Sociocultural Perspectives of Physical Activity Patterns in American Adolescents: 1. association patterns of health risk behaviors 2. Effects of peer influence

Ying Liu

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Approved by:
Penny Gordon-Larsen, PhD
Ted Mouw, PhD
Kari North, PhD
Barry M. Popkin, PhD
Dianne ward, EdD, MS
ABSTRACT

Ying Liu: Sociocultural Perspectives of Physical Activity Patterns in American Adolescents:
1. association patterns of health risk behaviors 2. Effects of peer influence
(Under the direction of Barry M. Popkin, PhD)

Promoting healthy lifestyles and increasing physical activity levels in adolescents has
long-term effects to prevent a series of chronic diseases. As part of daily activities,
physical activity has sociocultural attributes. However, in the etiological model of
adolescent physical activity, how physical activity is affected by its sociocultural
attributes is understudied. This study examines adolescent physical activity as a social
behavior and investigates its social determinants. The objectives are to find out how
physical activity associates with substance use behaviors; whether race/ethnicity affects
the association patterns of physical activity and substance use behaviors both at the
individual level and at the institutional level; whether interpersonal relationship
(friendship) affects the physical activity levels, and whether body weight status of friends
modify this effects. This study contributes to the understanding of the non-linear
association patterns of physical activity and substance uses behaviors in American
adolescents, thus showing the necessity to improving physical activity through promoting
healthy lifestyles. It highlights the necessity of appreciation and incorporation of
racial/ethic specific cultures for better communication between health educators and
target population, and the importance to reduce the negative impacts of persisting school /
residential segregation on shaping adolescent health behaviors. It proves the possibility of
using adolescent friendship to improve physical activity in adolescents with consideration
of type of physical activity and type of friendship features.
The cross-sectional study examined the association patterns of health behaviors in 19331 adolescents aged 11-22 in years 1994-1995 from the National Longitudinal Study of Adolescent Health (Add Health). Cross-sectional and longitudinal analysis of friendship and physical activity was conducted in the subsample (n=3072) of the Add Health using data from 1994-1995 and 1995-1996. A self-reported physical activity/inactivity, substance use behaviors, and friends’ name were obtained. Survey information of paired friends was linked through assigned identification number. Other pertinent information was also collected.
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I. Introduction

A. Background

The benefits of physical activity in the development of adolescent health and the prevention of obesity and its related chronic diseases are widely known; however, many American adolescent did not meet the recommended levels. Thus, improving physical activity levels of American adolescents is an important public health strategy to prevent the obesity epidemic in the American population. Physical activity is rooted in lifestyles and learned through socialization, which determines its sociocultural attributes. However, this sociocultural perspective of physical activity has not received enough attention among researchers, although increasing concerns have been given to different social contexts and environments (e.g., ‘built’ environments, communities, neighborhoods, and families) of physical activity.

In previous studies, physical activity was usually investigated as a single behavior. Its possibility of co-varying with other health behaviors and thus the implication of co-varying status has been ignored. Another understudied perspective of physical activity was the possibility that interpersonal relationship such as friendship may influence adolescent physical activity through the interpersonal interactions and socializations.

Our study investigated the modifiable social factors that might have effects on physical activity of American adolescents. We sough to better understand physical activity by investigating it as a typical social behavior. We investigated non-linear co-varying patterns of physical activity and substance use behaviors, and we also investigated the impacts of sociocultural and economics on these co-varying patterns. Further, we investigated how different
types of adolescent physical activity, as social behaviors, were influenced by friendship the most important relationship in adolescents.

The analyses were based on Wave I and Wave II data of the National Longitudinal Study of Adolescent Health (Add Health) conducted in 1994–1996. First, through the pattern recognition method, the full nationally representative Add Health cohort was chosen to find out the overall co-varying patterns of physical activity with substance use behaviors. Second, a special subgroup of 3702 subjects of the social network database in the Add Health was also used to explore the effects of peer influences on the adolescent physical activity using both cross-sectional and longitudinal analysis. We observed simplest dyadic friendship (two persons), since the effects of direction and trends of dyadic friendship are similar to those at the group levels.

B. Research Aims

The major goal of this research was to contribute to the etiology of physical activity, by investigating how adolescent physical activity, as a social behavior, is influenced by social determinants (e.g., race/ethnicity) and social context (e.g., friendship).

Aim 1. We hypothesized that as the components of daily life, physical activity and other health behaviors are associated. We also hypothesized that this association status is related to adolescent race/ethnicity at different observational levels (the individual level and the school levels).

a) We used cluster analysis to search for the meaningful patterns that physical activity co-varies with a series of health behaviors (e.g., alcoholic drinking, cigarette smoking, and drug use) in American adolescents.

b) Further, Multilevel Model was applied to find out how race/ethnicity was associated with these identified patterns both at the individual level and at the school level. Analysis was
based on the Wave I Add Health dataset (N=20774), and was conducted separately for males and females.

**Aim 2.** We tested the hypothesis that physical activity levels of adolescents are associated with those of their friends. Further, we also tested whether the difference of body weight status of a pair of friends modifies this association— an otherwise similarity of physical activity—after controlling for other covariates that might confound the estimation. Data used are the Wave II peer sample of the Add Health.

**Aim 3.** We tested the hypothesis that peer influence has a causal effect on physical activity levels of adolescents. To assess causality, we quantified the changes of physical activity of adolescents due to the baseline value of their friends after controlling for the baseline values of their own physical activity and other covariates. Data used are the Wave I and Wave II peer sample (N=2776) of the Add Health.
II. Literature Review

A. Inactivity in United States and demands for improving physical activity levels in American adolescents.

The health benefits of regular physical activity are well established. A certain level of regular physical activity can decrease mortality and morbidity related to several chronic diseases (osteoarthritis, obesity, cardiovascular disease, diabetes, and cancer) and can also improve mental health and physical functions (Pate, Pratt et al. 1995; USDHHS 1996; Blair and Wei 2000). Because of the importance of physical activity on a person’s health, physical activity is one of ten leading health indicators in Healthy People 2010, a national health promotion and disease prevention program that sets a series of health goals by year 2010 (USDHHS 2000). However, physical inactivity has been persisting in American population; 27.3% adults did not engage in any leisure time physical activity, 46.5% did not have enough physical activity, and only 26.2% met the recommended physical activity levels (Hootman, Macera et al. 2003). Further, physical activity levels in adulthood can be correlated to those in adolescence: (a) physical activity levels decline during the transition from adolescence to adulthood (Barnekw-Bergkvist, Hedberg et al. 1996; Telama and Yang 2000) and (b) physical inactivity in adolescence can predict physical inactivity in adulthood (Telama, Yang et al. 1997; Yang, Telama et al. 1999; Tammelin, Nayha et al. 2003). Moreover, about 1 of 3 young people did not participate in any vigorous physical activity in 2003 and only 25% of high school students participated in their school’s physical education classes in 1996 (USDHHS 1996). These facts emphasize the importance of improving physical activity levels in adolescents, especially since obesity is a major public health problem in United States (Fletcher 1997; USDHHS 2000).
Researchers have already realized the importance that social and environmental factors can have effects on individual physical activity levels (Sallis, Bauman et al. 1998; Stahl, Rutten et al. 2001; Stahl, Rutten et al. 2002). However, studies on physical activity in adolescents have neglected two important socialcultural aspects. The first neglected aspect is, “Should physical activity interventions need to consider other health behaviors such as smoking, alcoholic drinking, and drug use? If yes, why”? The second aspect is: “Should physical activity intervention strategies need to consider the interrelationships between adolescents and their peers? If yes, why”? The answers to these questions have important functions in improving the effectiveness of physical activity interventions that are targeted at adolescents.

Our study will explore and answer these questions by: (a) investigating the co-varying patterns of physical activity and other health behaviors and (b) investigating the mechanisms of peer influence affecting the physical activity of adolescents.

B. Relationships between physical activity and other health behaviors.

1. The important health indicators in American adolescents.

Tobacco use and alcoholic drinking are two preventable leading death causes in the United States (Mokdad, Marks et al. 2004). In 2000, 15.1 % of American adolescents in middle school and 34.5% in high school were tobacco users and 80% of them initiated smoking before they were 18 y old (CDC 2001). The prevalence of current alcoholic drinking in adolescents was nearly 40% in 1995 (Grube 2001). Although illegal use of drugs is not a direct leading death cause, it is associated with many health risk factors such as suicide, depression, and motor-vehicle injury. Illegal drug use can also cause serious blood infections such as HIV and hepatitis (Mokdad, Marks et al. 2004). However, about 5% of adolescents aged 15–18y used some type of illicit drugs (Olfson, Marcus et al. 2002). Because smoking, alcoholic consumption,
and physical inactivity contribute a large proportion of deaths in the United States, they—along with illicit drug use—are in the 10 leading objectives of *Healthy People 2010*.

2. Potential co-varying status of physical activity and other health behaviors.

Physical activity is a physiological term for body movement that expends energy. However, its components are rooted in daily activities and occur with specific social events or environments. Its origin makes it highly associated with socioculture and lifestyles (Kim, Ahn et al. 2005; Reeves and Rafferty 2005; Suris and Parera 2005). Based on this fact, it is reasonable to generate a hypothesis that patterns of physical activity correlate to patterns of other health behaviors such as smoking, alcoholic drinking, and illegal use of drugs in adolescents. If this hypothesis is true, health educators should be aware of the possibility that, as side effects, promoting physical activity might result in increasing or decreasing other health behaviors, or other health behaviors might prevent or improve physical activity levels. Thus, a physical activity intervention program should be multifaceted. Heath risk behaviors may also interact with each other to intervene the disease development; for example, patterns of combining physical activity, smoking, and alcoholic consumption might have interactions on the lipid profiles of cardiovascular diseases (Stamford, Matter et al. 1984; Senti, Elosua et al. 2001). However, the literature about the relationships between physical activity and other health behaviors in American population is insufficient, especially in adolescents.

There are studies on the patterns of health behaviors that included physical activity, but were mainly conducted with adults (Johnson, Nichols et al. 1998; McTiernan, Stanford et al. 1998; Liang, Shediac-Rizkallah et al. 1999; Berrigan, Dodd et al. 2003). These studies are very important to support the hypothesis that physical activity is not independent of other health behaviors. However, behaviors of adolescents differ from those of adults; therefore, an extension of results from adult studies to adolescents might not be appropriate. In adolescents,
the co-varying pattern of smoking, alcoholic consumption, and drug use had been intensively investigated as a “syndrome” of problematic behaviors in sociological studies (Donovan and Jessor 1985; Donovan, Jessor et al. 1988). Because physical activity is only a concern in public health, sociological researchers have neglected it in their studies.

3. Adolescent behavior patterns and their sociocultural determinants

Studies about the aforementioned hypothesis in adolescents were especially few. In a subgroup (n=4,293) of a nationally representative study of American adolescents, physical activity levels were found to be negatively associated with smoking, alcohol drinking, and drug abuse (Pate, Heath et al. 1996). Pate’s study indicated the possibility that physical activity of American adolescents might co-vary with other health behaviors. However, this study was very limited for drawing conclusions. First, this study had incomplete results about the association between physical activity and other health behaviors in some ethnic groups. Second, this study only investigated the correlation between two behaviors, and it was not helpful to determine the high-risk populations with multiple health behaviors. Third, this study failed to control its survey design and its results only reflected the chosen sample, but not the population of American adolescents. Fourth, this study did not investigate which specific types of physical activity were easy to correlate to smoking, alcoholic drinking, and drug use. Thus, this study only provided health educators with the clues that two health behaviors were co-varied. The existing information was not sufficient for generating detailed intervention strategies aimed at increasing physical activity levels and decreasing other unhealthy behaviors of adolescents.

Using the Add Health dataset, one of the largest nationally representative datasets, we can contribute to better understand the co-varying status of physical activity and other health behaviors (e.g., physical activity, smoking, alcoholic drinking, and drug abuse) at the population
level. We will use cluster analysis to determine the overall co-varying patterns of different health behaviors including physical activity.

Understanding how social demographic factors affect the co-varying patterns of different health behaviors is also helpful for an intervention program to target the high-risk population. There is substantial evidence that social demographic status (e.g., age, gender, income, education level, and occupation) affects individual health behaviors (Barnes and Welte 1986; Andreasson, Allebeck et al. 1993; Singer, Himmelgreen et al. 1998; Williams, Zhao et al. 1998; Gordon-Larsen, McMurray et al. 2000; Sallis, Prochaska et al. 2000; Steptoe, Wardle et al. 2002; DHHS 2003; Russo, Purohit et al. 2004; Moore, Gould et al. 2005). However, it may not be appropriate to extend these evidences directly to any combined multiple health behaviors.

In this study, the investigation of sociocultural determinants focused on race/ethnicity, because the multifaceted function of race/ethnicity on individual behaviors has not been fully understood in term of its cultural attributes and its social economic attributes. Due to immigrant history, each race/ethnicity of the U.S. has its own special culture that shapes norms, attitudes, and behaviors. However, practice and policy of public health has not paid enough attention to it; instead, most of current policy and practice regard race/ethnicity as the indicator of social status(Rajaram and Rashidi 1998; Simon 2006). Based on previous experience, Institute of Medicine (IOM) recognizes the demands to better investigate the relationship between social cultural backgrounds and health behaviors in order to improve communication efficiency (Nelson 2002).

Eliminating persistent racial/ethnic disparity of health status of American population is an important public health policy. There is an argument that persistent racial/ethnic segregation is the actual cause of health disparity among different race/ethnicity. This argument states that racial/ethnic segregation in economic status and further in residence prevents different
race/ethnicity to equally access to health service systems (Williams and Collins 2001). However, this argument is bases on limited evidence, and it needs more support from scientific research.

In order to contribute to the knowledge of race/ethnicity in the above aspects, this study investigated the effects of race/ethnicity to see how racial/ethnic identity of one person is associated with his/her behavior patterns, and how behavior patterns of students from different schools are affected by the racial/ethnic background of their schools.

C. Effects of peer support on physical activity in adolescents

Another important socialcultural perspective of physical activity of adolescents is the peer relationship. Physical activity, whether co-varying with other health behaviors or not, is learned from the socialization processes with others (Anderssen 1993). Peer relationships are regarded as important interpersonal relationships for adolescent development (Kandel 1978; Kandel 1996; Duncan 2002).

Many investigations of the effects of peer relationships on health behaviors narrowed and focused on peer support. Peer supports can be emotional, instrumental, informational, or appraisal, and they are one function of peer relationships that can always be “helpful” for a person’s behavior change (Heaney 2002). Studies have already found that peer support is a very important social environmental correlate of adolescent physical activities in cross-sectional studies (Zakarian, Hovell et al. 1994; Stahl, Rutten et al. 2001; Strauss, Rodzilsky et al. 2001; Bauer, Yang et al. 2004). Some behavior intervention studies have also found that programs with peer support strategies can significantly improve the efficiency of interventions (Cho, Hallfors et al. 2005; McCabe and Ricciardelli 2005).

However, there are several fundamental limitations about the studies of peer supports. The empirical limitation is that measures of “peer support” in these studies were self-reported, perceived values. Those self-reported values might be affected by the reporters’ cognitive status,
thus leading to bias. Further, the questions used to measure perceived “peer supports” were not comparable among most studies. These limitations made it difficult to precisely compare results among different studies or to quantify the effects of peer relationships.

The effect of peer support is only one of the functions (in terms of help) of peer relationships, and it cannot represent other peer relationship functions on the physical activity of adolescents. Supports from peers are always intended to be helpful; however, peer relationships also involve competition, rejection, and negative interactions (Deater-Deckard 2001; Bukowski and Adams 2005). Studies of peer support cannot answer many questions about the mechanism of peer relationships; for example; (a) How do the events of initiation, maintenance, and dissolution of peer relationships involve the shaping of adolescent physical activity? (b) To what extent do peers affect each other through these events? And (c) How and to what extent do peer characteristics affect each other’s physical activity? To fully understand the effects of peer relationships on physical activity of adolescents, studies about peer influence from sociological perspective are needed.

If peers’ physical activity patterns or characteristics can affect adolescents’ choices of physical activity, it may indicate an important peer-orientated strategy to improve the efficiency of physical activity intervention in adolescents that are only targeted on schools, neighborhoods or individuals. However, this hypothesis has not been systemically tested in the public health field. No studies have quantified the magnitude of physical activity levels of adolescents caused by their peers, nor have studies investigated how peers’ characteristics (age, gender, or body weight status) affect the choice of physical activity of adolescents.

We will apply sociological theories that were used in other sociological studies of peer influence, which will lead us to test our hypothesis and solve some of those questions listed above. First, instead of measuring self-reported “peer support”, our study will measure both physical activity levels and characteristics of adolescents and those of their friends. The
estimates of peer influence in our study will therefore be independent of the psychological status of reporters; it will also make it possible to quantify the total magnitude of the effect of peer influence on the physical activity of adolescents. Second, since the estimates of peer influence are based on the calculation of observed absolute values, the estimates will be most robust when compared to those based on subjectively perceived measures. Third, in order to answer how and to what extent the events of friendship (e.g., initiation, maintenance and dissolution) determine the physical activity levels of adolescents, we will quantify the effect of peer influence in a longitudinal study based on the time-varying status of peer relationship. Fourth, we will investigate a specific aspect of peer network function—how peers’ characteristics such as gender and body weight status—affect the choice of physical activity levels of adolescents.

D. The procedures of assortative selection and socialization—and their contributions to the similarity among peers.

Children first develop significant relationships with family members; however, as age increases, children will also develop their unique relationships with peers to meet their characteristics of having increasingly different personalities, social lives, and independence from parents (Rubin 2004). It is generally agreed that members within a peer group have similar behaviors and group normative beliefs about different perspectives of life. This phenomenon is called similarity (Kandel 1978; Poulin, Cillessen et al. 1997; Urberg, Degirmencioglu et al. 1998). There are two procedures that contribute to the similarity among friends: (a) assortative selection of friendships and (b) socialization.

Assortative selection means to choose a friend based on some pre-common interests or preferred characteristics. Assortative selection may lead to dissolving old friends and making new ones (Cohen 1977; Kandel 1978). Through the interaction among friends, the attitudes and behaviors of one person ("ego") can influence his/her friends ("alters") to have more similar
attitudes and behaviors (Kandel 1978). These internal influences among friendship groups develop through a procedure called socialization (Kandel 1978).

According to Kandel’s review, most studies of deviant behaviors in adolescents have shown that assortative selection is at least as important as socialization—regarding similarity among friends (Kandel 1996). Assortative selection and socialization among adolescent friends are important potential factors in physical activity interventions—if their effects are substantial. If our study finds that assortative selection effects are substantial, strategies to help inactive adolescents to make friends with active adolescents might help preventing these inactive adolescents from making friends with inactive adolescents, thus avoiding their negative attitudes about daily physical activity to be enhanced. However, if we find socialization is substantial, then strategies such as “peer supports” or “role models” in friendship groups would help to increase the efficiency of physical activity interventions that are targeted at the community or individual level.

E. Methods in quantifying socialization effects.

Quantifying the effects of peer influence on the similarity among peers is to quantify the attributes of socialization—controlling for the effects of assortative selection (Kandel 1978). However, most earlier studies on peer influence used a cross-sectional design to detect similarity among friends, which have led to an overestimation of the effect of socialization, since similarity also results from the selection of friendship based on preferred attitudes and behaviors (Kandel 1996). Most sociological researchers have noticed the importance to control the effects of assortative selection, but few studies are available to detect the effects of socialization and assortative selection based on the longitudinal process of initiation, maintenance, and dissolution of friendship (Cohen 1977; Kandel 1978; Chassin 1986; Ennett and Bauman 1994; Urberg, Degirmencioglu et al. 1997). Difficulties in obtaining the longitudinal peer network data
and the necessity to choose appropriate analysis methods led to this situation (Ennett and Bauman 1994; Kandel 1996). The researchers in these few studies have developed several empirical methods that can help researchers to separate, or to control, the effects of assortative (Urberg, Degirmencioglu et al. 1997) selection from the effects of socialization.

The first method was originally used in Kandel’s study of college students about them, and their friends’, different social behaviors (e.g., smoking, drug use, academic achievement, and policy attitudes) (Kandel 1978). Assortative selection and socialization are different procedures, but these procedures can occur at the same time. In most cases, they do not mutually exclude each other (e.g., an adolescent keeps changing a behavior and makes a new friend who he knows for a long time; however, how much his /her new friend influences him is not clear) (Kandel 1978; Maxwell 2002). However, Kandel and some other researchers believe that, in some cases, these two procedures can be separated using appropriate methods (Kandel 1978; Ennett and Bauman 1994; Urberg, Degirmencioglu et al. 1997). Using longitudinal data and contingency tables, both Kandel and Ennett have successfully separated these two procedures. In their studies for estimating effects of assortative selection, they chose to count the case numbers that came toward, or went away from, a given behavior for friends with a given initial behavior status. For estimating the effects of socialization, they chose to measure the behavior changes in the subgroup of friends that remained stable over time. By limiting the analysis to the stable friends over time, any changes in stable friends would be attributed to socialization effects, rather than assortative selection effects. Their method is very creative; however, it has these limitations:

(1) It can only answer the question “Which procedure contributes more to the similarity among friends— assortative selection or socialization?” but, it cannot answer the question “How many changes in behaviors of an adolescent are due to the influences of their friends?”.
(2) In order to compare the effects of the two procedures using contingency tables, behaviors have to be coded as binary variables distributed in a contingency table.

(3) It is possible to underestimate the effects of socialization by only using stable friends, because (a) the influence from short-term friends between Time 1 and Time 2 cannot be measured and (b) stable friends might not continue to be similar to each other over the entire course of the friendship (Urberg, Degirmencioglu et al. 1997).

The second method is to examine only the initiation of a certain behavior among adolescents — a behavior not possessed by the individual at Time 1 — but whose friends possessed this behavior at Time 1. Behaviors at Time 2 for this subgroup of adolescents will be due to the effects of socialization with the friends that possessed that certain behavior at Time 1. This method is most useful for behaviors in which there is a time point of onset, such as sexual activity, drug, or alcohol use (Urberg, Degirmencioglu et al. 1997).

The third method has been called “hierarchical regression.” In this method, a statistical method was used to control the effects of assortative selection and previous socialization, rather than restricting the analysis to the subgroups described above. The researchers predicted a subject’s Time 2 behavior by his/her friend’s Time 1 behavior, after removing the variance that this subject and his/her friends have in common (e.g., similarity) through entering this subject’s Time 1 behavior (Berndt and Keefe 1995; Urberg, Degirmencioglu et al. 1997; Maxwell 2002). The term “hierarchical regression” is derived from the fact that in the regression model, both behaviors in Time 1 and Time 2 are included.

