Exercise and Adolescent Depression

by

Daniel I. Rees, PhD
University of Colorado at Denver
Department of Economics
Campus Box 181
Denver, CO 80217-3364

Using data from the first two waves of the National Longitudinal Adolescent Health Study, the author estimates the effect of exercise frequency on depressive symptomatology. The relationship between inactivity (as measured by hours spent watching television, playing video or computer games, and listening to the radio) is also explored. The results suggest that, for males, frequency of moderate or vigorous physical activity is negatively related to depressive symptomatology, although after controlling for time-invariant factors through the inclusion of fixed effects the magnitude of this relationship is quite modest. The author finds only limited evidence that frequency of exercise is related to female depressive symptomatology.

A number of prospective studies have investigated the relationship between physical activity and depression [1-8]. Although one of these prospective studies used a sample of individuals ages 15 and over [4], most of the epidemiological work in this area has focused on adults. Similarly, intervention trials aimed at assessing the effect of exercise on depression have typically used adult participants [9].

In contrast, we know comparatively little about the relationship between physical activity and depression among adolescents. Several researchers using cross-sectional survey data have found that adolescents who exercise regularly or participate in sports have better mental health outcomes [10-14], but this association has not been confirmed using a prospective research design.

Drawing on data from the first two waves of the National Longitudinal Study of Adolescent Health, the present study examines the relationship between frequency of moderate to vigorous physical activity and the Center for Epidemiologic Studies Depression (CES-D) Scale, a widely used measure of depressive symptomatology. In addition, the role of inactivity is explored. Inactivity is measured as hours spent watching television, playing video or computer games, and listening to the radio.

Although the results provide little evidence that exercise frequency is related to female depressive symptomatology, they lend some support to the idea that exercise can reduce the symptoms of depression among male adolescents. Controlling for factors such as personal characteristics and family background using a standard regression framework, the frequency of moderate or vigorous physical activity is found to be negatively related to male CES-D scores. However, modifying the standard regression model to include individual fixed effects reduces

the magnitude of the estimated effect of exercise frequency considerably, although it is still statistically significant at conventional levels.

MATERIALS AND METHODS

The data used in this study come from the National Longitudinal Study of Adolescent Health, conducted by the Carolina Population Center at the University of North Carolina at Chapel Hill. The Adolescent Health data collection effort began with the identification of more than 26,000 schools in the United States that served 11th graders and had an enrollment of at least 30 students. Eighty high schools were chosen from this population with unequal probability based on their size, region of the country, level of urbanization, type (public vs. private), and racial mix. Most were then matched with a junior high or middle school from the same community, bringing the total number of participating schools to 132. From the student rosters of these 132 schools, a core sample was randomly chosen to be administered the Adolescent Health Wave I (baseline) in-home survey. In addition to this core sample, oversamples of black students with college-educated parents, Cuban and Puerto Rican students, and other groups were administered the Wave I in-home survey. Conducted between April and December of 1995, the Wave I in-home interviews produced a nationally representative sample of students in grades 7 through 12.

The Wave I in-home weighed sample contains information on 18,924 respondents. Of these, 13,569 were administered the Wave II in-home survey between April and August of 1996. Because an additional 751 observations had missing information with regard to one or more of the variables used in the analysis below, the sample size of the present study is 12,818. Further

information regarding the Adolescent Health data collection effort is available from a variety of sources [15, 16].

Measures

The outcome measure used in the analysis below is the Center for Epidemiologic Studies Depression (CES-D) Scale, originally developed by Radloff [17]. The Adolescent Health Study administered 18 of the 20 items that typically comprise this scale. Specifically, respondents were instructed to indicate the frequency with they had experienced certain feelings or emotions during the past week, including how often they felt "too tired to do things," how often they felt "fearful," and how often they "talked less than usual."* Possible responses were "rarely or none of the time" (= 0); "some or a little of the time" (= 1); "occasionally or a moderate amount of the time" (= 2); and "most or all of the time" (= 3).

