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Initial insight into why physical activity may help prevent adolescent smoking uptake

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ABSTRACT

Introduction: Whereas research supports the importance of regular physical activity to decrease the likelihood of smoking uptake, the mechanisms accounting for this relationship are poorly understood. We sought to determine whether the enjoyment or reward derived from physical activity is one mechanism underlying the relationship between smoking and physical activity.
Methods: The sample was composed of 1374 adolescents participating in a prospective longitudinal survey study of health behaviors. Variables were measured via self-report every six months for eight waves of data spanning four years.
Results: An associative processes latent growth curve model revealed a significant and negative indirect effect of baseline physical activity on baseline smoking through baseline physical activity reward ($b_{indirect} = -.18$, $z = -3.11$, $p = .002$; 95% CI = −.29, −.07). Similarly, there was a significant and negative indirect effect of physical activity trend on smoking trend through physical activity reward trend ($b_{indirect} = -.16$, $z = -2.09$, $p = .04$; 95% CI = −.30, −.01). The effect of physical activity on smoking at baseline and across time was completely mediated by physical activity reward. There was less support for the idea that smoking progression was associated with reduced physical activity reward and subsequent declines in physical activity.
Conclusions: This study provides the first evidence implicating physical activity reward as one mechanism by which physical activity reduces the likelihood of adolescent smoking uptake. Smoking prevention interventions that promote physical activity and target physical activity enjoyment may have an important impact on adolescent smoking initiation and progression.

1. Introduction

Cigarette smoking and physical inactivity are the leading preventable causes of morbidity and mortality in the U.S., accounting for almost 30% of all deaths (Mokdad et al., 2004). Adolescence is a critical period for the development of these health risk behaviors (Chassin et al., 1996; Raitakari et al., 1994; SAMHSA, 2008; Telama and Yang, 2000). Physical activity significantly decline across adolescence (Aaron et al., 2002; Boreham et al., 1999; Dovey et al., 1998; Kimm et al., 2002; Raitakari et al., 1994; Sallis et al., 2000; Stubbe et al., 2005; Telama and Yang, 2000; van der Aa et al., 2010; van Mechelen et al., 2000), while the prevalence of cigarette smoking almost doubles (13–25%; CDC, 2012). Currently, about 20% of adolescents in the United States regularly smoke cigarettes (CDC, 2012) and only 29% achieve the recommended 60 min of physical activity every day (CDC, 2012).

Research indicates that physical activity is protective against smoking uptake. Higher levels of physical activity across mid to late adolescence have been shown to reduce the odds of smoking initiation and progression by almost 50% (Audrain-McGovern et al., 2003). Consistently sedentary adolescents are more likely to initiate regular smoking compared to consistently active adolescents (30% versus 2%; Raitakari et al., 1994) and are five times more likely to become regular smokers (Kujala et al., 2007). In addition, adolescents with decreasing or erratic team sport participation during mid adolescence are almost three times more likely to regularly smoke by late adolescence, compared to those who are consistently involved in team sports (Rodriguez and Audrain-McGovern, 2004).

The mechanisms by which physical activity protects adolescents from smoking have yet to be formally evaluated. Researchers have speculated that individual, environmental, and biological factors may account for the relationship (Audrain-McGovern et al., 2012). One possible mechanism that may help explain the link between adolescent physical activity and smoking is physical activity enjoyment or the subjective reward derived from engaging in

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physical activity. Physical activity enjoyment represents an hedonic or rewarding rating associated with physical activity (Roemmich et al., 2008). Studies have shown that participation in physical activity is associated with greater physical activity enjoyment (Davison et al., 2007; Deforche et al., 2006; Dishman et al., 2005; Garcia Bengoechea et al., 2010). If an adolescent derives pleasure from physical activity, they may be less likely to seek alternative sources of reward, such as smoking. In addition, physical activity may create neuroadaptations that influence the likelihood that an adolescent will find smoking rewarding and escalate in use. Accumulating evidence indicates that physical activity influences many of the same neurotransmitters, intracellular signaling molecules, and neuroanatomical structures that mediate the positive reinforcing effects of drugs (Audrain-McGovern et al., 2006; Smith and Lynch, 2012).