F. Description of key variables

1. Description of friendship.

The interpersonal relationships can be described from different perspectives and the most widely accepted are “reciprocity”, “intensity”, and “durability” (Scott 2000). “Reciprocity”
describes whether the relation is in one direction or in mutual directions. One person can treat another as his/her friend; however, this cannot guarantee the proposed friend mutually treats him/her as a friend. “Intensity” describes how close the relations are. When intensity increases, the interaction between friends increases, and the influence on each other also increases. “Durability” describes how stable the relationship is through time (Scott 2000). These three perspectives of friendship affect the process of initiation, maintenance, and dissolution of friendship (Kandel 1978; Scott 2000). These perspectives of friendship affect how we measure peer influence in our study.

2. Peer characteristics and their effects on peer influence.

Demographic attributes of individuals (e.g. age, gender, body size, and race) constitute the peer structures, which have been found to be associated with the intensity and the duration of friendship—thus affecting peer influence. For example, in several studies on the relationships between peer influence and the initiation of smoking and sexual intercourse, the strength of peer influence was found to vary with age, gender, and race (Billy and Udry 1985; Bauman, Carver et al. 2001).

Body size is another factor to affect adolescents’ choices of friendship. A sociological study found that body size is associated with aggressive behaviors in peer groups (Unnever and Cornell 2003). Evidence has also shown that self body weight status is a concern about developing friendships among overweight female adolescents (Gerner and Wilson 2005). To date, several studies have reported that the potential similarity in body image could have an influence on diet restrictions and extreme weight loss in female adolescent friend groups (Patterson, Moore et al. 2004; McCabe and Ricciardelli 2005). Some public health studies on physical activity have shown that body image (perception, imagination, emotions, and physical sensations of and about bodies) is related to adolescent physical activity levels (Garcia, Pender
et al. 1998; Taylor, Yancey et al. 1999; Trost, Pate et al. 1999; Lee, Sohn et al. 2004; Taveras, Rifas-Shiman et al. 2004). Since friends are more likely to share the same expectation and beliefs, it is possible that body weight status of friends may affect each other’s attitudes towards their own body shapes—thus affecting physical activity levels of a friendship group. Our study will test the hypothesis that body mass index (BMI) as an indicator of body weight status can modify the effects of peer influence on physical activity patterns in adolescents.

3. Definition and classification of physical activity.

Physical activity is defined as “bodily movement produced by the contraction of skeletal muscles that increases energy expenditure above the basal level” (Caspersen, Powell et al. 1985). Physical activity consists of all the daily activities (e.g., walking, cooking, jogging to swimming, hiking, and so forth). Measurements of physical activity are multiple-faceted: frequency, intensity, time period (or duration), and type (or mode) (Kriska 2000). In epidemiology studies, physical activity questionnaires are mostly used in surveys because they are inexpensive and relative reliable in reflecting the amount and type of physical activity (Sallis, Prochaska et al. 2000).

Classification of physical activity is usually based on intensity—the amount of energy or effort a person expends in performing the activity (USDHHS 1996; Ainsworth, Haskell et al. 2000). In epidemiological studies, researchers usually use the compositional tables developed by the Center for Communicable Diseases (CDC) as the template to rate intensity. These tables classify all the daily activities into “light”, “moderate”, or “vigorous” categories according to metabolic equivalent (MET) values (one MET is defined as the energy expenditure used to sit quietly) (USDHHS 1999). Further, according to these tables, studies usually classify daily activity into such categories as “occupational”, “leisure time”, or “house work” to describe the pattern of physical activity (USDHHS 1999). “Inactivity” is a term for “not engaging in any
regular pattern of physical activity beyond daily functioning” (DHHS 2005). It is a term for a typical sedentary life style such as sitting, television and video viewing, television and video gaming, and reading. Some studies observed that watching television or video is associated with an increased obesity rate, even after controlling total energy intake (Crespo, Smit et al. 2001). Thus, some studies have used independent measures for physical inactivity (Biddle, Gorely et al. 2004; Biddle, Gorely et al. 2004). To highlight that being physically active or inactive are different life styles, we will measure inactivity using hours of “television and video viewing” and hours of “television and video gaming”. The detailed information about how physical activity will be measured in our study will be presented in Section D.

G. Potential confounders of peer influence on physical activity.

Whether correlates of physical activity confound the estimation of effects of peer influence on physical activity in adolescents is an understudied field and is not documented in the literature. The following is a brief review of the correlates of physical activity that might confound the estimation of the effects of peer influence. These correlates are evaluated in our study, using standard epidemiology methods, to determine if they confound the estimation.

1. Demographical or biological perspective.

Individual biological differences exist between physically active and inactive persons. Evidence has shown that overweight and underweight adolescents or children are more likely to be inactive than those with normal weight. Another biological factor is age. Studies have found that aging led to a decline of physical activity levels (Armstrong, Welsman et al. 2000; Sallis 2000). Gender also plays a major role in physical activity levels: some national or international surveys in adolescents reported that boys were more physically active than girls (Hamalainen, Smith et al. 2000; Sallis, Prochaska et al. 2000).
2. Psychological perspectives.

Psychological factors are important intrapersonal characteristics associated with physical activity of adolescents. According to Sallis’s review, the psychological correlates most investigated are: self-efficacy, self-esteem, depression, perceived body image, and self-motivation (Sallis, Prochaska et al. 2000). Among these psychological correlates of physical activity, depression and self-efficacy of barriers is the strongest and most consistent correlates in cross-sectional studies (Sherwood and Jeffery 2000). Cross-sectional studies have also shown perceived body expectation/image correlate with physical activity (Sallis, Prochaska et al. 2000). However, evidence is still not sufficient to clearly conclude the causal interrelationships between psychological status and physical activity levels.

3. Social environmental perspective.

Increasing attention is focusing on the modifiable environmental factors that might have influences on the individual’s amount and type of physical activity. Social economic status (SES) is intensively investigated. The usual indicators of adults’ SES are race, income, education level, and occupation. Studies have shown that Black and Hispanic girls are less active than White and Asian girls (Gordon-Larsen, Adair et al. 2002). A low SES has been correlated to physical inactivity (Gordon-Larsen, McMurray et al. 2000).

4. Family (parental) supports.

Studies have shown that family support may motivate family members to be more physical active (Anderssen and Wold 1992; Sallis, Alcaraz et al. 1992; Zakarian, Hovell et al. 1994; Aarnio, Winter et al. 1997; Hoefer, McKenzie et al. 2001; Davison, Cutting et al. 2003). However, it is not clear which aspect—heredity or family support—plays the main role. The
traditional parent-offspring studies can only provide an upper limit for the heritability, because the similarity among family members can come from both heredity and shared environments (Tan, Christensen et al. 2005). A substantial genetic propensity was found to be related to levels of physical activity—studies in the literature found 29%–75% of the variance of behaviors can be explained by heredity (Loos, Rankinen et al. 2005). A study has also shown that sedentary phenotypes of parents and their offspring are associated with their common genotypes (Loos, Rankinen et al. 2005).

Literature shows that parental influences and peer influence compete with each other to affect adolescent behaviors (Kandel 1996; Duncan 2002). There is also evidence that family support may mediate the effect of peer influence, because parents usually supervise the friendship of their children with other adolescents (Kandel 1978; Kandel 1996; Duncan 2002).

H. Statistical restriction and models

1. Nested structure and multilevel Model

   Multilevel model was developed for hierarchically structured data (e.g, individuals are nested in families, neighborhoods, provinces). The lowest levels are considered as micro level, and the upper levels are considered as macro levels called groups or contexts(Snijders and Bosker 1999). In a traditional regression model, exposures are required to be randomly distributed among all the observations (independence of observations); however, this prerequisite can not be met for the data with a hierarchical structure, because inside groups or contexts, there is an intra-class correlation which is a measure of group homogeneity. If this intra-class correlation equal to zero, the assumption of independent observations is not violated and a traditional linear model can be used. Instead, ignoring the intra-class correlation would result in an underestimation of the standard errors of the estimated parameters and increasing the
possibility of type I error (false positive). Multilevel model can control this hierarchical structure and achieve more accurate estimation of parameters.

Statistically, the variance of an outcome in a multilevel model is very similar to that in ANOVA model: The variance can be decomposed into the part due to the specific effect of the groups or contexts and the part due to a specific micro unit. In multilevel analysis, parameters of random effects are estimated if the effect of the groups or contexts varies across different groups; instead, parameters of fixed effects are estimated if the effect of the groups or contexts is the same across groups or contexts (Snijders and Bosker 1999).

Besides the benefit to improve the estimation of parameters, in the multilevel model, the group effects can be strongly reflected in the hierarchical interaction between the variables from micro levels and those from group levels, and this can help public health investigators to find out the mechanism of environments such as schools or neighborhoods impacting on individual health outcomes. Since adolescents are nested in schools, our study uses the multilevel model in Aim 1 to get more precise estimation for the effects of micro-level independent variables such as age, gender and SES and to evaluate how variables at school level interact with those micro-level variables to impact on individual adolescent behaviors. Our result about this interaction are helpful to find out which intervention channel, schools, individuals, or both, are efficient to shape a healthy lifestyle. School level variables are not our interests in aim 2 and aim 3, and to simplify the analysis, we use robust estimation for the clustered data rather than multilevel model.

2. Heterogeneity bias and endogeneity bias in the regression models.

In observation studies, unobservable variables are the core problems bringing bias that hinder the improvement of the estimation for the parameters (Zohoori and Savitz 1997; Halaby 2004). Heterogeneity bias results from the unobserved unit attributes that is unvarying through
time, and endogeneity bias results from the unobserved time varying variables. In the reality, bias due to the unobservable variables always exits to some extent. However, the estimation can be improved through careful variable identification and model specification to meet the statistical requirements.

a. Endogeneity due to the assortative selection of friends.

The similarity of physical activity levels between an adolescent and his/her friends results from both the effects of assortative selection and the effects of socialization. Assortative selection occurs when friendship pairs are purposefully formed based on their prior similar behaviors or attitudes of physical activities (e.g. two adolescents both playing basketball meet in the playground and become friends; active adolescents like those active and become friends with each other). These daily behaviors or attitudes related to friendship may never be known. In the cross sectional study, we can not measure or control these assortative selection effects on the similarity among adolescent friends, thus the estimated effects of peer influence from socialization actually also include the effects of assortative selection. This results in unavoidable bias from null.

b. Endogeneity due to previous socialization effect.

Our study use the panel data, measures of physical activity and other variables were only conducted in specific time points. It is impossible for us to know the exactly time point when friendship occurs. So, similarity of physical activity among friends observed at a given time also comes from the previous socialization. Thus, the estimated effects of peer influence also unavoidably include the unknown effects of this unobservable previous socialization. Bias due to previous existing effects of socialization in Aim 3 is reduced by using the ‘hierarchical regression’ method.
c. Other endogeneity.

Endogeneity also comes from the following two facts: First, the friendship is reciprocal, and it is born with the simultaneous effect, which overestimates the effect of friendship. Second, in the cross sectional study, many unobservable environmental or psychological factors might make an artificial association of physical activity between two adolescents. For example, the similarity between a pair of friends from a same neighborhood might be different from that of another pair of friends from the different neighborhoods; depressed adolescents from the broken families might intend to make friends with the same background, thus the similar inactivity between them is not due to the influence of each other, but due to the depression of themselves.

To reduce the bias, in Aim 2, through identifying these environmental or psychological confounders in the model specification, endogeneity bias along with heterogeneity bias can be reduced to some extent. In the longitudinal study of Aim 3, we choose to control the endogeneity due to the effects of assortative selection by restricting the subjects in the regression model to those stable friendship pairs during the study period. Thus, the similarity of physical activity between friends should be totally attributed to the effect of peer influence, although this restriction might bring to potential selection bias (e.g, those having stable friends might be different from those having no stable friends). Other potential biases in Aim 3 are reduced by careful model specification.

I. Summary

The term “physical activity” emphasizes its function as a measure of energy expenditure; however, it evolves from social life and studies of determinants of physical activity should not omit its sociocultural perspective. The behavior patterns as lifestyles—how physical activity levels co-vary with multiple health behaviors—need to be investigated in American adolescents.
The determination of the co-varying patterns of health behaviors has important public health significance for identifying high-risk population and conduct effective lifestyle interventions. Physical activity levels are known to be affected by the social environments; however, how the interpersonal social relationships—such as peers—affect the choice of physical activity levels of adolescents are not known well. We will use an interdisciplinary approach to investigate the peer influence mechanism and to quantify its effects. Our study will help to conclude whether peer-orientated intervention is an effective way to improve physical activity in adolescents.
III. RESEARCH DESIGN AND METHODS:

A. Data set of the National Longitudinal Study of Adolescent Health (Add Health).

Add Health was a nationally representative study that allowed testing many hypotheses related to influences of social contexts (e.g., community, neighborhood, family, friends, and so forth) on their multi-perspective health behavior outcomes in adolescents (grades 7 to 12 and late in their young adulthood). The Add Health study collected information about individuals, families, friends, schools, and neighborhoods. Nationally representative sampling was accomplished at the school level. School size, school type (public vs. private), urbanization, and ethnicity are important factors for sampling. There were 80 high schools and 52 feeder schools including 20,774 subjects in the study. The feeder schools were those that sent graduates to the selected high schools and that included a 7th grade. The study included three waves: 1994–1995, 1996, and 2000–2001.

B. Peer groups/social networks.

Add Health yielded a full social network (relation matrix) data for 3,702 students from 16 “saturated schools”, which provided detailed information about peers and their relationships. The difference between the adolescents in the saturated schools and unsaturated schools is:

a. Students from saturated schools were asked to nominate up to five male and five female friends. These friends were located by using school rosters and were also asked to nominate their own friends. Through this method, the entire friendship networks inside a school could be determined.

b. In unsaturated schools, the adolescents were only asked to nominate one best male friend and one best female friend. Because in unsaturated schools, only 200 students
were received by sampling, those adolescents that were nominated as friends might not be an individual sampled in the study and the information about friends may not be available; therefore, it is impossible to build up the entire social network in those unsaturated schools. In our study, we will use the adolescents in the saturated schools to investigate the peer influence.

C. Study dataset and differences from the nationally representative data set (Add Health).

Our Aim 1 will use the Wave I of the full cohort of Add Health to investigate the overall co-variant patterns of multiple health behaviors including physical activity in American adolescents. To make the results nationally representative, the analysis will control the survey designs. Subjects that had no missing values will be included in the study. Our Aim 2 and Aim 3 will only use data from the saturated schools in Waves I and II, because only saturated schools have peer network data. Wave III is excluded because adolescents’ social network was traceable only from Wave I to Wave II; only a small part of adolescents graduated, dropped out, or transferred to other schools during this period. However, it is impossible for us to track their social network from Wave II to Wave III since most of adolescents moved out of their parents’ homes for work or college.

The 16 saturated schools were not selected based on probability, and were not nationally representative. However, these schools did vary in size, type, urbanization, ethnicity, and region, which made it comparative to those of nationally representative schools (unsaturated and saturated together). In the analysis, it is necessary to present the difference between these two datasets in order to discuss possible selection bias when applying the estimations of peer influence from our study to other populations. Figure 1 shows that the major behaviors of adolescents from saturated schools did not significantly differ from those of adolescents in the nationally
representative schools, although the average age, ethnical groups of adolescents in the saturated school were different from those in nationally representative schools. This guarantees that although our estimation of peer influence is based on a convenient sample, the estimation can still have strong inference ability about the effects of peer influence.

Figure 1: Ethnic group differences between nationally representative (n=20,774) and saturated (n=3,074) samples (Add Health, Wave I: 1994–1995).
Figure 2: Differences in age and physical activity levels between nationally representative and saturated school samples.

Figure 3: Differences in the percentages of smoking, alcoholic drinking and drug use between nationally representative and saturated school samples.

A: Saturated sample
B: Nationally representative sample
D. Key measures

1. Measures of physical activity, inactivity and other health behaviors

a. Measures of physical activity, inactivity

Our study will use questionnaires to obtain information about type, intensity, and frequency of habitual daily life, which is similar to the questionnaire that was validated by more accurate measures (Booth, Okely et al. 2002). Physical activity is classified as low intensity, moderate to vigorous physical activity —based on the amount of energy or effort a person expends in performing an activity (USDHHS 1996; Ainsworth, Haskell et al. 2000). Our study can capture the moderate to vigorous physical activity whose intensity is equal to 5–8 METs; low intensity activity whose intensity is equal to 2–3 METs. We will also capture two categories of inactivity: TV& video viewing whose MET is equal to 1 and computer and video gaming whose MET is equal to 1. TV and video viewing, and computer and video gaming are common indicators for measuring inactivity in many studies (Crespo, Smit et al. 2001; Eisenmann, Bartee et al. 2002). In this study, frequencies of participating a type of physical activity is recorded as “bouts/week”, and this is different from most of studies, in which “bout” is defined as the unit of activity having certain intensity and specific time period.

b. Measures of current smoking, alcoholic drinking, and drug use

The questions in the Add Health study about health behaviors (smoking, alcoholic drinking, drug use, and gun carrying) are adopted and modified from the national Youth Risk Behavior Survey (YRBS), which showed good reliability and validity (Brener, Collins et al. 1995). In our proposed study, we will measure the current behavior status. Current smoking is defined as smoking cigarettes on 1 or more of the 30 days preceding the survey; current alcoholic drinking is defined as drinking any alcoholic beverage on 1 or more of the 30 days
preceding the survey; and current drug use is defined as using drugs on 1 or more of the 30
days preceding the survey. These definitions are consistent with the definitions from the
YRBS and from Add Health (Maxwell 2002; Weitzman and Chen 2005). The term “drug
use” is defined as using any of the following: cocaine, marijuana, inhalants (glue or solvents),
LSD, PCP, ecstasy, mushrooms, speed, ice, heroin, or illegal pills”.

The reason to choose the current health risk behavior measures rather than the
ever-behavior measures is to be consistent with the measures of physical activity levels in
terms of time. Physical activity is measured for the last week, which is considered the current
status.


a. Friendship pairs.

Most researchers and studies investigated “dyadic” friendship which is the smallest unit
for communication that needs two people only. Literature shows that the direction of the effects of
friendships at dyadic level and group level are the same (Fisher 1988; Ennett and Bauman 1994).
However, there is no standard definition for a friendship tie; it is more an empirical issue rather
than a methodological issue. In our study a friendship tie is counted if an ego nominated an alter
as his/her friends.

b. Measures of network structure.

A friendship (dyad) is the smallest unit for communication, which builds to form the
whole network in a given population. From a network perspective, the friendship tie is
embedded in a web of all the people, and cannot be independent from other ties (Ennett and
Bauman 1993). Therefore, some characteristics of a network interfere with the friendship
function. For example; (a) an influence from a person with many friends might be different from
that of a person with few friends and (b) change in attitudes or behaviors for a person with many friends might be different from that of a person with few friends, when both of them are exposed to the same friends’ behaviors or attitudes. In order to control the confounding effects from a peer network, we will consider controlling one important characteristic of the network—popularity—although our study does not touch the social network theory and its analysis. Popularity is the most widely concerned and investigated network characteristic in the peer influence studies. It is defined as “numbers of received nominations from others as friends” and it represents the acceptance of a person in a network and his/her potential function as a role model (Ennett and Bauman 1993; Ellen 2001). In some studies, researchers found that popular adolescents are different from others, they were more apt to be involved in smoking, alcoholic drinking or drug abuse (Ellen 2001). Whether popular adolescents have different physical activity levels than others is not known.


It is very important to realize that every adolescent is not isolated from other peers in the same school. School is an important setting for the education and socialization of adolescents (Alexander, Piazza et al. 2001; Cleveland and Wiebe 2003). In our Aim 2 and aim3, the school-wide average levels of physical activity are tested as an interesting social environmental factor that affects the adolescent physical activity.


In the literature, parental support usually has three perspectives: (1) informational and emotional support, through encouragement or discussion; (2) instrumental support, through offering transportation or buying sport equipments; and (3) indirect and direct modeling—it is indirect modeling if parents are more active but they do not play sports with their children; it is
direct modeling if parents play sports with their children (Hovell, Kolody et al. 1996; Duncan, Duncan et al. 2005). The effects of indirect/direct modeling have been highly investigated (Hovell, Kolody et al. 1996; Duncan, Duncan et al. 2005). In our study, we can only measure the direct modeling effect through the question: “Did you play sports with your parents in the last week?” This measure is consistent with other studies in the literature, although some of these studies also measured the frequency of playing sports with children (Stucky-Ropp and DiLorenzo 1993; Hovell, Kolody et al. 1996; Sallis, Alcaraz et al. 1999; Duncan, Duncan et al. 2005).

5. Measures of anthropometry and demography.

Individual demographic and anthropometrical measurements are available from the Add Health questionnaires.

Age was measured based on a self-reported birth date and interview date. Biological gender was observed by the interviewer, and will be used to represent sex status in the analysis. Individual height and weight were self-reported in Wave I, but measured in Wave II. We will use the Wave II data to analyze our proposed Aim 2, because this aim is a cross-sectional analysis and we can avoid the possible bias from the self-reported height and weight (Stevens, Keil et al. 1990; Plankey, Stevens et al. 1997; Kuczmarski, Kuczmarski et al. 2001).

The social economic status of parents is measured by their ethnic group origins, household income, and parental education level. Ethnic groups are generated from multiple questions of self-choice for race/ethnicity. Finally, ethnic groups are classified as non-Hispanic White, non-Hispanic Black, Hispanic, and others. Household income and parental education level is reported by the parents. Self-reporting is a standard method to gain information about social economic status (e.g. household income, parental education and ethnic origins) in U.S census and many nationally surveys. The way to classify ethnic groups are consistent with other studies of Add Health (Gordon-Larsen, Adair et al. 2002; Maxwell 2002). Observations with a missing
value in household income is substantial (14%) and we will use predicted values to replace those missing values, thus avoiding the reduction of sample size. The predictions are based on parental occupation, family structure, and the school community, which was similar to that in another study (Gordon-Larsen, Adair et al. 2003). A parental education level will be determined by the highest education level reported by the parents.


Body mass index—BMI is a widely used common indicator of weight status of adolescents in terms of underweight, normal weight and overweight. We will use BMI as the weight status of adolescents to determine if ego’s weight status confounds our estimation of peer similarity in Aim 2. However, the capability of BMI as an indicator of body weight status is dependent on the characteristics of the population. Most athletes generally have a bigger BMI than the common people, because their exercises usually make them more muscular. In our study, some of adolescents are athletes and use BMI to compare them to the common adolescents might result in misclassification bias.


In our study, we will measure two ego’s psychological or cognitive variables that might confound our estimation of peer similarity in Aim 2. These two psychological or cognitive variables are depression and perceived body expectation/image.

1. Depression: depressive symptoms will be measured using 19 self-reported items that were adopted and modified from the Center for Epidemiologic Studies Depression Scale (CES-D) scores (20 items) (Goodman and Huang 2002). CES-D scores are a valid and reliable measure that have been commonly used for assessing depression status in populations (Roberts, Lewinsohn et al. 1991). Subjects have to complete at least 80% of
the available items to be scored (Goodman and Huang 2002). Every item has a score from 0 to 3, and the final CES-D score can range from 0 to 57 in Add Health.

