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Effects of Aerobic Training, Resistance Training, or Both on Psychological Health in Adolescents with Obesity: The HEARTY Randomized Controlled Trial

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Objective: To determine the effects of aerobic training, resistance training, and combined training on mood, body image, and self-esteem in adolescents with obesity. **Method:** After a 4-week prerandomization treatment, 304 postpubertal adolescents (91 males, 213 females) with obesity ages 14–18 years were randomized to 1 of 4 groups for 22 weeks: aerobic training ($n = 75$), resistance training ($n = 78$), combined aerobic and resistance training ($n = 75$), or nonexercising control ($n = 76$). All participants received dietary counseling, with a daily energy deficit of 250 kcal. Mood was measured using the Brunel Mood Scale. Body image was assessed using the Multiple Body Self-Relations Questionnaire, and physical self-perceptions and global self-esteem were measured using the Harter Physical Self-Perceptions Questionnaire. **Results:** Median adherence was 62%, 56%, and 64% in aerobic, resistance, and combined training, respectively. Resistance and combined training produced greater improvements than control on vigor, and resistance training reduced depressive symptoms. All groups improved on body image and physical self-perceptions, but combined showed greater increases than control on perceived physical conditioning, while only resistance training showed greater increases than controls on global self-esteem. Both combined and resistance training demonstrated greater increases in perceived strength than control. Psychological benefits were more related to better adherence and reductions in body fat than changes in strength or fitness. **Conclusion:** Resistance training, alone or in combination with aerobic training, may provide psychological benefits in adolescents with overweight or obesity, and therefore could be an alternative to aerobic training for some individuals in the biological and psychological management of adolescent obesity.

What is the public health significance of this article?

The findings suggest that 6 months of resistance training at a frequency of 3–4 sessions per week, either alone or in combination with aerobic training, may improve psychological health in adolescents with obesity.

This trial demonstrated that resistance training may provide psychological benefits among adolescents with obesity, and therefore may represent a potential exercise alternative for youth who find aerobic training uncomfortable or unenjoyable.

Keywords: obesity, adolescents, resistance exercise, aerobic exercise, body image, mood, self-esteem

Childhood obesity is reaching epidemic proportions, with approximately 30% of North American children and adolescents classified as overweight or obese (Roberts, Shields, de Groh, Aziz, & Gilbert, 2012; Ogden, Carroll, Kit, & Flegal, 2014). Although the medical complications of obesity in youth and adulthood are well documented (Ball & McCargar, 2003), a growing body of evidence has suggested the adverse psychosocial sequelae of obesity may be just as concerning. For example, youth with obesity have an increased risk of depression (Goldfield et al., 2010b; Wardle & Cooke, 2005), weight-based teasing (Eisenberg, Neumark-Sztainer, & Story, 2003; Goldfield et al., 2010a), diminished self-esteem (Wang, Wild, Kipp, Kuhle, & Veugelers, 2009), and social marginalization, stigma, and discrimination (Puhl & Latner, 2007).

Body image disturbance is another psychosocial consequence of obesity in youth. Converging evidence based on systematic reviews has indicated that youth who are overweight/obese exhibit greater body dissatisfaction than normal-weight peers (Ricciardelli & McCabe, 2001). The clinical relevance of this is derived from the fact that body dissatisfaction often leads to strict dieting behavior in attempts to lose weight. Severe dietary restraint is a known risk factor in the development and maintenance of binge eating and other eating disorders (Polivy & Herman, 1985), and is cross-sectionally and longitudinally associated with obesity and weight gain in youth (Claus, Braet, & Decaluwé, 2006; Field et al., 2003). In addition, body dissatisfaction is associated with poor self-esteem and depression (Rawana, 2013), as well as substance abuse, delinquency, and school drop-out in adolescents (Marti, Stice, & Springer, 2010). Taken together, interventions that can enhance body image,

mood, and self-esteem in adolescents with obesity are much needed.

Although aerobic exercise is useful in the management of pediatric obesity (Epstein & Goldfield, 1999), the psychological effects in this population are less known. Systematic reviews have shown that aerobic exercise can reduce depression and anxiety (Larun, Nordheim, Ekeland, Hagen, & Heian, 2006) and improve self-esteem in youth, but few of these trials consisted of youth with obesity (Ekeland, Heian, & Hagen, 2005). In adolescents with obesity, aerobic exercise improved physical self-perceptions and global self-esteem in one trial (Daley, Copeland, Wright, Roalfe, & Wales, 2006) but not another (Goldfield, Adamo, Rutherford, & Murray, 2012). A recent meta-analysis of 57 studies found that aerobic exercise was associated with positive body image, but only two intervention studies were conducted in adolescents, and neither used obese samples. However, we recently showed aerobic exercise enhanced body image in a small sample of adolescents with obesity (Goldfield et al., 2012), providing evidence that this modality can be helpful.

Aerobic training is often poorly tolerated and perceived as uncomfortable in youth with obesity (Ekkekakis & Lind, 2006). Resistance training might be a more attractive alternative for youth with obesity because these individuals have a higher fat-free mass, which may lead to more rapid gains in strength, which, in turn, may lead to enhancements in psychological health. Very little research has examined the psychological effects of resistance training in youth with obesity. A recent systematic review showed small and inconsistent findings in preadolescent children, but only 13 studies were included and the quality of the data based on experimental design was rated as poor (Schranz, Tomkinson, &

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Olds, 2013). We only found one study that assessed the independent impact of resistance training on a marker of psychological health in adolescents with obesity. Schranz, Tomkinson, Parletta, Petkov, and Olds (2014) found that 6 months of supervised resistance training (3 sessions per week for 75 min) improved global self-esteem, exercise self-efficacy, and a trend toward improved physical-self-worth compared with nonexercising controls in 56 adolescent males with obesity in a randomized trial. Although these data are encouraging, additional research with larger samples, inclusion of both genders, and implementation of a broader measurement battery is warranted to better determine the psychological effects of resistance training in youth with obesity.

We designed the Healthy Eating Aerobic and Resistance Training in Youth (HEARTY) Trial to determine the effects of aerobic training, resistance training, or their combination on body composition, and found that all exercise modalities were effective in reducing body fat in adolescents with obesity (Sigal et al., 2014). The present article reports our results for prespecified secondary outcomes related to psychological health, reflected in body image, mood, and self-esteem in adolescents with overweight or obesity. We hypothesized that resistance training, either alone or in combination with aerobic training, would provide comparable or greater psychological benefits than aerobic training or nonexercising control. A secondary aim of this study was to compare the association between changes in psychological outcomes with changes in body composition, cardiorespiratory fitness, and body composition.

Method

Design

This was a single-blind, randomized controlled trial (RCT) with a parallel group design conducted at a single center. Once baseline testing was completed, participants entered a prerandomization period including supervised moderate-intensity exercise training four times weekly for 4 weeks, whereby participants were exposed to both aerobic and resistance training. To qualify for randomization, participants needed to attend at least 13 of 16 prescribed exercise sessions ($> 80\%$ adherence) during the prerandomization period. Participants ($n = 304$) were randomized into one of four groups for 22 weeks: aerobic training (aerobic, $n = 75$), resistance training (resistance, $n = 78$), combined aerobic and resistance training (combined, $n = 75$), or nonexercising control (control, $n = 76$). Outcome assessors were blinded to ensure unbiased measurement.

