Does cardiorespiratory fitness protect against depression during middle school?

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ABSTRACT

Objective: Cross-sectional studies demonstrate a robust association between depression, physical activity, and cardiorespiratory fitness in adolescents, but longitudinal evidence that can better parse the direction of these effects is scarce and conflicting. The present study sought to determine if cardiorespiratory fitness in the first year of middle school (6th grade) would protect against developing depression a year later (7th grade), even after controlling for other risk factors (i.e., pre-existing depression levels and weight status).

Method: Participants (N = 437 with 54.9% female) were recruited from six different middle schools during their 6th grade year and were re-assessed during the 7th grade. At each assessment, participants completed self-report measures of depression and fitness. Participants were also weighed and were asked to complete a shuttle-run at both points.

Results: A cross-lagged panel model indicated that cardiorespiratory fitness in the 6th grade was associated with significantly less depression by the 7th grade in girls, even after controlling for pre-existing depression as well as weight. The effect was in the same direction for boys, but was non-significant. In both cases, effects were modest to small.

Conclusions: Cardiorespiratory fitness had a small, but significant protective effect against developing depression in middle school girls, and may have a similar but smaller effect in boys. Promotion of cardiorespiratory fitness can be an important strategy for preventing depression in middle school adolescents, but needs to be coupled with interventions that more directly address symptom treatment.

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INTRODUCTION

Depression is a leading cause of disability worldwide, particularly among adolescents in developed countries.[1,2] By 2030, the World Health Organization projects depression will overtake all other medical conditions as the leading cause of disease burden.[3] Symptoms of depression, such as persistent sadness and loss of interest, frequently begin in adolescence and can follow a chronic or recurring pattern into adulthood.[4-6] Earlier onset of symptoms often portends a worse course,[7-10] underscoring the need for early interventions.[10]

One promising, malleable factor that may protect adolescents against depression is cardiorespiratory fitness (CRF). Often used interchangeably with aerobic capacity,[11] CRF is a component of physical fitness that reflects the overall capacity of the cardiovascular and respiratory systems[12,13] and the ability to perform prolonged strenuous exercise.[13,14] It is highly correlated with measures of physical activity,[15-18] but differs in an important way: physical activity can fluctuate from week-to-week whereas CRF reflects a physiological outcome achieved through prolonged physical activity.[11]

Research on CRF and depression in adolescents has been extensive though marked with methodological limitations. For example, many studies have reported strong associations between CRF and depression in adolescent populations,[19-30] yet the majority of these were cross-sectional in nature, which precludes the ability to determine the direction of effects. Randomized clinical trials involving exercise-based interventions provide more direct support; adolescent studies tend to find a small, but positive, effect from exercise on depression post-treatment,[31,32] mirroring effects seen in adult samples.[33] However, the extent to which these effects persist beyond a few months or prevent (as opposed to treat) depression over the long-term remains unclear. Moreover, these interventions involve other aspects of treatment (e.g., behavioral activation; increased social support) that may account for their benefit.

Longitudinal studies (e.g., > 1 year) of the link between CRF and depression in adolescents that would complement and inform this literature are even scarcer. In fact, most longitudinal studies have not considered CRF per se, focusing instead on physical activity and using primarily self-report methods.[34-38]

Even within these studies, findings are equivocal: two studies[35,36] found a small effect from physical activity on depression over the long-term, but two others[34,37] reported no such connection and a fifth[38] found only a partial effect. Reviews from the adult literature support a link,[33,39] although evidence specifically tied to CRF, as well as to long-term benefits (> 1 year), is much less robust. Thus, longitudinal evidence directly supporting the promotion of CRF for the prevention of adolescent depression is incomplete and remains inconsistent.

Given this background, the present study sought to assess whether CRF in middle-school students was prospectively related to lower depressive symptomatology from one school year to the next. Given that weight status has been shown to prospectively predict depression, we controlled for its effects as well. To test this research question, a diverse group of students were recruited and assessed in the 6th grade (Time 1) and then reassessed a year later in the 7th grade (Time 2). The study's primary hypothesis was that higher levels of Time 1 fitness as defined through an objective measure of aerobic capacity and self-report measures of physical self-concept (i.e., endurance, strength) would be associated with less depression at Time 2, even after controlling for pre-existing depression and BMI. In other words, we applied a strict test of the role of CRF, predicting the *new* development of depressive symptoms. We also hypothesized this association would be more apparent for girls than boys given the greater variability in rates of depression among females (i.e., restricted range of depression in males would attenuate any association).