As noted by Radloff, the CES-D Scale was not developed to be used as a diagnostic tool, and:

> interpretations of individual scores should not be made. Even group averages should be interpreted in terms of level of symptoms which accompany depression, not in terms of rates of illness [17, p. 400].

In order to avoid using the CES-D Scale as a diagnostic tool, no attempt is made to distinguish between depressed and non-depressed individuals in the empirical analysis. Instead, responses to the 18 items were simply summed to produce a score of between 0 and 54, which was re-scaled to correspond to the 20-item CES-D Scale.

---

* The two missing items from the CES-D questionnaire were "my sleep was restless," and "I had crying spells".

The independent variable of interest was constructed from a series of questions in the Adolescent Health data regarding the respondent's use of his or her free time. Specifically, respondents were asked during the past week, how often (not at all, 1 or 2 times, 3 or 4 times, 5 or more times) did they:

1. Go roller-blading, roller-skating, skate-boarding, or bicycling?
2. Play an active sport, such as baseball, softball, basketball, soccer, swimming, or football?
3. Do exercise such as jogging, walking, karate, jumping rope, gymnastics, or dancing?

Although the Adolescent Health data contain no information with regard to time spent in these activities, each has been classified as either "moderate" or "vigorous" based on its metabolic equivalent value [18].

Following Richmond et al. [19], who also made use of the physical activity questions in the Adolescent Health data, responses of "not at all" were assigned a value of 0; responses of "1 or 2 times" were assigned a value of 1.5; responses of "3 or 4 times" were assigned a value of 3.5; and responses of "5 or more times" were assigned the value of 6. Summing across the three sets of activities produced a continuous variable with a range of 0 to 18. At baseline, the average respondent engaged in moderate or vigorous physical activity approximately 7 times in the week prior to being interviewed. By follow-up the frequency of weekly exercise had fallen to 6.6. Almost all respondents (95% in Wave I and 94% in Wave II) reported engaging in some form of moderate or vigorous physical activity.

In addition to frequency of exercise, an alternative independent variable of interest, *Hours of Inactivity*, was constructed equal to the number of hours each respondent spent

watching television, playing video or computer games, and listening to the radio. Time spent watching television and playing video or computer games has been used by previous researchers interested in the correlates of adolescent physical activity and inactivity [18, 20].

At baseline (follow-up), the average respondent reported having spent approximately 39 (37) hours watching television, playing video or computer games, and listening to the radio during the week prior to being interviewed. Because time spent engaged in these activities is typically not available for exercise, it is hypothesized that the variable *Hours of Inactivity* will be positively related to CES-D scores.

Finally, the Adolescent Health study contains detailed information on personal characteristics such as race and ethnicity, and family background. This information was used to create the control variables used in the empirical analysis. Contextual variables such as the county unemployment rate and the crime rate in the respondent's county of residence are also available in the Adolescent Health data and are included as additional controls. Table 1 presents means and standard deviations for the full set of variables used in the analysis.

Statistical Models

A natural first step in estimating the relationship between exercise frequency and depressive symptomatology is to compare mean CES-D scores for respondents with different exercise habits. This approach, although straightforward, risks attributing the effects of factors such as personal characteristics and family background to exercise frequency. The effects of these factors can be "netted out" using a standard regression model in which the CES-D score of individual i at follow-up ($t = 2$) depends on exercise frequency at baseline ($t = 1$) and a set of controls also observable at baseline:

$$\mathrm{CESD}_{\mathrm{i,t=2}} = \alpha + \beta \mathrm{X}_{\mathrm{i,t=1}} + \delta \mathrm{Exercise}_{\mathrm{i,t=1}} + \varepsilon_{\mathrm{i,t=2}}, \quad i = 1, \ldots, n, \qquad (1)$$

where the variable $\mathrm{Exercise}_{\mathrm{i,t=1}}$ is equal to the number of times individual *i* engaged in moderate or vigorous physical activity in the week prior to the baseline interview; $X_{i,t=1}$ is a vector of controls that includes measures of age, disability status, personal and household characteristics, parental education, and a set of county-level variables; and $\varepsilon_{i,t=2}$ is a random error term. The effect of baseline exercise frequency on the CES-D score at follow-up is represented by the parameter δ.

