analysis of Research Question 1

1. How does pulse rate differ between women with and without chronic knee pain:

- A. While seated at rest?
- B. When anticipating change of position from sitting to standing?
- C. After standing?

In order to establish that a physiological change, or an “emotion,” occurred in response to the movement task, pulse rate at three different intervals was evaluated to determine if and when significant differences occurred between the two groups could be associated with pain. Calculations were based on three seconds of pulse data from pulse oximetry. Mean pulse rate was determined (1) while seated at rest occurred prior to any testing, (2) three seconds in advance of the event marker click prior to the first command to stand, (3) after the participant stood for the length of the first stand position after vocal testing, (4) following the second seated vocal testing, (5) three seconds in advance of the event mark click prior to the second command to stand, and (6) when the participant stood for the length of the second stand position after vocal testing.

Since two standing tasks occur, each participant had two sets of seated and standing data over the four tasks. While *Student's t*-test could be used to evaluate the data, the data did not meet the assumption of independence. A paired *t*-test was used to compare the non-pain and pain groups after establishing that each group's data did not differ related to time. An  $\alpha$  equal to or less than .05 was selected to demonstrate significance in statistical tests.

Mixed models method provided a method of evaluating change over the entire session given the correlation of individual data and the variance of pulse rates. It was thought that a difference would exist between the groups. Diagnostics of the model of pulse and movement

were completed and log transformation of the model was performed and entered into PROC MIXED to evaluate the model's stability to perturbation of input.

#### Analysis of Question 2

2. How do various acoustic parameters (i.e., mean fundamental frequency, lowest fundamental frequency, highest fundamental frequency, range of fundamental frequency, jitter, shimmer, amplitude perturbation quotient, and three formant frequencies) extracted from sustained vowel utterances of women with and without chronic knee pain differ with change of position?

It was not clear how change in position might influence the acoustic parameters so comparison of parameters sitting and standing of all subjects provided baseline information of the change in acoustics of women of this age when changing position. Comparison of mean values of the acoustic measures during seated and standing tasks were done to determine the level of change. The table of the mean values of the parameters at each position provided useful information about the role of movement on acoustic parameters. Use of mixed models allowed evaluation of the change over time of all the subjects controlling for group.

One subject in the pain group was found to have much higher frequencies in the first seated task and, on review of the recording, it was noted that she sang the vowels. Since these values influence all the pain group acoustic measurements of first seated, the first seated sustained vowel tokens of this subjects were deleted from the dataset.

The adjustment approaches of mixed models are the same as those in the General Linear Model (GLM) (Littell et al., 2006). In this study, the Dunnett's adjustment, the default adjustment for all pairwise comparisons in PROC MIXED, was used. An  $\alpha$  at the 0.05 level

was selected to demonstrate significance. It was thought that the change of position would cause a change in mean acoustic parameters and would be different between the non-pain comparison group and pain group.

### Analysis of Research Question 3

3. How do various acoustic parameters (i.e., mean fundamental frequency, lowest fundamental frequency, highest fundamental frequency, range of fundamental frequency, jitter, shimmer, amplitude perturbation quotient, and three formant frequencies) extracted from sustained vowel utterances of women with chronic knee pain differ with pain intensity?

This question addressed pain intensity differences and, since the non-pain group did not have pain, categorization of the pain group by pain intensity was required. In order to establish two intensity levels, the 100 mm on the VAS were divided into 10 equal portions and the definitions of mild, moderate, and severe pain based on a 0-10 scale (Kapstad, Hanestad, Langeland, Rustoen, & Stavem, 2008) was applied to the VAS-PI scores to categorize two pain groups. In studies of pain rating, researchers reported that with chronic and arthritis pain, written numerical rating scale scores of 0-4 could be considered mild pain, ratings of 5-6 could be considered moderate pain, and ratings of 7-10 could be considered severe pain (Paul, Zelman, Smith, & Miaskowski, 2005; Serlin, Mendoza, Nakamura, Edwards, & Cleeland, 1995). Because few subjects in the pain group reported severe pain and ratings were in the low to moderate range (range 0-99, median 10.25, SD = 22.56), a cut-point of 15 on the Visual Analog Scale for Pain Intensity (VAS-PI) was established. Those subjects with mean VAS-PI ratings from 0 – 14.9 mm comprised the low intensity class



(LIC) (N = 20). Subjects with mean VAS-PI ratings of 15 mm or greater comprised the moderate intensity class (MIC) (N = 12).

For this question, ratings of 0-4 or mild pain would include 0-49 mm on the VAS-PI, ratings of 5-6 or moderate pain would include 50-69 mm on the VAS-PI, and ratings of 7-10 or severe pain would include 70-100 mm on the VAS-PI.

Because the tokens of a subject who sang the sustained vowels at the first seated task influenced the acoustic measurements, this subjects data at first seated was removed from the LIC data. The other data of this subject was used in the study analyses.

Mixed models method was used to compare verbal pain ratings and written VAS-PI scores to acoustic parameters and compare the changes between groups that occurred across the four tasks. However, the non-normal distribution of data was observed in the LI and MI classes. Since there were small numbers of subjects in each group, nonparametric statistical analyses using Wilcoxon *rank sum* test for two independent samples. Monte-Carlo estimates of the exact test were performed as needed. The Wilcoxon *rank sum* test is also referred to as the Mann-Whitney test for two independent samples. While Fisher's exact test can be used to determine the probability of the Wilcoxon result, SAS 9.1.3 warns that these calculations require much time and computer memory. Monte Carlo estimation is "...a nonparametric method of statistical inference ... produces a sampling distribution based on the actual data" (Garson, 2008) and can be added to syntax to produce probability and confidence levels in SAS 9.1.3.

It was not known if differences in pain intensity would alter parameters significantly. Given Scherer's model, it was thought that higher intensity pain would be ergotropic, or

energy-expending, and thus alter acoustic parameters, rejecting the null hypothesis  $H_0: \mu_1 = \mu_2$  that the non-pain group means would be the same as the pain group means.

#### Analysis for Research Question 4

4. How do various acoustic parameters (i.e., mean fundamental frequency, highest fundamental frequency, lowest fundamental frequency, range of fundamental frequency, jitter, shimmer, amplitude perturbation quotient, and formant frequencies) extracted from sustained vowel utterances differ in relation to psychological variables (i.e., depression, anxiety, and anger) reported by women with and without chronic knee pain?

Frequencies, ranges, means, and standard deviations of scores on the psychological inventories were computed. A correlation matrix was developed to evaluate the relationship of the variables. Pearson product-moment correlation coefficients greater than 0.6 indicate a medium sized correlation (Green & Salkind, 2003) and indicate an association worthy of investigation. Mixed models method was then used to determine the influence of psychological variables on acoustic parameters using interaction statements. The sample mean for depression, state anxiety, trait anxiety, state anger, and trait anger was included in models as an interaction term in order to compare the change in acoustic parameters related to these variables between the groups. In other words, estimates were used to evaluate the difference in group means in relation to the sample mean level of the variable.

Diagnostic techniques were performed with those fixed effects models where significant group mean differences were observed to determine stability of model output to perturbation or changes in model input that could occur with future studies or samples.

Influence diagnostics evaluated changes of input that occur with deletion of observations and graphics indicated linearity of bivariate relationships.

Because multiple statistical tests were used, concern that multiple comparison statistical tests could cause an increase in Type 1 error was raised. Adjustments can be incorporated in mixed models and in SAS version 9.1.3, Dunnett's correction is the default and was used in this study

Cook's  $D$  statistic was used to determine likelihood distance of an observation and to assess the possibility of outlier influence of an observation on fixed effects estimates (Littell et al., 2006). The criterion for identification of influential subjects or outliers in this sample was a Cook's  $D$  statistic greater than 0.2. While this distance is greater than normally used, this level identified outlier and more influential data more readily in a sample known to have unequal variances.

The COVRATIO statistic evaluates the precision of using full data with values greater than 1.0 or use of a reduced data set with COVRATIO values less than 1.0 (Littell et al., 2006). COVRATIO was used to estimate model stability by observing the suggested number of deletions required.

Once diagnostics were performed on models with the interaction terms that have significant results, log transformation was done to address the unequal variance of the groups. This perturbation of input provided information about the potential stability of the model in future samples. Diagnostics were then performed on the log transformation model and, if improvement was evident in the plot of residuals, Cook's  $D$ , or COVRATIO, the log transformation model was entered into PROC MIXED. Significant findings in the log transformation model that matched the original model indicated the original model's stability

to perturbation. Original models judged stable identified the potential relationship of the psychological variable to the acoustic parameters and provide guidance for future investigations.

One pain group subject was identified as having an outlier score on the BDI-II that influenced the acoustic parameter analyses. This subject's data was omitted from the depression interaction analyses, but her data was included in other study analyses.

#### Analysis of Research Question 5

5. How does disability influence verbal and written reports of pain intensity and written report of pain unpleasantness reported by women with and without chronic knee pain?

Differences in the non-pain and in the LIC and MIC were expected in measures of disability and written and verbal report of pain intensity. Time required to move from sit to stand was determined using the time stamp on the video record and additional timing with Observer XT (Noldus Information Technology, 2007) software. Two VAS pain intensity, two VAS pain unpleasantness ratings, and two verbal pain ratings were obtained after the subject had been standing for the vocal tasks. Comparison of the pain and non-pain group and of the LIC and MIC observed disability, self-evaluated disability, pain intensity and pain unpleasantness ratings was done using paired *t*-tests to determine if differences across time within the group or class. If no difference was observed, the ratings from the stand tasks could be combined for the pain group. A correlation matrix of the variables was developed to provide information about the bivariate relationship of the measures of the pain subjects. Folded *F* test,  $F^l$ , was used to determine if equal variances existed that would allow use of the *t*-test comparison. Due to small sample size, when unequal variance was observed,

nonparametric statistical tests were planned and included Wilcoxon *rank sum* statistic, normal or *t*-approximation appropriate to sample size, and *Fisher's exact test*.

## CHAPTER 5

### RESULTS

The purpose of this investigation was to determine whether acoustic parameters change with chronic pain induction and if patterns of vocal signal indicate emotional reaction to chronic pain. Specifically, the study examined acoustic changes in women with and without pain when chronic pain was induced by a normal activity of daily living.

#### Characteristics of the Sample

Of the 103 persons who responded to recruitment flyers, 77 women qualified and were enrolled. Fifteen of the enrolled subjects were not included in the final analysis. Three women were excluded due to presence of conditions not revealed during the screening interview or enrollment. Two subjects became ill during the study and could not complete the session. Ten subjects had insufficient video, acoustic or pulse rate data for the analysis. Twenty-six persons were not enrolled. Fourteen did not meet inclusion criteria and 12 could not be reached for follow-up, were not interested in participation, or had transportation issues. Thirty subjects were enrolled in the non-pain group and 32 were enrolled in the pain group.

The sample was well-educated. The mean level of education of the non-pain group was 16.93 years (range of 12-24 years) and the mean level of education of the pain group was 16.31 years (range of 10-20 years). The group mean differences in education were not

significantly different [ $t(60) = 1.59, p = 0.12$ ]. Many subjects were employed at the university and of higher education levels. However, there were a few subjects with high school or less. Subjects did not have difficulty reading or completing instruments. Questions were related to metaphors used in the inventories (i.e., “I am a steady person,” “I boil inside, but try not to show it.”).

Because height is thought to influence acoustic parameters in men (Fitch, 2000), height was measured. Mean height of the non-pain group was 163.6 centimeters and the mean height of the pain group was 165.2 centimeters but the variances were unequal [ $F^1(29, 31) = 2.24, p = 0.03$ ]. Using the Satterthwaite  $t$ -test, the group differences in height were not statistically significant [ $t(50.1) = 0.91, p = 0.37$ ].

Mean weight in the non-pain group was 143.08 pounds (range: 101.8 to 220.5) and mean weight in the pain group was 200.66 pounds (range: 120.8 to 373.2). Variances were unequal [ $F^1(31, 29) = 6.14, p < .0001$ ]. Using Satterthwaite  $t$ -test results, group differences in weight were statistically significant [ $t(41.4) = 5.11, p = < .0001$ ].

Mean BMI of non-pain group was 24.04 (range: 18 – 35.3) while the mean BMI of the pain group was 33.49 (range: 20.4 - 62.1). Since a BMI of 25 indicates overweight and 30 indicates obesity, the non-pain group was observed to be of normal weight and the pain group was observed to be obese. Variances were unequal [ $F^1(31, 29) = 8.76, p = < .0001$ ]. Using Satterthwaite  $t$ -test results, group differences in BMI were statistically significant [ $t(38.4) = 4.94, p < .0001$ ].

While ethnic diversity was evident in the sample with White, Black, and mixed races represented in both groups (Table 11), the two groups did not differ significantly in terms of ethnic composition using ( $Z = -0.31, t$ -approx. = 0.76, *Fisher’s exact test* = 0.13). When the

pain group was classified by pain intensity, two of the eleven subjects in the moderate intensity pain class were black.

Table 11.

<i>Demographic Data: Number and Percentage of Sample and Group by Ethnicity</i>						
Ethnicity	Sample (N =62 )	Non-Pain (N = 30)	Pain (N = 32)	Z	t-approx- imation	Fisher's exact test
White	48 (77%)	24 (80%)	24 (75%)			
Black	10 (16%)	3 (10%)	7 (21.8%)	-0.31	-0.76	0.13
Asian	3 (4.8%)	3 (10%)	0			
Mixed	1 (1.6%)	0	1 (3.1%)			

The work status of subjects in the two groups was varied, with similar proportions in the work force or retired (Table 12). The non-pain group had 11 subjects working full-time outside-the-home compared to the pain group with 14 working full time. The pain and non-pain group had 6 subjects working part-time outside the home. Eight subjects of the non-pain group and ten subjects of the pain group were retired. Two non-pain subjects were retired, but working part-time while one pain subject was retired but working part-time. One non-pain subject identified herself as a homemaker and 1 non-pain subject described herself as unemployed. One pain group subject described herself as retired and “other.” Group differences in work status were not significant ( $Z = 0.61$ ,  $t$ -approx. = 0.55, *Fisher's exact test* = 0.77).



Table 12.

*Demographic Data: Number and Percentage of Sample and Groups by Work Status*

Work Status	Sample (N =62 )	Non-Pain (N = 30)	Pain (N = 32)	Z	t- approx- imation	Fisher's exact test
Full-Time Outside Home	25 (40.32%)	11 (36.67%)	14 (43.75%)			
Part-Time Outside the Home	12 (19.35%)	6 (20%)	6 (18.75%)			
Homemaker	1 (1.61%)	1 (3.33%)	0	0.61	0.55	0.77
Retired	18 (29.03%)	8 (26.67%)	10 (31.25%)			
Unemployed	1 (1.61%)	1 (3.33%)	0			
Retired, Working Part- Time	2 (3.23%)	2 (6.67%)	0			
Retired, “Other”	1 (1.61%)	0	1 (1.61%)			
Other	2 (3.23%)	1 (3.33%)	1 (1.61%)			

Living arrangements were similar between the two groups (Table 13). Nearly 40% of the sample lived alone with some relying on others for transportation. Eleven subjects of the non-pain group reported living alone, while 13 subjects in the pain group lived alone.

Table 13.

<i>Demographic Data: Number and Percentage of Sample and Groups by Living Arrangement</i>						
Living Arrangement	Sample (N =62 )	Non-Pain (N = 30)	Pain (N = 32)	Z	t-approx	Fisher's exact test
No One	24 (38.71%)	11 (36.67%)	13 (40.63%)			
Spouse/Partner	33 (53.23%)	17 (56.67%)	16 (50%)	0.15	0.88	0.96
Child	3 (4.84%)	1 (3.33%)	2 (6.25%)			
Spouse/Partner and Child	2 (3.23%)	1 (3.3%)	1 (3.13%)			

Seventeen subjects of the non-pain group lived with a spouse, partner, friend, or roommate while 16 subjects of the pain group reported living with a spouse, partner, friend or roommate. Only one subject in the non-pain group and two in the pain group reported living with a child. Only one subject in the non-pain group and 1 in the pain group (3.13%) reported living with a spouse or partner and a child. Using *Fisher's exact test*, group differences in living arrangements were not significant ( $Z = 0.15$ , 2-sided  $t$ -approximation = 0.88,  $p = 0.96$ ).

While the groups were similar in many respects, differences in report of pain and its impact were critical to the study aim. To verify group assignment, non-pain subjects who reported pain intensity and interference scores on the BPI were questioned following instrument administration. All indicated they had described pain related to headache, cardiac discomfort, eye strain, and not knee pain. After verifying the pain status of the non-pain

subject, scores on the BPI were changed to zero in order to comply with the instruction that only knee pain was to be addressed in the instruments.

In order to verify the presence or absence of pain of the non-pain and pain groups, the Visual Analogue Scale for Pain Intensity (VAS-PI) (Price et al., 1983) was administered at intervals during the study. The VAS-PI requires the subject to mark across a line to indicate the level of pain intensity experienced. Although subjects were instructed to mark how intense their knee pain was, some non-pain subjects placed marks slightly above the “no pain” point on the pain scale.

Univariate plots indicated non-normality of the interval level data related to pain intensity. Preliminary nonparametric statistical analyses that included Wilcoxon *rank sum* statistic, 2-sided normal approximation, and *Fisher’s exact test* determined that group differences in written pain intensity were statistically significant at all tasks (Table 14).

Table 14.

<i>Mean Scores and Difference in VAS-PI between Non-Pain and Pain Groups by Task</i>						
Task	Non-Pain (N = 30) <i>M</i> Score	Pain (N = 32) <i>M</i> Score	<i>SD</i> <i>Under</i> <i>Null</i>	<i>Z</i>	2-sided normal approximation	<i>Fisher’s exact</i> <i>test</i>
Before Inventories	21.37	*40.32	64.58	-4.47	<.0001	3.09E-06
After Inventories	17.83	44.31	68.62	-5.97	<.0001	4.55E-11
First seated	17.50	**43.50	65.13	-5.98	<.0001	3.33E-11
First Stand	18.37	*43.23	67.65	-5.60	<.0001	1.10E-09
Second Seated	***20.03	40.94	66.49	-4.77	<.0001	4.91E-07
Second Stand	20.73	41.59	67.97	-4.74	<.0001	6.18E-07

\*N = 31. \*\* N = 30. \*\*\*N = 29.

Duration of knee pain or osteoarthritis (OA) was collected in months on the BPI and presented a calculation issue for subjects. The non-pain group subjects who reported having OA but without knee or musculoskeletal pain reported a shorter mean duration of 36.9 ( $SD = 101.4$ ) months, or over three years. Subjects in the pain group reported having OA or knee pain for an average of 62.48 ( $SD = 82.93$ ) months, over five years. The variances were not different [ $F^1(27, 28) = 1.49, p = 0.3$ ] and the difference between the groups was not significant [ $t(55) = -1.04, p = 0.30$ ].

When the pain group's data was examined by intensity, duration was shorter for the moderate intensity pain ( $M = 59.78$  months,  $SD = 76.56$  months) than the low intensity pain group ( $M = 65.16$  months,  $SD = 89.69$  months). Subjects reported difficulty differentiating when symptoms began and when they were diagnosed.

In addition to duration, the BPI requested that subjects indicate pain location sites. The non-pain group described pain from headache, a cardiac disorder, wrist, leg, and hip but indicated they did not have knee or musculoskeletal pain currently. Three subjects (out of thirty) in the non-pain group listed more than one site for pain. In the pain group, three subjects listed only one site (knee pain) while 21 subjects listed more than one site for pain.

Cronbach's alpha was used to determine internal consistency of the psychological instruments indicative of enduring mood (Table 15). Initially, means were not imputed for missing items. Some subjects' STAI data were incomplete and their data was deleted from the Cronbach's alpha calculation because SAS 9.1 required complete subject data for computation of Cronbach's alpha. When STAI means were imputed, the raw and standardized Cronbach's alphas were 0.9 and the results were within acceptable norms reported for the instruments.

*Table 15. Cronbach's Alpha for Mood-Related Inventories*

Inventory/Scale	Norm	N	Raw alpha	Standardized alpha
BDI-II	0.93	61	0.895	0.899
STAI				
State Anxiety	0.93	54	0.76	0.77
Trait Anxiety	0.91	60	0.90	0.91
STAXI-2				
State Anger	0.92	60	0.88	.
Trait Anger	0.84	62	0.74	0.76
AX-I	0.76	62	0.62	0.60
AX-O	0.67	62	0.71	0.72
AC-O	0.85	61	0.85	0.86
AC-I	0.92	62	0.88	0.88

Cronbach's alpha was calculated for the pain-specific measures (Table 16). Because the non-pain sample did not complete the BPI pain severity and pain interference scales, Cronbach's alpha could not be calculated for the entire sample. In addition, some subjects did not complete all VAS-PI and VAS-UNP scales and their data were omitted from Cronbach's alpha analysis as complete data is required by SAS 9.1 for this statistical test. These subjects' data were included in subsequent sample analyses.

Table 16.

*Cronbach's Alpha for Pain-Specific Inventories*

Inventory/Scale	Norm	N	Raw alpha	Standardized alpha
ASES				
Pain Self-Efficacy	0.76	61	0.82	0.83
Function Self-Efficacy	0.89	61	0.92	0.94
Other Symptoms Self-Efficacy	0.87	61	0.92	0.92
BPI				
Pain Interference – 7 items	0.91	32	0.92	0.93
Pain Severity – 4 items	0.89	31	0.83	0.84
SOPA-35				
Pain Control	0.78	62	0.73	0.73
Disability	0.70	62	0.74	0.75
Harm	0.66	62	0.64	0.65
Emotion	0.81	62	0.72	0.71
Medications	0.78	62	0.59	0.62
Solicitude	0.81	60	0.79	0.79
Medical Cure	0.74	62	0.73	0.73
VAS-PI – 6 repeated		57	0.96	0.97
VAS-UNP – 6 repeated		57	0.97	0.97
VRP – 4 repeated		62	0.99	0.99

## Results of Research Question Analyses

### Research Question 1

The first research question addressed difference in pulse rates between women with and without chronic knee pain while seated, at rest, in anticipation of standing, and after standing in order to assess physiological arousal with the tasks. Pulse rates were based upon pulse oximetry data obtained during the acoustics session. Pulse rates were unable to be calculated for one non-pain subject at two rest periods and for one non-pain subject at second anticipation task. Because group variance in pulse rate was unequal, Wilcoxon *rank sum* statistic with 2-sided normal approximation and Fisher's exact test were performed.

Between groups, pulse rate across the tasks were different only at second anticipation (Table 17). Pulse rates for the non-pain and pain group did not differ at the first seated task ( $Z = -0.82$ , normal approx. = 0.41, *Fisher's exact test* = 0.41) or at second seated ( $Z = -0.92$ , normal approx. = 0.36, *Fisher's exact test* = 0.36). Pulse rates for the non-pain and pain group did not differ at the first anticipation task ( $Z = -1.71$ , normal approx. = 0.09, *Fisher's exact test* = 0.09), but did demonstrate difference at the second anticipation task ( $Z = -2.49$ , normal approx. = 0.01, *Fisher's exact test* = 0.01). Pulse rates were not different at the first stand task ( $Z = -0.87$ , normal approx. = 0.39, *Fisher's exact test* = 0.39) or at the second stand task ( $Z = -1.01$ , normal approx. = 0.31, *Fisher's exact test* = 0.32).

Table 17.

*Difference in Pulse Rate of Non-Pain and Pain Group by Task*

Task	Non-Pain (N = 30) M score	Pain (N =32) M score	Z	2-sided normal approximation	<i>Fisher's exact test</i>
First Seated	*29.02	32.80	-0.82	0.41	0.41
First Anticipation	*26.90	34.72	-1.71	0.09	0.09
First Stand	29.43	33.44	-0.87	0.39	0.39
Second Seated	29.30	33.56	-0.92	0.36	0.36
Second Anticipation	*25.03	36.41	-2.49	0.01	0.01
Second Stand	29.10	33.75	-1.01	0.31	0.32

\*N = 29.

Because sample weight and BMI data were not normally distributed and thought to influence pulse rate, non-parametric analyses using Wilcoxon *rank sum* with 2-sided *t*-approximations and *Fisher's exact test* were performed.

In order to analyze the effect of weight using Wilcoxon *rank sum*, the sample was divided into two groups based on weight. Using the Center for Disease Control guideline for overweight designated at BMI of 25 and the group mean height of 64.1 inches, a cut-point for overweight was established at 145 lbs using the formula for BMI [(lbs.(in.)<sup>2</sup>\*703](Centers for Disease Control and Prevention, 2006).

To evaluate the effect of weight on pulse rate with movement tasks, the sample was divided on the basis of 145 lb. indicating overweight given the mean height of the sample,



64.1 inches. The normal weight group ( $N = 18$ ) included 16 subjects from the non-pain group and 2 subjects from the pain group. The overweight group ( $N = 44$ ) included 14 subjects from the non-pain group and 30 subjects from the pain group. Because of the non-normal distribution of the sample, the nonparametric statistics, Spearman  $r_s$  and *Fisher's exact test*, were used to analyze the sample data. Significant difference in the normal and overweight group pulse rates was demonstrated at two pulse measurement time points. The normal weight group and overweight group demonstrated the largest differences in pulse with the two anticipation measurements. The 2-sided  $t$ -approximation and *Fisher's exact test* for first anticipation pulse was less than the 2-sided  $t$ -approximation and *Fisher's exact test* second anticipation pulse indicating differential effect of the task. Because pulse rate increased in anticipation of standing for the overweight group and the group was composed of non-pain and pain subjects, the response observed could be attributed to physical exertion as well as anticipation of pain.

Pulse rates for the normal weight and overweight groups' were not different at first seated ( $Z = -1.54$ ,  $t$ -approx. = 0.13, *Fisher's exact test* = 0.12) or at second seated ( $Z = -1.47$ ,  $t$ -approx. = 0.15, *Fisher's exact test* = 0.14). There was significant difference in pulse rate between the normal weight and overweight groups at first anticipation ( $Z = -2.80$ ,  $t$ -approx. = .007, *Fisher's exact test* = 0.004) and at second anticipation ( $Z = -3.03$ ,  $t$ -approx. = 0.004, *Fisher's exact test* = 0.002). Pulse rates were not different at first stand ( $Z = -1.34$ ,  $t$ -approx. = 0.19, *Fisher's exact test* = 0.18) or at second stand ( $Z = 1.19$ ,  $t$ -approx. = 0.24, *Fisher's exact test* = 0.24) (Table 18).

Table 18.

*Difference in Pulse Rate between Weight Classes by Task*

Task	Normal Weight (N = 21) <i>M</i> score	Overweight (N = 41) <i>M</i> score	<i>Z</i>	2-sided <i>t</i> - approximation	<i>Fisher's</i> <i>exact test</i>
First Seated	*25.98	33.45	-1.54	0.13	0.12
First Anticipation	*21.85	35.46	-2.8	0.007	0.004
First Stand	27.19	33.71	-1.34	0.19	0.18
Second Seated	26.76	33.93	-1.47	0.15	0.14
Second Anticipation	21.48	**36.0	-3.03	0.004	0.002
Second Stand	27.67	33.46	-1.19	0.24	0.24

\*N = 20. \*\*N = 40.

To evaluate the effect of BMI on pulse rate with movement tasks, the total sample was divided into two groups using BMI with the overweight/obese group consisting of subjects with a BMI equal to or greater than 25 and the normal weight group consisting of subjects with a BMI less than 25. The normal weight group (N = 24) included 20 subjects from the non-pain group and 4 subjects from the pain group. The overweight/obese group (N = 38) included 10 non-pain subjects and 28 pain subjects. When Spearman  $r_s$  and *Fisher's exact test* were used, significant difference was observed across all six of the pulse rate measurements with the two largest differences occurring with the two anticipation of standing measurements.

The normal weight and overweight/obese groups were significantly different in pulse rate at all tasks when the effect of BMI was included (Table 19). Group mean difference was significant at first seated ( $Z = -2.63$ ,  $t$ -approx. = 0.01, *Fisher's exact test* = 0.01) and second seated ( $Z = -2.55$ ,  $t$ -approx. = 0.01, *Fisher's exact test* = 0.01). Pulse rates as first anticipation ( $Z = -3.88$ ,  $t$ -approx. = 0.0003, *Fisher's exact test* = 5.68E-05) and second anticipation ( $Z = -4.0$ ,  $t$ -approx. = 0.0002, *Fisher's exact test* = 3.134E-05) were different between the groups. First stand ( $Z = -2.33$ ,  $t$ -approx. = 0.02, *Fisher's exact test* = 0.02) and second stand ( $Z = -2.09$ ,  $t$ -approx. = 0.04, *Fisher's exact test* = 0.04) pulse rates were significantly different when BMI was included.

Table 19.

*Difference in Pulse Rate between Classes based on BMI by Task*

Task	Normal Weight (N = 24) M score	Overweight / Obese (N =38) M score	Z	2-sided t- approximation	<i>Fisher's exact test</i>
First Seated	*23.28	35.67	-2.63	0.01	0.008
First Anticipation	*19.65	37.87	-3.88	0.0003	5.68E-05
First Stand	24.75	35.76	-2.33	0.023	0.02
Second Seated	24.13	36.16	-2.55	0.01	0.01
Second Anticipation	*19.30	38.08	-4.0	0.0002	3.13E-05
Second Stand	25.46	35.32	-2.09	0.04	0.04

To evaluate the effect of pain intensity on pulse rate with movement tasks, the pain group was divided into two classes based on average VAS-PI ratings collected during the study: low intensity pain class (LIC) and moderate intensity pain class (MIC). Subjects with a mean VAS-PI of 0 to 14.99 comprised the LIC (N = 20) and subjects with a mean of 15 and or greater (N = 12) comprised the MIC. The LIC and MIC demonstrated unequal variance in pulse rate [ $F^l(119,71) = 1.59, p = 0.03$ ] although the pulse rates were not significantly different [ $t(176) = 1.70, p = 0.09$ ].

Unlike the non-pain and pain group, the pain intensity classes demonstrated equal variance with weight [ $F^l(19, 11) = 2.03, p = 0.23$ ] and BMI [ $F^l(19, 11) = 1.65, p = 0.40$ ] and did not differ in weight [ $t(30) = 0.41, p = 0.68$ ] or BMI [ $t(30) = 0.46, p = 0.65$ ]. Because this sample was small, Wilcoxon *rank sum* statistic with 2-sided *t*-approximation and *Fisher's exact test* were performed to evaluate pulse rates between the classes. No significant difference was observed at any of the tasks (Table 20). However, the pulse rate was higher for the LIC across all tasks except the second stand task. Pulse rates were similar at first seated ( $Z = -0.84, t\text{-approx.} = 0.41, \text{Fisher's exact test} = 0.41$ ) and at second seated ( $Z = -0.88, t\text{-approx.} = 0.39, \text{Fisher's exact test} = 0.38$ ). The pulse rates at first anticipation of standing ( $Z = -0.68, t\text{-approx.} = 0.50, \text{Fisher's exact test} = 0.50$ ) and second anticipation of standing ( $Z = -1.15, t\text{-approx.} = 0.26, \text{Fisher's exact test} = 0.26$ ) demonstrated increasing difference but it was not significant. Pulse rates of the LIC and MIC at the first stand demonstrated the largest between class difference, but the difference did not reach statistical significance ( $Z = -1.50, t\text{-approx.} = 0.13, \text{Fisher's exact test} = 0.14$ ). Pulse rates of the MIC at second stand demonstrated a marked increase while the LIC pulse rate decreased. Despite

these changes, the LIC and MIC pulse rates were not different at second stand ( $Z = 0.25$ ,  $t$ -approx. = 0.80, *Fisher's exact test* = 0.80).

Table 20.

*Difference in Pulse Rate of Pain Intensity Classes by Task*

Task	Low Intensity Pain Class (N = 20) M score	Moderate Intensity Class (N = 12) M score	Z	2-sided <i>t</i> - approximation	<i>Fisher's</i> <i>exact test</i>
First Seated	17.60	14.67	-0.84	0.41	0.41
First Anticipation	17.40	15.00	-0.68	0.50	0.50
First Stand	18.45	13.25	-1.50	0.13	0.14
Second Seated	17.65	14.58	-0.88	0.39	0.38
Second Anticipation	18.00	14.00	-1.15	0.26	0.26
Second Stand	16.15	17.08	0.25	0.80	0.80

Research Question 2.

Various acoustic parameters (i.e., mean fundamental frequency, lowest fundamental frequency, highest fundamental frequency, range of fundamental frequency, jitter, shimmer, amplitude perturbation quotient, and three formant frequencies) were extracted from sustained vowel utterances of women with and without chronic knee pain to determine if difference in parameters occurred with change of position.

### *Mean Fundamental Frequency (MF<sub>0</sub>)*

Mean fundamental frequency (MF<sub>0</sub>) was similar between the two groups (Table 21) at the first seated task [ $t$ -value(658) = -0.02,  $p$  = 0.99]. There was a decrease in MF<sub>0</sub> for both groups with the first standing task [ $t$ -value(658) = 0.90,  $p$  = 0.37]; the pain group demonstrated a greater decrease in MF<sub>0</sub> than the non-pain group. The non-pain group MF<sub>0</sub> increased from the first seated task to the second seated task while the pain group MF<sub>0</sub> decreased [ $t$ -value(658) = 0.66,  $p$  = 0.51]. With the second stand task, both groups' MF<sub>0</sub> decreased at second seated to the same level as at first stand task [ $t$ -value(658) = 0.90,  $p$  = 0.37]. Group mean differences in MF<sub>0</sub> were not significant.

Table 21.

### *Group Means and Difference in Mean Fundamental Frequency by Task*

Task	Non-Pain N = 30 <i>M (SE)</i>	Pain N = 32 <i>M (SE)</i>	Group Mean Difference ( <i>SE</i> )	<i>df</i>	<i>t</i> -value	<i>p</i>
First Seated	180.06 (4.40)	180.17 (4.26)	-0.10 (6.13)	65.8	-0.02	0.99
First Stand	178.84 (4.40)	174.84 (4.26)	5.52 (6.13)	65.8	0.90	0.37
Second Seated	180.53 (4.40)	175.01(4.26)	4.05 (6.13)	65.8	0.66	0.51
Second Stand	179.98 (4.40)	174.46 (4.26)	5.52 (6.13)	65.8	0.90	0.90

*Note.* Means are in Hz.

### *Lowest Fundamental Frequency (Flo)*

The pain group demonstrated the lower frequencies than the non-pain group when Flo was measured across tasks (Table 22). In the first seated task, difference in Flo between

groups was small [ $t$ -value(66.7) = 0.14,  $p$  = 0.89]. Increased differences in Flo were observed at first stand [ $t$ -value(66.7) = 1.46,  $p$  = 0.15] and at second seated [ $t$ -value(66.7) = 1.23,  $p$  = 0.22]. The largest mean difference occurred at second stand [ $t$ -value(66.7) = 1.66,  $p$  = 0.10] when the pain group's Flo decreased to its lowest mean frequency. Group mean differences in Flo were not significant.

Table 22.

*Group Means and Difference in Lowest Fundamental Frequency by Task*

Task	Non-Pain N = 30 <i>M (SE)</i>	Pain N = 32 <i>M (SE)</i>	Group Mean Difference (SE)	<i>df</i>	<i>t</i> -value	<i>p</i>
First Seated	169.26 (4.46)	168.38 (4.32)	0.88 (6.21)	66.7	0.14	0.89
First Stand	169.31 (4.46)	160.27 (4.32)	9.04 (6.21)	66.7	1.46	0.15
Second Seated	171.5 (4.46)	163.85 (4.32)	7.65 (6.21)	66.7	1.23	0.22
Second Stand	171.42 (4.46)	161.11 (4.32)	10.31 (6.21)	66.7	1.66	0.10

*Note.* Means are in Hz.

#### *Highest Fundamental Frequency (Fhi)*

The highest fundamental frequencies occurring with the production of the sustained vowel were in the pain group in all but the second seated task (Table 23). There was increased variance in the pain group's Fhi at first seated and examination of the diagnostics indicated an outlier may have influenced this variance (Cook's  $D$  = 1.39). Further, this subject's data was quite different in the other tasks compared to the first seated data. Audio review indicated the subject sang the vowel with the seated task.

Diagnostics were performed initially on the full model and subsequently on the model with the first seated data of the outlier subject excluded. With the exclusion of first seated

data of this one subject, the largest Cook's  $D$  for the sample decreased from 1.39 to 0.08.

Because Fhi was used to calculate range of  $F_0$ , this reduced data set is used for subsequent analyses of Flo, Fhi, and range of  $F_0$ . No group mean differences in Fhi were significant.

When the reduced data set was entered into PROC MIXED, the non-pain group had lower Fhi than the pain group at first seated [ $t$ -value(76.9) = -0.67,  $p$  = 0.88]. Both the non-pain group and pain group Fhi decreased at first stand [ $t$ -value(76.5) = -0.46,  $p$  = 0.65]. At second seated, the non-pain group increased Fhi while the pain group had a decrease in Fhi [ $t$ -value(76.5) = 0.48,  $p$  = 0.64]. The non-group decreased Fhi at second stand while the pain group experienced and increase [ $t$ -value(76.3) = -0.01,  $p$  = 0.99]. No significant group difference in Fhi was observed.

Table 23.

*Group Means and Difference in Reduced Model of Highest Fundamental Frequency by Task*

Task	Non-Pain N=30 $M$ (SE)	Pain N=32 $M$ (SE)	Group Mean Difference (SE)	$df$	$t$ -value	$p$
First Seated	191.68 (4.84)	*192.67 (4.84)	-0.99(6.73)	76.9	-0.15	0.88
First Stand	188.51 (4.84)	191.6 (4.66)	-3.10 (6.72)	76.5	-0.46	0.65
Second Seated	190.88 (4.84)	187.68 (4.66)	3.20 (6.72)	76.5	0.48	0.64
Second Stand	189.34 (4.83)	189.38 (4.66)	-0.04 (6.71)	76.3	-0.01	0.99

\*N = 31. Note: Means are in Hz.

*Range of Fundamental Frequency*

Because range of  $F_0$  employed Fhi and Flo values and Fhi was shown to be influenced by an outlier, the deleted data set from the Fhi analysis (see previous Fhi analysis) was employed. Subjects demonstrated group mean differences in the range of frequencies



used during the two seated tasks (Table 24). Range of fundamental frequency for the non-pain group was less than the pain group range of  $F_0$  at the first seated task [ $t$ -value(141) = -1.3,  $p = 0.20$ ]. While range of  $F_0$  decreased from first seated to first stand in the non-pain group, range of  $F_0$  increased in the pain group resulting in a significant group mean difference [ $t$ -value(139) = -2.82,  $p = 0.006$ ]. At the second seated task, range of  $F_0$  for the non-pain group was nearly equal to first stand. Range of  $F_0$  decreased for the pain group at second seated and the difference in range of  $F_0$  between the groups was no longer significant at second seated [ $t$ -value(139) = -1.04,  $p = 0.30$ ]. The non-pain group range of  $F_0$  decreased at second stand while the pain group range of  $F_0$  increased resulting in significant difference [ $t$ -value(139) = -2.48,  $p = 0.01$ ]. Group mean differences in range of fundamental frequency were statistically significant at both stand tasks.

Table 24.

*Group Means and Difference in Reduced Model of Range of Fundamental Frequency by Task*

Task	Non-Pain	Pain	Group Mean			
	N = 30	N=32	Difference	<i>df</i>	<i>t</i> -value	<i>p</i>
	<i>M</i> ( <i>SE</i> )	<i>M</i> ( <i>SE</i> )	( <i>SE</i> )			
First Seated	22.52 (3.02)	*27.87 (2.96)	-5.47 (4.23)	141	-1.30	0.20
First Stand	19.46 (3.02)	31.33 (2.92)	-11.88 (4.21)	139	-2.82	0.006
Second Seated	19.47 (3.02)	23.83 (2.92)	-4.36 (4.21)	139	-1.04	0.30
Second Stand	17.83 (3.02)	28.27 (2.92)	-10.44 (4.21)	139	-2.48	0.01

\*N=31. *Note.* Means are cited in Hz.

Diagnostics were performed on the model with the reduced data set and the plot of residuals demonstrated some tortuous character (Appendix 23). No subjects had Cook's  $D$  greater than 0.2. Seven sample subjects had COVRATIO less than 1.0. Six subjects, 1 from

the non-pain group and 5 from the pain group, were identified as having increased Cook's  $D$  ranging from 0.63 to 0.16. COVRATIO was less than 1.0 for all the 6 influential subjects. Range of  $F_0$  was increased for all the influential subjects with 4 having one range of  $F_0$  measurement greater than 90 Hz.

Because of the tortuous nature of the residual plot and the range of the Cook's  $D$  statistics (Appendix 23), log transformation was done to examine model stability. With log transformation, the residual plot improved (Appendix 23), no subjects had Cook's  $D$  greater than 0.2, and 10 subjects had COVRATIO less than 1.0. Six subjects identified as influential in both diagnostic analyses had increased Cook's  $D$  (Appendix 23). COVRATIO ranged from 0.64 – 0.94 in the log transformation model. Since low COVRATIO indicates increased precision of estimates can be obtained with deletion of influential subjects (Littell et al., 2006), both models would require deletion to improve precision.

Influential subjects in the original model had one or more large range of  $F_0$  values while 3 influential subjects in the log transformation model had low range of  $F_0$  values and 3 subjects had high range of  $F_0$  values. Because range of  $F_0$  is determined by high and low fundamental frequencies, the influence of low values as well as high values must be considered. The log transformation model included influential subjects with high and low extreme scores while the original model did not.

The log transformation model was entered into PROC MIXED. Mean differences between groups were greatest at the stand tasks and the pain group had the larger ranges of  $F_0$  (Table 25). Group mean differences in range of  $F_0$  at the first seated [ $t$ -value(113) = 0.65,  $p$  = 0.52] and second seated tasks [ $t$ -value(111) = -0.84,  $p$  = 0.40] were not significant (Table 26). Group mean at first stand [ $t$ -value(111) = -2.22,  $p$  = 0.03] and second stand [ $t$ -value(111)

= -2.17,  $p = 0.03$ ] were significant with log transformation (Table 26). Since group mean differences in range of  $F_0$  at first and second stand were also significant in the original model, the original model was accepted as stable.

Table 25.

*Group Means and Difference of Log Transformation of Reduced Model of Range of Fundamental Frequency by Task*

Task	Non-Pain	Pain	Group Mean Difference
	(N=30)	(N=32)	
	<i>M (SE)</i>	<i>M (SE)</i>	
First Seated	20.0 (1.10)	*21.89 (1.10)	-1.89
First Stand	18.27 (1.10)	24.87 (1.10)	-6.6
Second Seated	17.87 (1.10)	20.08 (1.10)	-2.21
Second Stand	16.5 (1.10)	22.29 (1.10)	-5.79

\*N =31.

Table 26.

*Results of Log Transformation of Reduced Model of Range of Fundamental Frequency by Task*

Task	Group Mean Ratio	<i>SE</i>	<i>df</i>	<i>t</i> -value	<i>p</i>
First Seated	.91	1.15	113	0.65	0.52
First Stand	.73	1.15	111	-2.22	0.03
Second Seated	.89	1.15	111	-0.84	0.40
Second Stand	.74	1.15	111	-2.17	0.03

### *Jitter in Percent*

Jitter can be expressed in percent or as absolute measures that ignore speaker  $F_0$  (Baken & Orlikoff, 2000). To aid in interpretability, jitter in percent was selected.

The entire data set was used for the analysis of jitter. The non-pain group demonstrated less jitter than the pain group across all tasks. At the first seated task, the pain group demonstrated a higher level of jitter than the non-pain group [ $t\text{-value}(73.3) = -1.41, p = 0.16$ ]. While the mean level of jitter of both groups decreased from first seated to first stand, the pain group mean jitter remained higher than mean jitter in the non-pain group [ $t\text{-value}(73.3) = -1.91, p = 0.06$ ]. Jitter in both groups increased slightly at the second seated task [ $t\text{-value}(73.3) = -1.53, p = 0.13$ ]. However, at second stand, there was a decrease in the non-pain group jitter and an increase in jitter in the pain group [ $t\text{-value}(73.3) = -2.70, p = 0.009$ ]. Group mean difference in jitter in percent was significant at the second stand (Table 27).

Table 27.

#### *Group Means and Difference in Jitter in Percent by Task*

Task	Non-Pain <i>M (SE)</i>	Pain <i>M (SE)</i>	Group Mean Difference <i>M (SE)</i>	<i>df</i>	<i>t-value</i>	<i>p</i>
First Seated	0.94 (0.44)	1.11 (0.60)	-0.17 (0.12)	73.3	-1.41	0.16
First Stand	0.81 (0.33)	1.03 (0.61)	-0.23 (0.12)	73.3	-1.91	0.06
Second Seated	0.86 (0.46)	1.05 (0.67)	-0.18 (0.12)	73.3	-1.53	0.13
Second Stand	0.78 (0.50)	1.11 (0.63)	-0.32 (0.12)	73.3	2.70	0.009

Diagnostics were performed on the original model and tortuous character at both ends of the residuals plot was noted (Appendix 23). Eight subjects had Cook's  $D$  greater than 0.2 and 9 subjects had COVRATIO less than 1.0. Eight subjects, 3 from the non-pain group and 5 from the pain group, were identified as influential (Appendix 23) with Cook's  $D$  greater than 0.2 and COVRATIO ranged from 0.49 to 1.18. Jitter levels ranged from 0.2 to 0.36 with these subjects. All 8 subjects had one or more jitter values greater than 1.5% and 6 subjects had one jitter value greater than 2.0%.

When the log transformation was performed, the plot of residuals became more linear (Appendix 23). Three subjects had Cook's  $D$  greater than 0.2 Eight subjects had COVRATIO less than 1.0. The pain group had higher levels of jitter at all tasks. Three influential subjects were identified with Cook's  $D$  ranging from 0.29 to 0.35(Appendix 23); 1 subject was from the pain group and 2 were from the non-pain group. One subject had lower jitter levels ranging from 0.22% to 0.74% while the other 2 subjects had jitter levels greater than 1.5%. COVRATIO ranged from 0.66 to 0.78. Greatest group mean difference occurred at second stand (Table28). The log transformation model demonstrated significant difference in jitter between groups at the second stand task (Table 29). This significant difference also occurred at the second stand task in the original model. The original model was accepted as stable.

Table 28.

<i>Group Means and Difference in Log Transformation Model of Jitter in Percent by Task</i>			
Task	Non-Pain	Pain	Group Mean Difference
	(N=30)	(N=32)	
	<i>M (SE)</i>	<i>M (SE)</i>	
First Seated	0.85	0.95	-0.1
First Stand	0.74	0.90	-0.16
Second Seated	0.76	0.86	-0.1
Second Stand	0.68	0.93	-0.25

Table 29.

<i>Results of Log Transformation of Model of Jitter in Percent by Task</i>					
Task	Group Mean Ratio	<i>SE</i>	<i>df</i>	<i>t</i> -value	<i>p</i>
First Seated	0.89	1.13	71.4	-0.89	0.37
First Stand	0.82	1.13	71.4	-1.61	0.11
Second Seated	0.89	1.13	71.4	-0.97	0.33
Second Stand	0.73	1.13	71.4	-2.58	0.01

### *Shimmer*

Group mean differences in shimmer existed across all tasks (Table 30). Significant group mean difference was observed at first stand. Non-pain group level of shimmer was less than the pain group's shimmer level at the first seated task [ $t$ -value(69.7) = -0.79,  $p = 0.43$ ] After standing, mean level of shimmer decreased in the non-pain group and increased in the

pain group. The mean difference in shimmer between the groups at first stand was statistically significant [ $t$  – value (69.7) = -1.96,  $p$  = 0.05]. The non-pain group's mean shimmer increase from first stand to second seated task was greater than the pain group's mean shimmer level [ $t$ -value(69.7) = -1.35,  $p$  = 0.18]. Both groups' level of shimmer decreased at second stand although the decrease in the non-pain group shimmer was greater than the decrease in the pain group [ $t$ -value(69.7) = -1.62,  $p$  = 0.11].

Table 30.

*Group Means and Difference in Model of Shimmer in Percent by Task*

Task	Non-Pain	Pain	Group Mean			
	N = 30	N = 32	Difference	df	t-value	p
	M (SE)	M (SE)	(SE)			
First Seated	2.82 (0.93)	3.05 (1.43)	-0.23 (0.28)	69.7	-0.79	0.43
First Stand	2.53 (0.68)	3.09 (1.72)	-0.56 (0.28)	69.7	-1.96	0.05
Second Seated	2.71 (0.73)	3.10 (1.62)	-0.39 (0.28)	69.7	-1.35	0.18
Second Stand	2.53 (0.77)	2.99 (1.47)	-0.46 (0.28)	69.7	-1.62	0.11

Diagnostics were performed on the complete data set. Residual plots had tortuous tails, 4 subjects had Cook's  $D$  greater than 0.2, and 6 subjects had COVRATIO greater than 1.0. Four subjects were identified as influential with Cook's  $D$  ranging from 0.37 to 0.47: one in the non-pain group and 3 in the pain group. COVRATIO ranged from 0.37 to 0.7 with these subjects. Shimmer ranged from 1.54 to 7.77 and all influential subjects had a shimmer level at one task greater than 5.5. Because the plot of residuals was tortuous and the COVRATIO indicated the need for deletion, log transformation was performed.

With log transformation, the plot of residuals became more linear (Appendix 23), 4 subjects had Cook's  $D$  greater than 0.2, and 7 subjects had COVRATIO less than 1.0. After log transformation of the original model, 4 influential subjects had Cook's  $D$  greater than 0.2 with 3 of four subjects identified in the original model (Appendix 23): 1 subject from the non-pain group and 3 subjects from the pain group. Cook's  $D$  ranged from 0.29 to 0.37. COVRATIO ranged from 0.69 to 0.75. The log transformation model was judged more stable than the original model. The non-pain subject's shimmer levels (range : 0.91 to 2.53) were lower than 3 pain subjects' shimmer levels (range : 1.89 to 7.77). Although group mean differences in shimmer were greater at first and second stand (Table 31), no significant difference in shimmer between groups was observed when the log transformation model was entered into PROC MIXED (Table 32). The original model of group difference in shimmer was judged unstable.

Table 31.

*Group Means and Difference in Log Transformation of Model of Shimmer in Percent by Task*

Task	Non-Pain	Pain	Group Mean Difference
	(N=30)	(N=32)	
	$M (SE)$	$M (SE)$	
First Seated	2.69 (1.06)	2.79 (1.06)	-0.1
First Stand	2.44 (1.06)	2.78 (1.06)	-0.34
Second Seated	2.61 (1.06)	2.79 (1.06)	-0.18
Second Stand	2.41 (1.06)	2.71 (1.06)	-0.3



Table 32.

*Results of Log Transformation of Model of Shimmer in Percent by Task*

Task	Group Mean Ratio	SE	df	t-value	p
First Seated	0.96	1.09	71	-0.44	0.66
First Stand	0.88	1.09	71	-1.58	0.12
Second Seated	0.93	1.09	71	-0.79	0.43
Second Stand	0.88	1.09	71	-1.44	0.15

*Amplitude Perturbation Quotient (APQ)*

Amplitude perturbation quotient (APQ) was greater for the pain group than the non-pain group across all tasks (Table 33). The non-pain group APQ decreased across all time points. The difference between groups was not statistically significant at the first seated task [ $t\text{-value}(70) = -0.86, p = 0.39$ ]. With first stand, APQ decreased in the non-pain group while APQ increased in the pain group [ $t\text{-value}(70) = -1.99, p = 0.05$ ]. The pain group APQ decreased at the second seated task, while the non-pain group APQ did not change [ $t\text{-value} = -1.75, p = 0.08$ ]. The pain group APQ was higher than the non-pain group at the second stand. The groups were not different in APQ at second stand [ $t\text{-value}(70) = 1.56, p = 0.12$ ]. Group mean difference in APQ at the first stand task was significant.

Table 33.

*Group Means and Difference in Model of Amplitude Perturbation Quotient by Task*

Task	Non-Pain (N = 30)	Pain (N = 32)	Group Mean Difference	<i>df</i>	<i>t</i> -value	<i>p</i>
	<i>M</i> ( <i>SE</i> )	<i>M</i> ( <i>SE</i> )	( <i>SE</i> )			
First Seated	1.97 (0.64)	2.14 (1.00)	-0.18 (0.21)	70	-0.86	0.39
First Stand	1.90 (0.61)	2.31(1.34)	-0.41 (0.21)	70	-1.99	0.05
Second Seated	1.90 (0.50)	2.26 (1.14)	-0.36 (0.21)	70	-1.75	0.08
Second Stand	1.86 (0.54)	2.18 (1.01)	0.32 (0.21)	70	-1.56	0.12

Diagnostics were performed. In the original model, 6 subjects had Cook's *D* greater than 0.2 and 7 subjects had COVRATIO less than 1.0. Cook's *D* ranged from 0 to 0.8 with 6 subjects identified with Cook's *D* greater than 0.2(Appendix 23): 4 subjects from the pain group and 2 subjects from the non-pain group. COVRATIO ranged from 0.26 to 0.78 in this group of influential subjects indicating deletion could improve the model stability. Influential subjects' APQ data ranged from 1.11 to 5.71 with all 6 subjects having one APQ greater than 3.0.

Some improvement in the plot of scaled residuals was observed with log transformation (Appendix 23). Diagnostics of the log transformation model were performed and indicated 5 subjects with Cook's *D* greater than 0.2 and 7 subjects with COVRATIO less than 1.0. Cook's *D* ranged from 0 to over 0.45with 5 subjects having Cook's *D* greater than 0.2: 2 subjects from the non-pain group and 3subjects from the pain group. Three subjects were identified in the original model diagnostics. COVRATIO ranged from 0.55 to 0.83

indicating that deletion could improve the model. Influential subjects' APQ data ranged from 1.11 to 5.71.

The log transformation model was entered into PROC MIXED. The pain group had higher APQ across all tasks (Table 34). At first seated, the non-pain group APQ was the highest of the four tasks while the pain group APQ was at its lowest of the four tasks. Group mean difference in APQ was not significant [ $t$ -value(77.3) = -0.67,  $p$  = 0.5]. At first stand the non-pain group decreased APQ and the pain group increased APQ increasing group mean difference [ $t$ -value(77.3) = -1.64,  $p$  = 0.10]. At second seated the non-pain group APQ increased and the pain group APQ remained similar to first stand resulting in a change in group mean difference [ $t$ -value(77.3) = -1.52,  $p$  = 0.13]. At second stand both groups decreased APQ but the non-pain group decrease was larger than the pain group [ $t$ -value(77.3) = -1.57,  $p$  = 0.12]. Because the log transformation model (Table 35) did not identify significant difference at any of the tasks, the original model was judged unstable.

Table 34.

*Group Means and Difference in Log Transformation of Model of Amplitude Perturbation Quotient by Task*

Task	Non-Pain	Pain	Group Mean Difference
	(N=30)	(N=32)	
	<i>M (SE)</i>	<i>M (SE)</i>	
First Seated	1.88 (1.06)	1.98 (1.06)	-0.1
First Stand	1.81 (1.06)	2.06 (1.06)	-0.25
Second Seated	1.83 (1.06)	2.06 (1.06)	-0.17
Second Stand	1.78 (1.06)	2.01 (1.06)	-0.23

Table 35.

*Results of Log Transformation of Model of Amplitude Perturbation by Task*

Task	Group Mean Ratio	SE	df	t-value	p
First Seated	.95	1.08	77.3	-0.67	0.51
First Stand	.88	1.08	77.3	-1.64	0.10
Second Seated	.89	1.08	77.3	-1.52	0.13
Second Stand	.88	1.08	77.3	-1.57	0.12

*Formant Frequencies*

A stable waveform is necessary for accurate analysis of formant frequencies. Two seconds at the center of the four-second sustained vowel sample at each task were selected in order to remove perturbations that can occur at the beginning and end of an utterance.

Formant analysis was performed to obtain frequencies for the first three formants. No significant differences were found with formant frequencies between the non-pain and pain groups with the first seated and stand tasks (Table 36) or with the second seated and stand tasks (Table 37).

*First Seated*

Mean formant frequencies for  $F_1$  at the first seated task were higher for the non-pain group than the pain group [ $t$ -value(196) = 0.31,  $p$  = 0.75]. Mean formant frequencies of  $F_2$  [ $t$ -value(149) = - 0.49,  $p$  = 0.63] and at  $F_3$  [ $t$ -value(153) = - 0.43,  $p$  = 0.67] were higher for the pain group. No group differences in formant frequencies were statistically significant at the first seated task.

### *First Stand*

At the first stand, the non-pain group had higher frequencies in three formants than the pain group. While the pain group had lower  $F_1$ ,  $F_2$ , and  $F_3$  frequencies than the non-pain group, the pain group's formant frequencies were higher than frequencies demonstrated at first seated. Mean  $F_1$  frequencies were higher for both groups than at first seated [ $t$ -value(196) = 1.23,  $p = 0.22$ ].  $F_2$  frequencies also were higher [ $t$ -value(149) = 0.49,  $p = 0.63$ ].  $F_3$  frequencies increased for the non-pain group, but  $F_3$  frequencies decreased for the pain group [ $t$ -value(153) = 0.46,  $p = 0.65$ ]. No group differences in formant frequencies were statistically significant at first stand task.

### *Second Seated*

At the second seated task, mean formant frequencies for all formants were higher for the non-pain group than the pain group.  $F_1$  frequencies of the two groups were not statistically different at second seated [ $t$ -value(196) = 1.29,  $p = 0.20$ ]. The non-pain group increased frequencies at  $F_2$  while the non-pain group had lower  $F_2$  frequencies compared to first stand [ $t$ -value (149) = 1.15,  $p = 0.25$ ].  $F_3$  frequencies increased for both groups at second stand [ $t$ -value(153) = 0.91,  $p = 0.36$ ]. No group differences in formant frequencies were significant at the second seated task.

### *Second Stand*

A different pattern in the formants developed at second stand (Table 40). The non-pain group continued to have higher mean frequencies in  $F_1$  than the pain group, but group mean difference of  $F_1$  was not significant [ $t$ -value(196) = 1.40,  $p = 0.16$ ].  $F_2$  frequencies were higher for the non-pain group than the pain group at second stand [ $t$ -value(149) = 1.41,  $p = 0.16$ ] but the difference between groups was not significant. The pain group had higher

frequencies at F<sub>3</sub> than the non-pain group for the first time since the first seated task increasing the group mean difference [ $t$ -value = -1.64,  $p$  = 0.10]. No group differences in formant frequencies were significant at the second stand task.

Table 36.

*Group Means and Difference in Model of Formant Frequencies by First Seated and First Stand Tasks*

Task	Formant	Non-Pain <i>M</i> ( <i>SE</i> )	Pain <i>M</i> ( <i>SE</i> )	Group Mean Difference ( <i>SE</i> )	<i>df</i>	<i>t</i> - value	<i>p</i>
First Seated	1	758.58 (0.38)	*742.52 (0.36)	16.07 (0.52)	196	0.31	0.76
	2	1598.61 (0.89)	1659.38 (0.87)	-60.77 (1.25)	149	-0.49	0.63
	3	3137.69 (1.32)	3217.14 (1.28)	-79.45 (1.83)	153	-0.43	0.67
First Stand	1	824.90 (0.38)	760.35 (0.36)	64.55 (0.52)	196	1.23	0.22
	2	1664.91 (0.89)	1604.28 (0.87)	60.64 (1.25)	149	0.49	0.63
	3	3215.18 (1.32)	3130.74 (1.28)	84.43 (1.83)	153	0.46	0.65

\*N = 31. *Note.* Means are in Hz.

Table 37.

*Group Means and Difference in Model of Formant Frequencies by Second Seated and Second Stand Tasks*

Task	Formant	Non-Pain <i>M (SE)</i>	Pain <i>M (SE)</i>	Group Mean Difference ( <i>SE</i> )	<i>df</i>	<i>t</i> - value	<i>p</i>
Second Seated	1	826.25 (0.38)	758.68 (0.36)	67.56 (0.52)	196	1.29	0.20
	2	1731.94 (0.89)	1588.34 (0.87)	143.59(1.25)	149	1.15	0.25
	3	3326.60 (1.32)	3159.76 (1.28)	166.84(1.83)	153	0.91	0.36
Second Stand	1	816.42 (0.38)	742.84 (0.36)	73.58 (0.52)	196	1.40	0.16
	2	1730.49 (0.89)	1555.39 (0.87)	175.10 (1.25)	149	1.41	0.16
	3	3326.28 (1.32)	3025.22 (1.28)	301.06 (1.83)	153	1.64	0.10

*Note.* Means are in Hz.

Diagnostic techniques were applied to fixed effects models of acoustic parameters that had demonstrated significant differences with change of position. Log transformation was used to determine stability to perturbation and log transformation models were entered into PROC MIXED. Fixed effects models of range of  $F_0$  and jitter demonstrated stable significant differences between the pain and non-pain groups with stand tasks (Table 38). While significant group mean difference in jitter was demonstrated by the original sample at first stand task, significance was not demonstrated following log transformation indicating instability to perturbation of data input. Although shimmer and amplitude perturbation quotient demonstrated significant differences in the original models, significance was not

found in log transformation models indicating potential instability of the model in different samples or populations.

Table 38.

*Significant Acoustic Parameter Differences between Non-Pain and Pain Group by Task*

Parameter	Task	Non-Pain <i>M (SE)</i>	Pain <i>M (SE)</i>	Group Mean Difference ( <i>SE</i> )	<i>df</i>	<i>t</i> -value	<i>p</i>
Range of $F_0$	First Stand	19.46 (3.02)	31.33 (2.92)	-11.88 (4.21)	139	-2.82	0.006
	Second Stand	17.83 (3.02)	28.27 (2.92)	-10.44 (4.21)	139	-2.48	0.01
Jitter	Second Stand	0.78 (0.50)	1.11 (0.63)	-0.32 (0.12)	73.3	2.70	0.009



### Research Question 3

In order to determine if difference in acoustic parameters occurred with pain intensity, various acoustic parameters (i.e., mean fundamental frequency, range of fundamental frequency, lowest fundamental frequency, jitter, shimmer, amplitude perturbation quotient, and three formant frequencies) extracted from sustained vowel utterances of women with chronic knee pain who differed in level of pain intensity were evaluated. The pain group was divided into two classes based on average VAS-PI ratings collected during the study: low intensity pain class (LIC) and moderate intensity pain class (MIC). Subjects with a mean VAS-PI of 0 to 14.99 comprised the LIC (N = 20) and subjects with a mean of 15 and or greater (N = 12) comprised the MIC. Because one subject who had the influential outlier score on F<sub>1</sub> at the first seated task was in the pain group and, specifically, in the LIC, her data was deleted in the first seated analyses. Univariate analysis of the mean VAS-PI scores indicated non-normality with Shapiro-Wilk statistic of 0.83 ( $p < .0001$ ) and non-parametric analyses were conducted using Wilcoxon rank sum with 2-sided  $t$ - approximation and *Fisher's exact test*. As noted previously, Wilcoxon rank sum statistic is unable to address time-varying data and Wilcoxon rank sum statistics were performed for each task and for each formant.

#### *Mean Fundamental Frequency (MF<sub>0</sub>)*

The LIC (N = 20) demonstrated higher mean score across all tasks than the MIC (N = 12) (Table 37). At first seated, the LIC (N = 19) mean score was higher than the MIC mean score ( $Z = -0.34$ ,  $t$ -approx. = 0.73, *Fisher's exact test* = 0.73). The LIC MF<sub>0</sub> increased at first

stand as the MIC MF<sub>0</sub> decreased ( $Z = -1.03$ ,  $t$ -approx. = 0.31, *Fisher's exact test* = 0.31). At the second seated task, the LIC MF<sub>0</sub> score increased but the MIC MF<sub>0</sub> continued to decrease ( $Z = -1.07$ ,  $t$ -approx. = 0.29, *Fisher's exact test* = 0.29). At second stand, the LIC MF<sub>0</sub> decreased and the MIC MF<sub>0</sub> increased ( $Z = -0.45$ ,  $t$ -approx. = 0.66, *Fisher's exact test* = 0.66); both had higher mean scores at second stand than at first seated. No significant differences in MF<sub>0</sub> related to pain intensity class were observed at any of the tasks (Table 39).

*Table 39. Low and Moderate Intensity Pain Class Difference in Mean Fundamental Frequency*

Task	Low Intensity Class (N = 20) <i>M</i> score	Moderate Intensity Class (N = 12) <i>M</i> score	<i>Z</i>	2-sided <i>t</i> - approximation	<i>Fisher's</i> <i>exact test</i>
First Seated	*16.47	15.25	-0.34	0.73	0.73
First Stand	17.85	14.25	-1.03	0.31	0.31
Second Seated	17.90	14.17	-1.07	0.29	0.29
Second Stand	17.10	15.50	-0.45	0.66	0.66

\*N = 19.

### *Lowest Fundamental Frequency (Flo)*

Flo frequencies were higher in the LIC across all tasks (Table 40). Both classes' Flo frequencies increased at stand tasks. The LIC demonstrated lowest Flo at first seated while the MIC Flo at first seated demonstrated its second highest Flo ( $Z = -0.83$ ,  $t$ -approx. = 0.41, *Fisher's exact test* = 0.41). Both the LI and MI classes increased Flo at first stand ( $Z = -0.95$ ,  $t$ -approx. = 0.35, *Fisher's exact test* = 0.35). At second seated, the LIC increased Flo while the MIC had decreased Flo leading to the largest difference in Flo ( $Z = -1.5$ ,  $t$ -approx. = 0.14, *Fisher's exact test* = 0.14). Flo decreased in the LIC at second stand but Flo increased in the MIC at second stand ( $Z = -1.11$ ,  $t$ -approx. = 0.28, *Fisher's exact test* = 0.28). No significant differences in Flo related to pain intensity class were observed at any of the tasks.

Table 40.