METHOD

Participants and Procedures

Participants were male (n = 197) and female (n = 240) middle school students assessed in the 6th and 7th grades; they were drawn from the six middle schools from a metropolitan county in North Texas. Mean age in the 6th grade was 11.55 years (SD = .59). Participants were mostly White (89.0%) or African-American (9.2%), with a significant portion also identifying as Hispanic (23.6%). Based on federal guidelines, almost one fourth (23.5%) of the students qualified for the free or reduced lunch programs.

All participants were part of a larger, state-mandated district-wide program to assess physical fitness. As part of this study, students in these middle schools were assessed annually regarding their weight, height, physical fitness and other self-report measures of psychological well-being. Part of this annual assessment included the FITNESSGRAM testing protocol (see measures below), which was completed during their physical education class and supervised by the physical education teachers as well as the current researchers. During each year of this study, fitness testing (and the subsequent collection of measures of psychological well-being) was conducted during the same one week period for each school For example, if School A had completed their fitness testing during the second week of September during Time 1, they completed the measures and fitness assessment that same week of September during Time 2. The study was approved by the authors' Institutional Review Board, the school district's administrative offices, and the principals at each of the six middle schools that participated.

Of the students in this district-wide program, only those for whom written parental consent (and child assent) was obtained in both the 6th and 7th grades, and who completed the self-report measures in both grades, were included in this study. Originally, 1670 students had completed the depression and other measures in the 6th grade, but only 437 had parental consent to participate in the 7th grade. Students who re-consented in the 7th grade, versus those who did not, did not differ with respect to age, gender, Hispanic background, free lunch status, or BMI. However, 6th grade students who re-consented in the 7th grade were significantly less depressed (Cohen's d = -.19), more fit on the PACER test (Cohen's d = .19), and more likely to be Caucasian (89.0% versus 82.9%) compared to those who did not re-consent. Differences in depression and fitness suggest that our results may understate the relationship between fitness and depression.

Measures

Depression. The 20-item Center for Epidemiologic Studies Depression Scale for Children (CES-DC)[40,41] measures behavioral and cognitive symptoms of depression in children and adolescents experienced in the past week. In the present study, Cronbach's alphas were .89 and .92, respectively, across 6th and 7th grade. Previous studies have suggested the measure is a reliable and valid indicator of

depression in adolescents (ages 12-18) with a stable factor structure.[36,42] Scores above 14-16 may indicate the presence of a major depressive episode.[42]

CRF. Three indicators were used to measure CRF in each grade. The first was the number of laps completed by each student on the Progressive Aerobic Cardiovascular Endurance Run (PACER), which is a subtest of the FITNESSGRAM® test battery.[43] The PACER was completed and overseen by each school's physical education teachers and the study's authors during the same one week period each year. The PACER score reflects the number of laps completed by the student within the specified amount of time frame for each lap. The other indicators of CRF were obtained through two items from the Physical Self-Description Questionnaire (PSDQ).[44] Specifically, adolescents responded to a question concerning their endurance (i.e., "I can run a long way without stopping") and one about physical strength (i.e., "I am a physically strong person"). Together, the three indicators of fitness demonstrated adequate internal consistency at both time points (Cronbach's α = .71 and .73, respectively), suggesting they were measuring a similar construct.

Body composition. Body composition was represented by the students' body mass index (kg/m^2), which had been converted into percentiles based on their age and gender. Weight was measured by the physical education teachers using a Seca digital scale (Model 882) and recorded to the nearest .1 lb.

DATA ANALYSIS

All variables were assessed for departures from normality as well as for missingness. Depression, BMI percentile and PACER scores demonstrated skew and were transformed by taking the square root, which improved their skew (i.e., < 2 for all transformed variables); however, tables of means report untransformed scores to ease interpretation. Given inclusion criteria (i.e., measures completed at both time points), little remaining data was missing (i.e., < 2%) and was handled through the use of full information maximum likelihood estimation of the parameter estimates.