The standard regression model outlined above can generate an unbiased estimate of δ if the appropriate controls are included on the right-hand side. However, in practice it is often difficult to obtain information on all controls that potentially belong in the vector $X_{i,t=1}$. For instance, crime rates at the county level are available in the Adolescent Health contextual files, but there is no data on neighborhood crime. If the level of neighborhood crime does not appear in $X_{i,t=1}$ but is correlated with both the symptoms of depression and frequency of exercise, then the standard regression model will produce a biased estimate of δ.

One method of addressing this issue is to more fully exploit the longitudinal nature of the data by allowing each respondent to contribute two observations, one from the baseline survey ($t = 1$) and the other from the follow-up survey ($t = 2$), to the estimation of the following equation:

$$\mathrm{CESD}_{\mathrm{i,t}} = \alpha + \beta \mathrm{Age}_{\mathrm{i,t}} + \delta \mathrm{Exercise}_{\mathrm{i,t}} + \nu_{\mathrm{i}} + \varepsilon_{\mathrm{i,t}}, \quad i = 1, \ldots, n, \quad t = 1,2, \quad (2)$$

where v_i is a vector of individual-specific intercepts referred to as "fixed effects" in the econometrics literature [21]. The advantage of including fixed effects on the right-hand side of the estimating equation is that only the within-person variation over time is used to estimate the effect of exercise on the CES-D score. All time-invariant factors (including the baseline CES-D score, and baseline personal, family, and neighborhood characteristics) are captured by the fixed effects, thus eliminating the need to observe and measure a myriad of potentially important confounders. Because the time between the baseline and follow-up surveys was not uniform, the variable $Age_{i,t}$ is not perfectly co-linear with the fixed effects and can therefore be included as an explanatory variable.

RESULTS

Table 2 presents mean follow-up CES-D scores by gender and baseline exercise frequency. Males who exercised less than five times per week at baseline had an average follow-up CES-D score of 11.97 (95% CI: 11.59, 12.36). Increases in exercise frequency are associated with statistically significant reductions in male follow-up CES-D scores. Specifically, males who exercised between 5 and 8.5 times per week had an average follow-up CES-D score of 11.09 (95% CI: 10.77, 11.41); males who exercised 9 to 18 times per week had an average follow-up CES-D score of 9.91 (95% CI: 9.64, 10.18).

Females who exercised less than five times per week at baseline had an average follow-up CES-D score of 13.47 (95% CI: 13.15, 13.80). Females who exercised between 5 and 8.5 times had significantly lower scores than those who exercised less than 5 times, but their scores were statistically indistinguishable at the .05 level from those who exercised 9 or more times per

week. Specifically, females who exercised between 5 and 8.5 times per week had an average follow-up CES-D score of 12.78 (95% CI: 12.43, 13.13); females who exercised 9 to 18 times per week had an average follow-up CES-D score of 12.36 (95% CI: 11.92, 12.80).

Regression Estimates

Table 3 presents ordinary least squares (OLS) estimates of the effect of exercise frequency on the symptoms of depression, controlling for the factors represented in the vector $X_{i,t=1}$. For males, a one-unit increase in exercise frequency is associated with a 0.16 decrease in the CES-D score (95% CI: -0.21, -0.11). For females, the effect of exercise frequency is smaller in absolute magnitude and is not statistically significant at the .05 level: a one-unit increase in exercise frequency is associated with a 0.05 reduction in the CES-D score (95% CI: -0.13, 0.04).

Table 4 presents estimates of (2), which includes a vector of individual-specific fixed effects. The results suggest that important confounders may have been omitted from $X_{i,t=1}$, resulting in an estimate of the relationship between exercise frequency and male CES-D scores that was biased upwards in absolute magnitude.