2. Perceived Body expectation /image: Add Health asked the subjects about their attitudes toward body weight: “How do you think of yourself in terms of weight?” The answers had five scales ranging from “very underweight” to “very overweight”. This measure reflected the subjects’ perceived body expectation/image and will be tested as a potential confounder in our analysis. In the literature, there are no standard measures for body expectation/image but self-rated scales of body expectation/image, similar to our study’s measure, are commonly used (Berg, Simonsson et al. 2005; Raustorp, Stahle et al. 2005).

Although there is evidence that self-efficacy is strongly positively associated with physical activity levels, we do not have this measure in our study. Thus, we cannot evaluate if self-efficacy is a confounder of the estimations in our study.

E. Separating estimations for female and male adolescents.

Gender is a critical biological and social structural variable that makes people different in many aspects of life. We conduct the proposed study separately in females and males, based on substantial literature about differences in adolescent behaviors between genders (Perkins 1992; Gordon-Larsen, McMurray et al. 2000; Kirkland, Greaves et al. 2004; SAMHSA 2004).
IV. Association Patterns of Substance Use and Physical Activity in American Adolescents: Results from the National Longitudinal Study of Adolescent Health (Add Health)

A. Background

Physical activity is a well-established preventive factor for a range of chronic health problems including cardiovascular disease, type II diabetes, obesity and some cancers. However, many American adolescents need to improve their physical activity in order to meet the CDC recommended levels (Grunbaum, Kann et al. 1999; Gordon-Larsen, Adair et al. 2002). In extensive efforts to understand the social determinants of adolescent physical activity, the following issues should receive more attention.

First, physical activity is lifestyle activities, which may make it an integrated lifestyle component that co-varies (associates) with other behaviors such as substance use or diet (Dunn, Andersen et al. 1998). Understanding how health behaviors co-vary with one another in the daily life can offer understanding of how best to intervene through modifying lifestyles (Johnson, Nichols et al. 1998; Berrigan, Dodd et al. 2003), and may point to how health behavior patterns vary with social demographic factors and, as such, allow an intervention program to target subgroups of the population with multiple health risk behaviors (Berrigan, Dodd et al. 2003). Co-varying health behaviors of adults have been substantially investigated by various analytical methods (Burke, Milligan et al. 1997; Johnson, Nichols et al. 1998; Liang, Shendid-Rizkallah et al. 1999; Berrigan, Dodd et al. 2003); however, studies in
adolescents are limited (Neumark-Sztainer, Story et al. 1996; Pate, Heath et al. 1996; Nelson and Gordon-Larsen 2006).

Second, significant racial/ethnic disparities were documented for many diseases (Amey and Albrecht 1998; Graham-Garcia, Raines et al. 2001; CDC 2002; Basu, Lopez et al. 2005; Thomas, Eberly et al. 2005; Harris, Gordon-Larsen et al. 2006). However, how race/ethnicity affects the risks of these diseases is not clear. Race/ethnicity is generally a social construct variable for policy and stakeholders, and most research of racial/ethnic disparities of health didn’t disentangle the effects of race/ethnicity, social economic class, and residence. Thus, effects of race/ethnicity on health are often confounded by social economic status and residence (Murry, Smith et al. 2001).

However, investigation of independent effects of race/ethnicity has its public health significance, because race/ethnicity, as culture identity, may associate with lifestyles and health behaviors, and may contribute to these health disparities alone with genetic and economic reasons (Dunn, Andersen et al. 1998). Although there are many definitions of ‘culture’ regarding its contexts of ethnicity, age, gender, and economic status, most agrees it is a term for shared values, norms, and attitudes and it is integrated with ethnicity through the ethnicity and culture model (Nelson 1979). In most circumstances of talking the population structure of U.S, the term ‘race’ is used for the African American and the Whites, and the term ‘ethnicity’ is used for people with Hispanic origin. Thus, term race, ethnicity, and culture are commonly used to investigate the African and Latino American. There is evidence that racial/ethnic differences in psychology and behaviors exist as early as in childhood and adolescence (Belgrave, Van Oss Marin et al. 2000; McLaughlin Crabtree, Beal Korhonen et al. 2005; Delpit 2006; Heslin, Casey et al. 2006). Detecting early racial/ethnic disparities of adolescent health behaviors would be beneficial to find the specific needs of different ethnic groups and to conduct early lifestyle modifications through effective communications based
on the appreciation of different cultural values and practices. These efforts would produce
long term effects to eliminate disease disparities later in adulthood. However, only a few
studies have investigated how race/ethnicity associates with co-varying patterns of substance
use and physical activity in adolescents (Liang, Shediac-Rizkallah et al. 1999; Berrigan,

There is an argument that health disparities among different racial/ethnic groups are the
consequences of the racial/ethnic segregation that persists in the American society (Williams
and Collins 2001). The argument states that residential and school segregation prevents the
youths of minorities from obtaining the equal opportunities of education, occupation, and
health resources, and makes them exposed to racism and discrimination. However, this
argument lacks direct evidence for the relationship between racial/ethnic segregation and
health behaviors, because previous studies only observed the racial/ethnic effects on the
health outcomes of individuals, but ignored its effects on institutions (schools, communities,
and neighborhoods) due to behavior interaction, and even enforcement, within race/ethnic
groups and the inequality of social recourses between the segregated racial/ethnic groups
(Richmond, Hayward et al. 2006).

The National Longitudinal Study of Adolescent Health (Add Health), a nationally
representative survey of adolescents, provides a unique opportunity to investigate the above
arguments. The Add Health surveyed a range of daily activities (e.g., substance use and
moderate to vigorous physical activity), whose co-varying status can be studied as a
perspective of the lifestyles of American adolescent. However, the most important
methodological benefit of the Add health was its sample method: adolescents were nationally
sampled based on schools, and 142 schools were selected. This strategy created a hierarchical
dataset with sufficient statistical power to investigate lifestyle exposures both at the
individual level and at the institutional level. Using the Add Health data, this study
accomplished two specific aims: 1) Cluster analysis was conducted to obtain the co-varying patterns of substance use and physical activity behaviors in American adolescents. 2) a multilevel regression model that can analyze effects at both the individual and the institutional level in hierarchical dataset was used to explore how individual race/ethnicity, and school racial/ethnic and social economic background associated with these behavior patterns.

B. Methods

1. Data set

   Wave I of the Add Health study was conducted in 1994 and 1995, including a sample of 20,745 students from 80 high schools and 52 middle schools in the US, selected with unequal probability. The Add Health study design incorporated systematic sampling methods and stratification to ensure a nationally representative sample of students in grades 7 through 12 in 1994-95. These students were given questionnaires designed to investigate adolescent health behaviors, the effects of different social contexts on these behaviors, and the health outcomes in young adulthood. Details about Add Health have been described elsewhere (Popkin and Udry 1998; Gordon-Larsen, McMurray et al. 1999). The Institutional Review Board of the University of North Carolina at Chapel Hill, NC approved the Protocol of the Add Health.

   The analyzed sample consisted of 19,341 adolescents (49% males and 51% female), including 21.9% Blacks (non-Hispanic); 16.9% Hispanics; 7.1% Asians; and 53.6% Whites (non-Hispanic). Native Americans were not included in the analysis due to few cases. The mean age was 16.14 (± 1.71) years. Subjects excluded from the analysis were those who were physically or mentally disabled, pregnant, or missing any behavior variables. Native Americans were also excluded due to the small sample size (N = 178). Comparing the dataset
of this study with the full dataset of Add Health, only the percentage of Whites was significantly (p<0.05) larger than that (52.4%) of the full dataset.

2. Variables

a. The health behavior variables for clustering behavior patterns

Behavior patterns (clusters), the outcomes of this study, were obtained by clustering health behavior variables. The following self-reported health behaviors were investigated: (1) substance use; (2) moderate-to-vigorous physical activity (MVPA); (3) Screen time including TV and video viewing and video/computer game use; (4) other low-intensity activities that might co-vary with the above behaviors. Details on measurement are described below.

The Add Health substance use (i.e., cigarette smoking, tobacco chewing, alcoholic drinking, and drug use)survey items were adopted from the Young Risk Behavior Surveillance System (YRBSS)—a validated national survey conducted among adolescents for health-risk behaviors (Eaton, Kann et al. 2006). Frequencies of cigarette smoking, tobacco chewing, and drinking alcoholic beverages (for convenience, ‘drinking alcoholic beverages’ is referred to ‘drinking’ in the following texts) were recorded as the number of days during the preceding 30 days of the survey on which the interviewed adolescents smoked cigarettes, chewed tobacco or drank. Drug use behavior was indicated by marijuana use, and its frequency was recorded as the number of times during the preceding 30 days of the survey on which the subjects used marijuana. Other drug use behaviors (i.e., cocaine, illicit drugs, and inhalant use) were assessed in the Add Health, but were not included in the analysis, because they were not common in adolescents (i.e., the prevalence was less than 10%) and they were highly correlated to marijuana use. The prevalence of tobacco chewing
in males was more than 10%; however, it was less than 10% in females (approximately 6%), so it was excluded in the analysis of females.

Measures of physical activity and low-intensity activities were reported in the Add Health survey questionnaires, similar to those previously validated in other epidemiological studies (Heath, Pratt et al. 1994; Pate, Heath et al. 1996; Andersen, Crespo et al. 1998). Questionnaire items elicited information in the following form: “During the past week, how many times did you play an active sport, such as baseball, softball, basketball, soccer, swimming, or football?”

In this study, physical activity was defined as the number of bouts per week of moderate to vigorous physical activity (MVPA; 5 to 8 metabolic equivalents [METs], with one MET equivalent to the energy used by the body at rest (3.5 mL O₂/kg body per minute)(Ainsworth, Haskell et al. 2000). Activities assessed in the Add Health and in this study were active sports (e.g., baseball, softball, basketball, soccer, swimming, or football); Wheel-based activity (e.g., rollerblading, roller-skating, skate-boarding, or bicycling); and exercise (e.g., jogging, walking, karate, jumping rope, gymnastics, or dancing).

Low-intensity activities (2 to 3 METs) included hobbies (e.g., collecting baseball cards, playing a musical instrument, reading, or doing arts and crafts), house work (e.g., cleaning, cooking, laundry, yard work, or caring for a pet), and hanging-out with friends. They were also measured as bouts/week.

Screen time defined as hours of television and video viewing per week is a widely accepted practical indicator for sedentary lifestyles in the literature (Crespo, Smit et al. 2001; Eisenmann, Bartee et al. 2002; Eaton, Kann et al. 2006). In the Add Health, it was measured by two behaviors reported in hours per week: (1) TV and video viewing, and (2) video/computer game use.

b. Respondent race/ethnicity (the exposure at the individual level)
Respondent race/ethnicity was self-defined by the subjects, and the final racial/ethnic groups in this study were White, Black, Hispanic, and Asian.

c. Joint distribution of students’ racial/ethnic composition and mean family income (the exposure at the school level)

To investigate how social economic and racial/ethnic composition of students at schools affected adolescent behavior patterns, a categorical indicator was created to indicate the joint distribution of racial/ethnic composition and mean family income for the students from the same schools. Categories of this indicator were: (a) “Percentage of Whites < 25% and school-wide mean family income level < $40K”; (b) “Percentage of Whites < 25% and school-wide mean family income level ≥ $40K”; (c) “Percentage of Whites ranging from 25% to 75% and school-wide mean family income level < $40K”; (d) “Percentage of Whites ranging from 25% to 75% and school-wide mean family income level ≥ $40K”; (e) “Percentage of Whites >75% and school-wide mean family income level < $40K”; (f) “Percentage of Whites >75% and school-wide mean family income level ≥ $40K”. This indicator is referred to ‘schools’ race–SES’.

d. Measurement of covariates

Other social demographic variables as the controlled covariates in the regression models were those that potentially confounded (identified through DAGs) the relationship between the behavior patterns and the respondent race/ethnicity or the schools’ social economic environments. These covariates were provided in different questionnaires of the Add Health survey:

1) In-home self-reported questionnaires of adolescents provided information for age (continuous, calculated by interview date and birth date); religion (classified as
Baptist, Christian Church, Catholic, others, and non-religion); generation of immigration (first generation, second generation, and third and more generation); adolescent working status (Yes, vs. No); presence of father in household (Yes vs. No); presence of mother in household (Yes vs. No).

2) In-school self-reported questionnaires of adolescents provided information for whether participating in sport clubs (Yes, vs. No).

3) Parental interviews had information of family income (continuous, reported by the head of household, where missing [n=2901] was imputed); parental education (reported by parents, presented as highest level of either parents, and categorized as less than high school, high school and GED, some college, and college and higher).

4) School characters that confounded the relationship between the adolescent behavior patterns and the schools’ social economic environments in the models were obtained from the questionnaires of school administrators. They were school session (Yes vs. no); school size (big, middle, and small); school urbanicity (urban, suburban, and rural); geographic regions (west, middle west, south, and northeast). School-wide parental education backgrounds (indicated by the percentage of parents with different education levels) and student religion background (indicated by the percentage of students with different religions) were generated by collapsing the individual values across the schools.

3. Cluster Analysis to Obtain Behavior Patterns (the Outcomes in the Modeling Analysis)

Cluster analysis is a general term for various pattern recognition technologies with different algorithms (Everitt, Landau et al. 2001). It can determine objective and robust
clusters of datasets without *a priori* hypotheses. The optimized clusters maximize the heterogeneity between clusters and the homogeneity within clusters. Cluster analysis was applied to partition the subjects into subgroups (clusters) that had specific and meaningful behavior patterns.

FASTCLUS procedure in SAS 9.0 (SAS LTD, Cary, NC) was used to conduct sex-stratified cluster analysis. The FASTCLUS procedure uses a K-means method to group subjects into non-overlapping clusters. Given the clustering variables and numbers determined by investigators, FASTCLUS divides the datasets into optimized groups. However, clusters resulting from the K-means method are influenced by the initiation of partition: (i.e., which observation is treated as the first cluster center [seed]). For the given clustering variables and numbers, the best seed to determine the final cluster solution were selected through 1000 clustering procedures which had different observations as the first seeds. The best seed was the one that had the biggest r-squares (a ratio of the inter-variance vs. intra-variance of clustering variables—a measure of dissimilarity of clusters).

Compared to males, females usually used less substance and were less active due to unknown biological or sociocultural reasons; in this study, tobacco chewing was a typical behavior in males but not in females. Therefore, cluster analysis was accomplished separately for males and females.

Twelve behavior variables for males (Table 1) and 11 for females (Table 1) were used for clustering. All clustering variables in our study were transformed to z-scores to avoid potential over-emphasizing of the variables with large scales (Wirfalt E 2000). Distribution of cigarette smoking, tobacco chewing, drinking, TV and video viewing, and video/computer game use were skewed to the left and had large ranges. To avoid a distortion from large z-score values, these variables were first rescaled to small ranges and then z-scores were calculated as others have done (Wirfalt, Mattisson et al. 2000; Everitt, Landau et al. 2001;
Nelson, Gordon-Larsen et al. 2005). Dichotomizing these variables was not applied due to the less differentiation of clusters.

The differences of means for the clustering variables among the clusters were tested by analysis of variance between groups (ANOVA) with Bonferroni correction. The cluster analysis was controlled for sampling weight of Add Health to ensure representation and multiple stages of cluster sampling to allow for survey design effects.

4. Multilevel Models

Purpose of the multilevel models was to understand how race/ethnicity differentiated the membership across the behavior clusters at both the individual (within-school) level and the school level. To avoid the ecological fallacy in the single level (individual level) models due to the failure to take account of institutional effects (in this case, the school effects) that made respondents of the same schools correlated to each other, multilevel models were applied for this hierarchical (nested) structure (Bryk and Raudenbush 1992). Besides individual level, schools’ race–SES measured by students’ racial/ethnic composition and their mean family income at schools can also affect individual behavior patterns at the institutional level. For example, parents may select schools for their children according to their race/ethnicity and economic status, and thus schools’ social economic environments may associate with school administration and education resources, and thus may associate with behavior patterns at the institutional level. Therefore, multilevel models helped to fully understand effects of race/ethnicity both at the individual level and the institutional level. Modeling option of random regression intercepts were applied (Bryk and Raudenbush 1992). The software was HLM version 6.0 (Scientific Software International [SSI], Inc.). Missing values of covariates (6% in males and 5% in females) were imputed by means.

5. Model specification and simulations
Modeling was separately conducted for males and females. The multinomial (polytomous) outcomes of multilevel models were the membership of different behavior clusters, and the main exposures variables were respondents’ race/ethnicity (exposure at the individual level) and the indicator for school social economic environments (exposure at the school level). A logit link function —an extension of the Bernoulli model was used.

Models were initiated with the main exposure variables of respondents’ race/ethnicity at the individual level and the indicator of schools’ race–SES at the school level. Then covariate family income and its cross products with respondents’ race/ethnicity were added in the female model, and covariate parental education and its cross products with respondents’ race/ethnicity were added in the male model, because maximum likelihood ratio tests for these cross products were significant (p values <=0.1). Then, other covariates were added through backward selection at both the individual level and the school level. All available variables at the individual level were first added, and then a variable dropped if its inclusion brought the smallest change in the estimation of regression coefficients of respondent race/ethnicity. Model fitting continued by successively re-fitting reduced models and using the same rule to drop variables until all these covariates met a prior “change-in-estimate” criterion (in our case, a 10% change in the regression coefficients of race/ethnicity). At the school level, covariates of schools’ race–SES were also added through the same procedures. In the final female model, covariates at the individual level were parental education, family income, religion, generations of immigration, adolescent work status, and age; covariates at the school level were school-wide percentage of parental education at different levels, school-wide percentage of different religions, school urbanicity, school region, and school size. In the final male model, covariates were presence of mother in the household, presence of father in the household, and those as the same in the female model.
The models predicted subjects’ membership of different behavior clusters. For \( k \) categories of behavior patterns, multinomial logistic regression simultaneously estimates \( k \) probabilities of falling into each category (in our case, \( k \) was 7 for male and 6 for female). For each respondent, these \( k \) probabilities are conditional on each other, and sum of them equals to 1. Listing all regression coefficients of a predicting variable with \( n \) strata is redundant, because a model reports \((n-1)*k\) coefficients and can not demonstrate the dynamics of membership shifting according to each stratum of the predicating variable. Instead, simulation was conducted to visualize the dynamics as follows: for each respondent, the probabilities falling into each behavior category according to the main exposure variables were predicted using the coefficients from the full adjusted models; then, for each behavior category, the mean probabilities of all respondents at a specific stratum of exposure variables were calculated and shown in figures for comparison.

C. Results

1. Behavior Patterns Resulted from Cluster Analysis

   Characteristics and names of final behavior clusters were summarized in appendix 1. Males (Table 2) had seven non-overlapping clusters. Clusters 1, 2, and 3 were identified as the substance use groups, but they differed from each other in the types of substance used. Clusters 4 through 7 had low frequencies of substance use, but they differed from each other in the behaviors of active sports, Wheel-based activity, exercise, or screen time.

   Females (Table 3) had six non-overlapping clusters. Clusters 1 and 2 had higher frequencies of substance use, and were very similar to the male Clusters 1 and 2, respectively. Clusters 3 through 6 had lower frequencies of substance use, and were very similar to the male Clusters 4 through 7.

   However, distribution of behavior clusters in females was much more different from that in males.
2. Multivariate Research

The models tested provide complex multinomial logit results. For the males and females, Multinomial results are provided for each pairing [eg. in males, Cluster 1 vs clusters 2 to 7, etc). There are 7 and 6 factorial results for males and females, respectively. One example of the results for females is presented in Appendix 2 and Appendix 3; however it is not feasible to either present all these results. Simulations that allow us to examine the effects of individual and school level effects provide an interpretable alternative. These simulations, however, are only meaningful in statistical terms when the coefficients are significant in a majority of iterations. Maximum likelihood ratio tests showed that respondent race/ethnicity and Schools’ race-SES could significantly (p<0.05) predict the membership of behavior clusters. The respective statistical tests are listed in Appendix 4, 5, and 6.

3. Simulation in the Individual Level

What is demonstrated in the simulation is based on the adjusted probabilities of memberships of different behavior clusters predicted by race/ethnicity in the full multilevel.

Simulation shows that respondent race/ethnicity were strongly associated with the adjusted predicted probabilities of cluster memberships. The adjusted predicted probabilities of some behavior clusters varied greatly across racial/ethnical groups, and the extent of variation depended on specific behavior patterns.

In males (Figure 4), Whites had higher probabilities to be in Cluster 3 (tobacco chewers) and Cluster 4(wheel-based players) than other racial/ethnic groups. Blacks were distinguished from other racial/ethnic groups for their higher probability of being in Cluster 6 (TV watchers) and lower probabilities of being in Cluster 2 (smokers and drinkers).
Hispanics and Asians had higher probabilities to report lower level of every activities assessed.

The effects of race/ethnicity in females differed from those of males (Figure 1-2). Whites had 2–4 times higher probabilities of being in Cluster 2 (smokers and drinkers) than other races/ethnicities. They were also different from other races/ethnicities by their substantially lower chance of being in Clusters 5 (TV watchers) and 6 (others). Blacks and Hispanics were more likely to be in Cluster 6. Each racial/ethnic group had the same capability to predict the membership in Clusters 1 (drug users), 3 (wheel-based players), and 4 (sporters and exercisers).

4. Simulation at the school level

Schools’ race–SES significantly associated with the distribution of behavior clusters across schools; however its capabilities to explain the variation of behavior clusters at the school level were dependent on the specific gender and clusters (the variance of behavior clusters that was explained by schools’ race-SES was listed in Appendix 5 and Appendix 6). In males (Figure 5), association was stronger for Clusters 3 and 5 than others. For example, compared to the male students in other schools, those in the schools where the majority was White (percentage of Whites ≥ 75%) and the mean family incomes were below $40K had much more probabilities in Cluster 3 but fewer probabilities in Cluster 5.

Generally, schools’ race–SES had stronger association with Cluster membership in females than males. In females (Figure 6), association was stronger for Clusters 2, 4, and 6 than others. For example, Compared to female students in other schools, those in the schools where the majority was non-White and the mean family income was over $40K had greater chance being in Cluster 2, but more chance being in Cluster 4; however, if the mean household income level was below $40K, they were more likely to be in Cluster 6.
D. Discussion

This nationally representative study provides important evidence of the lifestyles of American adolescents. First, health behaviors of adolescents were found co-varying: each substance use behaviors were associated with each other, and being physical active was associated with lower substance uses. Besides substance users, substantial inactive adolescents were found in American adolescents. Second, this study shows how race/ethnicity was associated with lifestyles both at the individual level and at the institutional level.

