Exercise Effects on Depressive Symptoms and Self-Worth in Overweight Children: A Randomized Controlled Trial*

Karen H. Petty,1 PHD, Catherine L. Davis,1 PHD, Joseph Tkacz,1,2 MS, Deborah Young-Hyman,1 PHD, and Jennifer L. Waller,2 PHD

1Department of Pediatrics, Georgia Prevention Institute and 2Department of Biostatistics, Medical College of Georgia

**Objective** To test the dose–response effects of an exercise program on depressive symptoms and self-worth in children. **Method** Overweight, sedentary children (N = 207, 7–11 years, 58% male, 59% Black) were randomly assigned to low or high dose (20 or 40 min/day) aerobic exercise programs (13 ± 1.6 weeks), or control group. Children completed the Reynolds Child Depression Scale and Self-Perception Profile for Children at baseline and posttest. **Results** A dose–response benefit of exercise was detected for depressive symptoms. A race × group interaction showed only White children’s global self-worth (GSW) improved. There was some evidence that increased self-worth mediated the effect on depressive symptoms. **Conclusions** This study shows dose–response benefits of exercise on depressive symptoms and self-worth in children. However, Blacks did not show increased GSW in response to the intervention. Results provide some support for mediation of the effect of exercise on depressive symptoms via self-worth.

**Key words** children; depression; health behavior; health promotion and prevention; obesity; race/ethnicity; self-worth.

The prevalence and severity of childhood obesity has increased dramatically. Recent estimates of childhood obesity indicate that approximately 37% of children aged 6–11 are overweight (≥85th percentile) or obese (≥95th percentile), with an even higher rate (40%) in Black children (Barlow, 2007; Ogden et al., 2006). Childhood obesity is associated with many negative outcomes (Daniels et al., 2005), including low self-esteem (French, Story, & Perry, 1995; Strauss, 2000) and depression (Bell et al., 2007). Obesity and low self-esteem have been related to low physical activity (Stauss, Rodzilsky, Burack, & Colin, 2001). Inactivity is a major contributing factor to the development and increased prevalence of childhood obesity.

Little is known regarding the effects of physical activity on self-worth. Children may notice, or receive compliments on, improved body size or shape due to physical activity, and then regard themselves as more attractive or valuable. Children who become active may be approaching their own or others’ ideal for their behavior, thus potentially increasing their self-appraisal of worth and attractiveness. A handful of meta-analyses (Ekeland, Heian, Hagen, Abbott, & Nordheim, 2004; Gruber, 1986) and one quasi-experimental study (Annesi, 2005) have been conducted investigating the relationship between exercise and self-worth in children and adolescents. The studies indicate a moderate positive effect of exercise on self-worth, but underscore the need for more rigorous experimentation in this area.

The benefits of exercise on depression have been demonstrated experimentally in adults (Blumenthal et al., 2007; Dunn, Trivedi, Kampert, Clark, & Chambliss, 2005; Lawlor & Hopker, 2001), and in less rigorous investigations among children and adolescents (Annesi, 2005; Calfas & Taylor, 1994; Larun, Nordheim, Ekeland, Hagen, & Heian, 2006; Motl, Birnbaum,
Kubik, & Dishman, 2004). Exercise in rats has been shown to buffer stress through adaptations in serotonin and norepinephrine brain systems, which play a role in human depression (Dishman, Berthoud et al., 2006). Recent evidence in mice suggests a biological pathway by which exercise regulates genes responsible for its antidepressant action (Hunsberger et al., 2007). Given the link between exercise and biological mechanisms of depression, it is plausible then that there would be a dose–response benefit of exercise on depression.