To test hypotheses, analyses involved estimation of a cross-lagged panel model (see Figure 1 and 2) using multi-group structural equation modeling (SEM) to determine the relation between depression,

CRF and body composition across the 6th and 7th grades in boys and girls.[45] All parameters were estimated with maximum likelihood in Mplus.[46]

Manifest variables for the model included the total score of the CES-DC for depression and BMI percentile scores for body composition, in both grades. Latent variables included CRF measured by its three indictors (i.e., PACER score and self-reported endurance and physical strength) in both grades. The measurement model for the latent CRF variable had adequate fit (i.e., $\chi^2(18) = 45.55$, RMSEA = .08, CFI = .98, TLI = .96, SRMR = .07). Given gender differences in the model variables, we estimated path coefficients separately for boys and girls.

RESULTS

Mean and standard deviations for the observed depression, fitness, and BMI variables according to gender and grade are reported in Table 1. With respect to depression, the percentage of girls who had CES-DC scores consistent with possible depression (i.e., CES-DC > 14) was 28.3% in 6th grade and 28.5% in 7th grade; the percentages for boys were 22.3% and 18.8% for 6th and 7th grade, respectively. However, only 13.8% of the girls and 10.2% of the boys had elevated depression scores at both assessments.

Figures 1 and 2 display the final model estimated to test hypotheses for girls and boys, respectively, including standardized estimates and standard errors. The overall, multi-group cross-lagged panel model had acceptable fit, $\chi^2(47) = 116.15$, RMSEA = .08, CFI = .97, TLI=.94, SRMR = .06.

Girls. As represented in Figure 1, there were strong cross-sectional correlations among variables in the 6th grade, such that higher levels of fitness were associated with a leaner body composition and less depression. With respect to the longitudinal effects, Time 1 CRF and Time 1 Body Composition strongly predicted the same in the 7th grade and the same was true to a lesser extent for depression from one grade to the next. After controlling for 6th grade body composition and depression, 6th grade fitness continued to be a significant predictor of lower depression in the 7th grade. There was also a trend for 6th grade fitness to lead to lower BMI percentile scores in the 7th grade.

Boys. Similar to the girls, there were strong cross-sectional associations among depression, weight and fitness in the 6th grade (see Figure 2). All the within variable relations from 6th to 7th grade were significant; again the β's for fitness and body composition were higher than for depression. Similar to the girls, there was trend for 6th grade fitness to lead to lower BMI percentile scores in the 7th grade. However, fitness was no longer significantly associated with 7th grade depression after controlling for 6th grade depression and body composition, although the effect was in the expected direction. Instead, 6th grade depression in boys was a significant predictor of poorer fitness in 7th grade.

DISCUSSION

The present study assessed the extent to which CRF longitudinally protects against depression in male and female middle school students. To our knowledge, this is the first time any study has naturally assessed the long-term (i.e., 1 year) effects of CRF (as opposed to physical activity per se) on depression in this population. Our results showed that pre-existing levels of depression (i.e., in 6th grade) were the most powerful predictor of subsequent depression. However, even after controlling for 6th grade depression and body composition, higher levels of CRF in 6th grade were associated with significantly less depression by the 7th grade for the girls. The effect for boys was in the same direction, though it did not reach significance. Thus, for girls, CRF had salutary effects on depression. It is also worth noting that depression in the 6th grade had a negative effect on fitness a year later for boys.

Similar to other studies, the present one replicated findings showing a robust cross-sectional association between CRF and depression in each grade. In other words, once affected by depression, students are much more likely to show lower levels of CRF, and vice versa, regardless of their grade level. However, this effect was weaker longitudinally. This discrepancy between cross-sectional and longitudinal findings mirrors the larger literature on physical activity and exercise-based interventions reviewed earlier. Long-term studies on the effects of physical activity on depression in adolescents have been inconsistent.[34-38] One possible reason for these mixed findings is that studies measured physical activity, but not CRF. It is plausible that CRF mediates the effect of activity on depression. In other words, exercise-based interventions or other approaches that lead to increased physical activity may only

be effective in so far as they to lead to improved CRF. Alternatively, other factors may be at play. Depression is a multi-faceted disorder and other, broader factors, such as personality,[47] may have a more profound and direct role in predicting the onset and course of depression in adolescents.