A few big-scale previous studies pointed out the necessity of investigating adolescent lifestyles in order to better prevent substance use behaviors and improve physical activity levels in adolescence (Neumark-Sztainer, Story et al. 1996; Pate, Heath et al. 1996). This study patterned the complex co-varying status of several health behaviors, provided co-varying details that previous studies did not capture, and helped to estimate the prevalence of different health behavior patterns in adolescents. Seven co-varying health behavior patterns in male adolescents and six in female adolescents were found. Besides cigarette smoking and drinking, appropriately 1 out of 3 male substance users and 1 out of 2 female substance users had high frequencies of using marijuana. Approximately 70% of American adolescents reported very low frequencies of substance use; however, they were different from each other in participating in moderate to vigorous physical activity and spending time in front of screens. Active sports and exercise was major moderate to vigorous activities, and Wheel-based activity was only popular in a small portion of adolescents. A substantial amount of adolescents reported much more screen time or very low frequencies of every activity assessed. In a summary, approximately 33% American male adolescents and 25%
female adolescents required behavior intervention for substance use, and 36% males and 48%
females needed to improve physical activity levels.

This study furthered our knowledge of adolescent co-varying health behaviors by
demonstrating that patterns of association of substance use with physical activity in
adolescents were complicated and could not be described in a linear model: most active
adolescents didn’t use drug, use tobacco (smoking cigarettes, chewing tobacco) or drink;
however, substance users didn’t have substantial lower physical activity levels compared with
the whole surveyed population, and they were very different from each other in physical
activity levels.

Facing a racial/ethnical diverse population and the inequality of chronic diseases
across the racial/ethnic groups, Institute of Medicine (IOM) recognizes the demands to better
investigate the relationship between social cultural backgrounds and health behaviors in order
to improve communication efficiency (Nelson 2002). There is evidence in the literature that
considering racial/ethic specific cultural factors helps to improve the efficiency in adult
health cares(Rajaram and Rashidi 1998; Simon 2006). However, the literature in adolescents
mainly focuses on mental health and substance use(Unger, Rohrbach et al. 2001; Dornelas,
Patten et al. 2005; Knibbe, Joosten et al. 2006; Smokowski and Bacallao 2006; Smokowski
and Bacallao 2006; Unger, Shakib et al. 2006). Investigating how racial/ethnic specific
culture and other social factors simultaneously affect the co-varying health behaviors in
adolescents would be beneficial to evaluate and incorporate the social cultural differences
behind race/ethnicity and improve communication and intervention for other health behaviors
e.g., physical activity.

This study showed that racial/ethnical disparities of health behaviors began as early as
in adolescence. At the individual level, the disparities for some investigated health behaviors
among racial/ethnic groups were huge. For example, the probabilities of being in the cluster
of tobacco chewers or TV watchers varied more than 10 percentages across racial/ethnical groups. Ethnicity identity highly integrated with culture is a term of practices, norms, values, and beliefs that belong to a specific group of people. In this study, categories of ethnicity were combined with those of race because of geographical and historical reasons. Since analysis of this study controlled family income and parental education which are the covariates of race/ethnicity in shaping social economic status of families, results of this study revealed the reality that children of different racial/ethnic groups might receive different beliefs, norms, practices and attitudes, which may affect their current and future health behaviors. Thus, this study reminds the importance of considering and appreciating the social cultural differences in the research and policies of adolescent health behaviors.

Drinking or smoking is not socially acceptable in some ethnicity; however it is more acceptable in a society like the U.S. Ethnicity and culture was regarded as the ‘strongest’ social determinants of substance use behaviors(Rebhun 1998). The results of this study showed that drinking, smoking and chewing tobacco was more prevalent in the Whites than in others. Although acculturation of immigrants reduces the incompatibility of different cultures, some ethic specific values and practices can be reserved, and thus affect adolescent health behavior patterns (Rhee, Chang et al. 2003). Independent of social economic status, White and Black males are the most active ethnic group with the lowest level of being sedentary, and Hispanic and Asian males are more likely to be sedentary. White females are the most active ethnic group. All these findings pointed out that, besides economic reasons, social ethnic factors do participate in shaping adolescent behavior patterns and contribute to the racial/ethnic disparities of health status.

This study also demonstrated that schools’ race–SES was associated with adolescent behaviors. In the reality, race/ethnicity and family economic status determines preferred neighborhoods, and this neighborhood segregation extends to schools (Clark 1991; Orfield
and Eaton 1996). Evidence exists that the students were usually poor in the schools where most students were blacks or Hispanics (Orfield and Eaton 1996). These segregations determine the inequality of education systems and available neighborhood and community resources. Besides, although facing multiple overlapping cultures in a diverse population, families, friends and peers in the extremely isolated neighborhoods and communities are the social networks that affect and enforce adolescent behaviors of a specific race/ethnicity. These social structural segregation at the institutional level was regarded as the ‘cornerstone’ of racial/ethnic disparity of diseases (Williams and Collins 2001).

In this study, consequences of social structural segregation in adolescent health behaviors were revealed more in substance use behaviors and active sports both in males and females. For example, male adolescents from the schools mainly attended by whites generally reported higher frequencies of chewing tobacco than male adolescents from the schools mainly attended by minorities. The effects of social structural segregation on adolescent behaviors were also demonstrated by the differences between schools with students from high income families and those with students from low income families (schools had the same percentage of whites). For example, female adolescents from the schools attended mainly by high income minorities had approximately 2 times to participate in active sports than those from the schools attended mainly by low income minorities. These two behaviors are crucial adolescent behavior indictors of Healthy People 2010, and thus this study supported Williams and Collins’s arguments about the cornerstone of racial/ethnic disparity in health outcomes.

The findings were based on a cross-sectional dataset. More studies are needed to fully understand the relationship that was showed in this study. First, longitudinal studies are in need to understand the changing behavior patterns through time in adolescents, and to investigate its health implication. Second, intervention studies that integrate the ethnic specific values and needs to improve adolescent health behaviors should be done to see
whether it is a good strategy to improve behavior interventions. Third, intervention studies that aim to improve the school education system of minority and poor schools are in need to explore how to minimize the unequal opportunity of students to access to school resources.

The questionnaire assessing daily activities did not cover all the habitual behaviors, and as consequences, both in males and females, there was a group whose members reported low frequencies of every assessed activity. Thus, typical lifestyles of these adolescents were unknown to us. These adolescents counted more than 20% of total surveyed American adolescents. They are of an important public health concern, because they have low frequencies of physical activity, and are on the risk of obesity. To find out them and apply lifestyle intervention programs, their social characteristics, specific lifestyles and school performances are highly in need.

This study only investigated substance use behaviors and physical activity, and other behaviors such as eating, studying and sexual behaviors was missing; however, the aims of this study were only to demonstrate a lifestyle perspective to investigate health behaviors. Thus, missing some perspectives of behaviors should not affect accomplishing original study purpose.

This study used the nationally reprehensive dataset demonstrated the sociocultural nature of physical activity. Physical activity co-varies with other heath behaviors as the integrated lifestyles, which has important implication in behavior intervention and estimation of multiple disease exposures. Its sociocultural determinants strongly suggest the importance of appreciating culture differences for communications between professionals and the targeted minorities. It also drives attention to the impacts of racial/ethnic and economic segregation on the adolescent health behaviors.
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<td>Watching TV/video (hours/week)</td>
<td>Watching TV/video (hours/week)</td>
<td>z score, rescaled</td>
</tr>
<tr>
<td>PC/video game use (hours/week)</td>
<td>PC/video game use (hours/week)</td>
<td>z score, rescaled</td>
</tr>
<tr>
<td>Specific activities</td>
<td>Cluster 1 (n=1110, n/N=12%)</td>
<td>Cluster 2 (n=1036, n/N=11%)</td>
</tr>
<tr>
<td>--------------------------------------------------------</td>
<td>-------------------------------</td>
<td>-----------------------------</td>
</tr>
<tr>
<td>Marijuana use, cigarette smoking, alcoholic drinking</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cigarette smoking (days/month)</td>
<td>13.4</td>
<td>15.9</td>
</tr>
<tr>
<td>Chewing tobacco use (days/month)</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>Using marijuana (times/month)</td>
<td>15.0</td>
<td>37.6</td>
</tr>
<tr>
<td>Drinking alcohol (days/month)</td>
<td>4.5</td>
<td>6.7</td>
</tr>
<tr>
<td>Active sports (bouts/week)</td>
<td>1.5</td>
<td>1.1</td>
</tr>
<tr>
<td>Rollerblading/biking (bouts/week)</td>
<td>0.7</td>
<td>1.0</td>
</tr>
<tr>
<td>Exercising (bouts/week)</td>
<td>1.5</td>
<td>1.1</td>
</tr>
<tr>
<td>Hanging out (bouts/week)</td>
<td>2.4</td>
<td>0.8</td>
</tr>
<tr>
<td>House work (bouts/week)</td>
<td>1.9</td>
<td>0.9</td>
</tr>
<tr>
<td>Hobby (bouts/week)</td>
<td>1.3</td>
<td>1.1</td>
</tr>
<tr>
<td>Watching TV/video (hours/week)</td>
<td>20.8</td>
<td>19.4</td>
</tr>
<tr>
<td>PC/video game use (hours/week)</td>
<td>3.5</td>
<td>6.9</td>
</tr>
</tbody>
</table>

a Standard deviation.

b Bolded and italic mean values are those with significantly highest or lowest cross clusters (p<0.05, with Bonferroni correction).
Table 3. Main characteristics of behavior clusters and the means of clustering variables by clusters in females, National Longitudinal Study of Adolescent Health (Add Health)

<table>
<thead>
<tr>
<th>Specific activities</th>
<th>Characteristics of individual clusters compared to the whole population</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Cluster 1 (n=1150, n/N=12%)</td>
</tr>
<tr>
<td></td>
<td>Cluster 2 (n=1328, n/N=13%)</td>
</tr>
<tr>
<td></td>
<td>Cluster 3 (n=864, n/N=9%)</td>
</tr>
<tr>
<td></td>
<td>Cluster 4 (n=1870, n/N=19%)</td>
</tr>
<tr>
<td></td>
<td>Cluster 5 (n=1910, n/N=19%)</td>
</tr>
<tr>
<td></td>
<td>Cluster 6 (n=2725, n/N=28%)</td>
</tr>
<tr>
<td>Total (N=9847)</td>
<td></td>
</tr>
<tr>
<td>Marijuana use, Cigarette smoking, alcoholic drinking</td>
<td>Mean S D</td>
</tr>
<tr>
<td>(days/month)</td>
<td>14.7 13.1 15.5 12.3 1.2 2.5 0.3 2.1 0.1 1.1 4.0 9.3</td>
</tr>
<tr>
<td>Drinking alcohol, (days/month)</td>
<td>3.9 5.9 2.0 3.8 0.5 2.3 0.6 2.3 0.3 1.7 0.5 2.3 1.1 3.3</td>
</tr>
<tr>
<td>Active sports, (bouts/week)</td>
<td>1.0 1.0 0.9 1.0 1.7 1.1 2.1 1.0 0.8 0.9 0.5 0.7 1.1 1.1</td>
</tr>
<tr>
<td>Rollerblading/biking/biking (bouts/week)</td>
<td>0.4 0.7 0.3 0.5 2.4 0.5 0.3 0.5 0.3 0.5 0.2 0.4 0.5 0.8</td>
</tr>
<tr>
<td>Exercising (bouts/week)</td>
<td>1.6 1.0 1.5 1.0 2.1 0.9 2.5 0.7 1.4 0.9 1.2 0.9 1.7 1.0</td>
</tr>
<tr>
<td>Hanging out (bouts/week)</td>
<td>1.1 1.0 1.2 1.0 1.8 1.0 2.1 0.9 1.4 1.0 1.0 1.1 0.9 1.4 1.0</td>
</tr>
<tr>
<td>House work (bouts/week)</td>
<td>2.0 0.9 2.1 0.9 2.3 0.8 2.4 0.8 2.1 0.9 2.0 0.9 2.2 0.9 1.9 0.9 2.2 0.9 1.9 1.0</td>
</tr>
<tr>
<td>Hobby (bouts/week)</td>
<td>1.1 1.0 1.2 1.0 1.8 1.0 2.1 0.9 1.4 1.0 1.0 1.1 0.9 1.4 1.0</td>
</tr>
<tr>
<td>Watching TV/video, (hours/week)</td>
<td>1.2 4.3 0.9 2.9 2.2 6.3 0.7 2.1 3.9 5.3 0.0 0.0 1.3 3.9</td>
</tr>
</tbody>
</table>

a SD, Standard deviation
b Bolded and italic mean values are those with significantly highest or lowest cross clusters (p<0.05, with Bonferroni correction.)
Figure 4. Adjusted* predicted probabilities of different behavior patterns by Individual race/ethnicity in males and females, National Longitudinal Study of Adolescent Health (Add Health)

*The full model for males controlled for age, family income, parental education, religion, generation of immigration, adolescent working status, presence of mother or father in household, school session, the percentages of different parental education levels at schools, the percentages of different religions at schools, school urbanicity, school size, and geographic regions. The full model for females controlled for age, family income, parental education, religion, generation of immigration, adolescent working status, school session, the percentages of different parental education levels at schools, the percentages of different religions at schools, school urbanicity, school size and geographic regions.

Sum of adjusted predicted probabilities of all clusters for a race group equals to 1.

$ Clusters in Males, C1: Cluster 1, drug users; C2: Cluster 2, smokers and drinkers; C3: Cluster 3, tobacco chewers; C4: Cluster 4, in street players; C5: Cluster 5, sporters and exercisers; C6: Cluster 6, TV watchers; C7: Cluster 7, others.

@ Clusters in Females, C1: Cluster 1, drug users; C2: Cluster 2, smokers and drinkers; C3: Cluster 3, in street players; C4: Cluster 4, sporters and exercisers; C5: Cluster 5, TV watchers; C6: Cluster 6, others.
Figure 5. Adjusted* probabilities of falling into different behavior clusters—by schools’ race-SES in males, National Longitudinal Study of Adolescent Health (Add Health)

*The full model for males controlled for age, family income, parental education, religion, generation of immigration, adolescent working status, presence of mother or father in household, school session, the percentages of different parental education levels at schools, the percentages of different religions at schools, school urbanicity, school size, and geographic regions.

α Clusters in Males, C1: Cluster 1, drug users; C2: Cluster 2, smokers and drinkers; C3: Cluster 3, tobacco chewers; C4: Cluster 4, in street players; C5: Cluster 5, sporters and exercisers; C6: Cluster 6, TV watchers; C7: Cluster 7, others.
Figure 6. Adjusted* probabilities of falling into different behavior clusters– by schools’ race-SES in females, National Longitudinal Study of Adolescent Health (Add Health)

* The full model for females controlled for age, family income, parental education, religion, generation of immigration, adolescent working status, school session, the percentages of different parental education levels at schools, the percentages of different religions at schools, school urbanicity, school size and geographic regions.

α C1: Cluster 1, drug users; C2: Cluster 2, smokers and drinkers; C3: Cluster 3, in street players; C4: Cluster 4, sporters and exercisers; C5: Cluster 5, TV watchers; C6: Cluster 6, others.
V. Adolescent physical activity patterns are associated with activity patterns of their friends: results from the National Longitudinal Study of Adolescent Health (Add Health)

A. Introduction

Physical activity level—a major obesity determinant—is intertwined with daily life and influenced by different social contexts and psychological factors (Yen and Kaplan 1998; Gordon-Larsen, Adair et al. 2002; Wilson, Kirtland et al. 2004; Berg, Simonsson et al. 2005). However, in the etiological model of adolescent physical activity, one important social context—peer context (conceptualized as friends and their interactions in the literature of adolescent development)—has been understudied. Sociological studies have substantially demonstrated that friendship is an important factor that leads to similarity in various adolescent behaviors, with strongest similarity for deviant behaviors (e.g., smoking, drug use, antisocial behaviors) (Deater-Deckard 2001). However, the extent to which physical activity patterns are similar among friends is relatively unknown.

The latest article documented in American public health literature about friends and physical activity from a peer network perspective was by Voorhees and others (Voorhees, Murray et al. 2005). In their study, among the adolescents from six schools in or near Baltimore, the researchers found that adolescents who reported participating in physical activity together with their friends had higher physical activity levels than others (Voorhees, Murray et al. 2005). The drawback of this work is that observed association of physical activity among friends was based on subjective perception rather than direct
measurement of friends’ behaviors which is suspect to overestimation (Bauman and Ennett 1996). In contrast, physical activity data, derived directly from both a given individual and his/her friends and linked via self-reported friendship, may provide a more objective network perspective.

Using the unique peer sub-sample of Wave II of the National Longitudinal Study of Adolescent Health (Add Health), this study investigated the similarity of physical activity patterns between pairs of adolescent friends. The aims were to answer the following questions: (1) Is there an association between the physical activity patterns of a pair of friends? (2) Does the body weight status of friends modify the extent of this association? This work will generate essential information about the impact of peer activity patterns on adolescent physical activity and may provide insight for intervention strategies to increase physical activity in adolescents.

B. Methods

1. Data Source

Data used in the analysis were obtained from the Add Health study, a national study designed to be representative of the US school population in 1994-5. The Add Health study includes a wide variety of data from different social contexts (i.e., families, peers, schools, neighborhoods, and communities) that affect adolescents' health and risks. Details about the Add Health study have been described elsewhere (Popkin and Udry 1998; Alexander, Piazza et al. 2001). The Institutional Review Board of the University of North Carolina at Chapel Hill, NC approved the Add Health protocol.

2. Peer Network Data
This study used the Add Health special peer network sample of 16 schools. The peer network data were a convenience sample (i.e., observations were not selected based on probability), and thus not nationally representative for the entire population. Among the 16 schools, two of them were big (having 800-1700 students). One was predominately attended by Whites, one was diverse in race/ethnicity. Other schools were small (having <300 students) which varied in school type (i.e., public, private, and parochial), urbanicity, geographic regions, and racial/ethnic composition. All students listed on the rosters were invited to participate in an in-home-interview about friends, in addition to collecting the same information as collected from other adolescents in the full Add Health sample. Each respondent was asked to nominate up to five male and five female friends. The identification number uniquely assigned to all students on the rosters allowed the investigators to link survey data for any individual respondent to survey data from his/her nominated friends. Respondents were allowed to nominate friends from outside these 16 schools, but the information for outside-school friends was not attainable.

3. Study Dataset

We investigated the dyadic friendship based on friendship pairs consisting of two adolescents. Dyadic friendship is the smallest communication tie in the peer network, and the most used measure for adolescent peer relationship in the literature. Our sample consisted of 2776 adolescents from the Add Health Wave II survey (conducted in 1996) who were interviewed and in turn, nominated 15569 friends (average nomination per person was 5.6). The valid friendship pairs for analysis were reduced, because some nominated friends were from outside schools (n=6764); some did not participate in the Wave II survey (n=2389); some were also romantic or sexual partners (n=486, they may confound the friendship); some were actually the interviewed adolescents themselves
(n=113). 193 extra friendship pairs were excluded, because either the respondents or their friends were pregnant, disabled, or had any missing values in the investigated variables. Thus 5624 friendship pairs of 1957 adolescents were included in the final models. In the situation where friendship nomination was mutual, the friendship pairs were treated as two independent pairs as those in the previous studies (Kandel 1978). Preliminary analysis also showed that the similarity of physical activity for non-mutual friendship pairs was not different (p>0.10) than for mutual friendship pairs.

4. Studied Variables

Daily habitual activities in the past week were self-reported by the adolescents in the Add Health study. The typical questions were in the form of: “During the past week, how many times did you play an active sport, such as baseball, softball, basketball, soccer, swimming, or football? ” This format was similar to those physical activity studies that have been validated and used in other epidemiological studies (Sallis, Buono et al. 1993; Heath, Pratt et al. 1994; Andersen, Crespo et al. 1998). Add Health study measured moderate-to-vigorous physical activity (MVPA) of intensity ranging from 5–8 metabolic equivalent (MET) values according to the compendium coding theme based on energy expenditure rate (Ainsworth, Haskell et al. 2000). One MET equals the energy used by the body at rest (i.e., 3.5 mL O₂/kg of body weight per minute). In Add Health, thus in this study, physical activities included were (a) active sports (e.g., baseball, softball, basketball, soccer, swimming, or football); (b) wheel-based activity (e.g., rollerblading, roller-skating, skateboarding, or bicycling); and (c) exercise (e.g., jogging, walking, karate, jumping rope, gymnastics, or dancing). The measures of total MVPA levels were the sum of these component levels and reported in bouts per week. These variables have been published in

MVPA was dichotomized as (1) equal to or greater than five bouts/week and (2) less than five bouts/week in light of the CDC ACSM recommendation to engage in 30 minutes of moderate activity most, if not all, days per week (Pate, Pratt et al. 1995). Another reason for dichotomizing outcome is its non-normal distribution. Modeling results are consistent in direction when dichotomizing using different cut point. We also assessed three other physical activity variables, including active sports, wheel-based activity, and exercise, which were dichotomized as (1) more than zero bouts/week and (2) zero bouts/week. A substantial number of adolescents did not participate in these activities and they might be systematically different from those who did; therefore, these variables were dichotomized for later logistic regression.

Z-scores of body mass index (BMI), the indicator of body weight status of adolescents, were generated using measured height and weight and based on the CDC/NCHS age- and sex-specific growth curves (Kuczmarski, Ogden et al. 2000). The difference of BMI Z-scores between two friends was indicated by five BMI Z-score unit categories, ranging from < -1.5 to > 1.5.

Because there was limited documentation about the factors that may confound or modify the association between friendship and physical activity, selection of potential confounders or effect modifiers was based on two sources in the literature: (1) the correlates of physical activity of adolescents and (2) the structure of dyadic friendship and the peer network related factors that have been reported to influence adolescent behaviors.

The final covariates of adolescent physical activity in the regression models included adolescent age, gender, race/ethnicity, BMI Z-score and physical fitness perception. Age was calculated based on the self-reported birth date and the interview date.
The field interviewers confirmed respondents’ gender. Race/ethnicity were self-defined multiple choices and final racial/ethnic groups in our study were categorized as White (non-Hispanic White), Black (non-Hispanic Black), Hispanic, and Asian. Physical fitness perception was measured on a scale ranging from 1 to 5, representing strong agreement to strong disagreement to the description of: You are physically fit. A similar description was used in other physical activity studies to assess the adolescent’s perception of their body weight or fitness (Burns, Tijhuis et al. 2001; Brener, Eaton et al. 2004; Berg, Simonsson et al. 2005).

The final covariates of dyadic friendship features included in the models were the gender composition and racial/ethnic composition of a pair of friend and the difference of BMI Z-scores between these two friends. School averages of physical activity measures representing respective overall school-wide peer exposures were also included. Gender composition of friendship pairs was categorized as male-male, female-female, and mixed-gender (male-female or female-male) pairs. Racial/ethnic composition was categorized as White-White, Black-Black, Hispanic-Hispanic, Asian-Asian, and mixed race/ethnic pairs.