Experimental evidence is the strongest type of evidence for causation, providing both temporality and randomization to exclude confounders; thus, the randomized clinical trial is intended to provide strong evidence of the effect of a treatment. Dose–response is a pattern of graded response to treatment, which is considered stronger evidence for causation than a simple treatment vs. control comparison (Hill, 1965). Dose–response, or increasing effects with increasing treatment dose, is evidence that there is, in fact, an effect due to treatment, and is typically required to justify further studies of a new drug. If there is an effect of the treatment, further questions include which dose groups differ from control, and what is the minimum effective dose (Ruberg, 1995). An expert consensus conference found that evidence for a dose–response between physical activity and human health, particularly experimental evidence, was sparse (Kesaniemi et al., 2001) and urgently needed (Oja, 2001). Dunn, Trivedi, & O’Neal (2001) found the evidence for a dose–response of exercise on depression symptoms suggestive but not convincing, and called for randomized controlled trials (RCTs) to test dose–response and mechanisms. There are very few studies documenting dose–response benefits of exercise in children (Strong et al., 2005). This paper presents results of a study testing the hypothesis of a dose–response effect of exercise training on psychological outcomes in children.

The current study tested the hypothesis that an aerobic exercise program would decrease depressive symptoms and improve self-worth in a community sample of overweight children, in a dose–response fashion. Because of race and gender disparities in children’s physical activity and psychological factors (Gordon-Larsen, McMurray, & Popkin, 1999), we examined the influence of race and gender on the effect of exercise. The findings that low self-esteem predicts depression risk (Goodman & Whitaker, 2002) and that physical activity leads to increased self-worth (Ekeland et al., 2004) together suggest the hypothesis that self-worth mediates the effect of physical activity on depressive symptoms. We tested a mediation model, in which physical activity acted through improved self-worth to reduce depression symptoms (Baron & Kenny, 1986; Dishman, Hales et al., 2006).

**Methods**

**Participants and Recruitment**

Participants were part of a larger study examining the effect of exercise on metabolism, and were recruited via presentations and flyers distributed to children attending local public schools. Recruitment of children and subsequent study enrollment took place between November 2003 and June 2006, in six different cohorts (due to time and space restraints). Healthy Black or White children were eligible if they were 7–11 years old, overweight (≥85th percentile BMI), did not participate in a regular physical activity program more than 1 h per week, had no medical condition that would affect study results or limit physical activity, attended a school included in the study, and provided a blood sample. As shown in Figure 1, 222 children were enrolled and randomized, with 207 children [58% male, 59% Black (African American)] having completed baseline and posttest measures of interest to the current study. One child in the control group was excluded due to severe psychiatric illness. All children and parents completed the informed consent/assent process. The study was reviewed and approved by the Human Assurance Committee (Institutional Review Board) of the institution initially in 2002, and re-approved at least yearly. Children were offered incentives of a savings bond worth $50 (face value at maturity $100) for baseline and a savings bond worth $200 (face value at maturity $400) at posttest for completing an 8 h day of testing procedures, including those reported here.

**Randomization**

Children were randomly assigned to one of three experimental conditions: a no-exercise control condition \((n = 68)\), low dose (20 min/day, \(n = 69\)), or high dose (40 min/day, \(n = 70\)) aerobic exercise program. The high dose was chosen on the basis of a 40 min/day aerobic training program shown to improve the health of obese youths (Gutin, Riggs, Ferguson, & Owens, 1999). In fact, this dose is the basis of the current recommendation for 60 min daily physical activity for children, because it would take somewhat longer to achieve this dose in free-living conditions (Strong et al., 2005). The low dose was chosen to optimize statistical power for the dose–response analysis by specifying equal intervals, and because 20 min of vigorous activity is achievable in a physical education class. The selected exercise doses differ only in duration and therefore volume of exercise, not intensity...
or frequency. After baseline testing was complete, a statistician assigned the experimental condition via a computer-generated randomization sequence balanced by race and gender, which was concealed until the interventions were assigned. The study coordinator enrolled participants and shared their randomization status with them. All measures were administered by research staff at our laboratory. Children assigned to the control condition were not offered any transportation or after-school exercise program.

**Measures**

**Demographics**

Primary caregivers (89% mothers, 6% fathers) provided information on the child’s race, gender, and birthdate. Marital status and education level were self-reported at baseline by the child’s primary caregiver. Marital status was categorized as (1) married or (2) single, separated, divorced or widowed. Education level was quantified with the following scale: partial high school, high school graduate, partial college, college graduate, or postgraduate (Table 1).

