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ORIGINAL ARTICLE

Understanding low adherence to an exercise program for adolescents with obesity: the HEARTY trial

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Summary

Introduction

Despite efforts to improve adherence to physical activity interventions in youth with obesity, low adherence and attrition remain areas of great concern.

Objective

The study was designed to determine which physiological and/or psychological factors predicted low adherence in adolescents with obesity enrolled in a 6-month exercise intervention study aimed to improve body composition.

Methods

Three hundred four adolescents with obesity aged 14–18 years who volunteered for the HEARTY (Healthy Eating Aerobic and Resistance Training in Youth) randomized controlled trial completed physiological (body mass index, waist circumference, per cent body fat, resting metabolic rate and aerobic fitness) and psychological (body image, mood, self-esteem and self-efficacy) measures.

Results

One hundred forty-one out of 228 (62%) randomized to exercise groups had low adherence (completed <70% of the prescribed four exercise sessions per week) to the intervention protocol. Logistic regression revealed that there were no baseline demographic or physiological variables that predicted low adherence in the participants. Appearance concern (a subscale of body image) (odds ratio [OR] 1.46, 95% confidence interval [CI]: 1.01, 2.1, $P = 0.04$), depressive mood (OR 1.12, 95% CI: 1.01, 1.23, $P = 0.03$) and confused mood (OR 1.16, 95% CI: 1.05, 1.27, $P = 0.003$) (two subscales of mood) were significant predictors of low adherence.

Conclusions

Adolescents with obesity who had higher appearance concerns and depressive and confused moods were less likely to adhere to exercise. Body image and mood should be screened to identify adolescents who may be at high risk of poor adherence and who may need concurrent or treatment support to address these psychological issues to derive maximal health benefits from an exercise programme.

Keywords: attrition, body image, dropout, mood.

Introduction

Physical activity and exercise have well-documented physiological (1,2) and psychological health benefits (3,4) to children and adolescents living with obesity. However, health benefits derived from physical activity interventions will be greatest with high levels of adherence (2,5). Despite efforts to improve adherence to

physical activity interventions in youth with obesity, low adherence to prescribed exercise sessions and frequent dropout (terminating participation) remain the areas of great concern (6). Adherence to exercise training interventions in adolescents with obesity is not consistently defined, measured or reported (7–9), but exercise adherence rates reported in different studies have ranged from 56% to >99% (7,10–12). A systematic review of obesity interventions in children and adolescents showed dropout rates of 0–42% (13), while other recent studies have shown dropout rates of 25–45% from supervised exercise trials and multidisciplinary obesity treatment programmes (14–17).

Although adults have cited body image and self-consciousness as barriers to regular exercise in gyms (18), no previous studies have examined their role in predicting adherence to structured exercise interventions in gyms for adolescents. Adolescence has been identified as a critical period of development when body weight and shape are rapidly changing partly due to hormonal fluctuations (19) and when self-esteem is greatly influenced by body image and appearance-related factors (20,21). A systematic review (22) showed strong evidence that obesity in children and adolescents affects self-esteem; six of nine studies showed lower global self-esteem in youth with obesity compared with youth with normal weight. All of the studies included in the systematic review showed lower scores on sub-domains of self-esteem, particularly athletic/physical competence and physical appearance perceptions in children and adolescents with obesity (22). Although body image and self-esteem have been shown to improve in response to exercise interventions in youth with obesity (3,4), they have not been studied as potential predictors of low adherence.

Previous research has investigated physical and sociodemographic variables as potential predictors of exercise adherence in adults with obesity, not youth. A systematic review of lifestyle interventions in adults with obesity showed that the most prominent predictors of adherence included lower baseline body mass index (BMI), better baseline mood, being male and older age (18). Research has consistently shown decreases in physical fitness levels among youth in the past few decades (23–25) and decreases in physical activity levels from childhood to adolescence, most predominantly in girls (26–28). Motivators for physical activity differ by sex (29), but it is unclear if sex predicts adherence to exercise interventions in youth with obesity. Youth with obesity have lower fitness (30) and lower tolerance to exercise (31) compared with their counterparts of normal weight, but no studies have evaluated body composition and fitness as potential predictors of exercise adherence in adolescents with obesity.

Depressive symptoms have been well documented to be a predictor of low adherence to exercise interventions in adults living with obesity (32,33). Depression and depressive symptoms often peak during adolescence (34), and systematic review evidence shows that youth with obesity are at increased risk (35), but very little research has examined depression's importance relative to other factors related to mood in predicting adherence in youth with obesity. Ten per cent to 20% of adolescents worldwide experience mental health conditions including mood and emotional disorders, but diagnosis and treatment of these conditions are low in adolescence (36). Notably, multidimensional components of mood including fatigue, anger, tension, confusion and vigour in addition to depression have not been studied as potential predictors of exercise adherence in adolescents, despite the known association between mood dys-regulation and behavioural dys-regulation in adults (37,38).