*Low and Moderate Intensity Pain Class Difference in Lowest Fundamental Frequency by Task*

Task	Low Intensity Class <i>M</i> score	Moderate Intensity Class <i>M</i> score	<i>Z</i>	2-sided <i>t</i> - approximation	<i>Fisher's</i> <i>exact test</i>
First Seated	17.11	14.25	-0.83	0.41	0.41
First Stand	17.75	14.42	-0.95	0.35	0.35
Second Seated	18.45	13.25	-1.5	0.14	0.14
Second Stand	17.95	14.08	-1.11	0.28	0.28

### *Highest Fundamental Frequency (Fhi)*

The LIC Fhi demonstrated lower frequencies than the MIC at first seated ( $Z = 0.26$ ,  $t$ -approx. = 0.79, *Fisher's exact test* = 0.8) (Table 41). The LIC demonstrated increased Fhi at first stand while the MIC decreased Fhi at first stand ( $Z = -0.49$ ,  $t$ -approx. = 0.63, *Fisher's exact test* = 0.63). At second seated, the LIC increase resulted in higher Fhi than the MIC and the largest difference in Fhi between the classes occurred ( $Z = -0.88$ ,  $t$ -approx. = 0.38, *exact test* = 0.39). The LIC decreased Fhi at second stand while the MIC demonstrated increased Fhi ( $Z = -0.02$ , *Fisher's exact test* = 0.98) making Fhi of both classes similar at second stand (Table 41). No significant differences in Fhi related to pain intensity class were observed at any of the tasks.

Table 41.

*Low and Moderate Intensity Pain Class Difference in Highest Fundamental Frequency by Task*

Task	Low Intensity Class <i>M</i> score	Moderate Intensity Class <i>M</i> score	<i>Z</i>	2-sided <i>t</i> - approximation	<i>Fisher's</i> <i>exact test</i>
First Seated	15.63	16.58	0.26	0.79	0.8
First Stand	17.15	15.42	-0.49	0.63	0.63
Second Seated	17.65	14.58	-0.88	0.38	0.39
Second Stand	16.55	16.41	-0.02	0.98	0.98

### *Range of Fundamental Frequency*

The LIC range of  $F_0$  was narrower than the MIC across all tasks (Table 42). The LIC range of  $F_0$  was most narrow at first seated while the MIC range was widest at first seated ( $Z = 1.85$ ,  $t$ -approx. = 0.07, *Fisher's exact test* = 0.06). The LIC's range of  $F_0$  increased at first stand while the MIC decreased range of  $F_0$  at first stand ( $Z = 0.6$ ,  $t$ -approx. = 0.55, *Fisher's exact test* = 0.55). The LIC had reduced range of  $F_0$  at second seated while the MIC's range of  $F_0$  demonstrated increase at second seated ( $Z = 1.46$ ,  $t$ -approx. = 0.15, *Fisher's exact test* = 0.15). The LIC had increased range of  $F_0$  at second stand while the MIC's range of  $F_0$  decreased ( $Z = 1.23$ ,  $t$ -approx. = 0.23, *Fisher's exact test* = 0.22). No significant differences in range of  $F_0$  related to pain intensity class were observed at any of the tasks.

Table 42.

*Low and Moderate Intensity Pain Class Difference in Range of Fundamental Frequency by Task*

Task	Low Intensity Class <i>M</i> score	Moderate Intensity Class <i>M</i> score	<i>Z</i>	2-sided <i>t</i> - approximation	<i>Fisher's</i> <i>exact test</i>
First Seated	13.58	19.83	1.85	0.07	0.06
First Stand	15.7	17.8	0.6	0.55	0.55
Second Seated	14.60	19.67	1.46	0.15	0.15
Second Stand	14.9	19.17	1.23	0.23	0.22

## Jitter

The MIC had higher levels of jitter than the LIC across all tasks and the MIC level of jitter increased with each task (Table 43). At first seated, the MIC had an increased level of jitter compared to the LIC, ( $Z = 1.2$ ,  $t$ -approx. = 0.24, *Fisher's exact test* = 0.24). The LIC and MIC levels of jitter both increased at the first stand ( $Z = 1.07$ ,  $t$ -approx = 0.29, *Fisher's exact test* = 0.29). While the LIC demonstrated decreased jitter at second seated, the MIC continued to increase level of jitter ( $Z = 1.54$ ,  $t$ -approx. = 0.13, *Fisher's exact test* = 0.13). The LIC and MIC both demonstrated small levels of change in jitter at second stand ( $Z = 1.56$ ,  $t$ -approx. = 0.13, *Fisher's exact test* = 0.12). No significant differences in jitter related to pain intensity class was observed at any of the tasks.

Table 43.

*Low and Moderate Intensity Pain Class Difference in Jitter in Percent by Task*

Task	Low Intensity Class <i>M</i> score	Moderate Intensity Class <i>M</i> score	<i>Z</i>	2-sided <i>t</i> - approximation	<i>Fisher's</i> <i>exact test</i>
First Seated	14.42	18.50	1.2	0.24	0.24
First Stand	15.10	18.83	1.07	0.29	0.29
Second Seated	14.5	19.83	1.54	0.13	0.13
Second Stand	14.48	19.88	1.56	0.13	0.12

## Shimmer

The MIC had higher levels of shimmer than the LIC across all tasks (Table 44). At first seated, the MIC had a significantly greater level of shimmer than the LIC ( $Z = 2.53$ ,  $t$ -approx. = 0.02, *Fisher's exact test* = 0.01). At first stand, the LIC's level of shimmer demonstrated an increase to its highest level while the MIC's level of shimmer decreased to its lowest level of shimmer ( $Z = 1.46$ ,  $t$ -approx. = 0.15, *Fisher's exact test* = 0.15). The LIC level of shimmer decreased at second seated as the MIC level of shimmer increased resulting in significant difference ( $Z = 2.39$ ,  $t$ -approx. = 0.02, *Fisher's exact test* = 0.02). At second stand, the LIC had decreased shimmer level while the MIC shimmer level increased to its highest level ( $Z = 2.49$ ,  $t$ -approx. = 0.02, *Fisher's exact test* = 0.01). Significant differences in level of shimmer related to pain intensity class were observed at first seated, second seated, and second stand tasks.

Table 44.

*Low and Moderate Intensity Pain Class Difference in Shimmer in Percent by Task*

Task	Low Intensity Class <i>M</i> score	Moderate Intensity Class <i>M</i> score	<i>Z</i>	2-sided <i>t</i> - approximation	<i>Fisher's</i> <i>exact test</i>
First Seated	12.68	21.25	2.53	0.02	0.01
First Stand	14.6	19.67	1.46	0.15	0.15
Second Seated	13.4	21.67	2.39	0.02	0.02
Second Stand	13.28	21.88	2.49	0.02	0.01

### *Amplitude Perturbation Quotient (APQ)*

The LIC's level of APQ was less than the MIC's APQ in all tasks (Table 45). The MIC level of APQ was greater than the LIC at the first seated task when the LIC demonstrated its lowest APQ ( $Z = 1.93$ ,  $t$ -approx. = 0.06, *Fisher's exact test* = 0.05). The LIC demonstrated an increase in APQ at first stand while the MIC APQ decreased at first stand ( $Z = 0.45$ ,  $t$ -approx. = 0.45, *Fisher's exact test* = 0.66). At second seated, the LIC's APQ decreased while the MIC's APQ increased to the level of APQ demonstrated at first seated ( $Z = 1.62$ ,  $t$ -approx. = 0.12, *Fisher's exact test* = 0.11). The LIC's level of APQ continued to decrease at second stand while the MIC level of APQ increased to its highest level ( $Z = 2.00$ ,  $t$ -approx. = 0.05, *Fisher's exact test* = 0.04). Significant differences in amplitude perturbation quotient related to pain intensity class were observed at first seated and second stand tasks.

Table 45.

*Low and Moderate Intensity Pain Class Difference in Amplitude Perturbation Quotient by Task*

Task	Low Intensity Class <i>M</i> score	Moderate Intensity Class <i>M</i> score	<i>Z</i>	2-sided <i>t</i> - approximation	<i>Fisher's</i> <i>exact test</i>
First Seated	13.47	20.0	1.93	0.06	0.05
First Stand	15.9	17.5	0.45	0.66	0.66
Second Seated	14.4	20.0	1.62	0.12	0.11
Second Stand	13.9	20.83	2.00	0.05	0.04



## *Formant Frequencies*

### *First Seated*

At the first seated task,  $F_1$  frequencies were higher for the LIC than the MIC ( $Z = -0.29$ ,  $t$ -approx. = 0.77, *Fisher's exact test* = 0.77). In contrast,  $F_2$  frequencies ( $Z = 1.19$ ,  $t$ -approx. = 0.24, *Fisher's exact test* = 0.24) and  $F_3$  frequencies were higher for the MIC than the LIC ( $Z = 0.84$ ,  $t$ -approx. = 0.41, *Fisher's exact test* = 0.41). No significant differences in formant frequencies between pain intensity classes at the first seated task were observed (Table 46).

### *First Stand*

At the first stand task,  $F_1$  frequencies were higher for the LIC than the MIC ( $Z = -0.68$ ,  $t$ -approx. = 0.50, *Fisher's exact test* = 0.50). However,  $F_2$  frequencies ( $Z = 0.60$ ,  $t$ -approx. = 0.55, *Fisher's exact test* = 0.55) and  $F_3$  frequencies were higher for the MIC ( $Z = 0.25$ ,  $t$ -approx. = 0.80, *Fisher's exact test* = 0.80). No significant differences in formant frequencies between pain intensity classes at the first stand task were observed.

### *Second Seated*

At the second seated task,  $F_1$  frequencies were higher for the MIC than the LIC ( $Z = 0.18$ ,  $t$ -approx. = 0.86, *Fisher's exact test* = 0.86).  $F_2$  frequencies increased for the MIC as  $F_2$  decreased in the LIC resulting in a significant difference ( $Z = 2.28$ ,  $t$ -approx. = 0.03, *Fisher's exact test* = 0.02).  $F_3$  frequencies continued to be higher for the MI group than the LIC at second seated ( $Z = 1.03$ ,  $t$ -approx. = 0.31, *Fisher's exact test* = 0.31). Significant group mean difference in  $F_2$  between pain intensity classes at the second seated task was observed.

### Second Stand

At second stand,  $F_1$  frequencies were higher for the LIC ( $Z = -0.21$ ,  $t$ -approx. = 0.83, *Fisher's exact test* = 0.83).  $F_2$  frequencies were similar for LIC and MIC ( $Z = 0.0$ ,  $t$ -approx. = 1.0, *Fisher's exact test* = 1.0). MIC  $F_3$  frequencies were higher than the LIC  $F_3$  frequencies at second stand ( $Z = 0.06$ ,  $t$ -approx. = 0.95, *Fisher's exact test* = 0.95). No significant difference in formant frequencies between pain intensity classes at second stand was observed (Table 46).

Table 46.

<i>Low and Moderate Intensity Pain Class Difference in Formant Frequencies by Task</i>						
Task	Formant	Low	Moderate	Z	2-sided $t$ -approximation	<i>Fisher's exact test</i>
		Intensity	Intensity			
		Class (N = 20) <i>M</i> Score	Class (N = 12) <i>M</i> Score			
First Seated	$F_1$	16.9	15.8	-0.29	0.77	0.77
	$F_2$	14.95	19.08	1.19	0.24	0.24
	$F_3$	15.40	18.33	0.84	0.41	0.41
First Stand	$F_1$	17.4	15.0	-0.68	0.50	0.50
	$F_2$	15.70	17.83	0.60	0.55	0.55
	$F_3$	16.15	17.08	0.25	0.80	0.80
Second Seated	$F_1$	16.25	16.92	0.18	0.86	0.86
	$F_2$	13.55	21.42	2.28	0.03	0.02
	$F_3$	15.15	18.75	1.03	0.31	0.31
Second Stand	$F_1$	16.8	16.0	-0.21	0.83	0.83
	$F_2$	16.5	16.5	0.0	1.0	1.0
	$F_3$	16.4	16.67	0.06	0.95	0.95

When the influence of pain intensity on acoustic parameters with movement tasks was investigated, significant difference was observed with shimmer at first seated, second

seated and second stand tasks; with amplitude perturbation quotient at first seated and second stand; and with the second formant of the second seated task (Table 47).

Table 47.

*Significant Acoustic Parameter Differences between Pain Intensity Classes by Task*

Parameter	Task	Low	Moderate	Z	2-sided <i>t</i> - approximation	<i>Fisher's</i> <i>exact test</i>
		Intensity	Intensity			
		Class	Class			
		<i>M</i> score	<i>M</i> score			
Shimmer	First Seated	12.68	21.25	2.53	0.02	0.01
	Second Seated	13.4	21.67	2.39	0.02	0.02
	Second Stand	13.28	21.88	2.49	0.02	0.01
APQ	First Seated	13.47	20.0	1.93	0.06	0.05
	Second Stand	13.9	20.83	2.00	0.05	0.04
F <sub>2</sub>	Second Seated	13.55	21.42	2.28	0.03	0.02

#### Research Question 4

Various acoustic parameters (i.e., mean fundamental frequency, lowest fundamental frequency, highest fundamental frequency, range of fundamental frequency, jitter, shimmer, amplitude perturbation quotient, and three formant frequencies) were extracted from sustained vowel utterances of women with and without chronic knee pain to determine if difference occurred in relation to psychological variables (i.e., depression, anxiety, and anger) reported by women with and without chronic knee pain with change of position. Because emotion expression related to pain is presumed to be related to mood, mood states were evaluated using established, validated instruments for depression, anxiety, and anger (Table 48). State and trait measures of anxiety and anger were both evaluated to determine reaction to the study session.

Internal consistency of the inventories was assessed using Cronbach's alpha for the instruments' subscales. Because none of the subjects reported state anger, variance was not available to calculate Cronbach's alpha. Some missing data occurred with inventories and SAS deleted those subjects from the Cronbach's alpha analysis. Subject data was used in subsequent study analyses. Although lower than the norms, internal consistency was judged adequate for all the inventories.

Table 48.

*Cronbach's Alpha for Mood-Related Inventories*

Inventory/Scale	Norm	N	Raw Alpha	Standardized Alpha
BDI-2	0.93	61	0.895	0.899
STAI				
State Anxiety	0.93	54	0.76	0.77
Trait Anxiety	0.91	60	0.90	0.91
STAXI-2				
State Anger	0.92	60	0.88	.
Trait Anger	0.84	62	0.74	0.76

Sample means on the inventories were used to determine the influence of existing moods on the acoustic parameters (Table 49). Group and individual difference in a particular mood-related variable was adjusted by introducing the sample mean. If group mean difference increased and significant difference was demonstrated, support was provided for inferring that a particular variable exerted influence on a specific acoustic parameter.

In order to determine group mean differences on inventories, equality of variance was evaluated using  $F^1$ . Unequal variance between groups was demonstrated on all but one of the inventory scales and Satterthwaite  $t$ -test results were reported for those scales: depression, state anger, state anxiety, and trait anxiety (Table 49). Trait anger scores demonstrated equal variance and pooled  $t$ -test was reported.

Table 49.

*Sample and Group Means and Difference in Mood-Related Inventory Scores*

Inventory	<u>Sample</u>	<u>Non-Pain</u>		<u>Pain</u>		<i>df</i>	<i>t</i> -test	<i>p</i>
	<i>M (SD)</i>	<i>M (SD)</i>	Range	<i>M (SD)</i>	Range			
BDI-II	5.25 (6.28)	2.77 (3.19)	0 – 10	7.58 (7.6)	0 - 36	42.2	3.29	0.002
State Anxiety	25.31 (5.17)	24.77 (4.1)	20 - 37	25.8 (6.09)	20 - 43	54.6	-0.80	0.43
Trait Anxiety	33.00 (6.97)	31.37 (5.48)	23 - 47	34.53 (8.01)	23 - 52	55	-1.83	0.07
State Anger	15.5 (2.06)	15.2 (0.76)	14 - 18	15.78 (2.79)	14 - 30	35.9	-1.13	0.26
Trait Anger	15.2 (3.23)	15.17 (3.46)	10 - 22	15.28 (3.11)	10 - 24	60	-0.14 <sup>†</sup>	0.89

<sup>†</sup>Pooled *t*-test.

Among all the validated mood-related inventories administered, only depression scores demonstrated significant difference between the two groups ( $t = -3.29$ ,  $p = 0.002$ ). The non-pain group mean score on the BDI-II was 2.77 ( $SD = 3.19$ ) while the pain group mean score was 7.58 ( $SD = 7.6$ ). Neither group mean score was in the moderately depressed range established by Beck et al. (1996). No subjects in the non-pain group had scores above the cut-point score of 13 for mild depression. Four subjects in the pain group had BDI-II scores indicative of mild depression and one subject had a score indicative of severe depression. All subjects with scores above the minimal cut point (0-13) (Beck et al., 1996) were made aware of their score and provided a letter to inform their physicians (Appendix 17 ) about the results if the subjects desired.

The non-pain and pain groups reported similar low levels of trait anger [ $t(60) = 0.14$ ,  $p = 0.89$ ]. Trait anxiety was higher in the pain group but were not statistically significant [ $t(55) = -1.83$ ,  $p = 0.07$ ].

When mean scores on depression, state anxiety, trait anxiety, state anger, and trait anger were included as interactions in mixed models, significant group mean differences in acoustic parameters occurred.

### *Effect of Depression*

The BDI-II sample mean of 5.25 ( $SD = 6.28$ ) was lower than the mean reported for the non-depressed normative group ( $M = 7.65$ ,  $SD = 5.9$ ) and lower than the cut point of 13 used as an indicator of mild depressive symptoms established by the instrument's developers. Significant group mean differences related to depression were observed with the following acoustic parameters: (1) lowest fundamental frequency (Flo) at first and second stand; (2) range of fundamental frequency (range of  $F_0$ ) at first and second stand; (3) level of jitter at second stand; and (4) formant frequencies in the second seated and second stand tasks.

### *Depression and Lowest Fundamental Frequency (Flo)*

When depression was added as an interaction term to the original model, lowest fundamental frequencies were higher for the non-pain group than the pain group and increased across the four tasks (Table 50). Flo for the pain group (est.  $M = 167.48$ ) was lower than the non-pain group (est.  $M = 173.86$ ) at first seated; the difference was not significant [ $t\text{-value}(68.7) = 0.89$ ,  $p = 0.38$ ]. Flo in the pain group decreased at the first stand but increased for the non-pain group [ $t\text{-value}(68.7) = 1.98$ ,  $p = 0.05$ ]. Flo increased for both groups at the second seated task, but group mean difference was not significant [ $t\text{-value}(68.7) = 1.64$ ,  $p = 0.11$ ]. Flo decreased in the pain group at the second stand and significant difference between

the non-pain and pain groups was observed [ $t$ -value(68.7) = 2.20,  $p$  = 0.03]. Significant difference in Flo between pain and non-pain groups occurred at the two stand tasks.

Table 50.

*Group Means and Difference in Lowest Fundamental Frequency Related to Depression by Task*

Task	Non-Pain (N=30)  <i>M (SE)</i>	Pain (N=32)  <i>M (SE)</i>	Group Mean Difference  ( <i>SE</i> )	<i>df</i>	<i>t</i> -value	<i>p</i>
First Seated	173.86 (5.64)	167.48 (4.49)	6.39 (7.21)	68.7	0.89	0.38
First Stand	174.37 (5.64)	160.11 (4.49)	14.25 (7.21)	68.7	1.98	0.05
Second Seated	175.18 (5.64)	163.38 (4.49)	11.80 (7.21)	68.7	1.64	0.11
Second Stand	176.61 (5.64)	160.76 (4.49)	15.85 (7.21)	68.7	2.20	0.03

*Note.* Means are in Hz.

Diagnostics performed on the model indicated 3 subjects with Cook's  $D$  greater than 0.2 and 9 subjects with COVRATIO less than 1.0. In the 5 influential subjects identified, COVRATIO ranged from 0.27 to 14.4 (Appendix 23): 1 from the non-pain group and 4 from the pain group. The subject with the highest COVRATIO also had the highest BDI-II score of 38. Flo ranged from 89.65 to 312.57.

The log transformation model did not improve the residuals plot. Five subjects had Cook's  $D$  greater than 0.2 and 9 subjects had COVRATIO greater than 1.0. Of the 5 influential subjects, COVRATIO ranged from 0.269 to 14.42. BDI-II scores ranged from 1 to 36 for these 5 subjects.

A subject's data identified with high Cook's  $D$  and COVRATIO in both models was examined. This subject's BDI-II score was 36 and the next highest BDI-II score in this sample was 22. Diagnostics techniques identified this subject as an outlier influencing the



outcome. Her data was deleted from the depression analyses, but in this exploratory study, her data was retained for other analyses.

Another subject's data was identified as influential deleted in previous analyses of Flo, Fhi, and range of  $F_0$  due the effect of singing the vowel at the first seated task. Because of outlier status, this subject's first seated acoustic data were also deleted from depression and other mood-related analyses.

With these deletions, 30 subjects in the pain group were included in the first seated analyses and 31 subjects in the first stand, second seated, and second stand analyses of lowest fundamental frequency related to depression. The sample mean BDI-II score changed in response to these deletions ( $M = 4.75$ ,  $SD = 4.93$ ) as did the pain group BDI-II score distribution ( $M = 6.66$ ,  $SD = 5.56$ , range = 0 – 22). The revised sample mean for depression was entered as an interaction term in the reduced model and in the diagnostics.

The non-pain group had higher Flo across all tasks (Table 51). At first seated, the pain group Flo was the lowest of the four tasks. Group mean difference between the non-pain and pain groups in Flo related to depression was significant at first seated [ $t$ -value(69.7) = 2.30,  $p = 0.02$ ]. At first stand, the pain group's Flo decreased and difference increased and group mean difference in Flo related to depression was significant [ $t$ -value(69.7) = 1.99,  $p = 0.05$ ]. Flo increased for both groups at second seated and difference decreased [ $t$ -value(69.7) = 1.72,  $p = 0.09$ ]. The pain group decreased in Flo at second stand while the non-pain group demonstrated higher Flo and significant group mean difference in Flo related to depression was observed at second stand [ $t$ -value(69.7) = 2.22,  $p = 0.03$ ]. Group mean differences between non-pain and pain groups in Flo related to depression at first seated, first stand and second stand were significant.

Table 51.

*Group Means and Difference in Reduced Model of Lowest Fundamental Frequency Related to Depression by Task*

Task	Non-Pain (N=30) <i>M (SE)</i>	Pain (N=31) <i>M (SE)</i>	Group Mean Difference ( <i>SE</i> )	<i>df</i>	<i>t</i> -value	<i>p</i>
First Seated	172.94 6(5.0)	*156.90(4.45)	16.03 (6.74)	69.7	2.30	0.02
First Stand	173.35 (4.99)	159.84 (4.45)	13.41 (6.74)	69.7	1.99	0.05
Second Seated	174.44 (4.99)	162.82 (4.45)	11.62 (6.74)	69.7	1.72	0.09
Second Stand	175.56 (4.99)	160.64 (4.45)	14.93 (6.74)	69.7	2.22	0.03

\*N = 30. *Note.* Means are in Hz.

Diagnostics performed on the reduced model with the new sample mean identified 6 influential subjects; 1 subject was from the non-pain group and 5 subjects were from the pain group with Cook's *D* greater than 0.2. COVRATIO ranged from 0.38 to 1.26 with these 6 subjects (Appendix 23) and BDI-II scores ranged from 0 to 22 with the highest score associated with the highest COVRATIO. Flo ranged from 111.26 to 219.66 Hz.

Log transformation of the sample was performed. Diagnostics of the log transformation of the reduced model identified 6 influential subjects with Cook's *D* greater than 0.2 and 8 subjects with COVRATIO less than 1.0. COVRATIO ranged from 0.18 to 3.12. The non-pain group had the highest Flo at all tasks (Table 51). Influential subjects included 5 subjects identified in the reduced model. In addition to 5 pain group members with high Flo, one non-pain group subject not identified in the reduced model was identified as influential in the log transformation model. BDI-II scores of identified subjects ranged from 0 to 22. When the log transformation model was entered into PROC MIXED, group

mean differences were greater at second stand, first stand, and second seated respectively (Table 52).

Table 52.

*Group Means and Difference in Log Transformation of Reduced Model of Lowest Fundamental Frequency by Task*

Task	Non-Pain (N=30) <i>M (SE)</i>	Pain (N=31) <i>M (SE)</i>	Group Mean Difference
First Seated	170.32 (1.03)	*161.69 (1.03)	4.61
First Stand	171.52 (1.03)	158.90 (1.03)	12.62
Second Seated	172.41 (1.03)	161.74 (1.03)	10.67
Second Stand	173.43 (1.03)	159.25 (1.03)	14.18

\*N=30. *Note.* Means are in Hz.

Group mean difference in Flo at second stand remained significant [ $t$ -value(64.6) = 2.15,  $p$  = 0.04] as it was in the reduced model (Table 53). Because significant difference in Flo related to depression between the non-pain and pain group was observed only at second stand with the log transformation model (Table 53), and the reduced model identified significant difference at three tasks, the original model was judged unstable.

Table 53.

*Results of Log Transformation of Reduced Model of Lowest Fundamental Frequency Related to Task*

Task	Group Mean Ratio	SE	df	t-value	p
First Seated	1.05	1.04	64.7	1.31	0.20
First Stand	1.08	1.04	64.6	1.92	0.06
Second Seated	1.07	1.04	64.6	1.61	0.11
Second Stand	1.09	1.04	64.6	2.15	0.04

*Depression and Range of Fundamental Frequency*

When the revised sample mean for depression scores was added as an interaction term to the deletion model, range of  $F_0$  was wider for the pain group than the non-pain group in all tasks (Table 54). While the non-pain group range of  $F_0$  became narrower across the four tasks, the pain group range of  $F_0$  became wider at first stand [ $t$ -value(77.0) = -2.21,  $p$  = 0.03] and second stand [ $t$ -value(77.0) = -2.07,  $p$  = 0.04]. Group mean differences in range of  $F_0$  related to depression at first seated [ $t$ -value(77.3) = -0.80,  $p$  = 0.43] and second seated [ $t$ -value(77.0) = -0.85,  $p$  = 0.40] were not significant. Group mean difference between the non-pain and pain groups in range of  $F_0$  related to depression was significant at the first and second stand tasks.

Table 54.

*Group Means and Difference in Reduced Model of Range of Fundamental Frequency Related to Depression by Task*

Task	Non-Pain (N=30) <i>M (SE)</i>	Pain (N=31) <i>M (SE)</i>	Group Mean Difference ( <i>SE</i> )	<i>df</i>	<i>t</i> -value	<i>p</i>
First Seated	22.47 (2.88)	*25.56 (2.54)	-3.08 (3.84)	77.3	-0.80	0.43
First Stand	20.31 (2.88)	28.80 (2.54)	-8.49 (3.83)	77.0	-2.17	0.03
Second Seated	19.06 (2.88)	22.33 (2.54)	-3.27 (3.83)	77.0	-0.85	0.40
Second Stand	18.30 (2.88)	26.23 (2.54)	-7.94 (3.83)	77.0	-2.07	0.04

\*N = 30. *Note.* Means are in Hz.

Diagnostics were performed using the reduced model previously described. Six subjects had Cook's *D* greater than 0.2 and 7 subjects had COVRATIO less than 1.0. Four subjects had COVRATIO greater than 2.0. Six influential subjects from the pain group were identified with Cook's *D* greater than 0.2 and COVRATIO ranging from 0.1068 to 3.06. All subjects had one range of  $F_0$  over 30 Hz; 4 subjects had one range of  $F_0$  greater than 60 Hz. BDI-II scores of the 5 subjects ranged from 1 to 22. The subject with the highest COVRATIO had the smallest ranges of  $F_0$  of the 6 subjects and the highest BDI score.

Diagnostics of log transformation of the reduced model identified 6 influential subjects as having Cook's *D* greater than 0.2 and 10 subjects with COVRATIO less than 1.0. Two subjects had COVRATIO greater than 2.0. Subjects with Cook's *D* greater than 0.2 also had COVRATIO ranging from 0.40 to 3.19: 5 subjects from the pain group and 1 subject from the non-pain group. Three of the pain group subjects were identified in the reduced model diagnostics. The non-pain subject had one range of  $F_0$  measurement over 70 Hz and

BDI score was 10. The largest group mean differences were at the stand tasks (Table 55).

The log transformation of the deleted model showed improved residual plots (Appendix 23).

The log transformation model did not demonstrate significant difference in range of fundamental frequency between groups at any task (Table 56). The reduced model was judged unstable.

Table 55.

*Group Means and Difference in Log Transformation of Reduced Model of Range of Fundamental Frequency Related to Depression by Task*

Task	Non-Pain (N=30) <i>M (SE)</i>	Pain (N=31) <i>M (SE)</i>	Group Mean Difference
First Seated	20.42 (1.10)	*19.96 (1.09)	0.46
First Stand	19.17 (1.10)	22.63 (1.09)	-3.46
Second Seated	17.67 (1.10)	18.65 (1.09)	-0.98
Second Stand	16.82 (1.10)	20.66 (1.09)	-3.84

\*N=30. *Note.* Means are in Hz.

Table 56.

*Results of Log Transforamtion of Reduced Model of Range of Fundamental Frequency Related to Depression by Task*

Task	Group Mean Ratio	<i>SE</i>	<i>df</i>	<i>t</i> -value	<i>p</i>
First Seated	1.02	1.14	71.5	0.17	0.86
First Stand	0.85	1.14	71.2	-1.26	0.21
Second Seated	0.95	1.14	71.2	-0.41	0.68
Second Stand	0.81	1.14	71.2	-1.55	0.13

### *Depression and Jitter*

When the revised sample mean of depression scores was added as an interaction term to the original model, level of jitter was greater for the pain group than the non-pain group across all tasks (Table 57). Group mean difference in jitter at the first seated task was not significant [ $t$ -value(72.9) = -0.53,  $p$  = 0.82]. Both group's level of jitter decreased at the first stand [ $t$ -value(72.9) = -1.28,  $p$  = 0.20]. At second seated, both groups' levels of jitter was similar to first stand [ $t$ -value(72.9) = -1.22,  $p$  = 0.23]. At second stand, the pain group's jitter increased to a level greater than it's first seated level while the non-pain group's jitter was the lowest of all tasks [ $t$ -value(72.9) = -1.95,  $p$  = 0.06]. No significant group mean difference of the non-pain and pain group in jitter related to depression was observed.

Table 57.

*Group Means and Difference in Reduced Model of Jitter in Percent Related to Depression by Task*

Task	Non-Pain (N=30) <i>M (SE)</i>	Pain (N=31) <i>M (SE)</i>	Group Mean Difference ( <i>SE</i> )	<i>df</i>	<i>t</i> -value	<i>p</i>
First Seated	0.95 (0.10)	1.00 (0.09)	-0.06 (0.13)	72.9	-0.53	0.82
First Stand	0.81 (0.10)	0.98 (0.09)	-0.17 (0.13)	72.9	-1.28	0.20
Second Seated	0.82 (0.10)	0.98 (0.09)	-0.16 (0.13)	72.9	-1.22	0.23
Second Stand	0.76 (0.10)	1.02 (0.09)	-0.25	72.9	-1.95	0.06

\*N = 30. Note. Means are in Hz.

### *Depression and Formant Frequencies*

When the revised sample mean of depression scores was added as an interaction term to the model, formant frequencies were higher for the non-pain group with the exception of  $F_2$  and  $F_3$  at first seated (Table 58).

#### *First Seated.*

At first seated, the formants did not differ between groups at  $F_1$  [ $t$ -value(213) = 0.62,  $p = 0.53$ ],  $F_2$  [ $t$ -value(174) = -0.13,  $p = 0.89$ ] of  $F_3$  [ $t$ -value(176) = -0.01,  $p = 0.99$ ].

#### *First Stand.*

At first stand, the non-pain group increased frequencies in all formants while the non-pain group increased in  $F_1$  and  $F_3$ , but not in  $F_2$ . The formants at first stand did not differ between groups at  $F_1$  [ $t$ -value(213) = 0.89,  $p = 0.38$ ],  $F_2$  [ $t$ -value(174) = 0.18,  $p = 0.86$ ], and  $F_3$  [ $t$ -value(176) = 0.26,  $p = 0.80$ ].

#### *Second Seated.*

However, at the second seated task, the non-pain group demonstrated a marked increase in  $F_1$  and  $F_2$  while the pain group had decreases in  $F_1$  and  $F_2$  and significant mean difference between groups at  $F_1$  [ $t$ -value(213) = 2.03,  $p = .04$ ] and  $F_2$  [ $t$ -value(174) = 2.18,  $p = 0.03$ ] was observed. While the non-pain group had a marked increase in  $F_3$ , significant group difference in  $F_3$  at the second seated task [ $t$ -value(176) = 1.77,  $p = 0.08$ ] did not occur.

#### *Second Stand.*

At second stand, both group decreased frequencies in  $F_1$ ,  $F_2$ , and  $F_3$ .  $F_1$  differences between the two groups were not significant [ $t$ -value(213) = 1.91,  $p = 0.06$ ]. However, decreases in  $F_2$  [ $t$ -value(174) = 1.97,  $p = .05$ ] and decreases in  $F_3$  [ $t$ -value(176) = 2.20,  $p = 0.03$ ] by both groups at second stand influenced group mean differences. Significant group



mean differences in  $F_1$  and  $F_2$  at second seated and in  $F_2$  and  $F_3$  at second stand occurred with the interaction of depression.

Diagnostics performed on the reduced model identified 1 subject with Cook's  $D$  greater than 0.2 and 7 subjects with COVRATIO less than 1.0. The 1 influential non-pain group subject with Cook's  $D$  greater than 0.2 had COVRATIO of 0.00. Examination of this subject's mean formant data found marked increases in  $F_2$  and  $F_3$  at the second seated and second stand tasks. Five subjects had COVRATIO greater than 10.0 and ranging from 14.07 to 296.90: 2 subjects from the pain group and 4 from the non-pain group with the large COVRATIO indicating the need to consider this subject's data more carefully.

Diagnostics of the log transformation of the reduced model identified no subjects with Cook's  $D$  greater than 0.2, but 1 subject with Cook's  $D$  greater than 0.1: the same subject identified in the reduced model. Eleven subjects had COVRATIO less than 1.0. Six subjects had COVRATIO greater than 1.0: 3 from the non-pain group and 3 from the pain group. Five subjects were identified in reduced model diagnostics and 1 pain subject not previously identified became influential with log transformation. BDI-II scores ranged from 9-22 with these 6 subjects. Range of BDI-II scores for the non-pain group was 8 to 10 while range of BDI-II scores for the pain group was 17 to 22.

Table 58.

*Group Means and Difference in Reduced Model of Formant Frequencies Related to Depression by Task*

Task	Formant	Non-Pain (N =30) <i>M (SE)</i>	Pain (N = 31) <i>M (SE)</i>	Group Mean Difference ( <i>SE</i> )	<i>df</i>	<i>t</i> -value	<i>p</i>
First Seated	F <sub>1</sub>	772.47 (0.44)	*735.67 (0.39)	36.80 (0.59)	213	0.62	0.53
	F <sub>2</sub>	1609.51 (1.02)	*1627.70 (0.90)	-18.19 (1.36)	174	-0.13	0.89
	F <sub>3</sub>	3120.94 (1.56)	*3123.40 (1.37)	-2.46 (2.08)	176	-0.01	0.99
First Stand	F <sub>1</sub>	832.97 (0.44)	780.35 (0.39)	52.61 (0.59)	213	0.89	0.38
	F <sub>2</sub>	1634.00 (1.03)	1609.99 (0.90)	24.01 (1.36)	174	0.18	0.86
	F <sub>3</sub>	3193.65 (1.56)	3139.75 (1.37)	53.90 (2.08)	176	0.26	0.80
Second Seated	F <sub>1</sub>	885.17 (0.45)	764.91 (0.39)	120.26 (0.59)	213	2.03	0.04
	F <sub>2</sub>	1861.27 (1.02)	1563.10 (0.90)	298.17 (1.36)	174	2.18	0.03
	F <sub>3</sub>	3489.82 (1.56)	3121.95 (1.37)	367.86 (2.08)	176	1.77	0.08
Second Stand	F <sub>1</sub>	864.60 (0.44)	751.26 (0.39)	113.34 (0.59)	213	1.91	0.06
	F <sub>2</sub>	1824.42 (1.02)	1555.30 (0.90)	269.12 (1.36)	174	1.97	0.05
	F <sub>3</sub>	3420.28 (1.94)	3009.48 (1.37)	457.51 (2.08)	176	2.20	0.03

\*N = 30. *Note.* Means are in Hz.

Some improvement in plot of residuals was observed with the log transformation (Appendix 23). Although there were no subjects with Cook's *D* greater than 0.2, 11 subjects had COVRATIO less than 1.0. Six subjects had COVRATIO over 10.0. When the log transformation model was entered into PROC MIXED, the non-pain group had higher formant frequencies than the pain group except  $F_2$  and  $F_3$  at first seated (Table 59).

Table 59.

*Group Means and Difference in Log Transformation of Reduced Model of Formant Frequencies Related to Depression by Task*

Task	Formant	Non-Pain	Pain	Group Mean Difference
		(N=30)	(N=31)	
		<i>M (SE)</i>	<i>M (SE)</i>	
First Seated	$F_1$	725.87 (1.08)	*706.82 (1.07)	19.05
	$F_2$	1586.95 (1.05)	*1645.29 (1.05)	-58.34
	$F_3$	3096.94 (1.04)	*3200.53 (1.04)	-103.59
First Stand	$F_1$	814.50 (1.08)	732.43 (1.07)	82.07
	$F_2$	1607.40 (1.05)	1572.26 (1.05)	35.14
	$F_3$	3173.44 (1.04)	3093.54 (1.04)	79.9
Second Seated	$F_1$	839.47 (1.08)	720.66 (1.07)	118.81
	$F_2$	1733.63 (1.05)	1536.36 (1.05)	197.27
	$F_3$	3353.87 (1.04)	3073.80 (1.04)	280.07
Second Stand	$F_1$	839.22 (1.08)	719.65 (1.07)	119.57
	$F_2$	1732.76 (1.05)	1535.74 (1.05)	197.02
	$F_3$	3332.81 (1.04)	2975.51 (1.04)	357.3

\*N=30. Note. Means are in Hz.

Significant difference between the non-pain and pain groups was observed in formant frequencies with  $F_3$  at the second stand task when depression was entered into the analysis [ $t$ -value(170) = 2.09,  $p = 0.04$ ] (Table 60). Although the difference in  $F_3$  at second stand was Table 60.

*Results of Log Transformation of Reduced Model of Formant Frequencies Related to Depression by Task*

Task	Formant	Group Mean Ratio	SE	df	$t$ -value	$p$
First Seated	$F_1$	1.02	1.10	204	0.27	0.79
	$F_2$	0.96	1.07	167	-0.53	0.59
	$F_3$	0.97	1.06	170	-0.60	0.55
First Stand	$F_1$	1.11	1.10	203	1.08	0.28
	$F_2$	1.02	1.07	167	0.33	0.74
	$F_3$	1.03	1.06	170	0.47	0.64
Second Seated	$F_1$	1.16	1.10	203	1.55	0.12
	$F_2$	1.13	1.07	167	1.79	0.08
	$F_3$	1.09	1.06	170	1.61	0.11
Second Stand	$F_1$	1.16	1.10	203	1.56	0.12
	$F_2$	1.13	1.07	167	1.78	0.08
	$F_3$	1.12	1.06	170	2.09	0.04

observed in the reduced model,  $F_1$  and  $F_2$  differences at second seated and  $F_2$  difference at second stand were not observed following log transformation. The reduced model of the interaction of depression with formant frequency was judged unstable.

### *Effect of State Anxiety*

The sample mean of the state anxiety scale of the STAI ( $M = 25.3$ ,  $SD = 5.17$ ) was lower than the norm of 35.20 for working adult females established by instrument developers. With the addition of state anxiety, significant group mean difference with the interaction of state anxiety was noted with the following acoustic parameters: (1) range of fundamental frequencies across three tasks, (2) jitter at second stand, and (3) APQ at first stand. Range, jitter, shimmer, and APQ were higher for the pain group than the non-pain group in all tasks, but statistical difference was only found at the two stand tasks with range, jitter, and APQ.

#### *State Anxiety and Range of Fundamental Frequency*

Because range of  $F_0$  was influenced by one subject's Fhi at the first seated task, the reduced data set was used for the analysis of the effect of state anxiety on range of  $F_0$  (Table 61). When state anxiety was added as an interaction term to the model, the pain group had wider range of  $F_0$  than the non-pain group across all tasks. At first seated, the non-pain group demonstrated its widest range of  $F_0$  while the pain group had its second widest range of  $F_0$  [ $t$ -value(84) = -1.34,  $p = 0.18$ ]. Range of  $F_0$  for the pain group increased at the first stand while non-pain group range of  $F_0$  narrowed [ $t$ -value(84) = -3.40,  $p = .001$ ]. The pain group's range of  $F_0$  narrowed at second seated while the non-pain group's range of  $F_0$  did not change [ $t$ -value(84) = -1.32,  $p = 0.19$ ]. The pain group's range of  $F_0$  increased at second stand to a range greater than first seated while the non-pain group's range of  $F_0$  became more narrow [ $t$ -value(84) = -3.04,  $p = .003$ ]. The non-pain group demonstrated a narrower range of fundamental frequencies than the pain group. Non-pain group range of  $F_0$  narrowed across

the four tasks. Group mean differences between the non-pain and pain groups in range of  $F_0$  related to state anxiety were significant at first stand and second stand.

Table 61.

*Group and Means Difference in Reduced Model of Range of Fundamental Frequency Related to State Anxiety by Task*

Task	Non-Pain (N=30) <i>M (SE)</i>	Pain (N=31) <i>M (SE)</i>	Group Mean Difference ( <i>SE</i> )	<i>df</i>	<i>t</i> -value	<i>p</i>
First Seated	22.21 (2.57)	*26.99 (2.47)	-4.78 (3.56)	84	-1.34	0.18
First Stand	19.39 (2.57)	31.52 (2.47)	-12.12 (3.56)	84	-3.40	0.001
Second Seated	19.39 (2.57)	24.11 (2.47)	-4.72 (3.56)	84	-1.32	0.19
Second Seated	17.98 (2.57)	28.82 (2.47)	-10.84 (3.56)	84	-3.04	0.003

\*N = 30. *Note.* Means are in Hz.

Diagnostics were performed and 6 subjects were identified with Cook's  $D$  greater than 0.2 and 9 subjects with COVRATIO less than 1.0. In the group of 6 influential subjects, Cook's  $D$  ranged from 0.24 to 0.54 and COVRATIO ranged from 0.10 to 4.20: 5 subjects from the pain group and 1 subject from the non-pain group. State anxiety scale scores ranged from 20 (3 subjects) to 43.

Log transformation was performed and diagnostics of log transformation of the reduced model identified 6 subjects with Cook's  $D$  of 0.2 or higher and 12 subjects with COVRATIO less than 1.0. The 6 influential subjects had Cook's  $D$  of 0.2 or higher and COVRATIO ranging from 0.4 to 5.31: 3 subjects from the pain group and 3 subjects from the non-pain group. The non-pain subjects had state anxiety scores of 20 and 37. Pain group subjects had state anxiety scores ranging from 21 to 43. The highest COVRATIO was associated with the subject having the highest state anxiety score of 43. Residual plots

showed improvement with the log transformation model (Appendix 23) and the log transformation model was entered into PROC MIXED. The pain group had the largest range of  $F_0$  at all tasks (Table 62).

Table 62.

*Group Means and Difference in Log Transformation of Reduced Model of Range of Fundamental Frequency Related to State Anxiety by Task*

Task	Non-Pain (N=30) <i>M (SE)</i>	Pain (N=32) <i>M (SE)</i>	Group Mean Difference
First Seated	19.91 (1.09)	*21.98 (1.09)	-1.99
First Stand	18.21 (1.09)	24.96 (1.09)	-6.75
Second Seated	17.77 (1.09)	20.21 (1.09)	-2.44
Second Stand	16.61 (1.09)	22.57 (1.09)	-5.96

\*N = 30. *Note:* Means are in Hz.

In the log transformation of the reduced model, significant group mean difference in range of  $F_0$  between non-pain and pain groups was observed at first stand [ $t$ -value(75) = -2.54,  $p = 0.01$ ) and at second stand [ $t$ (75) = -2.47,  $p = 0.02$ ] (Table 63). Because these findings were similar to the original reduced model, the reduced model was judged as stable.

Table 63.

*Results of Log Transformation of Reduced Model of Range of Fundamental Frequency Related to State Anxiety by Task*

Task	Group Mean Ratio	SE	df	t-value	p
First Seated	0.91	1.13	75.5	-0.79	0.43
First Stand	0.73	1.13	75	-2.54	0.01
Second Seated	1.14	1.13	75	-1.03	0.30
Second Stand	0.74	1.13	75	-2.47	0.02

*State Anxiety and Jitter*

When state anxiety was added as an interaction term to the model, the level of jitter was greater for the pain group across all four tasks (Table 64). At first stand, the level of jitter was higher in the pain group than the non-pain group but group mean difference was not significant [ $t\text{-value}(73.1) = -1.12, p = 0.27$ ]. At first stand, the level of jitter decreased for both groups [ $t\text{-value}(73.1) = -1.93, p = 0.06$ ]. At second seated, jitter increased for both groups although the pain group jitter level remained higher than the non-pain group jitter level [ $t\text{-value}(73.1) = -1.49, p = 0.14$ ]. However, at second stand, the non-pain group level of jitter dropped while the pain group level increased and the group mean difference in jitter became significant [ $t\text{-value}(73.1) = -2.79, p = .007$ ]. Group mean difference in jitter related to state anxiety between the non-pain and pain groups was significant at the second stand task.



Table 64.

*Group Means and Difference in Model of Jitter in Percent Related to State Anxiety by Task*

Task	Non-Pain (N=30) <i>M (SE)</i>	Pain (N=32) <i>M (SE)</i>	Group Mean Difference ( <i>SE</i> )	<i>df</i>	<i>t</i> -value	<i>p</i>
First Seated	0.95 (0.09)	1.10 (0.08)	0.17 (0.12)	73.1	-1.12	0.27
First Stand	0.81 (0.09)	1.04 (0.08)	-0.23 (0.12)	73.1	-1.93	0.06
Second Seated	0.87 (0.09)	1.05 (0.08)	-0.18 (0.12)	73.1	-1.49	0.14
Second Stand	0.78 (0.09)	1.12 (0.08)	-0.34 (0.12)	73.1	-2.79	0.007

Diagnostics were performed and 4 subjects with Cook's *D* greater than 0.2 and 9 subjects with COVRATIO less than 1.0 were identified (Appendix 23). Four influential subjects were identified with Cook's *D* greater than 0.2: 2 subjects in the non-pain group and 2 in the pain group. COVRATIO of the 4 identified subjects ranged from 0.26 to 5.92. Examination of the data found one non-pain subject had low jitter levels ranging from 0.53 to 0.83 and a state anxiety score of 37. The second non-pain subject had jitter levels ranging from 0.56 to 2.77 and a state anxiety score below the mean of 20. One pain group subject's levels of jitter were all greater than 1.5 and state anxiety score was 47. The second pain group subject had jitter levels ranging from 0.8 to 2.18 and state anxiety score of 32.

Log transformation of the reduced model was performed and diagnostics of the log transformation model identified 4 influential subjects with Cook's *D* greater than 0.2. Three of those identified were influential subjects in the reduced model. The newly identified subject was from the pain group and had jitter levels ranging from 0.32 to 0.83 as well as a

state anxiety score of 36. Some improvement was noted in the residuals plot (Appendix 23) and the log transformation model was entered into PROC MIXED. The pain group had higher levels of jitter across all tasks (Table 65). Significant group mean difference in jitter related to state anxiety was observed at the second stand task [ $t$ -value (71.4) = -2.58,  $p$  = 0.01] (Table 66) as it had been in the original model. The original model was accepted as stable.

Table 65.

*Group Means and Difference in Log Transformation of Model of Jitter in Percent Related to State Anxiety by Task*

Task	Non-Pain (N=30) <i>M (SE)</i>	Pain (N=32) <i>M (SE)</i>	Group Mean Difference
First Seated	0.86 (1.09)	0.95 (1.09)	-0.09
First Stand	0.74 (1.09)	0.90 (1.09)	-0.16
Second Seated	0.77 (1.09)	0.86 (1.09)	-0.09
Second Stand	0.69 (1.09)	0.93 (1.09)	-0.24

Table 66.

*Results of Log Transformation of Model of Jitter in Percent Related to State Anxiety by Task*

Task	Group Mean Ratio	<i>SE</i>	<i>df</i>	<i>t</i> -value	<i>p</i>
First Seated	.91	1.13	71.7	-0.77	0.44
First Stand	.82	1.13	71.4	-1.62	0.11
Second Seated	.90	1.13	71.4	-0.88	0.38
Second Stand	.73	1.13	71.4	-2.58	0.01

### *State Anxiety and Amplitude Perturbation Quotient (APQ)*

When state anxiety was added as an interaction term to the reduced model, amplitude perturbation quotient (APQ) was higher across all tasks for the pain group (Table 67). At first seated, the non-pain group's level of APQ was at it highest level for the four tasks. However, group mean difference in APQ was not significant at first seated [ $t$ -value(70) = -0.59,  $p$  = 0.56]. The drop in the non-pain group's APQ at first stand was contrasted by the pain group increase in APQ and significant group mean difference was observed [ $t$ -value(70) = -1.98,  $p$  = .05]. Both groups had decreased APQ at the second seated but the difference was not significant [ $t$ -value(70) = -1.79,  $p$  = 0.08]. Decreases in APQ by both groups occurred at second stand, but group mean difference in APQ was not significant [ $t$ -value(70) = -1.59,  $p$  = 0.12].

Table 67.

#### *Group Means and Difference in Reduced Model of Amplitude Perturbation Quotient Related to State Anxiety by Task*

Task	Non-Pain (N=30) <i>M (SE)</i>	Pain (N=32) <i>M (SE)</i>	Group Mean Difference ( <i>SE</i> )	<i>df</i>	<i>t</i> -value	<i>p</i>
First Seated	1.96 (0.15)	*2.09 (0.15)	-0.12 (0.21)	70	-0.59	0.56
First Stand	1.89 (0.15)	2.31 (0.15)	-0.42 (0.21)	70	-1.98	0.05
Second Seated	1.89 (0.15)	2.26 (0.15)	-0.38 (0.21)	70	-1.79	0.08
Second Stand	1.85 (0.15)	2.19 (0.15)	-0.33 (0.21)	70	-1.59	0.12

\*N = 31.

Diagnostics were performed on the reduced model and 5 subjects had Cook's  $D$  greater than 0.2 and 8 subjects had COVRATIO less than 1.0 (Appendix 23). Five influential subjects, 4 from the pain group and 1 from the non-pain group, were identified with Cook's

*D* greater than 0.2 and COVRATIO ranging from 0.07 to 1.19. State anxiety scores for these four subjects ranged from 20 to 36, with 3 subjects having scores higher than the sample mean. The subject with state anxiety score of 20, the lowest of the four subjects, had APQ levels ranging from 6.01 and 7.33 indicating the subject's influence. Four COVRATIO less than 1.0 indicated that influential subject deletion could improve the model.

Log transformation was performed and identified 5 subjects with Cook's *D* greater than 0.2 and 8 subjects with COVRATIO less than 1.0. Of the influential subjects with Cook's *D* greater than 0.2 and COVRATIO less than 1.0, 4 had been identified in the reduced model diagnostics. One influential subject from the non-pain group was newly identified with log transformation from the non-pain group but had COVRATIO of 5.93. The pain group had greater APQ than the non-pain group (Table 68). Log transformation of the model did not improve linearity of the plot of residuals although the distribution of residuals was improved (Appendix 23). The non-pain subject's state anxiety score of 37 was elevated compared to the sample mean of 25.31, and this subject's COVRATIO was the highest of the sample. When the log transformation model was entered into PROC MIXED, the pain group continued to have higher APQ (Table 69). However, no significant difference in APQ related to state anxiety between the non-pain and pain groups was found at any of the tasks (Table 69). The reduced model of the effect of state anxiety on APQ was judged unstable.

Table 68.

*Group Means and Difference of Log Transformation of Reduced Model of Amplitude Perturbation Quotient Related to State Anxiety by Task*

Task	Non-Pain (N=30) <i>M (SE)</i>	Pain (N=32) <i>M (SE)</i>	Group Mean Difference
First Seated	1.88 (1.06)	*1.97 (1.06)	-0.09
First Stand	1.81 (1.06)	2.06 (1.06)	-0.25
Second Seated	1.82 (1.06)	2.06 (1.06)	-0.24
Second Stand	1.78 (1.06)	2.02(1.06)	-0.24

\*N=31.

Table 69.

*Results of Log Transformation of Reduced Model of Amplitude Perturbation Quotient Related to State Anxiety by Task*

Task	Group Mean Ratio	<i>SE</i>	<i>df</i>	<i>t</i> -value	<i>p</i>
First Seated	.95	1.08	71.6	-0.62	0.54
First Stand	.88	1.08	71.3	-1.66	0.10
Second Seated	.88	1.08	71.3	-1.56	0.12
Second Stand	.88	1.08	71.3	-1.60	0.11

*Effect of Trait Anxiety*

The sample mean for trait anxiety on the STAI trait anxiety scale was 33.0 (SD = 6.97) and this mean was lower than the norm for working females of 34.79 (SD = 9.22).

Significant group mean differences with the interaction of trait anxiety had been observed with the following acoustic parameters: (1) range of fundamental frequency, (2) jitter, and (3) formant frequencies. Because range of  $F_0$  was influenced by the Fhi and Flo of the subject who sang first seated vowels, the reduced data set was used for this analysis.

#### *Trait Anxiety and Range of Fundamental Frequencies*

When trait anxiety was added to the model as an interaction term, range of fundamental frequencies was greater for the pain group than the non-pain group at all tasks with significant difference observed at first stand and second stand (Table 70). Group mean differences at first seated [ $t$ -value(83.1) = -1.26,  $p = 0.21$ ] and second seated [ $t$ -value(83.1) = -1.24,  $p = 0.22$ ] were not significant. At first and second stand, the non-pain group had decreases in range of  $F_0$  while the pain group had increases in range of  $F_0$ . Significant group mean difference in range of  $F_0$  was observed at first stand [ $t$ -value(83.1) = 3.13,  $p = 0.002$ ] and second stand [ $t$ -value(83.1) = -3.03,  $p = 0.003$ ]. The non-pain group range of  $F_0$  at first seated task decreased across the next three tasks, ending with a range of  $F_0$  lower than the first seated range. In contrast to the non-pain group narrowing of range of  $F_0$ , the pain group's range of  $F_0$  pattern demonstrated an increase at first stand, a decrease at the second seated, and an increase at second stand to a level higher than the range of  $F_0$  obtained at first seated. Group mean differences in range of  $F_0$  related to trait anxiety were significant at first and second stand tasks.

Table 70.

*Group Means and Difference of Reduced Model of Range of Fundamental Frequency Related to Trait Anxiety by Task*

Task	Non-Pain (N=30) <i>M (SE)</i>	Pain (N=32) <i>M (SE)</i>	Group Mean Difference ( <i>SE</i> )	<i>df</i>	<i>t</i> -value	<i>p</i>
First Seated	21.74 (2.69)	*26.41 (2.54)	-4.67 (3.70)	83.1	-1.26	0.21
First Stand	19.22 (2.69)	30.78 (2.54)	-11.55 (3.70)	83.1	-3.13	0.002
Second Seated	19.04 (2.69)	23.64 (2.54)	-4.60 (3.70)	83.1	-1.24	0.22
Second Stand	17.79 (2.69)	28.98 (2.54)	-11.20 (3.70)	83.1	-3.03	0.003

\*N=31. *Note.* Means are in Hz.

Diagnostics were performed and identified 5 subjects with Cook's *D* greater than 0.2 and 8 subjects with COVRATIO less than 1.0. Five influential subjects with Cook's *D* greater than 0.2 were identified: 1 subject from the non-pain group and 4 subjects from the pain group. Three pain subjects also had at least one range of  $F_0$  greater than 90 Hz. COVRATIO of the 5 influential subjects ranged from 0.1098 to 0.7701. The subject with the highest COVRATIO also had the highest trait anxiety score, but did not have Cook's *D* greater than 0.2. Trait anxiety scores of the influential subjects ranged from 24 to 40 with 4 scores below the sample mean.

Log transformation improved the model residuals and identified 5 subjects with Cook's *D* greater than 0.2 and 10 subjects with COVRATIO less than 1.0. Of the 5 influential subjects identified with Cook's *D* greater than 0.2, 2 subjects were from the non-pain group and three from the pain group. Cook's *D* ranged from 0.21 to 0.58. For these 5 subjects, COVRATIO ranged from 0.39 to 4.07 with 3 COVRATIO below 1.0 indicating

model improvement with deletion. Trait anxiety scores of the 5 influential subjects ranged from 24 to 52 with 2 scores below the sample mean and the higher trait anxiety scores associated with the higher COVRATIOs.

The log transformation model was entered into PROC MIXED. The pain group demonstrated wider range than the non-pain group with the greatest mean differences at first stand and second stand (Table 71). After log transformation, significant group mean difference between non-pain and pain groups was observed in range of  $F_0$  related to trait anxiety at first stand [ $t$ -value(74.8) = -2.36,  $p = 0.02$ ] and second stand [ $t$ -value(74.8) = -2.58,  $p = 0.01$ ] (Table 72). Since these findings were present in the reduced model, the reduced model was judged as stable.

Table 71.

*Group Means and Difference of Log Transformation of Reduced Model of Range of Fundamental Frequency Related to Trait Anxiety by Task*

Task	Non-Pain (N=30) <i>M (SE)</i>	Pain (N=32) <i>M (SE)</i>	Group Mean Difference
First Seated	19.61 (1.10)	*21.48 (1.09)	-1.87
First Stand	18.02 (1.10)	24.34 (1.09)	-6.32
Second Seated	17.34 (1.10)	19.78 (1.09)	-2.44
Second Stand	16.28 (1.10)	22.60 (1.09)	-6.32

\*N=31. Note. Means are in Hz.



Table 72.

*Results of Log Transformation of Reduced Model of Range of Fundamental Frequency Related to Trait Anxiety by Task*

Task	Group Mean Ratio	SE	df	t-value	p
First Seated	0.91	1.14	75.1	-0.71	0.48
First Stand	0.74	1.14	74.8	-2.36	0.02
Second Seated	0.88	1.14	74.8	-1.04	0.30
Second Stand	0.72	1.14	74.8	-2.58	0.01

*Trait Anxiety and Jitter in Percent*

When trait anxiety was added to the model, jitter was higher for the pain group across all tasks (Table 73). At first seated, the difference between groups was not significant [ $t = -1.14$ ,  $p = 0.26$ ]. A decrease in the non-pain and pain groups' level of jitter and significant group mean difference occurred at first stand [ $t\text{-value}(77.3) = -1.97$ ,  $p = .05$ ]. The non-pain group jitter level increased at second seated and group mean difference was reduced [ $t\text{-value}(77.3) = -1.57$ ,  $p = 0.12$ ]. At second stand, an increase in jitter in the pain group and a decrease in jitter in the non-pain group occurred and significant group mean difference in jitter was observed [ $t\text{-value}(77.3) = -3.14$ ,  $p = .002$ ]. Group mean differences between the non-pain and pain groups in jitter with interaction of trait anxiety were significant at first stand and second stand with a reduced model.

Table 73.

*Group Means and Difference in Model of Jitter in Percent and Trait Anxiety by Task*

Task	Non-Pain (N=30) <i>M (SE)</i>	Pain (N=32) <i>M (SE)</i>	Group Mean Difference ( <i>SE</i> )	<i>df</i>	<i>t</i> -value	<i>p</i>
First Seated	0.92 (0.09)	1.07 (0.09)	-0.14 (0.13)	77.3	-1.14	0.26
First Stand	0.79 (0.09)	1.03 (0.09)	-0.25 (0.13)	77.3	-1.97	0.05
Second Seated	0.85 (0.09)	1.04 (0.09)	-0.20 (0.13)	77.3	-1.57	0.12
Second Stand	0.73 (0.09)	1.12 (0.09)	-0.39 (0.13)	77.3	-3.14	0.002

Diagnostics of the model were performed and 2 subjects had Cook's *D* greater than 0.2 and 9 subjects had COVRATIO less than 1.0. The 2 influential subjects identified with Cook's *D* greater than 0.2 were in the non-pain group. With these subjects, COVRATIO ranged from 0.32 to 4.91 with the subject with trait anxiety score of 47 also having the highest COVRATIO of the sample. Jitter ranged from 0.53 to 0.83 for the influential subject with the highest COVRATIO while jitter levels ranged from 0.56 to 2.77 for the influential subject with the COVRATIO less than 1.0.

Log transformation was performed improving the residual plots (Appendix 23). Diagnostics identified 3 subjects with Cook's *D* greater than 0.2 and 8 subjects with COVRATIO less than 1.0. Two of the influential subjects were in the non-pain group and were identified in the reduced model. In addition, 1 subject from the pain group was identified as influential with log transformation. Cook's *D* ranged from 0.20 to 0.42 and COVRATIO ranged from 0.61 to 4.48 with the influential subjects. The newly identified pain subject trait anxiety score was 47.

The log transformation model was entered into PROC MIXED. The pain group had jitter levels greater than the non-pain group across all tasks with greater mean difference at first stand (group mean difference = -0.16) and second stand (group mean difference = -0.28) (Table 74). Group mean difference in jitter with the interaction of trait anxiety was observed at second stand as in the original model, but not in first stand as previously observed (Table 75). The reduced model was judged unstable.

Table 74.

*Group Means and Difference in Log Transformation of Model of Jitter in Percent Related to Trait Anxiety by Task*

Task	Non-Pain (N=30) <i>M (SE)</i>	Pain (N=32) <i>M (SE)</i>	Group Mean Difference
First Seated	0.84 (1.09)	0.93 (1.09)	-0.09
First Stand	0.73(1.09)	0.89 (1.09)	-0.16
Second Seated	0.75 (1.09)	0.85 (1.09)	-0.10
Second Stand	0.65 (1.09)	0.93 (1.09)	-0.28

When the log transformation of the reduced model was entered into PROC MIXED, significant group mean difference in jitter with the interaction of trait anxiety was observed at second stand [t-value(-74.8) = -2.96,  $p = 0.004$ ] as in the reduced model. However, significant group mean difference was not observed at first stand [t-value(74.8) = -1.66,  $p = 0.10$ ] (Table 75) as in the reduced model (Table 73), the reduced model was judged unstable.

Table 75.

*Results of Log Transformation of Model of Jitter in Percent Related to Trait Anxiety by Task*

Task	Group Mean Ratio	SE	df	t-value	p
First Seated	.89	0.12	74.8	-0.90	0.37
First Stand	.81	0.12	74.8	-1.66	0.10
Second Seated	.88	0.12	74.8	-1.06	0.29
Second Stand	.69	0.12	74.8	-2.96	0.004

*Trait Anxiety and Formant Frequencies*

Formant frequencies demonstrated increasing difference across tasks when trait anxiety was added to the model as an interaction term with the non-pain group using higher frequencies (Table 76). However, it was not until F<sub>3</sub> at second stand that the difference became significant [ $t\text{-value}(153) = 1.94, p = 0.05$ ].

*First Seated.*

F<sub>1</sub> frequencies were higher for the non-pain group at all tasks. At first seated the non-pain group produced its lowest F<sub>1</sub> frequencies (est.  $M = 757.14$ ) as did the pain group (est.  $M = 725.25$ ) but group mean difference was not significant [ $t\text{-value}(194) = 0.57, p = 0.57$ ]. At first seated, F<sub>2</sub> was lower for the non-pain group (est.  $M = 1586.72$ ) than the pain group (est.  $M = 1637.37$ ) [ $t\text{-value}(151) = -0.39, p = 0.69$ ]. The pain group had higher F<sub>3</sub> (est.  $M = 3150.43$ ) than the non-pain group (est.  $M = 3124.28$ ) at first seated, but the difference was not significant [ $t\text{-value}(153) = -0.13, p = 0.89$ ].

### *First Stand.*

At first stand, both groups increased  $F_1$  with the non-pain group having a greater increase and greater difference occurred [ $t$ -value(194) = 1.16,  $p$  = 0.25]. The non-pain group  $F_2$  increased at first stand (est.  $M$  = 1639.44) while the pain group  $F_2$  decreased (est.  $M$  = 1602.27) [ $t$ -value(151) = 0.29,  $p$  = 0.77]. The pain group  $F_3$  decreased at first stand as the non-pain group  $F_3$  increased [ $t$ -value(153) = 0.42,  $p$  = 0.68].

### *Second Seated.*

At second seated, the pain group decreased  $F_1$  (est.  $M$  = 747.98) as the non-pain group increase  $F_1$  frequencies (est.  $M$  = 823.68) but the difference still was not significant [ $t$ -value(194) = 1.36,  $p$  = 0.18]. The non-pain group  $F_2$  continued to be higher than the pain group at second seated (est.  $M$  = 1757.00) as the pain group  $F_2$  continued to decrease at second seated (est.  $M$  = 1571.92). Group mean differences in  $F_2$  with the interaction of trait anxiety were not significant at second seated [ $t$ -value(151) = 1.44,  $p$  = 0.15]. The increase in  $F_3$  at second seated for the pain group was less than the increase seen in the non-pain group and difference increased but was not significant [ $t$ -value(153) = 1.22,  $p$  = 0.22].

### *Second Stand.*

The pain group decreased  $F_1$  at second stand (est.  $M$  = 742.32) as did the non-pain group (est.  $M$  = 821.63). The difference between groups in  $F_1$  with the interaction of trait anxiety at second stand was not significant [ $t$ -value(194) = 1.42,  $p$  = 0.16].  $F_2$  at second stand for the non-pain group (est.  $M$  = 1769.26) and pain group (est.  $M$  = 1558.82) were not significantly different [ $t$ -value(151) = 1.63,  $p$  = 0.10]. A drop in  $F_3$  at second stand by the pain group and an increase in  $F_3$  by the non-pain group resulted in the only significant group

mean difference in formant frequencies with the interaction of trait anxiety [ $t$ -value(153) = 1.94,  $p = 0.05$ ] (Table 76).