**Anthropometrics**

Children’s body weight (in shorts and T-shirt) and height (without shoes) were measured with an electronic scale (Detecto, Web City, MO) and stadiometer (Tanita, Arlington Heights, IL), and converted to BMI and BMI z-score (SAS code available from Centers for

---

**Figure 1.** Flow diagram of a dose–response trial of exercise in overweight children with results for secondary outcomes (Harter Self Perception Profile for Children and Reynolds Child Depression Scale).
Disease Control). BMI z-score reflects the number of standard deviations above or below the average value for a child’s age and gender based on the current childhood norms (Ogden et al., 2002) (Tables 1 and 2).

Reynolds Child Depression Scale (RCDS)
The RCDS (Reynolds, 1989) was administered to children at baseline and posttest. This is a 30-item self-report Likert scale of depressive symptoms in children. The RCDS total score can span from 30 to 121, with higher scores indicative of more severe pathology. A cutoff score of 74 is used to define clinically relevant levels of depression, and the healthy standardization sample demonstrated mean scores between 52 and 60 (Reynolds, 1989). Baseline scores on the RCDS in our sample (Table 2) were in the normal, nondepressed range with only 4%

### Table I. Characteristics of the Sample at Baseline by Group and Race

<table>
<thead>
<tr>
<th>Exercise group</th>
<th>Control</th>
<th>Low dose</th>
<th>High dose</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Black</td>
<td>White</td>
<td>Black</td>
<td>White</td>
</tr>
<tr>
<td>n</td>
<td>38</td>
<td>30</td>
<td>42</td>
<td>27</td>
</tr>
<tr>
<td>Age (years)</td>
<td>9.4 (1.2)</td>
<td>9.4 (1.1)</td>
<td>9.3 (0.9)</td>
<td>9.3 (1.0)</td>
</tr>
<tr>
<td>BMI (kg/m²)</td>
<td>28.3 (4.8)</td>
<td>24.3 (3.3)</td>
<td>26.8 (4.3)</td>
<td>24.3 (3.0)</td>
</tr>
<tr>
<td>Male (%)</td>
<td>38</td>
<td>50</td>
<td>36</td>
<td>55</td>
</tr>
<tr>
<td>Obese (%)</td>
<td>60</td>
<td>40</td>
<td>62</td>
<td>38</td>
</tr>
<tr>
<td>Parent married (%)</td>
<td>50</td>
<td>87</td>
<td>53</td>
<td>90</td>
</tr>
</tbody>
</table>