5. Statistical Models

The similarity of physical activity patterns between a pair of friends was tested by four separate logistic regression models for MVPA, active sports, wheel-based activity and exercise using Stata version 9.0 (StataCorp. 2005. Stata Statistical Software: Release 9. College Station, TX: StataCorp LP). The outcome for each model was the measure of respondents’ physical activity and the main exposure was that of respondent’s friends. Adolescents from the same schools were correlated to each other, so were friendship pairs nominated by the same respondents. Survey commands in Stata that can analyze the
A dataset that are nested in multiple strata were applied to get the unbiased variance (Juul 2006; Press 2006).

6. Analysis Procedures

In addition to the main exposure of physical activity of friends, other covariates in a final full model were those tested as (a) potential effect modifiers or confounders, and (b) the important demographic and biological variables in the literature (e.g., adolescent’s age, gender, race/ethnicity, and BMI-Z-score) that affect adolescent physical activity levels.

In order to test whether gender and racial/ethnic composition of a pair of friends, or their difference of BMI Z-score modified the association of their physical activity levels, two-way interaction terms (cross-products) of friend’s physical activity and dummy variables of gender composition, racial/ethnic composition, and the difference of BMI Z-score were respectively constructed. Existence of significant effect modification was determined by the Wald Test (p ≤ 0.1) between a full model containing the relevant interaction terms and a reduced model without the interaction terms. Interaction terms with a significant Wald Test would be kept in the models. Two three-way interactions, one among friend’s physical activity, the difference of BMI Z-score, and gender composition, and another among friend’s physical activity, the difference of BMI Z-score, and racial/ethnic composition, were also tested using the models containing two-way interaction terms as the reduced models. Confounders were selected using backward selection and a 10% “change-in-estimate” criterion based on the models specified from the tests of effect modification. All the available variables were added in the models, and then one variable was excluded if its inclusion brought the smallest change in the estimation of regression coefficients of friend’s physical activity. Model fitting continued by successively re-fitting reduced models and using the same rule to drop off variables.
until all left covariates met the priori “change-in-estimate” criterion. Estimation of the
effects of friend’s physical activity presented in the final results was stratified by the
strata of effect modifiers through post estimation commands right after the final full
models for the subgroups of observations in different strata of effect modifiers.

C. Results

1. Descriptive Analysis

a. Characteristics of adolescents from the 16 sample schools

Compared to the total 2776 subjects in the full peer group analysis, the 1957 subjects
in the analysis sample (Table 4) were more likely to be White (p<0.05), less likely to be
Hispanic (p<0.05), and were more likely to be involved in active sports ( p<0.05).

b. Dyadic friendship pair features

As shown in Table 5, approximately two-thirds were same-sex pairs, and the vast majority
of friendships were within race/ethnicity. The mean difference of BMI Z-scores between a
pair of friends was near to zero; however, the difference varied a lot among friendship
pairs (standard deviation equal to 1.33 Z-score unit).

2. Modeling Analysis

a. Adolescent physical activity levels were positively associated with those of their friends

In general, after adjusting for covariates, there was a moderate to strong likelihood of
shared physical activity patterns between friends across most types of activities (Table 6);
the magnitude of the likelihood varied by type of activity, gender composition and
race/ethnicity of friends. For example, in male-male friends, the likelihood of an
adolescent engaging in $\geq 5$ bouts/week MVPA was significantly associated with that of his
friend (Adjusted Odds Ratio [AOR]: 1.80, 95% CI [Confidence Interval]: 1.46–2.22), as was active sports [AOR=2.23, CI: 1.66–2.99] and wheel-based activity[AOR=1.78, 95% CI: 1.43–2.23]). However, the likelihood of a male adolescent’s participation in exercise was not significantly associated with that of his male friend (AOR=1.20 [0.86-1.68]). The likelihood of sharing physical activity patterns was weaker in female-female and mixed-gender friends. White-White and Asian-Asian friends were generally more likely to share the same physical activity patterns than other racial/ethnic friends. For instance, the likelihood of engaging in ≥ 5 bouts/week MVPA was significantly associated between White-White, and Asian-Asian friends, but not between Black-Black, Hispanic-Hispanic, and mixed gender friends.

b. Difference of BMI Z-scores modifies the association of physical activity patterns between two friends

The extent of similarities for patterns of active sports, wheel-based activity, and exercise between a pair of friends had a trend to vary across the strata of the between-pair differences of BMI Z-scores. For example, in Table 7, after controlling self BMI Z-scores, adolescents with the between-pair differences of BMI Z-scores ranging from 0.5 to 1.5 were more likely [AOR=1.51, CI: 1.17–1.95] to participate in active sports than other adolescents, if their friends also participated. The same trends were also found in wheel-based activity, and exercise. Adolescents with greater between-pair differences of BMI Z-scores—those exceeding 1.5 units—were also more likely to participate in active sports than other adolescents were, if their friends also participated. Adolescents with between-pair differences of BMI Z-scores ranging from -1.5 to -0.5 were also more likely to participate in wheel-based activity than others.
We found a strong joint effect modification of between-pair differences of BMI Z-score and gender status of friendship on the estimation of similarity of physical activity patterns of friends. This modification effect existed in all type of physical activity assessed; however, its magnitude was different for the different types. For example, in Table 8, male adolescents with BMI Z-scores that were 0.5 to 1.5 bigger than that of their male friends were 4 times [AOR=4.00, CI: 1.98–9.81] more likely to participate in active sports with their male friends than female adolescents did with their female friends whose between-pair differences of BMI Z-scores was within -0.5 to 0.5. The joint modification effect was weaker for wheel-based activity and total MVPA, and was not significant for exercise.

D. Discussion

Our study is among the first of several studies to investigate the effects of peers on adolescent physical activity patterns based on social network data. It suggests that, except for the contribution of other social contexts (e.g., schools and community services), peers might be an important intervention avenue to improve adolescent physical activity levels.

A moderate association of physical activity patterns among the friends of adolescents is found; however, it is interesting that the extent of association varies across different types of physical activity. For example, a stronger association is found for active sports than for exercise, which is consistent with the team format of many active sports. Individuals might get psychological satisfaction from each other by cooperation and competition during games, while exercise is more individual-focused, requiring less interaction among individuals. This indicates that peers may help adolescents to participate more in active sports than in exercise.
Our study also suggested that gender and race/ethnicity of friendship should be considered in the intervention programs that incorporate peer context strategies because gender or race/ethnicity of friendship modifies the magnitudes of similarity of some type of physical activity among friends. The similarity of active sports for a pair of male-male friends was much stronger than that for a pair of female-female or mixed-gender friends. This might indicate that male friendship is more involved in active sports than is female friendship. If true, this suggests that influences of male-male friends to participate in active sports may be stronger than female-female or mixed gender friends. It is also very interesting that White-White and Asian-Asian friends were more likely to participate in active sports together than Black-Black or Hispanic-Hispanic friends. In this case, potential social environmental effects (e.g., White and Asian boys have more access to playgrounds and equipment) or cultural effects (e.g. White boys may be more likely to value team sports or exercises than Hispanic and Black boys) might make White-White and Asian-Asian friends more involved in active sports and exercises.

The correlation of body weight status within friends is documented in the public health literature (Paxton, Schutz et al. 1999; Hay, Payne et al. 2004). There has also been some evidence that adolescent friends have similar body image/physical fitness concerns and share information about building muscles, gaining weight, or losing weight (Paxton, Schutz et al. 1999). However, to our knowledge, the question of how the body weights of peers are associated with individual physical activity patterns has not been investigated using dyadic peer social network data. We found that BMI status modifies the similarity of physical activity patterns between friends, and the modification effect is influenced by the type of physical activity and gender status of friends. Generally, adolescents with bigger BMI than their friends try to have the same physical activity patterns as their friends. This phenomenon is more obvious in male adolescents than in female adolescents. This might
indicate that male adolescents are more likely than female adolescents to mimic the physical activity patterns of ‘role models’ to change their body weight status. Our findings suggest that complicated dynamics of peer influence exist in physical activity patterns among friends, involving the type of activity, gender, and body weight status; this might be a potential area to find a new peer-orientated strategy for physical activity intervention. More investigations are needed to explore the psychosocial and behavioral processes through which the peer influences occur (e.g., [a] how friend’s characteristics or physical activity levels affect self-esteem or depression or [b] how peers share the same attitude about physical fitness perception or body image) (Deater-Deckard 2001; Bukowski and Adams 2005).

Previous work in this area has used data derived from the subject’s report of their peers’ behaviors rather than the peers’ own report. Since adolescents tend to report a higher prevalence of a friend’s behavior if they themselves also have this behavior (Bauman and Ennett 1996), this approach may have resulted in an overestimation of the association. The use of dyadic social network data in this analysis provides a more objective assessment of the impact of peers on behaviors through the collection of data from the target adolescents and, more importantly, from their peers. This is an important strength of the study.

The major limitation of this study is that it was based on the cross-sectional data, and the relationship revealed may be misleading. The similarities of physical activity found among friends are as likely to be a cause as an effect of those friendships. Evidence shows adolescents select friends that have similar behaviors, and thus selecting friends is endogenous and confounds the causality of the effects of friends through socialization. From a cross sectional study it is impossible to discern which of the two procedures, selection or socialization, contributes more to the observed similarity in physical activity
behaviors, and thus, longitudinal studies are needed to separate the effects of socialization from those of selection. Another limitation of this study is the differences of BMI Z-score might not accurately represent the differences of body fitness, because BMI can not differentiate muscle from fat. This made the estimations suspect to non-differentiated misclassification, and would biased the estimations towards null.
Table 4. Description of adolescents in the 16 schools for peer network study, N = 1957 (National Longitudinal Study of Adolescent Health [Add Health], Wave II).

<table>
<thead>
<tr>
<th>Variables</th>
<th>Respondents in our study (N=1957)</th>
<th>All the respondents in the 16 schools( N=2776)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>N</td>
<td>%</td>
</tr>
<tr>
<td><strong>Physical activity</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Moderate to vigorous physical activity (bouts/week)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>≥ 5 bouts/week</td>
<td>624</td>
<td>32.0</td>
</tr>
<tr>
<td>&lt; 5 bouts/week</td>
<td>1333</td>
<td>68.0</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>1957</td>
<td>100.0</td>
</tr>
<tr>
<td>Active sports (bouts/week)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>&gt; 0 bout/week</td>
<td>1402</td>
<td>71.6</td>
</tr>
<tr>
<td>= 0 bout/week</td>
<td>555</td>
<td>28.4</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>1957</td>
<td>100.0</td>
</tr>
<tr>
<td>Rollerblading/biking (bouts/week)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>&gt; 0 bout/week</td>
<td>743</td>
<td>38.0</td>
</tr>
<tr>
<td>= 0 bout/week</td>
<td>1214</td>
<td>62.0</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>1957</td>
<td>100.0</td>
</tr>
<tr>
<td>Exercise (bouts/week)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>&gt; 0 bout/week</td>
<td>1674</td>
<td>85.5</td>
</tr>
<tr>
<td>= 0 bout/week</td>
<td>283</td>
<td>14.5</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>1957</td>
<td>100.00</td>
</tr>
<tr>
<td><strong>Gender</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>994</td>
<td>49.2</td>
</tr>
<tr>
<td>Female</td>
<td>963</td>
<td>50.8</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>1957</td>
<td>100.0</td>
</tr>
<tr>
<td><strong>Race/ethnicity</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Non-Hispanic White</td>
<td>1114</td>
<td>56.9^b</td>
</tr>
<tr>
<td>Non-Hispanic Black</td>
<td>256</td>
<td>13.1</td>
</tr>
<tr>
<td>Hispanic</td>
<td>339</td>
<td>17.3^b</td>
</tr>
<tr>
<td>Asian</td>
<td>248</td>
<td>12.7</td>
</tr>
<tr>
<td>Others or missing</td>
<td>0</td>
<td>0.0</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>1957</td>
<td>100.0</td>
</tr>
<tr>
<td><strong>Age (years)</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1957</td>
<td>16.78</td>
<td>1.44</td>
</tr>
<tr>
<td><strong>Physical fitness perception score (of 5)</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1957</td>
<td>2.09</td>
<td>0.89</td>
</tr>
<tr>
<td><strong>Body Mass Index (BMI, kg/m^2)</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1957</td>
<td>23.24</td>
<td>5.18</td>
</tr>
</tbody>
</table>

Legend:  
^a. Standard deviation  
^b. p-value of Analysis of variance between groups (ANOVA) < 0.05 between respondents in our study and all the respondents in peer network data from all the 16 schools
Table 5. Features of randomly selected in-school dyadic friendship pairs of the adolescents in the 16 schools for peer network study, N=1957 (National Longitudinal Study of Adolescent Health [Add Health], Wave II).

<table>
<thead>
<tr>
<th>Dyadic friendship features</th>
<th>N</th>
<th>%</th>
<th>Mean</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Gender composition of egos and alters</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Male-Male</td>
<td>1902</td>
<td>33.8</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Female-Female</td>
<td>1824</td>
<td>32.4</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Male-female/female-male</td>
<td>1898</td>
<td>33.8</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>5624</td>
<td>100.0</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Race/ethnicity composition</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>White-White</td>
<td>3498</td>
<td>62.2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Black-Black</td>
<td>415</td>
<td>7.4</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hispanic-Hispanic</td>
<td>584</td>
<td>10.4</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Asian-Asian</td>
<td>518</td>
<td>9.2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mixed race/ethnicity</td>
<td>609</td>
<td>10.8</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>5624</td>
<td>100.0</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Age difference (years)</strong></td>
<td>5624</td>
<td></td>
<td>0.25</td>
<td>0.94</td>
</tr>
<tr>
<td><em><em>BMI Z-score</em> difference between a pair of friends</em>*</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>&lt; -1.5</td>
<td>670</td>
<td>11.9</td>
<td></td>
<td></td>
</tr>
<tr>
<td>-1.5 to -0.5</td>
<td>1182</td>
<td>21.0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>-0.5 to 0.5</td>
<td>1813</td>
<td>32.2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>0.5 to 1.5</td>
<td>1239</td>
<td>22.0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>&gt; 1.5</td>
<td>720</td>
<td>12.8</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>5624</td>
<td>100.0</td>
<td>0.09</td>
<td>1.33</td>
</tr>
</tbody>
</table>

Legend:

- a. Friends were from the same schools
- b. Standard Deviation
- c. Z-score calculated according to CDC/NCHS 2000 growth curves (Kuczmarski et al. 2000)
Table 6. The adjusted odds ratios (AOR) of engaging in any active sports, rollerblading/biking, excise and MVPA ≥ 5 bouts/week comparing the adolescents with their friends’ participation in the same measures to those without their friends’ participation. Results stratified by gender or race/ethnicity composition of a pair of friends. Data from the special peer network data, N=1957 (National Longitudinal Study of Adolescent Health [Add Health], Wave II.

<table>
<thead>
<tr>
<th>Gender composition of friends</th>
<th>Active sports &gt; 0 bouts/week vs. &lt; 0 bouts/week</th>
<th>Rollerblading/biking &gt; 0 bouts/week vs. &lt; 0 bouts/week</th>
<th>Exercise &gt; 0 bouts/week vs. &lt; 0 bouts/week</th>
<th>MVPA ≥ 5 bouts/week vs. &lt; 5 bouts/week</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>AOR(^a) CI(^b) P value</td>
<td>AOR(^c) CI(^b) P value</td>
<td>AOR(^d) CI(^b) P value</td>
<td>AOR(^e) CI(^b) P value</td>
</tr>
<tr>
<td>Male-Male</td>
<td>2.23 (1.66–2.99) 0.000</td>
<td>1.78 (1.43–2.23) 0.000</td>
<td>1.20 (0.86–1.68) 0.289</td>
<td>1.80 (1.46–2.22) 0.000</td>
</tr>
<tr>
<td>Female-Female</td>
<td>1.34 (1.08–1.65) 0.007</td>
<td>1.42 (1.13–1.79) 0.003</td>
<td>1.44 (0.94–2.21) 0.096</td>
<td>1.32 (1.02–1.69) 0.032</td>
</tr>
<tr>
<td>Mixed-gender</td>
<td>1.02 (0.78–1.32) 0.877</td>
<td>1.10 (0.96–2.53) 0.071</td>
<td>0.92 (0.62–1.36) 0.676</td>
<td>1.44 (1.16–1.78) 0.001</td>
</tr>
<tr>
<td>Race/ethnicity composition of friends</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>White-White</td>
<td>1.67 (1.37–2.04) 0.000</td>
<td>1.55 (1.32–1.81) 0.000</td>
<td>1.32 (1.01–1.71) 0.039</td>
<td>1.61 (1.37–1.88) 0.000</td>
</tr>
<tr>
<td>Black-Black</td>
<td>0.84 (0.54–1.32) 0.453</td>
<td>1.23 (0.77–1.97) 0.380</td>
<td>1.48 (0.68–3.21) 0.323</td>
<td>1.17 (0.73–1.88) 0.515</td>
</tr>
<tr>
<td>Hispanic-Hispanic</td>
<td>0.75 (0.52–1.70) 0.112</td>
<td>0.92 (0.64–1.33) 0.660</td>
<td>0.79 (0.39–1.63) 0.531</td>
<td>1.25 (0.82–1.89) 0.301</td>
</tr>
<tr>
<td>Asian-Asian</td>
<td>1.59 (1.04–2.43) 0.031</td>
<td>1.33 (0.92–1.92) 0.125</td>
<td>0.80 (0.36–1.78) 0.587</td>
<td>1.93 (1.14–3.26) 0.015</td>
</tr>
<tr>
<td>Mixed-race/ethnicity</td>
<td>1.68 (1.11–2.56) 0.014</td>
<td>1.01 (0.70–1.48) 0.926</td>
<td>0.54 (0.20–1.41) 0.207</td>
<td>1.50 (0.96–2.35) 0.077</td>
</tr>
</tbody>
</table>

a: AOR means Adjusted Odds Ratio, logistic regression model predicting likelihood of engaging in any active sports, adjusted for adolescent age, sex, race/ethnicity, gender- and age- specific BMI Z-score along with the confounders of physical fitness perception score, school-wide average levels.

b: CI means Confidence Interval
c: Rollerblading/biking, adjusted for adjusted for adolescent age, sex, race/ethnicity, gender- and age- specific BMI Z-score.
d: Exercise, adjusted for adolescent age, sex, race/ethnicity, gender- and age- specific BMI Z-score along with the confounders of physical fitness perception score, school-wide average levels.
e: ≥ 5 bouts MVPA, adjusted for adolescent age, sex, race/ethnicity, gender- and age- specific BMI Z-score.
Table 7. The odds ratios of engaging in any active sports, rollerblading/biking, exercise and MVPA ≥ 5 bouts/week comparing the adolescents with their friends’ participation in the same measures to those without their friends’ participation. Results stratified by the BMI-Z score difference between a pair of friends. Data from the special peer network data, N=1957 (National Longitudinal Study of Adolescent Health [Add Health], Wave II.

<table>
<thead>
<tr>
<th>Difference of BMI Z-score between a pair of friends</th>
<th>Active sports &gt; 0 bouts/week vs. &lt; 0 bouts/week</th>
<th>Rollerblading/biking &gt; 0 bouts/week vs. &lt; 0 bouts/week</th>
<th>Exercise &gt; 0 bouts/week vs. &lt; 0 bouts/week</th>
<th>MVPA ≥ 5 bouts/week vs. &lt; 5 bouts/week</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>AOR(a) CI(b) P value</td>
<td>AOR(c) CI (d) P value</td>
<td>AOR(e) CI (f) P value</td>
<td>AOR(g) CI (h) P value</td>
</tr>
<tr>
<td>≤ 1.5</td>
<td>1.14 (0.47–2.73) 0.774</td>
<td>1.23 (0.45–3.36) 0.682</td>
<td>1.07 (0.53–2.16) 0.841</td>
<td>1.48 (0.85–2.59) 0.165</td>
</tr>
<tr>
<td>- 1.5 to -0.5</td>
<td>0.78 (0.59–1.04) 0.089</td>
<td>2.00 (1.33–3.03) 0.001</td>
<td>0.99 (0.56–1.73) 0.967</td>
<td>2.05 (1.34–3.13) 0.001</td>
</tr>
<tr>
<td>- 0.5 to 0.5</td>
<td>1.17 (0.59–2.30) 0.660</td>
<td>1.30 (0.73–2.31) 0.378</td>
<td>0.99 (0.53–1.90) 0.997</td>
<td>1.36 (0.95–1.94) 0.092</td>
</tr>
<tr>
<td>0.5 to 1.5</td>
<td>1.75 (1.21–2.53) 0.003</td>
<td>1.83 (1.35–2.48) 0.000</td>
<td>1.89 (1.10–3.22) 0.020</td>
<td>2.15 (1.62–2.86) 0.000</td>
</tr>
<tr>
<td>&gt; 1.5</td>
<td>1.21 (0.83–1.78) 0.310</td>
<td>1.28 (0.77–2.13) 0.349</td>
<td>1.86 (1.01–3.42) 0.047</td>
<td>1.57 (1.06–2.31) 0.024</td>
</tr>
</tbody>
</table>

a: AOR means Adjusted Odds Ratio, logistic regression model predicting likelihood of engaging in any active sports, adjusted for adolescent age, sex, race/ethnicity, gender- and age-specific BMI Z-score along with the confounders of physical fitness perception score, school-wide average levels.
b: CI means Confidence Interval
c: Rollerblading/biking, adjusted for adjusted for adolescent age, sex, race/ethnicity, gender- and age- specific BMI Z-score.
d: Exercise, adjusted for adolescent age, sex, race/ethnicity, gender- and age- specific BMI Z-score along with the confounders of physical fitness perception score, school-wide average levels.
e: ≥ 5 bouts MVPA, adjusted for adolescent age, sex, race/ethnicity, gender- and age- specific BMI Z-score.
Table 8. The biggest and smallest adjusted odds ratios (AOR) for engaging in any active sports, rollerblading/biking, exercise and ≥ 5 bouts/week MVPA comparing the adolescents with their friends’ participation in the same measures to those without their friends’ participation. Results stratified by the joint distribution of gender composition and BMI-Z score difference of friends. Data from the special peer network data, N=1957 (National Longitudinal Study of Adolescent Health [Add Health], Wave II.