For males, adding fixed effects to the model results in an estimate of the impact of exercise frequency on the CES-D score of -0.05 (95% CI: -0.09, -0.02). This estimate, although still statistically significant, is about a third the magnitude of the estimate presented in Table 3. For females, the fixed-effects estimate of the relationship between exercise frequency and the CES-D score is -0.04 (95% CI: -0.09, 0.005), approximately of the same magnitude as that presented in Table 3 and statistically indistinguishable from 0 at the .05 level.

The Relationship between Inactivity and the CES-D

Table 5 shows estimates of (1) modified to examine the relationship between inactivity (as measured by hours spent watching television, playing video or computer games, and listening to the radio) and CES-D scores. For males, an additional hour of inactivity is associated with an increase of 0.009 in the CES-D score (95% CI: 0.002, 0.017), controlling for the factors in the vector $X_{i,t=1}$. Surprisingly, the comparable estimate for females is considerably larger in magnitude: an additional hour of inactivity is associated with a statistically significant increase of 0.021 (95% CI: 0.012, 0.029).

However, adding fixed effects to the model greatly reduces the size and significance of both of these estimates (Table 6). Specifically, for males, an additional hour of inactivity is associated with a statistically insignificant increase of 0.002 in the CES-D score (95% CI: -0.003, 0.007); for females, an additional hour of inactivity is also associated with a statistically insignificant increase of 0.002 (95% CI: -0.004, 0.007).

DISCUSSION

There are a number of mechanisms by which exercise might impact mental health. For instance, it has been suggested that exercise accelerates the transmission of monoamines in the brain such as serotonin and dopamine, leading to enhanced mood [22, 23]. Other researchers have hypothesized a role for endorphins, which are released during strenuous exercise [23]. In addition to these physiological mechanisms, a number of psychological explanations have been proposed [24].

In fact, there is considerable empirical evidence to support the hypothesis that exercise reduces the likelihood of developing depression. However, the case is far from air tight. For example, Strawbridge et al. [8] identified 7 prospective epidemiological studies in this area. Of these studies, 4 found no evidence of a link between physical activity and depression. Results from intervention studies also offer evidence in support of a link between exercise and depression, at least in the short term, but this vein of research has recently been criticized as "having important methodological weaknesses" [9].

As noted above, most of the previous work on physical activity and depression has focused on adults. Although a number of epidemiological studies have shown that adolescents who engage in physical activity have better mental health outcomes than those who do not, these studies have typically relied on cross-sectional data [10-14]. The consequence of this limitation is that it is difficult to assess the direction in which causality runs. The use of cross-sectional data also makes it impossible to exploit advances in panel data estimation techniques, including the use of individual-specific fixed effects.

A natural first step in evaluating the effect of exercise frequency on depressive symptomatology among adolescents is to compare mean CES-D scores for individuals with different exercise habits. When the Adolescent Health sample is divided roughly into thirds based on exercise frequency (Table 2), a clear trend emerges from the data: males who exercised more frequently scored lower on the CES-D scale, indicating the presence of fewer depressive symptoms. For example, males who exercised 9 to 18 times per week at baseline scored, on average, approximately 2 points lower at follow-up than their counterparts who exercised less than 5 times per week.

For females, the relationship between exercise frequency and the CES-D is not as strong. Female adolescents who exercised 9 to 18 times per week at baseline scored, on average, approximately 1 point lower at follow-up than their counterparts who exercised less than 5 times per week.

Controlling for race, ethnicity, family structure, parental education, and county-level factors such as the unemployment rate using a standard regression model confirms the existence of a gender gap in the relationship between exercise frequency and the symptoms of depression (Table 3). Specifically, a one-unit increase in exercise frequency is associated with a statistically significant 0.16 reduction in male CES-D scores. In contrast, for females the relationship between exercise frequency and the CES-D score is approximately a third the size and statistically indistinguishable from 0.

Controlling for time-invariant factors through the inclusion of individual-specific fixed effects reduces, but does not eliminate, the estimated effect of exercise frequency for males: a one-unit increase in exercise frequency is associated with a statistically significant reduction of 0.05 in the CES-D score (Table 4). For females, the fixed-effects estimate is of comparable size, but not statistically significant at the .05 level.