Participants

Of the 1,285 adolescents assessed, 358 met eligibility criteria and entered the prerandomization period, among whom 304 were randomized (see Figure 1). Inclusion criteria were postpubertal (Tanner stage IV–V; Marshall & Tanner, 1969; Marshall & Tanner, 1970) adolescents ages 14–18 years with a body mass index (BMI) in the 95th percentile or higher for age and sex (as described at <http://www.cdc.gov/growthcharts>) and/or the 85th percentile or higher with an additional diabetes or cardiovascular risk factor. Ninety-three percent (282 of 304) of participants were living with obesity. Exclusion criteria were habitual exercise more than twice

weekly for more than 20 min per session, diabetes mellitus, or any illness or disability rendering study exercise programs inadvisable or unfeasible. Routine school physical education classes were not an exclusion criterion. For participants taking medication likely to affect body composition (e.g., metformin, oral contraceptives, stimulants), the dose was required to have been stable over the previous 2 months and to remain unchanged throughout the trial. More detail on rationale, design, and method can be found elsewhere (Alberga et al., 2012).

The coordinator reviewed the study protocol, inclusion and exclusion criteria, and obtained informed consent according to the Canadian Tri-Council policy statement guidelines (Canadian Institutes of Health Research, Natural Sciences and Engineering Research Council of Canada, & Social Sciences and Humanities Research Council of Canada, 2010). A parent or guardian was asked to cosign the consent form of any participant under the age of 16 years. This study was reviewed and approved by the research ethics boards at the Children's Hospital of Eastern Ontario and Ottawa Hospital. The trial began in March 2005 and was completed in June 2011.

Intervention

All participants received counseling by a registered dietitian to promote healthy eating with a daily energy deficit of 250 kcal. In addition, the three exercising groups were asked to attend gyms four times weekly. The aerobic group exercised on treadmills, elliptical machines, and/or bicycle ergometers. Heart rate monitors (Polar Electro, Kempele, Finland) were used to adjust workloads to achieve target heart rates. Participants in the aerobic group gradually increased duration of exercise in each session, starting with 20 min and progressing to 45 min, as well as intensity, starting with 65% and progressing to 85% of maximum heart rate. The resistance group also progressed from 20–45 min per session, performing seven exercises using weight machines or free weights, and progressing from two sets of 15 repetitions at moderate intensity to three sets of eight repetitions at the maximum resistance (8-RM) that could be moved eight times. The combined group did the full aerobic training program plus the resistance training program during each session, and followed the same gradual progression as the aerobic and resistance training programs. Further details on the intervention can be obtained elsewhere (Alberga et al., 2012).

Setting

Exercise training took place at six community-based facilities and was supervised by personal trainers twice weekly during the prerandomization period, weekly from randomization to 3 months, and biweekly from 3–6 months. Personal trainers monitored attendance and exercise progression by reviewing sign-in sheets and exercise logs. Intervention adherence was calculated as total number of exercise sessions attended divided by the total number of sessions prescribed.

Measurements

Demographic and anthropometric variables. At baseline, background information was obtained from all participants, including demographics (e.g., age, race, ethnicity, parental education),

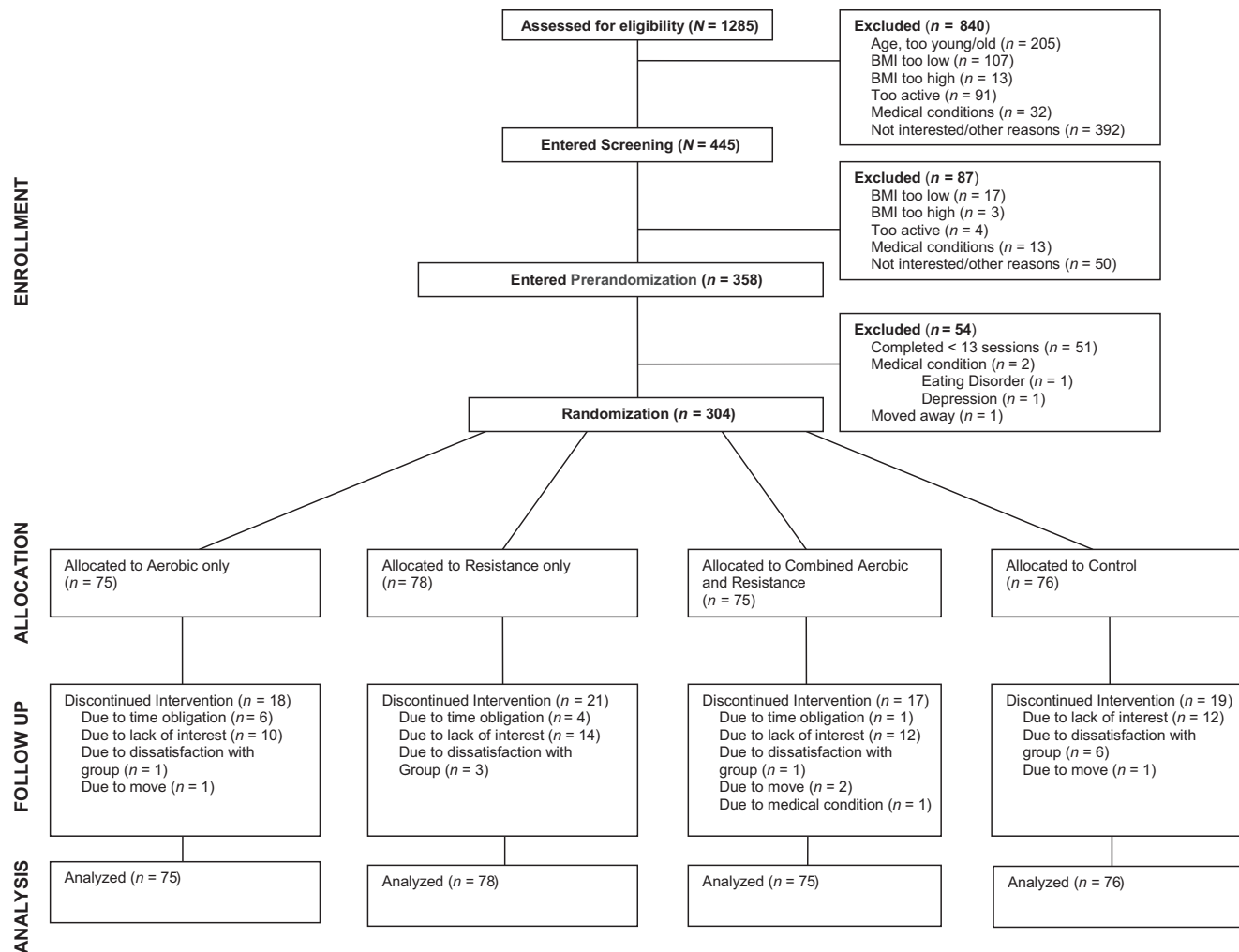


Figure 1. HEARTY Trial flow diagram. The sample size for the final analysis varied slightly across psychological outcomes. BMI = body mass index. Adapted from "Healthy Eating, Aerobic and Resistance Training in Youth (HEARTY): Study Rationale, Design and Methods," by A. S. Alberga, G. S. Goldfield, G. P. Kenny, S. Hadjiyannakis, P. Phillips, D. Prud'homme, . . . R. J. Sigal, 2012, *Contemporary Clinical Trials*, 33, p. 839–847, Copyright 2012 by Elsevier.

self-reported pubertal status (Marshall & Tanner, 1969; Marshall & Tanner, 1970), measured height and weight for BMI calculations, and self-reported physical activity, family medical history, and current medical status and medications to evaluate inclusion criteria. Body fat was assessed by magnetic resonance imaging (Echospeed, signal 11 version; GE Medical Systems) at baseline and 6 months. Participants lay in a supine position for whole-body cross-sectional images using protocols by Ross and colleagues (Ross, Léger, Morris, de Guise, & Guardo, 1992; Ross, Rissanen, Pedwell, Clifford, & Shragge, 1996).