<table>
<thead>
<tr>
<th>Gender composition of friends</th>
<th>BMI Z-score difference between friends</th>
<th>AOR^{a,c,d,e}</th>
<th>CI^{b}</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Active sports &gt; 0 bouts/week vs. &lt; 0 bouts/week</strong></td>
<td>Male-Male</td>
<td>0.5 to 1.5</td>
<td>4.00</td>
<td>(1.98–9.81)</td>
</tr>
<tr>
<td></td>
<td>Female-Female</td>
<td>-0.5 to 0.5</td>
<td>1.29</td>
<td>(0.81–2.06)</td>
</tr>
<tr>
<td><strong>Rollerblading/biking &gt; 0 bouts/week vs. &lt; 0 bouts/week</strong></td>
<td>Male-Male</td>
<td>-1.5 to -0.5</td>
<td>2.00</td>
<td>(1.33–3.02)</td>
</tr>
<tr>
<td></td>
<td>Female-Female</td>
<td>-0.5 to 0.5</td>
<td>0.98</td>
<td>(0.71–1.35)</td>
</tr>
<tr>
<td><strong>Exercise &gt; 0 bouts/week vs. &lt; 0 bouts/week</strong></td>
<td>Male-Male</td>
<td>0.5 to 1.5</td>
<td>1.56</td>
<td>(0.79–3.08)</td>
</tr>
<tr>
<td></td>
<td>Female-Female</td>
<td>-0.5 to 0.5</td>
<td>1.81</td>
<td>(0.82–4.01)</td>
</tr>
<tr>
<td><strong>MVPA ≥ 5 bouts/week vs. &lt; 5 bouts/week</strong></td>
<td>Male-Male</td>
<td>0.5 to 1.5</td>
<td>2.64</td>
<td>(1.71–4.06)</td>
</tr>
<tr>
<td></td>
<td>Female-Female</td>
<td>-0.5 to 0.5</td>
<td>0.88</td>
<td>(0.51–1.53)</td>
</tr>
</tbody>
</table>

a: AOR means Adjusted Odds Ratio, logistic regression model predicting likelihood of engaging in any active sports, adjusted for adolescent age, sex, race/ethnicity, gender- and age- specific BMI Z-score along with the confounders of physical fitness perception score, school-wide average levels.
b: CI means Confidence Interval
c: Rollerblading/biking, adjusted for adjusted for adolescent age, sex, race/ethnicity, gender- and age- specific BMI Z-score.
d: Exercise, adjusted for adolescent age, sex, race/ethnicity, gender- and age- specific BMI Z-score along with the confounders of physical fitness perception score, school-wide average levels.
e: ≥ 5 bouts MVPA, adjusted for adolescent age, sex, race/ethnicity, gender- and age- specific BMI Z-score.
VI. Baseline Peer Activities Predict Change in Target Adolescent Physical Activity: The Longitudinal Study of Adolescent Health (Add Health) Peer Subsample

A. Introduction

The health benefits of physical activity are well-known. However, two thirds of American adolescents do not participate physical activity five or more times per week as recommended by the CDC (Gordon-Larsen, McMurray et al. 1999), and thus American children fall behind the national goals of Healthy People 2010 (USDHHS 2000). Since physical activity is a social behavior (Butcher 1983; Higginson 1985; Anderssen 1993), it is possible for interpersonal social contexts—such as communities and peers—to play a role in adolescent physical activity. There is substantial evidence that the behavior of peers has an impact on adolescents for a variety of behaviors (i.e., substance uses, sexual behaviors, and school performance) (Kandel 1978; Berndt and Keefe 1995; Urberg, Degirmencioglu et al. 1997; Alexander, Piazza et al. 2001; Maxwell 2002; HANUSHEK, kAIN et al. 2003; Hay, Payne et al. 2004). However, research on the influences of peer physical activity on adolescent activity is relatively sparse. Several cross-sectional qualitative and semi-quantitative studies based on perceived support from friends and perceived friends’ physical activity have been reported, demonstrating a potential relationship between friendship and adolescent physical activity (Anderssen and Wold 1992; Gentle, Caves et al. 1994; Zakarian, Hovell et al. 1994; Voorhees, Murray et al. 1994;).
These studies provide important clues about the effects of peer contexts; however, they have major methodological drawbacks that threaten the validity of these studies.

When modeling the influences of peers, the temporal process of friendship should be considered to avoid overestimation of peer effects. There is a basic tendency to obtain similarity in behaviors within peer groups. Adolescents face pressure to have the same norms, attitudes, and behaviors as other members of a peer group, and they change themselves to retain membership (Cohen 1977; Kandel 1978). This dynamic is referred to as either ‘peer effects’ or ‘peer influences’, and is especially interesting to researchers because of its potential role in improving intervention programs for adolescent behaviors. In addition, adolescents may (a) select friends who are similar to themselves or (b) lose friends who are dissimilar. Thus, the process of friendship is temporal and involves the fundamental procedures of friendship selection, socialization (the process by which individuals accept the goals or the norms of a social group and integrate these goals with those of themselves), and dissolution of friendship (Cohen 1977; Kandel 1978; Ennett and Bauman 1994; Bauman and Ennett 1996; Urberg, Degirmencioglu et al. 1998). Of these, controlling for friendship selectivity is particularly important. Only longitudinal study designs can be used to model these longitudinal effects.

In cross-sectional studies (Anderssen 1993; Gentle, Caves et al. 1994; Zakarian, Hovell et al. 1994; Voorhees, Murray et al. 2005), inferring peer influences based on the similarity of behaviors among adolescents is misleading because similarity might result from a previous selection of friends based on shared interests or congruent behaviors (Cohen 1977; Kandel 1978; Maxwell 2002). Consideration of friendship selectivity effects is necessary because studies have documented that for some behaviors (i.e., smoking, drug use, alcoholic drinking), effects of selection are at least as strong as the effects of peer influences on behaviors (Cohen 1977; Kandel 1978). To control for
selectivity in inference of peer influences, longitudinal studies that can separate
procedures of selection, socialization, and dissolution are needed; however, to the
authors’ knowledge, there are no such studies in the physical activity literature. It is also
inappropriate to apply the inference of peer effects in other health behaviors to physical
activity, because the strength of peer influences may be behavior specific.

Another drawback of the cross-sectional, descriptive studies is the possible
artificial association of adolescent physical activity with the perceived activity of their
friends. The bulk of the literature in this area uses self-reports of behavior from the target
adolescent about his/her peers. In substance use studies, friends’ behaviors are usually
over-reported by adolescents when these adolescents projected their own actions onto
their friends (Bauman and Ennett 1994; Bauman and Ennett 1996). Because of this
limitation, measuring the behaviors of both the target adolescent and his/her friend(s)
would be more appropriate (Bauman and Ennett 1996).

The longitudinal peer sample in the National Longitudinal Study of Adolescent
Health (Add Health) provides an opportunity to address these research gaps and assess
peer influences on adolescent physical activity. This study quantified the magnitude to
which adolescent physical activity is influenced by the physical activity of his/her peers
using the Add Health data on activities reported by both the target adolescent and his/her
friend(s) across time.

B. Methods

1. The Add Health Study

Add Health is a nationally representative school-based survey of youth in grades
7–12 in the 1994-95 school year (Wave I, ages 11-22). At Wave II (1996, ages 12-23),
only respondents of school-age were followed (e.g., graduating seniors from Wave I were
not followed, high school drop-outs were followed). A third wave was conducted in 2001–2002 (ages 18-25). Add Health explores how social contexts (i.e., families, friends, schools, and neighborhoods) affect adolescent health and risk behaviors. Details of this survey were described elsewhere (Popkin and Udry 1998; Gordon-Larsen, McMurray et al. 1999). The survey was approved by the Institutional Review Board of the University of North Carolina at Chapel Hill, NC. This study used the Wave I and Wave II dataset, while respondents were adolescents. Friendships were not followed into Wave III when respondents transitioned to young adulthood, when respondents had left high school and likely formed new adult friendships.

2. The Peer Sample in Add Health Survey

The peer sample was a sub-survey of the Add Health study conducted in 16 schools and was designed to investigate peer contexts on adolescent risk behaviors. Two of these schools had large enrollments (i.e., 800–1700 students), one with a large white student enrollment and another with a diverse racial/ethnic student enrollment. The other 14 schools varied in type (i.e., public, private, and parochial), size, urban/rural location, geographic regions, and racial/ethnic composition. All students in these schools were invited to participate in an interview about friends. They were asked to nominate up to five female and five male friends in each wave. Pair wise linkage of the Add Health survey information of a respondent to that of his/her friends was achieved through assigned identification numbers. Friends from outside of school could be nominated, but were not traceable.

3. The Target Adolescents
The target adolescents in this study were respondents who nominated friend(s) who then had available survey information in both Wave I and Wave II. In Wave I, 3702 students in the peer subsample were 0.45 yrs older (p<0.05) than the full Add Health sample. Of these, 3032 respondents nominated at least one in-school friend who was not a romantic/sexual partner. When followed to Wave II, 2258 of these 3032 respondents along with their friends had available Wave II information. In addition, 134 respondents who only nominated friends in Wave II were also followed because they and their friends had survey information in Waves I and II. A small proportion (N=35) of respondents were eliminated because either they or their friends were physically or mentally disabled, pregnant, or had missing values in the Wave I or Wave II datasets. Thus, the final analysis sample included 2357 respondents. Selectivity analysis (see Appendix 1) through predicting participation status in Wave II (based on Wave I survey information) revealed that respondents eliminated from Wave II differed in age and race/ethnicity from those who remained. The remaining respondents were younger, due to the design of Add Health as only school-aged respondents were followed in Wave II, and whites were more likely than other racial/ethnic groups to be followed. The final sample included 50.8 % (n=1198) male, 49.2% female (n=1157), 53.8% (n=1267) White (non-Hispanic), 13.4 % (n=315) Black (non-Hispanic), 18.7% (n=441) Hispanic, 13.5% (n=319) Asian, and 0.6% (n=15) of other races. The mean age was 16.20 (±1.45) yrs.

4. Longitudinal Friendship Patterns

The primary interest of this study was the dyadic friendship of the target adolescents. Dyadic friendship (friendship based on two people) is the most widely investigated friendship form in studies of adolescent peer contexts.
In the longitudinal context of the two-wave panel data, three types of friendship were defined: (1) stable friendship (a respondent nominated the same person as his/her friend in both waves), (2) past friendship (a respondent nominated a person as his/her friend only in Wave I, but not in Wave II), and (3) new friendship (a respondent nominated a person as his/her friend only in Wave II, but not in Wave I). The longitudinal status of the friendship pairs is presented in Table 9. Previous studies observed that intensity of friendship differs for different types of friends (Unger, Rohrbach et al. 2001; Chen, Unger et al. 2002; Maxwell 2002), thus friendship structures in terms of gender and race/ethnicity of these longitudinal friendship types are illustrated in Figure 7.

5. Outcome Measure: One–year Change in Physical Activity

Habitual daily activities were assessed using a 7-day self-recall questionnaire, which was similar to other validated large-scale epidemiological studies (Sallis, Buono et al. 1993; Andersen, Crespo et al. 1998). Calculation of frequency (ranging 0 – ≥3 bouts per week) of an activity was available based on the questions worded in this format: “During the past week, how many times did you...” This study assessed three types of moderate–to–vigorous physical activity (MVPA): (1) sports (e.g., baseball, softball, basketball, soccer, swimming, and football), (2) exercise (e.g., jogging, walking, karate, jumping rope, gymnastics, and dancing), and (3) wheel-based activity (e.g., rollerblading, roller-skating, skate-boarding, and bicycling). The intensity of MVPA ranged from 5 to 8 METs (metabolic equivalents; 1 MET is the resting metabolic rate) (Ainsworth, Haskell et al. 2000). Total MVPA was calculated by summarizing the three types of activities. In this study, the unit ‘bout’ indicates frequencies of moderate to vigorous physical activity, which is different from the ‘bout’ in most studies that indicates the times of activity with certain intensity and defined time period (Murtagh, Boreham et al. 2005; Miyashita, Burns...
et al. 2006). The distribution of the change in physical activity from Wave I to Wave II is described in Table 10. Detailed distribution of physical activity in Wave I and II are in Appendix 8.

6. Measures of Potential Covariates

The association between peer context and adolescent physical activity has been previously understudied; therefore, covariates that might confound the effect estimation of friendship on physical activity were selected through backward selection. Covariates in the final regression models met the prior 10% “change-in-estimate” criterion of the main exposure variable determined by the methods described in the following section. Covariates were grouped as:

1) Individual and family attributes (obtained from the adolescent in-home questionnaires and parental questionnaires), such as sex (confirmed by interviewers), self-reported race/ethnicity (non-Hispanic White; non-Hispanic Black; Asian; others), and parental education (self-reported, classified as lower than high school; high school and GED; some college; college and above).

2) Individual and family time-varying variables in Wave I (obtained from the in-home questionnaires and parental questionnaires), including respondent physical activity levels, age (based on birth date and interview date), Z-score of BMI (based on self-reported height and weight, and CDC/NCHS growth chart(Kuczmarski, Ogden et al. 2002)), reported family income, CED-D depression scale, and physical fitness perception (worded as: “You are physically fit”, ranging from strongly disagree to strongly agree), and whether sports were played with parents. Measures of depression, physical
fitness perception, and parental involvement in sports were validated in or similar to previous studies (Farmer, Locke et al. 1988; Sallis, Alcaraz et al. 1992; Davison, Cutting et al. 2003; Trost, Sallis et al. 2003; Berg, Simonsson et al. 2005).

3) Friendship characteristics, including gender and racial/ethnic compositions, the order of friendship nomination, and the number of nomination received by friends.

4) Friends’ time-varying variables in Wave I, which were measured the same as those of the respondents.

5) School attributes (obtained from administrator questionnaires), including type (public/private), urban/rural (urban, suburban, and rural), geographic region, and size (large or small enrollment).

6) School-wide mean activity levels at Wave I, which represented the entire peer exposure at school level and were achieved by collapsing individual activities across schools (Alexander, Piazza et al. 2001).

7. Model Specification and Statistical Models

In the statistical model, the outcome was the one-year change in physical activity (from Wave I to Wave II) of respondents, and the main exposure was the baseline (Wave I) physical activity of his/her friends while controlling his/her own baseline physical activity and other covariates. The following equation describes the physical activity change of a respondent:

\[ \Delta PA = PAt1 + Nfri + Pfri + Nfri*PA f t1 + Pfri*PA f t1 + PAt1 + \Sigma COVt1 \]
Where $\Delta PA$ is a respondent’s change in physical activity, Nfri is the dummy indicator for new friendship, Pfri is the dummy indicator for past friendship, PAf t1 is the baseline physical activity of his/her friend(s), PAt1 is his/her own baseline physical activity, $\Sigma COVt1$ represents other covariates measured at Wave I, and Nfri*PA f t1 and Pfri*PA f t1 are production terms.

The modeling strategy includes effect estimation for peer effects based on predicting one-year physical activity change of the target respondent from the baseline physical activity of his/her stable friends, while controlling his/her own baseline physical activity and other covariates that might confound this prediction. This model specification overcomes biases due to the simultaneous nature of reciprocal, contemporaneous peer influences, which implicates that current “peer effects” may partly be the effects of adolescents themselves (Maxwell 2002; HANUSHEK, KAIN et al. 2003), resulting in an overestimation of the peer effects. Since the baseline physical activity of friends was predetermined, this model maximized the probability that the change was influenced by friends’ previous physical activities—but not from current reciprocal influences or interactions. However, this method was subject to underestimation due to restricting the effect estimation only of friends’ baseline behaviors.

Because the longitudinal friendship types (i.e., stable, past, new) involve adolescent behaviors through different mechanisms, analyses were stratified by friendship types. Estimations in stable friends represent peer effects, while past friendship represents dissolution and peer effects. Estimations in new friends represent effects of both selection and peer effects. Thus, stratifying estimates by the longitudinal friendship types can deal with selection effects which may overestimate peer effects.

In the models of one-year change in physical activity, friends’ baseline physical activity was as the main exposure, and respondent baseline physical activity as the main
controlled covariate. Dummy indicators of longitudinal status of friendship, the
cross-products of friends’ physical activity and the dummy indictors were entered for
further post-stratified analysis in the different longitudinal friendship pairs. Other
covariates were selected using the backward selection and a confounder selection strategy
of a 10% “change-in-estimate” criterion. Each available variable was added into the
model individually; those that met the selection criteria of confounders were selected for
the next step, and others were excluded. Then, all selected covariates were added in the
models. A variable was dropped if its inclusion brought the smallest change in the
estimation of regression coefficients of the baseline friends’ physical activity. Model
fitting continued by successively re-fitting reduced models and using the same rule to
drop variables until all remaining covariates met the a priori “change-in-estimate”
criterion. The effect estimation in stable friends, past friends, and new friends was
obtained through post estimation commands immediately after the final full models.
Modeling was conducted for active sports, exercise, and wheel-based activity.

Ordinal logistic regression models were applied in this study because the outcome
(i.e., the change of physical activity that had direction and orders) was an ordinal
categorical variable. The dataset were clustered at multiple levels, because friends of the
same target adolescents were correlated to each other, as were target adolescents of the
same schools. Thus, survey commands were applied to get the variance corrected for this
clustered structure(Juul 2006). We used Stata statistical software (StataCorp. 2005. *Stata*
*Statistical Software: Release 9. College Station, TX: StataCorp LP*) in all models. Models
were separately conducted for male-male, female-female, and mixed-gender friend pairs,
since friendship might have differential effects based on gender composition of friendship
pairs.
C. Results

1. Longitudinal Friendship Patterns

Because of multiple nominations of friendship from some respondents, the final 2357 targeted adolescents had 9781 friendship pairs. These friendship pairs were not stable because only approximately 25% of friendship pairs were maintained from Wave I to Wave II; of the remaining 75%, half were past friendships and half were new friendships (Table 9).

The demographic composition of friendship pairs was associated with longitudinal friendship pattern (Figure 7). Mixed gender friendship was generally not maintained over the period, with only 17.9% of mixed gender friendship stable across both waves. However, same-sex stable friendship over the two waves was higher: 25.3% for male-male friendship pairs and 29.6% for female-female friendship pairs (chi-square, p<0.05). A greater proportion of males than females had new friendships over time. White-White friendship pairs were most stable (chi-square, p<0.05), and new friendship was higher in white and blacks versus Hispanics and Asians (chi-square, p<0.05).

2. One–year Increase in Physical Activity from Wave I to Wave II

A substantial proportion of the sample had consistent physical activity levels over the one-year period, with greater maintenance of wheel-based activity and active sports relative to exercise. The distribution of physical activity change was negatively skewed, indicating a general one-year decline in physical activity (Table 10). The physical activity levels of target adolescents in Wave I and Wave II are listed in Appendix 8.

3. One-year Change in Physical Activity Was Associated with the Baseline Activity of Peers
Baseline friend physical activity was positively associated with target adolescent change in physical activity for active sports and exercise among male-male friends. Among stable male-male friends, a one-bout increase in the friends’ baseline active sports, the expected adjusted likelihood of the target adolescent having an increase of one additional bout of active sports (Adjusted Odds Ratio [AOR]: 1.38, 95% CI [Confidence Interval]: 1.20–1.60) and exercise [AOR=1.17, CI: 1.03–1.34] (See Table 11). Crude estimates are in Appendix 9.

Physical activity change was also associated with past friendship. Baseline active sports of past male friends was positively associated with one-year change in physical activity of the target adolescent [AOR=1.52, CI: 1.07–2.17] and similarly in mixed gender pairs [AOR=1.31, CI: 1.00–1.73].

Physical activity change was also associated with new friendship in males, thus indicating some degree of selectivity of friendship based on physical activity. If a male adolescent have a one-bout increase in active sports from Wave I to II, he was more likely to make a new male friend with a one-bout increase in baseline physical activity [AOR=1.59, CI: 1.12–2.27]. Similar, selectivity was found for exercise [AOR=1.40, CI: 1.02–1.40] and wheel-based activity [AOR=1.43, CI: 1.14–1.80].

Baseline levels of physical activity of female friends could not predict the change of target adolescents. Female target adolescents did not choose friends that had their preferred physical activity levels at baseline.

D. Discussion

The innovative study design, including longitudinal, self-reported behavior data from the target adolescent and his/her peer(s), provides the unique opportunity to examine
the temporal effect of peer physical activity on adolescent activity patterns. Using longitudinal data, this study was able to separate the effects of peer influences from those of selectivity of peers based on shared activity patterns and thus avoided a common source of bias in cross-sectional research. By predicting the physical activity change of the target adolescent based on the friends’ baseline activity, causal inference based on the temporal relationship in this study was more reliable than in cross-sectional studies.

This study found that adolescent friendship was not stable. Only about 25% of all friendship pairs still maintain after one year period. The percentage is a little bit lower than previous findings that investigated the friendship procedures through time in the younger subjects (Maxwell 2002). However, this unstableness of adolescent friendship provides opportunity of investigating peer influences, because evidence in the literature shows that influences of peers weaken with time (Bauman and Ennett 1996).

This study has several important findings. First, among adolescent males, physical activity behavior of a peer may influence physical activity change of others. After consideration of their own baseline activity level, males were more likely to add one extra bout of active sports and exercise over the one-year period with each bout of comparable baseline activity of a friend. Second, this study found evidence of selectivity in friendship based on physical activity pattern; males were more likely to have shared activity behaviors in new friendships. However, these effects may be overestimated due to the possibility of simultaneous peer effects and selectivity effects in real life. Third, we observed null results in female-female friends, suggesting the relative absence of peer effects in females. Consequently, the similarity of activity pattern for females observed in cross-sectional studies might be artificially inflated in such studies.

To summarize, the most important finding is that the association of peer activity behavior with target adolescent activity behavior varied by type of activity and gender
composition of the friendship. Male adolescents appeared to rely on both (a) making new friends and (b) changing behaviors to achieve a certain level of similarity in active sports and exercise, while new friendship seemed to have greater association with wheel-based activity activities. One important implication of this study is to target peer groups to improve sport and exercise levels in male adolescents. However, based on our findings, programs targeting peer groups might be less effective for females than for males.

Our results are consistent with previous studies of peer influences on other adolescent behaviors and contribute evidence of peer influences on adolescent physical activity. Effect estimation in most studies is not directly comparable to each other because of different methods for measuring behaviors and different methods for statistics (Kandel 1978; Bauman and Ennett 1994; Berndt and Keefe 1995; Biglan, Duncan et al. 1995; Maxwell 2002; Gritz, Prokhorov et al. 2003). However, peer influences were generally stronger for substance use and delinquent behaviors (e.g., smoking, illicit drug use, violence) than for others (political view, school adjustment). Effect of peer influences on adolescent physical activity exists, but only in male-male friends. Effect detected in this study seems not as strong as those on smoking, drinking or sexual debut (Maxwell 2002; Gritz, Prokhorov et al. 2003). This study is also consistent with previous studies in the findings that peer influences are sensitive to the features of friendship (e.g., friends’ gender, ethnicity) (Kandel 1978; Berndt and Keefe 1995; Gritz, Prokhorov et al. 2003), because effects only exist in male-male friends. A previous study showed that for substance use behaviors, effects of peer selection are as strong as effects of peer influences for achieving a certain level of peer similarity (Kandel 1978). Our study also proves that peer selection also contribute to the peer similarity in physical activity, and its effects might not be weaker than that of peer socialization because the estimate of effects
of peer selection in this study is not much different from the estimate of effects of peer socialization.