Diagnostics were performed and one subject had Cook's  $D$  greater than 0.2 and 10 subjects had COVRATIO less than 1.0. The 1 influential subject had a Cook's  $D$  value of 0.29 with COVRATIO of 0.00. This subject had a trait anxiety score of 38, higher than the sample mean. In addition to high trait anxiety, this subject's  $F_1$  ranged from 720.82 Hz to 1096.16 Hz,  $F_2$  ranged from 1384.01 Hz to 1916.47 Hz, and  $F_3$  ranged from 2898.31 Hz to 3361.68 Hz. In addition to this subject, 9 subjects had COVRATIO less than 1.0; of these, 4 were less than 0.5.

Log transformation of the reduced model was performed resulting in improvement noted in the residual plots (Appendix 23). Diagnostics identified the same influential subject identified in the reduced model diagnostics, but Cook's  $D$  was now 0.16 and COVRATIO of 0.01. Eleven additional subjects had COVRATIO less than 1.0 and 7 of these subjects had COVRATIO less than 0.5.

Because the residual plots demonstrated improvement, the log transformation model was entered into PROC MIXED. Differences in mean formant frequencies were observed after exponentiation with larger group mean differences associated with the later tasks (Table 77). However, no significant difference was found with the interaction of trait anxiety and formant frequencies at any task (Table 78). The reduced model was judged unstable.

Table 76.

*Group Means and Difference in Reduced Model of Formant Frequencies Related to Trait Anxiety by Task*

Task	Formant	Non-Pain (N =30) <i>M (SE)</i>	Pain (N = 32) <i>M (SE)</i>	Group Mean Difference ( <i>SE</i> )	<i>df</i>	<i>t</i> -value	<i>p</i>
First Seated	F <sub>1</sub>	757.14 (0.41)	*725.25 (0.38)	0.32 (0.56)	194	0.57	0.57
	F <sub>2</sub>	1586.72 (0.94)	*1637.37 (0.88)	-0.51 (1.29)	151	-0.39	0.69
	F <sub>3</sub>	3124.28 (1.43)	*3150.43 (1.35)	-0.26 (1.96)	153	-0.13	0.89
First Stand	F <sub>1</sub>	817.23 (0.41)	752.79 (0.38)	0.64 (0.56)	194	1.16	0.25
	F <sub>2</sub>	1639.44 (0.94)	1602.27 (0.88)	0.37 (1.29)	151	0.29	0.77
	F <sub>3</sub>	3205.27 (1.43)	3123.04 (1.35)	0.82 (1.96)	153	0.42	0.68
Second Seated	F <sub>1</sub>	823.68 (0.41)	747.98 (0.38)	0.76 (0.56)	194	1.36	0.18
	F <sub>2</sub>	1757.00 (0.94)	1571.92 (0.88)	1.85 (1.29)	151	1.44	0.15
	F <sub>3</sub>	3368.78 (1.43)	3129.28 (1.35)	2.40 (1.96)	153	1.22	0.22
Second Stand	F <sub>1</sub>	821.63 (0.41)	742.32 (0.38)	0.79 (0.56)	194	1.42	0.16
	F <sub>2</sub>	1769.26 (0.94)	1558.82 (0.88)	2.10 (1.29)	151	1.63	0.10
	F <sub>3</sub>	3399.71 (1.43)	3019.50 (1.35)	3.80 (1.96)	153	1.94	0.05

\*N=31. *Note.* Means are in Hz.

Table 77.

*Group Means and Difference in Log Transformation of Reduced Model of Formant Frequencies Related to Trait Anxiety by Task*

Task	Formant	Non-Pain (N =30) <i>M (SE)</i>	Pain (N = 32) <i>M (SE)</i>	Group Mean Difference
First Seated	F <sub>1</sub>	702.10 (1.07)	*693.24 (1.07)	8.86
	F <sub>2</sub>	1567.24 (1.05)	*1654.20 (1.05)	-86.96
	F <sub>3</sub>	3101.9 (1.04)	*3220.43 (1.04)	-118.53
First Stand	F <sub>1</sub>	790.35 (1.07)	698.11 (1.07)	92.24
	F <sub>2</sub>	1612.06 (1.05)	1562.7 (1.04)	49.36
	F <sub>3</sub>	3183.93 (1.04)	3068.89 (1.04)	115.04
Second Seated	F <sub>1</sub>	760.65 (1.07)	701.18 (1.07)	59.47
	F <sub>2</sub>	1656.18 (1.05)	1545.76 (1.04)	110.72
	F <sub>3</sub>	3253.45 (1.04)	3082.42 (1.04)	171.03
Second Stand	F <sub>1</sub>	788.45 (1.07)	708.73 (1.07)	79.72
	F <sub>2</sub>	1696.92 (1.05)	1540.05 (1.04)	156.87
	F <sub>3</sub>	3287.13 (1.04)	2990.72 (1.04)	296.41

\*N=31. *Note.* Means are in Hz.



Table 78.

*Results of Log Transformation of Reduced Model of Formant Frequencies Related to Trait Anxiety by Task*

Task	Formant	Group Mean Ratio	SE	df	t-value	p
First Seated	F <sub>1</sub>	1.01	1.10	184	-0.14	0.89
	F <sub>2</sub>	0.95	1.07	147	-0.85	0.40
	F <sub>3</sub>	0.96	1.05	149	-0.73	0.47
First Stand	F <sub>1</sub>	1.13	1.10	183	1.33	0.18
	F <sub>2</sub>	1.03	1.07	146	0.49	0.63
	F <sub>3</sub>	1.04	1.05	148	0.71	0.48
Second Seated	F <sub>1</sub>	1.08	1.10	183	0.87	0.38
	F <sub>2</sub>	1.07	1.07	146	1.08	0.28
	F <sub>3</sub>	1.06	1.05	148	1.05	0.30
Second Stand	F <sub>1</sub>	1.11	1.10	183	1.15	0.25
	F <sub>2</sub>	1.10	1.07	146	1.52	0.13
	F <sub>3</sub>	1.10	1.05	148	1.83	0.07

*Effect of State Anger*

The sample mean for state anger on the STAXI-2 was 15.5 ( $SD = 2.06$ ) and was lower than the norm of 17.9 ( $SD = 5.26$ ) with normal adult females established by the instrument developers. Significant group mean differences were observed with the

interaction of state anger on the following acoustic parameters: (1) range of fundamental frequencies and (2) jitter.

#### *State Anger and Range of Fundamental Frequencies*

When the mean state anger was added as an interaction term to the reduced model (deleting the first seated acoustic measurements of the subject who sang the first seated vowels), range of fundamental frequencies continued to be greater for the pain group than the non-pain group across all tasks (Table 79). At first seated, the pain group range of  $F_0$  was greater than the non-pain group [ $t$ -value(77.6) = -1.00,  $p$  = 0.32]. At first stand, the pain group's range of  $F_0$  increase as the non-pain group's range of  $F_0$  decreased resulting in significant difference [ $t$ -value(77.6) = -3.07,  $p$  = .003]. Both groups decreased range of  $F_0$  at second seated task, but the decrease was greater for the pain group and the difference between groups was no longer significant [ $t$ -value(77.6) = -0.99,  $p$  = 0.33]. At second stand, the pain group again increased range of  $F_0$  while the non-pain group's range of  $F_0$  was reduced [ $t$ -value(77.6) = -2.82,  $p$  = .006].

Table 79.

#### *Group Means and Difference in Reduced Model of Range of Fundamental Frequency Related to State Anger by Task*

Task	Non-Pain (N=30) <i>M</i> ( <i>SE</i> )	Pain (N=32) <i>M</i> ( <i>SE</i> )	Group Mean Difference ( <i>SE</i> )	<i>df</i>	<i>t</i> -value	<i>p</i>
First Seated	23.14 (2.72)	*26.80 (2.46)	-3.66 (3.67)	77.6	-1.00	0.32
First Stand	20.13 (2.72)	31.41 (2.46)	-11.28 (3.67)	77.6	-3.07	0.003
Second Seated	19.89 (2.72)	23.52 (2.46)	-3.63 (3.67)	77.6	-0.99	0.33
Second Stand	18.05 (2.72)	28.41 (2.46)	-10.36 (3.67)	77.6	-2.82	0.006

\*N=31. Note. Means are in Hz.

Diagnostics were performed and identified 4 influential pain group subjects with Cook's  $D$  greater than 0.2 and ranging from 0.29 to 1.96. COVRATIO ranged from 0.1 to 4061.4. The next highest COVRATIO was 20.5. Nine subjects had COVRATIO less than 1.0. State anger scores ranged from 15 (for three subjects) to 30. Range of  $F_0$  ranged from 15.19 to 105.19 Hz and 3 subjects had at least one range of  $F_0$  greater than 95 Hz. The pain group subject with the state anger score of 30 also possessed the highest COVRATIO, the largest Cook's  $D$ , and the most restricted ranges of  $F_0$  between 23.29 and 43.17.

Log transformation of the reduced model was performed and some improvement in the residuals plots was noted (Appendix 23). Three subjects had Cook's  $D$  greater than 0.2 and 9 subjects had COVRATIO less than 1.0. Three influential subjects were identified with Cook's  $D$  greater than 0.2; 2 pain group subjects were identified in the reduced model diagnostics and 1 non-pain group subject was identified with the log transformation. Cook's  $D$  ranged from 0.20 to 3.46. COVRATIO ranged from 0.4 to 3895.3. The high COVRATIO was identified with the same subject in the reduced model analysis. The newly identified non-pain subject had a state anger score of 19.5 and range of  $F_0$  from 22.33 to 30.13.

The log transformation model was entered into PROC MIXED. The pain group had the largest range of  $F_0$  related to state anger across all tasks (Table 80). At first seated, the difference between groups was not significant [ $t$ -value(75.5) = -0.35,  $p$  = 0.73] (Table 84). At first stand, the pain group increased its range of  $F_0$  while the non-pain group narrowed its range of  $F_0$  [ $t$ -value(75.1) = -2.10,  $p$  = 0.04]. Both groups narrowed range of  $F_0$  at the second seated task and group mean difference decreased [ $t$ -value(75.1) = -0.61,  $p$  = 0.54]. At second stand, the pain group range of  $F_0$  became wider as the non-pain group range of  $F_0$  narrowed

and significantly greater mean difference occurred [ $t\text{-value}(75.1) = -2.19, p = 0.03$ ].

Significant group mean difference in the interaction of state anger and range of  $F_0$  occurred at first stand [ $t\text{-value}(75.1) = -2.10, p = 0.04$ ] and second stand [ $t\text{-value}(75.1) = -2.19, p = 0.03$ ] (Table 81) and were found at the same tasks as the reduced model (Table 79). The reduced model was judged stable.

Table 80.

*Group Means and Difference in Log Transformation of Reduced Model of Range of Fundamental Frequency Related to State Anger by Task*

Task	Non-Pain (N=30) <i>M (SE)</i>	Pain (N=32) <i>M (SE)</i>	Group Mean Difference
First Seated	20.75 (1.10)	*21.72 (1.09)	-0.97
First Stand	18.94 (1.10)	24.81 (1.09)	-5.87
Second Seated	18.31 (1.10)	19.80 (1.09)	-1.49
Second Stand	16.81 (1.10)	22.27 (1.09)	-5.46

\*N=31. Note. Means are in Hz.

Table 81.

*Results of Log Transformation of Reduced Model of Range of Fundamental Frequency Related to State Anger by Task*

Task	Group Mean Ratio	<i>SE</i>	<i>df</i>	<i>t</i> -value	<i>p</i>
First Seated	.96	1.14	75.5	-0.35	0.73
First Stand	.76	1.14	75.1	-2.10	0.04
Second Seated	.92	1.14	75.1	-0.61	0.54
Second Stand	.76	1.14	75.1	-2.19	0.03

Although the reduced model was stable to perturbation, the COVRATIO of 4061.4 of one subject was extreme and the influence exerted on results with the small sample was explored. The data of the influential subject with the extreme COVRATIO were deleted along with the data of the subject with the sung vowel at first seated and this further reduced model of range of  $F_0$  related to state anger was re-entered into PROC MIXED. After these deletions, the pain group's range of  $F_0$  was wider than the non-pain group across all tasks while the non-pain group's range of  $F_0$  became narrower at each task. At first seated, the groups were not significantly different in range of  $F_0$  [ $t$ -value(76.0) = -1.32,  $p$  = 0.19]. At first stand, the pain group had it widest range of  $F_0$  and the groups were significantly different [ $t$ -value(75.7) = -2.97,  $p$  = 0.004]. At second seated, both groups had reduced range of  $F_0$  and significant difference was not observed [ $t$ -value(75.7) = -0.86,  $p$  = 0.39]. At second stand, the pain group had a wider range of  $F_0$  and the non-pain group range was more restricted and the group mean difference became significant [ $t$ -value(75.7) = -2.70,  $p$  = 0.009]. Changes were observed between results of the reduced model (Table 79) and the further reduced model (Table 82) but significant difference occurred at the same stand tasks. Table 82.

*Group Means and Difference in a Further Reduced Model of Range of Fundamental Frequency Related to State Anger by Task*

Task	Non-Pain (N=30) <i>M (SE)</i>	Pain (N=31) <i>M (SE)</i>	Group Mean Difference ( <i>SE</i> )	<i>df</i>	<i>t</i> -value	<i>p</i>
First Seated	23.14 (2.75)	*28.10(2.55)	-4.96 (3.75)	76.0	-1.32	0.19
First Stand	20.13 (2.72)	31.24 (2.55)	-11.11 (3.75)	75.7	-2.97	0.004
Second Seated	19.89 (2.75)	23.10 (2.55)	-3.21(3.75)	75.7	-0.86	0.40
Second Stand	18.05 (2.75)	28.41 (2.55)	-10.11 (3.75)	75.7	-2.70	0.009

\*N=30. Note. Means are in Hz.

Diagnostics demonstrated some improvement in linearity of the residuals (Appendix 23). Five subjects with Cook's  $D$  greater than 0.2 (range: 0.31 to 1.30) and 7 subjects with COVRATIO less than 1.0 (range: 0.09 to 142.66) were identified. The five influential subjects with Cook's  $D$  greater than 0.2 were all pain group subjects. The COVRATIO of these subjects ranged from .09 to 142.66. One subject with high Cook's  $D$ , high COVRATIO, and state anger score of 20 was not identified as an influential subject in the previous reduced data set. Two non-pain group subjects had COVRATIO less than 1.0. State anger scores for the influential subjects ranged from 15 (for three subjects) to 20.

Log transformation of this further reduced model was performed and linearity was improved over the non-transformed model (Appendix 23). Four subjects were identified with Cook's  $D$  greater than 0.2 (range: 0.21 to 1.27): 1 from the non-pain group and 3 from the pain group. Thirteen subjects had COVRATIO less than 1.0. Three of the 4 influential subjects had COVRATIO greater than 1.0 (range: 1.47 to 142.68). State anger scores ranged from 15 to 20.

The log transformation model was entered into PROC MIXED. The pain group had the broadest range of  $F_0$  across all tasks and the non-pain group range of  $F_0$  narrowed with each task (Table 83). The pain group range of  $F_0$  at first seated increased following the deletion of the second subject, increasing the group mean difference. The difference was not significant [ $t$ -value(76) = -0.47,  $p$  = 0.64]. At first stand, the pain group range of  $F_0$  was greater than the non-pain group, but less than the pain group range in the previous reduced model. The group mean difference in range of  $F_0$  related to state anger at first stand in the further reduced model was significant [ $t$ -value(75.7) = -2.07,  $p$  = 0.04]. At second seated, a narrowing of the pain group's range of  $F_0$  was observed while the non-pain group's range

also became narrower. The group mean difference at second seated was not significant [ $t$ -value(75.7) = -0.55,  $p = 0.58$ ]. At second stand, the pain group range of  $F_0$  was broader than it was at first seated and the non-pain group range was the most narrow of all tasks. The group mean difference in range of  $F_0$  related to state anger was significant at second stand [ $t$ -value(75.7) = -2.17,  $p = 0.03$ ]. The group mean differences in range of  $F_0$  related to state anger between the non-pain and pain group were significant at the first stand and second stand tasks (Table 84). Because group mean differences were the same in the log transformation of the reduced model and the further reduced model, the reduced model was judged stable. In subsequent analyses, the data of the subject with the extreme COVRATIO was included and the further reduced model was not used.

Table 83.

*Group Means and Difference in Log Transformation of Further Reduced Model of Range of Fundamental Frequency Related to State Anger by Task*

Task	Non-Pain (N=30) <i>M (SE)</i>	Pain (N=31) <i>M (SE)</i>	Group Mean Difference
First Seated	20.75 (1.10)	*22.05 (1.09)	-1.3
First Stand	18.94 (1.10)	24.74 (1.09)	-5.84
Second Seated	18.31 (1.10)	19.66 (1.09)	-1.35
Second Stand	16.81 (1.10)	22.27 (1.09)	-5.46

\*N=30. Note. Means are in Hz.

Table 84.

*Results of Log Transformation of Further Reduced Model of Range of Fundamental Frequency Related to State Anger by Task*

Task	Group Mean Ratio	SE	df	t-value	p
First Seated	.94	1.14	76	-0.47	0.64
First Stand	.77	1.14	75.7	-2.07	0.04
Second Seated	.93	1.14	75.7	-0.55	0.58
Second Stand	.75	1.14	75.7	-2.17	0.03

*State Anger and Jitter in Percent*

When state anger was added as an interaction term to the model of jitter, jitter was higher for the pain group across all tasks (Table 85). At first seated, the pain group's level of jitter was greater than the non-pain group jitter [ $t\text{-value}(77.1) = -0.84, p = 0.41$ ]. Both groups had decreased levels of jitter at first stand [ $t\text{-value}(77.1) = -1.56, p = 0.12$ ]. Both groups had increases in jitter at second seated but difference was not significant [ $t\text{-value}(77.1) = -1.23, p = 0.22$ ]. At second stand, the pain group's jitter level increased as the non-pain group's jitter decreased and resulted in a significant group mean difference. [ $t\text{-value} (77.1) = -2.35, p = 0.02$ ].



Table 85.

*Group Means and Difference in Model of Jitter in Percent Related to State Anger by Task*

Task	Non-Pain (N=30) <i>M (SE)</i>	Pain (N=32) <i>M (SE)</i>	Group Mean Difference ( <i>SE</i> )	<i>df</i>	<i>t</i> -value	<i>p</i>
First Seated	0.95 (0.09)	*1.06 (0.08)	-0.11 (0.13)	77.1	-0.84	0.41
First Stand	0.84 (0.09)	1.03 (0.08)	-0.20 (0.13)	77.1	-1.56	0.12
Second Seated	0.89 (0.09)	1.04 (0.08)	-0.16 (0.13)	77.1	-1.23	0.22
Second Stand	0.80 (0.09)	1.10 (0.08)	-0.30 (0.13)	77.1	-2.35	0.02

\*N = 31.

Diagnostics were performed and 3 influential subjects were identified with Cook's *D* greater than 0.2: 2 non-pain subjects and 1 pain group subject. COVRATIO was less than 1.0 in ten sample subjects: 2 non-pain group subjects and 8 pain group subjects. Cook's *D* ranged from 0.23 to 2.40 and COVRATIO ranged from 0.2 to 3686.7. State anger ranged from 17 to 30. The subject with the highest Cook's *D* and COVRATIO also had the highest state anger score of this group. Jitter ranged from 0.56 to 2.77.

Log transformation was performed and diagnostics of the log transformation model identified 3 influential subjects having Cook's *D* greater than 0.2: 2 non-pain subjects and 1 pain subject. Eleven subjects had COVRATIO less than 1.0 in the transformation model. One non-pain subject was not previously identified as influential in the reduced model replaced a non-pain subject in the transformation model. Cook's *D* ranged from 0.27 to 2.45 and COVRATIO ranged from 2.7 to 3616.7 with these 3 subjects. The subject with the highest Cook's *D*, COVRATIO, and state anger score was identified in the diagnostics of the reduced model and continued to be influential.

Improvement was noted in the residual plots (Appendix 23) and the log transformation model was entered into PROC MIXED. The pain group had higher levels of jitter than the non-pain group at all tasks with the largest difference occurring at second stand (Table 86).

Table 86.

*Group Means and Difference in Log Transformation of Model of Jitter in Percent Related to State Anger by Task*

Task	Non-Pain (N=30) <i>M (SE)</i>	Pain (N=32) <i>M (SE)</i>	Group Mean Difference
First Seated	0.86 (1.10)	*0.93 (1.09)	-0.07
First Stand	0.76 (1.10)	0.90 (1.09)	-0.14
Second Seated	0.78 (1.10)	0.85 (1.09)	-0.07
Second Stand	0.70 (1.10)	0.92 (1.09)	-0.22

\*N = 31.

At first seated, both groups had their highest level of jitter [ $t$ -value(75.3) = -0.54,  $p$  = 0.59]. At first stand, the non-pain group had larger decrease in jitter than the pain group [ $t$ -value(75) = -1.27,  $p$  = 0.21]. The pain group had a larger decrease in jitter than the non-pain group at second seated [ $t$ -value(75) = 0.74,  $p$  = 0.46]. Significant group mean difference in jitter related to state anger was observed at second stand [ $t$ -value(75) = -2.16,  $p$  = 0.03] as it was in the reduced model (Table 87). The original model was judged stable.

Table 87.

*Results of Log Transformation of Model of Jitter in Percent Related to State Anger by Task*

Task	Group Mean Ratio	SE	df	t-value	p
First Seated	0.93	1.13	75.3	-0.54	0.59
First Stand	0.85	1.13	75	-1.27	0.21
Second Seated	0.91	1.13	75	-0.74	0.46
Second Stand	0.76	1.13	75	-2.16	0.03

*Effect of Trait Anger*

The sample mean for trait anger on the STAXI-2 was 15.23 ( $SD = 6.97$ ) and was lower than the norm of 17.89 ( $SD = 4.94$ ) for adult women cited by the instrument's developers. Significant group mean differences between groups occurred with the interaction of trait anger with the following acoustic parameters: (1) range of fundamental frequencies and (2) jitter.

*Trait Anger and Range of Fundamental Frequencies*

When trait anger was added as an interaction term in the reduced model, range of  $F_0$  was greater for the pain group than the non-pain group at all four tasks (Table 88). At first seated, the pain group's range of  $F_0$  (est.  $M = 26.97$ ) was greater than the non-pain group range of  $F_0$  (est.  $M = 22.47$ ) but the difference was not significant [ $t\text{-value}(84.8) = -1.28, p = 0.20$ ]. Range of  $F_0$  increased at first stand for the pain group but decreased for the non-pain group resulting in a significant difference [ $t\text{-value}(84.8) = -3.39 = p = 0.001$ ]. At second

seated, the non-pain group had an increase in range of  $F_0$  (est.  $M = 19.44$ ) while the pain group experienced a decrease in range of  $F_0$  (est.  $M = 2389.56$ ). At second stand, the non-pain group decreased range of  $F_0$  to the group's lowest level (est.  $M = 17.82$ ) and the pain group increased range of  $F_0$  (est.  $M = 28.36$ ). The group mean difference in range of  $F_0$  related to trait anger was significant at second stand [ $t$ -value(84.8) = -3.00,  $p = 0.004$ ]. Significant differences were observed in range of  $F_0$  with the interaction of trait anger at first and second stand.

Table 88.

*Group Means and Difference in Reduced Model of Range of Fundamental Frequency Related to Trait Anger by Task*

Task	Non-Pain (N=30) $M$ (SE)	Pain (N=32) $M$ (SE)	Group Mean Difference (SE)	$df$	$t$ -value	$p$
First Seated	22.47 (2.53)	*26.97 (2.45)	-4.50 (3.52)	84.8	-1.28	0.20
First Stand	19.43 (2.53)	31/36 (2.45)	-11.94 (3.52)	84.8	-3.39	0.001
Second Seated	19.44 (2.53)	23.90 (2.45)	-4.45 (3.52)	84.8	-1.27	0.21
Second Stand	17.82 (2.53)	28.36 (2.45)	-10.55 (3.52)	84.8	-3.00	0.004

\*N=31. Note. Means are in Hz.

Diagnostics were performed on the model and three subjects had Cook's  $D$  greater than 0.2 and 8 subjects had COVRATIO less than 1.0. Three influential subjects had Cook's  $D$  greater than 0.2 and COVRATIO less than 1.0. These 3 subjects were from the pain group with Cook's  $D$  ranging from 0.21 to 0.46 and COVRATIO ranging from 0.09 to 0.22. Trait anger scores ranged from 12 to 15; lower than the norm stated by the STAXI-2 developers. Range of  $F_0$  for the 3 influential subjects ranged from 15.19 to 105.19 with both of these ranges from the same subject and all 3 subjects having a range greater than 90 Hz.

Log transformation of the reduced model was performed and improvement in the linearity of the plot of residuals occurred (Appendix 23). Diagnostics of the log transformation of the reduced model identified 2 subjects with Cook's  $D$  greater than 0.2 and 12 subjects with COVRATIO less than 1.0. The 2 influential subjects were from the pain group and identified in the diagnostics of the reduced model. Cook's  $D$  ranged from .24 to .26 and COVRATIO ranged from 0.35 to 0.56 with these 2 subjects. Trait anger scores were 12 and 13.

Because of the improvement in linearity of residuals with log transformation, the model was entered into PROC MIXED. The pain group had greater range of  $F_0$  than the non-pain group at all tasks with the non-pain group decreasing range of  $F_0$  at each task (Table 89). At first seated, the non-pain group had its highest range of  $F_0$  but pain group range of  $F_0$  was greater and the group mean difference was not significant [ $t$ -value(76.1) = -0.80,  $p$  = 0.43]. The pain group increased its range of  $F_0$  at first stand as the non-pain group range of  $F_0$  decreased and a significant difference in range of  $F_0$  occurred [ $t$ -value(75.8) = -2.57,  $p$  = 0.01] (Table 90). At second seated, both groups experienced a decrease in range of  $F_0$  and the pain group had its lowest range of  $F_0$ , but group mean difference was no longer significant [ $t$ -value(75.8) = -1.0,  $p$  = 0.32]. The pain group range of  $F_0$  increased at second stand while the non-pain group range of  $F_0$  decreased and the difference was significant [ $t$ -value(75.8) = -2.52,  $p$  = 0.01]. Because the log transformation model demonstrated significant group mean differences in range of  $F_0$  with the interaction of trait anger at the first and second stand tasks as were demonstrated in the reduced model, the reduced model was judged stable.

Table 89.

*Group Means and Difference in Log Transformation of Reduced Model of Range of Fundamental Frequency Related to Trait Anger*

Task	Non-Pain (N=30) <i>M (SE)</i>	Pain (N=32) <i>M (SE)</i>	Group Mean Difference
First Seated	19.95 (1.09)	*21.97 (1.09)	2.02
First Stand	18.24 (1.09)	24.90 (1.09)	6.66
Second Seated	17.83 (1.09)	20.13 (1.09)	2.3
Second Stand	16.48 (1.09)	22.36 (1.09)	5.88

\*N=31. *Note.* Means are in Hz.

Table 90.

*Results of Log Transformation of Reduced Model of Range of Fundamental Frequency Related to Trait Anger by Task*

Task	Group Mean Ratio	<i>SE</i>	<i>df</i>	<i>t</i> -value	<i>p</i>
First Seated	.91	1.13	76.1	-0.80	0.43
First Stand	.73	1.13	75.8	-2.57	0.01
Second Seated	.89	1.13	75.8	-1.00	0.32
Second Stand	.74	1.13	75.8	-2.52	0.01

### *Trait Anger and Jitter*

When the sample mean of trait anger was added as an interaction term to the model, jitter was higher in the pain group across all tasks (Table 91). Jitter was highest for the non-pain group at the first seated task but the group mean difference was not significant [ $t$ -value(78.8) = -1.21,  $p$  = 0.23]. Jitter decreased at first stand in both groups. With a greater decrease at first stand for the non-pain group, the group mean difference became significant [ $t$ -value(78.8) = -1.97,  $p$  = 0.05]. Jitter increased in the pain group and in the non-pain group at second seated, but group mean difference was reduced [ $t$ -value(78.8) = -1.61,  $p$  = 0.11]. At second stand, jitter increased in the pain group but decreased in the non-pain group contributing to the difference [ $t$ -value(78.8) = -2.79,  $p$  = 0.01].

Table 91.

<i>Group Means and Difference in Model of Jitter in Percent Related to Trait Anger by Task</i>						
Task	Non-Pain (N=30) <i>M (SE)</i>	Pain (N=32) <i>M (SE)</i>	Group Mean Difference ( <i>SE</i> )	<i>df</i>	<i>t</i> -value	<i>p</i>
First Seated	0.94 (0.08)	1.08 (0.08)	-0.14 (0.12)	78.8	-1.21	0.22
First Stand	0.80 (0.08)	1.03 (0.08)	-0.23 (0.12)	78.8	-1.97	0.05
Second Seated	0.86 (0.08)	1.05 (0.08)	-0.19 (0.12)	78.8	-1.61	0.11
Second Stand	0.78 (0.08)	1.11 (0.08)	-2.79 (0.12)	78.8	-2.79	0.007

Diagnostics were performed on the model of jitter related to trait anger and 2 subjects had Cook's  $D$  greater than 0.2 and 9 subjects had COVRATIO less than 1.0. The 2 influential subjects with Cook's  $D$  greater than 0.2 and ranging from 0.30 to 0.31 were from both the non-pain and pain groups. COVRATIO ranged from 0.23 to 1.14. Trait anger scores were 10

for the pain group subject and 13 for the non-pain group subject. Jitter ranged from 0.56 to 2.77 across the tasks.

Log transformation of the model was performed and diagnostics indicated improvement in the linear plot of residuals (Appendix 23). No influential subjects were identified with Cook's  $D$  greater than 0.2. Seven subjects were identified with Cook's  $D$  greater than 0.1. The subjects identified in the reduced model had a Cook's  $D$  ranging from 0.15 to 0.19 with the log transformation. In the group of 7 subjects having Cook's  $D$  greater than 0.1, COVRATIO ranged from 0.35 to 2.30. Trait anger scores ranged from 10 to 22.

Because of the improvement observed with transformation, the log transformation model was entered into PROC MIXED. The pain group level of jitter was higher than the non-pain group at all tasks (Table 92). At first seated, both groups demonstrated their highest levels of jitter for the study session but group mean difference was not significant [ $t$ -value(76.6) = -0.89,  $p$  = 0.34]. At first stand, both groups decreased in level of jitter with the non-pain group having a greater decrease increasing group mean difference [ $t$ -value(76.2) = -1.70,  $p$  = 0.09]. At second seated, the pain group decreased jitter level while the non-pain group increased jitter reducing group mean difference [ $t$ -value(76.2) = -1.07,  $p$  = 0.29]. At second stand, the non-pain group decreased jitter as the pain group increased jitter resulting in significant group mean difference in jitter related to trait anger [ $t$ -value(76.2) = -2.72,  $p$  = 0.008]. Because the log transformation model identified significant group mean difference only at the second stand task (Table 93) compared to the reduced model identification of significance at the two stand tasks, the original model was judged unstable.



Table 92.

*Group Means and Difference in Log Transformation of Model of Jitter in Percent Related to Trait Anger by Task*

Task	Non-Pain (N=30) <i>M (SE)</i>	Pain (N=32) <i>M (SE)</i>	Group Mean Difference
First Seated	0.85 (1.09)	0.94(1.08)	-0.09
First Stand	0.74 (1.09)	0.90 (1.08)	-0.16
Second Seated	0.76 (1.09)	0.86 (1.08)	-0.1
Second Stand	0.68 (1.09)	0.93 (1.08)	-0.25

Table 93.

*Results of Log Transformation Model of Jitter in Percent Related to Trait Anger by Task*

Task	Group Mean Ratio	<i>SE</i>	<i>df</i>	<i>t</i> -value	<i>p</i>
First Seated	.89	1.12	76.6	-0.89	0.34
First Stand	.82	1.12	76.2	-1.70	0.09
Second Seated	.88	1.12	76.2	-1.07	0.29
Second Stand	.73	1.12	76.2	-2.72	0.008

In summary, building on models of acoustic parameters with movement tasks of non-pain and pain subjects (Table 38), fixed effects were estimated using mixed model with an interaction term that included the sample mean of these mood-related measures. Acoustic parameter differences were found to be influenced by depression, anxiety, and anger.

Following use of diagnostic techniques, significant differences between the non-pain and

pain groups were observed with two acoustic parameters at stand tasks: (1) range of fundamental frequencies with state and trait anxiety and state and trait anger (Table 94) and (2) jitter with state anxiety and state anger (Table 95). No significant group mean differences were observed with the interaction of depression and any of the study acoustic parameters.

Table 94.

*Stable Significant Group Differences in Range of Fundamental Frequency Related to Mood-Related Variables*

Mood-Related Variable	Task	Non-Pain (N=30) <i>M (SE)</i>	Pain (N=32) <i>M (SE)</i>	Group Mean Difference (SE)	<i>df</i>	<i>t</i> -value	<i>p</i>
State Anxiety	First Stand	19.39 (2.57)	31.52 (2.47)	-12.12(3.56)	84	-3.40	0.001
State Anxiety	Second Seated	17.98 (2.57)	28.82 (2.47)	-10.84(3.56)	84	-3.04	0.003
Trait Anxiety	First Stand	19.22 (2.69)	30.78 (2.54)	-11.55 (3.70)	83.1	-3.13	0.002
Trait Anxiety	Second Stand	17.79 (2.69)	28.98 (2.54)	-11.20 (3.70)	83.1	-3.03	0.003
State Anger	First Stand	20.13 (2.78)	31.41 (2.51)	-11.28 (3.74)	83.6	-3.02	0.003
State Anger	Second Stand	18.05 (2.78)	28.41 (2.51)	-10.36 (3.50)	83.6	-2.77	0.007
Trait Anger	First Stand	19.43 (2.53)	31/36 (2.45)	-11.94 (3.52)	84.8	-3.39	0.001
Trait Anger	Second Stand	17.82 (2.53)	28.36 (2.45)	-10.55 (3.52)	84.8	-3.00	0.004

Table 95.

*Stable Significant Group Differences in Jitter in Percent Related to Mood-Related Variables*

Mood-Related Variable	Task	Non-Pain (N=30) <i>M (SE)</i>	Pain (N=32) <i>M (SE)</i>	Group Mean Difference ( <i>SE</i> )	<i>df</i>	<i>t</i> -value	<i>p</i>
State Anxiety	First Stand	0.81 (0.09)	1.04 (0.08)	-0.23 (0.12)	77.4	-1.92	0.06
State Anxiety	Second Stand	0.78 (0.09)	1.12 (0.08)	-0.34 (0.12)	77.4	-2.77	0.007
State Anger	Second Stand	0.80 (0.09)	1.10 (0.08)	-0.30 (0.13)	77.1	-2.35	0.02

## Research Question 5

The influence of disability on the verbal and written reports of pain intensity and written reports of pain unpleasantness of women with chronic knee pain was investigated. Disability in the non-pain and pain group for this the study was measured using (1) observation of the time to rise from sitting to standing position and (2) three self-evaluation measures of ability and disability: the pain interference scale of the BPI, the disability scale of the SOPA, and the self-efficacy for physical function scale of the ASES. Verbal and written self-reports of pain intensity were measured using the VRP and the VAS-PI. Written self-report of pain unpleasantness was measured using the VAS-UNP to explore the relationship of this measure of emotional reaction to pain intensity and disability measures. Initial evaluation of group and class differences with the variables was done using Wilcoxon

*rank sum* statistic. The Z continuity correction of 0.5 was included. The standard deviation expected under the null hypothesis was reported.

Variables of pain intensity, pain unpleasantness, and observed disability variables were measured across time. In order to combine the data for correlation analyses that would address the relationship of these variables, there was a need to confirm that there was no difference in the ratings within group or within class of the ratings across time. Analyses of the non-pain group using the VRP were not possible due to the absence of variance and floor effect. Analyses using the pain interference scale data were not possible with the non-pain group since subjects did not complete the scale. Because unequal variance within the LIC and MIC was present, correlation analyses of the LIC and MIC data were performed using the nonparametric Spearman rank correlation coefficient,  $r_s$ .

#### *Observed Disability*

Measurement of observed disability used the video recording of the movement from both sit to stand tasks. While the activity was intended to induce pain in the knee for the study, the time to rise was thought to be indicative of disability related to the knee pain. Movements of first stand and second stand were timed for this particular question.

#### *Non-Pain and Pain Group Observed Disability*

The non-pain group required less time to rise to standing at first stand ( $M = 5.31$ ,  $SD = 1.6$ ) than the pain group (first stand:  $M = 8.56$  sec,  $SD = 4.58$  sec). The non-pain group also required less time to rise to standing at second stand ( $M = 5.63$  sec,  $SD = 1.00$  sec) than the pain group ( $M = 9.41$  sec,  $SD = 4.87$  sec). Because variances were unequal, Wilcoxon *rank sum* statistic, 2-sided normal approximation, and Fisher's *exact test* were used and indicated significant group mean difference between the pain group and non-pain group in time to

stand with both stand tasks (first stand:  $Z = -3.44$ , normal approx.  $p = 0.0006$ , *Fisher's exact test* = 0.0004) (second stand:  $Z = -5.04$ , normal approx.  $p < .0001$ , *Fisher's exact test* = 6.00E-08) (Table 96).

Table 96.

*Difference in Observed Disability of Non-Pain and Pain Group by Task*

Task	Non-Pain (N = 30) <i>M</i> Score	Pain (N = 32) <i>M</i> Score	<i>SD</i> <i>Under</i> <i>Null</i>	<i>Z</i>	2-sided normal approximation	<i>Fisher's exact</i> <i>test</i>
First stand	*22.83	38.41	68.89	-3.44	0.001	4.11E-04
Second Stand	19.72	42.55	70.02	-5.04	<.0001	6.00E-08

\*N = 29.

Paired *t*-test results indicated there was no difference in the time to rise to standing at first and second stand for the non-pain group [pooled  $t(57) = -0.90$ ,  $p = 0.37$ ] or for the pain group [pooled  $t(62) = -0.71$ ,  $p = 0.48$ ].

*Low and Moderate Intensity Class - Observed Disability*

Because variances were known to be unequal between the LIC and MIC and sample size was small, LIC and MIC times to rise from sitting to standing at the two stand tasks were compared using Wilcoxon *rank sum* statistic, two-sided *t*-approximation, and *Fisher's exact test*. The LIC mean score on time to stand at first stand (*M* score = 15.63) was less than the MIC mean score (*M* score = 17.96) (Table 97). At second stand, the LIC mean time to stand (*M* score = 14.05) remained less than the MIC mean time to stand (*M* score = 20.58). The difference between the classes in time to rise from sitting to standing at first stand ( $Z = 0.66$ , *t*-approx. = 0.51, *Fisher's exact test* = 0.25) was not statistically significant (Table 97). However, a decrease in the LIC time and the increase in the MIC time were observed at the

second stand, and significant difference in observed disability between the LIC and MIC at second stand was demonstrated ( $Z = 1.90$ ,  $t$ -approx = 0.07, *Fisher's exact test* = 0.05).

Table 97.

<i>Difference in Observed Disability of Low and Moderate Intensity Pain Classes by Task</i>						
Task	Low	Moderate	<i>SD</i> Under Null	<i>Z</i>	2-sided <i>t</i> - approx.	<i>Fisher's</i> <i>exact test</i>
	Intensity	Intensity				
	Class	Class				
	( <i>N</i> = 20) <i>M</i> Score	( <i>N</i> = 12) <i>M</i> Score				
First Stand	15.63	17.96	25.57	0.66	0.51	0.51
Second Stand	14.05	20.58	25.48	1.90	0.07	0.05

#### *Self-Evaluated Disability*

Self-evaluation of disability was obtained from self-report data of the pain interference scale of the BPI, the self-efficacy for physical function scale of the ASES (FSE), and the disability scale of the SOPA.

#### *Self-Evaluated Disability – Pain Interference Scores for Pain Group.*

BPI directions instructed persons who had not had pain or taken pain medication in the past week not to complete the inventory after 10 items. Therefore, non-pain subjects did not complete the pain severity and pain interference scales related to knee pain.

Pain interference scale scores can range from 0 to 70. The non-pain group had 0 ratings for pain interference due to knee pain. The scores of the pain group on the seven-item pain interference scale of the BPI ( $M = 24.69$ ,  $SD = 18.39$ ) indicated that subjects in the pain group reported moderate level of pain interference in daily life activities. However, the range in scores from 0 to 61 indicates that some pain group subjects considered themselves more

disabled by pain than the pain group mean described. The non-pain and pain group demonstrated unequal variance ( $F^1 = \text{Infinity}$ ,  $p < .0001$ ) and significant difference [ $t(31) = -8.45$ ,  $p < .0001$ ].

The LIC and MIC pain interference scores demonstrated equal variance [ $F^1 (11, 19) = 2.17$ ,  $p = 0.13$ ] and significant difference in pain interference scores [ $t(30) = -2.84$ ,  $p = 0.01$ ]. Further investigation of LIC and MIC pain interference scores was done using Wilcoxon *rank sum* statistic with 2-sided *t*-approximation and *Fisher's exact test*. Results indicated that the LIC group had significantly lower pain interference scores than the MIC pain interference scores ( $Z = 2.57$ , *t*-approx.  $p = 0.02$ , *exact test* = 0.008).

*Self-Evaluated Disability – Self-Efficacy for Physical Function Scale of ASES.*

The FSE scale of the ASES (range = 9 - 90) uses a task-oriented measure of confidence in performing specific activities. Activities evaluated include those associated with hand function as well as mobility.

Mean FSE scores indicated both the non-pain group ( $M = 83.37$ ,  $SD = 11.66$ ) and pain group ( $M = 72.91$ ,  $SD = 17.32$ ) felt confident they could perform many of the tasks independently with the non-pain group more confident than the pain group. Wilcoxon *rank sum* statistic, 2-sided normal approximation, and *Fisher's exact test* were performed since unequal variance [ $F^1 (31, 29) = 2.21$ ,  $p = 0.04$ ] was present. When Wilcoxon *rank sum* was calculated, the non-pain group reported greater FSE ( $M$  score = 39.67,  $SD = 69.88$ ) than the pain group ( $M$  score = 23.85,  $SD = 69.88$ ) leading to a significant difference between the groups ( $Z = 3.50$ , normal approx.  $p = .0005$ , *Fisher's exact test* = 6.00E-04).

When the FSE scores of the LIC and MIC were evaluated, LIC and MIC FSE scores demonstrated equal variance [ $F^1(11, 19) = 2.38, p = 0.09$ ]. Significant group difference in FSE scores between the LIC and MIC was observed [ $t(30) = 3.96, p = 0.0004$ ].

#### *Self-Evaluated Disability – Disability Subscale of SOPA.*

Scores on the attitude about pain-related disability obtained from the SOPA disability subscale (range: 0 to 4) indicated some subjects had beliefs about pain that contribute to maladaptive coping.

The non-pain group scores ( $M = 0.55, SD = 0.54$ ) and pain group scores ( $M = 1.34, SD = 1.0$ ) indicated the pain group reported more attitudes related to maladaptive coping with pain than the non-pain group. Because variances were unequal [ $F^1(31, 29) = 3.38, p = 0.0014$ ], Wilcoxon *rank sum* statistic, 2-sided normal approximation, and *Fisher's exact test* were performed. Significant difference in disability subscale scores between the non-pain ( $M$  score = 23.82,  $SD = 70.39$ ) and pain group ( $M$  score = 38.70,  $SD = 70.39$ ) was observed ( $Z = -3.27$ , normal approx. = 0.001, *Fisher's exact test* = 0.0008).

Subject attitude about disability related to pain of the LIC and MIC subjects was evaluated using Student's *t*-test since the groups were independent and the nvariances were equal [ $F^1(19, 11) = 1.01, p = 1.00$ ]. No significant difference in attitude about disability due to pain between the classes was demonstrated [ $t(30) = -1.95, p = 0.06$ ].

#### *Pain Intensity*

Comparison of pain intensity between the groups used the mean of scores on the visual analogue scale of pain intensity (VAS-PI) (range: 0 to 100) and the Verbal Pain Rating (VRP) (range: 0 to 10) over the study session. Because movement tasks were intended to increase pain using a normal activity, only the VAS-PI and VRP ratings obtained during the



movement tasks during the acoustics session were used in the following analyses. Because of the unequal variances of the groups and classes, nonparametric statistical analyses were used.

*Pain Intensity – VAS-PI Scores for Non-Pain and Pain Groups*

Scores on the VAS-PI indicated that the non-pain group had low levels of pain ( $M = 0.5$  mm,  $SD = 0.90$  mm, median = 0) in comparison to the pain group ( $M = 19.84$  mm,  $SD = 23.92$  mm, median = 10 mm). Paired  $t$ -tests were used to determine within group differences in VAS-PI scores with seated and stand tasks. Within-group VAS-PI scores at the seated tasks were not different for the non-pain group [ $t(28) = -0.30$ ,  $p = 0.77$ ] or the pain group [ $t(29) = 1.14$ ,  $p = 0.26$ ]. Within-group VAS-PI scores at the stand tasks were not different for the non-pain group [ $t(29) = 1.18$ ,  $p = 0.25$ ] or for the pain group [ $t(30) = -0.59$ ,  $p = 0.56$ ] (Table 98).

Table 98.

*Within-Group Differences in Written Pain Intensity Scores of Non-Pain and Pain Group by Task*

Tasks	Group	VAS-PI $M (SD)$	$df$	$t$ -test	$p$
Seated	Non-Pain	-0.05 (0.94)	28	-0.30	0.77
	Pain	2.85 (13.64)	29	1.14	0.26
Stand	Non-Pain	0.15 (0.70)	29	1.18	0.25
	Pain	-1.31 (12.3)	30	-0.59	0.56

Because variances between non-pain and pain groups were unequal and both groups had 30 or more subjects, Wilcoxon *rank sum* statistic, 2-sided normal approximation (with a continuity correction of .5), and Fisher's *exact test* were used to determine between-group difference at the stand tasks.

Significant difference in VAS-PI ratings between the non-pain and pain groups was observed at all tasks (Table 99). At the first seated task, the non-pain group reported its lowest VAS-PI rating ( $M$  score = 17.5,  $SD$  = 65.13) while the pain group reported its highest VAS-PI rating ( $M$  score = 43.50,  $SD$  = 65.13). First seated VAS-PI ratings demonstrated the greatest group mean difference ( $Z$  = -5.98, normal approx.  $< .0001$ , *Fisher's exact test* =  $3.33E-11$ ). At first stand, the non-pain rating increased ( $M$  score 18.37,  $SD$  = 67.65) and pain group mean score decreased ( $M$  score = 43.23,  $SD$  = 67.65) but group difference remained statistically significant ( $Z$  = -5.60, normal approx.  $< .00001$ ,  $p$  =  $< .0001$ , *Fisher's exact test* =  $1.10E-09$ ). At second seated, non-pain group VAS-PI ratings increased ( $M$  score = 20.02,  $SD$  = 66.49) as the pain group VAS-PI ratings decreased ( $M$  score = 40.94,  $SD$  = 66.49). Significant difference between the non-pain and pain groups was observed in the VAS-PI ratings at the second seated ( $Z$  = -4.77, normal approx.  $< .0001$ , *Fisher's exact test* =  $4.91E-07$ ). At second stand, the non-pain group VAS-PI increased ( $M$  score = 20.73,  $SD$  = 67.97) as did the pain group VAS-PI ratings ( $M$  score = 41.59,  $SD$  = 67.97) and significant difference in non-pain and pain group VAS-PI scores continued ( $Z$  = -4.74, normal approx.  $p$   $< .0001$ , *Fisher's exact test* =  $6.18E-07$ ).

Table 99.

*Group Difference in Written Pain Intensity Scores of Non-Pain and Pain Groups by Task*

Task	Non-Pain (N = 30) <i>M</i> Score	Pain (N = 32) <i>M</i> Score	<i>SD</i> Under Null	<i>Z</i>	2-sided <i>t</i> - approximation	<i>Fisher's exact</i> <i>test</i>
First seated	17.50	*43.50	65.13	-5.98	<.0001	3.33E-11
First Stand	18.37	**43.23	67.65	-5.60	<.0001	1.10E-09
Second Seated	***20.03	40.94	66.49	-4.77	<.0001	4.91E-07
Second Stand	20.73	41.59	67.97	-4.74	<.0001	6.18E-07

\*N = 30. \*\*N = 31. \*\*\*N = 29.

*Pain Intensity - Written Rating of Pain Intensity of LIC and MIC*

In order for the research question to evaluate the relationship of report of pain intensity and disability, the data of persons with pain must be evaluated. Because variances of written pain intensity were not equal in LIC and MIC across all tasks [ $F^1(22, 39) = 17.49$ ,  $p < .0001$ ], written ratings of low intensity class (N = 20) and the moderate intensity class (N = 12) were compared using Wilcoxon *rank sum* statistic, 2-sided *t*-approximation, and *Fisher's exact test*.

At first stand, both groups reported their lowest written pain intensity ratings (Table 103). The LIC VAS-PI rating (*M* score 10.11, *SD* = 23.19) and MIC VAS-PI rating (*M* score = 24.82, *SD* = 23.19) were significantly different ( $Z = 4.40$ , 2-sided *t*-approx. = 0.0001, *Fisher's exact test* = 1.10E-07). At first stand, LIC VAS-PI ratings (*M* score = 10.65, *SD* = 24.20) and MIC VAS-PI ratings (*M* score = 10.65, *SD* = 24.20) were significantly different ( $Z = 4.40$ , 2-sided *t*-approx. = 0.0001, *Fisher's exact test* = 1.54E-07). At second seated, the LIC ratings decreased (*M* score = 10.60, *SD* = 25.56) while the MIC ratings increased (M

score = 26.33,  $SD = 25.56$ ) leading to the largest difference between the groups ( $Z = 4.60$ , 2-sided  $t$ -approx. =  $<.0001$ , *Fisher's exact test* =  $3.10E-08$ ). At second stand, LIC VAS-PI ratings increased ( $M$  score = 10.75,  $SD = 25.55$ ) as the MIC VAS-PI ratings decreased ( $M$  score = 26.08,  $SD = 25.55$ ) and significant difference continued ( $Z = 4.48$ , 2-sided  $t$ -approx.  $<.0001$ , *Fisher's exact test* =  $1.59E-07$ ) (Table 100). The LIC and MIC differed in written report of pain intensity at all tasks.

Table 100.

*Group Difference in Written Pain Intensity Scores of Low and Moderate Intensity Pain Classes by Task*

Task	Low Intensity Class (N = 20) Mean Score	Moderate Intensity Class (N = 12) Mean Score	<i>SD</i> Under Null	<i>Z</i>	2-sided <i>t</i> - approximation	<i>Fisher's exact</i> <i>test</i>
First seated	*10.11	24.82	23.19	4.40	0.0001	1.09E-07
First Stand	10.65	**25.73	24.20	4.40	0.0001	1.54E-07
Second Seated	10.60	26.33	25.56	4.60	$<.0001$	3.10E-08
Second Stand	10.75	26.08	25.55	4.48	$<.001$	1.59E-07

\*N = 19. \*\*N = 11.

*Pain Intensity – Verbal Rating of Pain Intensity of Non-Pain and Pain Groups*

Scores on the VRP indicated that the non-pain group reported no pain ( $M = 0$ ,  $SD = 0$ , median = 0) in comparison to the pain group report of mild pain ( $M = 2.46$ ,  $SD = 2.15$ , median = 2.0). When paired  $t$ -tests were used to determine within group differences in VRP with seated tasks, within group VRP scores were not different across the tasks in the non-

pain group [ $t(29) = -0.29, p = 0.77$ ] or in the pain group [ $t(29) = -0.34, p = 0.74$ ]. Using paired  $t$ -tests, VRP were not different for stand tasks for the non-pain group [ $t(29) = 0.54, p = 0.59$ ] or for the pain group [ $t(30) = -0.09, p = 0.93$ ] (Table 101). No significant within group difference was observed in verbal pain ratings across the two seated or the two stand tasks.

Table 101.

*Within-Group Difference in Verbal Rating of Pain Intensity of Non-Pain and Pain Group by Task*

Tasks	Group	VRP <i>M (SD)</i>	<i>df</i>	<i>t</i> -test	<i>p</i>
Seated	Non-Pain	-0.034 (0.64)	28	-0.29	0.77
	Pain	-0.82 (13.27)	29	-0.34	0.73
Stand	Non-Pain	0.07 (0.68)	29	0.54	0.59
	Pain	0.16 (10.14)	30	0.09	0.93

The VRP ratings of the non-pain group and pain group were not normally distributed and variances were not equal at first stand [ $F^1(31, 28) = \text{infinity}, p < .0001$ ] or second stand [ $F^1(31, 29) = \text{infinity}, p < .0001$ ]. The non-pain group reported no pain while the pain group reported mild levels of pain ( $M = 2.46, SD = 2.15$ ). Significant difference between the non-pain and pain group was present at all tasks when Wilcoxon *rank sum* statistic, normal approximation, and *Fisher's exact test* were used but the lack of variance in the non-pain group is evident in the results (Table102).

At first stand, the groups are different ( $Z = -6.13$ , normal approximation  $<.0001$ , *Fisher's exact test* =  $1.11\text{E-}11$ ) due to increased mean score of the pain group ( $M$  score = 43.69) compared to the non-pain mean score ( $M$  score = 18.5). The pain group kept this mean score through the remaining tasks. At first stand, the non-pain group VRP mean score

decreased ( $M$  score = 17.00) while the pain group VRP increased ( $M$  score = 49.30) and resulted in the largest difference ( $Z = -6.40$ , normal approximation  $<.0001$ , *Fisher's exact test* =  $9.48\text{E-}13$ ). At second seated, the non-pain group mean score increased ( $M$  score = 18.5) while the pain group mean score continues steady ( $M$  score = 43.69) with the difference similar to first seated ( $Z = -6.13$ , normal approximation =  $<.0001$ , *Fisher's exact test* =  $1.20\text{E-}11$ ). At second stand, the mean scores remained the same as at second seated but the mean difference changed ( $Z = -6.14$ , normal approximation  $<.0001$ , *Fisher's exact test* =  $1.28\text{E-}11$ ).

Table 102.

<i>Group Difference in Verbal Rating of Pain Intensity of Non-Pain and Pain Group by Task</i>						
Task	Non-Pain (N = 30) <i>M</i> Score	Pain (N = 32) <i>M</i> Score	<i>SD</i> Under Null	<i>Z</i>	2-sided <i>t</i> - approximation	<i>Fisher's</i> <i>exact test</i>
First seated	18.5	43.69	63.53	-6.13	$<.0001$	$1.11\text{E-}11$
First Stand	17.0	43.69	63.53	-6.40	$<.0001$	$9.48\text{E-}13$
Second Seated	18.5	43.69	63.51	-6.13	$<.0001$	$1.20\text{E-}11$
Second Stand	18.5	43.69	63.49	-6.14	$<.0001$	$1.28\text{E-}11$

#### *Pain Intensity – Verbal Rating of Pain of LIC and MIC*

Verbal rating of pain of the low and moderate pain intensity classes were compared using the Wilcoxon *rank sum* statistic, 2-sided *t*- approximation, and *Fisher's exact test* to determine if the classes differed in verbal rating of pain intensity by task. The MIC had higher verbal pain ratings at all tasks (Table 103). At first seated, the LIC VRP ( $M$  score = 10.73,  $SD = 25.27$ ) was less than the MIC VRP ( $M$  score = 26.13,  $SD = 25.27$ ) resulting in significant difference between the classes ( $Z = 4.55$ , 2-sided *t*-approx.  $<.0001$ , *Fisher's exact*

$test = 8.8E-08$ ). At first stand, both the LIC VRP ( $M$  score = 11.15,  $SD = 25.31$ ) and the MIC VRP ( $M$  score = 25.42,  $SD = 25.31$ ) increased and group difference remained significant ( $Z = 4.21$ , -sided  $t$ -approx. = .0002, *Fisher's exact test* = 2.08E-06). At the second seated, the LIC VRP decreased ( $M$  score = 10.80,  $SD = 25.24$ ) and MIC increased ( $M$  score = 26.00,  $SD = 25.24$ ) leading to the greatest difference of all the tasks ( $Z = 4.40$ , 2-sided  $t$ -approx. < .0001, *Fisher's exact test* = 3.54E-08). At second stand, the LIC VRP increased ( $M$  score = 10.83,  $SD = 25.17$ ) and MIC VRP decreased ( $M$  score = 25.96,  $SD = 25.96$ ) but the classes remained significantly different ( $Z = 4.50$ , 2-sided  $t$ -approx. < .0001, *Fisher's exact test* = 1.37E-07).

Table 103.

*Group Difference in Verbal Rating of Pain Intensity of Low and Moderate Pain Intensity Classes by Task*

Task	Low Intensity Class (N = 20) <i>M</i> Score	Moderate Intensity Class (N = 12) <i>M</i> Score	<i>SD</i> Under Null	<i>Z</i>	2-sided <i>t</i> - approximation	<i>Fisher's</i> <i>exact test</i>
First seated	10.73	26.13	25.27	4.55	< .0001	8.86E-08
First Stand	11.15	25.42	25.31	4.21	0.0002	2.08E-06
Second Seated	10.80	26.00	25.24	4.50	< .0001	3.54E-08
Second Stand	10.83	25.96	25.17	4.50	< .0001	1.37E-07

### Pain Unpleasantness

Because emotional reaction to pain was reported using the VAS-UNP, differences in ratings of pain unpleasantness were evaluated using the Wilcoxon *rank sum* statistic, 2-sided normal approximation for the non-pain and pain groups, 2-sided  $t$ -approximation for the LIC and MIC, and *Fisher's exact test*. This evaluation was added to determine the relationship of

the VAS-UNP to the pain intensity measures taken with movement, observational disability measures, and self-evaluation of disability measures.

#### *Pain Unpleasantness Ratings of Non-Pain and Pain Groups*

The Wilcoxon *rank sum* statistic was used to determine the difference in VAS-UNP between non-pain and pain groups. VAS-UNP ratings were significantly different at all tasks (Table 104). At first seated, the non-pain group report of pain unpleasantness ( $M$  score = 18.77,  $SD$  = 64.10) and the pain group report of pain unpleasantness ( $M$  score = 42.23,  $SD$  = 64.10) were significantly different ( $Z$  = -5.48, 2-sided normal approximation < .0001, *Fisher's exact test* = 3.17E-09). At first stand, the non-pain group VAS-UNP rating remained stable ( $M$  score = 18.77,  $SD$  = 66.56) while the pain group VAS-UNP increased ( $M$  score = 42.84,  $SD$  = 66.56) leading to greater difference ( $Z$  = -5.51, 2-sided normal approximation < .0001, *Fisher's exact test* = 2.69E-09). At second seated, the non-pain group reported increased pain unpleasantness ( $M$  score = 19.74,  $SD$  = 65.79) as the pain group reported a decrease in pain unpleasantness ( $M$  score = 41.20,  $SD$  = 65.79) reducing the difference ( $Z$  = -5.00, 2-sided normal approximation < .0001, *Fisher's exact test* = 1.56E-07). The pain group reported its highest level of unpleasantness at second stand ( $M$  score = 43.27,  $SD$  = 67.99) while the non-pain group VAS-UNP decreased from the second seated rating ( $M$  score = 18.95,  $SD$  = 67.99). Ratings of pain unpleasantness at second stand demonstrated the largest difference between non-pain and pain groups ( $Z$  = -5.53, 2-sided normal approximation < .0001, *Fisher's exact test* = 2.40E-09).



Table 104.

*Group Difference in Written Pain Unpleasantness Scores of Non-Pain and Pain Groups by Task*

Task	Non-Pain (N = 20) <i>M</i> Score	Pain (N = 12) <i>M</i> Score	<i>SD</i> Under Null	<i>Z</i>	2-sided <i>t</i> - approximation	<i>Fisher's</i> <i>exact test</i>
First seated	18.77	42.23	64.10	-5.48	< .0001	3.17E-09
First Stand	18.77	42.84	66.56	-5.51	< .0001	2.69E-09
Second Seated	41.20	41.20	65.79	-4.96	< .0001	1.56E-07
Second Stand	18.95	43.27	67.99	-5.53	< .0001	2.40E-09

*Pain Unpleasantness Ratings of LIC and MIC*

The VAS-UNP ratings by the LIC and MIC demonstrated significant difference at all tasks (Table 105). At first stand, the LIC reported its lowest level of pain unpleasantness (*M* score = 10.0, *SD* = 23.16) while the MIC had higher VAS-UNP (*M* score = 25.0, *SD* = 23.16) leading to the largest difference at all tasks (*Z* = 4.49, 2-sided *t*-approximation = 0.0001, *Fisher's exact test* = 1.83E-08). At first stand, the LIC reported its highest VAS-UNP rating (*M* score = 11.13, *SD* = 24.17) while the MIC VAS-UNP decreased (*M* score = 24.86, *SD* = 24.17). Difference at first stand decreased but remained significant (*Z* = 4.01, 2-sided *t*-approximation = 0.0004, *Fisher's exact test* = 6.63E-06). At second seated, LIC VAS-UNP ratings decreased (*M* score = 11.10, *SD* = 25.53) while MIC ratings of unpleasantness increased (*M* score = 25.5, *SD* = 25.53) and the difference between the classes was greater (*Z* = 4.21, 2-sided *t*-approximation = 0.0002, *Fisher's exact test* = 2.13E-06). The MIC reported its greatest pain unpleasantness at second stand (*M* score = 25.67, *SD* = 25.62) while the LIC group decreased VAS-UNP ratings. The difference in pain unpleasantness remained

significant at second stand ( $Z = 4.27$ , 2-sided  $t$ -approximation = 0.0002, *Fisher's exact test* = 1.08E-06).

Table 105.

*Group Difference in Written Pain Unpleasantness Scores of Low and Moderate Intensity Pain Classes by Task*

Task	Low Intensity Class (N = 20) <i>M</i> Score	Moderate Intensity Class (N = 12) <i>M</i> Score	<i>SD</i> Under Null	<i>Z</i>	2-sided <i>t</i> - approximation	<i>Fisher's</i> <i>exact test</i>
First seated	10.0	25.0	23.16	4.49	0.0001	1.83E-08
First Stand	11.13	24.86	24.17	4.01	0.0004	6.63E-06
Second Seated	11.10	25.50	25.53	4.21	0.0002	2.13E-06
Second Stand	11.00	25.67	26.62	4.27	0.0002	1.08E-06

Preliminary analyses of paired  $t$ -tests of the non-pain and pain groups and the LIC and MIC data at stand tasks were performed to determine if difference existed within each group at the stand tasks that would preclude combining group and class data for correlation analysis. Paired  $t$ -tests were performed using observed disability, VAS-PI, VRP, and VAS-UNP data.

Paired  $t$ -tests of observed disability ratings indicated no difference in the non-pain group data [ $t(28) = -0.82$ ,  $p = 0.42$ ] or in the pain group data [ $t(31) = -0.82$ ,  $p = 0.42$ ] at the two stand tasks. Paired  $t$ -tests of the VAS-PI ratings indicated no difference in written pain intensity rating in the non-pain group data [ $t(29) = 1.18$ ,  $p = 0.25$ ] at the two stand tasks or in the pain group data [ $t(30) = -0.59$ ,  $p = 0.56$ ] at the two stand tasks. Paired  $t$ -tests of the VRPs indicated no difference in verbal pain intensity rating of the non-pain group data at the two

stand tasks [ $t(29) = 0.54, p = 0.59$ ] or in the pain group data [ $t(30) = 0.09, p = 0.93$ ] at the two stand tasks. Paired  $t$ -tests of the VAS-UNP ratings indicated no difference in the written rating of pain unpleasantness in non-pain group data [ $t(29) = 0.54, p = 0.59$ ] at the two stand task or in the pain group data [ $t(30) = 0.09, p = 0.93$ ] at the two stand tasks. Because there was no change related to time, the VAS-PI, VRP, and VAS-UNP data of each group were combined for the correlation analysis.

#### Correlation of Disability and Pain Intensity Variables

Since the non-pain and pain group data were interval level and non-normal, the nonparametric correlation coefficient, Spearman  $r_s$ , was used. Lack of correlation in the non-pain group VRP and pain interference scores was related to lack of variance in VRP or lack of pain interference data and those data are not included (Table 106). Strong bivariate correlations, where  $r_s$  is greater than 0.5, existed between non-pain group VAS-PI and VAS-UNP ratings ( $r_s = 0.82, p < .0001$ ) and self-efficacy for physical function and scores on the SOPA disability scale ( $r_s = -0.57, p < .0001$ ). Moderate bivariate correlations existed between non-pain group scores for self-efficacy for physical function and VAS-UNP ( $r_s = -0.36, p = 0.005$ ) and self-efficacy for physical function and VAS-PI ( $r_s = -0.29, p = 0.02$ ). Weak bivariate correlation, those where  $r_s$  was greater than 0.1 but less than 0.29, existed between non-pain group scores for observed disability and scores on the SOPA disability scale ( $r_s = 0.10, p = 0.44$ ) and observed disability and self-efficacy for physical function ( $r_s = -0.10, p = 0.44$ ).

Table 106.

*Correlation of Non-Pain Group Disability and Pain Measures*

	Observed Disability	VAS - PI	SOPA Disability Scale	ASES Self-Efficacy for Physical Function	VAS - UNP
Observed Disability	1.0 59				
VAS-PI	0.03 0.85 59	1.0 60			
SOPA Disability Scale	0.10 0.44 59	-0.06 0.65 60	1.0 60		
ASES Self- Efficacy for Physical Function	-0.10 0.44 59	-0.29 0.02 60	-0.57 < .0001 60	1.0 60	
VAS-UNP	-0.03 0.83 59	0.82 < .0001 60	-0.08 0.53 60	-0.36 0.005 60	1.0 60

Pain group correlation data included the BPI pain interference scale and the VRP ratings (Table 107). When the pain group data was evaluated using Spearman  $r_s$ , strong bivariate correlations occurred with pain measures: (1) VAS-PI and VRP ( $r_s = 0.88$ ,  $p < .0001$ ), (2) VAS-UNP and VAS-PI ( $r_s = 0.88$ ,  $p < .0001$ ), and (3) VAS-UNP and VRP ( $r_s = 0.80$ ,  $p < .0001$ ). A number of strong bivariate correlations existed with disability measures: (1) self-efficacy for physical function and SOPA disability scale scores ( $r_s = -0.66$ ,  $p < .0001$ ), (2) pain interference scale and SOPA disability scale scores ( $r_s = 0.64$ ,  $p < .0001$ ), (3)

self-efficacy for physical function and pain interference scale scores ( $r_s = -0.56, p < .0001$ ), and (4) SOPA disability scale scores and observed disability ( $r_s = 0.51, p < .0001$ ).