Although many theoretical models for behaviour change have been proposed (39), they do not account for a sizable proportion of the variance in adherence to structured physical activity interventions. However, the most prominent construct included in most models predicting adherence is self-efficacy (40) or one's perceived ability to carry out an action or achieve a goal. Self-efficacy focused on attitudes, beliefs and intentions towards exercise has been identified as one of the most consistent predictors of adherence to physical activity (41). Although individuals with overweight and obesity reported higher rates of perceived exertion and less pleasure with exercise especially when intensity and volume are prescribed and not self-selected (42,43), one study in pre-adolescent children with obesity found that neither enjoyment nor perceived adequacy or predilection (self-efficacy) for physical activity predicted physical activity adherence during the intervention (44). Conversely, higher scores on physical self-perceptions such as physical (athletic) competence have been shown to be strong predictors of more regular and frequent free-living physical activity in children and youth (45,46), but few studies have examined how physical self-perceptions predict exercise adherence in youth with obesity.

Because adolescence is a critical period for drastic physiological and psychosocial changes (19) and theoretical models of behaviour change focusing on attitudes, beliefs and intentions, as well as known physiological factors explaining a limited proportion of variance in adherence to exercise intervention among adults and youth (39), further investigation on predictors of low adherence is warranted in adolescents with obesity.

The purpose of this study was to determine which demographic or physiological (age, sex, body weight, BMI, waist circumference, total per cent body fat, resting

metabolic rate and aerobic fitness) and/or psychological (body image, mood, self-esteem and self-efficacy) factors predict low adherence in adolescents with obesity enrolled in a 6-month structured exercise intervention study aimed to improve body composition – the Healthy Eating, Aerobic and Resistance Training in Youth (HEARTY) trial. The secondary aim was to examine whether predictors of exercise adherence differed by sex given the relative paucity of such data in the literature. This study is a secondary analysis of results obtained from the HEARTY trial whose primary outcome was to evaluate the effects of aerobic training, resistance training and their combination on total per cent body fat in adolescents with obesity (14,47). Because the targeted psychological variables are salient among adolescents, we hypothesized that self-efficacy, body image, depression and BMI would emerge as predictors of low exercise adherence.

Methods

Design

The HEARTY trial was a single blind, randomized controlled trial with a parallel group design conducted at a single centre (ClinicalTrials.Gov number NCT00195858). Once baseline testing was completed, participants entered a run-in period that included supervised progressive moderate-intensity aerobic and resistance exercise training four times weekly for 4 weeks. To qualify for randomization, participants needed to attend at least 13 of 16 prescribed exercise sessions (>80% adherence) during run-in. 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 non-exercising control (Control, n = 76).

Participants

Inclusion criteria included participants who were post-pubertal (Tanner stage IV–V) (48,49) adolescents aged 14–18 years with BMI ≥95th percentile for age and sex (http://www.cdc.gov/growthcharts) and/or ≥ 85th percentile with an additional diabetes or cardiovascular risk factor. Exclusion criteria included habitual exercise more than twice weekly for over 20 min per session, diabetes mellitus or any illness or disability rendering study exercise programs inadvisable or unfeasible. Participation in regular physical education classes at school was not an exclusion criterion. More details on the rationale, design and methods have been published previously (14,47).

The coordinator reviewed the study protocol and inclusion/exclusion criteria and obtained informed consent. A parent or guardian was asked to co-sign the consent form of any participant below 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 the Ottawa Hospital. The trial began in March 2005 and was completed in June 2011.

Intervention

A detailed description of the intervention has been previously published (47). The three exercising groups were asked to attend community-based fitness centres four times weekly. The Aerobic group exercised on treadmills, elliptical machines and/or bicycle ergometers. Heart rate monitors (Polar Electro Oy, Kempele, Finland) were used to adjust workloads and intensity of exercise to achieve target heart rates. Participants gradually progressed in exercise duration (from 20 to 45 min per aerobic exercise session) and intensity (from 65% to 85% of their predetermined maximum heart rate). The Resistance group performed seven exercises using weight machines or free weights, progressing from moderate to higher intensities, as described previously (14,47). The Combined group completed the full aerobic training program plus the resistance training programme during each session. Participants in all four groups received nutritional counselling at baseline, 3 and 6 months by a registered dietitian to promote healthy eating with a daily energy deficit of 250 kcal.

Setting

Exercise training took place at six community-based facilities in Ottawa/Gatineau, Canada. Exercise was supervised by personal trainers twice weekly during the run-in period, weekly from randomization to 3 months and biweekly from 3 to 6 months. Personal trainers monitored attendance and exercise progression by reviewing sign-in sheets and exercise logs. The personal trainers did not intervene on psychological variables (i.e. did not attempt to enhance motivation via self-efficacy or other variables under study).

Measurements

Intervention adherence was calculated as total number of exercise sessions the participant attended divided by the total number of sessions prescribed.

Anthropometric and physiological measures

Body mass index was measured by dividing the weight in kilograms by the height in meters squared. Waist

circumference was measured at the midpoint between the last floating rib and the iliac crest. Total per cent body fat was measured using magnetic resonance imaging and interactive slice editor program (Slice-o-matic v. 4.3, Tomovision, QC) using established protocols (50–52). Aerobic fitness was assessed using a modified Balke and Ware incremental treadmill protocol to assess aerobic power as estimated from the rate of peak oxygen consumption (VO_{2peak}) (53). Resting metabolic rate was assessed by indirect calorimetry using an automated metabolic system (MOXUS Modular Metabolic System, AEI Technologies Naperville, IL).