Although statistically significant, the fixed-effects estimate for males is nevertheless quite modest in magnitude. A male who did not engage in moderate or vigorous physical activity at baseline, but at follow-up indicated that he exercised 18 times in the previous week, is predicted to have experienced a 0.9 (18 x 0.05 = 0.9) reduction in his CES-D score from baseline to follow-up, or less than an eighth of a standard deviation. To put this change in perspective, it corresponds, more or less, to the difference between indicating “some or a little of the time”

instead of "rarely or none of the time" on one of the CES-D items contained in the Adolescent Health study.

In addition, it should be noted that fixed effects do not control for time-variant factors that are omitted from the model. To take a hypothetical example, if an increase in neighborhood crime over the period studied discouraged adolescents from exercising and at the same time directly affected their mood, then the fixed-effects estimate would likely be biased upwards in absolute magnitude. Changes in the level of household resources available to an adolescent could arguably bias the fixed-effects estimate in the same direction, as could changes in the respondent's mood or emotional state.

Finally, although the Adolescent Health Study did not ask how much time was spent exercising, it did ask respondents to estimate the number hours per week they spent watching television, playing video or computer games, and listening to the radio. Because time spent in front of the television is not available for exercise, it would be reasonable to expect a positive relationship the CES-D and the variable *Hours of Inactivity.*

In fact, for both males and females this is the case (Table 5). An additional hour in front of the television, playing video or computer games, or listening to the radio is associated with a 0.009 increase in male CES-D scores, and a 0.021 increase in female scores. However, as might be expected given the fact physical activity is not being directly measured, neither of these estimates is particularly large in magnitude. For instance, a one standard deviation increase in the variable *Hours of Inactivity* is associated with an increase in female scores of less than unity (30 x 0.021 = 0.63). Moreover, when time-invariant factors are controlled for through the inclusion of fixed effects, the estimated impact of *Hours of Inactivity* becomes even smaller and loses its statistical significance (Table 6).

In sum, the results of this study leave open the possibility that, for male adolescents, an increase in exercise frequency leads, in a causal sense, to a reduction in depressive symptomatology. However, if this effect exists, it is modest in magnitude. For females, there is very little evidence that exercise frequency is related to depressive symptomatology. The results also illustrate the role played by time-invariant factors. Estimates from a standard regression model clearly overstated the impact of exercise on the symptoms of depression among males, suggesting that important confounders were omitted from the vector of controls, $X_{i,t=1}$. Augmenting the standard model with fixed effects substantially reduced the estimated impact of exercise frequency on CES-D scores.

REFERENCES

1. Farmer ME, Locke BZ, Moscicki EK, Dannenberg AL, Larson DB, Radloff LS. Physical activity and depressive symptoms: the NHANES I Epidemiologic Follow-up Study. *Am J Epidemiol* 1988; 128:1340-51.

2. Camacho TC, Roberts RE, Lazarus NB, Kaplan GA, Cohen RD. physical activity and depression: evidence from the Alameda County Study. *Am J Epidemiol* 1991; 134: 220-31.

3. Kivela SL, Pahkala K. Relationships between health behaviour and depression in the aged. *Aging* 1991; 3: 153-159.

4. Weyerer S. Physical Inactivity and depression in the community: evidence from the Upper Bavarian Field Study *Int J of Sports Med* 1992; 13: 492-6.

5. Paffenbarger RS Jr, Lee IM, Leung R. Physical activity and personal characteristics associated with depression and suicide in American college men. *Acta Psychiatr Scand* (Suppl) 1994; 377: 16-22.

6. Cooper-Patrick L, Ford DE, Mead LA, Chang PP, Klag MJ. Exercise and depression in midlife: a prospective study. *Am J Public Health* 1997; 87: 670-3.

7. Kritz-Silverstein D. Barrett-Conner E, Corbeau C. Cross-sectional and prospective study of exercise and depressed mood in the elderly: the Rancho Bernardo Study. *Am J Epidemiol* 2001; 153: 596-603.

