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Identification of Latent Subgroups of Obese Adolescents Enrolled in a Healthy Weight Management Program

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IDENTIFICATION OF LATENT SUBGROUPS OF OBESE ADOLESCENTS
ENROLLED IN A HEALTHY WEIGHT MANAGEMENT PROGRAM

A dissertation submitted in partial fulfillment of the requirements for the degree of
Doctor of Philosophy at Virginia Commonwealth University

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Abstract

IDENTIFICATION OF LATENT SUBGROUPS OF OBESE ADOLESCENTS ENROLLED IN A HEALTHY WEIGHT MANAGEMENT PROGRAM

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In obesity research, it is assumed that the population is homogeneous. While this approach has yielded important insights, testing this supposition might reveal information that could impact our understanding of the phenomena and its treatment.

In this study, data from obese teenagers (*N* = 248, Mean BMI percentile = 99%; Mean age = 13.9, *SD* = 1.8) who were predominantly minority (*n* = 182), female (*n* = 169), and enrolled in a weight loss intervention were analyzed. Latent profile analysis (LPA) was used to segment patients into groups based on their scores on PedsQL 4.0

scales (physical-, emotional-, social-, and school functioning) and the Coopersmith Self-Esteem Scale.

A 3-class solution was parsimonious and demonstrated the best statistical fit (Bayesian information criterion = 10596.96; Lo-Mendell-Rubin-adjusted likelihood ratio test = 73.020, $p < .05$). The 3 groups were ordinal and composed of respondents with high- (HF; $n = 72$, 29%), medium- (MF; $n = 110$, 44%), and low functioning (LF; $n = 66$, 27%).

Further analyses (chi squares and linear regressions) showed that the LF group had a significantly higher proportion of Caucasians and males compared to the HF (referent) group. Also, when controlling for demographics and weight, the LF group had significantly higher blood pressure (diastolic and systolic), lower self-reported physical activity (on two different measures), and a higher total score on a scale of depressed mood. Four groups of ordinal regressions (since the pair of self-reported exercise variables and blood pressure variables were correlated, only one from each pair was included in each set) consistently found that self-reported physical activity and blood pressure improved significantly from the LF to HF groups. However, when depressed mood was included, it became the only significant variable.

These findings suggest that LF group members are demographically and clinically distinct and that depressed mood may be the critical factor connecting self-report and metabolic dysfunction. Theory suggests depressed mood is both associated with cognitive schemas that affect responses on self-report measures; skewing them negative, and is also manifested metabolically.

Identification of Latent Subgroups of Obese Adolescents Enrolled in a Healthy Weight Management Program

Childhood obesity is currently a worldwide epidemic and a public health crisis (Ogden, Carroll, Kit, & Flegal, 2012; Ogden, Carroll, Curtin, Lamb, & Flegal, 2010; Story, Nanney, & Schwartz, 2009; Deckelbaum & Williams, 2001; Ebbeling, Pawlak, & Ludwig, 2002) affecting all racial/ethnic and socioeconomic subgroups (Hedley, Ogden, Johnson, Carroll, Curtin, & Flegal, 2004; Flegal, Carroll, Ogden, & Johnson, 2002). The latest estimates indicate that nearly 18% of adolescents ages 12 to 19 are obese (Ogden et al., 2010; Ogden, Carroll, Curtin, McDowell, Tabak, & Flegal, 2006). This means that these youth are at or above the 95th percentile of body mass index (BMI), a widely used clinical measure which takes height and weight into account to categorize weight status (underweight to severe obesity; Ogden et al., 2010; Lobstein, Baur, & Uauy, 2004; Swallen, Reither, Haas, & Meier, 2005; Strauss & Pollack, 2001). This group is at immediate risk for developing physical (e.g., joint pain, Wake, Canterford, Patton, Hesketh, Hardy, & Williams, Waters, & Carlin, 2010), medical (e.g., hypertension, Type 2 Diabetes [T2DM]; Deckelbaum & Williams, 2001; Lobstein, Baur, & Uauy, 2004; Wang & Dietz, 2002), and psychosocial problems (Schwimmer, Burwinkle, & Varni, 2003) that can affect long-term functioning and quality of life (QoL; Must, Jacques, Dallal, Bajema, & Dietz, 1992; Fox, Pencina, Wilson, Paynter, Vasan, & D’Agostino, 2008).