The present study sought to provide initial evidence for physical activity reward as a potential mechanism underlying the relationship between smoking and physical activity. We hypothesized that higher levels of physical activity would be associated with greater physical activity reward, which in turn, would decrease the odds of adolescent smoking uptake. We also evaluated whether the relationship among these variables was reciprocal, such that smoking contributed to declines in physical activity because smoking makes physical activity less rewarding. Identifying evidence-based treatment targets will be important to inform smoking prevention and intervention efforts that incorporate physical activity as a treatment component.

2. Methods

2.1. Participants and procedures

Participants were high school students (51% female and 73% white) taking part in a longitudinal study of the relation between adolescent physical activity and smoking adoption. Participants were enrolled in one of four public high schools in suburban Philadelphia, PA. This cohort was drawn from the 1517 students identified through class rosters at the beginning of ninth grade. Students were ineligible to participate in this study if they had a special classroom placement (e.g., severe learning disability) or if they did not speak fluent English. Based on the selection criteria, a total of 1487 (98%) students were eligible to participate. Parents were mailed a study information letter (active information) with a telephone number to call to obtain answers to any questions and to decline consent for their adolescent to participate. Of these 1487 eligible teens, 1478 (99%) had a parent's passive consent to participate. Thirty adolescents were absent on the assent/survey days and 19 did not provide assent due to lack of interest in the study. Thus, 1429 of 1478 teens with parental consent (97%) provided their assent to participate and completed a baseline survey. Adolescents who declined assent or who were absent on the baseline survey day did not differ on race and gender from those who provided assent and completed the baseline survey.

The adolescent cohort was formed in the 9th grade and followed until the end of 12th grade. Each adolescent was assigned a study identification number at baseline. The identification number appeared on their survey at each survey time point. A survey face page with the participants name on it was removed when the self-report survey was handed to the student, ensuring that the adolescent received a survey with their unique identification number at each wave. A self-report 40-min survey was administered every six months (fall and spring semesters) on-site during compulsory classes each year of high school for a total of eight surveys. The sample size was the $n = 1374$ participants with complete data for the covariates in the model. University Institutional Review Board approval of the study was obtained.

2.2. Measures

2.2.1. Smoking. Smoking progression was derived from evaluating smoking practices with a series of standard epidemiological questions regarding smoking such as, "Have you ever tried or experimented with cigarette smoking, even a few puffs?", and "Have you smoked a cigarette in the past 30 days?" (Audrain-McGovern et al., 2009; Eaton et al., 2006). The 7-category ordered categorical smoking variable was coded as 0 = never smoked, 1 = puffed but did not smoke a whole cigarette, 2 = smoked a whole cigarette but not in the past month, 3 = smoked in the last month, 4 = smokes weekly, 5 = smokes ≤10 cigarettes daily, and 6 = smokes >10 cigarettes daily. Smoking was measured all eight waves.

2.2.2. Physical activity. Physical activity was assessed with the 7-day Physical Activity Recall (PAR; Sallis et al., 1985, 1997, 1999; Sallis and Owen, 1999). The PAR has excellent test–retest reliability ($r = 0.81$) and validity ($r = 0.72$ against heart rate monitors) in adolescents (Sallis et al., 1993). It is a widely used measure of habitual activity in observational studies (Gordon-Larsen et al., 2000; Sallis et al., 1985; Young et al., 1993). As in previous large-scale studies, adolescents self-administered the PAR (Dishman et al., 2005; Gordon-Larsen et al., 2000; Harris et al., 2006; McMurray et al., 2004; Motl et al., 2001; Raudsepp and Viira, 2008; Sallis et al., 2000). This required adolescents to report the number of days in the past seven days and the amount of time that they participated in 34 commonly reported activities of moderate to vigorous intensity. Activities were grouped into broad categories (e.g., sports and dance, exercise, general) with spaces to add activities that were not listed. Physical activity was defined as minutes of moderate and vigorous physical activity (MVPA) over the past seven days. Physical activity was measured all eight waves.