Adolescents have different social groups (cliques), some adolescents are attached to specific groups, and some belong to different groups. Evidence showed that, for some substance use behaviors, effect of peer influences on these types of adolescents were different (Ennett and Bauman 1994). How this affects the effects of peer influences on adolescent physical activity is an interesting topic to investigate. This study was conducted in a population consisting of diverse social groups that have different features, interests and socialization patterns, and it would be very interesting to investigate how peers affect adolescent behaviors in different social groups.

This study has limitations. First, interpretation of the results should be made with caution. Although the analysis deliberately controlled the possible overestimation biases as stated in the Methods section, other biases are possible. All observable attributes of the target adolescents and their friends were tested for potential confounding effects; however, unobserved confounders are possible. Biases could also come from time-varying latent variables that could create an artificial association between physical activity change and the baseline physical activity of friends.

Second, self-reported activity is a limitation and these findings should be replicated using direct measures in similar study designs. However, the truly unique longitudinal and paired friendship data in Add Health are rarely found. Third, regression coefficients may be underestimated in the case when the absolute change of physical activity was larger than one bout, because models in this study did not meet the restrictive assumption of proportional odds in ordinal categorical regression (Long and Freese 2006).

Forth, effect of friendship selection is overestimated. The estimation was based on the analysis in new and past friend pairs which included some effect of peer socialization
because friendship selection and socialization might occur at the same time, and it was not clear when friendship began or ended between two waves. Bias could also come from the unknown time sequences for target adolescents to change their behaviors first or change their friendship first when they made new friends.

The longitudinal design of Add Health provided effect estimates across past, stable, and new friendships. Our findings suggest that in males, both peer effects and peer selectivity based on shared physical activity patterns contribute to the similarity of adolescent physical activity among friends. It was found that adolescents can maximize the similarity of physical activity within their friendship pairs through changing their behaviors, as well as through changing their choices of friends. These two procedures of friendship are fundamental different, and how intervention programs can benefit from them needs to be studied.

<table>
<thead>
<tr>
<th>Table 9. The longitudinal status of friendship pairs in the 16 schools for peer network study, N = 9781 (National Longitudinal Study of Adolescent Health [Add Health], Wave I and Wave II).</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
</tr>
<tr>
<td>Stable friendship pairs</td>
</tr>
<tr>
<td>Past friendship pairs</td>
</tr>
<tr>
<td>New friendship pairs</td>
</tr>
<tr>
<td><strong>Total</strong></td>
</tr>
</tbody>
</table>
Figure 7. The distribution of longitudinal status of friendship pairs by gender composition and racial/ethnic composition in the 16 schools for peer network study, N = 9781 (National Longitudinal Study of Adolescent Health [Add Health], Wave I and Wave II).


Table 10. The distribution of one–year change in physical activity among participants in the 16 schools for peer network study, N = 2357 (National Longitudinal Study of Adolescent Health [Add Health], Wave I and Wave II).

<table>
<thead>
<tr>
<th>Change in PA (bouts/week)</th>
<th>Active sports</th>
<th>Exercise</th>
<th>Rollerblading/biking</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>n</td>
<td>(%)</td>
<td>n</td>
</tr>
<tr>
<td>≤-2</td>
<td>273</td>
<td>11.6</td>
<td>283</td>
</tr>
<tr>
<td>-1</td>
<td>489</td>
<td>20.8</td>
<td>506</td>
</tr>
<tr>
<td>0</td>
<td>997</td>
<td>42.3</td>
<td>880</td>
</tr>
<tr>
<td>1</td>
<td>381</td>
<td>16.2</td>
<td>485</td>
</tr>
<tr>
<td>≥2</td>
<td>217</td>
<td>9.1</td>
<td>203</td>
</tr>
<tr>
<td>Total</td>
<td>2357</td>
<td>100.00</td>
<td>2357</td>
</tr>
</tbody>
</table>
Table 11. The odds ratio of increasing adolescent physical activity from Wave I to Wave II according to the physical activity levels of his/her friends at Wave I, in the 16 schools for peer network study, N = 2357 (National Longitudinal Study of Adolescent Health [Add Health], Wave I and Wave II).*

<table>
<thead>
<tr>
<th>Activities</th>
<th>Male-Male friendship pairs (n=2956)</th>
<th>Female-female friendship pairs(n=2873)</th>
<th>Mixed-gender friendship pairs(n=3952)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>OR(^a) CI(^d)</td>
<td>OR(^b) CI</td>
<td>OR(^c) CI</td>
</tr>
<tr>
<td>Active sports</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Stable friends</td>
<td>1.38 (1.20 1.60)</td>
<td>1.11 (0.98 1.27)</td>
<td>1.07 (0.95 1.22)</td>
</tr>
<tr>
<td>Past friends</td>
<td>1.52 (1.07 2.17)</td>
<td>1.09 (0.86 1.38)</td>
<td>1.31 (1.00 1.73)</td>
</tr>
<tr>
<td>New friends</td>
<td>1.59 (1.12 2.27)</td>
<td>1.01 (0.80 1.28)</td>
<td>1.11 (0.84 1.46)</td>
</tr>
<tr>
<td>Exercise</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Stable friends</td>
<td>1.17 (1.03 1.34)</td>
<td>1.11 (0.97 1.27)</td>
<td>0.98 (0.85 1.13)</td>
</tr>
<tr>
<td>Past friends</td>
<td>1.26 (0.92 1.72)</td>
<td>1.29 (0.94 1.77)</td>
<td>1.09 (0.80 1.48)</td>
</tr>
<tr>
<td>New friends</td>
<td>1.40 (1.02 1.90)</td>
<td>1.22 (0.89 1.68)</td>
<td>1.05 (0.77 1.42)</td>
</tr>
<tr>
<td>Rollerblading/biking</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Stable friends</td>
<td>1.06 (0.91 1.23)</td>
<td>0.94 (0.78 1.12)</td>
<td>0.95 (0.82 1.10)</td>
</tr>
<tr>
<td>Past friends</td>
<td>1.16 (0.92 1.46)</td>
<td>1.11 (0.89 1.39)</td>
<td>0.84 (0.68 1.05)</td>
</tr>
<tr>
<td>New friends</td>
<td>1.43 (1.14 1.80)</td>
<td>1.06 (0.85 1.33)</td>
<td>1.07 (0.86 1.34)</td>
</tr>
</tbody>
</table>

OR: Odds ratio.
\(^a\) Ordinal logistic regression, controlled for friendship composition of race/ethnicity, wave I values of adolescent age, active sports, BMI Z-scores, and school-wide average active sports.
\(^b\) Ordinal logistic regression, controlled for friendship composition of race/ethnicity, wave I values of adolescent age, exercise, and BMI Z-scores.
\(^c\) Ordinal logistic regression, controlled for friendship composition of race/ethnicity, wave I values of adolescent age, rollerblading/biking, BMI Z-scores, physical fitness perception, and school-wide average active sports.
\(^d\) 95% Confidence Interval
*Boldface indicates statistical significance (p<0.05)
VII. Analysis of adolescents who reported lower frequencies of every assessed activity

In cluster analysis we found a group of adolescents who reported frequencies of every assessed activity significantly lower than other adolescents. They were 28% of females and 18% of males. This raised people’s concern about their study and health status, because they represented such a big portion of American adolescents. In order to better describe these adolescents, after cluster analysis, we further comparing different perspectives of them with those of other adolescents using ANOVA analysis. These perspectives include CED-D depression scale, whether having sex intercourse in the last year, BMI Z score (an indicator for body weight status), and self-reported GPA. The results were showed in Table 12 and Table 13.

We found that, reporting low frequencies of activity did not make these adolescents significantly different from other adolescents. Their values were comparable with the average of the whole population. Some possible explanation include that they spent most of time for studding, or for paid work (daily activity assessment didn’t include these two activities), or simply were inactive.
Table 12. Characteristics of behavior clusters in males, National Longitudinal Study of Adolescent Health (Add Health)

<table>
<thead>
<tr>
<th>Specific activities</th>
<th>Characteristics of individual clusters compared to the whole population</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cluster 1 (n=1110, n/N=12%)</td>
<td></td>
</tr>
<tr>
<td>Marijuana use, cigarette smoking, alcoholic drinking</td>
<td></td>
</tr>
<tr>
<td>Cigarette smoking, alcoholic drinking</td>
<td></td>
</tr>
<tr>
<td>Chewing tobacco, cigarette smoking, alcoholic drinking</td>
<td></td>
</tr>
<tr>
<td>Rollerblading/biking/biking</td>
<td></td>
</tr>
<tr>
<td>Active sports, exercise</td>
<td></td>
</tr>
<tr>
<td>More screen time</td>
<td></td>
</tr>
<tr>
<td>Total (N=9494)</td>
<td></td>
</tr>
<tr>
<td>Mean  SD</td>
<td>Mean  SD</td>
</tr>
<tr>
<td>BMI Z score</td>
<td>0.23  1.05</td>
</tr>
<tr>
<td>GPA</td>
<td><strong>2.20</strong>  0.88</td>
</tr>
<tr>
<td>Ever having sex intercourse in the last year(%)</td>
<td><strong>0.72</strong>  0.61</td>
</tr>
</tbody>
</table>

*a Standard deviation.

b Bolded and italic mean values are those with significantly highest or lowest cross clusters (p<0.05, with Bonferroni correction).
<table>
<thead>
<tr>
<th>Specific activities</th>
<th>Characteristics of individual clusters compared to the whole population</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Cluster 1 (n=1150, n/N=12%)</td>
</tr>
<tr>
<td>Marijuana use, alcoholic drinking</td>
<td>Mean  SD</td>
</tr>
<tr>
<td>Cigarette smoking, alcoholic drinking</td>
<td>15.79 9.22</td>
</tr>
<tr>
<td>Rollerblading/biking/biking</td>
<td>0.20 0.93</td>
</tr>
<tr>
<td>Active sports exercise</td>
<td>2.42 0.88</td>
</tr>
<tr>
<td>More screen time</td>
<td>Ever having sex intercourse in the last year(%)</td>
</tr>
<tr>
<td>Engaging in lower frequencies of every assessed activities</td>
<td>0.73</td>
</tr>
</tbody>
</table>

*a SD, Standard deviation

*b Bolded and italic mean values are those with significantly highest or lowest cross clusters (p<0.05, with Bonferroni correction.)
VIII. Synthesis

A. Overview of findings

Our research investigates the sociocultural attributes of physical activity in American adolescents using data from the National Longitudinal Study of Adolescent Health. This research contributes to a better understanding of physical activity as a typical social behavior and an essential part of daily life. Our research also provides important information for effective intervention and public health policy to improve physical activity levels in adolescence and to prevent chronic diseases in adulthood.

First, using the full dataset of the Add Health, we identified meaningful behavior patterns through pattern reorganization analysis base on different types of physical activity and substance use behaviors in adolescents. Then we examined how race/ethnicity, an important social determinant, both as the cultural indicator and as the source of the social segregation, was associated with the identified behavior patterns. Second, using the peer network data of wave II in the Add Health, we investigated how friendship, as a typical social resource, affects adolescent physical activity. We tested the hypothesis that target adolescents’ physical activity patterns were associated with those of their friends. We also proved that the extent of association was affected by the body weight status of target adolescents and their friends. Finally, using the longitudinal peer network data of Wave I and Wave II in the Add Health, we qualified the effects of friendship on adolescent physical activity. This section is the summary of this research and the synthesis of its findings.

1. Co-varying patterns of substance use and physical activity in American adolescents: results from the National Longitudinal Study of Adolescent Health (Add Health)
The purpose was first to use the nationally representative, ethnically diverse data to identify the meaningful patterns that describe how, as a lifestyle, physical activity and substance use behaviors (e.g., drug use, smoking, and drinking) were associated with each other. The second purpose was to examine how race/ethnicity affected the identified behavior patterns through its impact on individuals and schools. We identified seven typical robust groups in males and six in females according to their reported frequencies of participating in physical activity and substance use behaviors. For males, these groups are drug users, smokers and drinkers, tobacco chewers, wheel-based players who like rollerblading or biking activities, sporters and exercisers, TV watchers, and others. Group ‘others’ means that adolescents in this group reported low frequencies of every activity assessed. For females, they are drug users, smokers and drinkers, wheel-based players, sporters and exercisers, TV watchers, and others. The prevalence of every type of behavior pattern was no less than 9% in American adolescents.

Our modeling analysis illustrates that, independent of parental education and family income, adolescent race/ethnicity was strongly associated with different behavior patterns. For example, for males, Whites were more likely to be tobacco chewers and wheel-based players than other racial/ethnic groups. Blacks were more likely to be TV watchers, but less likely to be smokers and drinkers. Hispanics and Asians were more likely to report lower frequencies of every activity assessed. The effects of race/ethnicity for females differed from those for males. Finally, by multilevel modeling, our analysis also demonstrates that the school social economic background indicated by the racial/ethnic composition of students and their mean family incomes could be strongly associated with being sporters and exercisers, ‘others’ in all the adolescents, and being tobacco chewers in male adolescents.
2. Adolescent physical activity patterns are associated with activity patterns of their friends: results from the National Longitudinal Study of Adolescent Health (Add Health)

We applied logistic regression models to investigate, for a pair of friends, the extents that different types of physical activity of the target adolescent were associated with those of his/her friend. We also furthered our study by investigating how these associations were modified by the body weight status of a pair of friends. Peer network data of a unique subgroup of the Add Health was used. This data provided multiple nominations of friends by a target adolescent, and one of the friends was randomly selected for the analysis. Friends’ survey information was linked pair-wise. Several important findings regarding the role of friendship in shaping adolescent physical activity patterns are reached. First, different types of physical activity (e.g., active sports, exercise, and rollerblading/biking) were associated with friendship; however, the extents of associations differed by type of physical activity, gender status of friendship, and racial/ethnic status of friendship. For male-male friendship pairs, the odds of a target adolescent to participate in active sports was bigger if his friend reported no less than one time /week of active sports than the odds of another target adolescent if his friends reported no participation in active sports. This association was weaker in friendship pairs formed by same females or by mixed gender adolescents. Among different types of physical activity, this association was the strongest for active sports, but weaker for exercise and rollerblading/biking.

Second, body weight status of a pair of friends was found to modify the detected associations. We used the difference of BMI Z-scores of a pair of friends to indicate the relative body size of a target adolescent to that of his/her friend. The odds of target adolescents participating in active sports and exercise predicted by their friends’ participating status were found the biggest among those target adolescents who had relatively bigger body sizes than their friends. Finally, we found the existence of joint effects of relatively bigger body size of target
adolescent and male-male status of friendship on increasing the association magnitudes of physical activity patterns of paired friends.

This study is the first study to investigate the effects of friendship on physical activity based on both social networks and directly reported physical activity by friends themselves rather than by target adolescents. It provides evidence for the complex mechanisms that friendship involves in adolescent physical activity, and suggests the need for further understanding the mechanisms of friendship in shaping adolescent physical activity. To fully understand the roles of friendship in adolescent life, a series of studies using the similar methods for other health behaviors are needed.

3. Baseline peer activities predict change in target adolescent physical activity: the longitudinal study of adolescent health (Add Health) peer subsample

We used two waves of peer network data to quantify the effects of friendship on different types of adolescent physical activity while controlling for important confounding factors. Through the analysis of friendship procedures of formation, socialization, and dissolution, dynamics of friendship involved in different types of physical activity were demonstrated. In the modeling analysis, main strategies of controlling for confounding factors included modeling a one year change of physical activity of a target adolescent based on his/her friends’ baseline values. Strategies also included separating stable friendships from newly formed/dissolved friendships to eliminate the confounding effects from the friendship formatting based on similar physical activity levels. We found that the temporal features of friendship are complex. Most friendship pairs were not stable, and stable pairs were approximately 25% of all tracked ones. Male-male friendship was more stable than female-female and mixed gender pairs. The modeling analysis showed that baseline physical activity of friends can predict the one year changes of physical activity of target adolescents;
however, this effect only existed in male-male friendship pairs. For male-male friend pairs, the predicting capability was stronger for active sports than for exercise and rollerblading/biking. Analysis also showed that previous physical activity involved in friendship formation of males because male adolescents that increased their physical activity levels from wave I to wave II were more likely to choose male friends with higher levels of physical activity in Wave I.

This is the first study to provide empirical quantitative evidence for the effects of friendship on adolescent physical activity. Further studies of investigating the pathways and mechanisms of friendship affecting different types of adolescent physical activity are needed in order to effectively use this type of social resource to improve adolescent physical activity.

B. Strengths and Limitations

This study faces challenges and limitations. First, the questionnaires in the Add Health assessed limited daily activities. As a consequence, both in males and females, there was a subgroup of adolescents whose daily activities were not captured. This limitation prevents us from better describing the behaviors of these adolescents. Second, other important behaviors that characterize adolescent health risks, such as eating and sexual behaviors, were missing; however, the aims of this study were only to demonstrate an aspect of adolescent lifestyles for understanding co-varying health behaviors. Thus, missing some perspectives of behaviors should not affect accomplishing the original study purpose.

The limitations in the analysis of effects of friendship mainly exist in the following two aspects. First, demonstrating the phenomenon that body weight status of a pair of friends affected the extents of associations of their physical activity patterns were based on cross-sectional analysis, and thus it might be biased due to those unobserved factors. Second, body weight status of a pair of friends was indicated by the difference of their BMI Z-scores. Individual BMI Z-score was calculated based on measured weight and height, and was
gender and age specific; however, for adolescents with the same BMI, it can’t differentiate those with more muscles from those with more fat. Thus this might induce a bias from misclassification.

In the casual inference of the effects of friendship, endogeneity was not totally controlled. The most powerful method to control endogeneity is fixed effect models. However, the distribution of one year change of physical activity didn’t allow this method. Instead, we chose to predict the change of physical activity of target adolescents based on the baseline value of friends. By doing this, biases might come from time-varying latent variables that could create an artificial association between the physical activity changes of target adolescents and the baseline physical activities of friends.

Other important limitation of this study is the self-reported measures of substance use behaviors and physical activity. Objective methods for measuring drug use, smoking, drinking, and physical activity exist; however, their high expense prevents them being used in big-scale epidemiological studies. Compared to objective methods, the self-reporting methods of these variables are suspected of biases. However, as one of the biggest surveys of American adolescent health, it is not affordable to collect objective measures for all subjects. Questionnaires for collecting these measures were similar to those that were evaluated and validated in big-scale national studies, which guarantees the validity of our study.

Despite the above limitations, the obvious strengths of this study make it a significant and important contribution to the literature of physical activity. Relatively few works have been done using the nationally representative studies to better understand adolescent physical activity for its sociocultural characteristics as well as its sociocultural determinants. The Add Health provides us an opportunity to identify the lifestyles of American adolescents, and makes this study a significant and useful reference in describing lifestyle patterns of American adolescents and for applying specific lifestyle promotions.
Pattern recognizing procedure for the co-varying physical activity and substance use behaviors also provides a different scope to capture the relationship of these behaviors that can not be explained by linear regression models in the previous studies. The sampling design of the Add Health allows us to observe the effects of sociocultural factors, both at the individual level and at the school level, because its sample size of schools provides a great opportunity to model how a school’s social economic background can affect individual behavior patterns with enough statistical power and more appropriate model specifications. This study is among several studies to provide evidence about the link between social structural segregation and racial/ethnic disparity of health behaviors.

The peer network of the Add Health is one of the biggest network data sets of adolescents. It is not nationally representative; however, the schools and subjects in it were diverse in many perspectives, which make our study very important as empirical evidence. However, the outstanding and unique feature of this study is that it provides more convincing quantitative evidence than any other previous studies regarding the effects of friendship on adolescent physical activity. This claim is based on the fact that this study is the first study in the literature to investigate friendship and physical activity using directly reported measures from friends themselves, and is the first study to analyze them using a longitudinal method. Reporting friends’ physical activity by themselves rather than by target adolescents is an important methodological issue in the research of friendship because of the high probability of target adolescents to report friends’ behaviors based their predictions.

C. Public health significance

1. Our findings provide insights into the non-linear relationship between physical activity and substance use behaviors, and the hierarchical effects of race/ethnicity on adolescent behavior patterns.
We successfully identified typical behavior patterns of adolescents based on different types of physical activity and different substance use behaviors. The study is consistent with previous studies that investigated the relationship of different adolescent health behaviors, and expands the scope to describe adolescent behaviors by dividing them into meaningful subgroups. This pattern recognizing method is very helpful in determining the prevalence of different health behavior patterns and identifying typical high risk groups. Thus, our study may provide clues for future lifestyle interventions.

Our findings illustrate that race/ethnicity serves to do more than indicating the social economic status of individuals. Its function to convey specific norms, attitudes, and practices is demonstrated by its independent effects on shaping behavior patterns of adolescents, even after considering the parental education and family income. Thus, this study provides evidence for the claim of the Institute of Medicine (IOM) to improve communication efficiencies by considering race/ethnicity in behavior intervention programs (Nelson 2002).

The fact that race/ethnicity prevented adolescents from having equal opportunity to access social resources was showed in the finding that racial/ethnic and economic backgrounds of schools could predict the likelihoods of student behavior patterns. This finding reveals important evidence for the arguments that social structural segregation based on race/ethnicity is one of the core causes of the racial/ethnic disparity in American mortality and morbidity. Automatic or forced social segregation exists in residence, communities, and extends to school selections, which prevent schools from offering the same resources to students, and also prevent adolescents from knowing the attitudes and behaviors of other race/ethnicity.

This study shows the importance of generating creative programs and policies to equally allocate social resources among schools, and to reduce the negative effects of school segregation based on race/ethnicity. Active sports are the most important moderate to
vigorous physical activity in American adolescents; however, analysis shows that participating in active sports was strongly affected by schools’ social economic backgrounds. Thus, finding feasible ways to improve participation rate in active sports in the poor and minority schools are highly needed.

2. **Our finding also provides empirical evidence for considering intervention programs that incorporate peer context.**

   Studies on the effects of friendship on substance use behaviors such as drug use, smoking, and drinking are substantial; however, this study is the first one in the literature to quantitatively investigate the effects of friendship on adolescent physical activity. Our study shows the evidence that friendship can influence adolescent physical activity as it influence other behaviors (e.g., substance use, sexual experience, and school achievements). It reveals several important perspectives for considering friends as an intervention strategy. First, whether friendship affects adolescent physical activity is dependent on the friendship features. Male-male friendship was proved to have a causal effect on different types of adolescent physical activity. Second, effects of friendship on adolescent physical activity are sensitive to different types of physical activity. They are the strongest for active sports, but are weaker for exercise and rollerblading/biking. Third, body weight status of friends might modify these effects, and the modification effect might be specific to the types of physical activities and the gender status of friends. Generally, adolescents with bigger BMI than their friends try to have the same physical activity patterns as their friends than other adolescents. All this information is very important to develop the intervention strategies that aim to improve adolescent physical activity by mobilize social resources such as friends.