Body image. Body image was assessed using the 34-item Multiple Body Self-Relations Questionnaire—Appearance Scales (MBSRQ-AS; Cash, 2000). Participants rated their attitudes toward various aspects of their body weight and shape based on a 5-point Likert scale, ranging from 1 (*definitely disagree*) to 5 (*definitely agree*). The questionnaire includes five independent subscales previously developed through factor analysis: Appearance Evaluation, Appearance Orientation, Overweight Preoccupa-

tion, Self-Classified Weight, and the Body Areas Satisfaction Scale. Appearance Evaluation assesses feelings of physical attractiveness or unattractiveness, and satisfaction or dissatisfaction with one's looks. High scores reflect feeling more positive and satisfied with one's appearance. Appearance Orientation assesses the extent of investment in one's appearance. High scorers place more importance on how they look, pay attention to their appearance, and engage in extensive grooming behaviors. Low scorers are apathetic about their appearance; their looks are not especially important. The Body Areas Satisfaction Scale is similar to the Appearance Evaluation subscale, except that the former taps satisfaction with discrete aspects of one's appearance. High scores reflect contentment with most areas of the body, while low scores reflect unhappiness with the size or appearance of several areas. Overweight Preoccupation assesses a construct reflecting fat anxiety, weight vigilance, dieting, and eating restraint, with higher scores reflect-

ing greater fat anxiety and eating restraint. Self-Classified Weight reflects how one perceives and labels one's weight from very underweight to very overweight. Data on this subscale were not reported because all participants were overweight or obese and intervention rarely impacts perceived or actual weight classification. The MBSRQ-AS was developed for adolescents and adults, and has shown strong reliability, with Cronbach's alphas for males and females ranging from 0.70–0.91, and 1-month test–retest reliability ranging from 0.73–0.94. The MBSRQ-AS has also demonstrated excellent construct validity (Brown, Cash, & Mikulka, 1990). In the current study, Cronbach's alpha was 0.78 at baseline and 6 months, and subscales ranged from 0.62–0.89 at baseline and 6 months, indicating good internal consistency.

Physical self-perceptions and global self-esteem. Physical self-perceptions were assessed using the Physical Self-Perception Profile for Children (Fox & Corbin, 1989; Whitehead, 1995). This 36-item inventory is designed to measure youth's perceived competence in five domains of functioning: Sport, Physical Conditioning, Body Appearance, Strength, and a higher order construct, the Physical Self-Worth Scale. The Harter Global Self-Esteem subscale (Harter, 1985) was added to evaluate the extent to which the youth likes himself/herself as a person and is happy with the way he or she is. As such, this dimension constitutes a global dimension of one's self-worth as a person, rather than domain-specific competency or adequacy. These domains were discriminated from each other using factor analytic procedures (Fox & Corbin, 1989). This questionnaire adopts a response format that includes both positively and negatively worded phrases to control for socially desirable responses. Each response has two components whereby children first choose the direction and then the intensity of their response. For example, they would first circle one of the following two statements that are most true of themselves: "Some kids are often unhappy with themselves" BUT "other kids are pretty pleased with themselves." The second step in completing responses would be to rate whether the statement circled is "sort of true for me" or "really true for me." Items are scored on a 4-point rating scale (1–4), with higher numbers reflecting greater competence and self-esteem. In the current study, Cronbach's alphas were 0.93 at baseline and 0.95 at 6 months, with alphas on subscales ranging from 0.83–0.91 at baseline and 6 months.

Mood. Mood was assessed using the 24-item Brunell Mood Scale (BRUMS; Terry, Lane, Lane, & Keohane, 1999), which was adapted for adolescents based on the 65-item Profile of Mood States inventory developed by McNair, Lorr, and Droppleman (1971). Confirmatory factor analysis revealed that the BRUMS has six subscales; Fatigue, Anger, Tension, Confusion, Vigor, and Depression, with each subscale consisting of four items. Respondents indicate whether they have experienced such feelings on a 5-point scale (0 = *not at all*, 1 = *a little*, 2 = *moderately*, 3 = *quite a bit*, and 4 = *extremely*). The standard response timeframe for participants was: "How you have felt during the past week including today?" This questionnaire has been shown to have strong psychometric properties in adolescents, including strong internal consistency (Cronbach's alpha ranging from 0.75 to 0.86) and concurrent validity with other criterion measures of mood ($r = .52$ to $r = .80$) such as the Positive and Negative Affect Schedule and State-Trait Anger Expression Inventory (Terry et al., 1999). Cronbach alpha for this scale in the current study was strong (0.90)

at both baseline and 6 months. Cronbach alphas on subscales ranged from 0.63–0.87 from baseline to 6 months.

Cardiorespiratory fitness. Peak oxygen consumption ($\text{VO}_{2\text{peak}}$, in millimeters of oxygen per kilogram of body weight per minute) was measured at baseline and 6 months by indirect calorimetry using a metabolic cart (MOXUS Modular Metabolic System; AEI Technologies) during a Balke–Ware treadmill test, whereby participants terminated on volitional exhaustion or desire to stop (Balke, 1963).

Strength. An 8-RM evaluation was performed on bench press, leg press, and seated row machines to assess muscular strength at baseline and 6 months. However, only bench press was used in the analyses to reflect strength because most of the strength training exercises targeted upper body, thus we believed it to be the best marker of strength in our study.

Statistical Analysis

Linear mixed-effects regression modeling for repeated measures was used to assess the effects of exercise training modality on changes in psychological health over time, with indicators of body image, mood, and self-concept as the dependent variables, and Time, Group (aerobic, resistance, combined, control), and Time $\times$ Group interaction as the independent variables, with adjustment for age and sex. An unstructured covariance matrix was specified for the covariance of the repeated measures. The model fit was examined using residual plots. We performed analyses on an intention-to-treat basis that included all randomly allocated participants (including those who later withdrew). Although somewhat controversial, we did not adjust for multiple comparisons due to the novelty of this trial and to protect against increasing the odds of type II errors. In addition, as recommended by Rothman (1990), not making adjustments for multiple comparisons is preferable because it will lead to fewer errors of interpretation when the data under evaluation are not random numbers but actual observations on nature. Associations between changes from baseline to 6 months in body fat, strength fitness, and psychological outcomes and adherence were assessed by Spearman correlations. Analyses were conducted using SAS, Version 9.4 (SAS Institute, Cary, NC).