### Table II. Unadjusted Means (SD) for Depression and Self-Worth Scores by Group and Race

<table>
<thead>
<tr>
<th>Exercise group</th>
<th>Control</th>
<th>Low dose</th>
<th>High dose</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Black</td>
<td>White</td>
<td>Black</td>
<td>White</td>
</tr>
<tr>
<td>Depression**</td>
<td>Pre</td>
<td>48.3 (7.0)</td>
<td>53.1 (9.6)</td>
<td>54.5 (12.1)</td>
</tr>
<tr>
<td></td>
<td>Post</td>
<td>48.9 (9.8)</td>
<td>51.7 (11.2)</td>
<td>51.5 (10.7)</td>
</tr>
<tr>
<td>Self-worth</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Global***</td>
<td>Pre</td>
<td>3.3 (0.6)</td>
<td>3.2 (0.7)</td>
<td>3.1 (0.7)</td>
</tr>
<tr>
<td></td>
<td>Post</td>
<td>3.1 (0.7)</td>
<td>2.9 (0.6)</td>
<td>3.2 (0.62)</td>
</tr>
<tr>
<td>Physical appearance*</td>
<td>Pre</td>
<td>2.9 (0.8)</td>
<td>2.7 (0.7)</td>
<td>2.6 (0.8)</td>
</tr>
<tr>
<td></td>
<td>Post</td>
<td>2.9 (0.8)</td>
<td>2.6 (0.8)</td>
<td>2.8 (0.8)</td>
</tr>
<tr>
<td>Athletic</td>
<td>Pre</td>
<td>2.7 (0.6)</td>
<td>2.7 (0.7)</td>
<td>2.7 (0.6)</td>
</tr>
<tr>
<td></td>
<td>Post</td>
<td>2.7 (0.6)</td>
<td>2.7 (0.6)</td>
<td>2.9 (0.6)</td>
</tr>
<tr>
<td>Behavioral</td>
<td>Pre</td>
<td>3.0 (0.7)</td>
<td>2.9 (0.7)</td>
<td>3.2 (0.6)</td>
</tr>
<tr>
<td></td>
<td>Post</td>
<td>3.1 (0.7)</td>
<td>2.9 (0.7)</td>
<td>3.1 (0.6)</td>
</tr>
<tr>
<td>Social</td>
<td>Pre</td>
<td>2.9 (0.7)</td>
<td>2.8 (0.7)</td>
<td>2.7 (0.8)</td>
</tr>
<tr>
<td></td>
<td>Post</td>
<td>2.9 (0.6)</td>
<td>2.8 (0.6)</td>
<td>2.9 (0.7)</td>
</tr>
<tr>
<td>Scholastic</td>
<td>Pre</td>
<td>2.8 (0.6)</td>
<td>2.9 (0.6)</td>
<td>2.8 (0.7)</td>
</tr>
<tr>
<td></td>
<td>Post</td>
<td>2.8 (0.6)</td>
<td>3.1 (0.6)</td>
<td>2.9 (0.6)</td>
</tr>
<tr>
<td>BMI z-score*</td>
<td>Pre</td>
<td>2.3 (0.4)</td>
<td>1.9 (0.4)</td>
<td>2.2 (0.4)</td>
</tr>
<tr>
<td></td>
<td>Post</td>
<td>2.3 (0.4)</td>
<td>1.9 (0.4)</td>
<td>2.1 (0.4)</td>
</tr>
</tbody>
</table>

*For the Reynolds child depression scale, control n = 59, low dose n = 62, high dose n = 63.
*Linear dose–response effect, p < .05. No significant pairwise group comparisons were observed.
**Race by group interaction, p < .01.

Ogden et al., 2002 (Tables 1 and 2).
above the cutoff. The test takes approximately 10 min to complete. The RCDS has been found to have internal consistency of 0.90 for the total standardization sample, and test–retest reliability scores ranging from 0.81 to 0.92 over 4 weeks. A total of 204 children in this sample completed the RCDS at baseline and posttest; 19 of these were excluded due to invalid response patterns (Reynolds, 1989). Thus, valid data for the RCDS were available for 185 children; one of these did not complete the Self-Perception Profile for Children (SPPC) at posttest and was not included in analyses.

SPPC
The SPPC (Harter, 1985) measures children’s perceptions of themselves, and was completed by all subjects before and after the intervention. This 36-item Likert scale contains six separate subscales tapping five specific domains (Scholastic Competence, Social Acceptance, Athletic Competence, Physical Appearance, and Behavioral Conduct) as well as a sixth domain of global self-worth (GSW). It is important to note that the latter is not an aggregate of the more specific domains. The six subscale means determine a child’s profile, with each domain consisting of six items. Domain raw scores can range from 6 to 24, with higher scores indicating the higher ratings of competency or self-worth. Approximately 15 min are needed to complete this measure. There are no clinical cutoff scores, but the manual does provide subscale norms by gender for third and fourth grades, with means ranging from 2.5 to 3.2. Baseline mean scores in our sample (Table 2) were similar to the standardization sample (Harter, 1985). Internal consistency scores (Cronbach’s alpha) for the six scales range from .71 to .86 (Harter, 1985). Four-week test–retest stability scores measured by intraclass correlations were found to be .84 to .90 for all subscales (Muris, Meesters, & Fijen, 2003). In this study, 207 children completed the SPPC at baseline and posttest.