Several moderate bivariate correlations of pain measures existed : (1) VAS-PI ratings and self-efficacy for physical function scale scores ( $r_s = -0.46, p = 0.0002$ ), (2) VRP ratings and self-efficacy for physical function ( $r_s = -0.45, p = 0.0002$ ), (3) VRP ratings and SOPA disability scale scores ( $r_s = 0.44, p = 0.0003$ ), (4) VRP ratings and pain interference scale scores ( $r_s = 0.44, p = 0.0003$ ), (5) VAS-UNP ratings and self-efficacy for physical function scale scores ( $r_s = -0.40, p = 0.0001$ ), (6).VAS-UNP ratings and pain interference scale scores ( $r_s = 0.34, p = 0.006$ ), (7) VRP ratings and observed disability scores ( $r_s = 0.34, p = 0.005$ ), and (8) VAS-PI ratings and pain interference scale scores ( $r_s = 0.33, p = 0.008$ ). Moderate bivariate correlation of existed with observed disability and pain interference scale scores ( $r_s = 0.42, p = 0.0005$ ).

Weak bivariate correlation of pain measures existed: (1) VAS-PI ratings and SOPA disability scale scores ( $r_s = 0.29, p = 0.02$ ), (2) VAS-UNP ratings and SOPA disability scale scores ( $r_s = 0.21, p = 0.10$ ), (3) VAS-PI ratings and observed disability ( $r_s = 0.13, p = 0.32$ ), (4) VAS-UNP ratings and VAS-UNP ratings and observed disability ( $r_s = 0.10, p = 0.41$ ) and (5) VAS-PI ratings and observed disability scores ( $r_s = 0.10, p = 0.41$ ). Weak bivariate correlation occurred with disability measures of observed disability and self-efficacy of physical function ( $r_s = -.20, p = 0.11$ ).

Correlations of VAS-PI, VAS-UNP, and VRP with other pain measures were strong (Table 107). The VRP correlation with the VAS-PI and the correlation of the VAS-PI and

Table 107.

*Correlation of Pain Group Disability and Pain Measures*

	Observed Disability	VAS-PI	VRP	SOPA Disability Scale	BPI Pain Interference Scale	ASES Self- Efficacy for Physical Function	VAS- UNP
Observed Disability	1.00 64						
VAS-PI	0.13 0.32 63	1.00 63					
VRP	0.34 0.005 64	0.88 <.0001 63	1.00 64				
SOPA Disability Scale	0.51 <.0001 64	0.29 0.02 63	0.44 0.0003 64	1.00 64			
BPI Pain Interference Scale	0.42 0.0005 64	0.33 0.0008 63	0.44 0.0003 64	0.64 <.0001 64	1.00 64		
ASES Self-Efficacy for Physical Function	-0.20 0.11 64	-0.46 0.0002 63	-0.45 0.0002 64	-0.66 <.0001 64	-0.56 <.0001 64	1.00 64	
VAS-UNP	0.10 0.41 63	0.88 <.0001 63	0.80 <.0001 63	0.21 0.006 63	0.34 0.006 63	-0.40 0.001 63	1.00 63

VAS-UNP ( $r_s = 0.88, p < .0001$ ) were the highest correlation observed with the pain group. The correlation of the VAS-PI and VAS-UNP in the non-pain group was the highest of the variables investigated ( $r_s = 0.82, p < .0001$ ).

Correlations of the three self-evaluated disability/ability measures with other self-evaluated disability /FSE measures were strong. The negative correlation of FSE with the SOPA disability scale score ( $r_s = -0.66, p < .0001$ ) was the highest of these measures. The pain interference scale of the BPI was strongly correlated with the SOPA disability scale ( $r_s = 0.64, p < .0001$ ). The negative correlation of the self-efficacy for physical function scale with the pain interference scale was strong ( $r_s = -0.56, p < .0001$ ) but less than the correlation with the SOPA disability scale.

Correlations of observed disability with the self-evaluated disability/ self-efficacy for ability measures were varied. Observed disability correlations ranged from strong with the SOPA disability scale ( $r_s = 0.51, p < .0001$ ) to moderate with the BPI pain interference scale ( $r_s = 0.42, p = 0.0005$ ) to weak with the FSE ( $r_s = -0.20, p = 0.11$ ).

Correlations of the pain measures with self-evaluated disability measures were varied. The VRP was moderately correlated with the BPI pain interference scale (measured only with the pain group) ( $r_s = .44, p = 0.0003$ ) and with the SOPA disability scale ( $r_s = .44, p = 0.0003$ ). VAS-PI correlations were weaker than those of the VRP with self-evaluated disability/ self-efficacy for ability. The VAS-PI was moderately correlated with FSE ( $r_s = -0.46, p = 0.0002$ ) and pain interference ( $r_s = 0.33, p = 0.008$ ). Weak correlation was observed with VAS-PI scores and the SOPA disability scale ( $r_s = 0.29, p = 0.02$ ). VAS-UNP ratings were moderately correlated with FSE scores ( $r_s = -0.40, p = 0.001$ ) and pain interference

scores ( $r_s = 0.34, p = 0.006$ ). Correlation of the VAS-UNP scores with the SOPA disability scale scores were weak ( $r_s = 0.21, p = 0.10$ ). High ratings on the VRP appear more strongly associated with measures that tap domains other than pain and physical disability than the VAS-PI and the VAS-UNP.

Correlation of pain measures and observed disability were not strong. Correlation of the VRP with observed disability in the pain group was moderate ( $r_s = 0.34, p = 0.005$ ) but stronger than the other two written pain measures. The VAS-PI and observed disability were weakly correlated ( $r_s = 0.13, p = 0.32$ ). The VAS-UNP and observed disability were more weakly correlated ( $r_s = 0.10, p = 0.41$ ) than the VAS-PI. When the VRP is multiplied by 100 to equate to the VAS-PI, subjects rated pain lower on the VRP.

While it was thought that increased disability was related to increased report of pain, in this sample, disability was not strongly correlated to pain characterized by low and moderate intensity chronic knee pain. In addition, when asked to rate pain intensity, subjects' verbal ratings of pain were lower than written reports of pain intensity.



## CHAPTER SIX

### DISCUSSION

Pain has been described as a homeostatic emotion due to its ability to effect physiological change and motivate behavioral change to reduce or avoid its aversive nature (A. D. Craig, 2003b). Emotion influences vocal signal (Banse & Scherer, 1996; Wallbott & Scherer, 1986) and differences in vocal signal have been related to predictions of emotion expression proposed by a componential theory of affective expression (K. Scherer, 1986; K. Scherer & Ellgring, 2007b). Because nurses and health care providers rely on verbal self-report of pain to assess and modify care, investigation of vocalization associated with an increase in chronic pain and its emotional response is relevant to pain management.

This exploratory study investigated whether change in acoustic parameters of the vocal signal occurs with an increase in chronic pain and if change in acoustic parameters could indicate the specific type of emotional reaction to chronic pain.

#### The Method

The study required development of an innovative method to assess the emotional reaction to pain independent of the cognitive influence required by written or verbal numerical scales for pain measurement. The method included strategies for recording observational data as well as applying statistical techniques that would allow comparison of the observed data with theoretical predictions. The observational method required increasing

chronic pain and measuring of acoustic and physiological data at rest and during the pain induction activity. Because emotion is defined by the occurrence of a physiological response to a stimulus or event, physiological data was obtained to determine that an emotion occurred in anticipation of a painful stimulus in the pain group. Comparison of outcomes for the chronic pain sample and a non-pain sample allowed evaluation of differences in acoustic parameters associated with a movement task thought to increase knee pain.

The purpose of the study was to develop a real-time indicator of emotional reaction to chronic pain in contrast to written psychological instruments designed to measure state and trait levels of mood, or the enduring pattern of emotional response in an individual. Because chronic pain is associated with negative affective states of depression, anxiety, and anger and these moods may influence short-term emotional reaction, assessments of these mood states required use of validated instruments to provide information on subjects' enduring patterns of emotion. Although moods are not emotions, mood state measured by the inventories provided a proxy for emotional state. Change in acoustic parameters were predicted to occur with emotional state (K. Scherer, 1986) and use of the proxy for emotional state allowed comparison of observed acoustic parameter changes with these predictions of acoustic parameter changes. Because the non-pain group was expected to be more closely aligned with the predictions based on normal response to emotion, significant difference between the non-pain and pain group could signal increased pain presence. Therefore, sample mean scores on scales for depression, anxiety, and anger became proxies for emotional states. Since group mean levels of depression, anxiety and anger were lower than norms established by instrument developers, it suggests that these moods all related to Scherer's lower intensity emotional states not higher intensity emotions: sadness/dejection not grief/despair,

anxiety/worry not fear/panic, and irritation/cold anger not rage/hot anger (K. Scherer, 1986). Sadness/dejection is identified as a more trophotropic emotion associated with parasympathetic nervous system predominance. Anxiety/worry and irritation/cold rage are identified as more ergotropic emotions and associated with sympathetic nervous system predominance.

Anticipating that performance anxiety and equipment would affect the acoustic samples of the first task, a second movement task was included in the study's protocol. Acclimation of subjects to the equipment and learning of the procedure was seen as influencing the difference in the two movement tasks. While some nervous behavior was present with the first task, subjects demonstrated learning of the behaviors required with the second task. Because anxiety was a mood of interest, the decision to analyze both tasks was made in order to detect differences between the two tasks that could relate to performance anxiety. No difference in within group pulse rate between the two movement tasks was observed indicating that the level of anxiety was not significant.

The sample of 62 volunteers was recruited from a university setting and was well-educated. The intent was to study chronic knee pain common in community-living women in order to obtain data about natural response to chronic knee pain. Because of the exploratory nature of this study, the need to recruit a variety of subjects to determine more information about the relationship of movement, pain, and voice was important. Although the sample size was small, ethnic diversity was present.

Ability to read, understand, and speak English was a requirement; however, information about cultural background beyond racial group membership was not collected. Because the university community attracts persons from various parts of the country and

world, speech patterns, speech rates, and pronunciation were varied and regional dialects were present. The study design included a connected speech sample to allow capture of the vowel /ə/ in the context of usual speech. However, it was difficult to capture /a/ in the connected speech sample because of the substitution of /ei/ and /e/ that is prevalent in southern United States. In addition, some subjects spoke quickly or slurred words leading to limited length of vowel samples for analysis. Because connected speech samples could not be obtained for the sample, connected speech vowels were not analyzed with this sample.

Use of the head-mounted microphone facilitated capture of the acoustic samples with the movement tasks. Placement of the microphone near the outer corner of the mouth reduced noise interference with subject movement and wearing the head-mounting did not bother subjects. Default settings for intensity were used with the Computerized Speech Laboratory and Multi-Dimensional Voice Program, and high intensity bursts from a few subjects meant samples could not be analyzed. Occurrence of bursts required repeating the vowels and connected speech samples. The restriction of vocal intensity to 60-65 dB to accommodate older women and the multiple tokens may have been unnecessary.

In this study, reports of Fhi results identified a subject's first seated tokens demonstrated much higher  $F_0$  that subsided with correction in the subsequent tokens. When the subject's videotape was reviewed to determine what might have caused this error, the subject was found to have sung the vowel at the first seated task and was prompted to speak for the subsequent tasks. The association of singing with the sustained vowel production was unexpected, but important to correct in acoustic data collection.

Use of other acoustical analysis programs could be incorporated, but CSL and MDVP system allowed rapid collection of the multiple samples and analysis of several parameters. While learning features of the programs and adjusting the settings required technical support, advice was available from KayPENTAX and a committee member. While the equipment was transportable within the building, the desktop computer system, CSL hardware, and speaker were cushioned by pneumatic tires to protect the sensitive electronics.

The protocol's requirement of five 4-second long sustained vowels with each task may have promoted mouth dryness or fatigue that was intended to demonstrate physiological arousal. Room temperature also increased during the acoustic sessions in the summer due to lack of air conditioning. Subjects were allowed to take drinks of water if desired during the study. Therefore, it is possible that the fluid intake by some subjects, but not all, confounded the effect of decreased saliva production on formants associated with sympathetic nervous system activation.

Although the use of pulse oximetry prevented subject disrobing, obtaining several seconds of pulse uninterrupted by voice or movement at rest, in anticipation of standing, and while standing to assess physiological changes with the two sit-to-stand tasks proved difficult. A three-second observation was the largest period obtainable for most of the sample and, coincidentally, three seconds was the shortest interval that could be programmed on the pulse oximetry equipment to average pulse. Since emotional change may occur in periods shorter than three seconds, the magnitude of a brief change in pulse rate that lasted for only one or two seconds could be reduced with pulse oximetry averaging and the restricted time period selected for measurement.

Videotaping of the recording session used a camcorder that captured the head-to-toe image of the subject's for the timing of the sit-to-stand task that assessed observed disability. Image resolution was sufficient for this measurement. Although the audio track of the recording was not used for acoustical measurements, the audio track verified the activation of the marker for the physiological data, an important cue for the pulse rate measurement. When pulse rate data was erratic, the recording clarified subject activity important in answering research questions.

Recommendations on improvements to implementation of this method are addressed later in the implications for future research.

### The Outcomes

This investigation demonstrated that pulse rates differed in non-pain and pain samples subjected to sit-to-stand task as a means of increasing pain on movement. Pulse rate was selected in this study for its rapid response rate and ability to be monitored with movement and voice recordings during the study. The choice of pulse oximetry was attractive as it avoided disrobing subjects or further restricting movement with electrocardiographic leads. However, data analysis demonstrated problems related to averaging that occurs with pulse oximetry.

Emotion research has viewed physiological change as an important indicator of arousal necessary to appraisal in the emotion experience. Because appraisal theory predicts that anticipation of a stressful event will increase arousal, it was thought that physiological change at the anticipation of standing would be greater due to unconscious anticipation of painful movement and greatest at the first anticipation of standing measurement due to uncertainty about the procedure. Nonparametric analyses determined pulse rates were

significantly different between the groups at all tasks related to weight and BMI. The influence of body size suggested that factors in addition to arousal could be involved in the pulse rate differences. However, the differences between the groups at the two anticipation tasks were much greater than the group differences at other tasks.

The inclusion of the sit-to-stand task and the exertion required to change position may have introduced a confounder to measurement of pulse as indicator of emotion with this sample. Because of the difference in weight and BMI, the sit-to-stand task may have introduced physiological and anatomical changes like Valsalva maneuver and lung capacity changes that are influenced by body size factors and were not measured. In addition, weight-shifting from one leg to the other observed in the pain group with stand tasks may have influenced pulse, lung expansion, and acoustic parameters as well.

Because weight and BMI were not different between the LIC and MIC, the data of the LIC and MIC were analyzed to further explore the influence of pain intensity on pulse rate. The lack of significant difference in pulse rate was unexpected given the difference between the LIC and MIC in pain intensity and unpleasantness ratings. Two possible reasons for this absence of difference in pulse exist. First, the trend of the MIC to have lower pulse rates than the LIC until the second stand task suggests possible adaptation to chronic pain and the restorative function of the parasympathetic nervous system thought to dampen sympathetic nervous system reactivity (Hellhammer et al., 2004). Second, the lack of correlation of the pulse with pain intensity in the MIC supports earlier findings of a gender difference in pulse with pain intensity (Tousignant-Laflamme et al., 2005). The decrease in pulse rate of the LIC and the increase in pulse rate of the MIC at the second stand task suggests appraisal

processing differences related to coping potential or self compatibility checks resulting in different neuroendocrine system activation (K. Scherer, 2001a).

In addition to the increased pain and unpleasantness at the second stand task, subjects' recognition that this task signaled the end of the study session may have triggered thoughts about other activities, increasing mental load and, subsequently, increasing pulse rate. Scherer (2001a) suggests that a delay in response can occur when an appraisal requires more complex processing of information related to the stimulus. Physical exertion and fatigue associated with both sustained vocalization and movement tasks may have added physical stress to the mental loading. The observed pulse rate increase of the MIC at the second stand task could be indicative of this additive effect of multiple stressors of mental load as well as emotional arousal that are described by Myrtek et al. (2005).

The increase in pulse in the pain group at the anticipation of standing, likely due to the larger number of LIC subjects, cannot be attributed to anticipation of a painful activity alone. Possible reasons for the pulse increase in the pain group or lack of variation in the non-pain group include medications, level of conditioning, room temperature, metabolism of the snack prior to the acoustic measurements, and fear of pain being inflicted. These factors were not controlled in this exploratory investigation and could contribute to the results. Since the purpose of measuring pulse rate was to indicate an emotion had occurred, the findings do not clearly establish emotion change.

Non-pain versus pain group differences in acoustic parameters were notable for differences in range of  $F_0$  and jitter but not for  $MF_0$ ,  $F_{lo}$ ,  $F_{hi}$ , shimmer and APQ. Analysis of acoustic parameters demonstrated change in range of  $F_0$  and jitter with increased pain was associated with the movement tasks in the pain and non-pain group. Observation of a



significant difference between non-pain and pain groups with an acoustic parameter capable of being perceived by ear was a desired, although not expected, outcome of this study with the low level of activity required. While human hearing has been shown to be sensitive to acoustic changes associated with emotion (Luo, Fu, & Galvin, 2007), cues to emotion often rely on fundamental frequency, or its perceptual correlate, pitch. Although higher frequencies capture the attention of the listener and are used to notify of the need for assistance (Luo et al., 2007; Noyes, Hellier, & Edworthy, 2006), human hearing is reported to be more sensitive to changes in lower frequencies (Johnson, 2003). However, the lower frequencies used by the pain group may attract less listener attention in a noisy environment despite this sensitivity.

While change in fundamental frequency is easily detected by listeners and increase in  $F_0$  is known to occur with acute pain (B. J. Stevens, Johnston, & Horton, 1994), no significant difference in  $F_0$  or  $MF_0$  were demonstrated in this sample. Because lower pitch occurs in older women, this finding verified the groups did not differ due to an decrease or increase in  $F_0$  for one group. In addition, this finding suggests that non-pain and pain subjects were not experiencing acute pain in response to the movement task, but could indicate the chronic pain group was experiencing a different type of stimulus.

Based on reports of monotone with depression, three additional characteristics of fundamental frequency were investigated:  $F_{lo}$ ,  $F_{hi}$ , and range of  $F_0$ . Along with the higher pulse rate with movement tasks, the pain group demonstrated lower  $F_0$ , lower  $F_{lo}$ , and increased range of  $F_0$  compared to the non-pain group. This association of heart rate and lower  $F_0$  supported Orlikoff and Baken (1989) suggestion that changes in mean  $F_0$  during heartbeat were related to the systolic increase in blood volume to the vocal folds' muscular body resulting in decreased  $F_0$ . In this sample of older women, use of medications and

medical conditions that affect cardiovascular performance are acknowledged as possible confounders. Since detailed medication histories were not taken, the effects of medications may have increased or decreased the observed pulse rate and cardiac output to musculature underlying the vocal fold mucosa and, thus, may have influenced  $F_0$ .

The increase in group mean differences in  $F_{lo}$  across tasks, although not statistically significant, was interesting. While discussion of range of  $F_0$  often indicates use of higher frequencies in females, the difference in the non-pain and pain group occurred due to use of lower frequencies. Differences in  $F_{lo}$  at first stand (9.04 Hz) and second stand (10.68 Hz) were large enough to be detectable by ear. Since the pain group demonstrated lower frequencies, there is potential use for  $F_{lo}$  as an indicator of chronic pain if significance can be demonstrated in a larger sample.

Though not statistically significant, group mean differences in  $F_{hi}$  between non-pain and pain groups ranged between 0.04 to 3.20 Hz across the four tasks. These differences would not be easily detected by ear. Increased use of higher frequencies indicative of more acute pain were not expected with chronic pain.

Range of  $F_0$  was different between the non-pain and pain groups and the difference was statistically significant. This difference is unusual because range of  $F_0$  became significantly wider due to use of lower frequencies for the pain group compared to the non-pain group although the groups did not differ in  $F_0$  and  $MF_0$ . In depression, restricted pitch variability has been reported (Cannizzaro, Harel, Reilly, Chappell, & Snyder, 2004).

Although the pain group demonstrated significantly greater depression than the non-pain group, the pain group's mean level of depression was less than mild depression level reported by the instrument's designer. Because the pain sample was ambulatory and not severely

disabled, their use of a wide range of  $F_0$  with lower frequencies may demonstrate the early effects of low level depression. Because studies with clinically depressed subjects report narrower or more restricted use of low frequencies, findings of narrow range of  $F_0$  may develop as the level of depression increases. Because treatment of depression has been shown to reduce chronic pain, an early indicator of depression could signal the impact of pain as well as lead to earlier recognition and treatment of depression.

While jitter is not a feature of speech detectable by ear and levels are usually low in healthy voices (Baken & Orlikoff, 2000), statistically significant difference in jitter was observed between the non-pain and pain groups at the second stand task with higher levels of jitter in the pain group at all tasks. Increases in jitter and shimmer that occur in aging may relate to this sample (Baken, 2005) and increased jitter and shimmer have been associated with restriction in vocal intensity (Brockmann et al., 2007). Although both groups were instructed and monitored to produce vowels at the same 60-65 dB level, only the pain group demonstrated the increased level of jitter although the groups did not differ in age. Significant difference in jitter was observed between the non-pain and pain groups at the second stand task. The lack of significant difference at first stand may result from low statistical power, an additive effect, or fatigue.

Shimmer and APQ are measures related to short-term perturbation in amplitude. While statistically significant differences between the non-pain and pain groups in shimmer and APQ were not stable to log transformation, shimmer and APQ demonstrated significant difference in the LIC and MIC when pain intensity was considered. Elevation of shimmer may have been influenced by restriction of intensity and (Brockmann et al., 2007). The MIC had the higher levels of shimmer and APQ when compared to the LIC making its presence as

an indicator of pain intensity important. Since these parameters are not normally observed, the appearance of significant and increased levels of shimmer and APQ in this small pain group is noteworthy.

The difference in formant frequencies between the non-pain and pain groups did not achieve significance. Although formants demonstrated increasing difference with the second movement tasks compared to the first movement tasks, the increasing difference in frequencies in later tasks may be more related to fatigue or mouth dryness, than emotional response. The production of five tokens of four seconds in length and the use of an open vowel may have reduced saliva production more than a change due to a change in emotion; thus, decreasing the opportunity to capture articulation differences predicted to influence formants because of emotion change.

Predictions of acoustic parameters associated with emotional states were provided to encourage testing of Scherer's sequential evaluation theory of emotion differentiation (K. Scherer, 1986, 2003) but predictions were based on persons who were not having pain. While the level of pain reported was limited to the low and moderate range, the movement tasks may not have increased pain intensity in pain subjects enough to influence  $F_0$ . Significant difference in acoustic parameters of range of  $F_0$  and jitter between pain and non-pain groups with the low effect size of the movement task and following log transformation was encouraging.

The impact of pain intensity differences on acoustic parameters was statistically significant with shimmer, APQ and  $F_2$ . However, because class sizes based on pain intensity were small and variances of the parameters were unequal, nonparametric statistical techniques were required with ranked data for comparison. Although a few subjects reported

severe levels of pain, the majority of this ambulatory and community-based sample reported mild and moderate levels of pain intensity.

Unlike findings using the non-pain and pain groups, parameters based on frequency (e.g., range of  $F_0$  and jitter) did not demonstrate significant difference between classes based on pain intensity. However, difference between the low intensity class (LIC) and moderate intensity class (MIC) was observed with parameters related to perturbation of amplitude (e.g., shimmer and APQ) and with  $F_2$  at the second seated task. Although the classes were statistically different with respect to pain intensity, weight and BMI were not different between classes as in non-pain and pain groups. The moderate intensity class demonstrated greater levels of shimmer and APQ across all the tasks. Shimmer and APQ are parameters not normally observed at the level seen in the LIC and MIC and were not observed in the non-pain group. Because the LIC had lower levels of shimmer and APQ across tasks and a different response to stand tasks from the MIC, these parameters have potential for differentiating changes in intensity of pain and significance observed in this small sample is encouraging.

Significant difference between the LIC and MIC was observed with  $F_2$  at the second seated task. Coincidentally, the second seated task was also the task demonstrating the largest difference in VAS-PI for the LIC and MIC. Significant difference was not observed in any other tasks' analyses of formant frequencies. A decrease in the frequencies used could be related to relaxation of vocal folds after the standing task, but the increase in  $F_2$  observed by the MIC is usually associated with increased sympathetic nervous system activity, unusual with a seated task expected to relieve pain. If Scherer's theory were applied, this increase could be related to ergotropic emotional reactions related to unpleasantness checks, i.e.,

anxiety or anger. Increased flexion of the knee joint when seated may have caused increased pain in the MIC women due to more joint involvement.

Examination of group differences in acoustic parameters with the relation of depression, anxiety, or anger provided further insight into the potential role of acoustic parameters in pain assessment since persons with pain may respond with these mood states or emotions. Recruitment of clinically depressed, anxious, or angry subjects was not feasible and experimental induction of mood or emotion was not within the focus of this study of the influence of a natural increase in chronic pain on acoustic parameters. However, the influence of these three psychological variables on acoustic parameters could be estimated using mixed models with the addition of an interaction statement. Although a combination of these psychological variables exists in every individual, the aim of this exploratory study was to determine if presence of an emotion would influence acoustic parameters with any selectivity.

Enduring moods were used as proxies for emotional states since these moods can be measured with validated instruments and have been used with chronic pain research. While moods measured by the psychological inventories are not emotions, level of mood can be indicative of the subject's enduring pattern of mood likely to influence behavioral responses to pain. Scherer predictions of acoustic parameters did not consider the presence of pain. Thus, when significant differences in acoustic parameters between the non-pain and pain group with these interactions occurred, the presence of chronic pain may contribute to the acoustic parameter differences.

Because predictions of the acoustic parameter changes come from the component process model of emotion, the moods measured were classified based on neuroendocrine

activation. While the emotion state of sadness/dejection is described as being driven by a predominance of parasympathetic nervous system input, or trophotropic arousal. Depression, a trophotropic mood, was reported with low but significantly different scores between the non-pain and pain groups. The low level of depression may contribute to the lack of acoustic difference observed between the groups when sadness/depression was considered.

The emotion states of anxiety/worry and irritation/cold anger were described by the model as being driven by a predominance of sympathetic nervous system input, or ergotropic arousal (K. Scherer, 1986). Since pulse rate difference was not observed when the effect of weight and BMI were considered, sympathetic activation cannot be assumed. Because sympathetic activation is a criterion of the emotional states of anxiety and anger in appraisal theory, these emotions were not experienced, but it is unclear what level of sympathetic activation is required for anxiety/worry or irritation/cold anger.

Acoustic parameters that had demonstrated significant findings in non-interaction models of the non-pain and pain groups were included in analyses that incorporated the mood-related inventory sample mean as an interaction term:  $F_{00}$ , range of  $F_0$ , jitter, and formant frequencies. The stringent requirement that significant findings in the log transformation model mirror significant findings in the non-interaction model was applied in order to accept an acoustic parameter as associated with a particular emotion. Insufficient power and low sample mean scores on the inventories may have contributed to the lack of significant difference at the same tasks observed in the non-interaction models.

### *Depression*

No acoustic parameters were found to match the significant differences seen in the reduced models after log transformation. Because depression literature has indicated

monotone and decreased pitch are characteristics of depression, report of parameters that continued to demonstrate significant difference after log transformation is included: Flo at second stand and  $F_3$  at second stand.

Fundamental frequency-related parameters did not demonstrate stability with the interaction of depression in this study, although research on depression (Alpert, 1983; Sobin & Alpert, 1999) found pitch to be lower with sadness and depression. Flo was expected to be different between the groups given the significant difference in BDI-II scores. The occurrence of significant difference in Flo only at the second stand could indicate latency of the response or an additive effect. Given the findings related to range of  $F_0$  with other emotions, Flo remains theoretically interesting with depression.

Formant frequencies were measured to indicate change in muscle tension of the vocal tract and facial musculature and change in saliva production resulting from emotional reaction to increased pain. While the presence of  $F_3$  at second stand with increased pain intensity is potentially important, all significant differences identified in reduced models, e.g.,  $F_1$  and  $F_2$  at second stand, did not survive log transformation.

Formant frequencies should not be discounted on the basis of these findings, however. In the emotional differentiation theory, the evaluation of unpleasantness, as when pain is anticipated or experienced, results in faucal (the section between the mouth and pharynx) and pharyngeal tension that reduces the space for air in the vocal tract and increases formant frequencies. Higher frequencies located in  $F_2$  and  $F_3$  would be expected as well as higher  $F_1$  mean. In contrast, relaxation of the vocal tract with the evaluation of pleasantness or with greater parasympathetic activation would increase space for air, reduce formant frequencies, and lower the  $F_1$  frequency. Thus, observation of the raising and lowering of



formant frequency provides information about physiological and emotional state through the effect of arousal (Johnstone, Van Reekum, & Scherer, 2001; K. Scherer, 1986). Given predictions based on unpleasantness, higher  $F_3$  observed in the non-pain group would indicate unpleasantness while the pain group lower  $F_3$  frequencies would indicate pleasantness. Because the non-pain and pain group demonstrated significantly different VAS-UNP scores with the pain group having higher unpleasantness scores at second stand, the lower  $F_3$  frequency for the pain group after log transformation would seem to contradict theoretical predictions. However, higher frequencies in the non-pain group could reflect unpleasantness related to the heat or fatigue while lower formant frequencies of the pain group could reflect the effect of the parasympathetic nervous system related to significantly different level of depression or the presence of moderate intensity chronic pain. The significance at the second stand could indicate that parasympathetic dominance suppressed acoustic parameter change and that an additive effect is needed to demonstrate a difference.

### *Anxiety*

Because the levels of anxiety reported by both groups on state and trait measurement of anxiety were lower than norms reported by Spielberger (1999), significant differences between the non-pain and pain groups in range of  $F_0$  and jitter when the interaction emotional state of anxiety/worry was introduced were unexpected. The low level of anxiety may be more characteristic of anxiety/worry as described by Scherer (1986) than fear as measured by the anxiety instrument. Although the STAI was completed in a strange, novel environment, state anxiety was not measured while wearing equipment used in the acoustics session. The need to perform vocal tasks and wear strange equipment may have evoked a

different state when the acoustic parameters were captured than the state measured earlier in the study session.

Although higher frequencies are associated with acute anxiety (Fuller, Horii, & Conner, 1992), the groups were not different with respect to state anxiety and higher frequencies were not expected. Range of  $F_0$  was predicted to increase with fear/terror, but no prediction was given for the state of anxiety/worry. Range of  $F_0$  decreased with the non-pain group despite the interaction and did not support the prediction. In contrast, the wider range of  $F_0$  with a low level of anxiety reported in the pain group supported the prediction and could suggest the increase in pain intensity not present in the non-pain group influenced this increase in range of  $F_0$  with standing or an evaluation check of goal/need obtrusiveness occurred to explain this disparate finding.

While jitter was predicted to occur with more intense emotions of fear/terror and rage/hot anger, jitter was observed with the pain group at the second stand task with both state and trait anxiety interactions following log transformation. This finding is important, though unexpected, given the low levels of anxiety. Because pain unpleasantness was highest for the pain group at the second stand task and pulse significantly different at the second anticipation task, difference in jitter could indicate (1) the additive effect of the movement and cognitive tasks or (2) the latency of the emotional reaction to chronic pain presence or some other physiological source associated with standing.

### *Anger*

Significant difference between non-pain and pain groups was observed when state and trait anger were included as interaction statements with range of  $F_0$  and jitter in a reduced model. Anger is demonstrated through sympathetic nervous system response to unexpected

and interference with goal achievement by an outside agent (K. Scherer, 1986). The levels of anger reported on the state and trait anger scales were lower than the norm reported for women (Spielberger, 1999) and irritation/cold anger emotional state was used for predictions of acoustic parameters changes. Effort to provide a pleasant environment that would highlight natural pain presence due to movement may have resulted in lower levels of state anger (or irritation) description for evaluation of feelings “right now” compared to trait anger or how subjects “generally feel.” Since anger expression is not socially appropriate for females in different cultures (Driscoll, Zinkivskay, Evans, & Campbell, 2006; Thomas, 2005), low state and trait anger scores may result from concern about self-presentation on the inventory.

Differences between the non-pain and pain groups in range of  $F_0$  at both stand tasks despite low levels of state and trait anger were stable to log transformation. Scherer’s (1986) predicted decrease in range of  $F_0$  as an indicator of irritation/cold anger was supported by the decrease in range of  $F_0$  in the non-pain group. However, the increase in range of  $F_0$  by the pain group with both stand tasks suggests the possible influence of another emotion’s presence. Specifically, the presence of chronic pain is suggested as another influence in this sample. The occurrence of significant difference between the groups in range of  $F_0$  at both stand tasks coincides with the occurrence of significance at both stand tasks when state and trait anxiety were considered.

Significant difference between non-pain and pain groups in the model of jitter with the interaction of state and trait anger was observed only at the second stand task, the same pattern observed with state and trait anxiety. Jitter is predicted to occur with rage/hot anger in the component process model (K. Scherer, 1986), but not with low levels of anger, or

irritation/cold anger, evidenced in this sample. Irritation/cold anger could be similar to the frustration that correlated with pain intensity in women reported by Riley et al. (2001) although the highest levels of pain intensity were not at the second stand were the highest levels of jitter occurred. Stability of jitter demonstrated at only the second stand task with the state and trait anger interaction may be indicative of the low state anger scores, an additive effect of movement, or latency of the effect of pain or other physiological mechanism. Although the presence of jitter in the non-pain group may be related to the low intensity restriction on vowel production, the occurrence of increased jitter with the pain group suggests that pain presence may have provided additional sympathetic activation that contributed to differences not predicted in Scherer's theory.

With respect to the influence of emotion on acoustic parameters, differences between non-pain and pain groups occurring with the interaction of mean state and trait anxiety scores and mean state and trait anger scores were observed with range of  $F_0$  at both standing tasks, mirroring the differences observed in the reduced models. Therefore, range of  $F_0$  is seen as an acoustic parameter potentially useful in indicating sympathetically-driven emotion and chronic pain presence. While the differences between non-pain and pain groups in jitter with the interaction of state and trait anxiety and state and trait anger were significant following log transformation at the second standing task, the differences did not mirror the significant differences at first and second standing task with the original model. However, jitter should be considered potentially important given its demonstrated stability to log transformation. However, limited sample size, the use of statistical techniques to evaluate the effect of mood, and the occurrence of confounders should be considered.

The relationship of written and verbal pain intensity ratings to disability was not strong and differed based on method of rating intensity. The verbal rating of pain correlated more highly with the observed disability measure than the written pain intensity measure. The written pain unpleasantness scale demonstrated a weak correlation with observed disability. The SOPA disability scale and BPI pain interference scale that incorporate psychosocial aspects of chronic pain demonstrated stronger correlation with observed disability than pain intensity and unpleasantness measures suggesting that pain should not be considered a complete determinant of functional disability.

Ratings of pain intensity at seated and stand tasks within each group did not differ across time indicating that repeated measurement did not alter within group findings. The occurrence of written pain intensity ratings by the non-pain group was unexpected since subjects were recruited as having no musculoskeletal pain and non-pain group VRP ratings were zero. Differences in responses on the VAS-PI and VRP by the pain group were also noted with VRP mean ratings higher than the mean VAS-PI ratings.

Although it seemed logical to assume that disability associated with knee pain would be related to the pain experienced, that assumption is not borne out by the results of this study. While it cannot be assumed that the non-pain group was not limited in some way given the occurrence of VAS-PI ratings, the non-pain group provided the measure of “normal” ability to rise from seated to standing for this study. The non-pain group effectively demonstrated limitations of the pain group. While the non-pain group’s time to rise from sitting to standing ranged from 3 to 10 seconds, the pain group required from 2 to 31 seconds. To further clarify the relationship of observed disability and pain intensity, the pain group was divided by pain intensity. The lower intensity pain class (LIC) required from 3 to 16 seconds to rise from sit-

to-stand, while the moderate intensity class (MIC) required from 2 to 31 seconds. The LIC demonstrated greater observed disability than the non-pain group along with low intensity pain reports. Greater observed disability was present in the MIC although there were subjects demonstrating low observed disability scores with moderate reports of pain. While the subjects were required to be mobile in order to participate in this study, this sample of community-living women over 45 years of age demonstrated obvious mobility problems despite the low to moderate reports of pain intensity.

Timing of highest pain intensity ratings of the non-pain group and pain group as well as the lower intensity and moderate intensity classes demonstrated interesting differences. The non-pain group's VAS-PI mean score was highest at the second stand task and could be associated with movement. In contrast, the pain group reported its highest VAS-PI mean score at the first seated task and this task demonstrated the largest difference in VAS-PI between the non-pain and pain groups. While the first seated mean score was not associated with the sit-to-stand movement tasks, the rating followed travel from the BBL to the acoustic testing room and equipment acclimation. Not surprisingly, the largest difference in non-pain and pain group VAS-PI mean scores was at this first seated task and suggests that this task presented greater difficulty for pain group subjects. The largest difference between LIC and MIC occurred with the second seated task when the MIC reported its highest intensity pain. Seated position, not standing, as a source of greater pain intensity was unexpected.

Despite the VAS-PI differences at seated tasks, the difference in VRP between the non-pain and pain group was greatest at the first stand task. While the highest VRP ratings of the MIC occurred at the first seated task, the highest LIC mean VRP ratings occurred at first stand. Because the LIC composed the larger portion of the pain group, the LIC's influence on

the VRP at the first stand could explain the difference. It should be noted that when standing, many subjects shifted weight from one leg to the other, apparently to relieve pressure or pain on the affected knee(s).

Multiplication of the VRP by would be expected to have an equivalent VAS-PI rating since both are measures of pain intensity. However, VRP ratings were higher than VAS-PI scores in all groups except the MIC. Difference in the VAS-PI ratings compared to a numerical rating scale has been reported in acute pain (Holdgate, Asha, Craig, & Thompson, 2003) and this difference may address pragmatic factors of social interaction that occur when seeking pain relief from another person.

The level of pain unpleasantness, a written measure of emotional response to pain was thought to play a role in disability and VAS-UNP ratings were scrutinized more carefully. Consideration of the difference between intensity and “bother” when marking the scales took very little time with this sample. During the study, subjects tended to mark the VAS-UNP at the same point they marked the VAS-PI. The non-pain group VAS-UNP ratings demonstrated this tendency with mean ratings on the scales differing by about 0.1 mm across tasks. The largest VAS-UNP scores in the pain group occurred at second stand although the highest VAS-PI occurred at the first seated task. This finding of greater unpleasantness at second stand as well as the stability of range of F0 and jitter at the second stand supports the Rainville et al. (2004; 2005) observation that unpleasantness predicted changes in arousal and dominance. The ratings were not the same for pain unpleasantness as for pain intensity in the pain group as they were in the non-pain group indicating that subjects with pain may differentiate intensity and unpleasantness better than those reporting no pain.

When the LIC and MIC mean ratings of pain intensity and pain unpleasantness were examined, patterns were somewhat different. The classes' largest difference in VAS-PI occurred with the second seated task while the greatest difference between the classes with VAS-UNP occurred with the first seated task. Movement to standing increased pain intensity and unpleasantness for the LIC subjects but seated position increased pain intensity and unpleasantness for the MIC subjects. In addition, appraisal of the stimulus for some subjects appears to have been insufficient to generate a physiological response. Some pain group subjects noted stiffness in the knees improved with walking to the acoustics testing room and several commented that climbing stairs would have increased pain more than rising from sitting position.

Self-efficacy was considered as a possible contributor to the difference in VAS-PI and VAS-UNP. The pain group self-efficacy for physical function scores were lower than the non-pain group. When the LIC and MIC self efficacy scores were reviewed, LIC self-efficacy for physical function was more similar to those in the non-pain group than the MIC, indicating that self-efficacy for physical function might play a role in the LIC pain intensity and pain unpleasantness ratings.

The pain group reported pain interference with everyday activities on the BPI pain interference scale. The degree to which pain interfered was more evident when the LIC and MIC pain interference scales scores were compared. Although 7 of the 20 LIC members had pain interference scores greater than 20, only 3 of the 10 MIC members had pain interference scores less than 20, with 6 having scores greater than 35. Because the original BPI pain interference scale was used, subjects were reporting mood, function and activities. The BPI



pain interference scale demonstrated higher correlation with the VRP than the VAS-PI or the VAS-UNP.

Disability reported on the SOPA scale was greater for the pain group in comparison to the non-pain group. The MIC reported a significantly greater amount of disability on the SOPA than the LIC. Because the SOPA scale was designed to measure beliefs about pain, this finding provides a link between pain ratings and disability that incorporates the individual's perceptions about or reaction to pain's effect on activity.

The weak correlation of the pain intensity scales with observed disability indicated that although pain contributes to disability, pain may not be contributing as much to observed or self-evaluated disability as expected. The higher correlation of the VRP rating than the VAS-PI with observed disability is interesting given that the VRP and VAS-PI did not appear to measure the same construct in the LIC as in the MIC. Higher VRP correlations with self-evaluations of disability than the correlation with the VAS-PI demonstrate that the two pain intensity scales tapped different aspects of pain experience in this sample.

In contrast to the relationship of the pain intensity measures with disability, the VAS-PI and VRP correlated negatively with the ASES Self Efficacy for Physical Function scale but at nearly the same level. Confidence that one can perform an activity might provide a better self-evaluation measure when function is the area of interest.

The current study did not use the modified BPI and its revised procedure for scoring pain interference and severity with chronic pain samples (Mendoza et al., 2006). However, the findings of this study would support the new pain interference scale and its recognition of the need to separate pain, mood, and activity factors in the scale.

Findings indicate that pain intensity ratings did not have a strong relationship with observed disability. While correlated to disability, pain intensity and unpleasantness ratings do not explain the level of disability observed. Further, pain intensity measures used in this study, the VAS-PI and VRP, may not communicate the same characteristics of pain intensity given the difference in ratings of the persons with different intensity pain. Verbal communication of pain appears to involve social and pragmatic issues different from the cognitive skills used with written communication of pain. Because verbal and written communication of pain vary and may not be possible in some clinical situations, additional assessments beyond the VAS-PI and VRP are necessary to determine the impact of chronic pain on the individual and level of function.

### Strengths and Limitations

While the bulk of emotion research has measured facial expression and is now more focused on brain imaging, voice provides an important source of information readily available to nurses and other health care providers that is under-utilized and has been understudied. Although vocal signaling of infants experiencing acute pain has been measured by researchers in order to remove the cognitive influence of culture and learning, chronic pain experience is strongly influenced by culture and learning. Study of emotional response to pain, therefore, needs to study signaling of adults in order to appreciate the difference in the acute and chronic pain phenomena. Since adults comprise the largest chronic pain population, this study's focus on voice quality in an adult sample with a common chronic pain disorder addressed a gap in the literature on communication of pain.

The study was among the first to incorporate study of voice quality in pain expression with adults and one of a few studies to include movement with acoustic measurement. Because movement is an important part of function and function has become a criterion for successful pain management, the ability to identify the effect of pain on movement is important in maintaining and promoting physical activity. The aims of this study required the development of an innovative measurement method designed to capture of the emotional change in voice that occurs in reaction to an increase in chronic pain with movement. Problems were discovered in the use of the movement task; however, preliminary results indicate that acoustic parameters may describe differences in non-pain and pain subjects and different pain intensities.

The use of the CSL and MDVP programs provided strength to the study. The equipment coupled with the recommended microphone allowed capture of data and analysis of a variety of parameters important to demonstration of this method's feasibility. Early pilot testing indicated the need for more environmental control of noise interference and the use of the head-mounted microphone with its close-to-mouth proximity reduced low level room interference. While such environmental control is not possible in clinical settings, in this early stage of method development, this control was necessary.

Strength of this exploratory study and quasi-experimental design was provided by use of a pain group and non-pain, comparison group. Subjects were of the same sex, similar age and spoke English. Comparison of the acoustic parameters was free of the variation that could occur with age, sex, and language differences. Subjects came from a variety of ethnic backgrounds and provided a level of heterogeneity important in an exploratory study. The

non-pain group acoustic parameters allowed comparison with acoustic parameters predicted to change with emotions.

Because the study intended to capture natural emotional reaction to pain, strength of this study was provided by the recruitment of subjects who were not actors. Emotion studies that have relied on emotion portrayal have found the emotional reaction captured using actors is of larger effect size than natural emotion observed in everyday settings (Bänziger & Scherer, 2005). By using non-actors, it was expected that the effect size would be small, but more representative of the natural presentation of pain.

Limitations of the study are related to sample size. Use of additional methods of recruitment such as the following could be more productive than flyers: advertisement in local papers and on buses, inclusion on the University clinical trial web announcements, and attendance at more community agency functions. Because the equipment selected for acoustical and physiological data collection was not easily transportable and sound attenuation was important, subjects were required to travel to the testing site. This requirement influenced recruitment. The location of the testing site and the times for testing may have limited participation of women with more significant limitation of ambulation although some women used assistive devices.

Telephone recruitment screening was limited to subject report of health problems. Although exclusion criteria were numerous, exclusion of pain clinic patients and persons treated for psychopathology was omitted. The influence of subjects who reported pain clinic treatment and/or treatment for depression after enrollment was observed in analyses of depression and pain intensity. Influence of this data was reduced by deletion of an

observation when outlier status was established, but the remaining subject data were retained for subsequent analyses.

The variance in the sample weight and BMI, small sample size, and the averaging of pulse rate limited the measurement of change due to emotional arousal. The differences observed in this sample provide an avenue of research related to the relation of cardiovascular response to movement and chronic pain. Because a significant change in jitter with a standing task could indicate a link to heart rate and exertion related to body size, use of jitter as a potential indicator of change in reaction to pain requires clarification of the effect of heart rate and body size on acoustics with standing. Small sample size and variance limited the use of parametric statistics that would have provided a more definitive answer to questions related to pulse rate and movement

The study was limited to study of middle-aged and older females. Therefore, results cannot be generalized to different age groups of females or males. Subjects were usually residents of the university community in southeastern United States and generalization to a broader population is not possible. While heterogeneity was desired, the presence of various regional dialects resulted in inability to use connected speech samples due to the use of /e/ or /eɪ/ instead of /ə/.

The range of pain intensity was limited in this study. Although the intent of the study was to use multiple levels of the chronic knee pain intensity present in community-living women as the stimulus, travel to the study site may have limited recruitment to women who were willing and able to leave home for participation in research.

Inclusion of the second movement task to address acclimation to equipment may have introduced a limitation. While elimination of one task's data could have simplified data analysis, use of both sit-to-stand tasks and the occurrence of missing data required use of longitudinal analyses that were more complex than the repeated measures ANOVA originally planned. The decision to retain data that could have been eliminated if ANOVA methods were used required use of mixed model strategies. The mixed models were limited to fixed effects for this study. Other mixed model techniques could have provided greater information and could be employed with later analyses. Variance of the sample was statistically challenging, but provided useful information for future sample selection and exclusion criteria.

#### Implications for Future Research

The method requires further refinement and testing. In order for that to occur with pain samples, more precise measurement of moment-to-moment changes in physiological and emotional, or feeling, state will need to be included in future studies. Increase in pulse with anticipation of standing by the pain group warrants further attention. The difference in pulse increase may indicate an involuntary signal of the emotional or cognitive preparation for what is perceived by the individual with arthritis as a stressful task, but normal activity for the rest of the population. The significant difference in group weight and BMI and their effect on the heart rate and acoustics should be controlled in future studies. Because movement is often reduced with chronic pain, inclusion of movement tasks in this method seemed important. The physiological and anatomical changes that occur with movement and speech require more careful study with non-pain subjects. Once the timing of the change in

heart rate and acoustic changes are better understood in normal subjects, movement studies that compare non-pain and pain subjects matched by BMI would more clearly define this phenomenon.

While this study focused on the sit-to-stand task as a means of inducing a change in pain intensity, the onset and frequency of a weight-shifting strategy from one leg to the other seemed to be an immediate and unconscious action by pain group subjects that may provide an indicator of disease progression or an indirect measure of pain. Studies that collect radiological findings along with the observation of the unconscious weight-shifting behavior would be important to determining how the observed behavior is related to the degree of joint involvement.

Because within group differences in this sample in pulse did not change over time, future studies may be able to eliminate the repetition of the sit-to-stand task when assessing emotional response to movement. This change could be advantageous in terms of reduced subject burden and less complex statistical analyses. Devising movement tasks that increase pain intensity would increase the effect size and promote capture of changes that occur with appraisal.

Increasing vocal intensity of subjects during collection of tokens could clarify the occurrence of jitter, shimmer, and APQ observed in this sample and age group. Readjustment of the microphone head placement and the analysis program intensity settings will be necessary. Although not measured in this study, individual differences like thickness of musculature, missing teeth or dentures, and nasal congestion, for example, could also cause changes in formants from person to person.

Although differences in the low and moderate intensity pain classes was observed with acoustic parameters, samples with higher intensity pain should be recruited from clinical settings to. While study of subjects in their natural settings would provide more natural data, transport of acoustic equipment to homes would be expensive, if not impossible, and sound attenuation could not be controlled.

Instruments used to assess pain compared well with each other, but appear to capture different aspects of the pain response when compared with other instruments. Careful instruction of subjects on the completion of the VAS scale is vital to its use and interpretation, especially with non-pain subjects. Alternatives to paper and pencil methods of collecting VAS information are recommended with a movement task that includes other equipment or sensors that interfere with writing ability. While the difference observed between written and verbal pain intensity self-report is not new, understanding of the differences observed between verbal and written pain intensity ratings in clinical settings continues to be important to assessment and management of pain.

Subjects' ratings were often higher on the VRP than the VAS-PI. The difference between written and verbal ratings raises questions about influence of self-presentation and pragmatism on verbal report. Study of the patient-preferred pain management strategy and the written and verbal pain intensity rating could demonstrate the place of pragmatics and negotiation in clinical settings more fully.

The difference in the association of the VAS-PI and VRP to disability measures is of special concern. Because observed disability was not strongly correlated with pain intensity, provider judgments about disability used as an indicator of pain intensity in acute and chronic conditions may erroneous. Healthcare providers may need to consider multiple factors in



chronic pain assessment: observe movement tasks, self-report of pain, self-report of level of function. Use of additional methods of assessment of pain and disability are needed to identify and address needs of persons with pain and chronic conditions.

Findings of this study can provide direction for future studies of acoustics and pain by demonstrating those acoustic parameters that have potential value, strategies that confound or contribute to better studies, and information on aging voice. While range of  $F_0$  may not be easily perceived by ear in a short utterance, the possibility that attentive caregiver could detect this change in a patient provides potential for further study. Because jitter is not detected by ear, its use would require use of specialized equipment by caregivers. It would be premature to say that acoustic parameters are able to capture the emotional aspect of chronic pain. However, differences observed in range and jitter associated with the stand tasks warrant further investigation. A larger sample, more stringent controls, and refinement of recording protocol would lead to clearer specification of elements of voice quality involved in pain expression.

Future studies of acoustic parameters of males and persons with different chronic pain conditions would be important to compare changes thought to be due to pain experience. Because gender-specific differences have been demonstrated with pain and voice, it is expected that differences in male and female acoustic responses to pain may differ. Once parameters can be established with verbal and cognitively stable persons, use of acoustic parameters with cognitively impaired or unconscious individuals is seen as a method of more accurately assessing pain in these groups.

Provider-patient interaction models have been developed (Cox, 1986; Hadjistavropoulos & Craig, 2002) and have addressed content about what is literally said in

words. While words carry information and are easily captured and transcribed, *how* the words are said communicates meaning. Nursing intervention relies on accurate interpretation of communication that includes emotion expression. Being alert to change in vocalization provides a means of assessing change and reduces intuition or chance from chronic pain management.

### Conclusions

Of several acoustic parameters investigated, significant difference in range of fundamental frequency, jitter, shimmer, and amplitude perturbation quotient were associated with movement tasks that increased knee pain in women with chronic knee pain. While it is not clear why subjects with pain demonstrate these parameters with standing, this association was significant in a small sample. Statistical influence of measures of depression, anger, and anxiety through mixed model interaction has been shown to affect acoustical parameters involved in emotion expression that supports some predictions of the component process model of emotion.

## APPENDICES

## Appendix 1. Preliminary Work

In preparation for this investigation, a course project in sociolinguistics introduced acoustic analysis. Later, a course in linguistic phonetics introduced the techniques involved in phonetic analysis. Course activities included a small research project involving recruitment and voice sample collection that prompted plans for this investigation with assistance of the UNC School of Nursing, Biobehavioral Laboratory (BBL). The aim of the preliminary work was to determine if an adequate signal could be obtained with currently available equipment and to develop the study protocol.

#### Room Noise

Preliminary data collection indicated room noise levels could be interfering with the capture of a clean signal with the Sony Vaio notebook computer (PCG-GRX 500P Pentium 4) with Creative Labs soundcard and Praat software (Boersma & Weenink, 2004). This computer was used to record voice and collect physiological measures, heart rate and  $spO_2$ , from the Ohmeda pulse oximeter (Datex-Ohmeda, 1998) using a Dataq analog-to-digital converter (Dataq Instruments Inc., 2005).

Frequency-weighted sound level measurements are based on the threshold of hearing, or 0.0dB, and would correspond to an anechoic chamber. The A scale, the most commonly used weighting, uses a set of filters to adjust the component frequencies to approximate the contribution the frequencies make to the perception of loudness via the human ear (Baken & Orlikoff, 2000). Room sound levels were measured with a RadioShack digital sound level

meter (RadioShack Corporation, 2000) in the BBL and environmental noise ranges from 54-61 dB A-weighting in the BBL as well as other areas in the new addition to the building when measured at the level of the microphone and chair location. Attempt to minimize turbulence by covering the vent screen over the duct did not reduce the noise appreciably. Although a sound-attenuated chamber is located on campus in Dey Hall, it is located some distance from parking making it difficult for participants to find and involves considerable walking. Recording for analysis in this chamber requires turning off the lights and fan which would make videotaping impossible, and these conditions would likely interfere with participant comfort and feeling of security.

In order to search for quieter surroundings, a sound level meter capable of measuring sound below 50dB, the lowest level the RadioShack meter, was needed. Dr. Joseph Hall, of the Audiology Department, UNC School of Medicine, subsequently measured sound pressure levels (SPLs) in various rooms being considered. A Larson-Davis 800B sound level meter with a Model 2559 ½ inch random incidence microphone and Model 826B preamplifier (Larson Davis, 1994) was used to determine A-weightings (Table 1).

Because Room 310 B in the School of Nursing, with 28 dB of room noise, was much quieter and could be reserved for use in the late afternoon and evening, it was determined that it would be an optimal environment for voice recording. However, using this room required participants to walk the length of the hall to the elevator, ride to third floor via elevator, and make a similar return trip when the subject's acoustic studies were completed. Activity tolerance was monitored by observing the subject's respirations while walking and

Table 1.

Sound Level in Potential Recording Sites

Room	Sound Level (A weighting) in dB
BBL	44
BBL, Room 16	44
BBL, Room 17	46
Room 310 B	28
Room 310 C	27
Room 3	39

measuring vital signs after she reached the testing room.

#### Soundcard and Notebook Noise

Because the effect size was anticipated to be small (0.34) in the proposed study, effort to reduce error due to noise was important. In addition to room noise, the noise introduced by the sound card housed in the laptop could interfere with recording quality (Deliyski, Evans et al., 2005). Since specifications for the computer's soundcard were not available, a Creative Labs Sound Blaster Audigy 2 notebook soundcard (Creative Labs, 2005) for the Sony Vaio laptop was purchased. This soundcard allowed 8, 16, and 24-bit analog-to-digital conversion during recording and sampling rates ranged from 11.025 to 96 kHz.

Recent research indicated that notebook computer soundcard, fan noise, and environmental noise introduce measurement error that can be remedied by use of specific

microphone and vocal analysis systems (Deliyski, Evans et al., 2005; Titze & Winholtz, 1993) . Research on voice quality and clinical measurement of non-dysphonic and aging voice have also reported data using the Computer Sound Laboratory and the Multi Dimensional Voice Program by Kay Elemetrics (now KayPENTAX) (Bhuta et al., 2004; Xue & Hao, 2003; Yiu, L., Longland, & Mitchell, 2000) so the CSL 4500 and Multi-Dimensional Voice Program (MDVP) software was viewed as another, more expensive, means of reducing internal noise and obtaining comparable results for the current research..

Consultation with Dr. Ditimar Deliyski at the University of South Carolina, Columbia obtained advice to further improve the sound issues in the study. To overcome the 60 dB environmental noise, samples would need to have an intensity 30-40 dB greater than the room noise (Deliyski, Shaw et al., 2005). However, this advice raised concern that the older age women would not be able to sustain the intensity needed for 5 seconds. Addition of an Auto-Buddy preamplifier by M-Audio (M-Audio, 2005) was suggested as an inexpensive addition to complement the microphone and amplify the signal. This preamplifier has a frequency response of 5Hz-50 kHz that includes range of normal voice and maximum microphone gain of 60 dB (M-Audio, 2005). After addition of the preamplifier, signal improvement was observed when the preamplifier gain was set at approximately 6 dB and a surge protection device was used.



## Recording and Analysis Software

Praat v. 4.3.12, a vocal analysis program (Boersma & Weenink, 2004), was becoming more popular in linguistic education, cited in linguistic research, but little use has been reported in clinical research. Praat was used for recording among volunteers in the feasibility study. The program had the advantage of being available at no cost and it is frequently updated to provide new and more precise features. The program also has the capability of providing acoustic parameters like pitch, intensity, formants and spectrograph information. Availability of a program, Vowel Data Capture (Kendall, 2003), that provided vowel information –  $F_0$ ,  $F_1$ ,  $F_2$ ,  $F_3$ , and duration – would reduce error and investigator influence when hand scaling to determine parameters from the midpoint of the vowel selection and provided the means to transfer data to text files used in data analysis programs.

Because an intensity of 60-65 dB is needed to compensate for the noise interference, monitoring of intensity was important. While Praat software is easy to use to detect intensity of the speech sample, it required 5-10 seconds for each sample (with three vowels in each sample). It was difficult to evaluate intensity with Praat to insure the adequacy of intensity, return to the recording window, and provide suggestions to the participant prior to the next data collection in a period of one minute. Because adequacy of the vowel production is important to analyses, it is important to insure intensity of the tokens, but increased time spent could interfere in capturing the acoustic changes desired.

Although problems were encountered in recording with Praat, the program's algorithms were available and measurements provided an additional means for comparison with other research with non-clinical samples. Since data saved as .wav files can be reanalyzed, there is the possibility of re-analysis with Praat

## Disability Measure and Camcorder Placement

Because access to radiographic information and physician diagnoses was not planned, an estimate of disease involvement based on mobility was needed. Specifically, in this study time to rise from a seated position was been suggested as an indicator of restricted mobility due to osteoarthritis of the knee and hip. While it was understood that this measure was subject to a number of causes, it provided a comparison measure across the participants in the sample.

Coding of the position change was planned to start from the time the participant's back moved away from the chair back, but that angle could be obtained with one camera. During testing, it was observed that four of five persons placed their hands on the armrests before moving forward in the chair. One subject who had recently had knee surgery placed hands and arms on the armrests to lift herself forward in the chair. Given these results, coding was planned to consider the possibility that several movements are possible starting points like shift of gaze, replanting of feet in front of chair, leaning over the knees. Stand was also evaluated and an upright position with back straight, weight on both legs, and hands at sides was determined to be the ending position. Because time-stamping is included on the videotape, duration of the movement changes can be determined to the nearest hundredth second. Use of the Observer XT program (Noldus Information Technology, 2007) to code and obtain frame-by-frame advancement of the video recording was also added to obtain more fine-grained assessment of the time of start to stand and completed stand. The Observer XT time format was not compatible with the Excel spreadsheet and SAS 9.1.3 so time to convert to compatible data was required.

## Written Instruments

Written instruments were administered to volunteers between 45 and 85 years of age to determine the time needed for testing. During this time, Multidimensional Pain Inventory (MPI)(Kerns, Turk, & Rudy, 1985) and Biobehavioral Pain Profile (Dalton, Feuerstein, Carlson, & Roghman, 1994) were also administered. It was subsequently decided that the Brief Pain Inventory (Cleeland, 1991a) and the Survey of Pain Attitudes-35 Items (SOPA-35)(Jensen & Karoly, 1989; Jensen et al., 2000) provided a more consistent response format with the Beck Depression Inventory-II(Beck et al., 1996), Arthritis Self-Efficacy Scale (Lorig, Chastain, Ung, Shoor, & Holman, 1998), Spielberger State-Trait Anxiety Inventory (STAI)(Spielberger, 1983), and the Spielberger State-Trait Anger Expression Inventory (STAXI). The BPI also includes a pain interference measure, and is reported to require slightly less time to complete than the MPI. Since the BPI and SOPA-35 have established reliabilities (Jensen et al., 2000; Keller et al., 2004; Tan, Jensen, Thornby, & Shanti, 2004) and have been used in chronic pain research for some time, the change reduced the need for participants to learn many formats and provide more reliable data.

## Participant Sample for Preliminary Study

A study of normal participants was performed to determine implementation and analysis issues that could influence outcome. Data obtained with this convenience sample will not be used in the analysis or included for publication.

Heterogeneity in sample selection for the feasibility study was important to determine problems with equipment, instruments, and protocol. Because the age of onset of osteoarthritis pain symptoms is around 40-50 years of age and voice changes occur with aging (Linville & Fisher, 1985; Xue & Hao, 2003), recruitment of participants that provide

comparable ages and different pitch ranges was important. Since chronic pain's effect on acoustic parameters of voice has not been reported, recruitment of participants who have chronic pain due to osteoarthritis or other conditions affecting the knee was important to evaluating instrument sensitivity to change of position from non-weight-bearing sitting position to full weight-bearing position standing.

Racial and ethnic diversity was important since African Americans have greater incidence of osteoarthritis than White Non-Hispanic, Hispanic, and Asian ethnic groups (Elliott et al., 2007; Sowers, Lachance, Hochberg, & Jamadar, 2000; Wright, Riggs, Lisse, & Chen, 2008) and willingness to express pain varies in cultures (Mechanic, 1976). This need for diversity prompted a visit to recruit at a senior center with a large number of black attendees. Educational level has been reported to influence scores on some instruments (Brandt, Spencer, & Folstein, 1988; de Jager, Budge, & Clarke, 2003; Tombaugh & McIntyre, 1992). Inclusion of participants with no high school, high school, and college level experience is important and data on educational level was obtained in order to define the groups' level of education for comparison. Evaluation of independence in ambulation included subjects' use of canes, crutches, walkers, and wheelchairs. Inclusion of persons who use such assistive devices could demonstrate problems in the use of heart rate monitoring equipment, the head-mounted microphone, and method to time the transition from sitting to standing position.

In order to obtain reasonable estimates of the time necessary to complete instruments, acclimate to equipment, as well as to refine the protocol, the convenience sample criteria included women who:

Had osteoarthritis of the knee or similar orthopedic problem of the knee to judge time needed to rise to standing and standing tolerance.

Were over 65 years to provide estimates of time to complete instruments.

Had pitch differences to provide testing of recording and analysis equipment.

Could critique the process and voice the participant's perspective.

Wore glasses to use with head-mounted microphone.

Had a hearing aid to use with head-mounted microphone.

Were able to read and write English.

Were willing to complete telephone interview.

Were willing to complete instruments.

Were able to come to the BBL

Had no cardiovascular or respiratory conditions limiting breathing with activity.

Were independent in ambulation and standing- with assistive devices, when necessary.

Were able to use hands to complete instruments.

Four female volunteers and one male volunteer were recruited to practice the protocol and troubleshoot equipment, instrument, and environmental issues. Because the age and educational level of participants used in the vocal analysis protocol were unlike the older, community sample anticipated, two female volunteers from a community, both over 70 years of age, completed the battery of written instruments.

### Summary of Preliminary Work

As mentioned earlier, change of written instruments was thought to provide more continuity for participants in terms of response formats. Subsequent retesting with volunteers

confirmed that the time needed was somewhat less and new instrument formats did not cause confusion.

The trial of the protocol uncovered problems associated with the complexity of the system, i.e., lack of event marks during the movement and expression tasks, calibration of the heart rate data, and consistent signaling method for participant vocalization. While these findings were important to the protocol, limited data was collected that could be compared. Since most of the protocol practice used a male voice, that data was not able to be compared to female volunteers.

Given the number of possible areas of error introduced by environmental noise, soundcard and laptop noise, and the problems associated with intensity evaluation, purchase of the Computerized Speech Laboratory and MDVP software used in research (Carson et al., 2003; Childers, 1997; Nicastrì et al., 2004; Yiu et al., 2000) was arranged. The advantage of determining intensity while recording as well as the demonstrated performance of the system (Deliyski, Evans et al., 2005; Deliyski, Shaw et al., 2005) made this system's acquisition important to the reliability of the study.

Changes in the protocol were made in response to observations during the trials. Heart rate did increase with the change in position as well as in response to vocalization and emotional reaction. Event marks on the physiological data needed to be indicative of those events important to study hypotheses. Change of position, pain presence, and reaction to pain were considered to be important. After trials had begun, it became apparent that reaction to the change of position caused a change in heart rate that could confound measurement of arousal in response to pain. Event mark prior to the time of the command to stand was planned to be the time indicator. When the event mark was not recorded, the sound of the

event mark on the video was used as an indicator of timing for the pulse oximetry file and three second interval could then be evaluated for mean pulse rate. It was anticipated that arousal would occur with the anticipation of standing in persons who experience pain consistently on standing and this physiological change would indicate emotional arousal. Increase in heart rate immediately following the command rather than after standing seemed theoretically sound given the appraisal and arousal literature. While a pulse increase after standing would have relevance to cardiovascular status, an increase while still seated would not be prompted by the same cardiovascular demand, but more likely due to a sympathetic nervous system stress response.