Results

Table 1 shows baseline characteristics of the sample. There were no intergroup baseline differences. Most participants (282 of 304 [92.8%]) met criteria for obesity ($\text{BMI} \geq 95\text{th}$ percentile for age and sex). The sample was mainly White and came from well-educated parents.

Adherence and Attrition

From baseline to 26 weeks, median exercise training adherence was 62% (interquartile range [IQR], 36%–81%) in aerobic, 56% (IQR, 37%–75%) in resistance, and 64% (IQR, 39%–75%) in combined, with no significant differences between groups. Seventy-five participants (25%) withdrew between randomization and 6 months: 18 (24%) from aerobic, 21 (28%) from resistance, 17 (23%) from combined, and 19 (25%) from control. Attrition rates did not differ between groups. The main reasons for withdrawal were lack of interest and lack of time.

Table 1
Baseline Participant Characteristics ($n = 304$)

Variables	Total sample ($n = 304$)	Aerobic training group ($n = 75$)	Resistance training group ($n = 78$)	Combined training group ($n = 75$)	Control group ($n = 76$)
Age (years)	15.6 (1.4)	15.5 (1.4)	15.9 (1.5)	15.5 (1.3)	15.6 (1.3)
Height (cm)	167.8 (7.4)	166.8 (7.0)	168.3 (7.5)	167.5 (7.6)	168.8 (7.7)
Weight (kg)	98.0 (16.9)	96.7 (15.1)	99.9 (17.4)	97.5 (16.3)	97.9 (18.8)
BMI (kg/m^2)	34.6 (4.5)	34.6 (4.2)	35.1 (4.6)	34.6 (4.2)	34.1 (4.9)
Males No. (%)	91 (29.9)	22 (29.3)	23 (29.5)	22 (29.3)	24 (31.6)
Females No. (%)	213 (70.1)	53 (70.7)	55 (70.5)	53 (70.7)	52 (68.4)
Race/ethnicity, n (%)					
White	219 (72.0)	54 (72.0)	55 (70.5)	47 (62.7)	63 (82.9)
Black	31 (10.2)	6 (8.0)	11 (14.1)	12 (16.0)	2 (2.6)
Mixed	14 (4.6)	5 (6.7)	2 (2.6)	3 (4.0)	4 (5.3)
Arabic	11 (3.6)	4 (5.3)	1 (1.3)	4 (5.3)	2 (2.6)
Asian	10 (3.3)	1 (1.3)	5 (6.4)	2 (2.7)	2 (2.6)
Hispanic	9 (3.0)	4 (5.3)	2 (2.6)	3 (4.0)	0
Other	6 (2.0)	1 (1.3)	2 (2.6)	2 (2.7)	1 (1.3)
Native Canadian	4 (1.3)	0	0	2 (2.7)	2 (2.6)

Note. Continuous data are presented as means (standard deviations); categorical data are presented as frequency counts and percentages. BMI = body mass index.

Body Image

Table 2 presents the effects of exercise interventions on dimensions of body image. There was no significant Group $\times$ Time interaction for Appearance Evaluation, $F(6, 284) = 0.65$, $p = .69$. However, the main effect of Time was significant, $F(2, 217) = 34.0$, $p < .001$, with all groups showing significant improvements.

The Group $\times$ Time interaction for Body Areas Satisfaction Scale was not significant, $F(6, 281) = 1.71$, $p = .12$, indicating the changes between groups over time did not significantly differ. However, the main effect of Time was significant, $F(2, 214) = 45.5$, $p < .001$, because groups showed significant improvements from baseline to 6 months, as shown in Table 2.

The Group $\times$ Time interaction on the Overweight Preoccupation subscale was not significant, $F(6, 290) = 1.3$, $p = .29$, indicating that changes between groups did not significantly differ from baseline to 6 months. However, there was a main effect of Time, $F(2, 222) = 6.0$, $p = .003$, whereby only the combined group significantly changed over time, but no other within-group or between-groups changes emerged.

There were no significant within-group or between-group differences over time on Appearance Orientation.

Mood

Table 3 presents the effects of exercise intervention on indicators of mood. The Group $\times$ Time interaction on Anger was not significant, $F(6, 296) = 0.36$, $p = .90$. However, there was a main effect of Time, $F(2, 226) = 14.9$, $p < .001$, whereby all exercise groups showed significant reductions in anger from baseline to 6 months, but no changes over time were found for controls.

The Group $\times$ Time interaction on Depression was not significant, $F(6, 292) = 0.7$, $p = .65$, indicating that changes between groups over time did not differ. However, there was a significant main effect of Time, $F(2, 223) = 6.8$, $p < .001$, whereby only the resistance group showed a significant reduction in depressive symptoms from baseline to 6 months ($p = .02$).

The Group $\times$ Time interaction for Vigor was significant, $F(6, 298) = 3.34$, $p = .003$, whereby aerobic, resistance, and combined showed greater increases than controls ($ps < .05$), as shown in Table 3. The main effect of Time was significant, $F(2, 229) = 15.33$, $p < .001$, whereby all exercise groups increased from baseline to 6 months, but not controls.

There were no significant Group $\times$ Time interactions or main effects of Time on the Confusion, Fatigue, or Tension subscales, as shown in Table 3.

Physical Self-Perceptions and Global Self-Esteem

Table 4 presents data on the effects of exercise intervention on physical self-perceptions and global self-esteem. The Group $\times$ Time interaction on Self-Perceived Sport skills was not significant, $F(6, 255) = 0.33$, $p = .92$. However, there was a significant main effect of Time, $F(2, 195) = 31.5$, $p < .001$, whereby all groups increased significantly from baseline to 6 months ($ps < .001$).

The Group $\times$ Time interaction for perceived Physical Conditioning was significant, $F(6, 266) = 2.85$, $p = .03$, with the combined group showing greater increases than controls. There was also a significant main effect of Time, $F(2, 205) = 55.7$, $p < .001$, whereby all groups showed significant increases from baseline to 6 months ($ps < .001$).

The Group $\times$ Time interaction in perceived Strength was significant, $F(6, 260) = 2.37$, $p = .03$, with both resistance and combined showing greater increases than control. The main effect of Time was significant, $F(2, 199) = 39.8$, $p < .001$, as all groups reported significant increases from baseline to 6 months.

The Group $\times$ Time interaction on perceptions of Physical Self-Worth was not significant, $F(6, 255) = 0.81$, $p = .56$. However, there was a significant main effect of Time, $F(2, 195) = 48.5$, $p < .001$, whereby all groups reported increases from baseline to 6 months.