Psychological measures

Body image was evaluated using the Multiple Body Self-relations Questionnaire-Appearance Scales (54). This 34-item scale requires the participants to rate their attitudes towards 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 subscales (Appearance Evaluation [feelings of physical attractiveness or unattractiveness and satisfaction or dissatisfaction with one's appearance], Appearance Orientation [the extent of investment in one's appearance], Overweight Preoccupation [fat anxiety, weight vigilance, dieting and eating restraint], Self-Classified Weight [how one perceives one's weight from very underweight to very overweight] and the Body Areas Satisfaction Scale [satisfaction with specific aspects of one's appearance]). The Multiple Body Self-relations Questionnaire-Appearance Scales has been developed and validated in adolescents and adults and has demonstrated strong reliability and construct validity (55).

Mood was assessed using the 24-item Brunell Mood Scale (56). The Brunell Mood Scale is composed of six subscales 'Fatigue (state of tiredness and low energy), Anger (state of hostility, for others), Tension (state of musculoskeletal tension and worry), Confusion (state of feeling stunned and instability in emotions), Vigour (state of energy and physical force) and Depression (emotional state of despondency, sadness and unhappiness)' (57) with each subscale consisting of four items. Respondents rate the intensity of their feelings on a 5-point Likert scale anchored by 'not at all' to 'extremely', with higher scores reflective of greater emotion.

Self-esteem was assessed using The Harter Global Self-Esteem subscale (58) of the 36-item Physical Self-Perception Profile for Children (59,60). The Harter Global Self-Esteem subscale (58) evaluates the extent to which the youth likes himself or herself as a person and is happy with the way he or she is (a global dimension of one's self-worth (59)). The Physical Self-Perception Profile for Children was also used to assess five domains of physical self-perceptions, including perceived sport competence, perceived physical conditioning, perceived body appearance, perceived strength and a higher order construct – the Physical Self-Worth subscale.

Perceived adequacy, predilection and enjoyment for physical activity were assessed by the Children's Self-Perception of Adequacy and Predilection for Physical Activity (CSAPPA) scale, which is broadly conceptualized as a motivation scale for physical activity. This 20-item inventory assesses children's attitudes towards physical activity across three domains of functioning: Adequacy, Predilection and Enjoyment (61). These domains were discriminated from each other through factor analytic procedures, indicating good construct validity of each factor (61).

Exercise self-efficacy was assessed using the 12-item Exercise Self-Confidence Survey (62). The Exercise Self-Confidence Survey assesses two factors of exercise self-efficacy: resisting relapse and making time for exercise. This questionnaire has shown good reliability, high internal consistency and high criterion validity in association with exercise behaviours (62).

Attendance was calculated as the number of gym sessions attended divided by the number of prescribed sessions during the same period (four sessions per week). When participants attended all the exercise sessions prescribed, we categorized participants as maintaining 100% adherence. Participants were considered 'low adherence' if they attended less than 70% of the prescribed sessions from baseline to the end of the 6-month intervention (an average of less than 2.8 sessions per week). Participants had 'high adherence' if their gym attendance from baseline to the end of the 6-month intervention was at least 70% (on average attended at least 2.8 sessions per week). As reported in the HEARTY methods paper (47) and in the main outcome paper of this trial (14,47), the a priori primary analysis of the primary outcome variable per cent body fat used an intention-to-treat analysis (including all participants regardless of exercise adherence). The HEARTY methods paper also specified a priori that per-protocol analyses would be conducted on participants who had high adherence defined as attendance of at least 70% of the prescribed exercise sessions from baseline to the end of the 6-month intervention (on average attended at least 2.8 sessions per week) to determine the effect of exercise adherence to the prescribed program. With regard to the clinical significance of this 70% adherence cut-off (or two to three exercise sessions per week), in two previous publications from the current HEARTY trial (4,63), it was previously shown that participants who engaged in at least two or more sessions per week of combined aerobic and

resistance training (with more benefits with three or more sessions per week) over 6 months showed greater increases in fitness and psychosocial benefits.