Interventions
The exercise sessions were held on school day afternoons in the research gymnasium and instructed by trained research staff. The children assigned to the intervention groups were provided free transportation via school bus to our research gymnasium, and then home or to a neighborhood school each weekday after the exercise classes ended. Polar heart rate monitors (s610i; Polar Electro, Oy, Finland) were used to monitor intensity and incentivize adherence to the exercise dose. The emphasis was on intensity, enjoyment, and safety, not competition nor the enhancement of skills; therefore, activities were selected based on ease of comprehension, fun, and ability to elicit a heart rate greater than 150 bpm. Examples of these activities include running games, jump rope, basketball, and soccer (Gutin et al., 1999; Turner & Turner, 2000). In the high dose group, 20 min bouts of intermittent vigorous exercise were done in a fashion consistent with guidelines for children, in short bursts of intense physical activity interspersed with lower intensity activity (recovery) (Bailey et al., 1995; Corbin & Pangrazi, 2004). The two exercise groups exercised in the same gymnasium. After the first 20 min bout, the low dose group was escorted to a separate room where they engaged in supervised sedentary activities, while the high dose group completed a second 20 min bout. Children remained at our laboratories for approximately 75 min each day due to time required for changing, water breaks, and the like. Those assigned to the exercise groups received 12.8 ± 1.6 (low dose: 13.0 ± 1.5; high dose: 12.6 ± 1.7) weeks of the exercise intervention between baseline and posttest. Average attendance was 84 ± 13% (84.5 ± 12.0 for 20 min; 84.0 ± 14.5 for 40 min) of available days between baseline and posttest. Average heart rates during the classes were similar at 166 ± 7.3 and 165 ± 9.0 bpm for the low and high dose groups, respectively (p > .05).

Statistical Methods
Data were screened for violation of assumptions. Degree of overweight (BMI z-score) was examined for association with SPPC and RCDS scores at baseline. Association between SPPC and RCDS scores at baseline and changes with group and control variables (race, gender, cohort, parental marital status, and parental education level) were evaluated using analysis of variance and correlation coefficients. Interactions of group with race and gender were tested. Any significant associations between SPPC or RCDS scores and control variables resulted in the control variable being adjusted for in further analyses. To address socioeconomic status, parental marital status and education level were evaluated as possible confounders in models showing any significant race effects. To evaluate the possible influence of weight loss, BMI z-score change was included in all analyses comparing dose groups.

Intent-to-treat analyses of covariance compared groups’ adjusted posttest values on all six scales of the SPPC, the RCDS, and BMI z-score. A priori linear contrasts tested dose–response effects, and post hoc pairwise comparisons (one-tailed) were performed (Ruberg, 1995). The linear contrast approach was selected, rather than the traditional omnibus F-test followed by post hoc pairwise comparisons, because a pre-specified contrast conditioned on the ordering of responses is more powerful to detect the
expected pattern, without sacrificing control of type I error (Phillips, 1998). In essence, rather than treating the quantitative independent variable as a qualitative one, this approach more parsimoniously tests the specific hypothesis of whether there is a dose–response effect of the treatment. Conditional on a significant linear contrast, the pairwise comparisons then ask further questions: which dose groups differed from control, and whether the low dose group differed from the high dose group. Mediation models were tested, in which improved self-worth might account for reduced depressive symptoms (Baron & Kenny, 1986; Dishman, Hales et al., 2006). If significant interactions with terms in the mediation model were detected, a moderated mediation model was tested (Preacher, Rucker, & Hayes, 2007).

**Results**

A race difference was detected on BMI z-score at baseline \[ t(205) = 4.32, p < .001 \], with Blacks having higher values \( 2.2 \pm 0.4 \) than Whites \( 1.9 \pm 0.4 \). No group, race, gender, cohort, caregiver marital status or education level effects were detected on SPPC or RCDS scales at baseline, or heart rate or attendance during the intervention. There was a race difference for marital status \( \chi^2 = 25, p < .001 \), with a greater proportion of Black than White children’s caregivers (48% vs. 13%) reporting unmarried status. Black children’s caregivers also had a lower education level \( 4.8 \pm 1.1 \) when compared to White children \( 5.3 \pm 0.9, t(185) = 2.9, p = .004 \). The RCDS correlated significantly with all SPPC scales \((- .24 \text{ to } - .43)\), and BMI z-scores correlated significantly with the RCDS \((- .15)\) and the Physical Appearance \((- .18)\) subscales of the SPPC \( p < .05 \). ANCOVA adjusting baseline BMI z-score, race, gender, and cohort showed a dose–response reduction on BMI z-score (linear contrast \( p < .0001 \), Table 2).