Short-Term Effects of Obesity

Recently, obese children have begun to develop serious medical conditions that were rarely seen until adulthood (e.g., hypertension, T2DM; Deckelbaum & Williams, 2001; Lobstein, Baur, & Uauy, 2004). Studies estimate that 4% of these adolescents have T2DM (Sinha, Fisch, Teague, Tamborlane, Banyas, Allen, & Savoye et al., 2002; Fagot-Campagna, Pettitt, Engelau, Burrows, Geiss, Valdez, & Beckles et al., 2000), and as many as 5% of adolescents may have undiagnosed diabetes or impaired fasting glucose (IFG; Sinha et al., 2002), a precursor for T2DM. Cardiovascular disease (CVD) risk factors are also increasing. One study found that 14% of obese children were hypertensive, 30% had high cholesterol levels, and 55% had elevated triglyceride concentrations (Fagot-Campagna, Knowler, & Pettitt, 1998). Obese adolescents also report psychosocial problems. For example, those seeking weight-loss treatment experience psychosocial distress, including body image disturbance, low self-esteem, depressed mood, social stigmatization (Dietz, 1998; Dixon, Dixon, & O'Brien, 2003; Cash, 1995; Goodman & Whitaker, 2002), and rate their health-related quality of life (HRQoL) even lower than children undergoing cancer treatment (Schwimmer, Burwinkle, & Varni, 2003).

Long-Term Effects of Obesity

Analyses have also found that childhood obesity is associated with long-term physical and psychosocial dysfunction (Serdula, Ivery, Coates, Freedman, Williamson, & Byers, 1993; Ebbeling, Pawlak, & Ludwig, 2002; Dean & Flett, 2002; Lobstein, Baur, & Uauy, 2004). For example, being overweight (BMI > 85^{th} percentile for age and sex) during adolescence correlated with an 8.5-fold increase in hypertension, a 2.4-fold increase in high total serum cholesterol, a 3-fold increase in high, low-density lipoprotein (LDL) cholesterol, and an 8-fold increase in low, high-density lipoprotein (HDL) cholesterol levels in young adulthood (ages 27 to 31; Srinivasan, Bao, Wattigney, & Berenson, 1996; Lauer & Clarke, 1989; Lauer, Lee, & Clarke, 1988). Furthermore, psychosocial problems during childhood such as peer rejection and lack of friendships are related to problems in adulthood including decreased psychological functioning, life satisfaction, and perceived competence (Bagwell, Newcomb, & Bukowski, 1998). Lower HRQoL (Jia & Lubetkin, 2005) and self-esteem also remain problematic (Lobstein, Baur, & Uauy, 2004).

Interventions

In light of this growing problem, interventions have been designed to address the complex biopsychosocial phenomena that contribute to obesity in children and adolescents (Givhan, 2010; Deich, Dobbins, Cohen, & The Finance Project Group, 2004; Centers for Disease Control, 2003). Most take a multifaceted approach by including dietary, exercise, physiological, and psychological components (Kirk, Scott, & Daniels, 2005; Reilly, 2006) and are targeted to specific populations (e.g., school-aged children, pre-diabetic adolescents) using group-based formats (e.g., group psycho-educational sessions) and standardized protocols (Luttikhuis, Baur, Jansen, Shrewsbury, O'Malley, Stolk, & Summerbell, 2009).

Understandably, most of these interventions are designed to help as many individuals as possible. Therefore, it is common to group individuals together based on their medical diagnosis and then utilize a multidisciplinary approach. The assumption is that participants will differentially benefit from treatment components (Borsboom, Mellenbergh, & VanHeerden, 2003; Turk, 2005) to improve their habits and ultimately lose weight. Yet, despite the number of obesity trials, current results suggest only modest short- to medium term improvements (about 10-20% decrease in percentage of overweight or a few units of change in BMI; Whitlock, Williams, Gold, Smith, & Shipman, 2005). Moreover, not all participants will benefit from the intervention. Some will drop out; others will not lose weight. Some may even gain weight. The fact remains that little is known about these participants, including what makes some obese children lose weight while others do not.