The Group $\times$ Time interaction on Global Self-Esteem was significant, $F(6, 253) = 3.31$, $p = .02$, whereby resistance was

Table 2

Intention-to-Treat Analysis of Body Image at Baseline and Changes After 6 Months

Variable	n	M (SE)		Mean difference [95% confidence interval]		p	ES
		Baseline	6 months	Within-group change from baseline to 6 months	Between-group change from baseline to 6 months		
Appearance evaluation							
Aerobic	72	2.4 (0.1)	2.7 (0.1)	0.3 [0.1, 0.4]		<.001	0.46
Resistance	78	2.4 (0.1)	2.8 (0.1)	0.4 [0.3, 0.6]		<.001	0.67
Combined	73	2.3 (0.1)	2.7 (0.1)	0.4 [0.2, 0.5]		<.001	0.62
Control	75	2.5 (0.1)	2.7 (0.1)	0.2 [0.1, 0.4]		.004	0.39
Aerobic vs. control					0.1 [−0.2, 0.3]	.61	0.07
Resistance vs. control					0.2 [−0.0, 0.4]	.09	0.22
Combined vs. aerobic					0.1 [−0.1, 0.3]	.49	0.09
Combined vs. resistance					0.0 [−0.3, 0.20]	.63	−0.06
Combined vs. control					0.2 [−0.1, 0.4]	.22	0.17
Appearance orientation							
Aerobic	72	3.4 (0.1)	3.4 (0.1)	0.0 [−0.1, 0.1]		.87	0.02
Resistance	78	3.3 (0.1)	3.4 (0.1)	0.1 [−0.1, 0.1]		.95	0.01
Combined	73	3.4 (0.1)	3.5 (0.1)	0.1 [−0.1, 0.2]		.18	0.18
Control	75	3.4 (0.1)	3.4 (0.1)	0.0 [−0.2, 0.1]		.56	−0.08
Aerobic vs. control					0.0 [−0.1, 0.2]	.61	0.07
Resistance vs. control					0.1 [−0.1, 0.2]	.66	0.06
Combined vs. aerobic					0.1 [−0.1, 0.2]	.42	0.11
Combined vs. resistance					0.0 [−0.1, 0.3]	.38	0.12
Combined vs. control					0.1 [−0.1, 0.3]	.18	0.18
Body satisfaction							
Aerobic	72	2.6 (0.1)	3.0 (0.1)	0.4 [0.2, 0.5]		<.001	0.71
Resistance	75	2.7 (0.1)	3.1 (0.1)	0.4 [0.2, 0.5]		<.001	0.7
Combined	71	2.6 (0.1)	3.0 (0.1)	0.4 [0.2, 0.5]		<.001	0.68
Control	75	2.8 (0.1)	3.0 (0.1)	0.2 [0.1, 0.3]		.002	0.42
Aerobic vs. control					0.2 [−0.0, 0.4]	.09	0.23
Resistance vs. control					0.2 [−0.0, 0.4]	.08	0.23
Combined vs. aerobic					0.0 [−0.2, 0.2]	.73	−0.05
Combined vs. resistance					0.0 [−0.2, 0.2]	.67	−0.06
Combined vs. control					0.2 [−0.1, 0.3]	.17	0.18
Weight preoccupation							
Aerobic	73	2.5 (0.1)	2.6 (0.1)	0.1 [−0.0, 0.3]		.11	0.21
Resistance	78	2.5 (0.1)	2.5 (0.1)	0.0 [−0.1, 0.2]		.60	0.07
Combined	73	2.5 (0.1)	2.7 (0.1)	0.2 [0.0, 0.4]		.02	0.31
Control	75	2.6 (0.1)	2.6 (0.1)	0.0 [−0.2, 0.2]		.81	−0.03
Aerobic vs. control					0.1 [−0.1, 0.4]	.19	0.17
Resistance vs. control					0.0 [−0.2, 0.3]	.58	0.07
Combined vs. aerobic					0.1 [−0.2, 0.3]	.60	0.07
Combined vs. resistance					0.2 [−0.1, 0.4]	.20	0.17
Combined vs. control					0.2 [0.0, 0.5]	.06	0.25

Note. ES = effect size (Cohen's *d*).

the only group to report greater increases than control. There was a main effect of Time, $F(2, 194) = 21.2, p < .001$, whereby all the exercise groups reported significant increases in Global Self-Esteem ($ps < .01$) from baseline to 6 months, but not controls.

Body Composition, Cardiorespiratory Fitness, and Strength

The Group $\times$ Time interaction on Percent Body Fat was significant, $F(3, 217) = 3.87, p = .01$, whereby compared with control, resistance training (-1.6 vs. $-0.3, p = .002$) and combined training (-1.4 vs. $-0.3, p = .01$) showed greater reductions, but aerobic training showed a nonsignificant trend (-1.1 vs. $-0.3, p = .06$). The main effect of Time was significant, $F(1, 217) = 54.7, p < .001$, as all exercise groups

but not the control group reduced body fat significantly from baseline to 6 months.

A Group $\times$ Time interaction on Aerobic Fitness ($\text{Vo}_{2\text{peak}}$) was significant, $F(3, 205) = 3.6, p = .015$, whereby the aerobic group showed a greater increase than controls. There were no other significant group differences over time. The main effect of Time was significant, $F(1, 205) = 24.36, p < .001$, whereby the aerobic and combined groups significantly increased their Fitness from baseline to 6 months.

A Group $\times$ Time interaction on Strength (8-RM bench press) was significant, $F(6, 239) = 8.6, p < .001$, whereby the combined and resistance groups demonstrated greater increases than both the aerobic and control groups. However, no differences over time in Strength were found between the combined and resistance training groups. A main effect of Time was significant, $F(2, 183) = 79.5,$