D. **Direction for further research**
Many possible directions exist to help us better understand physical activity and its sociocultural etiology in adolescence.

One important area is to develop and evaluate a framework or an index for systemically describing the patterns of adolescent lifestyles using as few as possible health behaviors. To date, no literature exists for a systematic description of the adolescent lifestyles. This limits our capability to fully capture the nature of adolescent health behaviors. Every activity, including different types of physical activity, integrates in daily life, and missing consideration of the whole picture of adolescent lifestyles may create a pitfall where intervening one specific behavior is not as effective as intervening lifestyles because of the interdependency of different health behaviors. The proposed framework or index will also help for quick screening adolescents with multiple risk behaviors at the population level and apply interventions as early as possible.

It is also important to continue the current study on the association between peer influences and adolescent physical activity in the following directions: 1) The causal effects of bodyweight status of friends on adolescent physical activity levels, and 2) The role of adolescent social positions among friends on adolescent physical activities. Besides multivariate models, structural equation models might be a promising method to do the pathway analysis from friends’ characteristics (e.g., friends’ body size, and their popularity among peers), through adolescent psychological status, and finally to adolescent physical activity outcomes. These studies will help us better understand friendship and its potential role in behavior interventions.

In order to provide a better picture of friendship in adolescent life, broadening the current study of peer influences on other health behaviors such as dieting, anorexia, and other extreme practices of losing weight in adolescents will also be considered as a potential direction.

Parents and schools are other important social contexts compared to friends in adolescent physical activity; however, no literature provides us information about whether the effects of
friends, parents, and schools are independent or associated with one another. Studies are in need to find out whether they are competing or synergic in affecting adolescent physical activity.

Romantic relationships are also important social relationship in adolescence. However, their effects on adolescent health behaviors have not been fully understood. It would be a natural extension from investigating friendship to investigating romantic relationship. The logic of investigating the effects of a romantic partner will be similar to those of friendship because both analyses focus on the performance and interrelation between a pair of people. The result, however, is necessary for sketching a full scene of adolescent social relationships and their lifestyles.

Physical activity is a social behavior, and participating in a type of physical activity is a decision. Borrowing economic theories to explore the decision making procedures for physical activity would further our understanding of the social nature of physical activity. For example, these theories would explain how the pathway through which environmental change causes behavior change. From an economic perspective, people conduct rational choices to maximize their welfare from given resources. The major challenge for this research is to transform the economic decision models into models for health behavior choices. The key to this perspective is to clarify the analogy between economic factors in the economic models and the environmental factors in the health behavior models. This type of research will be helpful in designing meaningful and effective intervention programs that can lead people to make a decision for improving their physical activity levels by manipulating possible social environmental factors.

In conclusion, acquired risks play important roles in the determination of chronic diseases such as obesity and its relative complicates. Improving physical activity levels in adolescents is an important public health policy to prevent chronic diseases in adulthood. We reveal the co-varying patterns of physical activity, and investigate effects of race/ethnicity
from the cultural perspective and the social segregation perspective. We also reveal the 
effects of friendship, the most important social relationship of adolescents, on physical 
activity. Thus, our study has important contributions for current and future physical activity 
promotions because it provides the above insights of sociocultural natures of physical activity 
and its determinants that have been unstudied in previous studies.
### Appendix 1. Final solution of clusters and cluster characteristics in males and females, National Longitudinal Study of Adolescent Health (Add Health)

<table>
<thead>
<tr>
<th>Cluster name</th>
<th>Characteristics</th>
<th>n</th>
<th>n/N(%)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Males (N=9494)</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cluster 1 Drug users</td>
<td>Using marijuana, smoking cigarettes, and drinking</td>
<td>1110</td>
<td>12</td>
</tr>
<tr>
<td>Cluster 2 Smokers and drinkers</td>
<td>smoking cigarettes and drinking</td>
<td>863</td>
<td>9</td>
</tr>
<tr>
<td>Cluster 3 Tobacco chewers</td>
<td>Chewing tobacco, smoking cigarettes, and drinking</td>
<td>1036</td>
<td>11</td>
</tr>
<tr>
<td>Cluster 4 Wheel-based players</td>
<td>Doing more rollerblading/biking</td>
<td>1216</td>
<td>13</td>
</tr>
<tr>
<td>Cluster 5 Sporters and exercisers</td>
<td>Doing more active sports and exercise</td>
<td>1803</td>
<td>19</td>
</tr>
<tr>
<td>Cluster 6 TV watchers</td>
<td>spending more screen time</td>
<td>1741</td>
<td>18</td>
</tr>
<tr>
<td>Cluster 7 others</td>
<td>Reporting low frequencies of activity assessed</td>
<td>1725</td>
<td>18</td>
</tr>
<tr>
<td><strong>Females (N=9847)</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cluster 1 Drug users</td>
<td>Using marijuana, smoking cigarettes, and drinking</td>
<td>1150</td>
<td>12</td>
</tr>
<tr>
<td>Cluster 2 Smokers and drinkers</td>
<td>smoking cigarettes and drinking</td>
<td>1328</td>
<td>13</td>
</tr>
<tr>
<td>Cluster 3 Wheel-based players</td>
<td>Doing more rollerblading/biking</td>
<td>864</td>
<td>9</td>
</tr>
<tr>
<td>Cluster 4 Sporters and exercisers</td>
<td>Doing more active sports and exercise</td>
<td>1870</td>
<td>19</td>
</tr>
<tr>
<td>Cluster 5 TV watchers</td>
<td>spending more screen time</td>
<td>1910</td>
<td>19</td>
</tr>
<tr>
<td>Cluster 6 others</td>
<td>Reporting low frequencies of activity assessed</td>
<td>2725</td>
<td>28</td>
</tr>
</tbody>
</table>
Appendix 2. Regression coefficients of schools’ race-SES for subjects’ falling into alternative behavior clusters rather than the reference cluster in female adolescents, National Longitudinal Study of Adolescent Health (Add Health)

<table>
<thead>
<tr>
<th>Cluster 1</th>
<th>Grand-centered random intercepts</th>
<th>Schools’ race-SES (2)</th>
<th>Schools’ race-SES (3)</th>
<th>Schools’ race-SES (4)</th>
<th>Schools’ race-SES (5)</th>
<th>Schools’ race-SES (6)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coefficients</td>
<td>-1.0328</td>
<td>0.0887</td>
<td>0.3131</td>
<td>0.6266</td>
<td>0.3309</td>
<td>0.9098</td>
</tr>
<tr>
<td>T-ratio</td>
<td>-14.5260</td>
<td>0.2010</td>
<td>1.3350</td>
<td>2.6900</td>
<td>1.0730</td>
<td>4.4070</td>
</tr>
<tr>
<td>P-value</td>
<td>&lt;0.001</td>
<td>0.842</td>
<td>0.184</td>
<td>0.008</td>
<td>0.286</td>
<td>&lt;0.000</td>
</tr>
</tbody>
</table>
Appendix 3. Regression coefficients\(^\text{a}\) of respondent race/ethnicity for subjects' falling into alternative behavior clusters rather than the reference cluster\(^\text{b}\) in female adolescents, National Longitudinal Study of Adolescent Health (Add Health)

<table>
<thead>
<tr>
<th>Respondent race/ethnicity(^\text{c})</th>
<th>Hispanic</th>
<th>Black</th>
<th>Asian</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Cluster 1</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Coefficients</td>
<td>-0.5343</td>
<td>-0.6819</td>
<td>-1.5533</td>
</tr>
<tr>
<td>T-ratio</td>
<td>-4.138</td>
<td>-5.482</td>
<td>-7.331</td>
</tr>
<tr>
<td>P-value</td>
<td>&lt;0.001</td>
<td>&lt;0.001</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td><strong>Cluster 2</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Coefficients</td>
<td>-1.03861</td>
<td>-1.71404</td>
<td>-0.91946</td>
</tr>
<tr>
<td>T-ratio</td>
<td>-7.617</td>
<td>-12.411</td>
<td>-4.949</td>
</tr>
<tr>
<td>P-value</td>
<td>&lt;0.001</td>
<td>&lt;0.001</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td><strong>Cluster 3</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Coefficients</td>
<td>-0.84853</td>
<td>-0.62646</td>
<td>-0.33032</td>
</tr>
<tr>
<td>T-ratio</td>
<td>-5.307</td>
<td>-4.268</td>
<td>-1.701</td>
</tr>
<tr>
<td>P-value</td>
<td>&lt;0.001</td>
<td>&lt;0.001</td>
<td>0.088</td>
</tr>
<tr>
<td><strong>Cluster 4</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Coefficients</td>
<td>-0.63593</td>
<td>-0.40676</td>
<td>-0.32389</td>
</tr>
<tr>
<td>T-ratio</td>
<td>-5.54</td>
<td>-3.952</td>
<td>-2.239</td>
</tr>
<tr>
<td>P-value</td>
<td>&lt;0.001</td>
<td>&lt;0.001</td>
<td>0.025</td>
</tr>
<tr>
<td><strong>Cluster 5</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Coefficients</td>
<td>-0.45457</td>
<td>-0.04651</td>
<td>-0.03117</td>
</tr>
<tr>
<td>T-ratio</td>
<td>-3.961</td>
<td>-0.465</td>
<td>-0.214</td>
</tr>
<tr>
<td>P-value</td>
<td>0.001</td>
<td>0.641</td>
<td>0.831</td>
</tr>
</tbody>
</table>

\(^{a}\)Maximum likelihood ratio test between the full model with respondent race/ethnicity and the reduced model was statistically significant (p<0.05). The models controlled for females controlled for age, family income, parental education, religion, generation of immigration, adolescent working status, school session, the percentages of different parental education levels at schools, the percentages of different religions at schools, school urbanicity, school size and geographic regions.

\(^{b}\) Cluster 6, the cluster whose members reported low levels of every activities assessed.

\(^{c}\) White was the reference group.
Appendix 4. Likelihood ratio tests for respondent race/ethnicity and schools’ race-SES in males and females, National Longitudinal Study of Adolescent Health (Add Health)

<table>
<thead>
<tr>
<th>Deviance of the full models$^3$</th>
<th>Males</th>
<th>Females</th>
</tr>
</thead>
<tbody>
<tr>
<td>Likelihood ratio test for schools’ race-SES</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Deviance of reduced model for schools’ race-SES</td>
<td>-3.573924E+004</td>
<td>-3.207555E+004</td>
</tr>
<tr>
<td>Likelihood ratio ($\chi^2$)</td>
<td>190.81</td>
<td>122.48</td>
</tr>
<tr>
<td>df</td>
<td>30</td>
<td>25</td>
</tr>
<tr>
<td>P-value</td>
<td>&lt;0.005</td>
<td>&lt;0.005</td>
</tr>
</tbody>
</table>

Likelihood ratio test for respondent race/ethnicity

<table>
<thead>
<tr>
<th>Deviance of the reduced model for race/ethnicity</th>
<th>Males</th>
<th>Females</th>
</tr>
</thead>
<tbody>
<tr>
<td>Likelihood ratio ($\chi^2$)</td>
<td>85.94</td>
<td>26.12</td>
</tr>
<tr>
<td>df</td>
<td>18</td>
<td>15</td>
</tr>
<tr>
<td>P-value</td>
<td>&lt;0.005</td>
<td>&lt;0.05</td>
</tr>
</tbody>
</table>

$^3$: For males, controlled for individual school size and school region. For females, controlled for
### Appendix 5. Variance at the school level for subjects' falling into alternative behavior clusters rather than the reference cluster in male adolescents, National Longitudinal Study of Adolescent Health (Add Health)

<table>
<thead>
<tr>
<th>Model specification</th>
<th>Cluster 1</th>
<th>Cluster 2</th>
<th>Cluster 3</th>
<th>Cluster 4</th>
<th>Cluster 5</th>
<th>Cluster 6</th>
</tr>
</thead>
<tbody>
<tr>
<td>Empty model with random intercepts only</td>
<td>0.3339</td>
<td>0.2486</td>
<td>0.7874</td>
<td>0.5930</td>
<td>0.0750</td>
<td>0.1811</td>
</tr>
<tr>
<td>Reduced model without schools’ race-SES (adjusted for school size)</td>
<td>0.3140</td>
<td>0.2400</td>
<td>0.7759</td>
<td>0.5302</td>
<td>0.0641</td>
<td>0.1637</td>
</tr>
<tr>
<td>Full Model with schools’ race-SES (adjusted for school size)</td>
<td>0.3036</td>
<td>0.1916</td>
<td>0.4510</td>
<td>0.4871</td>
<td>0.0424</td>
<td>0.1618</td>
</tr>
<tr>
<td>Variance explained by schools’ race-SES</td>
<td>0.0104</td>
<td>0.0484</td>
<td>0.3249</td>
<td>0.0431</td>
<td>0.0217</td>
<td>0.0019</td>
</tr>
<tr>
<td>Variance relatively explained by race-SES#</td>
<td>0.0311</td>
<td>0.1947</td>
<td>0.4126</td>
<td>0.0727</td>
<td>0.2893</td>
<td>0.0105</td>
</tr>
</tbody>
</table>

\$ Cluster 7 whose members reported low levels of every activity assessed was the reference group.
\#calculated by subtracting the variance of full model from the reduced model and being divided by the variance of model with only random intercepts

### Appendix 6. Variance at school level explained by schools’ race-SES for subjects' falling into alternative behavior clusters rather than the reference cluster in female adolescents, National Longitudinal Study of Adolescent Health (Add Health)

<table>
<thead>
<tr>
<th>Model specification</th>
<th>Cluster 1</th>
<th>Cluster 2</th>
<th>Cluster 3</th>
<th>Cluster 4</th>
<th>Cluster 5</th>
<th>Cluster 6</th>
</tr>
</thead>
<tbody>
<tr>
<td>Model with random intercepts only</td>
<td>0.5412</td>
<td>0.4617</td>
<td>0.7183</td>
<td>0.3092</td>
<td>0.1508</td>
<td></td>
</tr>
<tr>
<td>Reduce model without schools’ race-SES (adjusted for school size)</td>
<td>0.5174</td>
<td>0.4517</td>
<td>0.5934</td>
<td>0.2795</td>
<td>0.0934</td>
<td></td>
</tr>
<tr>
<td>Full Model with schools’ race-SES (adjusted for school size)</td>
<td>0.4170</td>
<td>0.1741</td>
<td>0.4733</td>
<td>0.1529</td>
<td>0.0909</td>
<td></td>
</tr>
<tr>
<td>Variance explained by schools’ race-SES</td>
<td>0.1004</td>
<td>0.2777</td>
<td>0.1201</td>
<td>0.1266</td>
<td>0.0025</td>
<td></td>
</tr>
<tr>
<td>Variance relatively explained by race-SES#</td>
<td>0.1855</td>
<td>0.6014</td>
<td>0.1673</td>
<td>0.4095</td>
<td>0.0164</td>
<td></td>
</tr>
</tbody>
</table>

\$ Cluster 6 whose members reported low levels of every activity assessed was the reference group.
\#Calculated by subtracting the variance of full model from the reduced model and being divided by the variance of model with only random intercepts
Appendix 7. Wave I characteristics of participants for the sample selection, in the 16 schools for peer network study (National Longitudinal Study of Adolescent Health [Add Health], Wave I and Wave II).

<table>
<thead>
<tr>
<th>Variables</th>
<th>Adolescents who responded to peer interviews</th>
<th>Respondents who nominated at least one friend</th>
<th>Respondents who nominated at least one valid friend$</th>
<th>Respondents along with their friends were both in wave I and Wave II</th>
<th>Respondents in final models</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sex</td>
<td>n</td>
<td>n/N(%)</td>
<td>n</td>
<td>n/N(%)</td>
<td>n</td>
</tr>
<tr>
<td>Male</td>
<td>1892</td>
<td>51.1</td>
<td>1801</td>
<td>50.9</td>
<td>1539</td>
</tr>
<tr>
<td>Female</td>
<td>1810</td>
<td>48.8</td>
<td>1739</td>
<td>49.1</td>
<td>1493</td>
</tr>
<tr>
<td>Total</td>
<td>3702</td>
<td>100.00</td>
<td>3540</td>
<td>100.00</td>
<td>3032</td>
</tr>
<tr>
<td>Race/ethnicity</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>White</td>
<td>1803</td>
<td>48.7</td>
<td>1734</td>
<td>49.0</td>
<td>1541</td>
</tr>
<tr>
<td>Black</td>
<td>562</td>
<td>15.2</td>
<td>534</td>
<td>15.1</td>
<td>408</td>
</tr>
<tr>
<td>Hispanic</td>
<td>754</td>
<td>20.4</td>
<td>724</td>
<td>20.5</td>
<td>597</td>
</tr>
<tr>
<td>Asian</td>
<td>553</td>
<td>14.9</td>
<td>523</td>
<td>14.8</td>
<td>465</td>
</tr>
<tr>
<td>Others</td>
<td>30</td>
<td>0.8</td>
<td>25</td>
<td>0.6</td>
<td>21</td>
</tr>
<tr>
<td>Total</td>
<td>3702</td>
<td>100.00</td>
<td>3540</td>
<td>100.00</td>
<td>3032</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Mean± Standard Deviation</th>
<th>n</th>
<th>Mean±SD@</th>
<th>n</th>
<th>Mean±SD@</th>
<th>n</th>
<th>Mean±SD@</th>
<th>n</th>
<th>Mean±SD@</th>
<th>n</th>
<th>Mean±SD@</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (yrs) at wave I</td>
<td>3702</td>
<td>16.6±11.56</td>
<td>3540</td>
<td>16.6±1.55</td>
<td>3032</td>
<td>16.6±1.55</td>
<td>2392</td>
<td>16.2±1.45</td>
<td>2357</td>
<td>16.2±1.45</td>
</tr>
<tr>
<td>MVPA* at Wave I</td>
<td>3700</td>
<td>3.62±2.10</td>
<td>3540</td>
<td>3.62±2.10</td>
<td>3032</td>
<td>3.64±2.10</td>
<td>2392</td>
<td>3.83±2.10</td>
<td>2357</td>
<td>3.83±2.10</td>
</tr>
</tbody>
</table>

MVPA* Moderate to Vigorous physical activity having 5–8 MET values.
SD@ Standard Deviation

Valid friend$, Friends who were in the same schools, not romantic/sexual partners.
Appendix 8. The physical activity levels of participants in the 16 schools for peer network study, N = 2357 (National Longitudinal Study of Adolescent Health [Add Health], Wave I and Wave II).

<table>
<thead>
<tr>
<th>Variables</th>
<th>Wave I</th>
<th></th>
<th>Wave II</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>n (%)</td>
<td>Mean</td>
<td>SD</td>
<td>n (%)</td>
</tr>
<tr>
<td>Active sports</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>=0 bout/week</td>
<td>581</td>
<td>24.6</td>
<td>0.00</td>
<td>—</td>
</tr>
<tr>
<td>&gt;0 bout/week</td>
<td>1776</td>
<td>75.4</td>
<td>1.99</td>
<td>0.85</td>
</tr>
<tr>
<td>Total</td>
<td>2357</td>
<td>100.00</td>
<td>1.50</td>
<td>1.13</td>
</tr>
<tr>
<td>Exercise</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>=0 bout/week</td>
<td>352</td>
<td>14.9</td>
<td>0.00</td>
<td>—</td>
</tr>
<tr>
<td>&gt;0 bout/week</td>
<td>2005</td>
<td>85.1</td>
<td>1.97</td>
<td>0.83</td>
</tr>
<tr>
<td>Total</td>
<td>2357</td>
<td>100.00</td>
<td>1.68</td>
<td>1.04</td>
</tr>
<tr>
<td>Rollerblading/biking</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>=0 bout/week</td>
<td>1392</td>
<td>59.1</td>
<td>0.00</td>
<td>—</td>
</tr>
<tr>
<td>&gt;0 bout/week</td>
<td>965</td>
<td>40.9</td>
<td>1.68</td>
<td>0.80</td>
</tr>
<tr>
<td>Total</td>
<td>2357</td>
<td>100.00</td>
<td>0.65</td>
<td>0.94</td>
</tr>
<tr>
<td>MVPA</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>&lt;5 bout/week</td>
<td>1471</td>
<td>62.4</td>
<td>2.49</td>
<td>1.23</td>
</tr>
<tr>
<td>≥5bout/week</td>
<td>886</td>
<td>37.6</td>
<td>6.08</td>
<td>1.08</td>
</tr>
<tr>
<td>Total</td>
<td>2357</td>
<td>100.00</td>
<td>3.84</td>
<td>2.10</td>
</tr>
</tbody>
</table>

α: Standard deviation
Appendix 9. The crude odds ratio of increasing adolescent physical activity from Wave I to Wave II, according to the physical activity levels of his/her friends at Wave I, in the 16 schools for peer network study, N = 2357 (National Longitudinal Study of Adolescent Health [Add Health], Wave I and Wave II).*

<table>
<thead>
<tr>
<th>Activities</th>
<th>Male-Male friendship pairs (n=2956)</th>
<th>Female-female friendship pairs(n=2873)</th>
<th>Mixed-gender friendship pairs(n=3952)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>OR</td>
<td>CI&lt;sup&gt;a&lt;/sup&gt;</td>
<td>OR</td>
</tr>
<tr>
<td>Active sports</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Stable friends</td>
<td>1.32</td>
<td>(1.23 1.42)</td>
<td>1.20</td>
</tr>
<tr>
<td>Past friends</td>
<td>1.39</td>
<td>(1.18 1.64)</td>
<td>1.13</td>
</tr>
<tr>
<td>New friends</td>
<td>1.39</td>
<td>(1.18 1.64)</td>
<td>1.14</td>
</tr>
<tr>
<td>Exercise</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Stable friends</td>
<td>1.21</td>
<td>(1.07 1.55)</td>
<td>1.11</td>
</tr>
<tr>
<td>Past friends</td>
<td>1.37</td>
<td>(0.98 1.79)</td>
<td>1.29</td>
</tr>
<tr>
<td>New friends</td>
<td>1.62</td>
<td>(1.05 2.34)</td>
<td>1.26</td>
</tr>
<tr>
<td>Wheel-based activity</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Stable friends</td>
<td>1.11</td>
<td>(0.95 1.29)</td>
<td>1.01</td>
</tr>
<tr>
<td>Past friends</td>
<td>1.28</td>
<td>(0.901.45)</td>
<td>1.17</td>
</tr>
<tr>
<td>New friends</td>
<td>1.59</td>
<td>(1.18 1.87)</td>
<td>1.13</td>
</tr>
</tbody>
</table>

<sup>a</sup> 95% Confidence Interval
<sup>*</sup> Boldface indicates statistical significance (p<0.05)


Bauer, K. W., Y. W. Yang, et al. (2004). """"How can we stay healthy when you're throwing all of this in front of us?"" Findings from focus groups and interviews in middle schools on environmental influences on nutrition and physical activity." Health Educ Behav. 31(1): 34-46.


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