## Appendix 2. Institutional Review Board Approvals






THE UNIVERSITY  
of NORTH CAROLINA  
at CHAPEL HILL

OFFICE OF HUMAN RESEARCH ETHICS

TO: Susan Rasmussen  
School of Nursing  
CB: 7460

FROM: Public Health-Nursing 

APPROVAL DATE: 11/08/2006

EXPIRATION DATE OF APPROVAL: 11/07/2007

RE: Notice of IRB Approval by Expedited Review

Submission Type: Initial

Expedited Category:

Study #: 06-0504

Study Title: Acoustic Parameters of Emotion Expression of Women with Chronic Knee Pain

Study Description:

The purpose of this study is to determine whether acoustic parameters of vocalizations associated with chronic pain induction are related to change in pain intensity and/or indicate the type of emotional reaction to chronic pain. Study participants will include one group of 40 women 45 years of age and older with knee pain of 6 months duration or more and a control group of 40 women 45 years of age and older with no musculoskeletal pain. Study procedures will include demographic and baseline physiological data and psychological inventories prior to the collection of voice samples. Voice samples will be taken at four time points: two times while seated, and two times while standing. Samples will consist of saying vowel [a] for 3.75 seconds, saying the words "heed-head-hid-had" and stating numerical rating of pain. Written ratings of pain intensity, pain unpleasantness, and emotion presence will also be obtained at baseline, after psychological testing, and the four voice sample time points. Heart rate and oxygen saturation via pulse oximetry will be monitored throughout the voice sampling.

Confidentiality and privacy measures are in place. Written consent will be obtained from each individual. Documentation of education in human research ethics is provided. The risk is no more than minimal. This study is approved by expedited review per category 4, 6, and 7.

This submission has been approved by the above IRB for the period indicated.

Federal regulations require that all research be reviewed at least annually. It is the Principal Investigator's responsibility to submit for renewal and obtain approval before the expiration date. You may not continue any research activity beyond the expiration date without IRB approval. Failure to receive approval for continuation before the expiration date will result in automatic termination of the approval for this study on the expiration date.

This study was reviewed in accordance with federal regulations governing human subjects research, including those found at 45 CFR 46 (Common Rule), 45 CFR 164 (HIPAA), and 21 CFR 50 & 56 (FDA), where applicable.

CC: Jo Ann Dalton, School of Nursing, , Faculty Advisor




UNIVERSITY OF NORTH CAROLINA  
AT CHAPEL HILL  
CHapel Hill, NC 27599-4105

OFFICE OF HUMAN RESEARCH ETHICS  
Medical School Building 52  
Mason Farm Road  
CB #7097  
Chapel Hill, NC 27599-4105  
(919) 966-3113  
Web site: [ohre.unc.edu](http://ohre.unc.edu)  
<https://myresearch.unc.edu> for IRB status  
Federalwide Assurance (FWA) #4801

**TO:** Susan Rasmussen  
School Of Nursing  
CB: 7460

**FROM:** Public Health-Nursing IRB

  
Authorized signature on behalf of IRB

**APPROVAL DATE:** 10/30/2007

**EXPIRATION DATE OF APPROVAL:** 10/28/2008

**RE:** Notice of IRB Approval by Expedited Review (under 45 CFR 46.110)

**SUBMISSION TYPE:** Renewal

**EXPEDITED CATEGORY:** 6.Voice/image research recordings,7.Surveys/interviews/focus groups,4.Noninvasive clinical data

**STUDY #:** 06-0504

**STUDY TITLE:** Acoustic Parameters of Emotion Expression of Women with Chronic Knee Pain

This submission has been approved by the above IRB for the period indicated. It has been determined that the risk involved in this research is no more than minimal.

**Study Description:**

The purpose of this study is to determine whether acoustic parameters of vocalizations associated with chronic pain induction are related to change in pain intensity and/or indicate the type of emotional reaction to chronic pain. Study participants will include one group of 40 women 45 years of age and older with knee pain of 6 months duration or more and a control group of 40 women 45 years of age and older with no musculoskeletal pain. Study procedures will include demographic and baseline physiological data and psychological inventories prior to the collection of voice samples. Voice samples will be taken at four time points: two times while seated, and two times while standing. Samples will consist of saying vowel [a] for 3.75 seconds, saying the words "heed-head-hid-had" and stating numerical rating of pain. Written ratings of pain intensity, pain unpleasantness, and emotion presence will also be obtained at baseline, after psychological testing, and the four voice sample time points. Heart rate and oxygen saturation via pulse oximetry will be monitored throughout the voice sampling.

**Submission Description:**

This renewal includes an amendment, dated 10/10/2007, to make minor changes to the study. Removing the availability of the Bell Tower parking lot and replacing with more available parking after 5pm. Removing the use of the Tripp Lite Model 1B2-0 Isoblok Noise Filter and Surge

Suppressor with the Monster Power Center Model PC800HP.

**Investigator's Responsibilities**

Federal regulations require that all research be reviewed at least annually. It is the Principal Investigator's responsibility to submit for renewal and obtain approval before the expiration date. You may not continue any research activity beyond the expiration date without IRB approval. Failure to receive approval for continuation before the expiration date will result in automatic termination of the approval for this study on the expiration date.

When applicable, enclosed are stamped copies of approved consent documents and other recruitment materials. You must copy the stamped consent forms for use with subjects unless you have approval to do otherwise.

You are required to obtain IRB approval for any changes to any aspect of this study before they can be implemented (use the modification form at [ohre.unc.edu/forms](http://ohre.unc.edu/forms)). Should any adverse event or unanticipated problem involving risks to subjects or others occur it must be reported immediately to the IRB using the adverse event form at the same web site.

CC: Jo Ann Dalton, School Of Nursing

### Appendix 3. Recruitment Flyers

# **Women 45 years and older with Knee Pain**



**Have trouble  
getting out of  
chairs or cars ?  
Knee hurts after  
standing and  
walking?  
Had this pain over  
6 months?**

**You may qualify for a  
study of chronic  
pain and its effect  
on pain expression  
at the [UNC-CH  
School of Nursing](#).**

**Please take card  
Voice and Knee  
Pain Study  
919-968-8774**

**No blood drawn and  
no invasive  
procedures.**

**Call for more  
information or to  
see if you qualify.**

# Are you a Healthy Woman 45 years or older?



Healthy female volunteers are needed to compare with women who have chronic knee pain.



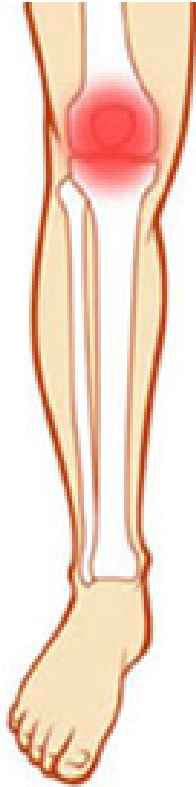
You may qualify for a study of chronic pain and its effect on pain expression at the [UNC-CH School of Nursing](#) if you have no musculoskeletal pain.

Please take card  
Voice and Knee  
Pain Study  
919-968-8774

No blood drawn and  
no invasive  
procedures.

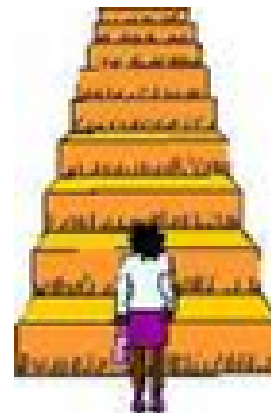
Call for more  
information or to  
see if you qualify.

# Got Knees?



Women 45 years of age and older **with** and **without** knee pain are asked to participate in a nursing research study to determine the effect of pain on voice.

No blood drawn  
Snack and \$30 provided



Call for information about participation: 919-968-8774

Voice and Knee Pain Research  
**919-968-8774**

Voice and Knee Pain Research  
**919-968-8774**

# Got pain in your knee? Or even if you don't!

If you are a  
**woman 45 years**  
**of age or older**,  
with no singing or  
acting training, you  
can participate in a  
nursing  
research study  
of the effect of  
pain on voice.  
please call  
**919-968-8774**



No blood draws!  
\$30 after  
completion of  
inventories and  
audio and video  
recording  
Sandwich and  
drink

919-968-8774

919-968-8774

919-968-8774



#### Appendix 4. Recruitment Telephone Screening Script

## Recruitment Telephone Screening Script

Obtain ID # from log and enter caller's name on log.

Caller's ID number \_\_\_\_\_

Date: \_\_\_\_\_ Time: \_\_\_\_\_

Person taking call: \_\_\_\_\_

Information for the telephone interviewer: The investigator or research assistant will identify himself or herself to the woman. Text in italics will be read to callers.

### Step 1

*Thank you for calling about the study. I am \_\_\_\_\_. This telephone interview will take about 20 minutes of your time. Is it convenient for you to talk now?*

Continue if OK now and if the present time is not convenient, arrange a time for interview and note in the log the preferred time for a return call.

*Before I explain more about the research study, I'd like to know where you found out about the study.*

Write contact source in log.

*To give you an overview, this nursing research study is aimed at looking for the reaction of women with chronic pain in acoustic, or sound, measurements of voice. In addition, group of women without chronic pain will be needed for comparison. I will be asking each participant to complete several written tests, wear a head-mounted microphone and have pulse monitoring, and sit and then rise to standing position where she will remain for several minutes. The sit-to-stand task will be done two times. Video and audio recording will take place during the voice and sit-to-stand movement parts of the study.*

*If you are willing to be in the research study, I will ask your age, sex, general questions about your pain, and your vocal training. There is additional screening about health problems to help determine if you match what is needed in the study. If at any point during the questions, you do not match what I need, I will stop the interview. You may also stop the interview at any time.*

*Do you have any questions before I continue?*

*If you are willing to answer these questions, please give me your consent to continue with this interview and for me to ask you the questions.*

Verbal Consent given by \_\_\_\_\_ to \_\_\_\_\_  
(caller) (researcher)

on \_\_\_\_\_ at \_\_\_\_\_ AM or PM.  
(date) (time)

Go to Step 2

Step 2

*First, are you a woman?*

YES – Go to step 3

NO – End interview with thanks for interest

Step 3

*Are you 45 years of age or older?*

YES - Go to step 4

NO – End interview with thanks for interest

Step 4

Do you have a regular health care provider?

YES – Go to next step

NO – End interview with thanks for interest

Step 5

*Has a doctor told you that you have osteoarthritis in your knee?*

YES – Go to step 6

NO – Go to step 9

Step 6

*Do you have osteoarthritis or pain in your knee?*

YES – Go to step 7

NO – Go to Step 8

Step 7

*Which knee is affected?*

(Mark all that apply)

Right \_\_\_\_

Left \_\_\_\_

Both \_\_\_\_

Go to step 8

Step 8

*Do you have pain in your feet, ankle, hip, back, or anywhere other than your knee that affects walking or standing for any period of time?*

YES - *Would you say your pain is greatest in the knee?*

YES – Continue screening .

Go to Step 10

NO - *You may qualify for the non-pain group in this research study. May I ask you questions to see if you qualify for that group?*

NO- End interview with thanks for interest

Step 9

*How long have you had pain in your knee?*

If less than 6 months – end interview with thanks for interest

If more than 6 months, write it in the blank

\_\_\_\_\_months / years (Circle time)

Go to step 10

Step 10

*Have you had surgery on either of your knees?*

YES – *How long has it been since your surgery?*

(If less than 1 year, end interview with thanks for interest)

Go to step 11 if more than one year since last surgery.

NO - Go to step 11

Step 11

*Are you able to stand and walk unassisted?*

YES –Go to step12

NO – End interview with thanks for interest

Step 12

*Are you able to rise from a seated position to standing unassisted?*

YES – Go to step 13

NO – End interview with thanks for interest

Step 13

*Are you able to stand for five minutes?*

YES – Go to step 14

NO – End interview with thanks for interest

Step 14

*Could you say “ah” and continue to say it at a comfortable loudness for 4 seconds?*

YES – *Would you please demonstrate for me now?*

(Time the duration of the vowel production.)

*Thank you.*

Go to step 15

NO – End interview with thanks for interest

Step 15

*Are you a trained singer or actor?*

YES – End interview with thanks for interest

NO – Go to step 16

Step 16

*Can you read and write English?*

YES – Go to step 17

NO – End interview with thanks for interest

Step 17

*Are you able to read magazines and the newspaper in English?*

YES – Go to step 18

NO – End interview with thanks for interest

Step 18

*You may qualify for this research study. I would like to ask you some questions about your health history that may take 10 minutes more. Are you interested and have the time to answer these questions now or is there a better time?*

YES – Go to step 19

NO – Schedule a time to call back. Write time and day in log.

*Thank you for your time. I will look forward to talking with you again at:*

\_\_\_\_\_AM/PM on \_\_\_\_\_day \_\_\_\_\_date.

Step 19 \*

\*Go to Health Screening Questionnaire (HSQ) (Appendix 6)

After completion of the HSQ – determine from items selected on HSQ if caller qualifies for the study.

Step 20

*You qualify to be a participant in this study. If you consent to participate, testing that is part of the study would take an additional 2-2 ½ hours and takes place at the UNC-CH School of Nursing. Psychological testing, physical measures like height, weight, and blood pressure as well as measurement of aspects of voice while sitting and standing will be done. The movement tasks and the associated voice measurements will require audio and videotaping. If elevation of vital signs or any factors measured on the personality tests are elevated, you will be given a letter to provide to your primary care provider. If there is*

*concern about your safety, you may be asked to contact the provider or I will notify the provider of the specific concern.*

*I will provide you with \$30, partially to cover expenses you may encounter. A visitor parking pass can be arranged for the Bell Tower parking lot and sessions can be scheduled in the evening when parking is free and closer to the School of Nursing. Should you withdraw before completing the study, I will provide you with \$10.*

*If you are interested in participating, I can schedule an appointment if that is convenient.*

YES – Go to Step 22

NO – Go to Step 21

#### Step 21

*I am sorry that you are not interested in proceeding at this time*

*If it is not convenient to schedule at this time, please keep the card and number and call when it is more convenient for you. (end interview with thanks for interest)*

#### Step 22

*Is an afternoon or evening appointment more convenient?*

Afternoon – Go to step 23

Evening – Go to step 27

#### Step 23

##### AFTERNOON APPOINTMENTS

*In scheduling afternoon appointments, I ask that you avoid eating a large meal three hours prior to the testing. I will provide a light snack and drinks. Parking is available at Bell Tower parking lot. A map will be included in the appointment reminder I plan to send you. If someone is bringing you, I suggest that you ask to be dropped off at the Medical Drive entrance to the ground floor of the School of Nursing. Bus service is available to Carrington*

*Hall. Please let me know your preference. I will be waiting to help you to the testing area and you will identify me by the yellow apron I will wear.*

Check the appointment book to see what is available.

*Do you have any questions so far? I have been giving you a lot to absorb.*

Allow some time and then proceed.

*What day is better for you?*

Attempt to schedule within the next two weeks of the call if at all possible.

Schedule day in appointments.

Go to Step 24

#### Step 24

*In anticipation of you providing written consent and participating in this research study, I prefer to schedule a two-hour session. When is it convenient for you to arrive on \_\_\_\_\_?*

*(date)*

YES –Go to Step 25

NO – *Would an evening time be better?*

Go to Step 27

#### Step 25

*Then I will plan for you to arrive at \_\_\_\_\_ on \_\_\_\_\_. I would expect you would need to be here until \_\_\_\_\_. I would like to provide a sandwich and drink for you. Is there a type of sandwich and beverage you prefer (i.e., ham, turkey, with cheese, vegetarian, soft drink, tea)? Are there dietary restrictions I need to consider?*

YES – Fill in the information with the appointment

NO – Go to Step 26



Step 26

*I would like to send an appointment reminder for the screening with a map. Would you mind giving me an address where the reminder can be sent?*

YES – Go to Step 30

NO – fill in the information below

Mailing address: I will get name from log book

---

---

---

ZIP code

Step 27

EVENING APPOINTMENTS

*In scheduling evening appointments, we ask that you avoid eating a large meal three hours prior to the session. I do provide a light snack and drinks. Parking is available in the Bell Tower lot. Parking may be available across Medical Drive from the School of Nursing after 5 PM . Maps will be included in the appointment reminder I plan to send. Please let me know your preference I will be waiting to help you to the testing area since doors are locked at 5:30 PM and, you will identify me by the yellow apron I will wear.*

*Are there any questions so far?*

Allow some time for the questions.

*What evening is better for you?*

Gives evening.

Go to step 28

Step 28

*I prefer to schedule for a two-hour session in anticipation of you providing written consent and participating in this research study. What time is it convenient for you to on \_\_\_\_\_?  
(date)*

Gives time – check schedule

Go to Step 29

Step 29

*Then I will plan for you to arrive at \_\_\_\_\_ on \_\_\_\_\_. If you decide to participate in  
(time) (date)  
this research study, I have included time for you to be here 2 hours. I would like to provide a sandwich and drink for you. Is there a type of sandwich and beverage you prefer (i.e., ham, turkey, with cheese, vegetarian, soft drink, tea)? Are there dietary restrictions I need to consider?*

YES – Write down on sheet with address information. Go to Step 30

NO – Continue with Step 30

Step 30

*I would like to send an appointment reminder for the screening with maps. Would you mind giving me your name and an address where the reminder can be sent?*

YES – go to Step 32

NO – fill in the information below

Mailing address: I will get name from log book

\_\_\_\_\_

\_\_\_\_\_

\_\_\_\_\_ ZIP code

Go to Step 31

Step 31

*If there is a number where you can be reached to be reminded of this appointment, I can give you a reminder call. Do mind receiving a reminder call?*

YES – go to step 33

NO – go to step 32

Step 32

*The telephone number where you may be reached is?*

\_\_\_\_\_  
(telephone number of caller)

Go to Step 33

Step 33

*Thank you for your interest in this research study and agreeing to consider participation. I appreciate you taking time to help me. If you need assistance finding the School of Nursing, you may call my mobile number:*

919-360-6350

*If I don't answer, please leave a voice message with a number where you may be reached and I will return your call.*

Go to Step 35

Step 34

*Thank you for your interest in this research study. If it is not convenient to schedule at this time and you wish to at a later date, please keep the card with our telephone number to reach me later. I appreciate you taking time to talk. Thank you and goodbye.*

Step 35

*Thank you for your interest in this research study. I appreciate you taking time to talk and look forward to seeing you on \_\_\_\_\_ at \_\_\_\_\_. Thank you and goodbye.*

date                      time

## Appendix 5. Agencies for Subject Recruitment

*Flyer Placement Approved by Agencies*

Type of Agency	Name	Address	Contact Person
Senior Center	Chapel Hill Senior Center at Galleria	400 S. Elliott Road Chapel Hill, NC 27516	Myra Austin
	Hillsborough Senior Center	515 Meadowlands Drive Hillsborough, NC	Myra Austin
	Northside Senior Center	404 N. Caldwell Chapel Hill, NC 27514	Corina Riley
	Seymour Center	2551 Homestead Drive Chapel Hill, NC 27516	Myra Austin
Pharmacy	CVS Pharmacy	300 N. Greensboro Carrboro, NC 275110	Glen
	Eckerd Pharmacy	Glenwood Shopping Center Chapel Hill, NC 27517	Carol
	Kerr Drug	University Mall Chapel Hill, NC 27514	
Wellness Center	UNC Wellness Center at Meadowmont	100 Sprunt Street Chapel Hill, NC 27517	Betsy Carter
Public Library	Chapel Hill Public Library	100 Library Drive Chapel Hill, NC 27514	Claudia Dayson
Community Group	Arthritis Support Group		Cindy Johnson

*Flyer Placement Approved by Agencies*

Type of Agency	Name	Address	Contact Person
Orthopedics Clinic	UNC Orthopaedics Clinic	Dept. of Orthopaedics CB# 7055 UNC School of Medicine Chapel Hill, NC 27599- 7055	Tom Bush, NP
Retirement Community	The Cedars of Chapel Hill	Program Director 100 Cedar Club Circle Chapel Hill, NC 27517	Joan Welch
	Carolina Meadows	100 Carolina Meadows Drive Chapel Hill, NC 27517	Bobbie Gray
UNC - Chapel Hill	Campus Buildings	Schools of Medicine, Pharmacy, Social Work, Education, Public Health, Information & Library Science: Undergraduate Library, Davis Library	Administrative Staff in Dean's Office or Library
Churches	Newman Catholic Student Center Parish	218 Pittsboro Street Chapel Hill, NC 27516	Tracy Ocampo
	Holy Trinity Lutheran Church	300 E Rosemary Street Chapel Hill, NC 27514	Audrey Burke

*Flyer Placement Approved by Agencies*

Type of Agency	Name	Address	Contact Person
Fitness Center	Peak Fitness	257 Elliott Road Chapel Hill, NC 27514	
Physical Therapy Center	Comprehensive Physical Therapy Center	115 Timberhill Place Chapel Hill, NC	
	Balanced Movement Studio	304 W. Weaver Street Carrboro, NC 27510	

## Appendix 6. Health Screening Questionnaire



## Health Screening Questionnaire

(Step 19 of Telephone Screening)

*"I will read several lists of health problems or illnesses that may affect your ability to participate in this study. Please let me read the list and then tell me if you have had any of the problems in the list. You do not need to tell me which conditions just answer 'Yes' at the end of the list."*

Do you have now or have you ever had:

Cardiovascular Problems like:

Stroke

Transient Ischemic Attacks or TIA

Surgery to clear arteries to the brain or endarterectomy

Hypertension not under control

Taking beta-blockers

Heart attack

Change in memory, ability to talk or solve problems 24 hours after the heart attack

Heart surgery

Resuscitated or had CPR

Yes\_\_\_ No\_\_\_

Metabolic Problems like:

Liver disease

Kidney disease requiring renal dialysis

Insulin dependent diabetes mellitus

Drink beer, wine, or other alcoholic beverages every day or less often

If daily, more than three drinks/day

Yes\_\_\_ No\_\_\_

Neurological Problems that would include:

Learning problems or learning disability

Head injury with a loss of consciousness longer than 5 minutes

Unconscious longer than 1 hour other than for surgery

Seizures

Brain tumor

HIV, AIDS, Syphilis

Brain surgery

Parkinson's Disease

Meningitis or encephalitis

Illness or surgery that resulted in a decrease in memory or other mental function

Depression or psychosis

Had electroshock therapy

Yes\_\_\_ No\_\_\_

ENT Problems like:

Vision problems that prevent you from reading ordinary print even with glasses

Difficulty understanding conversations

Difficulty with slurring of speech

Poorly fitting dentures

Yes\_\_\_\_ No\_\_\_\_

Respiratory Problems like

Smoking cigarettes or cigars for more than 1 year

Cancer of the lung, larynx (or voice box), mouth, or lip in past five years

Cleft lip or palate

Asthma, COPD, allergies that cause wheezing, or other respiratory disease

Routine use of inhaled corticosteroids

Yes \_\_\_\_ No \_\_\_\_

Skin Problems like

Currently have open areas or rash on hands or forearms

Yes\_\_\_\_ No \_\_\_\_

Hormonal Problems like

Treatments requiring use of male hormones

Yes \_\_\_\_ No \_\_\_\_

Musculoskeletal Problems like

Difficulty using hands - to hold pencils

Difficulty writing your name

Unable to walk unassisted

Unable to stand unassisted

Unable to stand for any length of time

Tripping or falls

Lupus or SLE

Yes \_\_\_\_ No \_\_\_\_

ANY YES REPLIES - *I am sorry that you do not match characteristics we need for this study. I do appreciate your willingness to help and the time you have spent on the interview.*

*Thank you. (End the conversation)*

ALL NO REPLIES – Return to Telephone Script, Step 20 to encourage participation.

## Appendix 7. Follow-Up Reminder Notice and Map

Date

Name

Address

Dear

Thank you again for volunteering to participate in the Voice and Knee Pain Research Study. You are presently scheduled to come to the Biobehavioral Laboratory, Room 10 at the School of Nursing at the University of North Carolina on:

\_\_\_\_\_ at \_\_\_\_\_.

(Date)

(Time)

As you may recall, the aim of the study is to determine the relationship between acoustic measures in voice to the pain induced by movement from sitting to standing in women 45 years of age and older with and without chronic knee pain. Your participation should not cause you more pain than usual if you have knee pain. In total, the testing has taken about two hours, including the time for the snack, but time usually passes pretty quickly.

Please do not have a big meal within 3 hours of coming because a big meal may alter your voice measurements. I will provide you with a snack and a beverage.

I am including a sheet of instructions and a map of the campus. On the day of your appointment, I would appreciate you calling me (919-360-6350) as you leave so I can be waiting for you at your destination point here at the School. I will wear a yellow apron so you can identify me. If you need a wheelchair for long distances, please call me at least 2 days in advance so I may have one available for you to use.

I very much want to make this experience to be as enjoyable as possible, so please call me with any questions or concerns. You will be provided \$30 to cover any costs incurred as a result of participating in this study. Needless to say, I look forward to meeting you and thank you again for volunteering.

Sincerely,

Susan R. Rasmussen, MSN, APRN-BC  
Doctoral Student

### Information Sheet

1. The School of Nursing is located at the corner of South Columbia Street and Medical Drive.
2. The study is being conducted at the Biobehavioral Laboratory, Room 10, of Carrington Hall, the School of Nursing building. The telephone number to the laboratory is 919-966-7598 should you need help finding it. You can also call me for instructions 919-360-6350.
3. If you would prefer not to drive, you may ride one of the Chapel Hill Transit buses free of charge. There is a bus stop located directly in front of the School of Nursing on Columbia Street that serves many of the routes.
4. If you will be dropped off by someone else, I recommend turning left onto Medical Drive from Columbia Street, and I will meet you on the sidewalk at the west end of the building closest to Columbia Street.
5. If you choose to drive, more specific directions follow. On the day of your appointment, call me as you are leaving home and meet me on Medical Drive (see the directions on the following page).

## Directions to School of Nursing

### 1. **North on 15-501 Bypass (from Burlington/Carrboro):**

Take the Chapel Hill-Pittsboro exit. At the stoplight, make a left onto South Columbia Street. Follow the road up the hill and go through the South Columbia and Manning Drive intersection. Start to get into the right lane, if parking on Medical Drive, go past the School of Nursing (on your right) and immediately turn right onto Medical Drive. UNC disability parking spaces are on the left and are available after 5 PM. If going to the Bell Tower lot, continue past the School of Nursing bearing to the right and make a right turn onto South Road. Turn right at the next stop light. I will meet you wearing a yellow apron and will escort you to the laboratory.

### 2. **South on 15-501 Bypass (from University Mall/Durham):**

After passing University Mall, move to the right lane in order to turn right at the third (Manning Drive - Smith Center) exit. There is a stoplight where you will need to make a right turn onto Manning Drive. Follow the road up the hill, pass through the construction and pass the hospital moving to the right lane, and make a right turn onto South Columbia Street. There are a changing number of traffic lights, but usually Columbia is the 5<sup>th</sup> light. If parking on Medical Drive, stay in the right lane and follow the buses. After you pass Carrington Hall, you will immediately turn right onto Medical Drive. UNC disability parking spaces are on the left and are available after 5 PM. I will be in the yellow apron. I will meet you wearing a yellow apron and will escort you to the laboratory.

### 3. **From Highway 54 (RTP or Raleigh):**

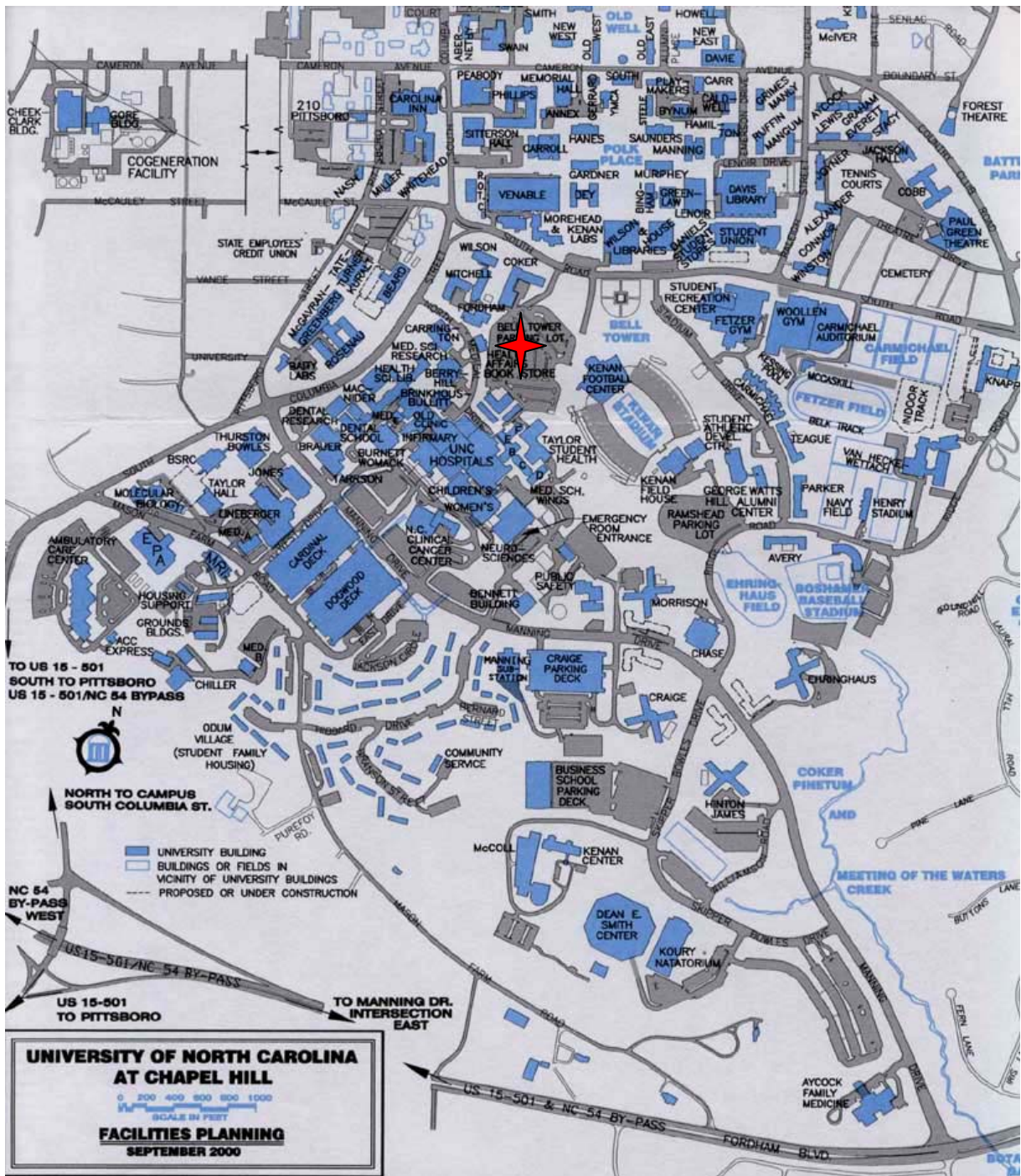
Take Highway 54 (Raleigh Road), past Glen Lennox, and go under the 15-501 bypass. Go up the hill to the stop light at Country Club Drive. The School of Government will be to your left. Continue on (Raleigh Road changes to) South Road through stoplight at Raleigh Road (Fetzer Gymnasium is to your left). If going to park on Medical Drive, proceed through the intersection at Columbia, going up the hill on what is now McCauley Street. Turn left at the traffic light at Pittsboro Road. Stay in the left lane, bearing left as Pittsboro divides. Turn left onto Columbia Street and

move to the right lane. You will pass one traffic light at the Health Sciences Library. Follow buses as you will be turning right immediately after the Carrington Hall bus stop. UNC disability parking spaces are on the left and are available after 5 PM. I will be in the yellow apron. I will meet you and escort you to the laboratory.

4. **From Downtown Chapel Hill (Coming from Franklin Street):**

At the stoplight at the intersection of Franklin and Columbia, make a left turn onto South Columbia Street (Spanky's is on this corner). At the second stop light, make a right turn onto Cameron Avenue and move into the left lane. At the next stoplight, make a left onto Pittsboro Street. To park on Medical Drive, stay in the left lane, bearing left as Pittsboro divides. Turn left onto Columbia Street and move to the right lane. You will pass one traffic light at the Health Sciences Library. Follow buses as you will be turning right immediately after the Carrington Hall bus stop. UNC disability parking spaces are on the left and are available after 5 PM. I will be in the yellow apron. I will meet you and escort you to the laboratory. To park in the Bell Tower lot, remain in the left lane and turn left on McCauley Street. Follow the street through the traffic light at Columbia. The street name becomes South Road. Turn right at the next stop light at the Bell Tower parking lot. I will meet you at the gate in a yellow apron and will escort you to the laboratory.

PLEASE REFER TO THE MAP





## Appendix 8. Consent Form

**University of North Carolina-Chapel Hill  
Consent to Participate in a Research Study  
Adult Participants  
Social Behavioral Form**

THIS CONSENT DOCUMENT SHOULD BE USED ONLY  
BETWEEN 10/30/07 AND 10/28/08  
APPROVED BY  
INSTITUTIONAL REVIEW BOARD, UNC-CHAPEL HILL

---

**IRB Study # 06-0504**

**Consent Form Version Date: 10-10-07**

**Title of Study:** Acoustic Parameters of Emotion Expression of  
Women with Chronic Knee Pain

**Principal Investigator:** Susan R. Rasmussen, MSN, APRN, BC

**UNC-Chapel Hill Department:** Nursing

**UNC-Chapel Hill Phone number:** 966-4260

**Email Address:** srasmuss@email.unc.edu

**Co-Investigators:** None

**Faculty Advisor:** Jo Ann Dalton, EdD, RN

**Faculty Email:** jdalto2@emory.edu

**Faculty Phone Number:** 404-727-5998

**Study Contact telephone number:** 919-968-8774

**Study Contact email:** srasmuss@email.unc.edu

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**What are some general things you should know about research studies?**

You are being asked to take part in a research study. To join the study is voluntary.

You may refuse to join, or you may withdraw your consent to be in the study, for any reason, without penalty.

Research studies are designed to obtain new knowledge. This new information may help people in the future. You may not receive any direct benefit from being in the research study. There also may be risks to being in research studies.

Details about this study are discussed below. It is important that you understand this information so that you can make an informed choice about being in this research study.

You will be given a copy of this consent form. You should ask the researchers named above, or staff members who may assist them, any questions you have about this study at any time.

**What is the purpose of this study?**

The purpose of this research study is to learn about the effect of pain on voice in women who have chronic pain. Because voice can carry information about reactions to stressors, it is thought that measurements of voice might indicate the effect pain has on the individual. Because emotion is thought to play a role in pain, information about emotions such as anxiety, anger, and sadness or depression will be collected.

You are being asked to be in the study's (1) pain group because you have chronic knee pain that is caused by movement from sitting to standing and standing for a length of time or (2) non-pain group because you do not have joint pain that is affected by movement. Comparison of the measurements of the two groups will provide information about voice as an indicator of reaction to chronic pain.

**Are there any reasons you should not be in this study?**

You should not be in this study if you have:

1. Professional singing and acting experience.
2. Cognitive impairment, inability to understand and follow directions due to learning problems or learning disability, illness or surgery that resulted in a decrease in memory or

- 
- other mental function.
3. Respiratory or oral conditions that limit breathing or speaking including:
    - a. Cancer of the lung, larynx (or voice box), mouth, or lip in past five years,
    - b. Cleft lip or palate,
    - c. Asthma, COPD, or other respiratory disease,
    - d. Allergies that cause wheezing, or
    - e. Routine use of inhaled corticosteroids
  5. Cardiovascular problems like:
    - a. Stroke,
    - b. Transient ischemic attacks, or TIAs,
    - c. Condition requires of beta blocker medication, or
    - d. Heart attack in the past three months.
  6. Metabolic problems like:
    - a. Liver disease
    - b. Kidney disease requiring renal dialysis, or
    - c. Condition requiring fluid restriction.
  7. Neurological problems like: . .
    - a. Seizures,
    - b. Parkinson's Disease,
    - c. Learning problems or learning disability, or
    - d. Illness or surgery that resulted in a decrease in memory or other mental function.
  8. Eye, ear, nose and throat problems like:
    - a. Vision problems that prevent reading ordinary print even with glasses,
    - b. Difficulty understanding conversations,
    - c. Difficulty with slurring of speech,
    - d. Poorly fitting dentures, or
    - e. Hearing aids required to hear normal conversation.
  9. Skin problems that include open areas or rash on hands and fingers.
  10. Hormonal problems requiring the use of male hormones.
  11. Joint pain on movement for the non-pain group.

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12. Inability to say a vowel at an intense, but comfortable level for 4 seconds.

13. Musculoskeletal problems like:

- a. Inability to stand independently for five minutes.
- b. Difficulty using hands - to hold pencils
- c. Difficulty writing your name
- d. Inability to walk unassisted
- e. Inability to stand unassisted
- f. History of tripping or falls.

**How many people will take part in this study?**

If you decide to be in this study, you will be one of approximately 80 women in this research study. Forty will have chronic knee pain and forty will not have joint pain.

**How long will your part in this study last?**

You will need to be present at the UNC School of Nursing for testing for 2-2 ½ hours.

**What will happen if you take part in the study?**

As part of the study you will be asked to answer questions about yourself, your pain, your family, and about how you feel your pain has affected you. You will complete written tests and your voice and pulse will be recorded. Testing in the School of Nursing will take about 2 ½ hours today, and will take place on the ground floor and third floor of the School. The vocal and physical tasks – rising from sitting to standing position twice - will be audio-taped and videotaped. No names will be used during the taping.

**What are the possible benefits from being in this study?**

Research is designed to benefit society by gaining new knowledge. You may not benefit personally from being in this research study.

**What are the possible risks or discomforts involved from being in this study?**

There is the possibility that you will experience some pain with the physical tasks, but this risk is not expected to be greater than your risk in usual daily activities.

You may experience a psychological reaction to the questions posed in the tests. You are free to withdraw from the study at any time without consequences.

There may be uncommon or previously unknown risks. You should report any problems to the researcher.

**How will your privacy be protected?**

While your name, address, and telephone number are needed prior to your written consent, once you are enrolled in the study, this personal information will be available only to the researcher in a log book that is stored in a locked office in a locked cabinet.

Nothing that you say will be told to people other than those who are working with the study. Reports may be given in professional meetings or in professional publications but your name will not be used. Participants will not be identified in any report or publication about this study. A participant identification number will be assigned at the time you consent to be in the study and will be the only identifier used for the remainder of the study. Although voice and videotaped samples are obtained, digitized, and stored on a CD, these will only be available to persons assisting with the study. These CDs will be stored in a locked office and locked cabinet as well. It is anticipated that these CDs may be kept for additional analyses over the next three years.

Although every effort will be made to keep research records private, there may be times when federal or state law requires the disclosure of such records, including personal information. This is very unlikely, but if disclosure is ever required, UNC-Chapel Hill will take steps allowable by law to protect the privacy of personal information. In some cases, your information in this research

study could be reviewed by representatives of the University, research sponsors, or government agencies for purposes such as quality control or safety.

**What will happen if you are injured by this research?**

All research involves a chance that something bad might happen to you. This may include the risk of personal injury. In spite of all safety measures, you might develop a reaction or injury from being in this study. If such problems occur, the researchers will help you get medical care, but any costs for the medical care will be billed to you and/or your insurance company. The University of North Carolina at Chapel Hill has not set aside funds to pay you for any such reactions or injuries, or for the related medical care. However, by signing this form, you do not give up any of your legal rights.

**Will you receive anything for being in this study?**

You will be receiving \$30 and light snack for taking part in this study. Monetary payment is intended to cover expenses for transportation and parking. If the participant chooses to withdraw prior to completion of the inventories and vocal testing, a monetary payment of \$10 will be provided. All monetary payments are provided as cash.

**Will it cost you anything to be in this study?**

Your costs will include child care if necessary.

**What if you are a UNC student?**

You may choose not to be in the study or to stop being in the study before it is over at any time. This will not affect your class standing or grades at UNC-Chapel Hill. You will not be offered or receive any special consideration if you take part in this research.

**Taking part in this research is not a part of your University duties, and refusing will not affect your job. You will not be offered or receive any special job-related consideration if you take part in this research.**

**You have the right to ask, and have answered, any questions that you may have about this research. If you have questions, or concerns, you should contact the researchers listed on the first page of this form.**

All research on human volunteers is reviewed by a committee that works to protect your rights and welfare. If you have questions, or concerns about your rights as a research subject you may contact, anonymously if you wish, the Institutional Review Board at 919-966-3113 or by email to [IRB\\_subjects@unc.edu](mailto:IRB_subjects@unc.edu).

I have read the information provided above. I have asked all the questions I have at this time. I voluntarily agree to participate in this research study.

Date \_\_\_\_\_

Signature of Person Obtaining Consent

Date \_\_\_\_\_

Printed Name of Person Obtaining Consent



## Appendix 9. Enrollment and Data Collection Script

## Enrollment and Data Collection Script

The participant will be directed to parking by staff or investigator wearing yellow apron at the time of arrival. Assistance to the BBL will be provided as the entrances are locked after 5:30 PM and several entrances exist. The need for wheelchair or avoidance of steps will be determined at the time of the telephone contact as well as on arrival of the participant. While the participant proceeds to the BBL, assessment of the ability to stand for three to five minutes independently is done using the following criteria: requires one-person-assist to transfer from car, unable to transfer to wheelchair independently, unstable gait with assistive device, shortness of breath with ambulation and transfer, and dizziness when standing. Any of these observations will be noted and transferred to Demographic Data Sheet.

*Hello, \_\_\_\_\_. I am Susan Rasmussen, the (nurse researcher/doctoral student) you talked with on the telephone about the voice and chronic pain study. Thank you for your interest in the project and welcome to the School of Nursing and the Biobehavioral Laboratory. There are several rooms here as well as restroom facilities. After your drive, do you need a drink or restroom?*

Bottled water will be provided once in the BBL.  
Participant and significant other will be shown to the restroom. It will also allow further assessment of mobility.

IF YES – Assist participant to restroom, a drink, and then proceed to main room  
IF NO – Offer a chair.

Once comfortable, the investigator and participant (and friend/family, if present) will return to the main room of the BBL where the consent will be discussed and inventories will be reviewed and administered. Comfortable seating with arms is available at tables with fluorescent lighting. Explanation of the study will commence.

*As I mentioned on the telephone, the purpose of this study is to determine if aspects of voice change when persons have pain. It would be helpful for nurses to know what to listen for when caring for patients since no studies of chronic pain and voice have been reported. Since persons with knee pain experience pain with normal activity, I would expect that you are familiar with pain.*

*I will ask you to provide personal information and complete several questionnaires that look at anxiety, depression, anger, activity, and pain that take about 30-60 minutes. This information will be kept confidential. There will be a break for a snack and beverage before we move to the other room. There, you will be asked to wear a head-mounted microphone and a pulse monitor on your finger.*

*While you are sitting, I will signal with my hand for you to repeat "ah", holding it for 4 seconds. Then there will be a pause of about 30 seconds. Then I will ask you to say "ah" again. I will ask that you do that five times for a total of 5 "ah"s and a statement about your pain rating. Then, I will ask you to stand and repeat "ah" five times like before, holding it for four seconds and pausing for 30 seconds between. While you are standing I will ask you to rate your pain, how unpleasant it is, and rate emotions you*

*might be experiencing on a form and say, “My pain is about a (number from 0-10).”*

*You will need to be able to stand for 3 minutes. You may use a walker or cane, but you can not have a person help you. There will be videotaping of this part of the study to provide me a way to accurately check some times later. All of these records will be stored in a locked area with access restricted to only me and persons helping with the study. This vocal part of the study will take about 30-40 minutes. Do you think you are able to do this?*

IF YES – *Fine. I will continue to explain the study.*

IF NO – *Thank you for your time in coming here today. I am sorry you made this trip unnecessarily. (Provide with snack and drink, incentive for non-participant of \$10).*

*I do not anticipate there are any risks outside usual, but the questionnaires may upset you and the voice exercise might make your mouth dry or cause you to feel you are running out of breath. There are no needle sticks and no blood drawing involved. You should feel free to ask for a break or drink at any time. Should you desire, you may also quit the study at any time. I will provide monetary reimbursement for your time and travel in the form of \$30 if you complete the study and \$10 if you withdraw. Do you have any questions?*

IF YES – (Answer as completely as possible. Demonstrate [a] exercise if needed.)

IF NO- (Proceed to explain the consent.)

*I will then ask you to read this consent form and sign one copy that will remain with me. You will keep the second copy. I will give you some time to read it over. If you have questions, please feel free to ask.*

[Two copies of the Consent (Appendix 8) are given to the participant and significant other to review while investigator remains in the room.]

*Any questions?*

IF YES – Answer the questions posed.

IF NO – Proceed.

*Thank you for agreeing to participate. I will ask your family/friend to wait outside or return for you about 3 hours.*

(Escort family/friend to hall and provide reading material or map of the campus.  
Synchronize watches to be able to meet them at an agreed upon time on return.)

*I would like to start by getting some routine measurements of height, weight, temperature, and routine vital signs.*

[Demographic information collection begins (Appendix 8)]. Vital signs are obtained using the IVAC Electronic Oral Thermometer and Dynamap 1846 SX. Weight is obtained using the Scale-Tronix 5600 Portable Stand On Scale and recorded in pounds and

kilograms. Height will be obtained using the stadiometer in the BBL. Respirations are counted for 1 minute as participant reads materials.]

(VAS for Pain Intensity of clipboard)

*There are some measures I will be doing a few times while you are here. First, I am going to ask you to place a mark on the line to indicate how much your pain hurts right now.*

(VAS for Pain Unpleasantness)

*Now, I am going to ask you to place a mark on the line to indicate how much your pain bothers you right now.*

*I will be asking if you experience any emotions or feelings at intervals during the study. Please indicate if you felt any of these before coming and up to right now. Next time, you will be recalling from this time to the time I give you the form.*

*Thank you. Now I will move on to the questionnaires I mentioned. These may take some time. There are no right or wrong answers. Just answer the questions as honestly as you can.*

(Place the Demographic Information and Data Sheet, VAS-PI, VAS-UPL in folder. Take a questionnaire packet out of box. Provide participant with pencils with grips.)

*Are you comfortable in this chair? Is the lighting and temperature alright? Would you like a drink?*

IF NO – make necessary adjustments

IF YES – hand participant the envelope

*In this envelope are several questionnaires. Some of them are psychological inventories since chronic pain often causes persons to become anxious, sad, or angry. Although I do not expect there to be any problem, if there is any indication that you are at risk, I will let you know and ask to notify your health care provider. I ask that you answer all the questions. It is best to give the answer that first comes to you and move on to the next item rather than spending too much time considering your answer. One of the questionnaires was designed for persons with cancer pain. When you encounter questions that refer to “diagnosis,” answer questions as if they were “arthritis.”*

*I will stay nearby in case you have questions about the directions. Each questionnaire is different and some have questions printed on the back of the page. Please make sure you answer all the questions.*

*Are you ready?*

IF NO – find out reason(s) and remediate.

IF YES – You can begin.

Respirations are counted for 1 minute and recorded while the participant completes the questionnaires. When the participant has completed the questionnaires, they are collected

and reviewed for missing items. Completed questionnaires are placed in the participant folder. The participant is asked to review incomplete questionnaires.

After ½ hour, the opportunity for a break is presented.

After completion of the questionnaires, a snack and drink are provided at the table before moving to vocalization. Provision of time for handwashing and glucose testing is included before the snack.

*If you are finished and ready, we can move to the other room. We need to walk to the elevator and then the length of the hall to get to a more quiet room. Are you ready for a walk?*

Monitor participant respiratory and ambulation status.

(Entry to Room 310B may be intimidating if the participant has never seen camcorder, computer equipment, and oximeter. Effort to acclimate the participant to equipment and reduce situational anxiety is attempted.)

*Before you sit down, I will make sure the camera is set to get a picture of you from head-to-toe when you stand. So if you could stand in front of this chair for a moment, I will adjust the camera.*



Once in the room, participant is shown to a chair with arms. Before sitting, camcorder focus is adjusted to allow head-to-toe video capture and the camera is placed on “Standby.”

*That’s done. Thank you. Please have a seat.*

*I realize this looks like a lot of equipment, and you are probably wondering what it does.*

*First, none of it should hurt you. Can I show you what it does?*

IF YES – Proceed to give a brief demonstration of the microphone, oximeter, and camcorder. Allow her to handle and try the equipment to become acclimated to the environment.

IF NO – Ask if there is something wrong.

*In order to record your voice, I have this special microphone that will allow you to stand up without moving the microphone. The company says it can be used by singers and aerobics instructors but I don’t think you will need to move around that much. You may need to take off glasses while I fit this to you so it doesn’t wobble.*

(Adjust the headband of the AKG 420C to participant. Adjust distance from microphone head to lips – 5 cm.)

*How does that feel? Need any adjustment?*

(Replace glasses.)

*If that is feeling okay, I'll need to use one finger to record your pulse. Are you right-handed?*

IF YES – use left hand for Ohmeda 3900 oximeter sensor and hypoallergenic tape to hold snugly.

IF NO- use right hand for Ohmeda 3900 oximeter sensor and hypoallergenic to hold snugly.

*This is a pulse oximeter and records your pulse rate and measures the level of oxygen in your blood.*

*Let's see if we are connected and registering.*

(Show participant tracing of pulse and her  $\text{spO}_2$ . Turn off alarm. Turn camcorder to RECORD.)

*I am going to ask you to rate your pain intensity, pain unpleasantness, and emotions again. Are you able to mark the line with your free hand?*

(Provide the VAS-PI and VAS-UNP one at a time on clipboard with pencil.

When completed, remove sheets and place in folder. Leave two blank forms and the Emotion Presence form for the last rating to one side. Turn WinDaq to RECORD.)

*Thank you. Now, I am going to show you how I would like you to say “ah” for me.*

(Refer to Appendix for vocal data collection process.)

*Before you leave, I would like to check your blood pressure and vital signs one last time.*

(Check vital signs and record on the data sheet as post-study vital signs. Write these on a card for the participant to take.)

(If there are abnormally high or low vital signs, refer participant to their health care provider.) (Enclose letter to provider if BDI score greater than 13)

*Do you need a drink or to use the restroom before you leave?*

(Direct to the restroom facilities in room. Get a bottle of water.)

*If you would like to provide comments about the study, I have a form with some areas listed or you can write any comments down that you like on the back as well. You may send it back later in this stamped, self-addressed envelope. Please do not sign the form or put your address on the envelope.*

[Provide the Comments sheet (Appendix 15) and envelope.]

*Thank you for participating in this study. Here is a record of your height, weight, blood pressure and pulse while you were here. Reimbursement for your time and travel expenses is in this envelope. If you wish to know how about the results of the study, please leave me the address where you would like a brief summary sent.*

*If that is all I can do for you, I will help you to your car.*

## Appendix 10. Demographic Information and Data Sheet

### Demographic Information and Data Sheet

Participant ID \_\_\_\_\_

Date of Telephone Interview \_\_\_\_\_

Date of Testing \_\_\_\_\_ Time \_\_\_\_\_

Weather \_\_\_\_\_

Barometric Pressure \_\_\_\_\_

#### Mobility Observation

1. Requires one-person-assist to transfer from car \_\_\_\_
2. Uses assistive device \_\_\_\_
3. Unable to transfer to/from wheelchair independently \_\_\_\_
4. Unstable gait with assistive device \_\_\_\_
5. Shortness of breath with ambulation and transfer \_\_\_\_
6. Dizziness when standing \_\_\_\_

What is your age? \_\_\_\_\_

Which of the following do you consider as your race or ethnicity?

White Black Asian Hispanic American Native Mixed Other \_\_\_\_\_

Do you live alone? Yes No

IF YES

With whom do you live?

What is the relationship of that person to you?

Participant ID \_\_\_\_\_

Do you have children: Yes No

Name or Gender of Children	Age

Do you have chronic illnesses that I should be aware of while you are here? Yes No

What are they?

Allergies?

Sensitivities to:

Do you have a regular health care provider? Yes No

What is your health care provider's name? \_\_\_\_\_

Do you know the address? Yes No

\_\_\_\_\_

\_\_\_\_\_

Participant ID \_\_\_\_\_

Are you currently considering surgery for your knee pain? Yes No

How soon do you anticipate having surgery?

\_\_\_\_\_days \_\_\_\_\_weeks\_\_\_\_\_months\_\_\_\_\_year(s)

Have you known anyone who has had surgery on his/her knee? Yes No

Did they have a good experience? Yes No

What medications do you currently take?

When did you last take pain medication(s)?

\_\_\_\_\_ taken at \_\_\_\_\_

(name and dose)

(time)

\_\_\_\_\_ taken at \_\_\_\_\_

(name and dose)

(time)

Do you drink caffeinated beverages (coffee, Coke/Pepsi, tea)? Yes No

Have you had a caffeinated beverage in the past four hours? Yes No

Do you drink alcoholic beverages? Yes No

Have you had an alcoholic beverage in the past four hours? Yes No



Participant ID \_\_\_\_\_

Physical Data

Height \_\_\_\_ft \_\_\_\_inches \_\_\_\_\_cm

Weight \_\_\_\_\_lbs \_\_\_\_\_Kg

BMI\_\_\_\_\_

Pre-Study Vital Signs

Temperature \_\_\_\_\_

Pulse \_\_\_\_\_

Blood Pressure \_\_\_\_\_/\_\_\_\_\_

Respirations (Counted 1 minute)\_\_\_\_\_

After Completion of Inventories

Pulse \_\_\_\_\_

Respirations \_\_\_\_\_

Blood Pressure\_\_\_\_\_/\_\_\_\_\_

After Arrival to Acoustics Room

Time Recording Began \_\_\_\_\_

Pulse \_\_\_\_\_

Respirations \_\_\_\_\_

Blood Pressure \_\_\_\_\_/\_\_\_\_\_

Post-Study Vital Signs

Time Recording Finished \_\_\_\_\_

Temperature \_\_\_\_\_

Pulse \_\_\_\_\_

Respirations (Counted 1 minute)\_\_\_\_\_

Blood Pressure\_\_\_\_\_/\_\_\_\_\_

Referral Letter Given to Participant for BDI score? **YES NO**

Referral Letter Given to Participant for Vital Signs? **YES NO**

## Appendix 11. Instruments

Written instruments used to measure independent variables in this investigation included:

Brief Pain Inventory (BPI) (Cleeland, 1991b),  
Survey of Pain Beliefs-35 (SOPA-35) (Jensen & Karoly, 1989)  
Beck Depression Inventory – Second Edition (BDI-II) (Beck et al., 1996)  
Spielberger State-Trait Anxiety Inventory (STAI) (Spielberger, 1983)  
Spielberger State-Trait Anger Expression Inventory (STAXI-2) (Appendix 16)  
Modified Arthritis Self Efficacy Scale (ASES) (Lorig et al., 1989; Stanford Patient Education Research Center)

Instruments used to measure dependent variables were:

Visual Analogue Scale for Pain Intensity (Appendix 10)  
Visual Analogue Scale for Pain Unpleasantness (Appendix 11).  
Emotion Presence and Rating Scale (Appendix 18)  
Verbal Rating of Pain (Appendix 26)  
Computerized Speech Laboratory (KayPENTAX, 2004)  
Multi-Dimensional Voice Program (KayPENTAX Corporation, 2005)  
AKG C420 Microphone (AKG Acoustics, 2005)  
Datex-Ohmeda 3900 Pulse Oximeter (Datex-Ohmeda, 1998)  
Sony Digital Handicam Digital Camera Recorder Model DCR-TRV103

## Appendix 12. Visual Analogue Scale for Pain Intensity

*Participant ID* \_\_\_\_\_

Place a mark on the line to indicate how much the pain **hurts right now.**

Pain as bad as I can imagine

No pain

### Appendix 13. Visual Analogue Scale for Pain Unpleasantness

Participant ID \_\_\_\_\_

Place a mark on the line to indicate how much your pain **bothers** you **right now**.

The most unpleasant pain I can imagine

Not unpleasant at all

## Appendix 14. Emotion Presence and Rating Scale



Participant ID \_\_\_\_\_

Please indicate **if** you experienced any of these emotions.

If you did experience any of the emotions, please circle the number that indicates how much you felt that particular emotion.

1. I felt <b>irritated</b> or <b>angry</b> .	Yes	No
1	2	3
slightly		very much

2. I felt <b>sad</b> or <b>depressed</b> .	Yes	No
1	2	3
slightly		very much

3. I felt <b>anxious</b> or <b>fearful</b> .	Yes	No
1	2	3
slightly		very much

## Appendix 15. Post-Study Comments

In order to improve research procedures, please take some time to jot some comments about what might be done to make this type of study better in the future?

1. Getting word of the study to you?
2. Calling to sign up?
3. Parking?
4. Paper and pencil tests?

Pain

Anxiety

Depression

Anger

Arthritis

Health screening

5. Voice testing?
6. Microphone?
7. Pulse equipment?
8. Snacks?
9. Room?
10. Chair?

## Appendix 16. Physical Data Card

Name \_\_\_\_\_ Date \_\_\_\_\_

Ht. \_\_\_\_\_ inches

Wt. \_\_\_\_\_ lbs.

BMI \_\_\_\_\_

Temperature	Pulse	Respirations	Blood Pressure

Susan Rasmussen, MSN, APRN, BC  
Voice and Pain Study  
UNC-CH School of Nursing

## Appendix 17. Physician Referral Letter for BDI-II Score



Dear Health Care Provider,

Your patient, \_\_\_\_\_, was seen on \_\_\_\_\_ as part of a nursing research project, Acoustic Measurement of Emotion Expression of Women with Chronic Knee Pain.. As part of the study, participants undergo evaluation for depression with the Beck Depression Inventory – Second Edition. Her score was \_\_\_\_ of a maximum of 63 points. Person with scores of 14-19 are considered to have mild depression. Persons with scores of 20-28 are considered to have moderate depression. Persons with scores of 29-63 are considered to have severe depression.

Because I do not know if this score represents a change or if she is currently treated, I am referring her to you for follow-up. I have also mentioned the mental health services here at UNC Healthcare to her and her family member.

If you receive this letter from her, it is an indication of her concern as well.

Sincerely,

Susan R. Rasmussen, MSN, APRN, BC  
314-M Carrington Hall  
University of North Carolina at Chapel Hill  
Chapel Hill, NC 27599-7460

## Appendix 18. Physician Referral Letter for Abnormal Vital Signs





Dear Health Care Provider,

Your patient, \_\_\_\_\_, was seen today as part of a nursing research project, Acoustic Parameters of Vocalizations of Women with Chronic Pain. As part of the study routine vital signs were taken using the Dinamap 1846 SX and verified by auscultation. The blood pressure was \_\_\_\_\_/\_\_\_\_\_, pulse was \_\_\_\_\_, and respirations (full minute) \_\_\_\_\_ with  $\text{spO}_2$  \_\_\_\_\_.

Because I do not know if these readings represent a change or if she is currently treated, I am referring her to you for follow-up.

If you receive this letter from her, it is an indication of her concern as well.

Sincerely,

Susan R. Rasmussen, MSN, APRN, BC  
314-M Carrington Hall  
University of North Carolina at Chapel Hill  
Chapel Hill, NC 27599-7460

## Appendix 19. Check List for Study Session

## Room

Lights on –fluorescent

Temperature, barometric pressure, weather, recorded

Bottled water chilled, cup, straw

Snack ready

Yellow apron

## Equipment

Camcorder (check battery), power cord, tripod, remote (check battery), tape cassette  
rewound

Cart – mic, thermometer, pulse oximeter sensor, pad of paper , pencil, clipboard with  
pen, VAS-PI (3) , VAS-UNP (3), Emotion Presence (1), RadioShack sound  
level meter, tissues

Arm chair positioned under light

Turn on computer, CSL, oximeter, camcorder, printer

Silence oximeter alarm, pulse rate volume turned down

Synchronize clock on computer with camcorder

Camcorder to tripod. On standby. Camcorder remote near computer.

Microphone with clean windscreen to Channel 1 of CSL.

Open DATAQ – Open WinDaq File, name file (ddmmyy#), set file size to 2 hrs.,

STOP

Record file name and participant in log, Rasmussen data file folder named with ID  
number

WinDaq to RECORD

Calibrate oximeter and record

Analog – change 0 to 1 volt

Waveform menu

WinDaq to STOP/STBY after calibration

MDVP Advanced Program on, sampling rate to 44,100, Protocol - Multiple tokens;

Formant History settings to max number.

### Participant Session

Participant arrives and is accompanied to testing area

Restroom facilities pointed out and comfortable chair selected.

Availability of water and beverage of choice (will have been ascertained in telephone interview)

Explanation of the study and consent signed. Demographic information obtained. Vital signs, height, and weight measured.

Pain intensity, unpleasantness, and emotion presence recorded.

Instruments explained. Instrument packet and pencils provided.

Participant completes instruments while investigator available for questions.

Will take between 30-60 minutes. Provide beverage of choice.

Snack provided on completion of instruments.

Participant vital signs after written instruments completed.

Bathroom break before move to 310B

Walk the length of hall to elevator – monitor tolerance, time. Elevator to third floor and then walk to 310B.

Participant enters, to chair – observe ht and adjust camcorder to capture head when standing

Participant BP, HR, R, pain, unpleasantness, and emotion presence ratings recorded..

Drink of water, microphone, and oximeter fitted to participant

Check pulse ox. tracing

Check camcorder focus, to record using remote,

WinDaq to RECORD, write down time of start.

New file in CSL Main Program

Test intensity – 65 dB target with RadioShack meter on

Demonstrate and practice sustained phonation of /a/

using screen or clock to demonstrate 4 seconds, intensity needed, signals,

stop if need drink or break. Check CSL Analysis for intensity. Show filling of window on screen and play back.

Discard and start participant file in MVDP Advanced Program.

Review test with participant.

Event mark #1 before Cue. Click OK to record once participant has started.

Record and save each of five tokens to Raw Data-Participant ID# folder;

Attempt to record q. 30-45 sec

Record “My pain is about a \_\_\_\_.” Save as .wav

After Seated T4 – MDVP Analysis, Save as ID#a

Event mark x 2 – give verbal command to stand

Observe for Hands on armrests, back from chair, balance

Event mark x 3 – Back straight, fully standing.

Record and save each of five tokens to Raw Data-Participant ID# folder.

Attempt to record within a few seconds of fully standing. Then q. 30-45 sec.

for remaining tokens

Record “My pain is about a \_\_\_\_.” Save as .wav

After Standing T6 – MDVP Analysis, Save as ID#b.

Pain intensity and unpleasantness ratings and Emotion Presence form.

Participant may sit –

Event mark x 4 when seated. Write time.

Drink of water? Rest?

Repeat sitting and standing tasks

While sitting, record and save each of five tokens to Raw Data-Participant ID#folder;

Attempt to record q. 30-45 sec.

Record “My pain is about a \_\_\_\_.” Save as .wav

After Seated T8 – MDVP Analysis, Save as ID#c

Pain intensity and unpleasantness ratings and Emotion Presence form.

Event mark x 5 – give verbal command to stand

Observe for Hands on armrests, back from chair, balance

Event mark x 6 – Back straight, fully standing.

Record and save each of five tokens to Raw Data-Participant ID# folder.

Attempt to record within a few seconds of fully standing.

Then q. 30-45 sec. for remaining tokens

Record “My pain is about a \_\_\_\_.” Save as .wav

After Standing T10 – MDVP Analysis, Save as ID#d.

Pain and unpleasantness ratings and Emotion Presence form.

Participant may sit –

Event mark x 7 when seated. Write time.

Remove mic and oximeter sensor; measure BP, HR, R.

Drink of water?

WinDaq – make sure cal marks on file before EXIT, save to Desktop: file

“Rasmussen/ Raw Data/Participant#”

Camcorder to standby via remote

MDVP files to participant data folder; raw WinDaq file to data folder

Offer drink of water, incentive, comments envelope, and thanks. Accompany

participant to door and family member/car

Data Calibration and Save

Copy WinDaq file for calibration; rename copy,

Raw WinDaq in “Rasmussen” –“Raw Data” folder

Open WinDaq “Cal” file

Cursor at 0 point of calibration

Highlight channel; Edit

Low cal – SpO2 0, Engr = %; HR 20, Engr=BPM

Cursor to well into 1 point of calibration

High Cal – SpO2 100; HR 255

Once WinDaqCal file calibrated – Save all

Move WinDaqCal file to Desktop:RasmussenData – Cal Data folder#

Remove camcorder tape

Rewind – note total time of recording

Follow steps of digitizing protocol, burn CD

CD to computer CD-ROM, open

Drag sound files and WinDaq files in Desktop:RasmussenData folder ID #

to “data” box on right

Right click to initiate CD burning

Label with ID# using permanent marker; Store in jewel case in locked file.

Archive copy made



## Appendix 20. Equipment Set-Up

## Equipment Set-Up

### Monster Surge Protector

Plug into outlet to reduce 60-cycle interference

Mounted on cart.

### Check Tires

### Dell Optiplex Desktop Computer

Power supply to power strip

Turn on

Click on Clock to show setting information

### Sony Digital x 360 Camcorder, power cord

Spare batteries for remote

Install 8 mm tape – make sure it is free of recording, rewind

Turn on, open viewer

Menu – Clock setting

Set date, clock to 1 minute ahead of computer clock

Press Menu – Clock –

when computer clock reaches 59 seconds to synchronize with  
computer;

compare to computer clock.

Close Menu.

Attach to tripod – adjust height, attach power cord, focus on chair

Remote to STBY.

May need to push red standby button to activate if wait is too long.