At the same time, it seems that improvements in weight and its related outcomes are possible to achieve as many adolescents do benefit from weight management programs. However, it seems necessary to utilize alternative methodological approaches to increase understanding of the barriers to weight loss for different subsets of adolescents and to identify those subsets of individuals at the start of an intervention so that researchers might design more effective interventions.

Thus, the purpose of this study was to utilize a different approach to conceptualizing adolescents' experience with severe obesity on two key variables—self-reported HRQoL and global self-esteem—that are typically low in this population. The methodology was used because it was believed to provide unique information about this group that would increase our understanding of adolescents' psychosocial functioning. To accomplish this goal first required describing the current approach to conceptualizing and treating obesity, followed by a presentation of a rather complicated statistical approach that differs from traditional methods. In the following section, the assumptions of current treatment approaches are reviewed, including how obesity interventions work to reduce weight.

Current Method to Conceptualize Obesity

Inherent in obesity treatments are a series of assumptions made by researchers. Two are described here. The first is the mechanism by which change occurs. Specifically, a child's behavior is a manifestation of a latent variable or an unobservable attribute that is measured indirectly by observable indicators (Borsboom, Mellenbergh, & VanHeerden, 2003). The goal of the intervention is to improve participants' position on the latent variable, which has a continuous scale with a bell-shaped distribution. For example, most obesity interventions incorporate nutrition education that focuses on improving healthy eating habits, which lead participants to reduce their caloric intake thereby lowering weight. The implication is that increasing adolescents' knowledge, and thus their rank on the latent variable, will lead them to make better choices about the foods they eat. Subsequently, these decisions will eventually be manifested as a reduction in weight.

Second, the statistical analyses imply that the sample is homogeneous (Borsboom, Mellenbergh, & VanHeerden, 2003; Collins & Lanza, 2010). This approach is often described as "variable-centered" (Collins & Lanza, 2010; Lanza, Savage, & Birch, 2009) because it assumes that pre-determined characteristics or variables (e.g., demographics, frequency of self-reported exercise) form a linear combination of predictors that can be used to explain the dependent variable (DV), in this case, weight, and that everyone in the sample will, on average, experience a change in the DV in the same way. For example, if a researcher finds that a two-unit decrease in BMI is associated with improved HRQoL scores, this is assumed to be true, on average, for all participants. While this is important, it provides little information about the participants that did not respond or respond as strongly.

Alternative Method to Conceptualize Obesity

Another approach is to assume the latent variable is not continuous but rather has a finite number of levels that can either be ordered (ordinal) or unordered (nominal; Magidson & Vermunt, 2002; Bauer & Curran, 2004). This has important implications for how one would treat obese adolescents in an intervention. For example, imagine nutrition education is not a continuous latent variable but instead has an ordinal scale such that an adolescent's knowledge would either be low, medium, or high. If this were true, then it would behoove a researcher to conceptualize the intervention differently for the groups because those in the high group already have the knowledge but are not applying it versus those who do not have the knowledge and thus cannot apply it. Therefore, it is likely that adolescents with both levels would differentially respond to an intervention. With this in mind, interventions that are developed for the specific needs of each group might yield better overall results. While this conceptualization of nutrition education is probably unlikely, it still exemplifies how re-conceptualizing the latent variable can potentially alter how one views the respondents and how they would be treated.

This approach has been called a "person-centered approach" (Collins & Lanza, 2010; Lanza, Savage, & Birch, 2009; Bergman & Magnusson, 1997; Bergman, Magnusson, & El-khouri, 2003), and researchers are increasingly conceptualizing latent variables in this manner by using appropriate statistical methods to group patients with similar characteristics (Lanza & Collins, 2006; Kudel, Farber, Mrus, Leonard, Sherman, & Tsevat, 2006; Turk, 2005). This approach has been most widely utilized in pain research. Specifically, patients' self-reported pain perceptions on the West Haven-Yale Multidimensional Pain Inventory (YMPI; Kerns, Turk, & Rudy, 1985) consistently yield three distinct profiles (Turk, 2005; Turk & Rudy, 1990; Etscheidt, Steger, & Braverman, 1995; Geisser, Robinson, & Henson, 1994; Turk, Okifuji, Sinclair, & Starz, 1998; Hellstrom & Jansson, 2001): 1) Adaptive Copers (AC), which are characterized by low distress/positive coping, 2) Interpersonally Distressed (ID) Copers, defined by limited social support/interpersonal difficulties, and 3) Dysfunctional Copers (DYS), including patients with high emotional distress (e.g., depression, feelings of low control, catastrophizing). Consistent across studies and various pain conditions, ID and DYS groups report higher emotional distress than AC group patients (Etscheidt, Steger, & Braverman, 1995; Geisser, Robinson, & Henson, 1994), whose distress levels, in one study, were even lower than those reported by community members experiencing pain (Hellstrom & Jansson, 2001).