Table 3

Intention-to-Treat Analysis of Mood at Baseline and Changes After 6 Months

Variable	<i>n</i>	<i>M (SE)</i>		Mean difference [95% confidence interval]		<i>p</i>	ES
		Baseline	6 months	Within-group change from baseline to 6 months	Between-group change from baseline to 6 months		
Anger							
Aerobic	73	4.1 (0.4)	3.1 (0.4)	−1.0 [−1.8, −0.2]		.02	−0.3
Resistance	78	4.2 (0.4)	2.9 (0.4)	−1.3 [−2.2, −0.5]		.001	−0.41
Combined	72	4.4 (0.4)	3.3 (0.4)	−1.1 [−1.9, −0.3]		.01	−0.35
Control	75	4.9 (0.4)	4.3 (0.4)	−0.6 [−1.4, 0.1]		.11	−0.21
Aerobic vs. control					−0.3 [−1.4, 0.8]	.57	−0.07
Resistance vs. control					−0.7 [−1.8, 0.4]	.22	−0.16
Combined vs. aerobic					−0.1 [−1.2, 1.0]	.85	−0.02
Combined vs. resistance					0.2 [−0.9, 1.4]	.63	0.06
Combined vs. control					−0.4 [−1.6, 0.7]	.44	−0.10
Confusion							
Aerobic	73	3.4 (0.4)	2.6 (0.4)	−0.8 [−1.7, 0.0]		.05	−0.26
Resistance	78	3.3 (0.4)	2.9 (0.4)	−0.4 [−1.3, 0.4]		.29	−0.14
Combined	71	3.7 (0.4)	3.0 (0.4)	−0.7 [−1.6, 0.1]		.08	−0.23
Control	75	3.3 (0.4)	3.3 (0.4)	0.0 [−0.7, 0.9]		.84	0.03
Aerobic vs. control					−0.8 [−2.1, 0.3]	.12	−0.20
Resistance vs. control					−0.4 [−1.7, 0.6]	.37	−0.12
Combined vs. aerobic					0.1 [−1.1, 1.3]	.86	0.02
Combined vs. resistance					−0.3 [−1.5, 0.9]	.64	−0.06
Combined vs. control					−0.7 [−2.0, 0.3]	.17	−0.18
Depression							
Aerobic	73	2.5 (0.3)	2.1 (0.4)	−0.4 [−1.3, 0.4]		.32	−0.13
Resistance	78	2.7 (0.3)	1.7 (0.4)	−1.0 [−1.9, −0.1]		.02	−0.29
Combined	72	2.6 (0.3)	2.6 (0.4)	0.0 [−0.8, 0.8]		.99	0
Control	75	2.8 (0.3)	2.7 (0.4)	−0.1 [−0.9, 0.8]		.96	−0.01
Aerobic vs. control					−0.3 [−1.6, 0.8]	.5	−0.09
Resistance vs. control					−0.9 [−2.2, 0.2]	.08	−0.21
Combined vs. aerobic					0.4 [−0.8, 1.6]	.48	0.09
Combined vs. resistance					1 [−0.2, 2.2]	.1	0.21
Combined vs. control					0.1 [−1.2, 1.2]	.98	0
Fatigue							
Aerobic	73	6.7 (0.4)	5.8 (0.5)	−0.9 [−2.1, 0.2]		.1	−0.2
Resistance	78	7.4 (0.4)	7.0 (0.5)	−0.4 [−1.62, 0.74]		.46	−0.09
Combined	72	6.8 (0.5)	6.9 (0.5)	0.1 [−1.0, 1.2]		.88	0.02
Control	75	6.6 (0.4)	6.6 (0.5)	0.0 [−1.1, 1.2]		.95	0.01
Aerobic vs. control					−0.9 [−2.6, 0.6]	.23	−0.15
Resistance vs. control					−0.4 [−2.1, 1.2]	.56	−0.07
Combined vs. aerobic					1.0 [−0.6, 2.7]	.2	0.16
Combined vs. resistance					0.5 [−1.1, 2.2]	.52	0.08
Combined vs. control					0.1 [−1.6, 1.7]	.95	0.01
Tension							
Aerobic	73	3.7 (0.4)	3.3 (0.4)	−0.4 [−1.3, 0.5]		.39	−0.11
Resistance	78	3.4 (0.4)	2.9 (0.4)	−0.5 [−1.5, 0.4]		.27	−0.14
Combined	72	4.0 (0.4)	3.2 (0.4)	−0.8 [−1.6, 0.2]		.12	−0.2
Control	75	3.7 (0.4)	3.7 (0.4)	0.0 [−1.0, 0.9]		.94	−0.01
Aerobic vs. control					−0.4 [−1.7, 0.9]	.58	−0.07
Resistance vs. control					−0.5 [−1.8, 0.8]	.46	−0.1
Combined vs. aerobic					−0.4 [−1.6, 1.0]	.64	−0.06
Combined vs. resistance					−0.3 [−1.5, 1.1]	.78	−0.04
Combined vs. control					−0.8 [−2, 0.6]	.3	−0.14
Vigor							
Aerobic	73	7.4 (0.4)	8.8 (0.4)	1.4 [0.6, 2.3]		.001	0.43
Resistance	78	6.6 (0.3)	7.8 (0.5)	1.2 [0.3, 2.0]		.01	0.34
Combined	72	7.3 (0.4)	8.4 (0.4)	1.1 [0.3, 2.0]		.01	0.35
Control	75	7.7 (0.4)	7.6 (0.4)	−0.1 [−1.0, 0.7]		.73	−0.05
Aerobic vs. control					1.5 [0.4, 2.8]	.01	0.34
Resistance vs. control					1.3 [0.1, 2.5]	.03	0.28
Combined vs. aerobic					−0.3 [−1.5, 0.9]	.61	−0.07
Combined vs. resistance					−0.1 [−1.3, 1.2]	.93	−0.01
Combined vs. control					1.2 [0.1, 2.4]	.04	0.28

Note. ES = effect size (Cohen's *d*).

Table 4

Intention-to-Treat Analysis of Physical Self-Perceptions and Self-Esteem at Baseline and Changes at 6 Months

Variable	n	M (SE)		Mean difference [95% confidence interval]		p	ES
		Baseline	6 months	Within-group change from baseline to 6 months	Between-group change from baseline to 6 months		
Sport competence							
Aerobic	65	14.0 (0.5)	15.5 (0.5)	1.5 [0.7, 2.3]		<.000	0.5
Resistance	74	13.5 (0.4)	15.1 (0.5)	1.6 [0.8, 2.4]		<.001	0.53
Combined	65	12.9 (0.5)	14.6 (0.5)	1.7 [0.9, 2.4]		<.001	0.57
Control	70	13.5 (0.5)	15.0 (0.5)	1.5 [0.7, 2.2]		<.000	0.53
Aerobic vs. control					0.0 [−1.1, 1.1]	.97	0.01
Resistance vs. control					0.1 [−1.0, 1.2]	.87	0.02
Combined vs. aerobic					0.2 [−1.0, 1.2]	.81	0.03
Combined vs. resistance					0.1 [−1, 1.2]	.9	0.02
Combined vs. control					0.2 [−0.9, 1.2]	.77	0.04
Physical condition							
Aerobic	65	12.1 (0.4)	14.2 (0.4)	2.1 [1.2, 2.9]		<.001	0.65
Resistance	74	11.9 (0.4)	13.8 (0.4)	1.9 [1.0, 2.7]		<.001	0.6
Combined	65	11.6 (0.4)	14.2 (0.4)	2.6 [1.8, 3.4]		<.001	0.86
Control	70	11.7 (0.4)	13.1 (0.4)	1.4 [0.7, 2.3]		<.001	0.51
Aerobic vs. control					0.7 [−0.6, 1.7]	.34	0.13
Resistance vs. control					0.5 [−0.8, 1.6]	.5	0.09
Combined vs. aerobic					0.5 [−0.6, 1.8]	.33	0.13
Combined vs. resistance					0.7 [−0.4, 1.9]	.2	0.17
Combined vs. control					1.2 [0, 2.3]	.05	0.27
Body satisfaction							
Aerobic	65	9.7 (0.4)	10.7 (0.5)	1 [0.1, 1.9]		.03	0.3
Resistance	74	9.7 (0.4)	11.6 (0.5)	1.9 [1, 2.8]		<.001	0.58
Combined	65	9.2 (0.4)	11.2 (0.5)	2.0 [1.1, 2.8]		<.001	0.62
Control	70	10.2 (0.4)	11.2 (0.5)	1.0 [0.2, 1.9]		.02	0.33
Aerobic vs. control					0.0 [−1.3, 1.2]	.96	−0.01
Resistance vs. control					0.9 [−0.3, 2.2]	.15	0.2
Combined vs. aerobic					1.0 [−0.3, 2.2]	.12	0.22
Combined vs. resistance					0.1 [−1.2, 1.3]	.94	0.01
Combined vs. control					1.0 [−0.3, 2.2]	.12	0.22
Physical strength							
Aerobic	65	16.2 (0.5)	17.8 (0.5)	1.6 [0.7, 2.4]		<.001	0.48
Resistance	74	15.9 (0.4)	18.7 (0.5)	2.8 [2, 3.7]		<.001	0.9
Combined	65	15.7 (0.5)	17.9 (0.5)	2.2 [1.4, 3]		<.001	0.72
Control	70	16.3 (0.5)	17.3 (0.5)	1.0 [0.1, 1.8]		.02	0.32
Aerobic vs. control					0.6 [−0.6, 1.8]	.32	0.14
Resistance vs. control					1.8 [0.7, 3.1]	.002	0.44
Combined vs. aerobic					0.6 [−0.5, 1.9]	.28	0.15
Combined vs. resistance					−0.6 [−1.8, 0.6]	.29	−0.14
Combined vs. control					1.2 [0.1, 2.4]	.03	0.3
Physical self-worth							
Aerobic	65	11.0 (0.4)	13.3 (0.5)	2.3 [1.3, 3.2]		<.001	0.64
Resistance	74	11.3 (0.4)	14.1 (0.6)	2.8 [1.8, 3.8]		<.001	0.79
Combined	65	10.9 (0.4)	13.5 (0.5)	2.6 [1.6, 3.5]		<.001	0.74
Control	70	11.3 (0.4)	13.0 (0.5)	1.7 [0.7, 2.6]		<.005	0.5
Aerobic vs. control					0.6 [−0.7, 2.0]	.36	0.13
Resistance vs. control					1.1 [−0.2, 2.5]	.09	0.24
Combined vs. aerobic					0.3 [−1.1, 1.6]	.69	0.05
Combined vs. resistance					−0.2 [−1.6, 1.1]	.7	−0.05
Combined vs. control					0.9 [−0.4, 2.2]	.18	0.19
Global self-esteem							
Aerobic	65	15.3 (0.5)	17.2 (0.6)	1.9 [0.9, 2.9]		<.000	0.52
Resistance	74	15.1 (0.5)	17.5 (0.6)	2.4 [1.4, 3.4]		<.001	0.67
Combined	65	15.4 (0.5)	16.6 (0.6)	1.2 [0.2, 2.1]		.01	0.34
Control	70	15.4 (0.5)	16.3 (0.6)	0.9 [0, 1.9]		.06	0.27
Aerobic vs. control					1 [−0.4, 2.4]	.16	0.2
Resistance vs. control					1.5 [0.1, 2.9]	.03	0.3
Combined vs. aerobic					−0.7 [−2.1, 0.7]	.31	−0.14
Combined vs. resistance					−1.2 [−2.6, 0.1]	.08	−0.25
Combined vs. control					0.3 [−1.1, 1.6]	.7	0.05