Statistical analysis

Baseline demographic, anthropometric, physiological and psychological characteristics were summarized between low and high adherence groups as means and standard deviation for continuous variables and frequencies with percentages for categorical data. The internal consistency of each subscale was assessed with the overall standardized Cronbach's coefficient alpha. Univariate logistic regressions analyses were conducted to predict reasons for low adherence from the HEARTY trial. As reported in the methods paper of the HEARTY trial (47), the choice of examining the associations within each sex separately was decided a priori in the design of the HEARTY intervention. Demographic/physiological (age, sex, body weight, BMI, waist circumference, total per cent body fat, resting metabolic rate and aerobic fitness) and psychological (body image [appearance evaluation, appearance orientation, body areas satisfaction, overweight preoccupation and self-classified weight], mood [anger, confusion, depression, fatigue, tension and vigour], self-perceptions [perception of sport competence, perception of physical education, perception of attractive body, perception of physical strength, perception of physical self and perception of global self-worth], motivation for physical activity [adequacy, predilection, enjoyment and total motivation score] and exercise self-efficacy) baseline variables were assessed as possible predictors of low adherence with effect sizes summarized as odds ratios (OR) and 95% confidence intervals (CI). Analysis was repeated in both female and male subgroups. Where clinically meaningful differences for a single factor were observed by sex, interaction was assessed with the factor by sex interaction entered into the full cohort model. All analyses were two-tailed with an alpha level of significance set at 0.05. Analyses were conducted in SAS version 9.4 (The SAS Institute, Cary, NC).

Results

Overall sample

From baseline to 26 weeks, median exercise training adherence in the original sample (N = 304) was 62% (interquartile range, 36% to 81%) in Aerobic, 56% (interquartile range, 37% to 75%) in Resistance and 64% (interquartile range, 39% to 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. When asked for primary reasons for withdrawal, self-report revealed mainly lack of interest and lack of time emerged as the most frequent reasons. For this secondary analysis, however, only the three exercise groups were included for a total sample of n = 228 (i.e. Aerobic, n = 75; Resistance, n = 78; and Combined, n = 75).

Out of the 228 participants in the Aerobic, Resistance or Combined exercise groups with complete physiological and psychosocial data, 141 were categorized as low adherence (61.8%). In males, 35 (52.2%) were categorized as low adherence as compared with 106 (65.8%) of females, P = 0.07. The rate of low adherence did not appear to vary significantly across exercise groups with 40 (53.3%) in the Aerobic, 55 (70.5%) in the Resistance and 46 (61.3%) in the Combined exercise groups categorized as low adherence, P = 0.09.

Tables 1 and 2 show baseline demographic, anthropometric, physiological and psychosocial characteristics of the HEARTY sample, respectively. Subscale measures appeared to be internally consistent with the majority of measures with Cronbach's alpha greater than 0.9. Only those scales based on a limited number of items in the questionnaire resulted in a Cronbach's alpha less than 0.7 (overweight preoccupation, self-classified weight and vigour). There were no demographic or physiological differences between participants with low adherence versus high adherence at baseline.

Table 3 presents the logistic regression results of the physiological and psychological predictors of low adherence from the HEARTY study. Females were nonsignificantly more likely to have low adherence than males (OR 1.75, 95% CI: 0.99, 3.13, P = 0.06). In the overall sample, participants in the Resistance group had 2.09 higher odds (95% CI: 1.08, 4.07, P = 0.03) of having low adherence than those in the Aerobic group, whereas participants in the Combined group had nonsignificantly higher odds of low adherence compared with the Aerobic group (OR 1.39, 95% CI: 0.72, 2.66, P = 0.32).

None of the demographic, anthropometric or physiological variables including total per cent body fat, age, body weight, BMI, waist circumference, aerobic fitness and resting metabolic rate were significant predictors of low adherence in the overall sample ($P > 0.05$). Psychological variables, namely, confusion, depression and appearance concerns were the only significant predictors of low adherence in the overall sample ($P < 0.05$). The odds of low adherence from the HEARTY study were 1.16 (95% CI: 1.05, 1.27, P = 0.003) higher with greater confusion, 1.12 (95% CI: 1.01, 1.23, P = 0.03) higher with greater depression and 1.46 (95% CI: 1.01, 2.1, P = 0.04) higher with greater appearance concerns.

Table 1 Participants' baseline demographic and physiological characteristics

	Overall sample (*N* = 228)	Low adherence (*n* = 141)	High adherence (*n* = 87)	*P* value
Age (years)	15.6 ± 1.4	15.7 ± 1.4	15.5 ± 1.4	0.21
Body weight (kg)	98.1 ± 16.3	97.4 ± 15.9	99.2 ± 16.9	0.43
BMI (kg m^{-2})	34.8 ± 4.3	34.7 ± 4.4	34.9 ± 4.3	0.70
zBMI	2.9 (0.6)	2.9 (0.6)	3.0 (0.6)	0.41
Waist-to-height ratio	0.58 (0.056)	0.58 (0.057)	0.58 (0.055)	0.38
Waist circumference (cm)	97.4 ± 10.7	96.7 ± 10.6	98.4 ± 10.9	0.25
Total per cent body fat (%)	49.8 ± 5.6	50.1 ± 5.7	49.3 ± 5.5	0.30
Resting metabolic rate (kcal d^{-1})	1,995 ± 391	1,958 ± 395	2,056 ± 378	0.07
Cardiorespiratory fitness (VO_{2peak}; mlO_2 kg^{-1} min^{-1})	30.3 ± 5.1	29.9 ± 5.4	31.0 ± 4.4	0.10

Data are presented as mean ± standard deviation.
BMI, body mass index.
VO_{2peak}, peak oxygen consumption.