In both girls and boys, effects from CRF were modest in comparison to effects from pre-existing depression. Initial consideration, then, suggests optimal prevention would couple fitness efforts with more direct interventions that target pre-existing symptoms or related vulnerabilities. Close to a third of the girls in the present sample reported elevated depressive symptoms at the start of the study. Psychotherapies, such as cognitive-behavioral or interpersonal therapy, have been shown to be effective in clinical trials for treating depression in adolescents, at least in the short-term.[48] Group-based therapies that target psychological vulnerabilities to depression and that can be implemented on a school-wide basis (e.g., Penn Resiliency Program)[49] may be an alternative to individual-based programs.

Further consideration, however, makes clear that although effects may be modest, promoting CRF may nevertheless be an effective approach to managing depression in this group. Providers trained in empirically supported therapies that directly target depression may be scarce or expensive, and other barriers (e.g., stigma from seeking treatment) may make this option difficult, particularly on a large-scale. Medication-based treatments come with their own expenses and risks.[50] Moreover, evidence that treatments directly targeting depression in young adolescents are effective after a year is weak or inconclusive.[48,50] The latter means that promoting CRF may be as effective as other approaches.

Furthermore, exercise-based programs are already integral to middle school curriculums, so increasing their presence and impact would be less difficult than implementing more specialized, depression-focused treatments. Beyond depression, there are ancillary benefits to promoting fitness as well: in both boys and girls, there was a trend ($p < .10$) for fitness in the 6th grade to be associated with healthier weight a year later, which carries its own mental and physical health benefits. Finally, measurement and design issues means that the present study was likely to underestimate the true effect of fitness. For all of these reasons, promoting CRF is likely to represent an effective approach to protecting middle school students against depression.

Several study limitations warrant acknowledgement. Foremost among them, the study was naturalistic in design, with no random assignment or manipulation, limiting casual interpretations. Other factors (e.g., genetic predispositions, psychosocial factors, personality) that are correlated with but distinct from CRF may account for the observed effects. We attempted to control for these by controlling for a well-known factor (i.e., body composition), as well as for depression, which would have controlled for numerous pre-existing, stable factors such as biological or personality-based vulnerabilities. This strict control is unusual in longitudinal studies and partially mitigates the concern. However, other third factors (e.g. social milieu of fit students) may have still played a role and biologically-based vulnerabilities may only have become activated between assessment points, given that students were in a critical period of development. Beyond lack of experimental design, other limitations included a study length of only a year, leaving unanswered whether or not effects persist beyond that period. Finally, the study relied on several self-report measures (e.g., depression) and was unable to complete sub-analyses to determine if effects differed across racial groups.

With these limitations in mind, the present study nevertheless suggests that CRF is an important factor for protecting students against depression in middle school, particularly female students. Although results were modest, they are arguably as large as other interventions in this area.[31] Moreover, promoting fitness can be accomplished within most existing school curricula, making this approach feasible and acceptable to different stakeholders. Moving forward, stakeholders as well as researchers concerned about depression during middle school would benefit from regular assessment of not simply physical activity, but levels of CRF as well.