Note. ES = effect size (Cohen's *d*).

$p < .001$, where all groups showed increases in Strength from baseline to 6 months.

Correlations Between Changes in Body Composition, Fitness, Strength, and Psychological Health

Correlational analyses of change scores from baseline to 6 months posttreatment indicated that reductions in Body Fat were associated with increases in Body Satisfaction ($r = -0.22, p = .002$), Physical Self-Worth ($r = -0.20, p = .008$), and Global Self-Esteem ($r = -0.18, p = .01$). Increases in measured Strength were associated with increases in Perceived Physical Condition ($r = .19, p = .02$), Perceived Strength ($r = .24, p = .005$), and Physical Self-Worth ($r = .21, p = .009$). However, changes in Fitness (maximal VO_2) were not related to any changes in psychological measures. The pattern of correlation was similar when examined by exercise modality.

The relationship between adherence and changes in psychological outcomes varied by group. Adherence to the aerobic condition was not associated with any changes in psychological health indicators. However, adherence to resistance training was positively related to Appearance Evaluation ($r = .30, p = .03$), and physical self-perceptions, such as Perceived Athletic Competence ($r = .28, p = .05$) and Physical Condition ($r = .30, p = .04$). Adherence to the combined training was associated with improvements in multiple domains of body image, such as Appearance Evaluation ($r = .26, p = .05$), Appearance Orientation ($r = -0.31, p = .02$), and Overweight Preoccupation ($r = -0.33, p = .01$), as well as improvement in Perceived Strength ($r = .31, p = .02$), Physical Self-Worth ($r = .27, p = .05$), and Global Self-Esteem ($r = .28, p = .05$). Adherence was not related to any mood indicators when exercise groups were collapsed or separated by modality.

Discussion

This was the first RCT comparing effects of aerobic training, resistance training, and their combination on psychological health in a large sample of adolescents with overweight or obesity. The primary findings were that resistance training produced significantly greater improvements than controls in global self-esteem and perceived strength, while combined training produced greater changes in perceived physical conditioning. Aerobic, resistance, and combined training produced greater improvements than controls in vigor but no other group differences were found on indicators of mood. Improved psychological health was more closely associated with reductions in body fat than with changes in objectively measured fitness or strength. Adherence was associated with improved body image, physical self-perceptions, and global self-esteem in the resistance and combined training groups, but adherence was not related to any psychological outcome in the aerobic group.

In the only study to examine the independent effects of resistance training in adolescent males with obesity, Schranz et al. (2014) found that resistance training had a positive impact on physical self-worth and global self-concept compared with nonexercising controls. The current study's findings are consistent with those of Schranz et al. (2014) in that resistance training was the only group to produce greater increases than controls in global

self-esteem, extending the literature beyond benefits to self-esteem induced by aerobic exercise in youth with obesity (Goldfield et al., 2012; Daley et al., 2006). Our study examined a broader scope of physical self-perceptions than Schranz et al. (2014); we found that compared with controls, the resistance group demonstrated greater improvements in perceived strength, whereas the combined group showed greater increases in perceived conditioning and strength. Our findings that resistance training, either alone or part of a multicomponent exercise intervention, has a beneficial impact on physical self-perceptions and global self-esteem are consistent with research in normal-weight adolescents (Velez, Golem, & Arent, 2010; Morgan, Saunders, & Lubans, 2012) and young adults (Moore, Mitchell, Bibeau, & Bartholomew, 2011). It is interesting, however, that similar to Schranz et al. (2014), increases in measured strength demonstrated by the resistance training group were not associated with changes in global self-esteem, suggesting that another variable, besides strength, may be mediating or moderating this relationship. Resistance training leads to faster gains than aerobic training and perhaps this led to enhanced self-efficacy, as shown by Schranz et al. (2014), which, in turn, may have enhanced global self-esteem. Alternatively, there may be specific elements that are unique to resistance training that may enhance self-esteem, which future research should investigate.

Youth with obesity consistently report greater body dissatisfaction than normal-weight peers (Goldfield et al., 2010b; Ricciardelli & McCabe, 2001). While systematic reviews have shown that exercise improves body image in adolescents (Campbell & Hausenblas, 2009), very few studies were comprised of obese samples, and none examined the effects of resistance training on body image in adolescents with obesity. Although a few trends were observed favoring greater improvements in body image for resistance training compared with controls, fewer than expected differences existed between exercise and control groups. This stands in contrast to our hypotheses that resistance training would produce greater improvements in body image than aerobic and control conditions due to its potential to reshape the body and improve muscle size, shape, and tone. Although our findings are consistent with those of Anderson, Foster, McGuigan, Seebach, and Porcari (2004) who found no differences between aerobic training, resistance training, and nonexercising control on body image in adults, other research has found that resistance training, with or without aerobic training, enhances body image in adults with obesity (Kerksick et al., 2009) and without (Speck et al., 2010). It is important to note that although aerobic, resistance, and combined training all produced significant improvement in body image over time in the current study, the diet-only control group also demonstrated significant increases in body image, which nullified group differences. Given that body dissatisfaction is predictive of eating disturbances (Polivy & Herman, 1985), weight gain (Claus et al., 2006; Field et al., 2003), psychiatric disorders, and substance abuse in youth (Rawana, 2013; Marti et al., 2010), future research is needed to build on these initial findings to better determine the effects of resistance, aerobic, or combined training on body image in youth with obesity.