8. Strawbridge WJ, Deleger S, Roberts RE, Kaplan GA. Physical activity reduces the risk of subsequent depression for older adults. *AmJ Epidemiol* 2002; 156: 328-34.

9. Lawlor DA, Hopker SW. The effectiveness of exercise as an intervention in the management of depression: systematic review and meta-regression analysis of randomised controlled trials. *BMJ* 2001; 322: 763-7.

10. Norris R, Carroll D, Cochrane R. The effects of physical activity and exercise training on psychological stress and well-being in an adolescent population. *J Psychosom Res*1992; 36: 55-65.

11. Steptoe A, Butler N. Sports participation and emotional wellbeing in adolescents. *Lancet* 1996; 347:1789-92.

12. Field T, Diego M, Sanders C. Adolescent depression and risk factors. *Adolescence* 2001; 36: 491-8.

13. Kirkcaldy BD, Shephard RJ, Siefen RG. The relationship between physical activity and self-image and problem behaviour among adolescents. *Soc Psychiatry Psychiat Epidemiol* 2002; 37: 544-50.

14. Haarasilta LM, Marttunen MJ, Kaprio JA, Aro HM. Correlates of depression in a representative nationwide sample of adolescents (15-19 years) and young adults (20-24 years). The *European J Public Health* 2004; 12: 280-285.

15. Harris, KM, Florey F, Tabor J, Bearman PS, Jones J, Udry JR. The National Longitudinal Study of Adolescent Health: research design. Available at http://www.cpc.unc.edu/projects/addhealth/design.html. Accessed August 11, 2006.

16. Harris KM, Duncan GJ, Boisjoly J. Evaluating the role of "nothing to lose" attitudes on risky behavior in adolescence. *Social Forces.* 2002; 80: 1005-1039

17. Radloff, LS. The CES-D Scale: A self-report depression scale for research in the general population. *Applied Psychological Measurement*. 1977; 1: 385-401.

18. Gordon-Larsen P, McMurray RG, Popkin BM. Adolescent physical activity and inactivity vary by ethnicity: The National Longitudinal Study of Adolescent Health. *J Pediatr* 1999; 135:301-306.

19. Richmond TK, Hayward RA, Gahagan S, Field AE, Heisler M. Can school income and racial/ethnic composition explain the racial/ethnic disparity in adolescent physical activity participation? *Pediatrics* 2006; 117: 2158-2166.

20. Gordon-Larsen P, McMurray RG, Popkin BM. Determinants of adolescent physical activity and inactivity patterns. *Pediatrics* 2000; 105: E83.

21. Greene, WH. *Econometric Analysis* (5th ed). Chapter 13. New Jersey: Prentice Hall, 2003.

22. Ransford CP. A role for amines in the antidepressant effect of exercise: a review. *Med Sci Sports Exerc* 1982; 4: 1-10.

23. Chaouloff F. Physical exercise and brain monoamines: a review. *Acta Physiol Scand* 1989; 137: 1-13.

24. Paluska SA, Schwenk TL. Physical activity and mental health: current concepts. *Sports Medicine* 2000; 29: 167-80.

Table 1

Variable Means and Standard Deviations, by Gender

	Males (n = 6,255)	Females (n = 6,563)		Males (continued)	Females (continued)
			Household Variables:		
CES-D at baseline (*t*=1)	11.03 (7.28)	13.05 (8.68)	**2 Parents**	.682	.661
CES-D at follow-up (*t*=2)	10.80 (7.41)	12.95 (8.68)	**2 Parents Missing**	.112	.123
Exercise Freq. (*t*=1)	7.91 (4.44)	6.04 (4.02)	**Welfare**	.082	.092
Exercise Freq. (*t*=2)	7.39 (4.23)	5.72 (3.87)	**Welfare Missing**	.102	.114
Hours of Inactivity (*t*=1)	40.39 (30.01)	37.68 (30.23)			
Hours of Inactivity (*t*=2)	37.72 (28.58)	35.31 (27.38)	**Parental Education:**		
Age (*t*=1)	15.61 (1.64)	15.47 (1.58)	**No High School**	.104	.109
Age (*t*=2)	16.53 (1.64)	16.39 (1.59)	**Some College**	.187	.173
Disability	.021	.024	**College**	.159	.145
			Prof. Degree	.123	.128
Race/Ethnicity Variables:			**Education Missing**	.102	.111
Black	.152	.163	**County-Variables:**		
Other Race	.130	.117	**Crime Rate**	7.27 (5.68)	7.33(5.69)
Hispanic	.129	.126	**Unemployment**	.067 (.023)	.067 (.024)
			Rural	.268 (.273)	.268 (.274)
			Urban	.621 (.384)	.620 (.385)