### Datex-Ohmeda 3900/3900P Pulse Oximeter

Plug unit to power strip

Connection of pulse oximeter to Dataq Di-158U A-D converter

Analog inputs -  $\text{spO}_2$  , pulse rate, event marker

A-D converter to computer via USB port

Press Power button

Turn HR volume down to lowest setting, alarm off

Pad of paper and pencil to record time of recording

Clipboard for participant forms

Bottled water, chilled, for participant

Hewlett-Packard 5940 DeskJet printer

Available to print radial graph of MDVP Analysis, Letter to HCP

Adequate ink in tricolor and black ink cartridges

Adequate paper supply

WinDaq Data Acquisition Program

Select DATAQ Instrument Hardware Manager program icon

“Find Devices”

“Start WinDaq”

File

Record

Name File – ddmmyy#

Change recording time from 0 to 2 hours

OK

Check the voltage limits on each channel. Adjust in Options-Limits if necessary

Pulse rate and spo2 should be -1.25 and +1.25. Event marker -2 and +2

Oximeter Calibration

Press Menu button

Press button next to Settings on screen

Press first button - associated with arrow down - to move to Analog

Change from 0 to 1.0 volt by pressing second button associated with +/-

Watch waveform on WinDaq file

Should see the increase to .5 and 1.0 volt

Allow to run for 3 seconds

Resume 0 volt setting to end calibration mark step

Change from Menu to Waveform, Alarm off

Place sensor on finger to observe waveform on oximeter and WinDaq

Remove sensor

WinDaq to STOP/STBY until participant arrives

#### CSL – Sound Conditioning Unit

Press “Power” button

Gain set at second mark on Channel 1

Do not press MRP button

#### AKG-C420 Head-Mounted Microphone

Insert mic head into clean foam windshield

(cleaned with antibacterial detergent and dried after each participant; rotation of 4 windscreens)

Insert XLR connection of mic into Channel 1 XLR connection CSL

Once CSL on – press F12 to check mic is recording

#### Earphones

Insert in earphone input of CSL

#### CSL Programs

CSL – ready for demo and to test participant intensity,

Multi-Dimensional Voice Program (MDVP)

Multi-Dimensional Voice Program (MDVP) Advanced

#### RadioShack Sound Level Meter

Batteries functioning? Extra available on cart

## Appendix 21. Recording Session Protocol

## Recording Session Protocol

### Participant Preparation

Participant arrives after completion of instruments, snack, ht and wt measurement

Welcome, assess tolerance of walking,

Have participant stand in front of chair briefly

- Focus camera

- Adjust for standing height

Seat in Chair, ask to sit with back close to back of chair

Turn camcorder to RECORD, write the time on pad

- Take vital signs

Obtain pain intensity, pain unpleasantness, and emotion presence ratings

Bottle of water within participant's reach.

### Oximeter to Seated Participant

Explain oximeter, place sensor on participant

- Non-dominant hand, middle finger,

- Make sure Waveform setting is observed

- WinDaq to RECORD

Observe waveform on oximeter screen

- Should note voltage changes in spO2 and HR recordings on WinDaq

### Microphone to Seated Participant

Explain microphone and CSL. Position mic on participant

Note if hearing aid (?feedback)

- Remove glasses first if present

- Place mic, adjust to fit snugly to back of head to minimize shifting when standing

- Replace glasses

- Position mic head 4 cm (use small ruler), 45 degree angle from lips

Show participant how to signal (hand to mouth like holding a glass) if needing drink

## CSL Practice

Open CSL Main Program

Demonstrate recording to reduce anxiety – Name file #p

Ask participant to say /a/ when cued by hand

Cue; Press F12

Participant says /ə/ at normal sound level for 4 sec, fill screen

Press Space bar to stop

Activate B window

Select CSL Analysis/Energy Contour/

Note intensity on RadioShack Sound level meter – must be 30-40 dB  
over room noise of 30 dB – about 65dB

If not reaching 60 dB, practice until level is obtained

## Vocalization Recording

Select “MDVP Advanced”

Record mono sound

Set sampling rate at 44.1 kHz

Set Formant History at “36”

Participant to phonate /ə/ for 4 secs to fill screen

Have Participant Practice /ə/ and “My pain is about a \_\_\_\_.”

Refer to visual aids prior to task

Cue to start

Click OK to record when phonation begins

Press space bar to stop recording when screen filled

Nod to participant to stop.

MDVP Analysis/Energy Contour – Check for intensity

#### Seated Recordings -Time 4

WinDaq - Event Mark #1 to indicate start of recordings

MDVP Advanced Program – Protocols/Multiple Tokens/Record and Analyze

Five Tokens

Settings – sampling at 44.1 kHz, formant hx at 36

Window should appear asking if you wish to record

If inadequate sample, do not save but repeat the recording until 5 adequate tokens are obtained

Seated #T4 – name #a file,

Hand Cue to begin /ə/ 4 secs

Press OK – continue to fill screen, space bar to stop recording

Save recording to Raw Data folder - #a1

Observe radial graph

Aim for 30-45 seconds between recordings

Seated #a2 – name file #a2

Hand Cue to begin /ə/ 4 secs

Press OK – continue to fill screen, space bar to stop recording

Save recording to Raw Data folder - #a2

Observe radial graph

Seated #a3 – name file #a3, Hand Cue to begin

Hand Cue to begin /ə/ 4 secs

Press OK – continue to fill screen, space bar to stop recording

Save recording to Raw Data folder - #a3

Observe radial graph



Seated #a4– name file #a4, Hand Cue to begin

Hand Cue to begin /ə/ 4 secs

Press OK – continue to fill screen, space bar to stop recording

Save recording to Raw Data folder - #a4

Observe radial graph

Seated #a5 – name file #a5 Hand Cue to begin

Hand Cue to begin /ə/ 4 secs

Press OK – continue to fill screen, space bar to stop recording

Save recording to Raw Data folder - #a5

Observe radial graph

While seated, participant ready? Has visual aid?

Name file #apain”

Hand cue to begin

Says “My pain now is about a (0-10).”

Participant remains seated.

Completes pain rating and unpleasantness rating and Emotion

Presence forms

Select MDVP Analysis/NumericalData

Type in Participant ID#T4 as “Name”

“Save”

Type of File – “All Files”

Select “Comma”

Save in Raw Data folder/Participant ID#

“Need a drink?”

## Standing Recordings – Time 6

WinDaq Event Mark #2

Instruct participant you will cue next recordings to occur after  
she stands

Event mark prior to command

Instruct to stand

WinDaq Event mark #3 when back straight after fully standing

Select MDVP Advanced/ Protocol/Multiple Tokens/Record  
and Analyze 5 Tokens

Standing #b1– name file #b1

Hand Cue to begin /ə/ 4 secs

Press OK – continue to fill screen, space bar to stop recording

Save recording to Raw Data folder - #b1

Observe radial graph

Standing #b2 – name file #b2

Hand Cue to begin /ə/ 4 secs

Press OK – continue to fill screen, space bar to stop recording

Save recording to Raw Data folder - #b2

Observe radial graph

Standing #b3 – name file #b3

Hand Cue to begin /ə/ 4 secs

Press OK – continue to fill screen, space bar to stop recording

Save recording to Raw Data folder - #b3

Observe radial graph

Standing #b4– name file #b4

Hand Cue to begin /ə/ 4 secs

Press OK – continue to fill screen, space bar to stop recording

Save recording to Raw Data folder - #b4

Observe radial graph

Standing #b5 – name file #b5

Hand Cue to begin /ə/ 4 secs

Press OK – continue to fill screen, space bar to stop recording

Save recording to Raw Data folder - #b5

Observe radial graph

MDVP Advanced/Protocol/MDVP Analysis/Numerical

Type Participant ID#b as “Name”

Save As Type – “All Files”

Select “Comma”

Select “Raw Data Folder/Participant ID#”

Name file #bpain

Participant standing – ready? has visual aid?

Hand cue to begin

Says “My pain now is about a (0-10).”

Save file as bpain.wav

Participant Remains Standing

Completes pain rating and unpleasantness rating and Emotion Presence forms

Participant Sits

WinDaq Event Marker #4 when seated

When participant feels rested, has had a drink, and restroom break, recording session resumes.

### Seated Recordings – Time 8

Seated #c1 – name #c1 file,

Hand Cue to begin /ə/ 4 secs

Press OK – continue to fill screen, space bar to stop recording

Save recording to Raw Data folder - #

Observe radial graph

Aim for 30-45 seconds between recording

Seated #c2 – name file #c2

Hand Cue to begin /ə/ 4 secs

Press OK – continue to fill screen, space bar to stop recording

Save recording to Raw Data folder - #

Observe radial graph

Seated #c3 – name file #c3, Hand Cue to begin

Hand Cue to begin /ə/ 4 secs

Press OK – continue to fill screen, space bar to stop recording

Save recording to Raw Data folder - #c3

Observe radial graph

Seated #c4 – name file #c4, Hand Cue to begin

Hand Cue to begin /ə/ 4 secs

Press OK – continue to fill screen, space bar to stop recording

Save recording to Raw Data folder - #c4

Observe radial graph

Seated #c5 – name file #c5, Hand Cue to begin

Hand Cue to begin /ə/ 4 secs

Press OK – continue to fill screen, space bar to stop recording  
Save recording to Raw Data folder - #c5  
Observe radial graph

While seated, participant ready? Has visual aid?

Name file #cpain

Hand cue to begin

Says “My pain now is about a (0-10).”

Participant remains seated.

Completes pain rating and unpleasantness rating and Emotion

Presence forms

Select MDVP Analysis/NumericalData

Type in Participant ID#cpain as “Name”

“Save”

Type of File – “All Files”

Select “Comma”

Save in Raw Data folder/Participant ID#

“Need a drink?”

### Standing Recordings - Time 10

WinDaq Event Mark #5 – Before command

Instruct participant you will cue next recordings to occur after she  
stands

Instruct to stand

WinDaq Event mark #6 when back straight after fully standing

Select MDVP Advanced/ Protocol/Multiple Tokens/Record and Analyze 5 Tokens

Standing #d1 – name file #d1

Hand Cue to begin /ə/ 4 secs

Press OK – continue to fill screen, space bar to stop recording

Save recording to Raw Data folder - #

Observe radial graph

Standing #d2 – name file #d2

Hand Cue to begin /ə/ 4 secs

Press OK – continue to fill screen, space bar to stop recording

Save recording to Raw Data folder - #

Observe radial graph

Standing #d3 – name file #d3

Hand Cue to begin /ə/ 4 secs

Press OK – continue to fill screen, space bar to stop recording

Save recording to Raw Data folder - #

Observe radial graph

Standing #d4 – name file #d4

Hand Cue to begin /ə/ 4 secs

Press OK – continue to fill screen, space bar to stop recording

Save recording to Raw Data folder - #

Observe radial graph

Standing #d5 – name file #d5

Hand Cue to begin /ə/ 4 secs

Press OK – continue to fill screen, space bar to stop recording

Save recording to Raw Data folder - #

Observe radial graph

MDVP Advanced/Protocol/MDVP Analysis/Numerical

Type Participant ID#dpain as “Name”

Save As Type – “All Files”

Select “Comma”

Select “Raw Data Folder/Participant ID#”

Participant Remains Standing

Hand cue to begin

Says “My pain now is about a (0-10).”

Name file #dpain

Completes pain intensity rating, unpleasantness rating and  
Emotion Presence forms

Participant Sits

WinDaq Event Marker #7 when seated

Video camcorder to STANDBY.

Note time on pad for length of recording

Remove oximeter sensor

Take off glasses

Remove Mic

Replace glasses

Obtain Vital signs – record on data sheet

Participant given Comments sheet and envelope

Provide Incentive and Thanks

Escort/Assist to car

## Appendix 22. Verbal Rating of Pain Visual Aid



My pain now is

383

about a \_\_\_\_\_.

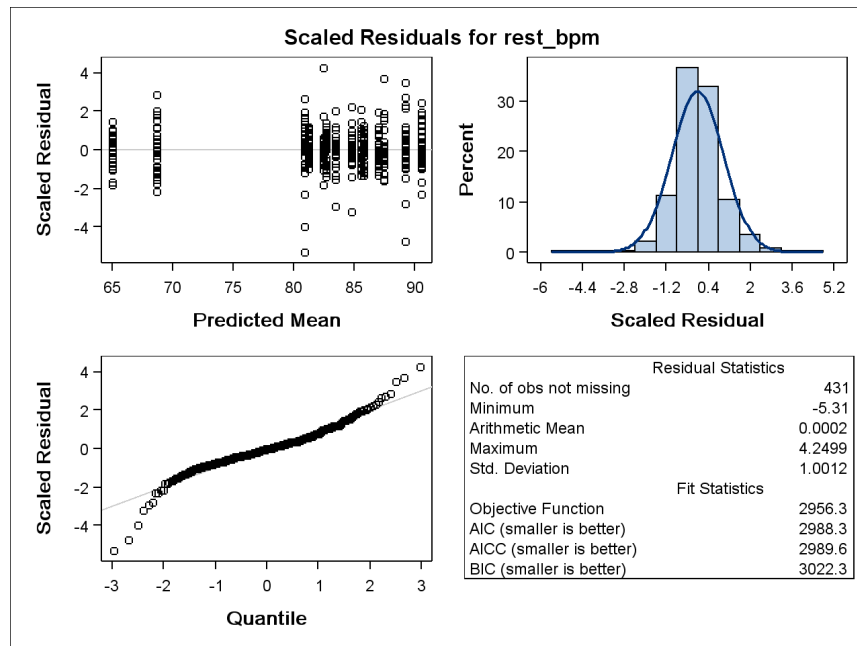
NO  
PAIN

PAIN AS  
BAD AS I  
CAN  
IMAGINE

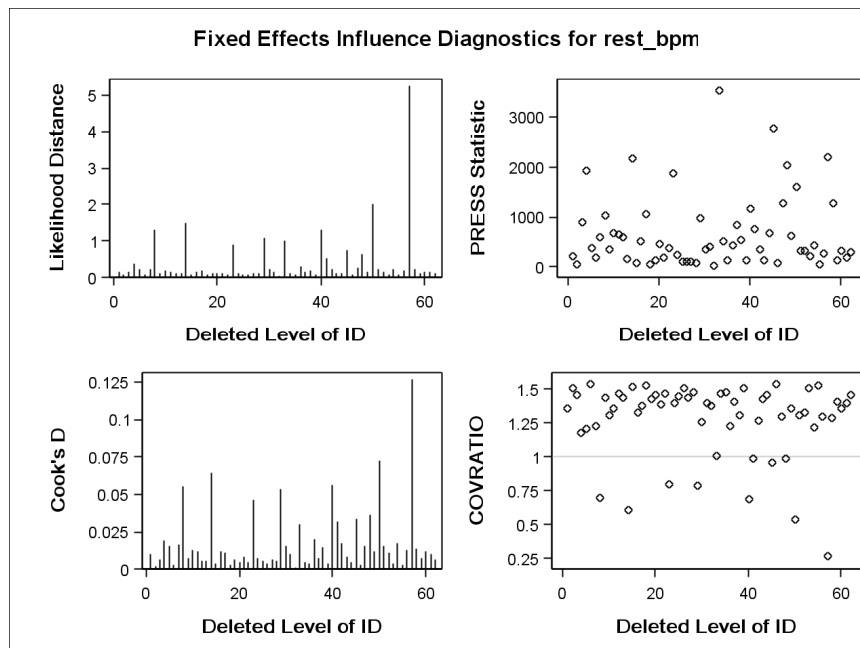
0	1	2	3	4	5	6	7	8	9	10
---	---	---	---	---	---	---	---	---	---	----

## Appendix 23. PROC MIXED Influence Diagnostics Graphic Output

## Research Question 1. Change in Pulse Rate with Movement

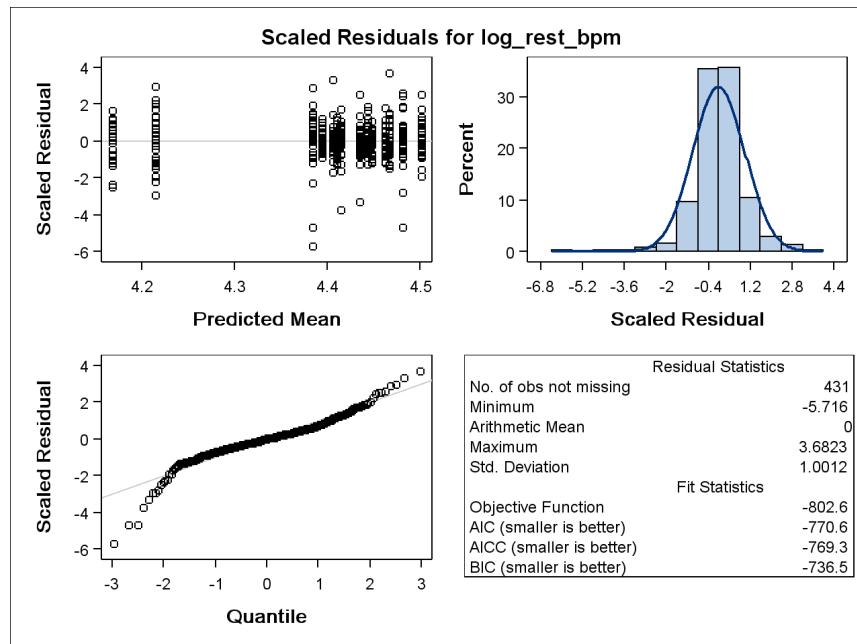


Plot of residuals for original model of pulse rate change with movement tasks.

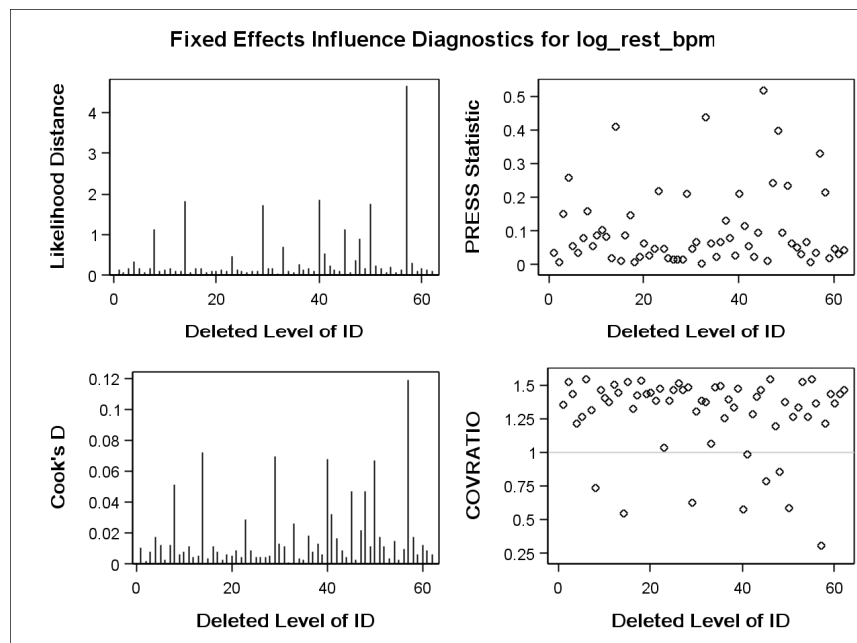


Influence diagnostics of original model of pulse rate change with tasks.

# Research Question 1 (Continued). Change in Pulse Rate with Movement

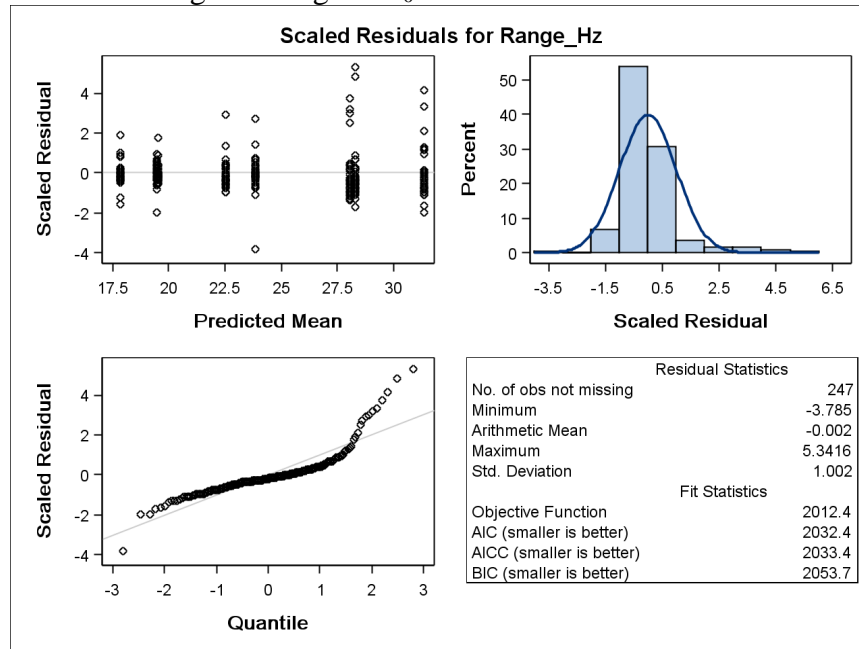


Plot of residuals of log transformed model of pulse rate change with movement tasks.

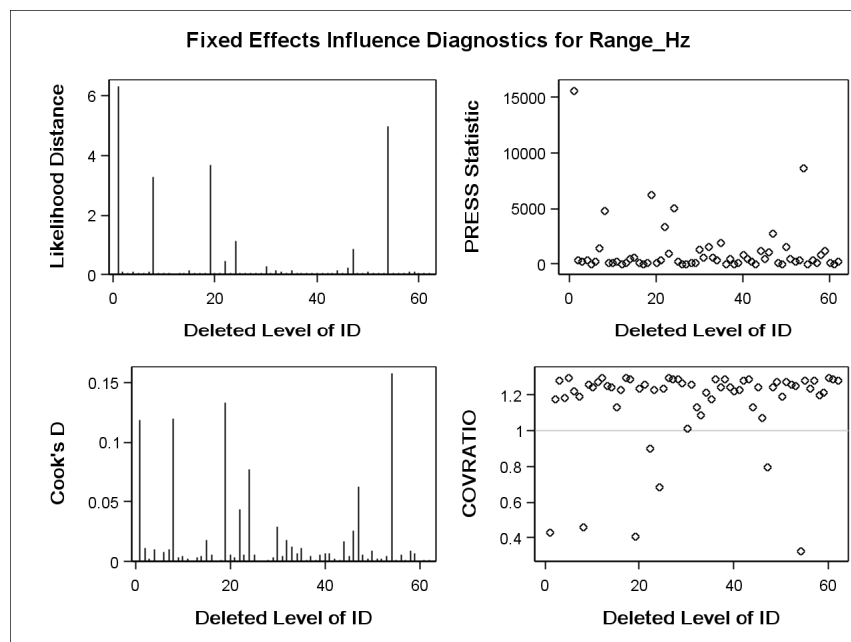


Influence diagnostics of log transformed model for pulse change with tasks.

## Research Question 2. Change in Range of $F_0$ with Tasks

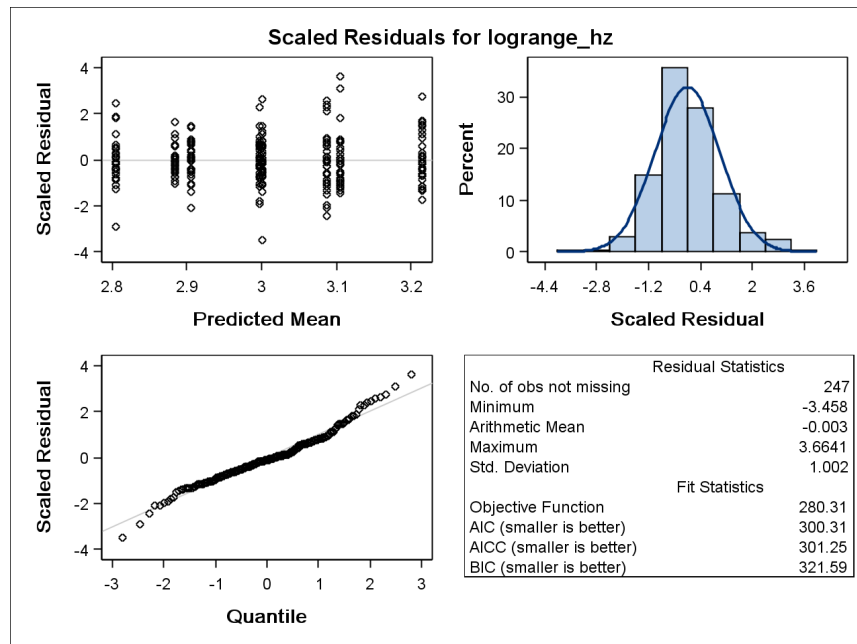


Plot of residuals for original model of range of fundamental frequency with reduced data set.

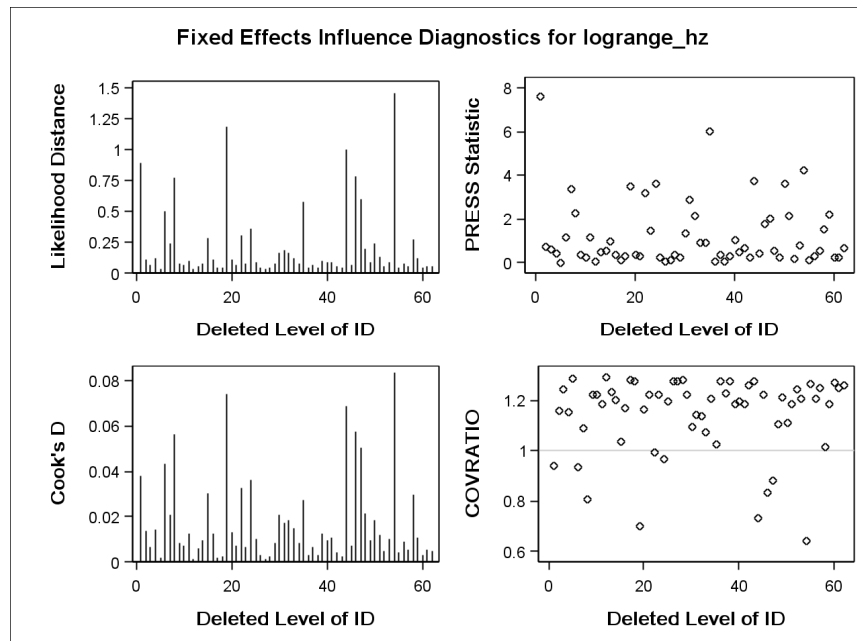


Influence diagnostics of original model of range of fundamental frequency with reduced data set.

## Research Question 2 (Continued). Change in Range of $F_0$ with Tasks

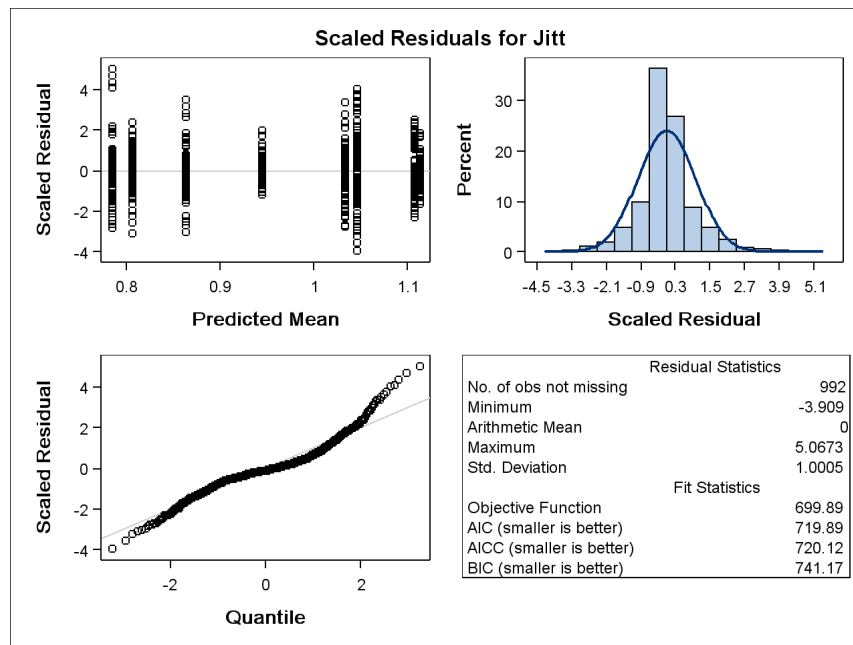


Plot of residuals of log transformation model of range of fundamental frequency with reduced data set.

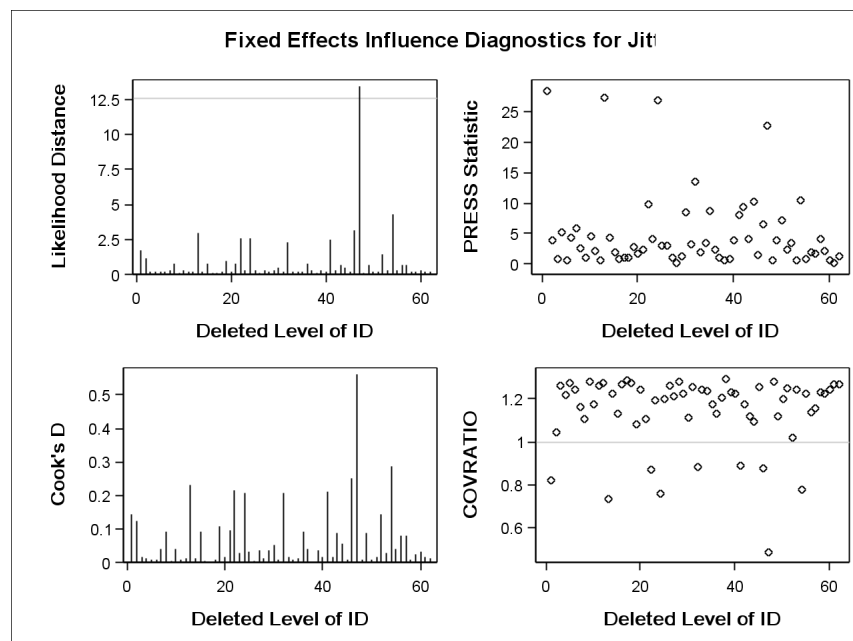


Influence diagnostics of log transformation model of range of fundamental frequency with reduced data set.

## Research Question 2 (Continued). Change in Jitter with Tasks



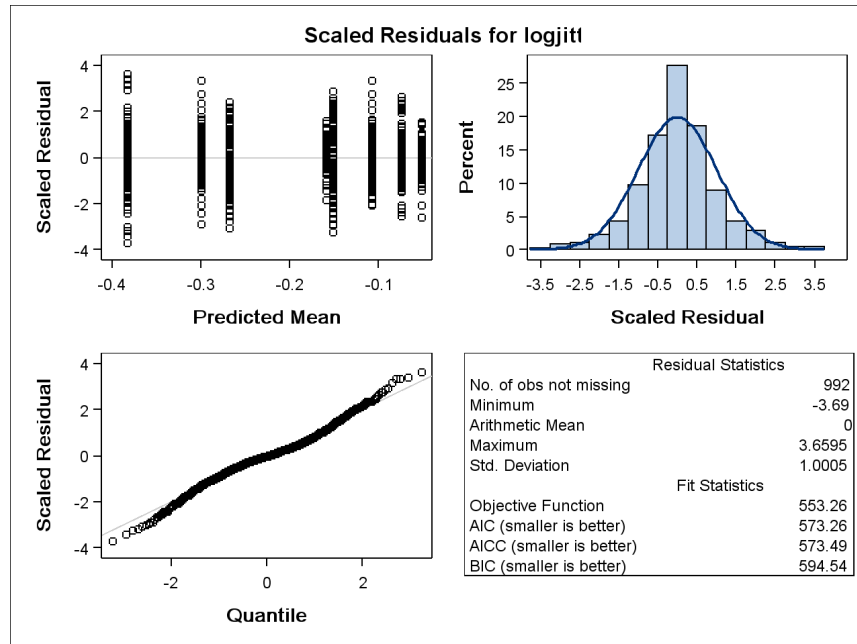
Plot of residuals for original model of jitter in percent



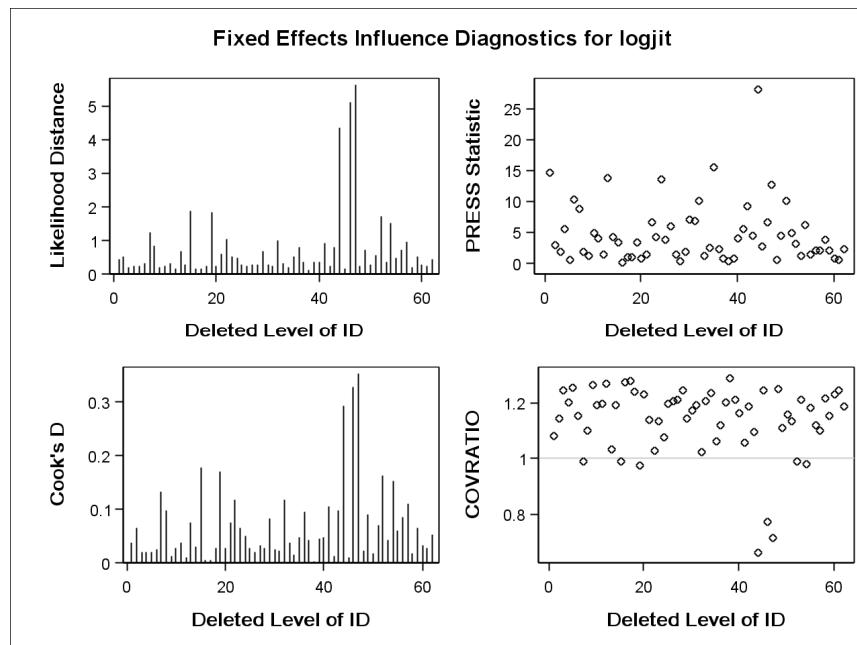
Influence diagnostics of original model of jitter in percent.



## Research Question 2 (Continued). Change in Jitter with Tasks

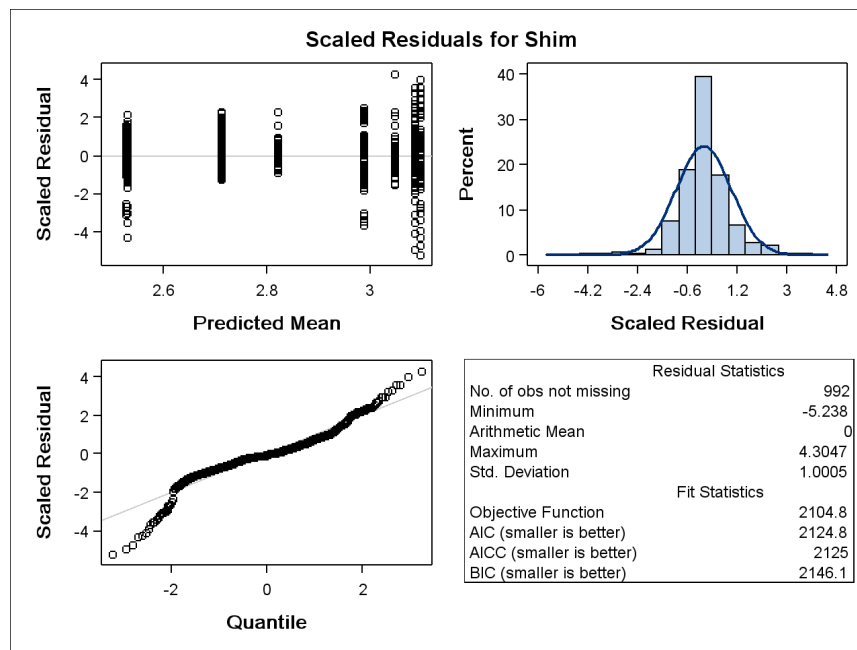


Plot of residuals for log transformation model of jitter in percent.

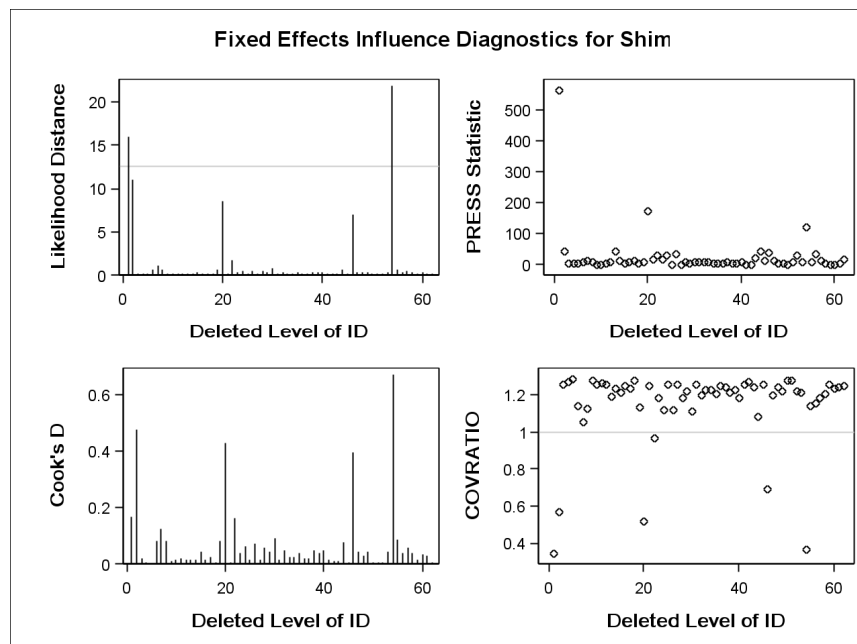


Influence diagnostics of log transformation model of jitter in percent.

## Research Question 2 (Continued). Change in Shimmer with Tasks

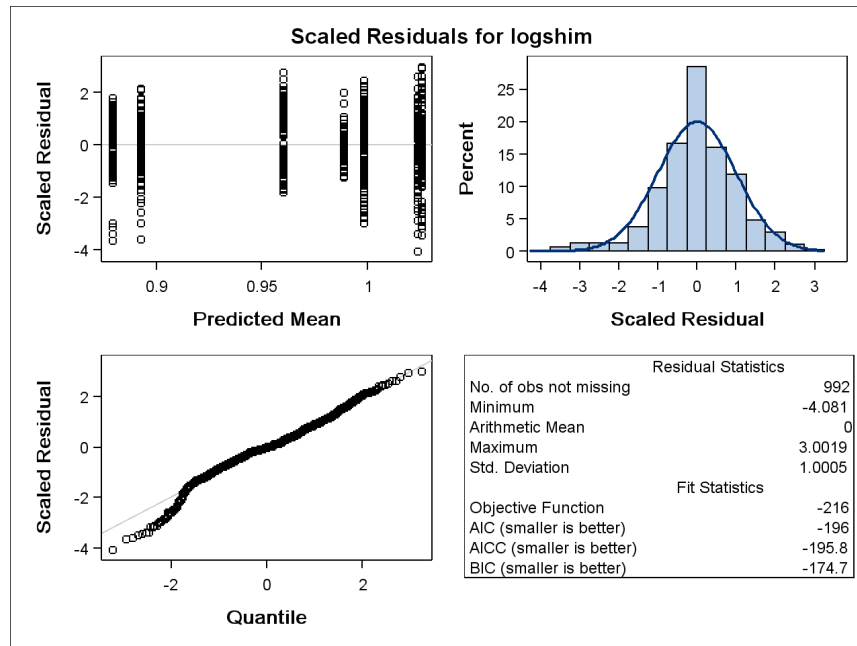


Plot of residuals for original model of shimmer.

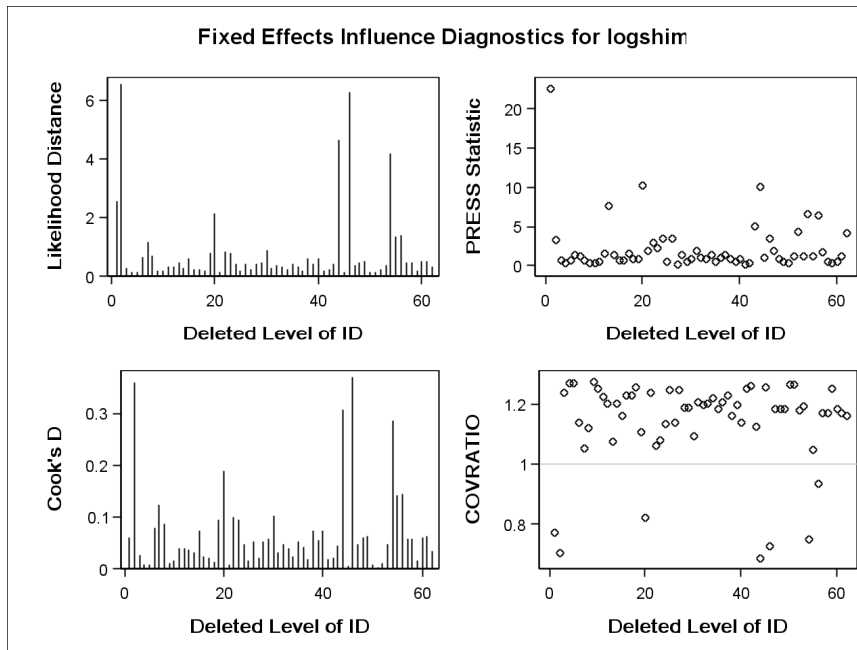


Influence diagnostics for original model of shimmer.

## Research Question 2 (Continued). Change in Shimmer with Tasks

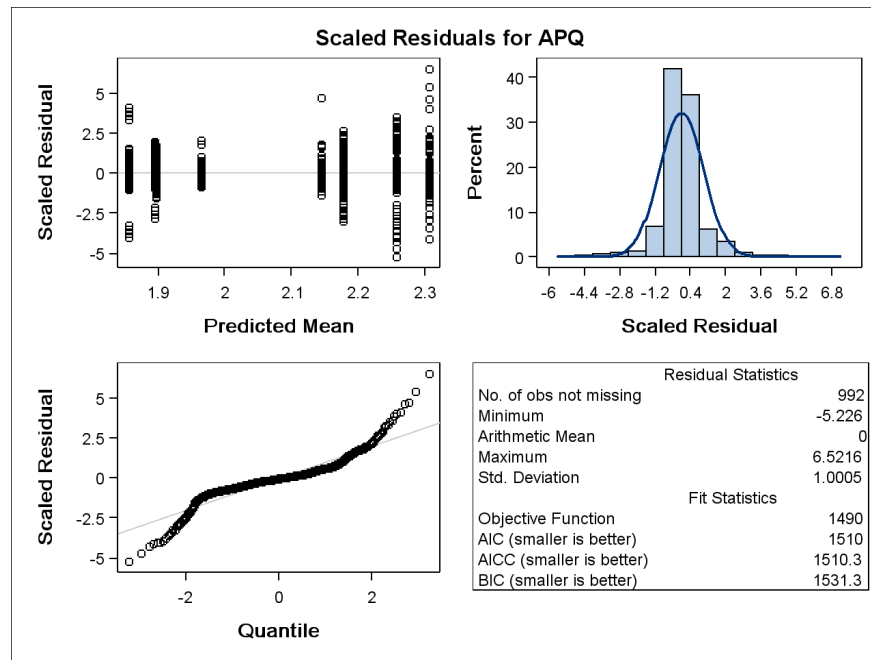


Plot of residuals for log transformation model of shimmer.

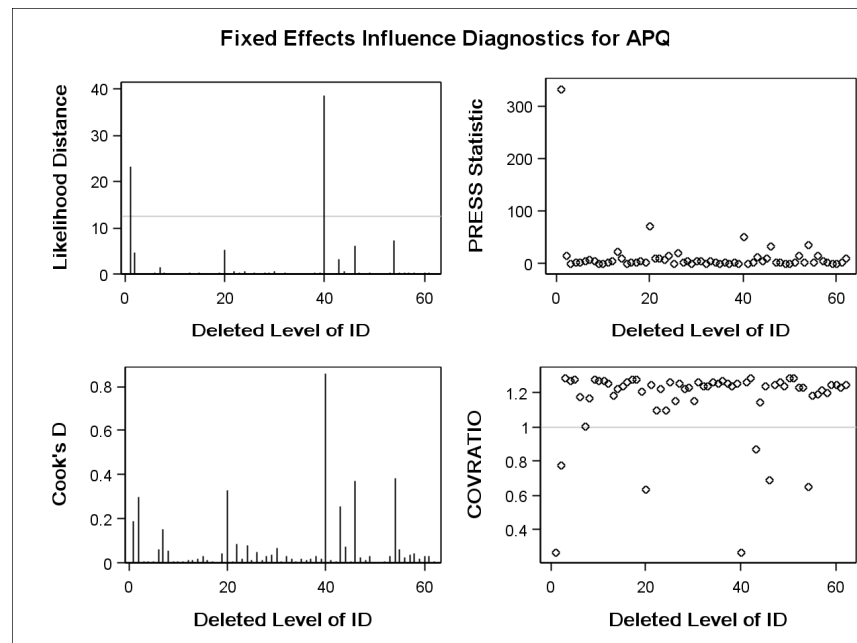


Influence diagnostics of log transformation model of shimmer.

## Research Question 2 (Continued). Change in Amplitude Perturbation Quotient with Tasks

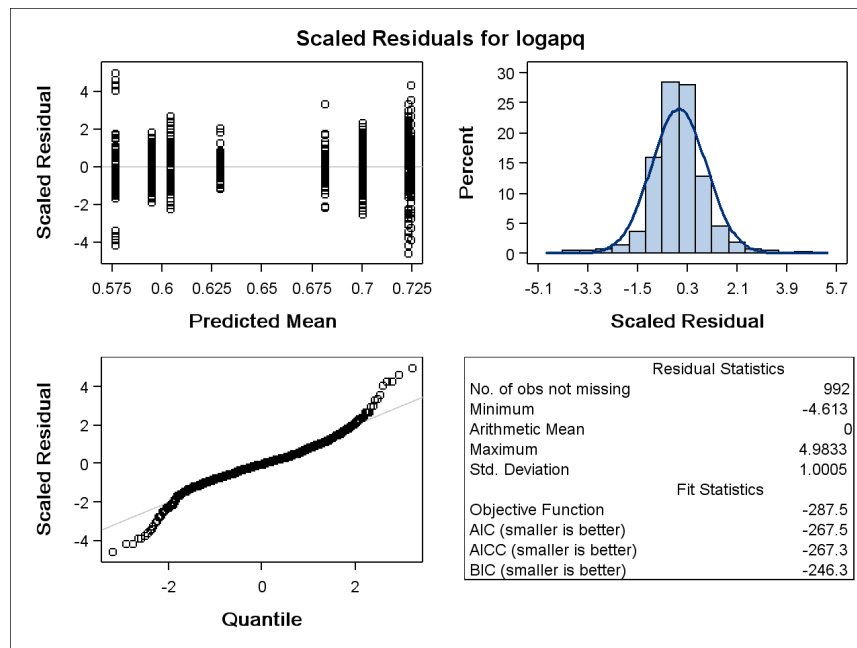


Plot of residuals for original model of APQ.

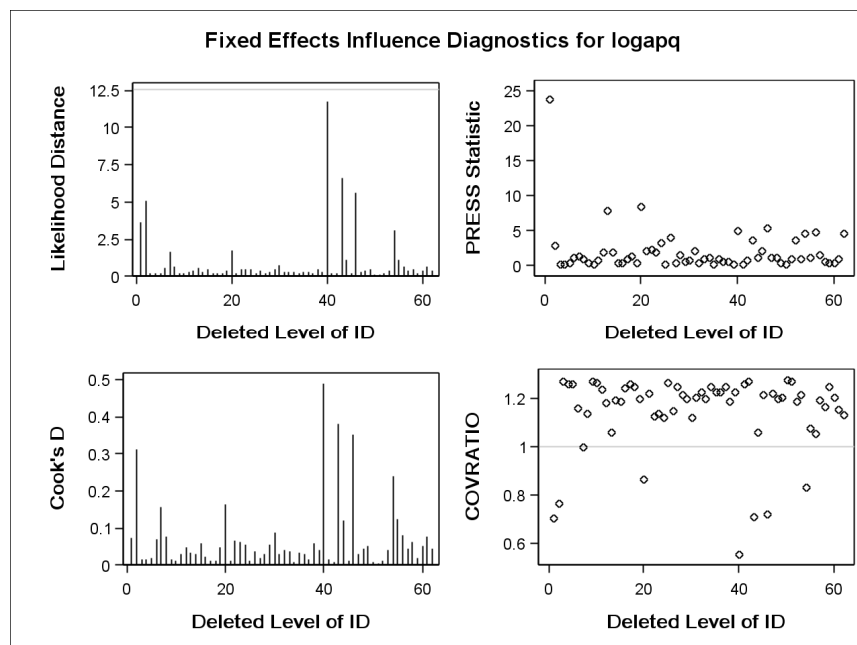


Influence diagnostics of original model of APQ.

## Research Question 2 (Continued). Change in Amplitude Perturbation Quotient with Tasks

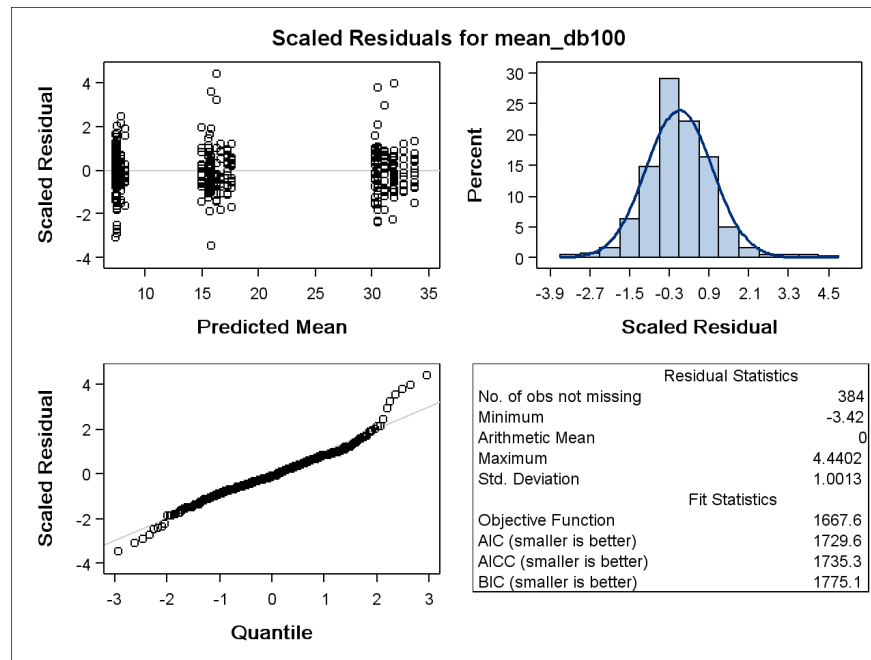


Plot of residuals for log transformation model of APQ.

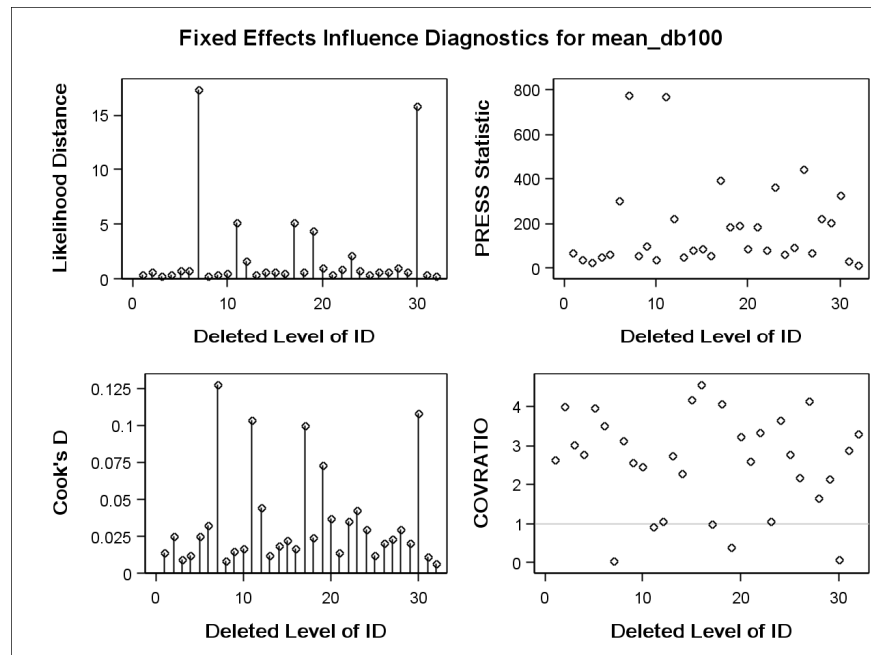


Influence diagnostics of log transformation model of APQ.

### Research Question 3. Change in Formant Frequencies with Tasks Related to Pain Intensity

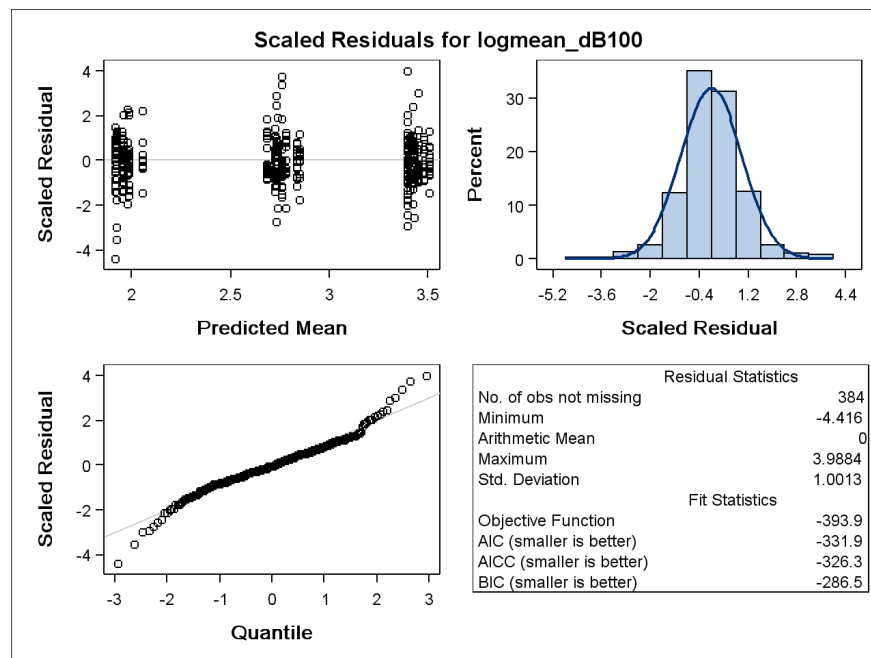


Plot of residuals of original model of formant frequencies related to pain intensity over tasks.

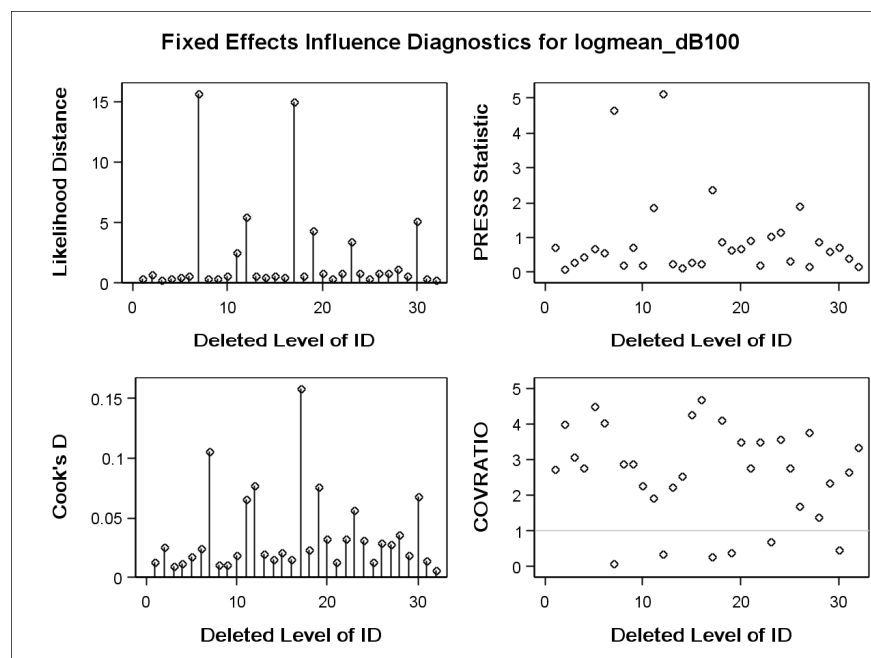


Influence diagnostics of original model of formant frequencies.

### Research Question 3. Change in Formant Frequencies with Tasks Related to Pain Intensity

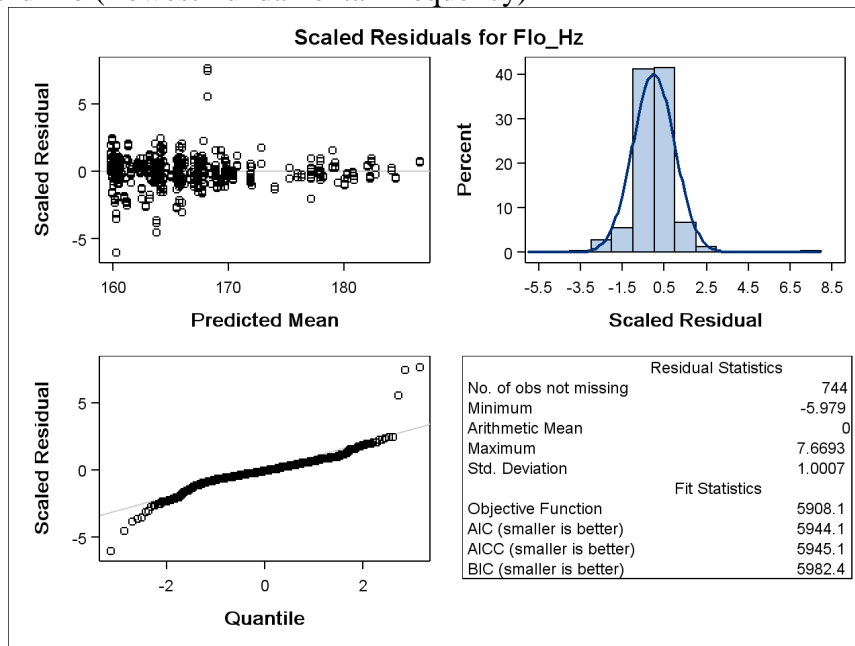


Plot of residuals of log transformation model of formant frequencies related to pain intensity over tasks.

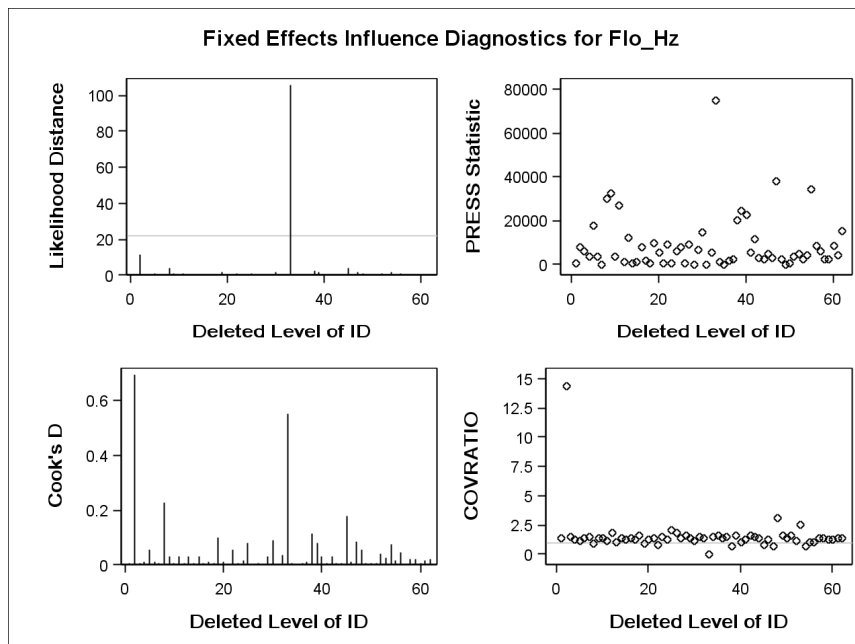


Influence diagnostics of log transformation model of formant frequencies.

Research Question 4. Change in Acoustic Parameters with Psychological Variables – Depression and Flo (Lowest Fundamental Frequency)



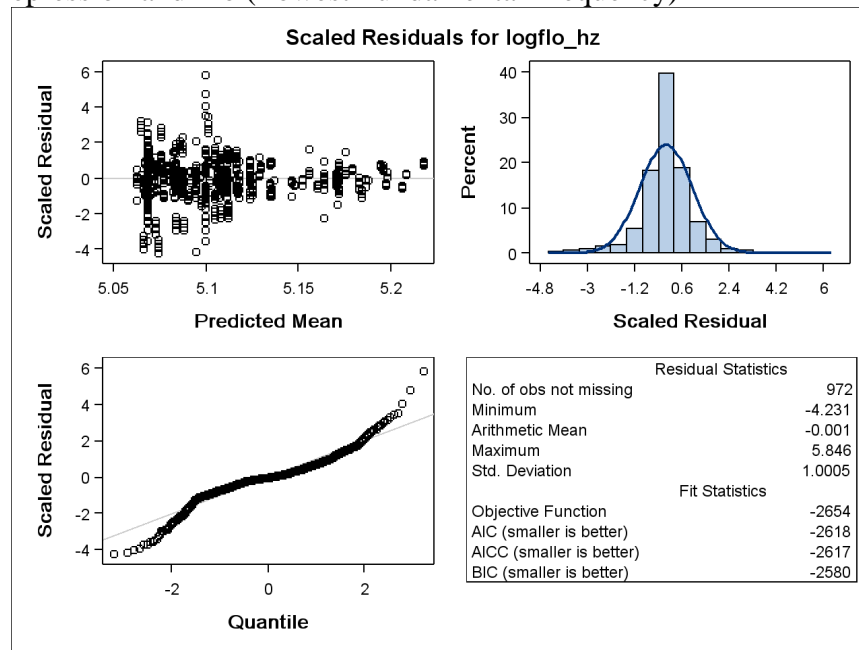
Plot of residuals of original model for interaction of depression with lowest fundamental frequency.



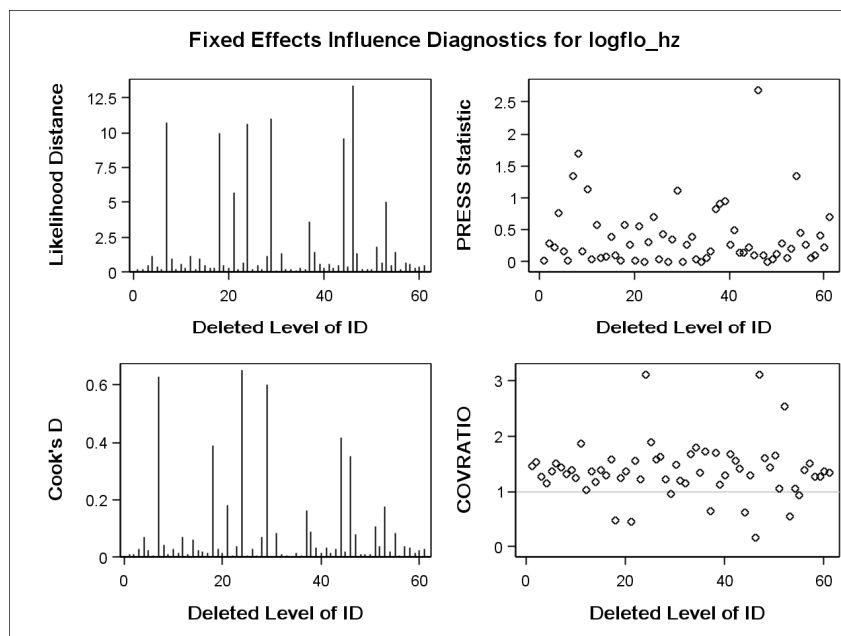
Influence diagnostics for original model for interaction of depression with lowest fundamental frequency.



Research Question 4 (Continued). Change in Acoustic Parameters with Psychological Variables –Depression and Flo (Lowest Fundamental Frequency)

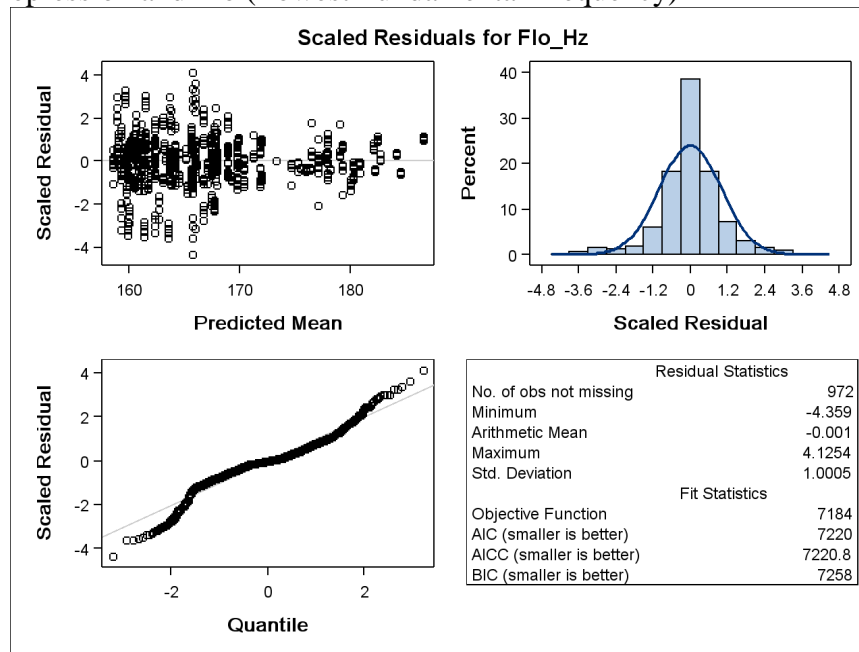


Plot of residuals for log transformation of original model of interaction of depression with lowest fundamental frequency.