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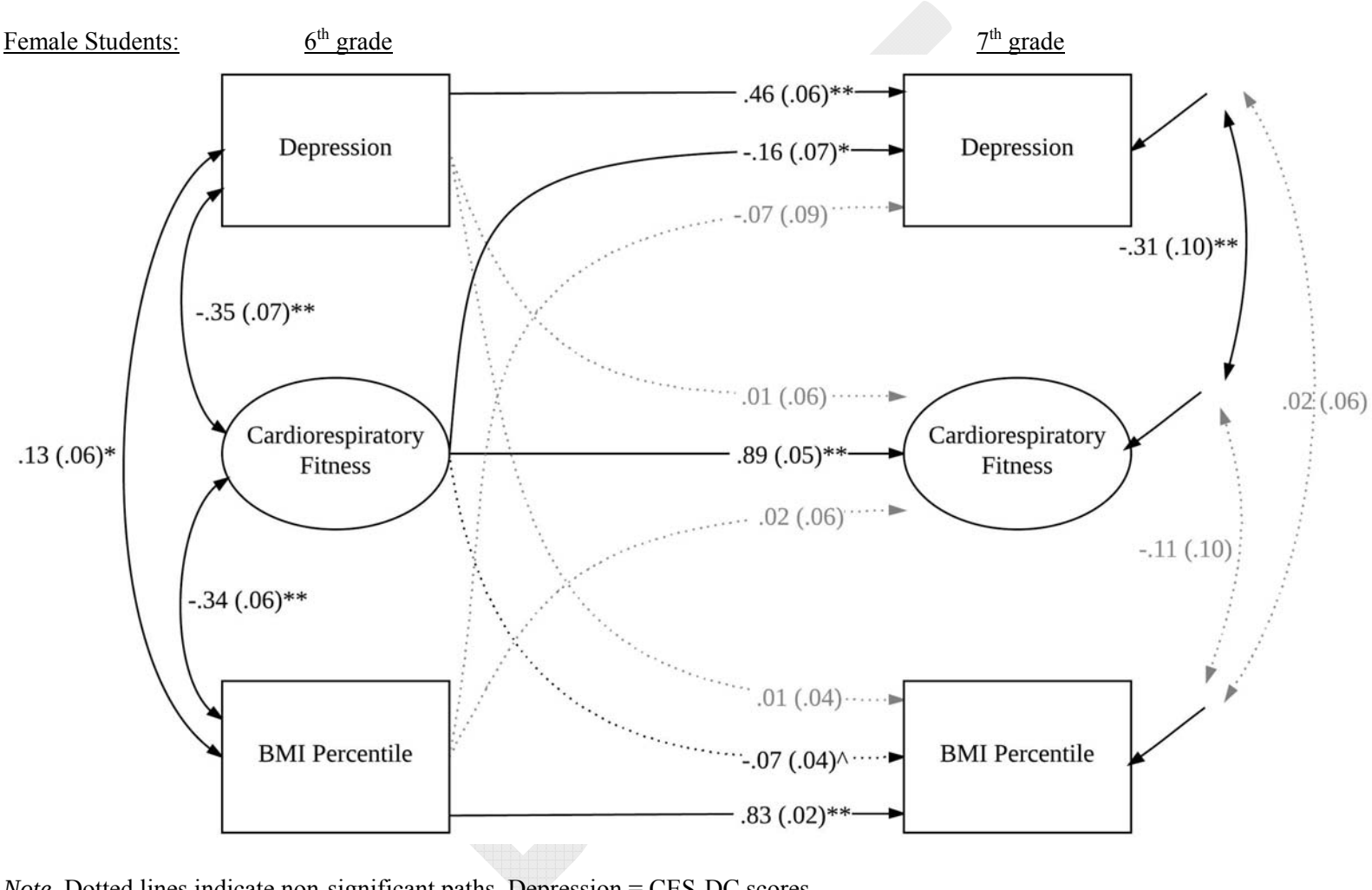
Table 1
Mean (*SD*) depression, CRF and weight variable scores by gender and grade (*N*=437)

	6th grade	7th grade
Female (n=240)		
Depression	11.38 (10.01)	11.90 (10.58)
PACER	27.96 (12.21)	35.28 (14.96)
Endurance	3.89 (1.47)	4.14 (1.51)
Physical Strength	4.36 (1.36)	4.66 (1.27)
BMI percentile	60.63 (27.92)	60.68 (28.52)
Male (n=197)		
Depression	10.54 (8.52)	10.18 (10.39)
PACER	35.43 (16.19)	41.60 (16.92)
Endurance	4.20 (1.54)	4.32 (1.57)
Physical Strength	4.57 (1.37)	4.84 (1.21)
BMI percentile	65.27 (29.52)	59.19 (31.03)