The *a priori* linear contrast in the ANCOVA adjusting for baseline RCDS score and BMI z-score change revealed a dose–response benefit of the intervention for the RCDS \( p = .045 \) (Figure 2). There was no interaction of group with race or gender. Pairwise comparisons on the RCDS indicated that the 40 min group was significantly lower than the control group \( p = .02 \) and, while not statistically significant, the 20 min group was lower than the control group \( p = .07 \). However, the difference between the 20 min and 40 min groups was not significant \( p = .27 \).

Analysis of each posttest SPPC scale controlling for baseline score and BMI z-score change revealed a linear contrast for GSW \( p = .01 \) indicating a dose–response benefit. Pairwise comparisons on the GSW indicated that the 40 min group was significantly higher than the control group \( p = .006 \) and, while not statistically significant, the 20 min group was higher than the control group \( p = .09 \). The 20 and 40 min groups were not significantly different \( p = .11 \). However, a significant race \( \times \) group interaction effect \( F (2, 207) = 4.16, p = .02 \) indicated that only White children’s GSW scores improved as a function of intervention (Figure 3). This interaction remained after baseline RCDS score \( p = .03 \), and other SPPC scales as a group \( p = .03 \) and individually \( p < .05 \) were adjusted. The interaction was unaffected by controlling for the primary caregiver’s marital status \( p = .02 \) and education level \( p = .02 \).

A dose–response effect of exercise, controlling for baseline Physical Appearance score and BMI z-score change, was also detected on the Physical Appearance scale of the SPPC \( p = .04 \). Pairwise comparisons on the PASW indicated that the 40 min group was significantly
higher than the control group \( (p = .02) \) and, while not statistically significant, the 40 min group was higher than the 20 min group \( (p = .06) \). However, the control and 20 min groups were not significantly different \( (p = .29) \). No group differences were detected on remaining scales of the SPPC, and there were no other significant interactions \( (p_s > .05) \). Group means and standard deviations by race at baseline and posttest for BMI \( z \)-score, SPPC, and RCDS scores can be viewed in Table 2. No quadratic trends were detected on any outcome.

Toward testing mediation of the effect of exercise on depressive symptoms via self-worth, the proposed mediators (improvements in GSW and physical appearance self-worth) were tested in the reduced sample \( (N = 184, \text{ restricted due to missing or invalid RCDS data}) \). The effect of exercise on physical appearance self-worth was not significant in the reduced sample \( (p = .20) \), but because it was significant in the larger sample, this was considered Type 2 error. When physical appearance self-worth was included in the above model predicting RCDS, it was a significant covariate \( (p < .001) \) and the linear contrast (exercise dose effect) was weakened \( (p = .08) \), suggesting partial mediation.

For GSW, a moderated mediation model was tested \( (Preacher et al., 2007) \). The interaction of race with exercise group on the mediator, GSW, was incorporated into the mediation model. GSW change was a significant predictor when included in the model \( (p = .007) \), such that depressive symptoms decreased as GSW increased. Exercise group was no longer a significant predictor of RCDS \( (p = .61) \), thus satisfying traditional criteria for mediation \( (Baron & Kenny, 1986) \). The conditional indirect effect was nearly significant in Whites \( (p = .09) \), and non-significant in Blacks \( (p = .95) \).

**Discussion**

Engaging in regular, vigorous aerobic exercise with peers in an organized setting decreased depressive symptoms in dose–response fashion among overweight children. This randomized trial in a community sample is the first experimental demonstration of a dose–response benefit of physical training on depressive symptoms in children (that is, where increasing amounts of training result in increased benefits, demonstrating a cause–effect relationship). This finding extends the experimental \( (Larun et al., 2006) \) and quasi-experimental \( (Annesi, 2005) \) evidence in children. Indeed, this is one of the first experimental studies to find evidence of a dose–response effect of exercise on depressive symptoms in any population, extending the experimental literature in adults as well \( (Blumenthal et al., 2007; Dunn et al., 2005; Dunn et al., 2001; Fox, 1999; Lawlor & Hopker, 2001) \). The 40 min daily dose of aerobic exercise was clearly superior to the control condition for reducing depressive symptoms, increasing physical appearance self-worth, and in White children, increasing GSW, thus demonstrating efficacy. The results suggested that a daily 20 min bout of aerobic exercise might be effective to reduce depressive symptoms and increase self-worth, but further study is needed. It is important to note, however, that the children in this sample were not clinically depressed; only 4% scored above the cutoff for depression on the RCDS. However, the effects of exercise on depressive symptoms may be important for prevention of clinical depression in later childhood and adolescence \( (Fox, 1999) \). It may even have a protective effect on later weight gain \( (Goodman & Whitaker, 2002) \).