These findings have important implications for treatment and attrition. For example, based on their baseline YMPI profiles, Turk and colleagues (1998) found differential results of a pain intervention of patients with fibromyalgia syndrome (FMS). DYS patients improved in most areas, whereas ID group patients, despite similar levels of pain/disability, did not benefit from treatment (Turk, 2005). Turk (2005) suggested that DYS patients, many of whom were depressed, might have responded well to the cognitive-behavioral (CBT) intervention components due to their focus on improving maladaptive beliefs (e.g., cognitive restructuring). However, those in the ID group may have needed more specialized treatment to enhance interpersonal skills and build social support, thus, a group-based format may not have been appropriate for these patients. Finally, those in the AC group might have acquired greater gains if provided with more reassurance, maintenance, and relapse prevention strategies rather than standard CBT components (Talo, Forssell, Heikkonen, & Puukka, 2001; Turk et al., 1998; Turk, 2005).

Turk and colleagues (1993) have tested such an intervention for DYS Copers with Temporomandibular Disorder (TMD). Participants were assigned to one of two treatment groups: 1) interocclusal appliance (IA), biofeedback-assisted relaxation (BF), and supportive counseling (IA + BF + SC), or 2) IA + BF treatment plus cognitive therapy (CT) for depression (IA + BF + CF). Both groups received six weekly treatment sessions, followed by post-treatment and 6-month follow-up evaluations of psychosocial functioning. Results showed that both groups improved on measures of psychosocial functioning, but those assigned to the IA + BF + CT group had the greatest improvements, particularly on measures assessing pain and depression. These findings support that DYS patients benefit from treatment components that are tailored to meet their unique profile.

Tailoring treatment to these groups may also reduce attrition. For example, Carmody (2001) found that ID (47%) and DYS (33%) patients were significantly more likely to drop-out of group rehabilitation treatments than AC group members (11%).

Thus, patients who receive a treatment that does not match their needs may be more likely to drop-out because they do not believe it to be helpful (Turk, 2005; Whitlock et al., 2005).

Specific to weight-related research, Lanza and colleagues (2009) used a similar statistical methodology called latent class analysis (LCA) to group women's responses to 14 weight loss strategies into four classes. They included: No Weight Loss Strategy (Class 1, low probability of endorsing weight-control strategies; 10%, 2) Dietary Guidelines (Class 2, high probability of practicing healthy dietary strategies; 26.5%), 3) Guidelines + Macronutrients (Class 3, high probability of trying a low carbohydrate diet; 39.4%), and 4) Guidelines + Macronutrients + Restrictive (Class 4, tried nearly all weight-loss strategies, both healthy and unhealthy, including restrictive eating practices; 24.2%). Secondary analyses were used to determine whether psychosocial factors (body satisfaction, depression, dietary restraint, and disinhibition), which are associated with self-reported dieting, were related to class membership. It was found that Class 4 had greater body dissatisfaction, dietary restraint, and disinhibition compared to Class 1. Further, having both high dietary restraint and disinhibition were strong predictors of practicing extreme, unhealthy weight loss behaviors. The authors' suggested that an important next step would be to study the relation among weight loss strategy latent classes and outcomes such as weight and weight change.

In sum, these studies demonstrate that it might be possible to use self-report data to group adolescents with severe obesity into a meaningful typology, which may better elucidate our understanding of the population (Whitlock et al., 2005; Lanza et al., 2009).