Table 2 Participants' baseline psychological characteristics

	Cronbachs alpha	Low adherence (*n* = 141)	High adherence (*n* = 87)	*P* value
Body image (MBSRQ-AS)				
Appearance evaluation	0.76	2.4 ± 0.68	2.4 ± 0.68	0.38
Appearance orientation	0.87	3.5 ± 0.74	3.3 ± 0.75	0.04
Body areas satisfaction	0.76	2.6 ± 0.55	2.7 ± 0.57	0.37
Overweight preoccupation	0.65	2.5 ± 0.80	2.5 ± 0.76	0.57
Self-classified weight	0.60	4.3 ± 0.60	4.3 ± 0.48	0.92
Mood (BRUMS)				
Anger	0.77	4.5 ± 3.4	3.7 ± 3.1	0.06
Confusion	0.81	4.0 ± 3.5	2.6 ± 2.6	0.0009
Depression	0.83	2.9 ± 3.2	2.0 ± 2.8	0.03
Fatigue	0.85	7.1 ± 4.0	6.8 ± 3.8	0.53
Tension	0.78	3.8 ± 3.3	3.5 ± 2.7	0.36
Vigour	0.65	7.2 ± 3.1	7.0 ± 3.0	0.77
Self-esteem (PSPP-C)				
Perception of sport competence	0.83	13.3 ± 3.7	13.8 ± 3.9	0.29
Perception of physical condition	0.81	11.9 ± 2.9	11.8 ± 3.4	0.7
Perception of attractive body	0.84	9.5 ± 2.9	9.8 ± 3.3	0.49
Perception of physical strength	0.87	15.8 ± 3.7	16.3 ± 3.6	0.33
Perception of physical self	0.86	11.0 ± 3.3	11.3 ± 3.8	0.54
Perception of global self-worth	0.82	15.0 ± 4.1	15.7 ± 3.7	0.25
Motivation for PA (CSAPPA)				
Adequacy	0.87	16.5 ± 4.4	17.0 ± 4.4	0.47
Predilection	0.86	23.8 ± 5.8	24.1 ± 6.0	0.73
Enjoyment	0.91	7.6 ± 2.7	8.1 ± 2.8	0.16
Total	0.93	47.9 ± 11.5	49.1 ± 11.8	0.43
Exercise self-efficacy				
Exercise self-confidence	0.84	45.4 ± 9.3	45.7 ± 7.5	0.77

Data are presented as mean ± standard deviation. For the MBSRQ-AS, higher scores on appearance evaluation and body areas satisfaction are more favourable indicating more satisfaction and contentment with one's appearance and discrete aspects of one's appearance, respectively. Higher scores on appearance orientation and overweight preoccupation are unfavourable indicating more importance on how one looks, greater fat anxiety and eating restraint, respectively. Higher scores on self-classified weight are unfavourable reflecting labelling oneself as more overweight. For the BRUMS, higher scores on anger, confusion, depression, fatigue and tension are unfavourable, whereas lower scores on vigour are unfavourable. For the PSPP-C and CSAPPA, higher scores are more favourable on self-perceptions and motivation for physical activity (PA). For self-efficacy, higher scores on the exercise self-confidence survey are more favourable. Physical self-perceptions were assessed using the PSPP-C.
BRUMS, Brunell Mood Scale; CSAPPA, Children's Self-Perception of Adequacy and Predilection for Physical Activity; MBSRQ-AS, Multiple Body Self-relations Questionnaire-Appearance Scales; PSPP-C, Physical Self-Perception Profile for Children.

Table 3 A series of univariate logistic regressions predicting low adherence from HEARTY