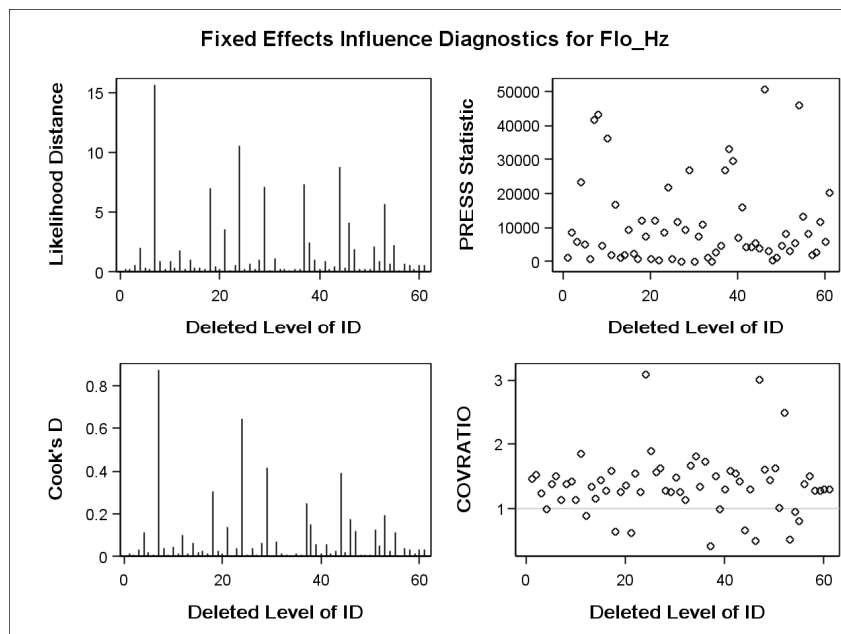


Influence diagnostics for log transformation of original model of interaction of depression with lowest fundamental frequency.

Research Question 4 (Continued). Change in Acoustic Parameters with Psychological Variables –Depression and Flo (Lowest Fundamental Frequency)

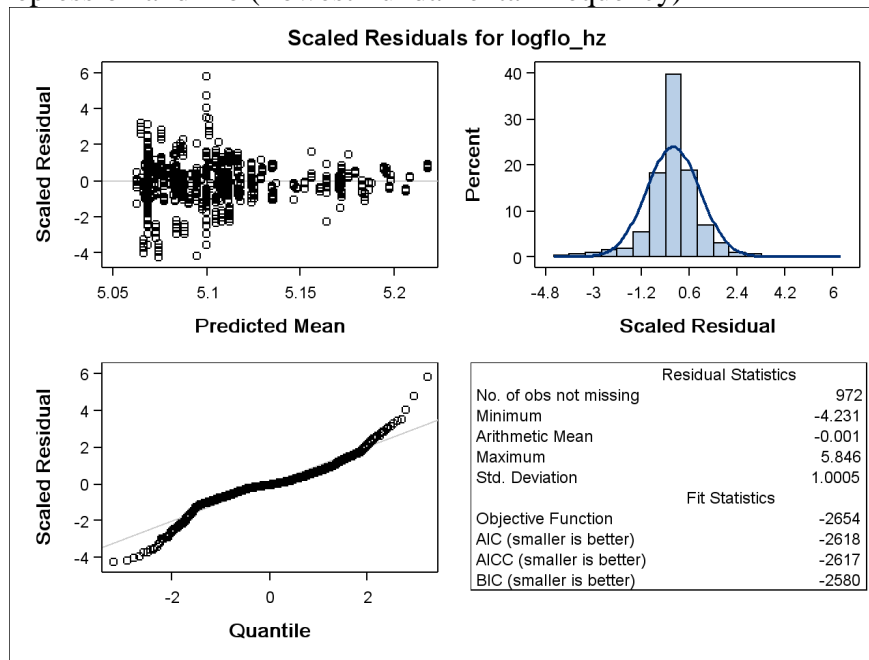


Plot of residuals of reduced model for interaction of depression on lowest fundamental frequency.

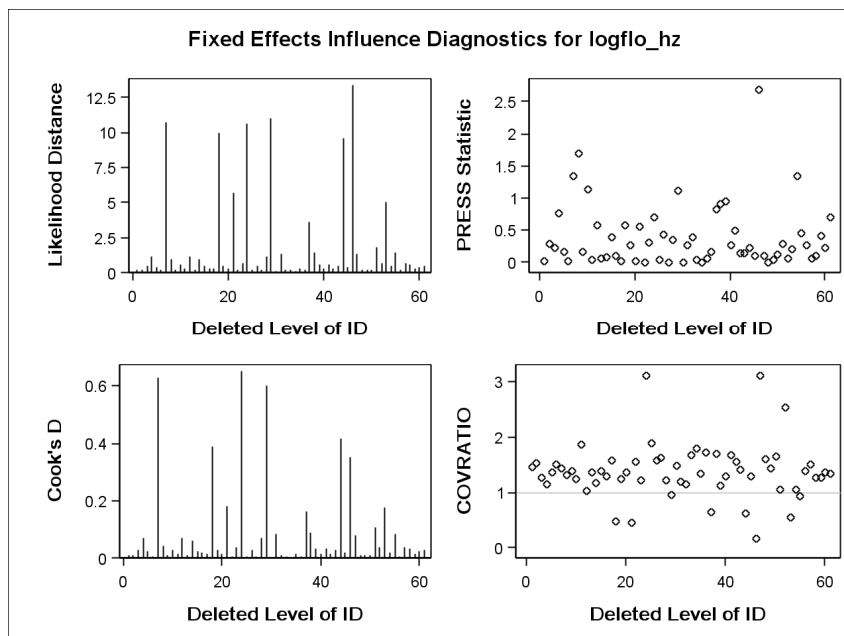


Influence diagnostics of reduced model for interaction on depression on lowest fundamental frequency.

Research Question 4 (Continued). Change in Acoustic Parameters with Psychological Variables –Depression and Flo (Lowest Fundamental Frequency)

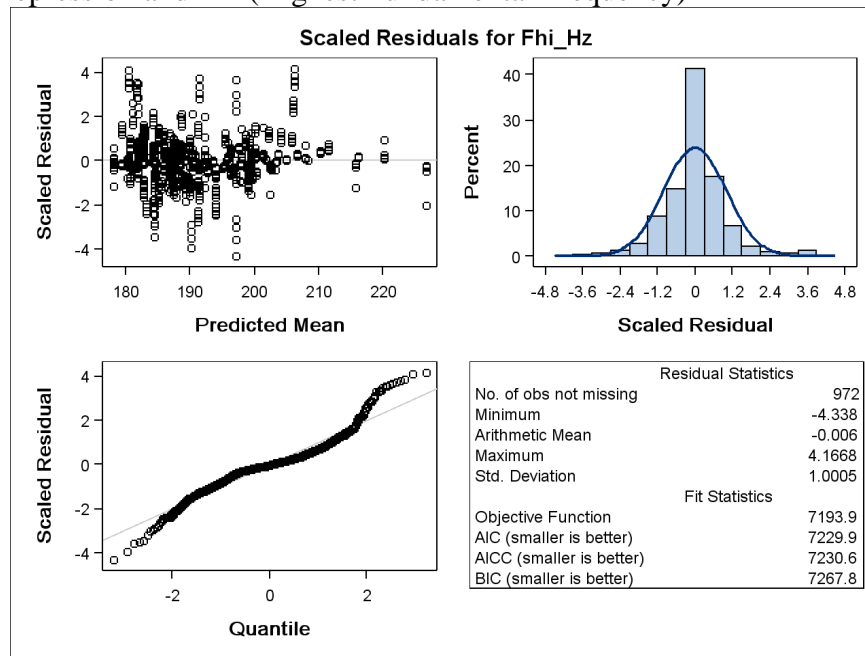


Plot of residuals for log transformation of reduced model of interaction of depression with lowest fundamental frequency.

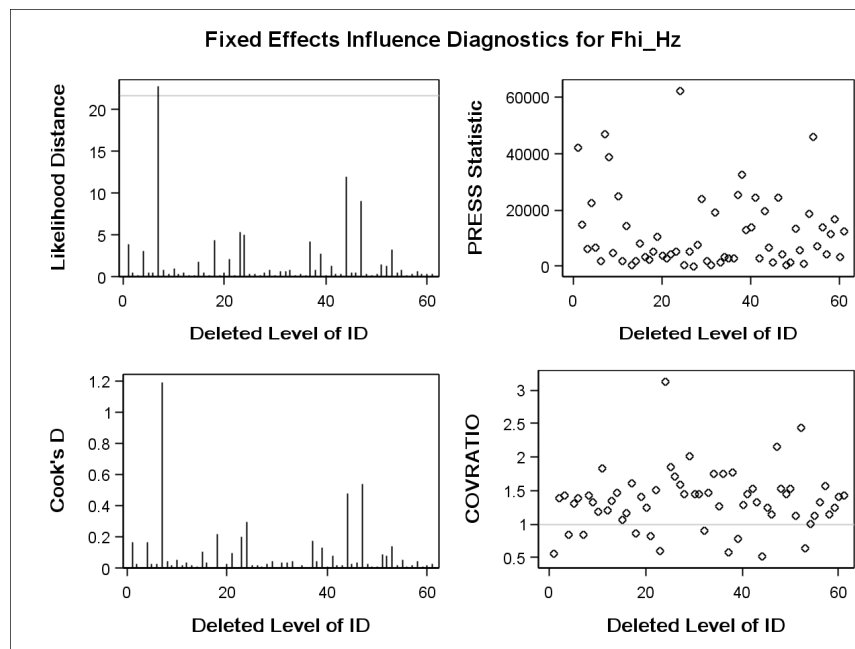


Influence diagnostics of log transformation of reduced model of interaction of depression with lowest fundamental frequency.

Research Question 4 (Continued). Change in Acoustic Parameters with Psychological Variables –Depression and Fhi (Highest Fundamental Frequency)

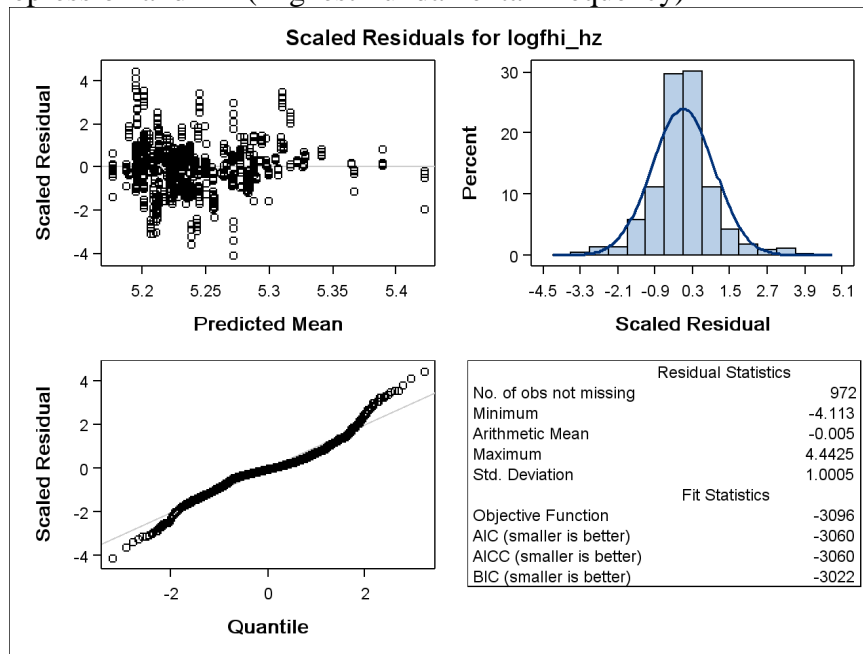


Plot of residuals of reduced model for interaction of depression with highest fundamental frequency with new BDI-II sample mean.

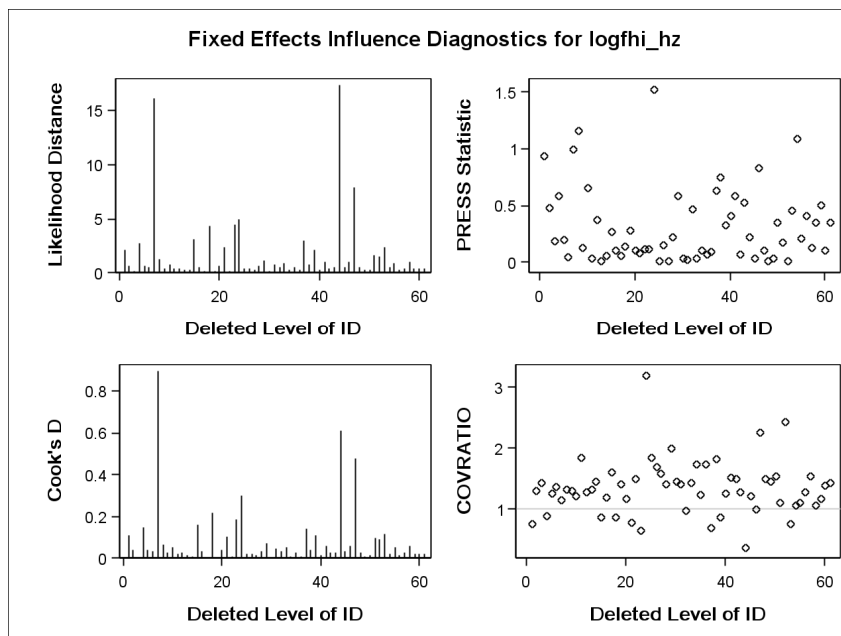


Influence diagnostics of reduced model for interaction of depression with highest fundamental frequency with new BDI-II sample mean.

Research Question 4 (Continued). Change in Acoustic Parameters with Psychological Variables –Depression and Fhi (Highest Fundamental Frequency)

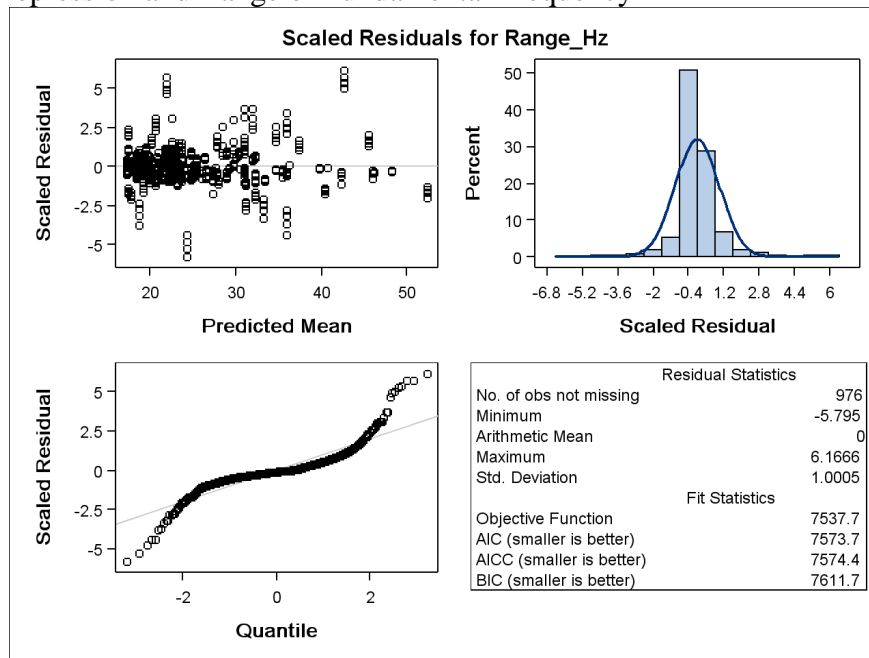


Plot of residuals for log transformation of reduced model of interaction of depression with highest fundamental frequency with new BDI-II sample mean.

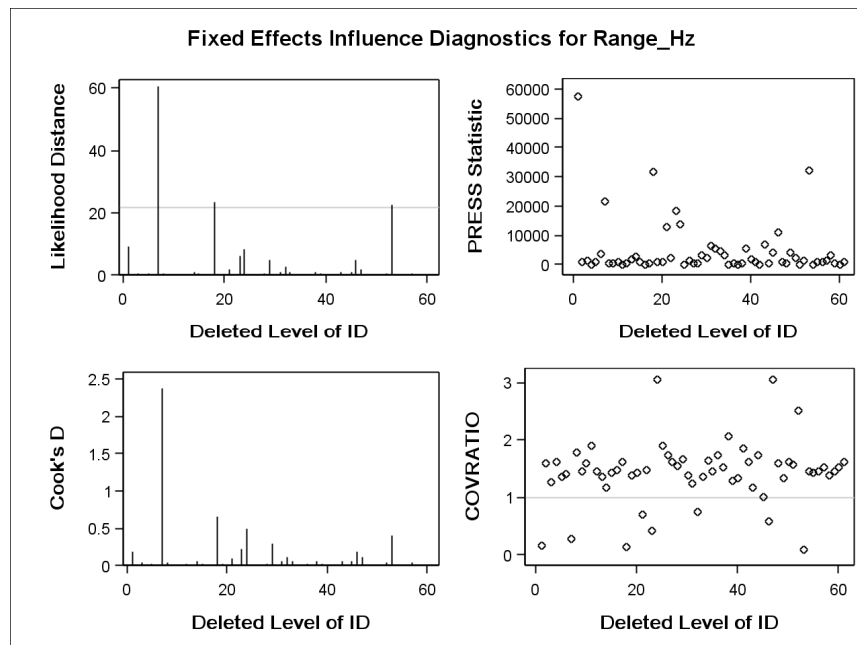


Influence diagnostics of log transformation of reduced model of interaction of depression with highest fundamental frequency with new BDI-II sample mean.

Research Question 4 (Continued). Change in Acoustic Parameters with Psychological Variables –Depression and Range of Fundamental Frequency

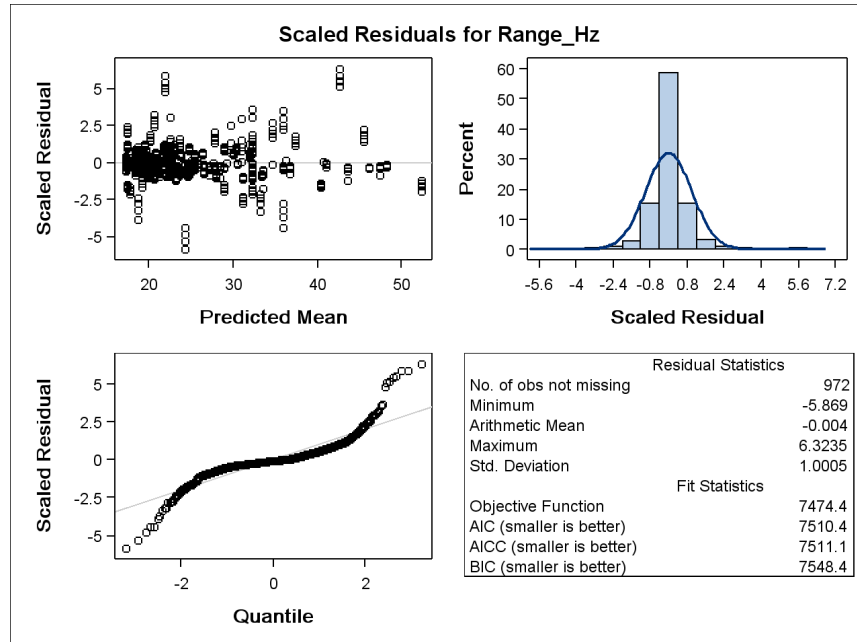


Plots of residuals for reduced model of interaction of depression with range of fundamental frequency.

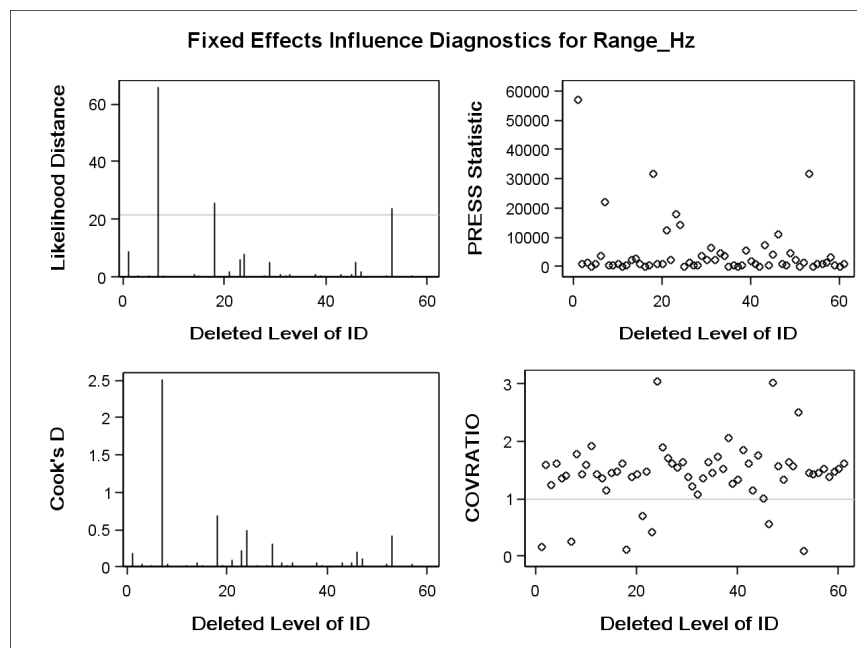


Influence diagnostics for reduced model of interaction of depression with range of fundamental frequency.

Research Question 4 (Continued). Change in Acoustic Parameters with Psychological Variables –Depression and Range of Fundamental Frequency

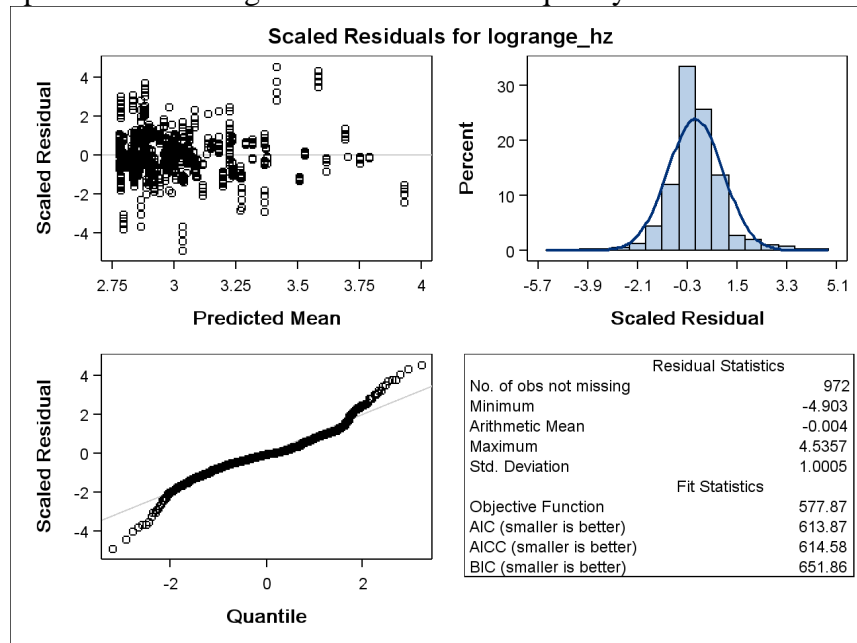


Plots of residuals for reduced model of interaction of depression with range of fundamental frequency with new BDI-II sample mean.

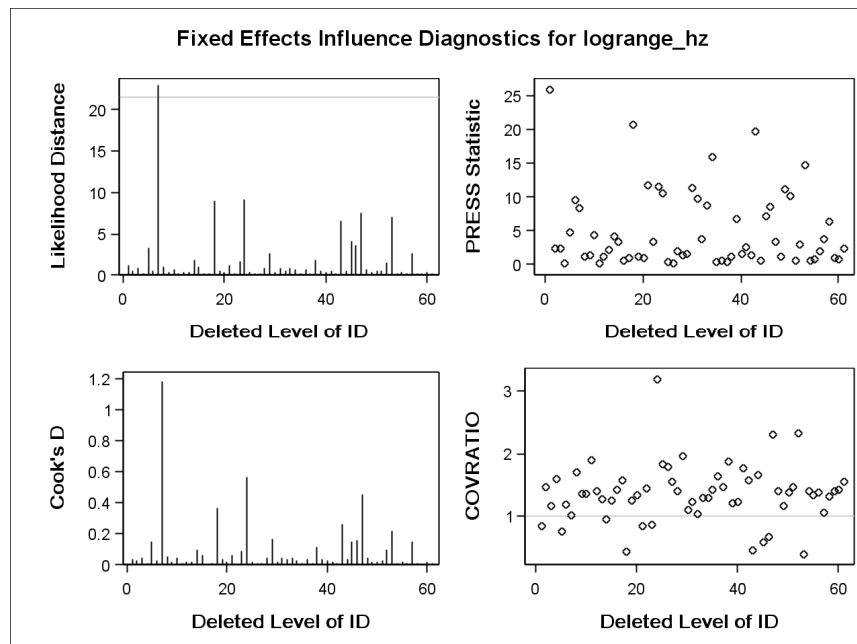


Influence diagnostics for reduced model of interaction of depression with range of fundamental frequency with new sample BDI-II mean.

Research Question 4 (Continued). Change in Acoustic Parameters with Psychological Variables –Depression and Range of Fundamental Frequency



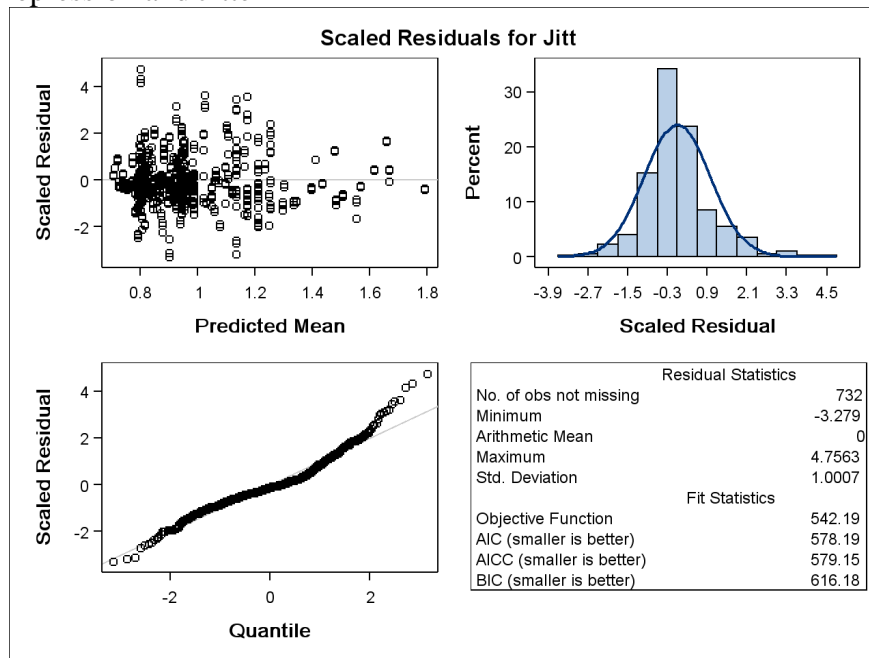
Plot of residuals for log transformation of reduced model of interaction of depression with range of fundamental frequency.



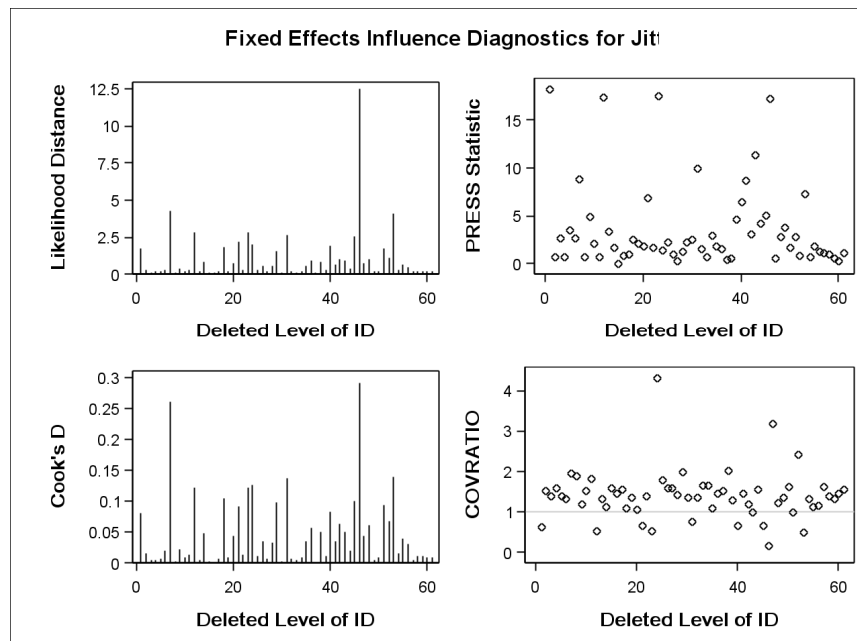
Influence diagnostics of log transformation of reduced model of interaction of depression with range of fundamental frequency.



Research Question 4 (Continued). Change in Acoustic Parameters with Psychological Variables –Depression and Jitter

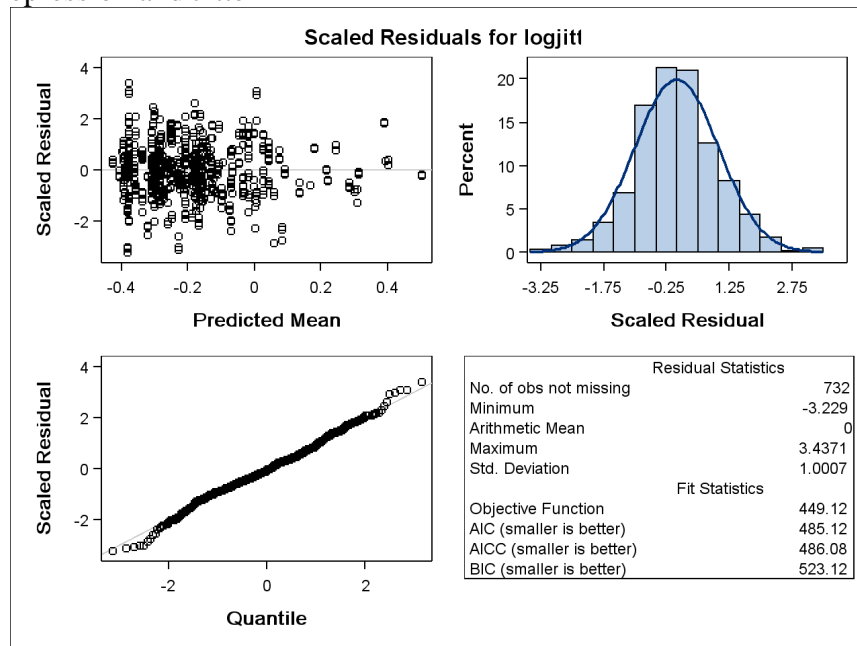


Plots of residuals of reduced model of interaction of depression with jitter.

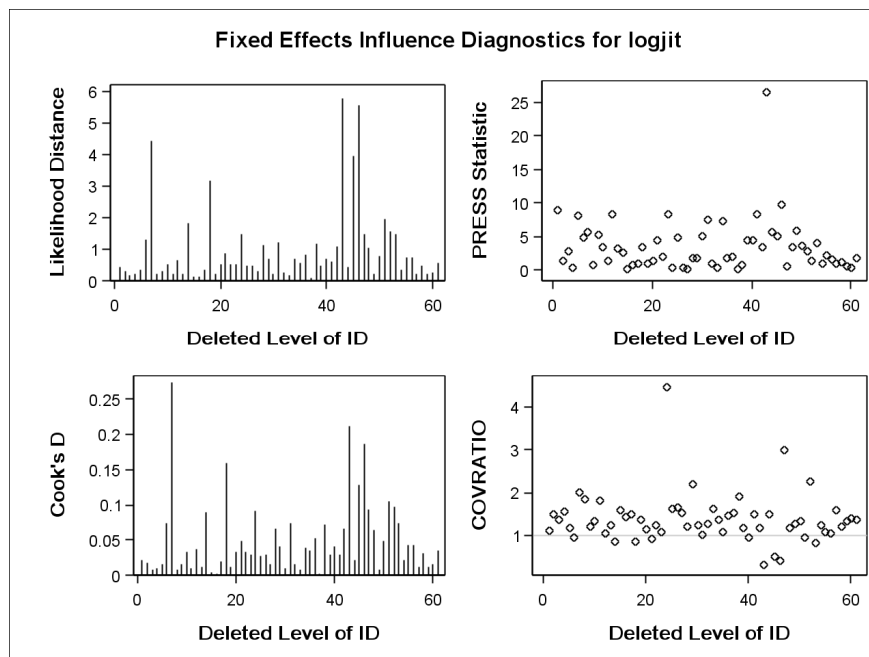


Influence diagnostics of reduced model of interaction of depression with jitter.

Research Question 4 (Continued). Change in Acoustic Parameters with Psychological Variables –Depression and Jitter

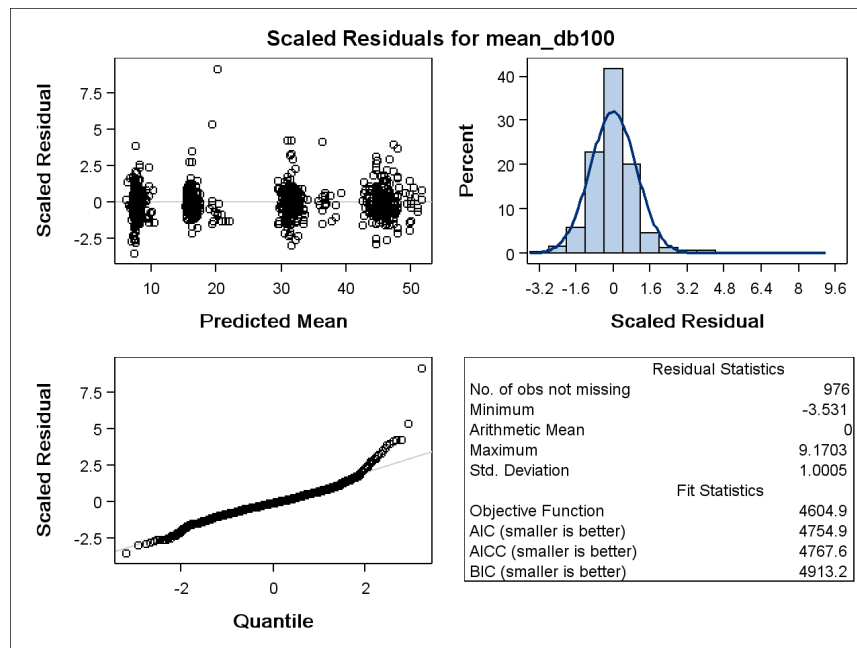


Plot of residuals for log transformation of reduced model of interaction of depression with jitter.

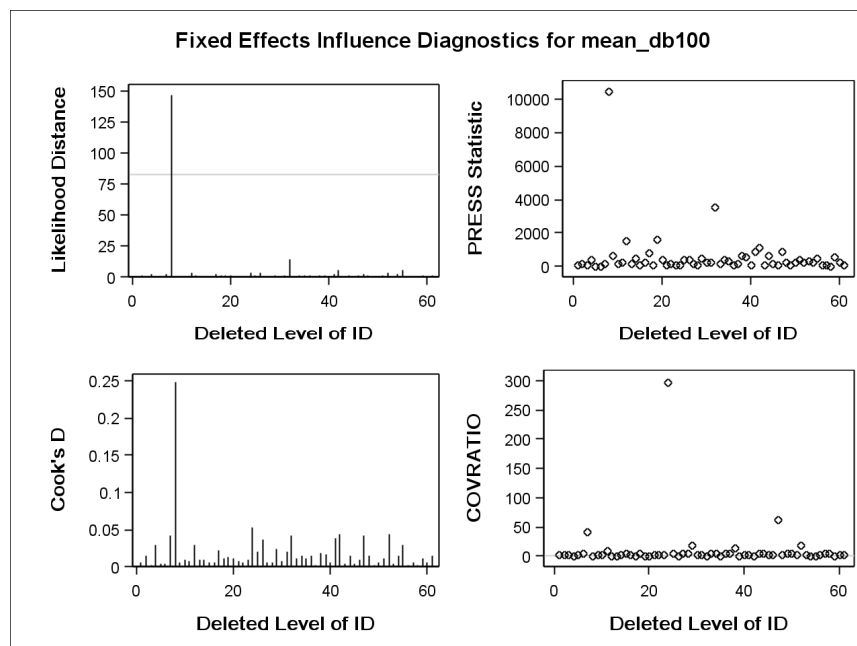


Influence diagnostics of log transformation of reduced model of interaction of depression with jitter.

Research Question 4 (Continued). Change in Acoustic Parameters with Psychological Variables –Depression and Formant Frequencies

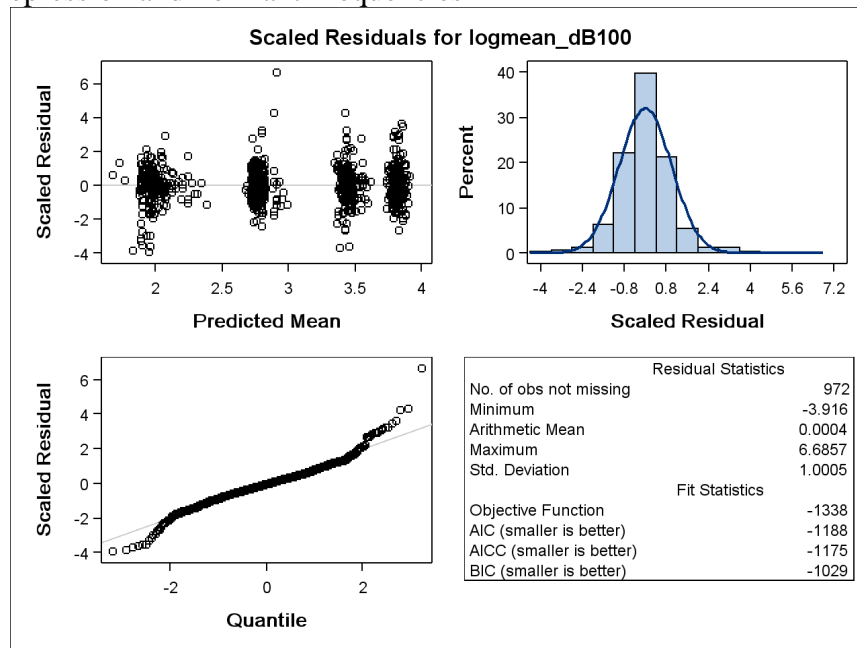


Plots of residuals of reduced model of interaction of depression with formant frequencies.

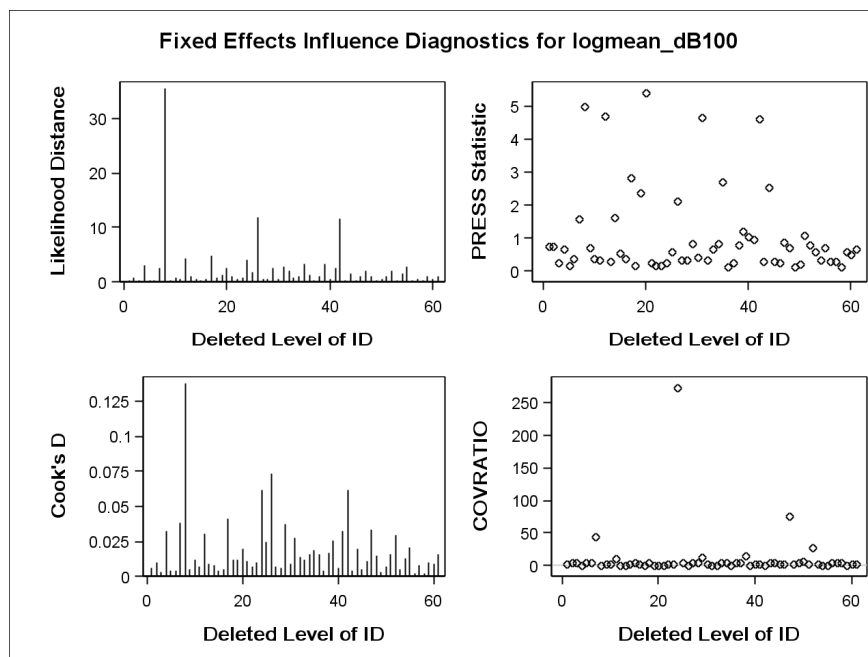


Influence diagnostics of reduced model of interaction of depression with formant frequencies.

Research Question 4 (Continued). Change in Acoustic Parameters with Psychological Variables –Depression and Formant Frequencies

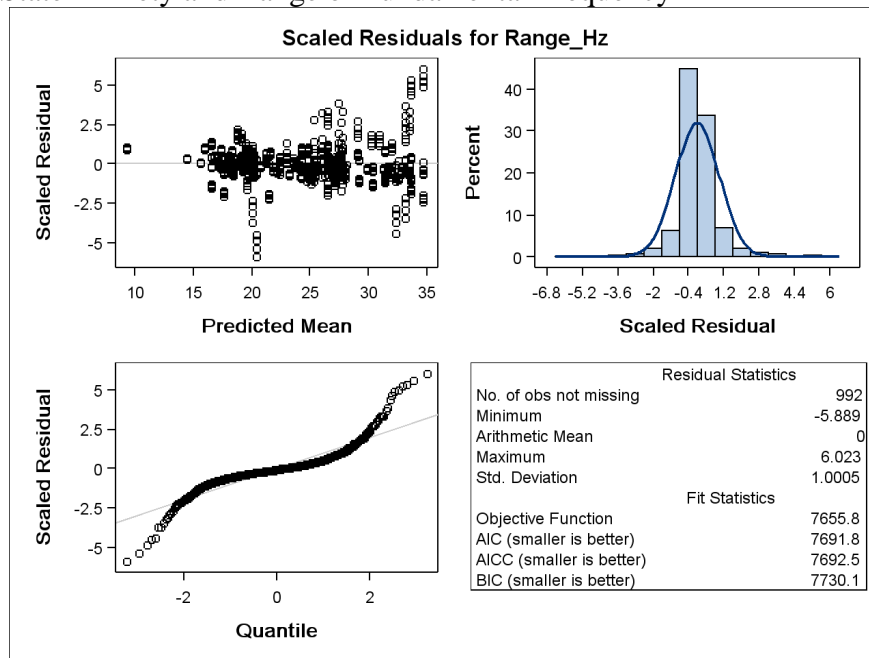


Plots of residuals of log transformation of reduced model of interaction of depression with formant frequencies.

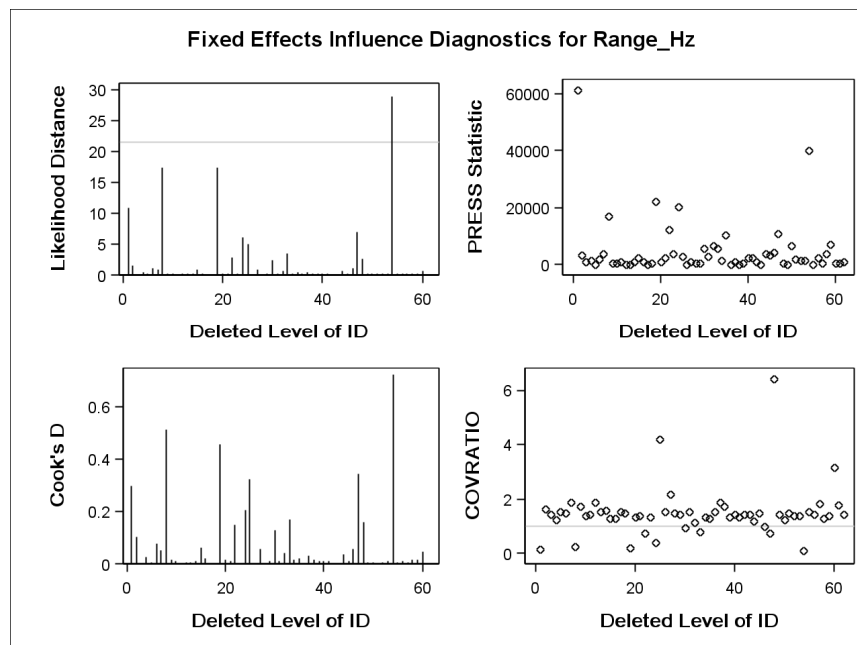


Influence diagnostics of log transformation of reduced model of interaction of depression with formant frequencies.

Research Question 4 (Continued). Change in Acoustic Parameters with Psychological Variables – State Anxiety and Range of Fundamental Frequency

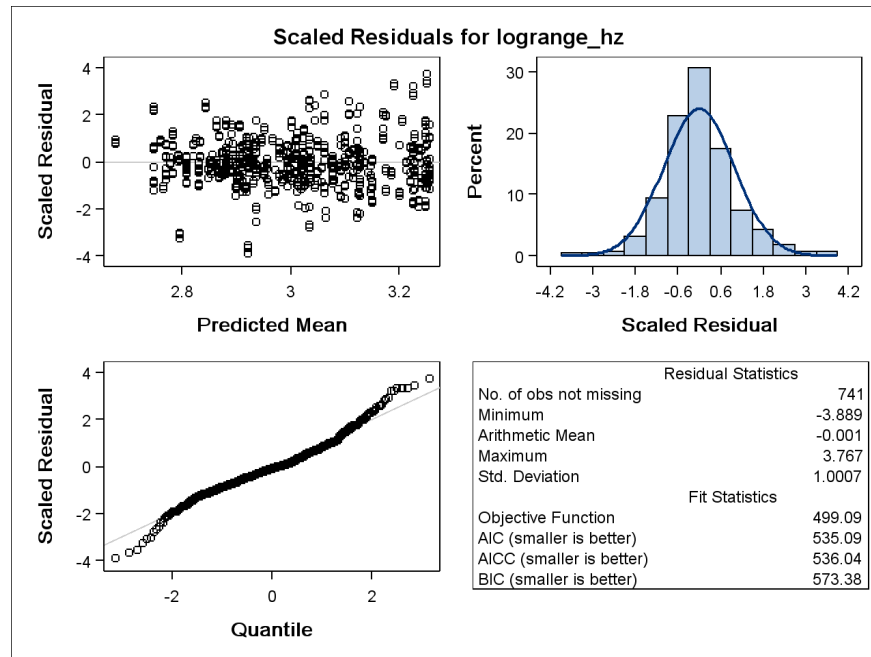


Plots of residuals of model of interaction of state anxiety with range of fundamental frequency.

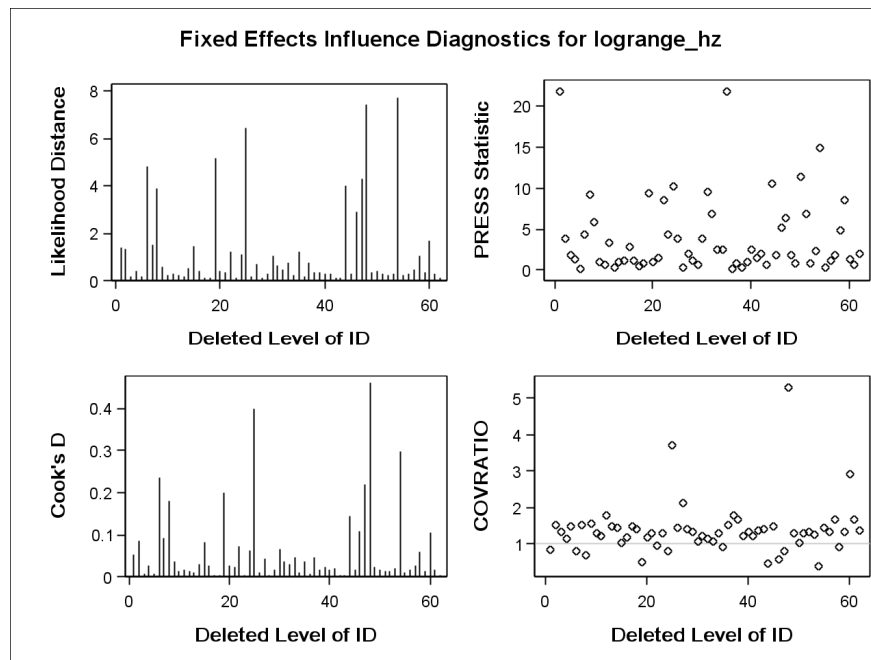


Influence diagnostics of model of interaction of state anxiety with range of fundamental frequency.

Research Question 4 (Continued). Change in Acoustic Parameters with Psychological Variables – State Anxiety and Range of Fundamental Frequency

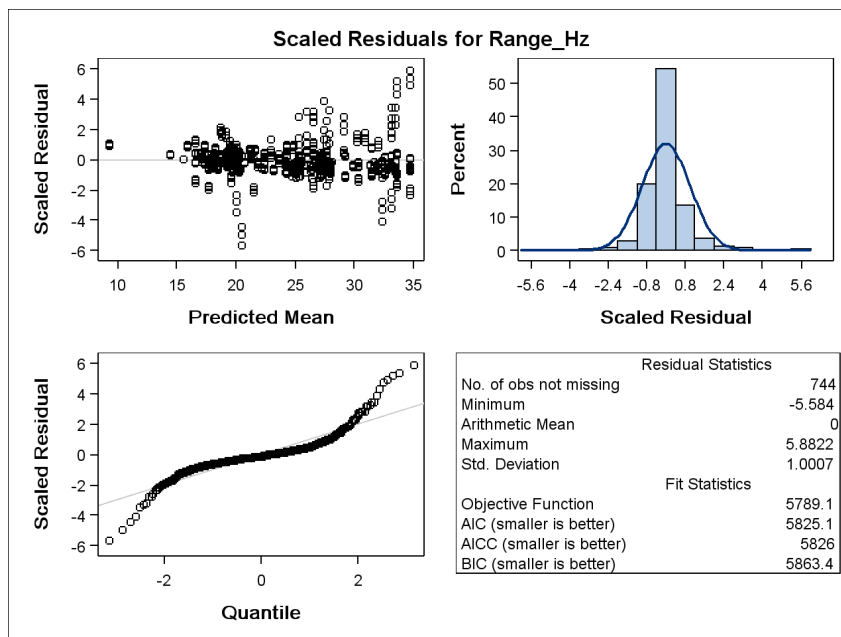


Plot of residuals for log transformation of reduced model of interaction of state anxiety with range of fundamental frequency.

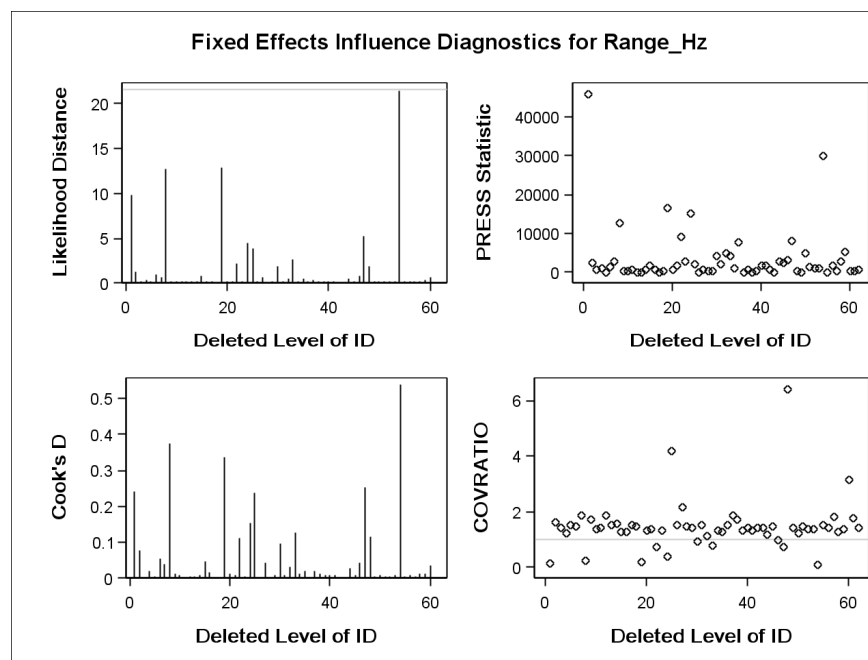


Influence diagnostics of log transformation of reduced model of interaction of state anxiety with range of fundamental frequency.

Research Question 4 (Continued). Change in Acoustic Parameters with Psychological Variables – State Anxiety and Range of Fundamental Frequency

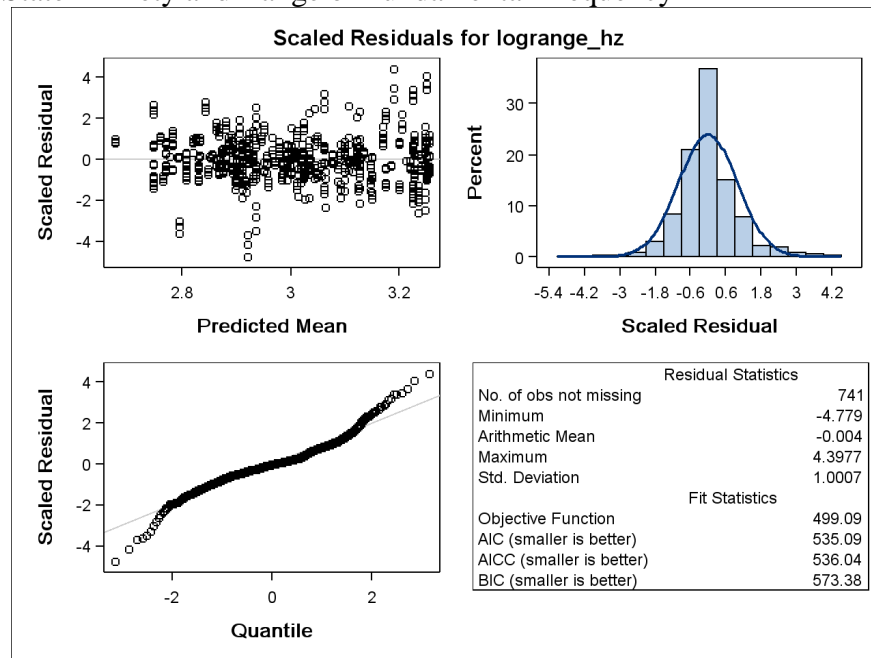


Plot of residuals of deleted model of interaction of state anxiety with range of fundamental frequency.

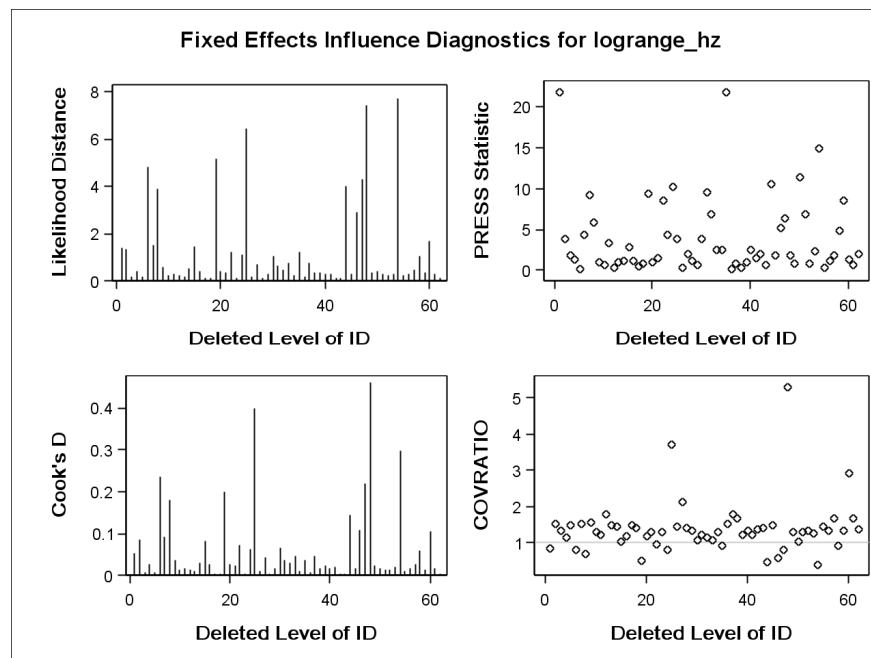


Influence diagnostics of deleted model of interaction of state anxiety with range of fundamental frequency.

Research Question 4 (Continued). Change in Acoustic Parameters with Psychological Variables – State Anxiety and Range of Fundamental Frequency



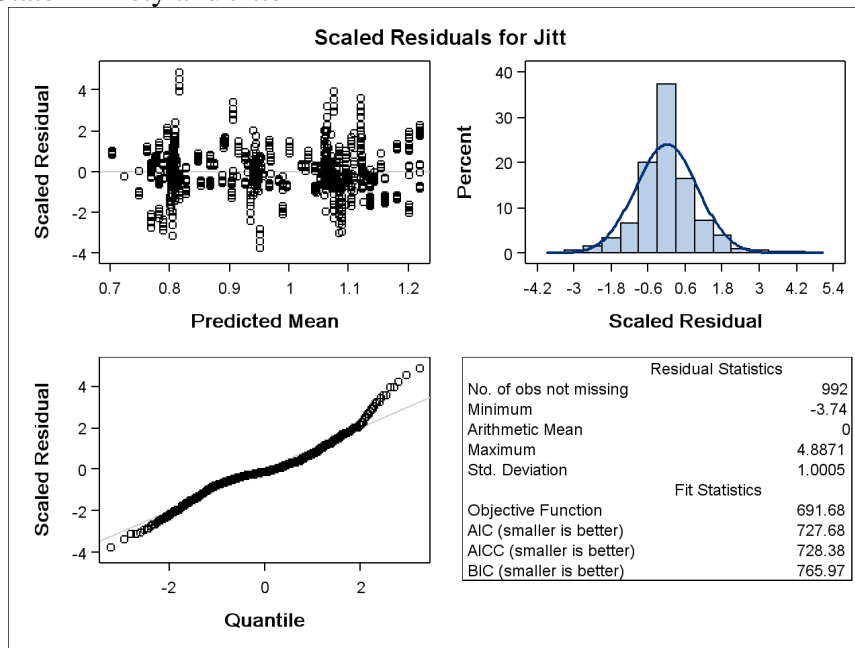
Plots of residuals of log transformation of reduced model interaction of state anxiety with range of fundamental frequency.



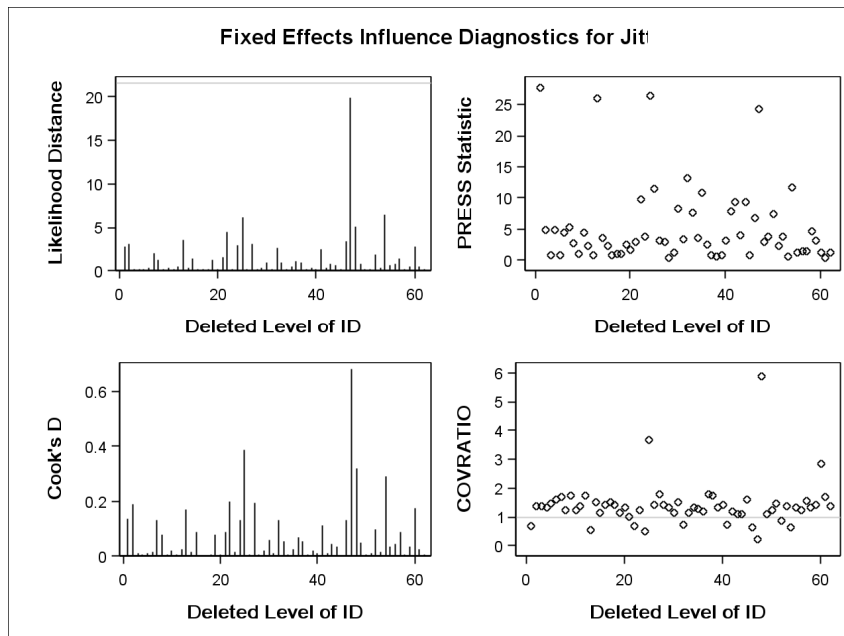
Influence diagnostics of log transformation of reduced model of interaction of state anxiety with range of fundamental frequency.



Research Question 4 (Continued). Change in Acoustic Parameters with Psychological Variables – State Anxiety and Jitter

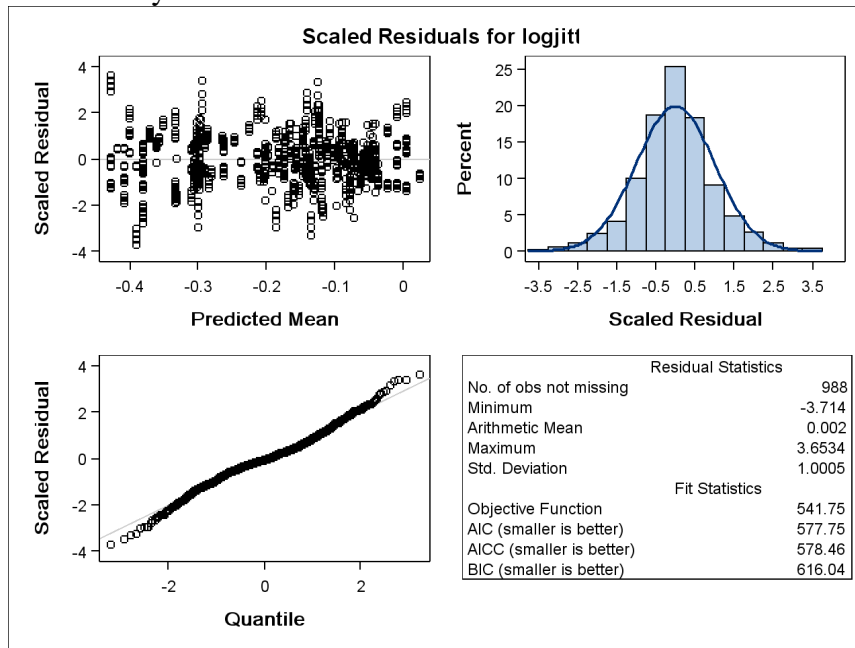


Plots of residuals for original model of interaction of state anxiety with jitter.

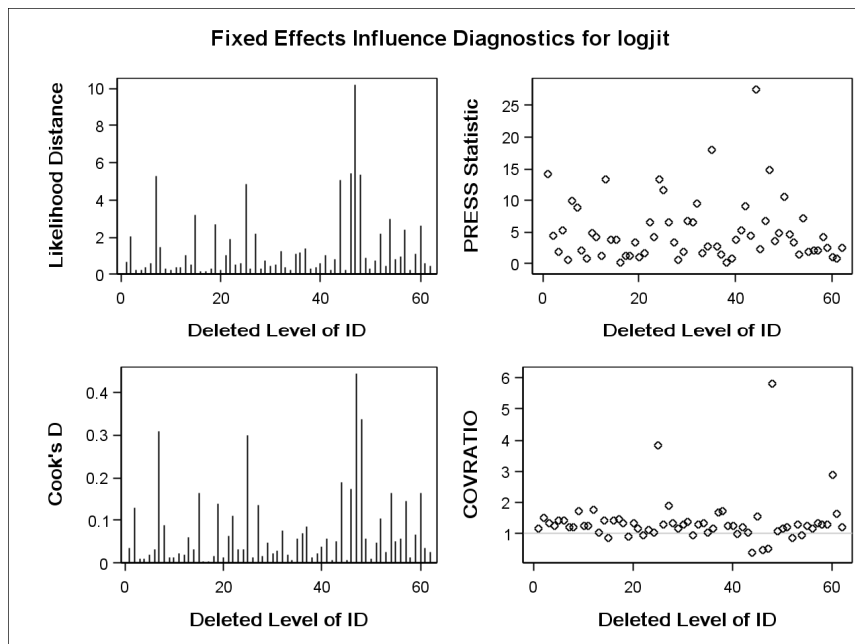


Influence diagnostics for original model of interaction of state anxiety with jitter.

Research Question 4 (Continued). Change in Acoustic Parameters with Psychological Variables – State Anxiety and Jitter

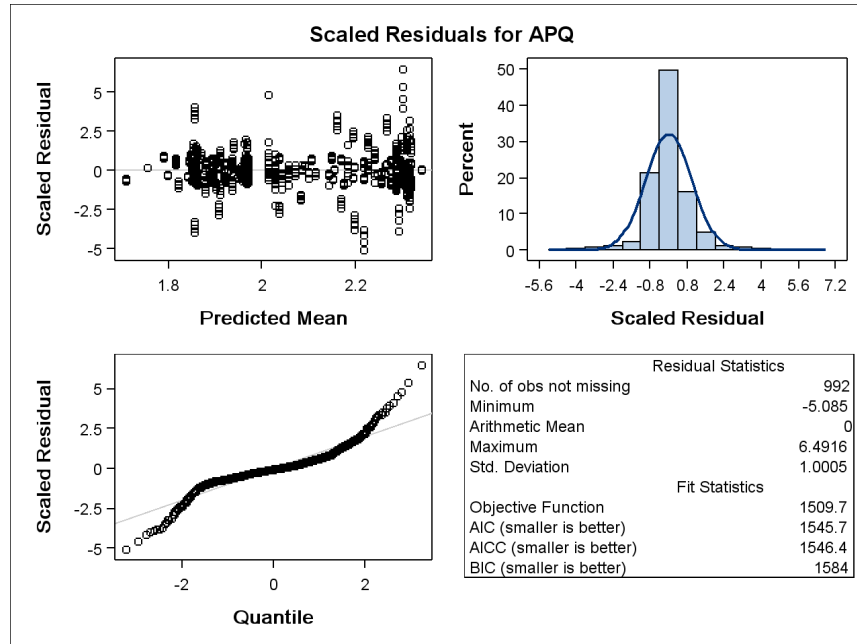


Plots of residuals of log transformation of reduced model of interaction of state anxiety with jitter.