Table notes: Data from the National Longitudinal Study of Adolescent Health. Sample weights were used in the calculations. Standard deviations are in parenthesis. There are 18,924 adolescents are in the weighted baseline in-home survey. Of these, 13,569 were re-interviewed at follow-up. An additional 751 observations were lost due to missing exercise habits, CES-D score, age, or county data. The variable *disability* is dichotomous and equal to 1 for youth that indicated in the baseline interview that they have difficulty using their hands, arms, legs, or feet because of a permanent physical condition; 0 otherwise. The variables *black* and *other race* are dichotomous, mutually exclusive, and based on a series of questions from the baseline in-home interview. Hispanic is a dichotomous variable equal to 1 for youth who self-identified as being of Hispanic origin; 0 otherwise. The household variables are also dichotomous and come from the questionnaire completed by the respondent's parent/caregiver at baseline. The variable *2 Parents* indicates that the parent/caregiver who completed the Adolescent Health parent survey lived with a spouse or partner at the baseline interview. The variable *2 Parents Missing* indicates missing information with regard to family structure. The variable *Welfare* is equal to 1 if the parent/caregiver who completed the Adolescent Health parent survey received public assistance; 0 otherwise. The variable *Welfare Missing* indicates missing information with regard to welfare receipt. The parental education variables are dichotomous, mutually exclusive, and are based on the responses pertaining to the best-educated parent/caregiver living in the household. The county controls are taken from the Adolescent Health contextual files. The crime rate variable is the number of violent crimes per 1000 population in the respondent's county of residence. The unemployment variable is the county unemployment rate. The rural and urban variables are the fraction of the county population that resided in rural or urban areas, respectively.

Table 2

Mean Follow-up CES-D Scores by Gender and Exercise Frequency at Baseline.

Exercise Frequency:	**Males**	**Females**
< 5 times per week	11.97 (11.59, 12.36) [*n* = 1,572]	13.47 (13.15, 13.80) [*n* = 2,680]
5 to 8.5 times per week	11.09 (10.77, 11.41) [*n* = 2,046]	12.78 (12.43,13.13) [*n* = 2,334]
9 to 18 times per week	9.91 (9.64, 10.18) [*n* = 2,637]	12.36 (11.92, 12.80) [*n* = 1,549]

95% CI are in parenthesis and sample sizes are in brackets.

Table notes: Data from the National Longitudinal Study of Adolescent Health. Sample weights were used in the calculations.

Table 3

Regression Results: The Effect of Baseline Exercise Frequency on the CES-D Score at Follow-up, by Gender