GSW increased in dose–response fashion among White, but not Black children. The effect of exercise in White children is consistent with previous randomized controlled trials finding a moderately positive effect of exercise training on GSW \( (Ekeland et al., 2004; Gruber, 1986) \), as well as cross-sectional studies reporting an association between higher levels of physical activity and improved self-esteem \( (Strauss et al., 2001) \). One small study did not confirm a relationship of physical activity with GSW in children \( (Goldfield et al., 2007) \). The more specific result of the dose–response improvement of physical appearance self-worth in both Black and White children in exercise groups is consistent with cross-sectional \( (Crocker, Eklund, & Kowalski, 2000) \) and prospective \( (Goldfield et al., 2007) \) work in children, and a quasi-experimental study in which physical activity was associated with increased physical self-worth in children \( (Annesi, 2005) \). The 40 min dose was superior to the control condition, demonstrating efficacy; however, the effect of the 20 min dose was not significantly different from that of the control condition. The current results contrast with Dishman, Hales et al. \( (2006) \) where perceived appearance was not related to self-reported physical activity in adolescent girls. Thus, the effect of exercise on perceived appearance may be specific to children, or may be lost in girls as they enter adolescence. However, since that study was cross-sectional, relied on self-reported physical activity, and utilized different measures of psychological constructs, further study is needed to resolve these questions \( (Dishman, Hales et al., 2006) \).

There is limited evidence to suggest that Black children, teens, and adults do not experience the decreased self-esteem in relation to obesity that their White
counterparts do (Strauss, 2000; Young-Hyman, Schlundt, Herman-Wenderoth, & Bozylinski, 2003). One study found a weaker relationship in Black girls (Kimm et al., 1997). Indeed, there is some evidence that the Black culture is more accepting of obesity among women (Smith, Thompson, Racynski, & Hilner, 1999). This has led some to postulate that race may be a protective factor with regard to weight concerns and weight-related self-esteem. The findings of the current investigation support this idea, in that White overweight children experienced increased self-esteem due to exercise, but Black children did not. This study is among few to test race as a moderator of psychological risk among overweight children (Kimm et al., 1997; French et al., 1995).

Improvements in physical appearance self-worth appeared to partially mediate the effect of exercise on depressive symptoms, regardless of race. While this does contrast with the finding of Dishman, Hales et al. (2006) that perceived appearance was not related to physical activity, their finding that physical self-worth mediated the effect of physical activity on depression is consistent with our finding that GSW mediated the effect of exercise on depressive symptoms. It is possible that GSW might explain the mediation of both of these models, as physical self-worth could be considered a part of GSW. However, the different measures used in the two studies make the results difficult to compare. Interestingly, the mediating effect of GSW, transmitting the effect of exercise on depressive symptoms, was specific to Whites. Thus, for overweight White children, participating in a vigorous exercise program reduced depressive symptoms in part by improving GSW. While there are no known studies that have investigated the mediation of GSW on the effects of exercise training on depressive symptoms, this finding is consistent with studies noting an effect of physical activity on self-worth (Ekeland et al., 2004; Gruber, 1986) and with research in which low self-esteem predicts later depression (Goodman & Whitaker, 2002).