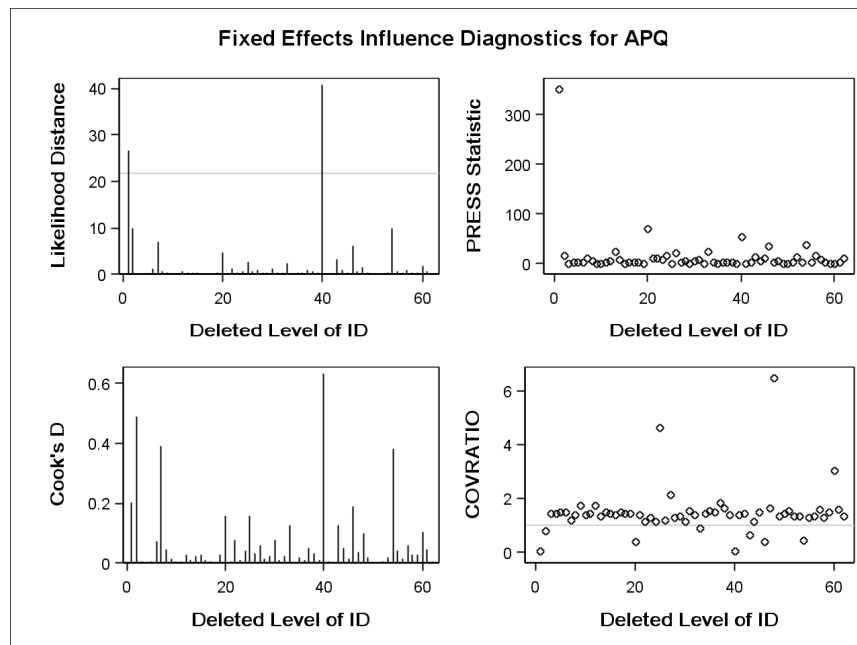


Influence diagnostics of log transformation of reduced model of interaction of state anxiety with jitter.

Research Question 4 (Continued). Change in Acoustic Parameters with Psychological Variables – State Anxiety and Amplitude Perturbation Quotient

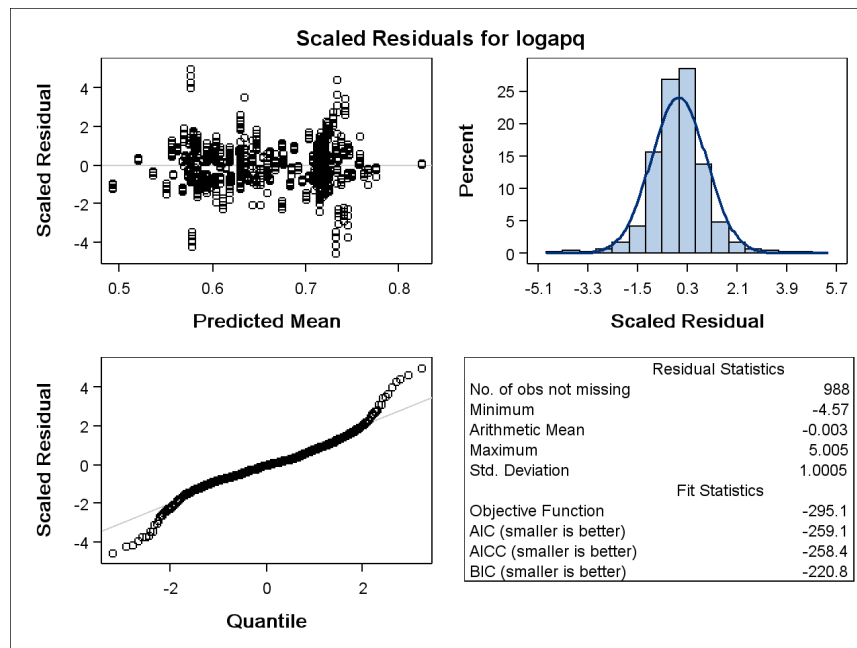


Plot of residuals for reduced model of interaction of state anxiety with APQ.

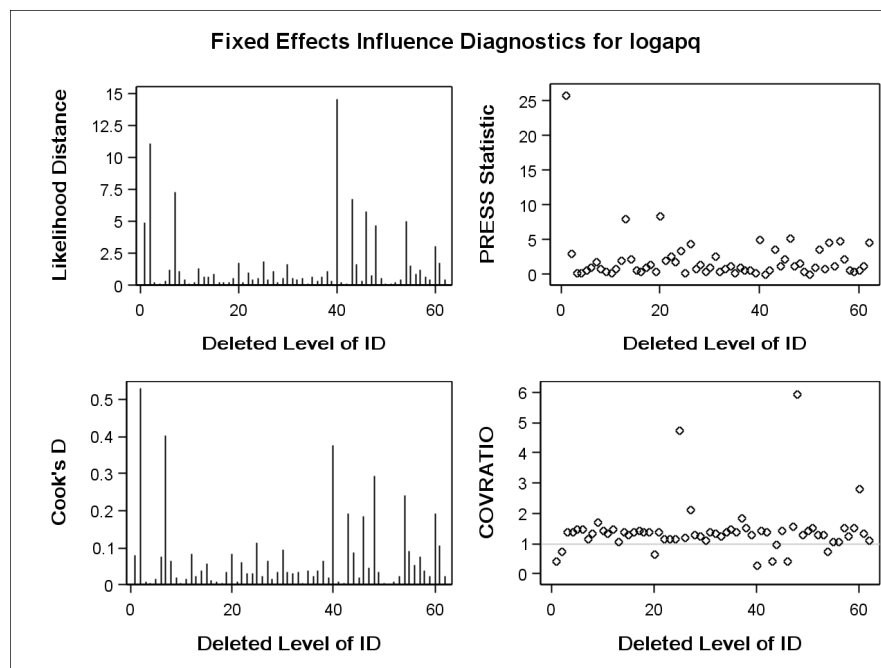


Influence diagnostics for reduced model of interaction of state anxiety with APQ.

Research Question 4 (Continued). Change in Acoustic Parameters with Psychological Variables – State Anxiety and Amplitude Perturbation Quotient

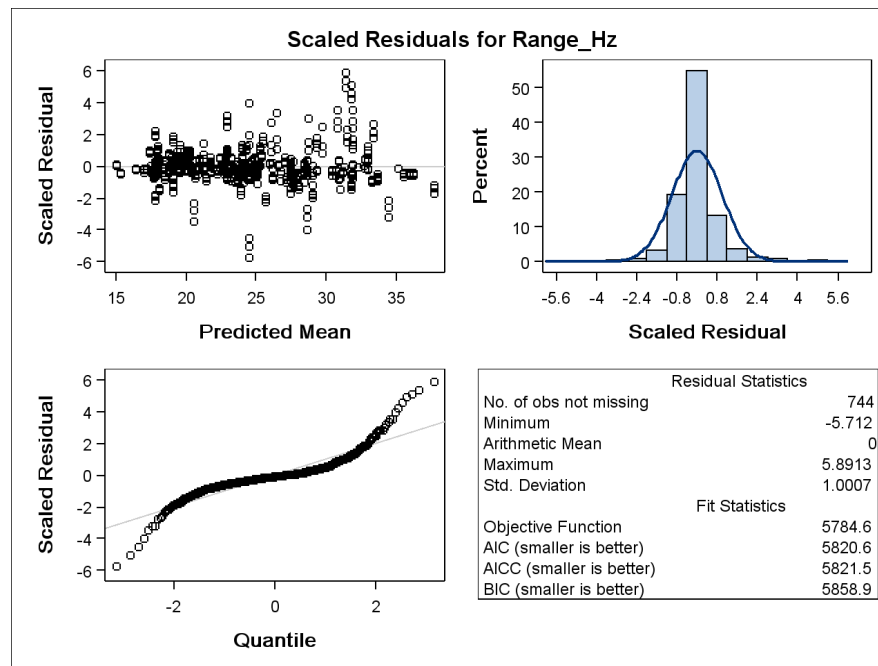


Plots of residuals for log transformation of reduced model of interaction of state anxiety with APQ.

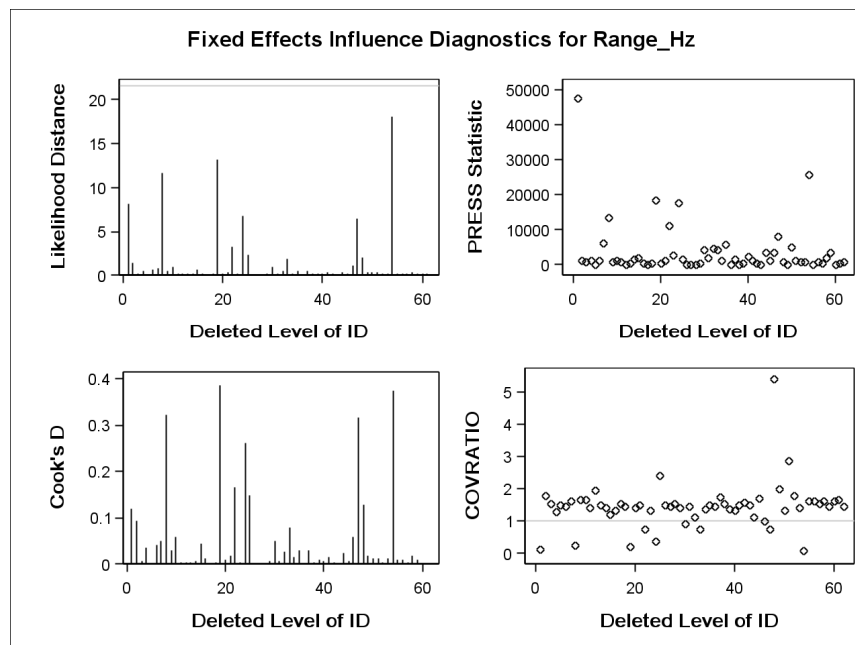


Influence diagnostics for log transformation of reduced model of interaction of state anxiety with APQ.

Research Question 4 (Continued). Change in Acoustic Parameters with Psychological Variables – Trait Anxiety and Range of Fundamental Frequency

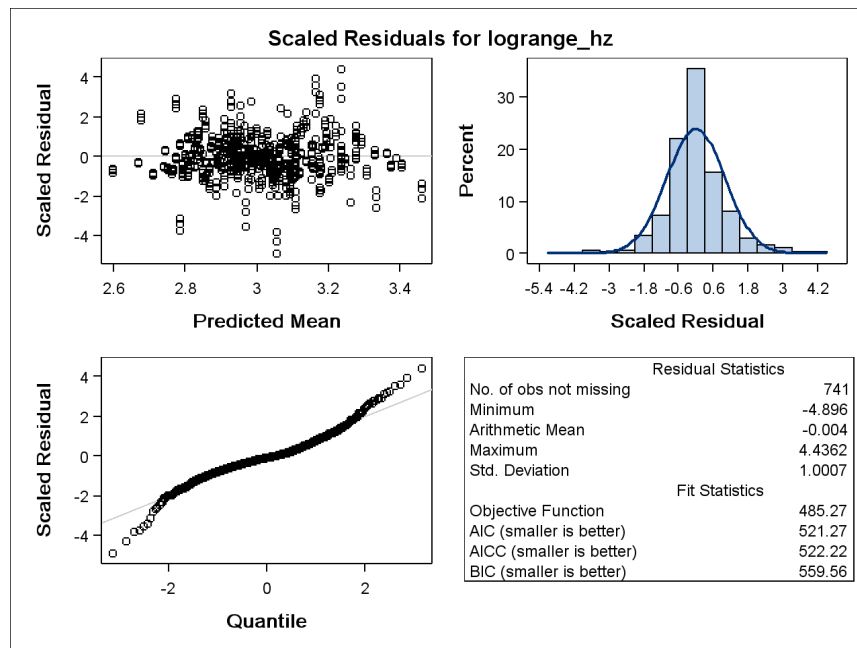


Plot of residuals of reduced model of interaction of trait anxiety with range of fundamental frequency.

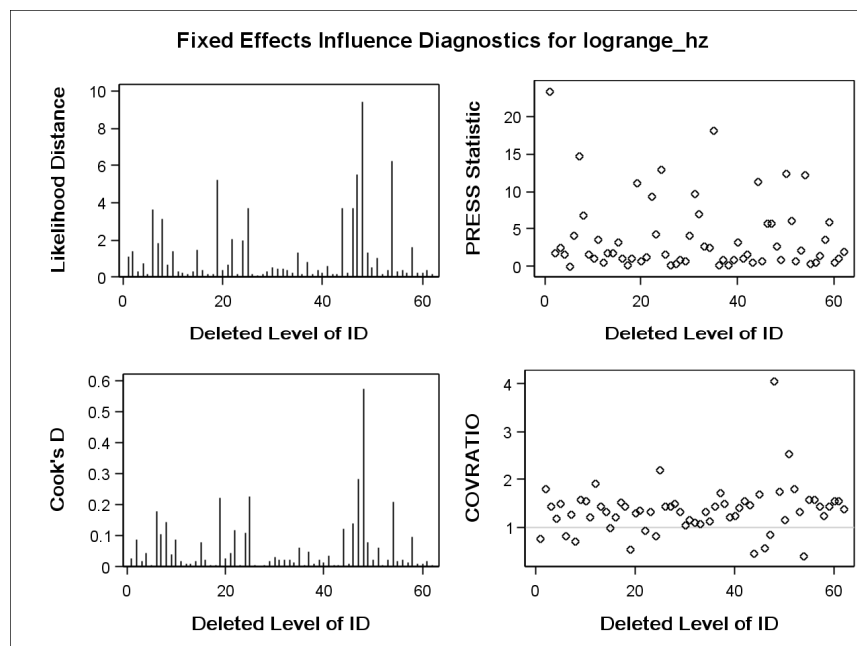


Influence diagnostics for reduced model of interaction of trait anxiety with range of fundamental frequency.

Research Question 4 (Continued). Change in Acoustic Parameters with Psychological Variables – Trait Anxiety and Range of Fundamental Frequency

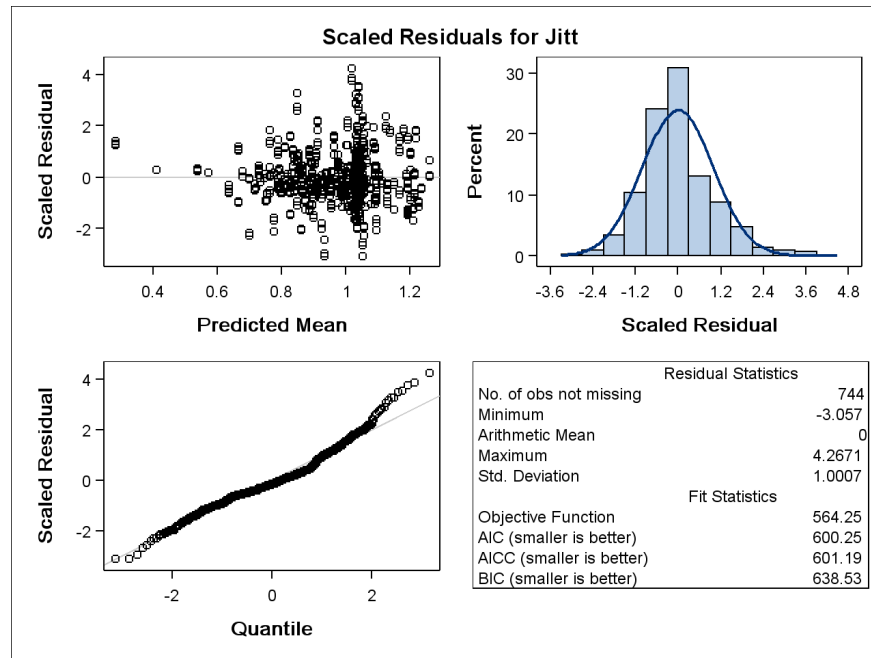


Plots of residuals for log transformation of reduced model of interaction of trait anxiety with range of fundamental frequency.

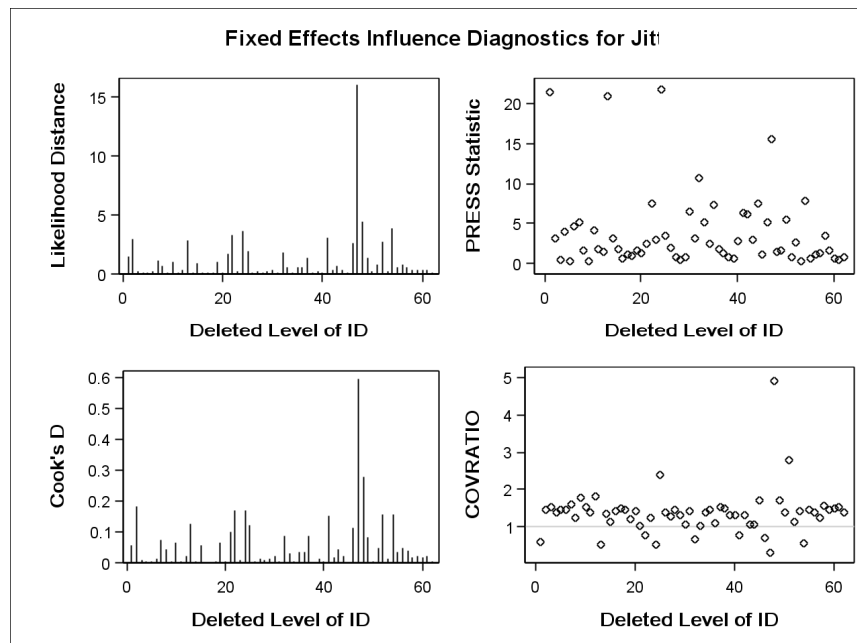


Influence diagnostics for log transformation of reduced model of interaction of trait anxiety with range of fundamental frequency.

Research Question 4 (Continued). Change in Acoustic Parameters with Psychological Variables – Trait Anxiety and Jitter

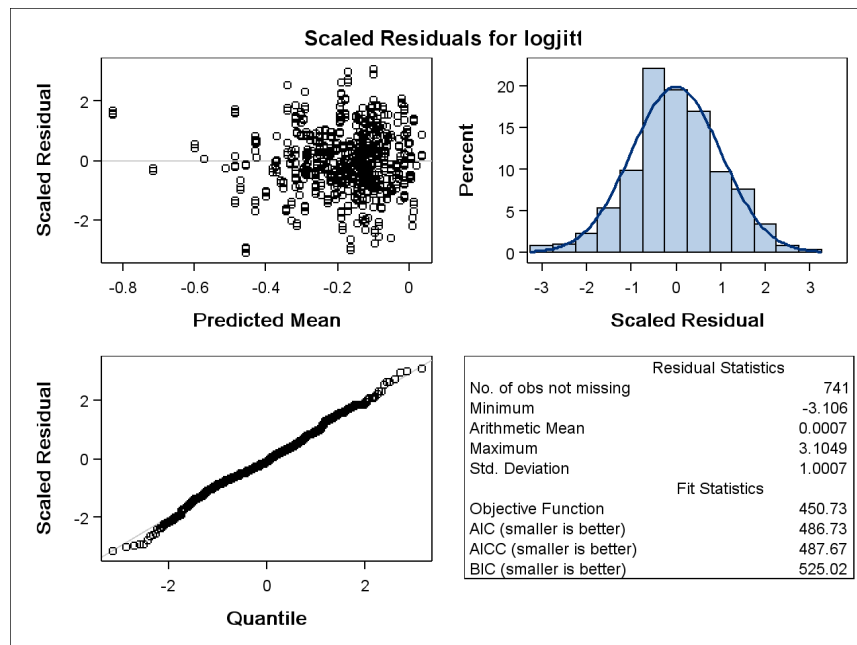


Plots of residuals of reduced model of interaction of trait anxiety with jitter.

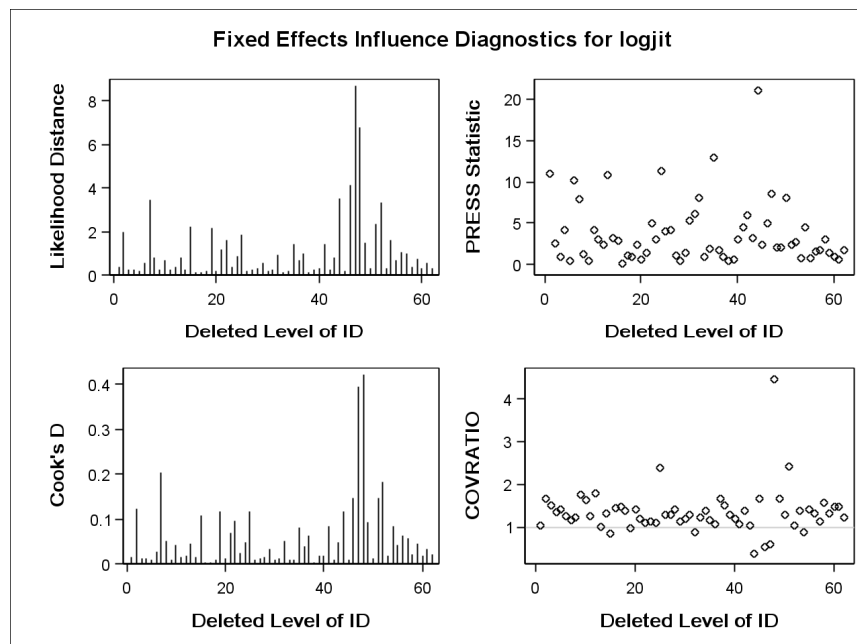


Influence diagnostics of reduced model interaction of trait anxiety with jitter.

Research Question 4 (Continued). Change in Acoustic Parameters with Psychological Variables – Trait Anxiety and Jitter



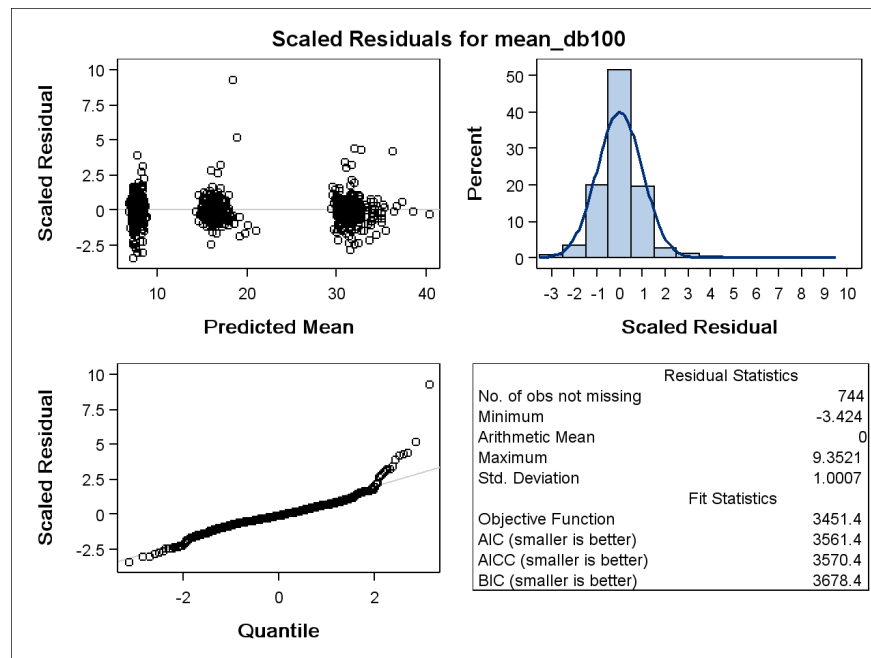
Plots of residuals of log transformation model of interaction of trait anxiety with jitter.



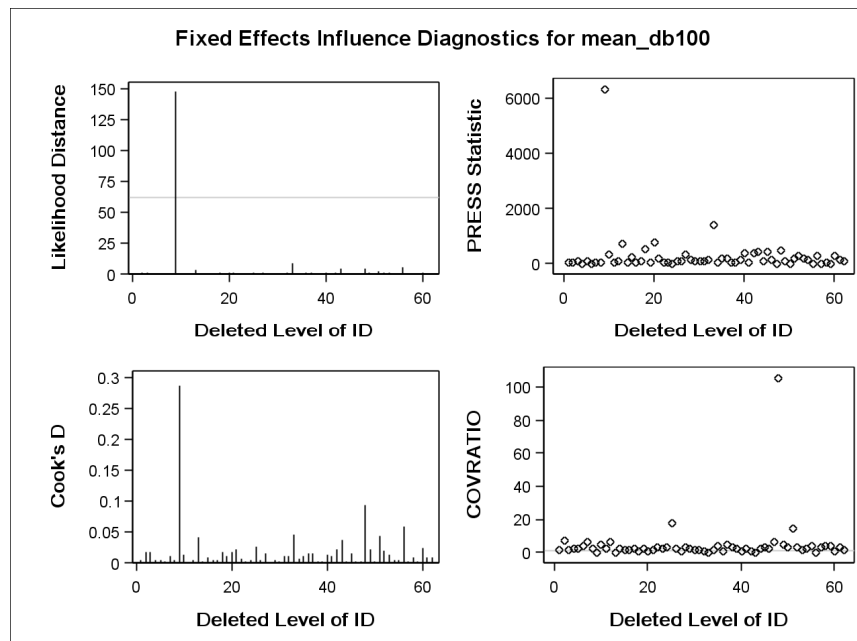
Influence diagnostics of log transformation model of interaction of trait anxiety with jitter.



Research Question 4 (Continued). Change in Acoustic Parameters with Psychological Variables – Trait Anxiety and Formant Frequencies

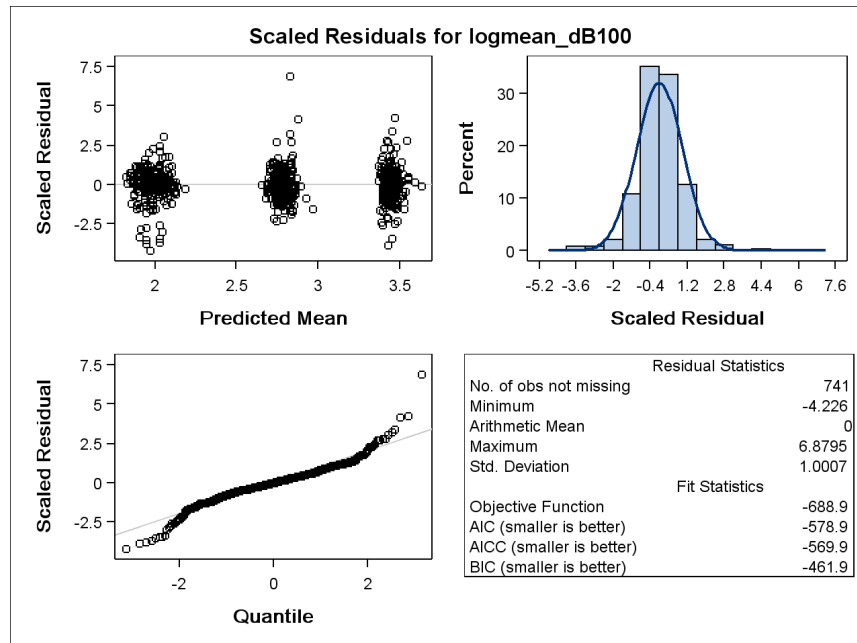


Plots of residuals of reduced model interaction of trait anxiety with formant frequencies.

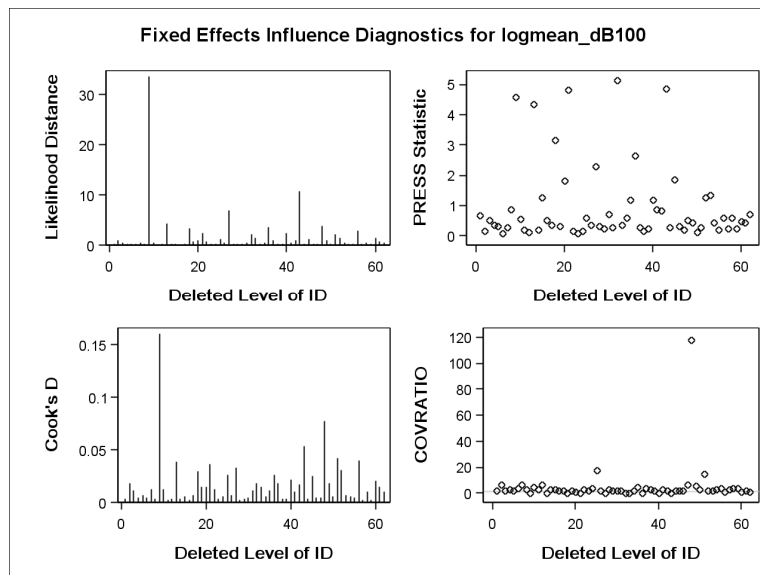


Influence diagnostics of reduced model of interaction of trait anxiety with formant frequencies.

Research Question 4 (Continued). Change in Acoustic Parameters with Psychological Variables – Trait Anxiety and Formant Frequencies

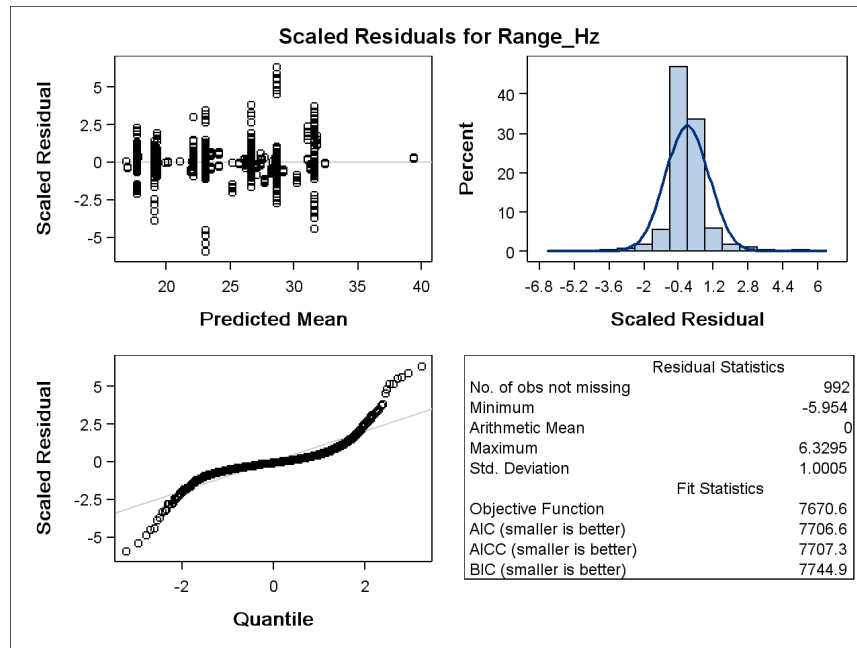


Plots of residuals with log transformation of reduced model of interaction of trait anxiety with formant frequencies.

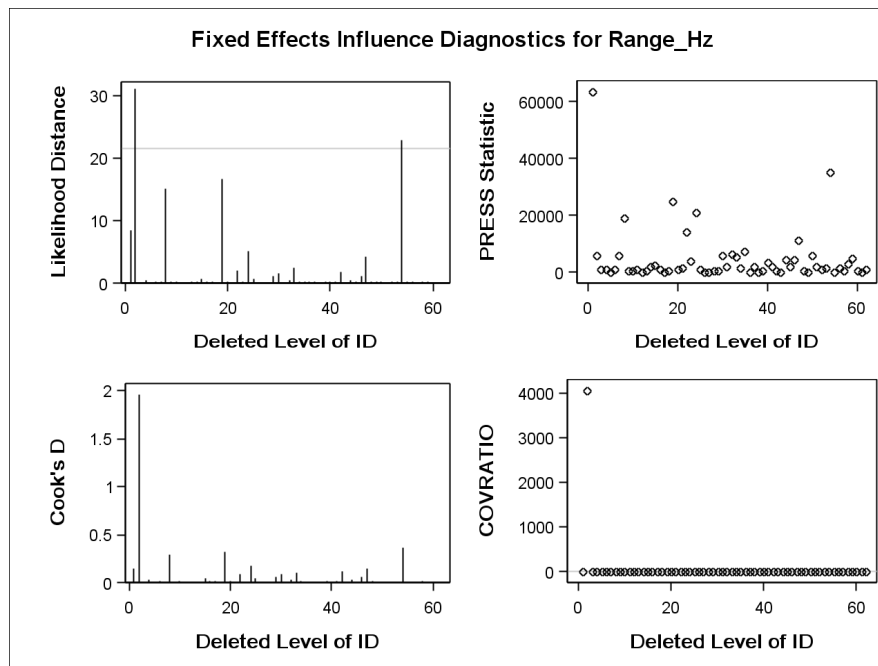


Influence diagnostics of log transformation of reduced model of interaction of trait anxiety with formant frequencies.

Research Question 4 (Continued). Change in Acoustic Parameters with Psychological Variables – State Anger and Range of Fundamental Frequency

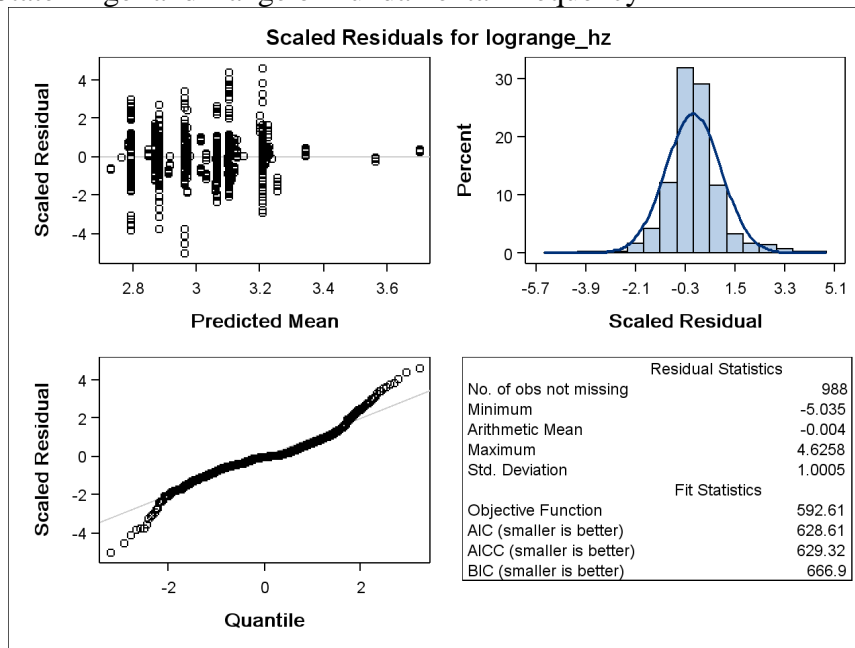


Plots of residuals of the reduced model of interaction of state anger with range of fundamental frequency.

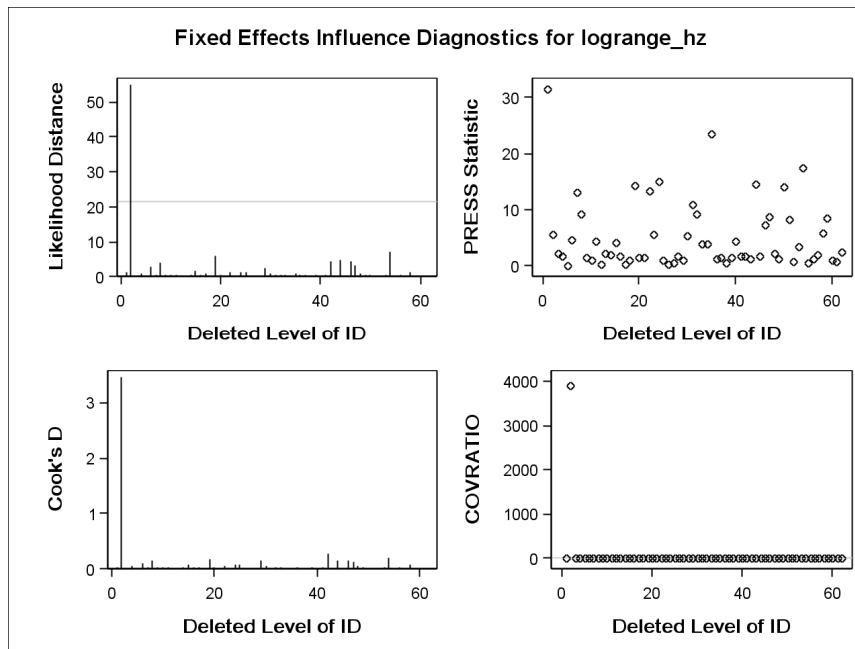


Influence diagnostics of reduced model of interaction of state anger with range of fundamental frequency.

Research Question 4 (Continued). Change in Acoustic Parameters with Psychological Variables – State Anger and Range of Fundamental Frequency

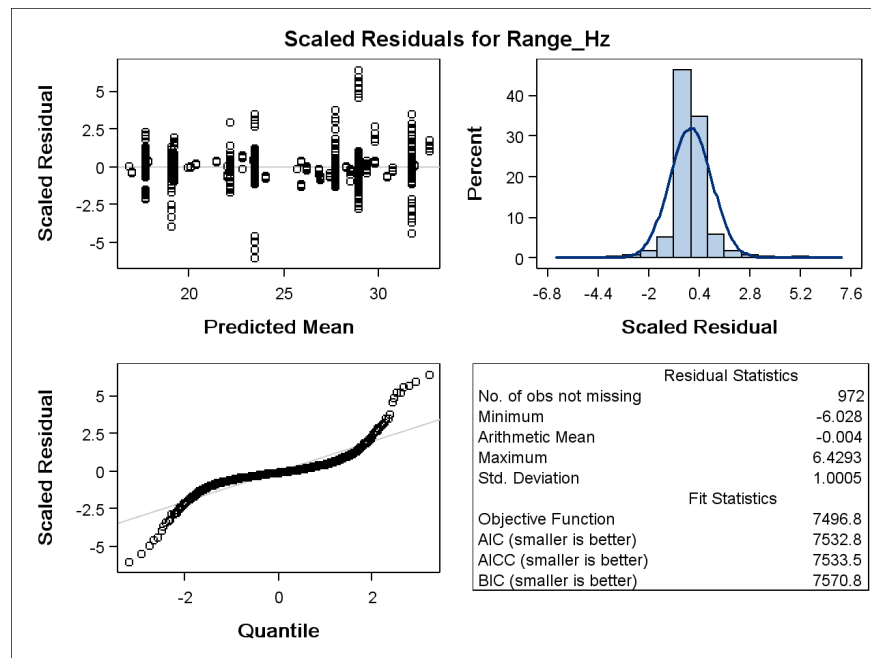


Plots of residuals with log transformation of reduced model of interaction of state anger with range of fundamental frequency.

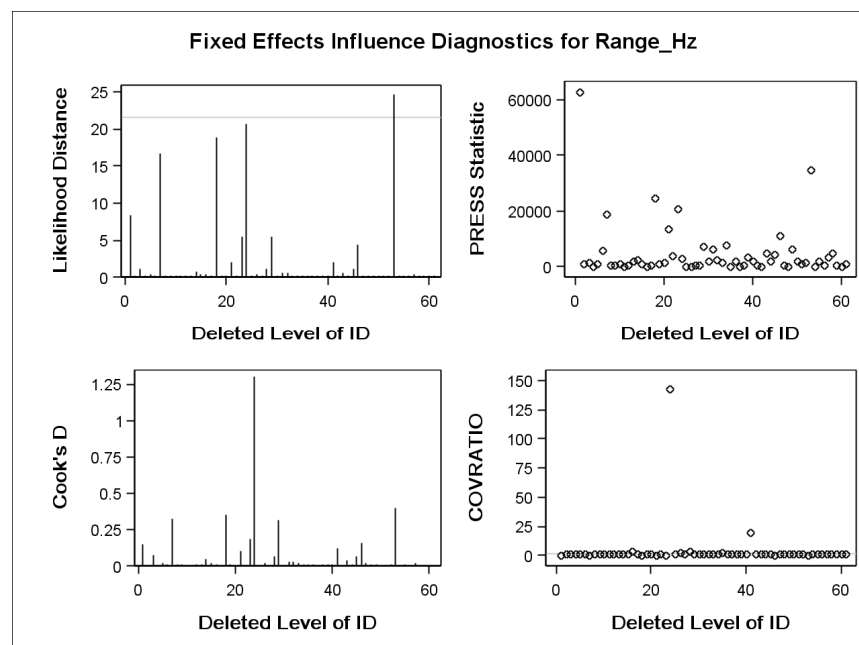


Influence diagnostics of log transformation of reduced model of interaction of state anger with range of fundamental frequency.

Research Question 4 (Continued). Change in Acoustic Parameters with Psychological Variables – State Anger and Range of Fundamental Frequency

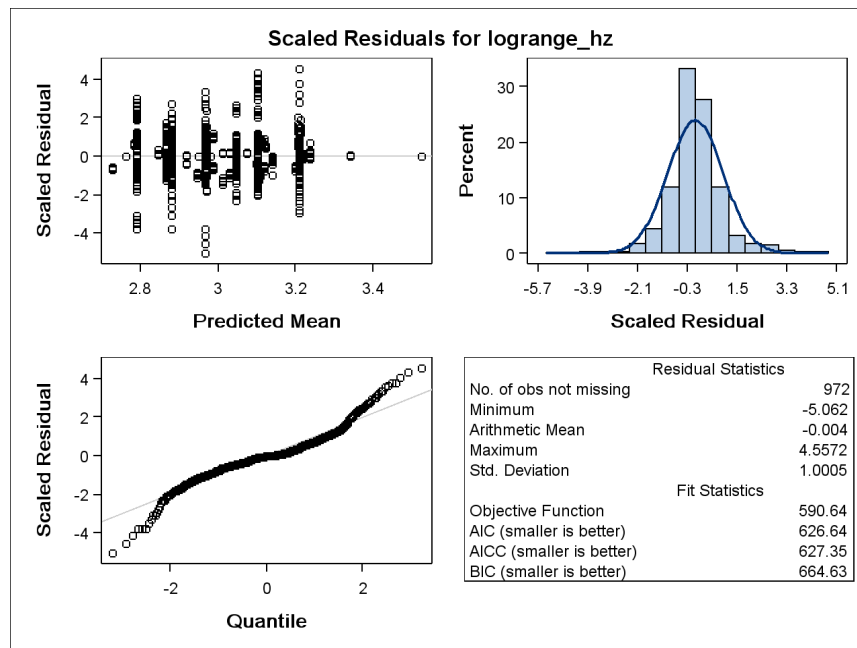


Plots of residuals of the further reduced model of interaction of state anger with range of fundamental frequency– subject with high COVRATIO deleted.

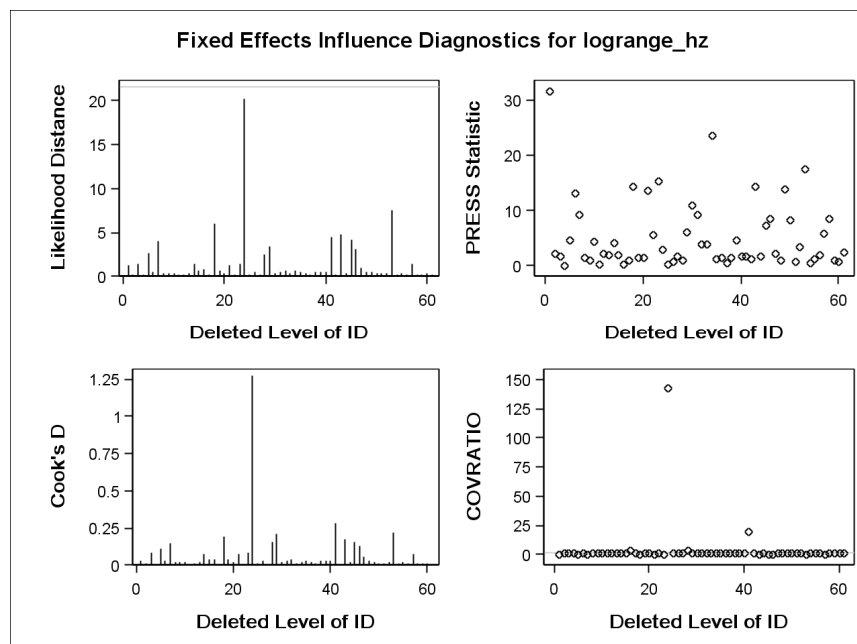


Influence diagnostics of further reduced model of interaction of state anger with range of fundamental frequency – subject with high COVRATIO deleted.

Research Question 4 (Continued). Change in Acoustic Parameters with Psychological Variables – State Anger and Range of Fundamental Frequency

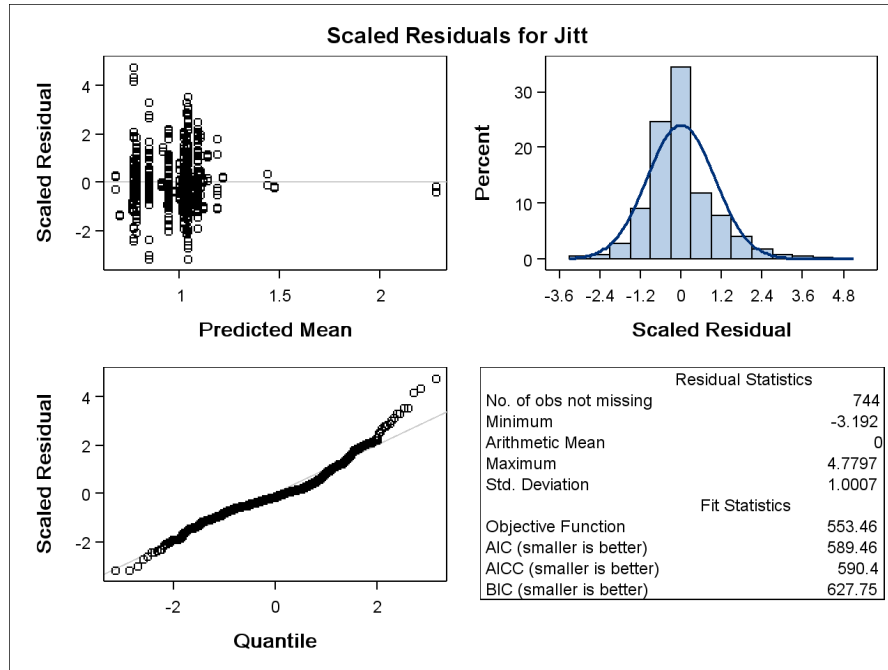


Plots of residuals of the log transformation of further reduced model of interaction of state anger with range of fundamental frequency – subject with high COVRATIO deleted.

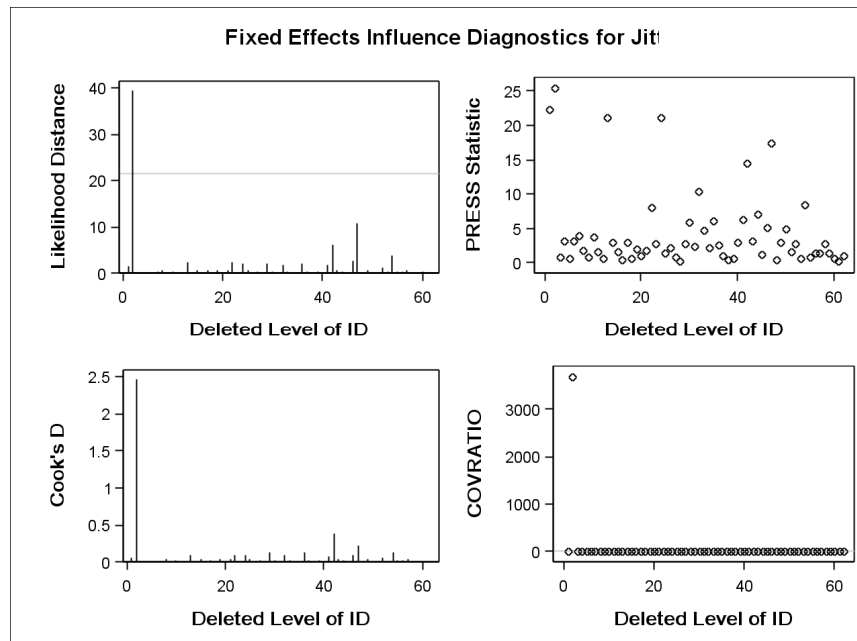


Influence diagnostics of the log transformation of further reduced model of interaction of state anger with range of fundamental frequency– subject with high COVRATIO deleted.

Research Question 4 (Continued). Change in Acoustic Parameters with Psychological Variables – State Anger and Jitter

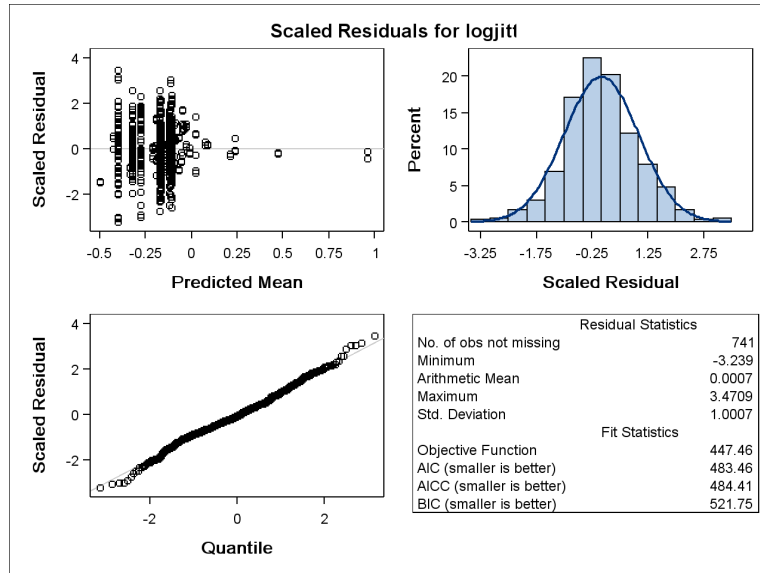


Plots of residuals of model of interaction of state anger with jitter.

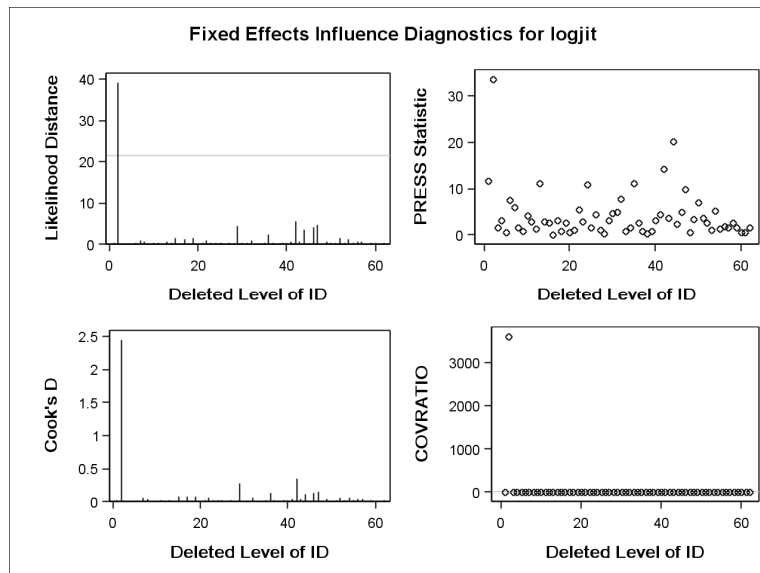


Influence diagnostics of model of interaction of state anger with jitter.

Research Question 4 (Continued). Change in Acoustic Parameters with Psychological Variables – State Anger and Jitter



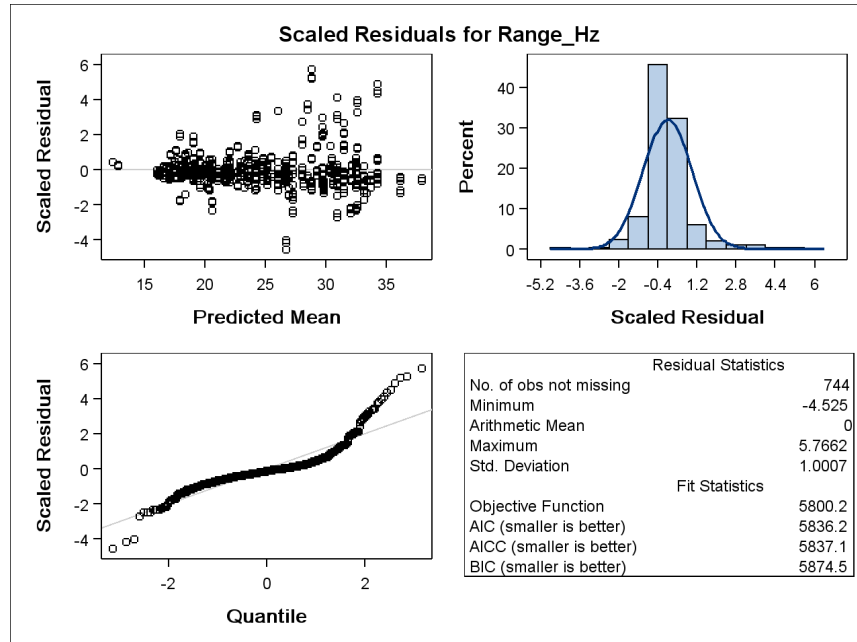
Plots of residuals of log transformation model of interaction of state anger with jitter.



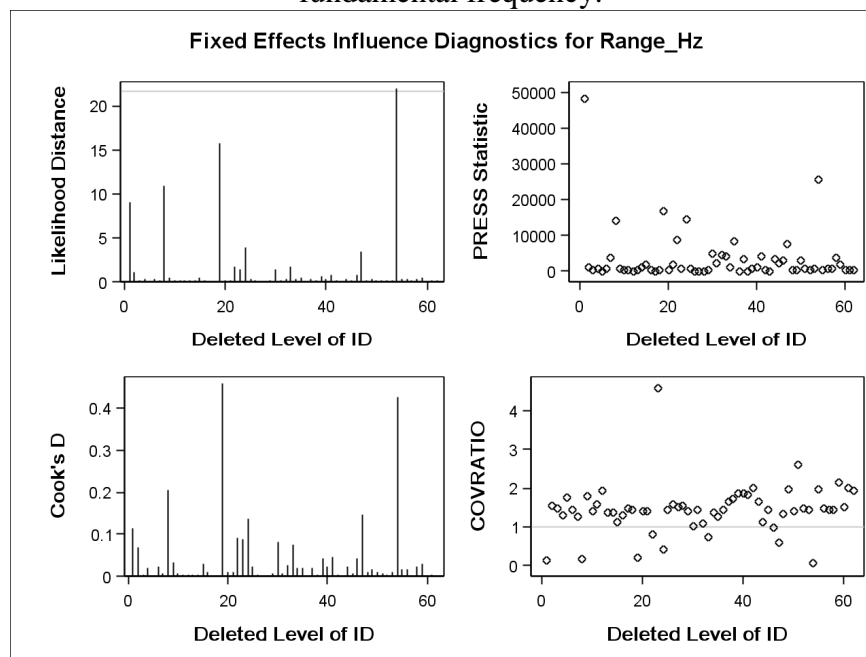
Influence diagnostics of log transformation of model of interaction of state anger with jitter.



Research Question 4 (Continued). Change in Acoustic Parameters with Psychological Variables – Trait Anger and Range of Fundamental Frequency

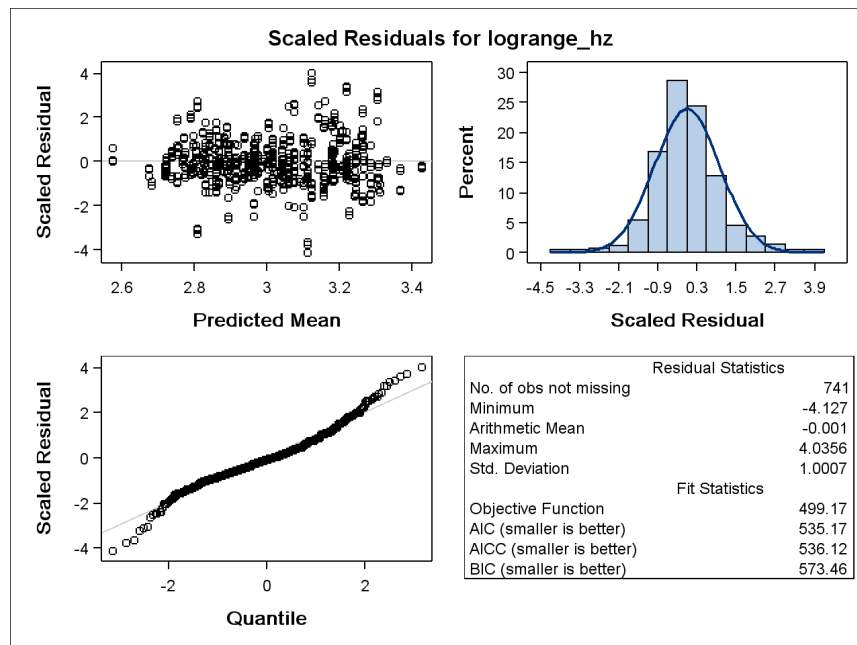


Plots of residuals of reduced model of interaction of trait anger with range of fundamental frequency.

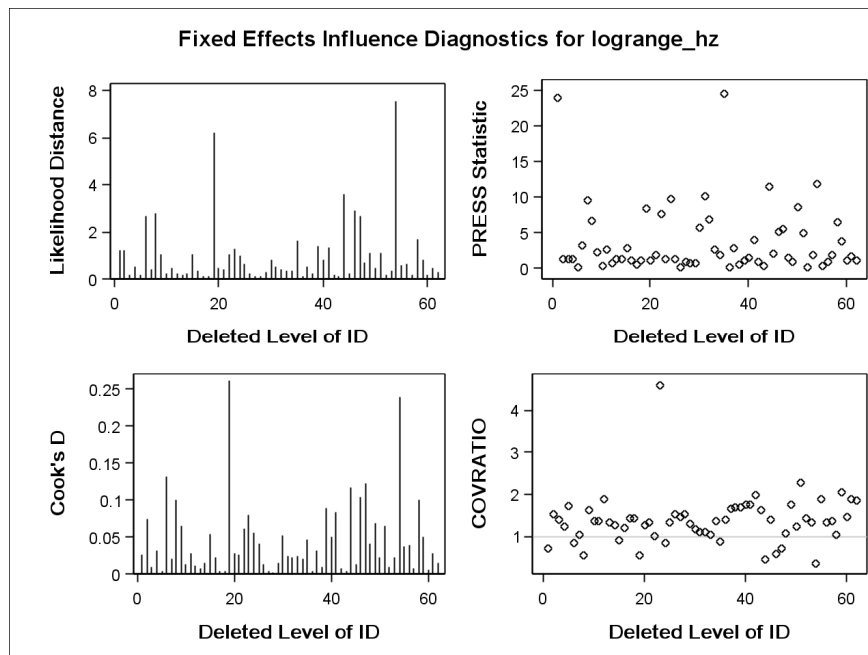


Influence diagnostics of reduced model of interaction of trait anger with range of fundamental frequency.

Research Question 4 (Continued). Change in Acoustic Parameters with Psychological Variables – Trait Anger and Range of Fundamental Frequency

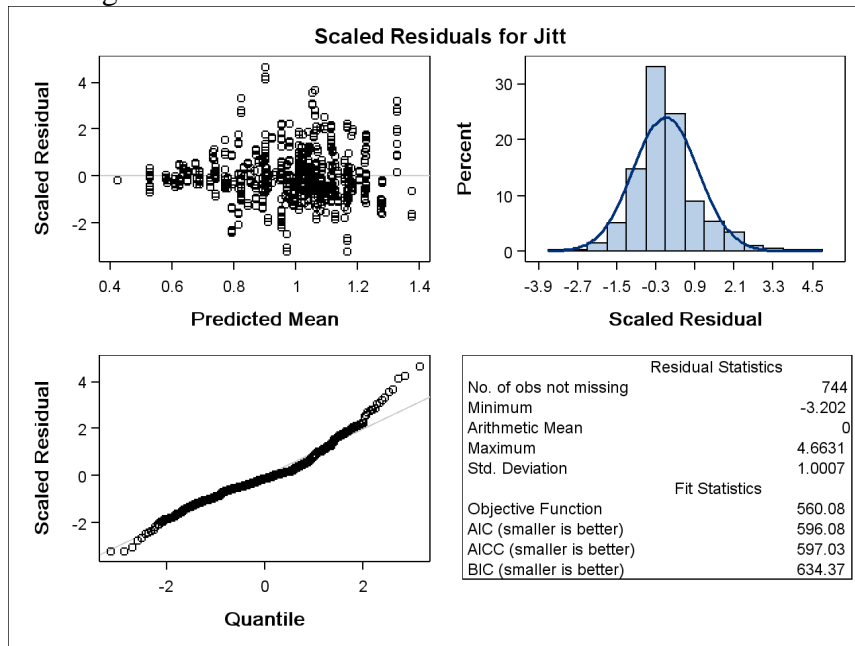


Plots of residuals of log transformation of reduced model of interaction of trait anger with range of fundamental frequency

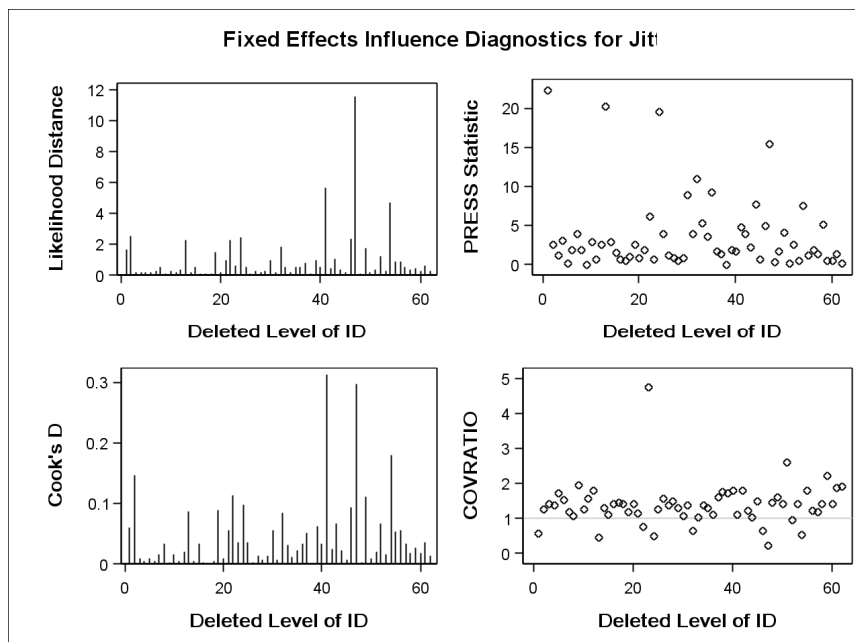


Influence diagnostics of log transformation of reduced model of interaction of trait anger with range of fundamental frequency.

Research Question 4 (Continued). Change in Acoustic Parameters with Psychological Variables – Trait Anger and Jitter

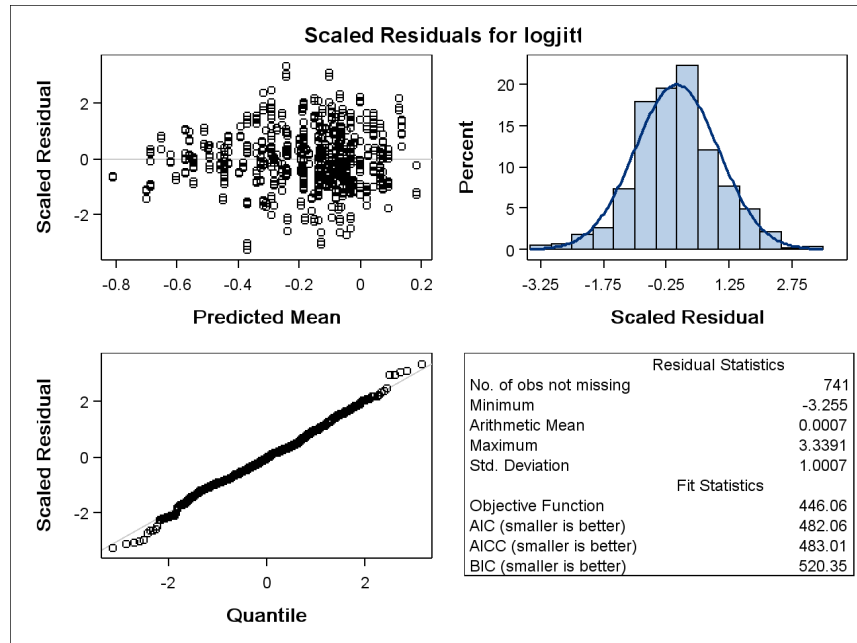


Plots of residuals for reduced model of interaction of trait anger with jitter.

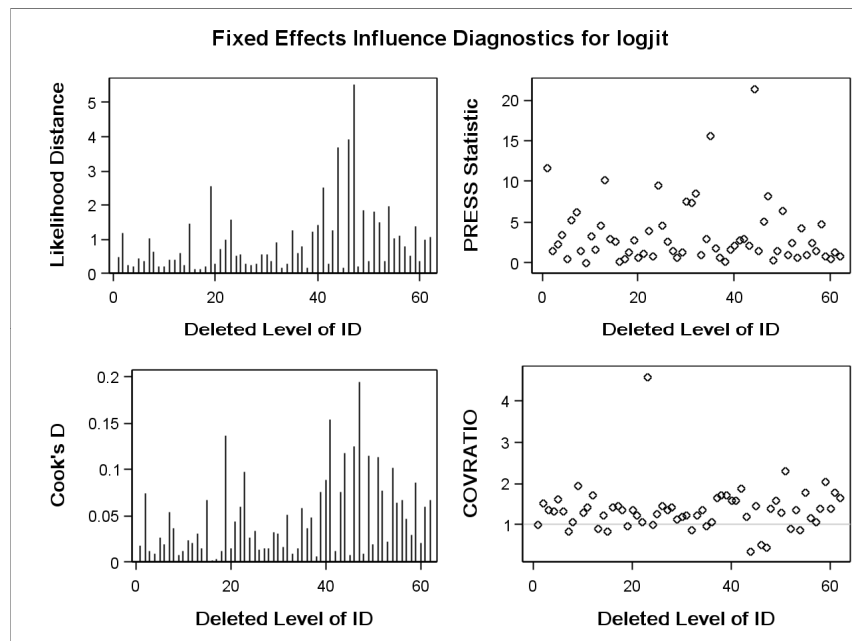


Influence diagnostics for reduced model of interaction of trait anger with jitter.

Research Question 4 (Continued). Change in Acoustic Parameters with Psychological Variables – Trait Anger and Jitter



Plots of residuals of log transformation of reduced model of interaction of trait anger with jitter.



Influence diagnostics of log transformation model of interaction of trait anger with jitter.

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