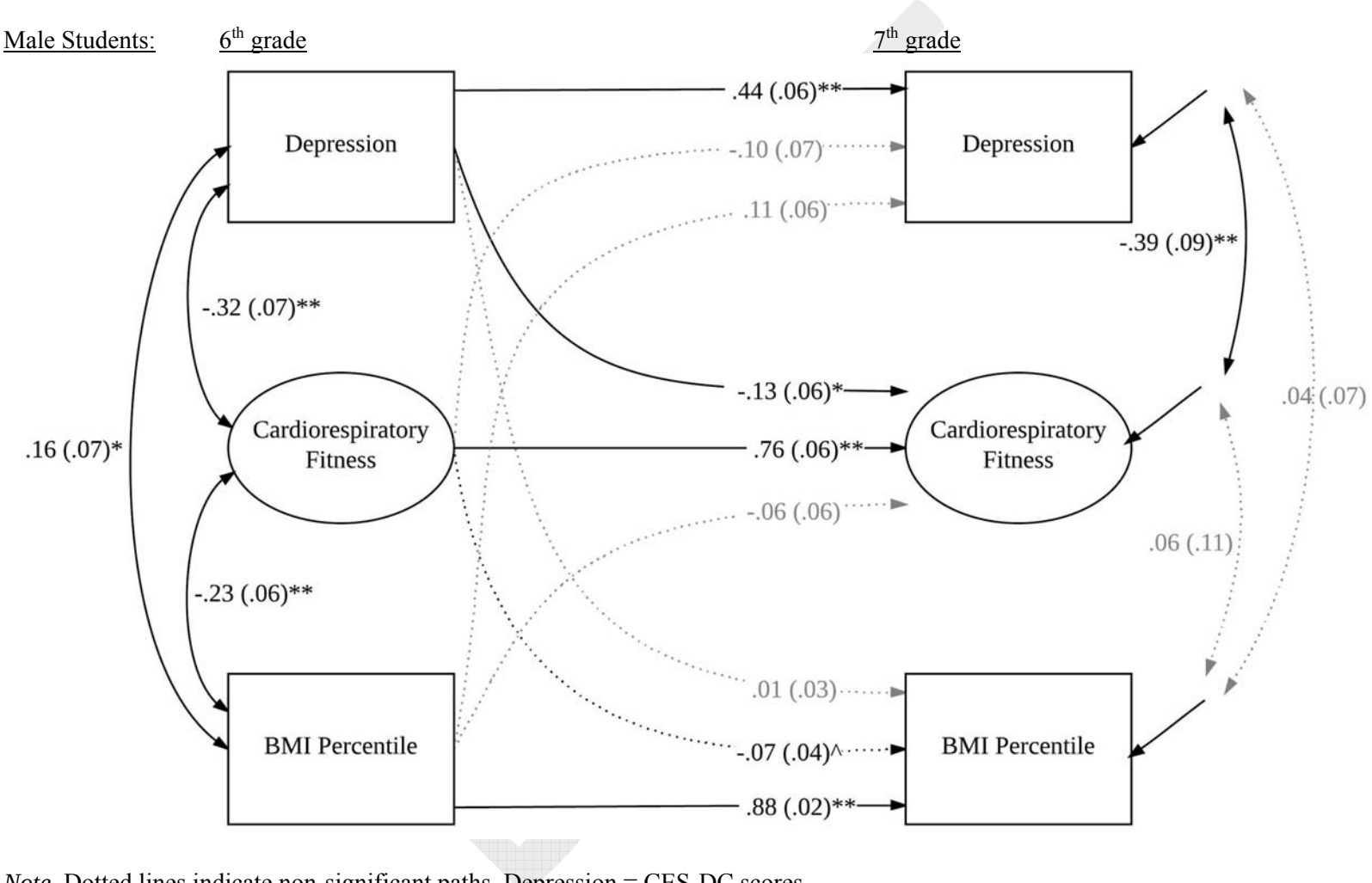
Note. Depression (based on total CES-DC scores, which can range from 0, low, to 60, high). PACER (Progressive Aerobic Cardiovascular Endurance Run; mean represents the number of laps run and can range from 2 to 100); Endurance and Strength (from the Physical Self-Description Scale, each score can range from 1, low, to 6, high); BMI (percentiles based on gender and age).

Figure 1
SEM standardized estimates (and standard errors) for female middle school students (n = 240)



Note. Dotted lines indicate non-significant paths. Depression = CES-DC scores.
**p < .01, *p < .05, ^p < .10.

Figure 2
SEM standardized estimates (and standard errors) for male middle school students (n = 197)



Note. Dotted lines indicate non-significant paths. Depression = CES-DC scores.
**p < .01, *p < .05, ^p < .10.