2.2.3. Physical activity reward. The 16-item Physical Activity Enjoyment Scale (PACES) was used to assess physical activity reward (Heesch et al., 2006; Motl et al., 2001). Items such as "When I am active. . .I enjoy it". . .I get something out of it". . .it feels good" are rated on a 5-point bipolar scale (Motl et al., 2001) ("1 = Disagree a lot" and "5 = Agree a lot") with scores ranging from 16–80 (Dishman et al., 2005; Kendzierski and DeCarlo, 1991; Motl et al., 2001; Wilson et al., 2005). Internal and cross-structure analyses support the single factor structure of the PACES, and its reliability (alpha = .88–.94) and discriminant validity (Davison et al., 2007; Kendzierski and DeCarlo, 1991; Motl et al., 2001; Neumark-Sztainer et al., 2003; Wilson et al., 2005). Negatively worded items are reverse coded (e.g., "I dislike it") and scores across items were summated to provide a single summed score of physical activity enjoyment. Physical activity enjoyment was measured all eight waves.

2.3. Covariates

We controlled for gender (1 = female), race (1 = white, 0 = else), and parental education (0 = both parents have greater than a high school education, 1 = at least one parent has a high school education or less, 2 = both parents have a high school education or less). Peer and household smoking exposure was controlled for using a single exposure variable (0 = no exposure to peer or household smoking, 1 = exposure to either peer and/or household smoking) (Audrain-McGovern et al., 2004; Choi et al., 1997; Tercyak et al., 2002). Also, we controlled for impulsivity using the impulsivity subscale of the Temperament and Character Inventory (TCI) (5 true/false items KR-20 = .70) (Cloninger et al., 1994a, b), and the availability and access to physical activity in an adolescent's neighborhood using three subscales of the Neighborhood Environment Walkability Scale (crime, traffic and infrastructure for walking, biking, etc.) (Saelens et al., 2003). Test–retest reliabilities for these subscales have ranged from .60 to .80 (Saelens et al., 2003; Sallis et al., 1997).

2.4. Data analysis

Univariate statistics were generated to describe the study population in terms of demographics, smoking, physical activity, and physical activity enjoyment. Univariate estimates were generated with SAS 9.1.3 software.

2.4.1. Latent curve growth modeling (LGCM). Two separate associated-processes LGCM's were conducted to assess the longitudinal, bi-directional relation of repeated measures of physical activity, physical activity enjoyment, and smoking. LGCM is a Structural Equation Modeling method that models repeated observed measures (measured variables) on factors (latent variables) representing random effects (ηs) (Duncan and Duncan, 1995). A level factor is used to represent baseline level and trend factors are used to represent rate of change across time (i.e., each unit change in time is associated with a η change in a given process). Latent variables define the form of the rate of change across time (e.g., linear, quadratic, cubic). Factor loadings (i.e., correlations between the observed and latent variables) are fixed to define baseline or level (factor loadings are restricted to equal 1 from the level/intercept factor to each observed measure) and trend. For a linear trend, the factor loadings are set so they increase uniformly with each unit increase in time (six months in the present study). In the present model, the factor loading from the linear trend factor to the first observed measure was constrained to equal zero as the first observed measure is the baseline level. The second factor loading is constrained to equal one, indicating a unit increase in the rate of change in each process (i.e., physical activity, physical activity reward, and smoking) for a unit increase in time. The remaining factor loadings for the linear trend factor were constrained similarly to define a linear growth form (i.e., 2, 3, 4, 5 and 6, for waves 3 through 8, respectively).

In the present analysis, we conducted associated processes mediation LGCMs. Associated processes LGCM is a multivariate method that allows testing paths among random effects (i.e., levels [η_0] and trends [$\eta_{1,2\ldots}$]) from two or more LGCMs (Duncan et al., 1999). One associated processes model was run in the present study to assess the impact of repeated observed measures of physical activity (continuous variables) on smoking (ordered categorical variable) through physical activity reward (continuous variable). This model evaluated whether physical activity reduces the odds of smoking uptake because physical activity is rewarding. A second model assessed the impact of smoking on physical activity through physical activity reward (i.e., the reciprocal model). This model evaluated whether smoking