	Males	**Females**
Exercise Frequency	-0.16 (-0.21, -0.11)	-0.05 (-0.13, 0.04)
Baseline controls:		
Disability	2.82 (1.06, 4.58)	4.64 (1.96, 7.33)
Age:		
14 – 15	1.72 (1.03, 2.41)	1.94 (1.25, 2.63)
16 – 17	1.77 (1.04, 2.50)	1.82 (1.14, 2.51)
18 – 21	3.58 (2.37, 4.79)	2.26 (0.83, 3.70)
Race/ethnicity variables:		
Black	1.39 (0.59, 2.19)	1.68 (0.68, 2.69)
Other	1.55 (0.49, 2.61)	1.61 (0.54, 2.70)
Hispanic	0.72 (-0.16, 1.60)	1.46 (0.35, 2.58)
Household variables:		
2 Parents	0.13 (-0.60, 0.85)	-0.83 (-1.51, 0.142)
2 Parents Missing	-1.47 (-3.71, 0.76)	-1.06 (-3.52, 1.41)
Welfare	1.20 (0.26, 2.14)	0.86 (-0.39, 2.12)
Welfare Missing	0.59 (-2.43, 3.61)	0.47 (-1.68, 2.61)
Parental education:		
No high school	1.88 (0.87, 2.88)	1.25 (0.12, 2.37)
Some college	-0.61 (-1.33, 0.10)	-0.21 (-1.03, 0.62)
College	-0.55 (-1.24, 0.46)	-1.21 (-2.02, -0.39)
Prof. degree	-1.88 (-2.56, -1.19)	-2.16 (-2.91, -1.41)
Education Missing	1.80 (-1.30, 4.88)	0.90 (-2.13, 3.94)
County-level variables:		
Crime Rate	0.01 (-0.07, 0.05)	0.08 (-0.17, 0.003)
Unemployment	9.44 (-6.42, 25.30)	11.97 (-1.72, 25.67)
Rural	0.76 (-1.70, 3.23)	-0.88 (-3.61, 1.85)
Urban	1.18 (-0.58, 2.93)	-0.50 (-2.45, 1.45)
Constant	8.43 (6.38, 10.48)	12.15 (9.61, 14.67)
R^2	0.085	0.059
Sample size	6,255	6,563

95% CI are in parenthesis (adjusted for clustering by school).

Table notes: Data from the National Longitudinal Study of Adolescent Health. Sample weights were used in the calculations. The omitted age category is eleven to thirteen; the omitted race category is white; and the omitted parental education category is high school. See the notes to Table 1 for definitions of the control variables.

Table 4

Fixed Effects Regression Results: The Effect of Exercise Frequency on the CES-D Score, by Gender

	Males	**Females**
Exercise Freq.	-0.05 (-0.09, -0.02)	-0.04 (-0.09, 0.005)
Age	-0.15 (-0.33, 0.03)	-0.27 (-0.48, –0.06)
Constant	14.12 (11.15, 17.10)	17.89 (14.48, 21.30)
Sample Size	12,510	13,126

95% CI are in parenthesis.

Table notes: Data from the National Longitudinal Study of Adolescent Health. Each respondent contributes two observations to the estimation of this model (one from the baseline survey, the other from the follow-up survey). As a consequence, both the baseline and follow-up CES-D scores are utilized in the estimation of the parameters. Age is not captured by the individual fixed effects because the time between the baseline and follow-up interviews was not uniform across respondents. All other baseline control variables are absorbed by the individual fixed effects.

Table 5

Regression Results: The Effect of Baseline Hours of Inactivity on the CES-D Score at Follow-up, by Gender

	Males	**Females**
Hours of Inactivity	0.009 (0.002, 0.017)	0.021 (0.012, 0.029)
R^2	0.078	0.063
Sample size	6,255	6,563

95% CI are in parenthesis (adjusted for clustering by school).

Table notes: Data from the National Longitudinal Study of Adolescent Health. Sample weights were used in the calculations. The control variables are listed in Table 3. See the notes to Table 1 for definitions of the control variables.

Table 6

Fixed Effects Regression Results: The Effect of Hours of Inactivity on the CES-D Score, by Gender

	Males	**Females**
Hours of Inactivity	0.002 (-0.003, 0.007)	0.002 (-0.004, 0.007)
Age	-0.11 (-0.29, 0.07)	-0.25 (-0.46, –0.04)
Constant	13.01 (10.09, 15.93)	17.26 (13.87, 20.63)
Sample Size	12,510	13,126

95% CI are in parenthesis.

Table notes: Data from the National Longitudinal Study of Adolescent Health. Each respondent contributes two observations to the estimation of this model (one from the baseline survey, the other from the follow-up survey). As a consequence, both the baseline and follow-up CES-D scores are utilized in the estimation of the parameters. Age is not captured by the individual fixed effects because the time between the baseline and follow-up interviews was not uniform across respondents. All other baseline control variables are absorbed by the individual fixed effects.