	Overall		Female		Male	
Variable	OR (95% CI)	*P* value	OR (95% CI)	*P* value	OR (95% CI)	*P* value
Physiological variables						
Age (per year)	1.13 (0.93, 1.37)	0.21	1.02 (0.81, 1.28)	0.88	1.38 (0.96, 1.99)	0.09
Sex (female versus male)	1.75 (0.99, 3.13)	0.06	N/A	N/A		
Body weight (per kg)	0.99 (0.98, 1.01)	0.42	1.00 (0.98, 1.02)	0.78	1.00 (0.97, 1.03)	0.82
BMI (per kg m^{-2})	0.99 (0.93, 1.05)	0.70	0.99 (0.92, 1.06)	0.69	1.02 (0.91, 1.15)	0.72
zBMI	0.84 (0.55, 1.28)	0.41	0.90 (0.54, 1.50)	0.68	1.01 (0.42, 2.43)	0.97
Waist-to-height ratio (per 0.01 increase)	0.98 (0.93, 1.03)	0.37	0.99 (0.93, 1.04)	0.61	0.99 (0.90, 1.08)	0.81
Waist (per cm)	0.99 (0.96, 1.01)	0.25	0.99 (0.96, 1.03)	0.69	0.99 (0.94, 1.04)	0.77
Total per cent body fat	1.03 (0.98, 1.08)	0.30	1.02 (0.95, 1.09)	0.64	0.98 (0.89, 1.08)	0.66
Resting metabolic rate (odds ratio per 100 kcal d^{-1} increment)	0.94 (0.87, 1.00)	0.07	0.96 (0.87, 1.07)	0.5	0.96 (0.83, 1.11)	0.59
Cardiorespiratory fitness (per VO_{2peak} in mlO_2 kg^{-1} min^{-1})	0.96 (0.91, 1.01)	0.10	0.92 (0.85, 0.99)	0.02	1.06 (0.97, 1.17)	0.22
Psychological variables						
Body image (MBSRQ-AS)						
Appearance evaluation	0.84 (0.56, 1.25)	0.38	0.85 (0.53, 1.38)	0.52	1.01 (0.46, 2.23)	0.98
Appearance orientation	1.46 (1.01, 2.1)	0.04	1.39 (0.86, 2.25)	0.18	1.29 (0.66, 2.53)	0.45
Body areas satisfaction	0.8 (0.49, 1.31)	0.37	0.92 (0.49, 1.71)	0.79	0.72 (0.31, 1.67)	0.45
Overweight preoccupation	1.11 (0.78, 1.57)	0.57	1.41 (0.91, 2.18)	0.12	0.45 (0.21, 0.95)	0.04
Self-classified weight	0.98 (0.6, 1.59)	0.92	0.92 (0.52, 1.63)	0.77	1.11 (0.42, 2.93)	0.83
Mood (BRUMS)						
Anger	1.08 (0.99, 1.18)	0.07	1.02 (0.93, 1.12)	0.7	1.32 (1.06, 1.63)	0.01
Confusion	1.16 (1.05, 1.27)	0.003	1.12 (1.01, 1.24)	0.04	1.27 (1.00, 1.60)	0.049
Depression	1.12 (1.01, 1.23)	0.03	1.07 (0.96, 1.19)	0.22	1.43 (1.01, 2.02)	0.04
Fatigue	1.02 (0.95, 1.1)	0.53	1.00 (0.91, 1.09)	0.96	1.06 (0.94, 1.19)	0.34
Tension	1.04 (0.95, 1.14)	0.38	1.05 (0.94, 1.16)	0.41	0.99 (0.83, 1.19)	0.91
Vigour	1.01 (0.93, 1.11)	0.77	0.96 (0.86, 1.06)	0.39	1.19 (1.00, 1.43)	0.05
Self-esteem (PSPP-C)						
Perception of sport competence	0.96 (0.89, 1.04)	0.29	0.96 (0.87, 1.06)	0.4	0.98 (0.85, 1.12)	0.75
Perception of physical condition	1.02 (0.93, 1.12)	0.70	1.04 (0.92, 1.17)	0.54	1.01 (0.86, 1.19)	0.88
Perception of attractive body	0.97 (0.88, 1.06)	0.49	1.01 (0.89, 1.14)	0.9	0.94 (0.79, 1.11)	0.47
Perception of physical strength	0.96 (0.89, 1.04)	0.33	0.99 (0.9, 1.09)	0.81	0.92 (0.79, 1.08)	0.30
Perception of physical self	0.97 (0.9, 1.06)	0.53	0.97 (0.87, 1.07)	0.51	1.02 (0.88, 1.18)	0.76
Perception of global self-worth	0.96 (0.89, 1.03)	0.25	0.96 (0.88, 1.04)	0.33	0.97 (0.84, 1.11)	0.64
Motivation for PA (CSAPPA)						
Adequacy	0.98 (0.92, 1.04)	0.47	0.97 (0.9, 1.04)	0.43	1.02 (0.89, 1.16)	0.80
Predilection	0.99 (0.95, 1.04)	0.73	1.01 (0.95, 1.07)	0.78	0.98 (0.90, 1.06)	0.55
Enjoyment	0.93 (0.84, 1.03)	0.16	0.92 (0.81, 1.04)	0.19	0.97 (0.81, 1.16)	0.71
Total	0.99 (0.97, 1.01)	0.43	0.99 (0.96, 1.02)	0.62	0.99 (0.95, 1.04)	0.75
Exercise self-efficacy						
Exercise self-confidence survey	1 (0.96, 1.03)	0.78	0.99 (0.95, 1.03)	0.71	1 (0.94, 1.05)	0.87
Exercise group						
Aerobic	Ref	Ref	Ref	Ref	Ref	Ref
Combined exercise	1.39 (0.72, 2.66)	0.32	1.77 (0.8, 3.94)	0.16	0.83 (0.25, 2.74)	0.76
Resistance exercise	2.09 (1.08, 4.07)	0.03	1.87 (0.84, 4.14)	0.12	2.74 (0.81, 9.31)	0.11

Low adherence was coded as 1 and high adherence as 0 (higher OR means higher rate of low adherence).
BMI, body mass index; VO_{2peak}, peak oxygen consumption; BRUMS, Brunell Mood Scale; CI, confidence interval; CSAPPA, Children's Self-Perception of Adequacy and Predilection for Physical Activity; MBSRQ-AS, Multiple Body Self-relations Questionnaire-Appearance Scales; OR, odds ratio; PA, physical activity; PSPP-C, Physical Self-Perceptions were assessed using the Physical Self-Perception Profile for Children.