This study exhibits multiple strengths, including the fact that a randomized clinical trial of dose–response can provide very strong evidence for causation of an outcome, such as depressive symptoms or self-worth, by an intervention that temporally precedes it. Further, the substantial dose of vigorous exercise offered was monitored (heart rate and attendance records), which allowed examiners to quantify adherence and ensure a robust dose comparison. A considerable sample size and good retention in a community sample permit generalization to similar populations of schoolchildren. Inclusion of a substantial minority population permitted tests of moderation. The SPPC and RCDS are established measures with good psychometric qualities. Finally, a number of potential confounders were tested to assess robustness of results.

Despite these strengths, there are some limitations. Although the results of the a priori linear contrasts and the ordered nature of the means together confirmed the hypothesis that there is a linear dose–response relation of aerobic training with psychological outcomes, the post hoc pairwise comparisons did not discriminate the lower dose from the other conditions. Thus, further studies are needed to determine whether there is an effective dose of exercise below 40 min of daily aerobic training, because the 20 min dose was not proved efficacious. Nonetheless, this study provided more information than could a study that did not include the low dose condition. For instance, the pattern of results reveals a linear relation of dose with increasing benefits, rather than a quadratic relation. These findings are limited to a sample of White and Black overweight children, and cannot be generalized to lean children, or children of other races without further research. Results from this healthy, community sample may not extend to clinically depressed children. As a result, there may be floor effects—there could be greater effects on depressive symptoms and self-worth in a clinically depressed sample. Use of a no-exercise control group does not isolate exercise per se; an attention-control condition would be necessary to rule out effects of enrollment in an after-school program (such as social support). However, the dose–response findings belie this explanation, given that both dose groups spent equal time at our facility with peers and instructors. The finding that exercises improved self-worth in White, but not Black children suggests that the SPPC may not be an appropriate measure of self-worth in Black children. The construct of self-worth may vary by culture, and the SPPC may not assess the values associated with self-worth for the Black culture. Furthermore, the mediation effect could be due to confounding between similar contemporaneous self-report measures of related constructs (SPPC and RCDS). Younger children may have difficulty reporting mood states over time. While analyses met traditional criteria for mediation of the effect of exercise on depressive symptoms via GSW, the empirical test of the indirect effect in Whites did not reach the $p < .05$ level. This sample may not have provided adequate power for this empirical test of moderated mediation.

This study is the first experimental demonstration of a dose–response benefit of exercise on depressive symptoms and self-worth in overweight, sedentary children. The unexpected finding that exercise led to increased GSW only in Whites calls for further study on the influence of race on psychosocial consequences of obesity.
and exercise. This work may be helpful in engaging minority children in health promotion programs. Ideally, programs offering attractive, affordable, and enjoyable opportunities for regular, vigorous physical activity would be offered to all children. After-school programs would be needed to impart 40 min of daily aerobic activity, the dose that was efficacious to reduce depressive symptoms and improve aspects of self-worth.

Acknowledgments

Dr Andrew F. Hayes assisted with the moderated mediation analysis. Kashala Carter, Catrina Creech, Shena Givens, Sara Groves, Abby Messick, Stephanie Moore, Jennifer Murphy, Ankur Pogula, Laura Power, and Deena Walker are acknowledged for data collection, entry, and management. This manuscript reports additional results from the same study as the following: Davis, Boyle, Tkacz, Gregoski, & Lovrekovic (2006), Obesity, 14(11), 1985–91; Tomporowski, Davis, Miller, & Naglieri (2008), Educational Psychology Review, 20(2), 111–131; Davis, Waller, Boyle, Tomporowski, Gregoski, Miller, & Naglieri (2007), Research Quarterly for Exercise and Sport, 78, 510–9; Tkacz, Davis, Young-Hyman, & Boyle (2008), Pediatric Exercise Science, 20(4), 390–401; Tomporowski, Davis, Lambourne, Gregoski, & Tkacz (2008), Journal of Sport & Exercise Psychology, 30(5), 497–511; Davis & Lambourne (in press), in Audiffren, McMorris & Tomporowski (Eds.), Exercise & Cognition, John Wiley and Sons.

Funding

National Institutes of Health (grant numbers DK60692, DK70922 to C.L.D. and HL66993).

Conflicts of interest: None declared.

Received September 24, 2007; revisions received January 13, 2009; accepted January 16, 2009

References