Adolescence is a period of development where onset of depression reaches its peak (Merikangas & Avenevoli, 2002). Youth with obesity are at increased risk of depression and other mood disorders (Kalarchian & Marcus, 2012), possibly due to widespread weight-based teasing and bullying by peers (Goldfield et al.,

2010a), as well as discrimination and bias they often experience (Puhl & Latner, 2007). The current study is the first to show that, in youth who are overweight or obese, resistance training reduced depressive symptoms, and was the only exercise modality to do so. Aerobic, resistance, and combined training all demonstrated greater improvements than controls in vigor, while all exercise groups but not controls reported significant reductions in anger. While no comparable studies exist in adolescents, Taspinar, Aslan, Agbuga, and Taspinar (2014) found that resistance training produced greater improvements in mood than nonexercise (control) in sedentary adults. Although several hypotheses exist on how aerobic exercise may improve mood (e.g., increased endorphin/neurotransmitter release, sense of accomplishment, distraction from stress, improved sleep), the mechanisms through which resistance training improves mood are not as well understood. As previously mentioned, resistance training may produce indirect effects on mood via enhanced self-efficacy or other unmeasured variables or could be a direct effect of the exercise modality itself. Given that increases in strength, which were greatest in resistance training and combined training, were not associated with any changes in mood, increased strength is unlikely the mechanism. Our results support future research examining the mechanisms by which resistance training, alone or in combination with aerobic training, impacts mood in adolescents, and to determine if these processes differ from those involved in aerobic training.

A secondary aim of the study was to gain insight into how exercise may lead to improvements in psychological health by examining patterns or correlations. We found that reductions in body fat were associated with the greatest amount of psychological benefits, including improved body image, physical-self-worth, and global self-esteem, while increases in strength were associated with improvements in physical self-perceptions, but changes in fitness were unrelated to changes in psychological indicators. These findings conflict with those of Goldfield et al. (2012) who found that improvements in aerobic fitness were more predictive of psychological change than changes in body composition in youth with obesity, but are consistent with other exercise weight-loss studies in adults with obesity (Annesi & Unruh, 2008; Annesi & Whitaker, 2010). Given that youth with obesity experience widespread weight-based teasing, discrimination, and bias (Puhl & Latner, 2007), reducing adiposity may lead to feeling less stigmatized and more psychologically empowered. Our findings suggest that even modest reductions in body fat from exercise interventions may provide greater short-term psychological benefits than those targeting changes in strength or fitness.

Exercise adherence is critical to positive outcomes (Epstein & Goldfield, 1999), and we expected that adherence would be better with resistance training because aerobic training is uncomfortable and not well tolerated in youth with obesity (Ekkekakis & Lind, 2006), and because progress can be achieved faster with resistance training than aerobic training. However, there were no group differences in adherence, and, like many exercise studies, adherence was problematic as evidenced by a 62% median adherence rate to prescribed sessions. This may explain, in part, the fewer-than-expected group differences in psychological and physiological outcomes (Sigal et al., 2014). Interestingly, adherence was not related to any psychological outcomes for the aerobic group, which conflicts with previous findings (Annesi & Whitaker, 2010), but was associated with improved body image and physical self-

perceptions in the resistance training group, and improved body image, physical-self-perceptions, and global self-esteem in the combined group. Taken together, these findings suggest that if participants can better adhere to resistance training, either alone or combined with aerobic training, they may derive greater psychological benefit than from aerobic training alone. This has important clinical implications given that many individuals with obesity do not enjoy aerobic exercise (Ekkekakis & Lind, 2006).

Although some differences in psychological outcomes between exercise and control groups emerged, which future research should build on, fewer than expected differences were observed, while many significant within-group improvements were noted. We believe many of these between-group, null findings were due to unexpected increases in psychosocial outcomes of interest by the diet-only control group. This may have been due to the control group successfully making dietary changes, receiving attention from the dietitian and research staff, achieving small decreases in adiposity, and/or being offered the exercise intervention after 6 month posttreatment. We designed our trial such that the control group received some contact with health professionals (dietitians) to partially control for attention and to examine the incremental effects of exercise above diet alone. We believed this approach was more cost-effective than employing a full attention–placebo control group, while balancing ethical concerns (raised by our host institution) of not providing anything to controls. Future research is needed to determine if the pattern of results obtained remain when either full attention–placebo groups or “pure” untreated control groups are used.

The current study has several strengths and limitations. The strengths include an RCT design, which provides the highest quality of evidence on which to base conclusions. In addition, this was the first study to comparatively examine the effects of resistance training, with or without aerobic training, on psychological health outcomes in adolescents with obesity, a population known to be at high risk of psychosocial maladjustment. Moreover, the current study used the largest sample size of any study examining the effects of resistance training on outcomes of interest in adolescents with obesity. Furthermore, the volume of training and duration of the intervention prescribed to participants matches or exceeds that of any previous study. The study also employed the broadest scope of psychological measurement, extending the current literature that focused primarily on outcomes of self-concept to include mood and body image, which are important indicators of mental health.

Limitations of the study include control participants not having an attention control group (although controls had some contact with dietitians). Although this is the largest RCT to date assessing the effects of resistance training in adolescents with obesity, the current study did not account for the potential role that sex-specific hormones (e.g., androgens, estrogens) may have on biological or psychological responses. Also, similar to many exercise trials involving person with and without obesity (Pavey et al., 2012), adherence to the exercise prescription was a problem for some participants, which may have contributed to many null findings, and also limits the generalizability of the findings. In addition, most participants were female, and, even though females are more likely to seek treatment for obesity, it is possible that the psychological effects of resistance training would have been more pronounced if more males participated given the ideal male body type

is large and muscular, whereas the slim and lean look is more typical of the female ideal (McCabe, Ricciardelli, & Holt, 2010).

Conclusion

The HEARTY Trial showed that resistance training produced significantly greater improvements than controls in global self-esteem, some indicators of mood and perceived strength, while combined training produced greater changes than controls in physical self-perceptions in adolescents with overweight or obesity. The effect sizes for these group differences were typically small to moderate in magnitude. Although no group differences emerged on body image, both exercise and diet-only control reported significant improvements over time, and these effects were large in magnitude. Improvements in psychological health, such as enhanced body image and self-esteem, were more closely associated with reductions in body fat than with changes in objectively measured fitness or strength. Adherence to resistance training and combined training was positively associated with improved body image, physical-self-perceptions, and global self-esteem, but adherence to aerobic training was not associated with any psychological outcomes. Taken together, the findings suggest that 6 months of resistance training at a frequency of 3–4 sessions per week, either alone or in combination with aerobic training, may provide psychological benefits for youth with obesity, which appear to be enhanced by greater adherence. As such, resistance training, alone or in combination with aerobic training, may represent a potential alternative to traditional aerobic training in the psychological and biological management of obesity in adolescents. Future research, with longer follow-up evaluation, is needed to determine if adolescent boys and girls differ in their psychological responses to resistance or combined training, and which training volume, intensity, and frequency produces the greatest psychological benefits.

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