Results of analyses stratified by sex

For females, lower VO_{2peak} (OR 0.92, 95% CI: 0.85, 0.99, $P = 0.02$) and higher confusion (OR 1.1, 95% CI: 1.01, 1.24, $P = 0.04$) were associated with increased odds of low adherence. In males, higher anger, higher confusion, greater depressive mood, greater vigour and lower weight preoccupation were predictors of low adherence (all $P < 0.05$).

With regard to mood, higher confusion was associated with increased odds of low adherence in both sexes. Greater depressive mood was associated with increased odds of low adherence in males, but not in females. With regard to body image, appearance orientation was only a significant predictor in the overall sample, not in either sex alone ($P = 0.45$ in males and $P = 0.18$ in females). Lower overweight preoccupation increased the odds of low adherence in males (OR 0.45, 95% CI: 0.21, 0.95, $P = 0.04$), but not in females ($P = 0.12$). The results showed an opposite trend among females (test for interaction of sex × overweight preoccupation, $P = 0.01$) where higher overweight preoccupation tended to be associated with increased odds of low adherence (OR 1.41, 95% CI: 0.91, 2.18, $P = 0.12$).

Discussion

The results supported that one of the hypotheses, body image, specifically the subscale of appearance orientation, which reflects the degree of investment in appearance, was a significant predictor of low adherence. In addition, the results demonstrate that adolescents who scored higher on dysphoric mood subscales such as confusion and depression were less likely to adhere to the exercise intervention. Lower aerobic fitness and high confusion were predictors of low adherence in females, whereas altered mood states (higher anger, confusion, depression and vigour) and lower weight preoccupation were predictors of low adherence in males. The results presented herein found no demographic, anthropometric or physiological predictors of low adherence in the overall sample.

Female sex was a near-significant predictor of low adherence. Sex-specific analyses showed that HEARTY females with lower cardiorespiratory fitness at baseline had greater odds of having low adherence throughout the exercise program than those with higher VO_{2peak}. It is plausible that lower fitness at baseline can decrease exercise performance (31) and increase discomfort that may be linked to slower exercise improvement. An integrative review of 23 articles that assessed predictors of attrition in paediatric obesity management interventions in children and adolescents aged 0–18 years showed that baseline sex and weight status did not predict attrition (64). However, this review included studies that did not assess body image, mood and self-efficacy to enable comparison with the current study. Furthermore, the majority of the included studies were multidisciplinary interventions incorporating dietary, lifestyle and other behaviour changes alongside physical activity promotion (64). It is plausible that the review's predictors of attrition from multidisciplinary interventions were not related to their exercise program *per se*, and thus, comparisons were not possible with the HEARTY diet and exercise randomized controlled trial.

The results show that age was not a significant predictor of low adherence. Although adherence and dropout are distinct but conceptually related constructs, these findings differ from the review by Dhaliwal *et al*. (64) showing that older children were more likely to dropout, and this was supported by Fidelix *et al*. (2015) where adolescents older than 15 years were more at risk to dropout from the 12-week multidisciplinary behavioural intervention. The current sample (15.6 [1.4] years) was very similar in age to the Fidelix *et al*. sample (15.2 [1.57] years); however, their study incorporated monthly clinical consultations, nutritional and psychological counselling in addition to the supervised aerobic training three times per week for a shorter duration (12 weeks). More research is warranted to assess demographic and physiological predictors of low adherence from supervised, exercise interventions with adolescents with obesity.

The results showed that adolescents with obesity with higher appearance orientation (i.e. more investment in how they look) were more likely to have low adherence. It is known that adolescents with higher body weight report more body dissatisfaction compared with normal weight and underweight peers, especially in girls (65). Furthermore, greater body dissatisfaction and body insecurity have been identified as barriers to physical activity in youth with obesity (66) compared with peers without obesity (67,68). A previous publication from the HEARTY trial showed that participants in all exercise groups improved body image following the 6-month intervention (4), which is in line with a meta-analysis demonstrating a relationship between exercise involvement and body image (69).

In the overall sample, participants in the Resistance group had higher odds of having low adherence than those in the Aerobic group. However, there were nonsignificantly more participants who had low adherence in the Resistance training group than in the Aerobic group in the females-only and males-only sex specific analyses. Although explanations for this trend to lower adherence rate in the Resistance group remain unclear, perhaps it may be related to body image concerns. In a study of

571 female fitness class participants aged 18–71 years, Prichard *et al*. (70) showed that aerobic exercise was the preferred fitness activity and was motivated by appearance-focused reasons (i.e. weight control), whereas time spent performing resistance training type activities was not related to body image concerns (70). Studies have supported the notion that many female adults choose aerobic exercise primarily to control their weight. This desire to control their weight through exercise has been associated with greater body image and eating disturbances (71–73). HEARTY participants were more likely to have lower adherence if they had higher appearance orientation at baseline. Perhaps if HEARTY participants perceived that aerobic training would yield greater weight loss or change their body shape (i.e. they perceived aerobic training as better for inducing their ideal appearance), there would be a greater adherence for the aerobic group compared with the resistance training group because there would be alignment between the type of exercise (i.e. aerobic) and their ideal appearance goals. Given these speculations, future studies aimed to examine the role of appearance orientation on adherence to different forms of exercise training among adolescents with obesity are needed.

A notable finding from the results was that body image disturbances might predict low adherence differently by sex. If males had lower weight preoccupation (i.e. they were not preoccupied much with being overweight), they tended to have lower exercise adherence. Although not statistically significant, female adolescents tended to show the opposite trend, whereby if females were more preoccupied with being overweight, they were more likely to have low adherence. More research is needed to confirm these initial findings and understand how body image disturbances like overweight preoccupation may affect exercise adherence differently in male versus female adolescents.

The current study showed that depressive and confused moods were significant predictors of low adherence. Depressive mood is defined as 'negative self-schema characterised by themes such as hopelessness, personal deficiency, worthlessness and self-blame', whereas confused mood has been defined as 'feelings of bewilderment, uncertainty, and is associated with a general failure to control attention and emotions' (74). It has been suggested that depression plays a role in the development and persistence of obesity in adolescents (75), and the current results showed it may also influence exercise adherence. This is not surprising considering that adolescents with obesity often experience weight-based teasing and have low self-esteem, depression, anxiety and suicidal thoughts (76–78). Mechanisms to explain why adolescents with greater depressive and confused mood are more likely to have low adherence or to dropout from exercise interventions remain unclear. Although these are speculations and need to be supported by research evidence, perhaps adolescents may have unrealistic expectations when enrolling in exercise interventions such as the HEARTY trial, and these negative emotions may lead them to adhere less to exercise because exercising may become unpleasant. Participants may have expected extreme and rapid weight loss from the intervention, and more modest or absent weight loss may be related to greater disappointment, deepened feelings of sadness and depression and consequently more reasons to participate less in prescribed exercise sessions (79). Alternatively, negative or low mood state is well known to directly dampen motivation to participate in many leisure activities, including exercise (32,33). Future interventions in adolescents with obesity should consider screening for or targeting cognitive–behavioural and multidisciplinary strategies to address low mood to improve adherence to exercise programmes (79).

Although self-efficacy has been identified as one of the most consistent motivational predictors of exercise adherence (41), the results did not show that exercise self-confidence was a predictor of high adherence. Moreover, none of the motivational indicators from the CSAPPA (adequacy, predilection or enjoyment) significantly predicted higher adherence. This is also somewhat surprising given individuals with obesity find exercise less comfortable (43) and enjoyment of physical activity and attitudes towards physical activity are strong predictors of physical activity in children (80). However, one study in children with obesity found that motivational-related attitudes, including self-efficacy as measured by the CSAPPA did not predict physical activity change (44), which is a similar pattern of results as the present study. Although all scales used in the current study have sound psychometric properties, it is possible that other models of motivation, such as constructs within self-determination theory that is rapidly gaining scientific momentum (81,82), may be more predictive of adherence in this population. Future research is needed to clarify the role of enjoyment and motivation as predictors of exercise adherence in youth with obesity given that this population is at high risk of poor adherence and attrition (6) and is understudied.

This study is the first to investigate psychosocial predictors (i.e. body image, mood and self-efficacy) of low adherence among a large sample size of adolescents with obesity enrolled in a randomized controlled exercise trial. Given that 70% of the sample were girls, the current study did not have enough statistical power in the sex-specific analyses in boys. Although the results suggest differences in predictors between sexes, future studies

with larger samples are needed to more rigorously examine sex-specific predictors of adherence in adolescents with obesity. While the run-in program was necessary in the design of the HEARTY trial to ensure safety and adherence to the HEARTY exercise intervention (47), this may have limited the variability in adherence in the present study because participants were excluded if they had low adherence (less than 80% of the sessions) during the run-in program. The odds ratios presented in the results that were statistically significant suggest small effects, suggesting that other potential variables may play a role in exercise adherence, warranting further research. Univariate logistic regression analyses were conducted because results were exploratory for measures of association rather than for creation of a predictive model. Multiple comparisons were not adjusted for in this study because of the novelty in examining predictors of low adherence in adolescents undergoing an exercise intervention that is deemed more hypothesis generating.

Conclusion

This study found that adolescents with obesity who placed more importance on their appearance (greater appearance orientation) and had more dysphoric mood states (higher depressive and confused moods) were less likely to adhere to their prescribed exercise programme. Lower aerobic fitness and high confusion were predictors of low adherence in females whereas altered mood states (higher anger, confusion, depression and vigour) and lower weight preoccupation were predictors of low adherence in males. Despite the study's aforementioned methodological limitations, the findings suggest that potential sex differences between predictors of adherence between male and female adolescents with obesity warrant verification in larger studies. The results highlight the potential importance of addressing mental health issues when considering behavioural interventions and programs geared to adolescents with obesity. The results highlight the potential importance of screening of body image and mood prior to commencement and throughout an exercise program and examining the adjunctive use of a body image and mood-therapy module to be able to address potential adherence or dropout barriers and help maintain physical activity participation in adolescents.

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Conflict of Interest Statement

No conflict of interest was declared.

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