The Current Study

Our literature search revealed no extant studies having used a person-centered approach to understand obese adolescents' psychosocial functioning. Therefore, the goal of this project was to determine whether a categorical approach could be used to sort adolescents' responses on self-report measures into a meaningful typology. Specifically, self-reported baseline HRQoL and global self-esteem were used from participants of the Teaching, Encouragement, Exercise, Nutrition, Support (TEENS) Healthy Weight Management Program (Gary Francis: PI; funded by Virginia Premier Health Plan, Inc.). Additional baseline data, including demographics, self-reported physical activity, and metabolic data (fasting glucose and insulin levels; blood pressure: total, systolic, and diastolic; serum cholesterol: total cholesterol [TC], [LDL], [HDL], and triglycerides) were used to better understand the relationships between self-report and metabolic data.

Literature Review

The following section reviews the obesity literature and reports the associations among the variables used in this study. This includes:

1) self-reported HRQoL, including its relationship to obesity in each domain of functioning (physical, emotional, social, and school)
2) global self-esteem in adolescents with severe obesity
3) self-reported physical activity
4) demographic differences in HRQoL and self-esteem
5) obesity-related clinical and metabolic indicators

Finally, theories describing the relationship among the variables are reviewed. This includes the biopsychosocial theory of disease and major theories explaining the connection between psychosocial factors and pathophysiology.

Health-Related Quality of Life (HRQoL)

Health-related quality of life (HRQoL) is a subjective evaluation of physical and psychosocial functioning (*Healthy People*, 2020). It is associated with obesity and its comorbid diseases such as diabetes and hypertension (Centers for Disease Control [CDC], 2012), and in this study, it is defined by four domains, including physical, emotional, social, and school functioning (Varni, Burwinkle, Seid, & Skarr, 2003).

In general, cross-sectional and longitudinal studies indicate that obese adolescents perceive their overall HRQoL significantly lower than their average-weight peers (Schwimmer, Burwinkle, & Varni, 2003; Williams, Wake, Hesketh, Maher, & Waters, 2005; Swallen et al., 2005). In particular, it seems that adolescents most at risk for poor functioning are those with severe obesity (Wake et al., 2010; Atlantis & Baker, 2008).

Physical functioning. In general, obese adolescents show the largest discrepancies in physical functioning compared to other domains (Sullivan, Karlsson, Sjostrom, & Taft, 2001; Schwimmer et al., 2003; Wake et al., 2010; Brown, Mishra, Kenardy, & Dobson, 2000; Swallen et al., 2005). This seems to be because excess weight is associated with pain (joint pain and headaches; Meredith & Dyer, 1991; Janke, Collins, & Kozak, 2007), fatigue (Wake et al., 2010), and ambulatory difficulties (Strauss, 1999).

Emotional functioning. In general, obese adolescents experience greater weight stigmatization (Dietz, 1998) and negative body-image (Friedman, Reichmann, Costanzo,

& Musante, 2002; Cargill, Clark, Pera, Niaura, & Abrams, 1999) which, according to some results, are associated with increased symptoms of depressed mood and anxiety (Erermis, Cetin, Tamar, Bukusoglu, Akdeniz, & Goksen, 2004; Carpenter, Hasin, Allison, & Faith, 2000; Marzocchi, Moscatiello, Villanova, Suppini, & Marchesini, 2008; Wadden, Womble, Foster, McGuckin, & Schimmel, 2001). Similarly, Janicke and colleagues (2007) found that depression mediated the relationship between obesity and QoL.

Some studies have also found that those with the most severe obesity (BMI $\geq 95^{th}$ percentile) have the worst emotional functioning (Wake et al., 2010). In one study, 48% of severely obese adolescents reported moderate to severe depressive symptoms, and 35% reported a high level of anxiety. In this same study, extreme obesity was also significantly related to an increased risk of suicidal ideation (Dong, Li, Li, & Price, 2006).

Social functioning. Obesity can contribute to social difficulties among adolescents. For example, obese children generally report having fewer friends and being teased about their weight (Strauss & Pollack, 2003; Thompson, Shroff, Herbozo, Cafri, Rodriguez, & Rodriguez, 2007). Further, researchers have found that obese adolescents are more likely to be friends with peers who were considered to be less popular (Strauss & Pollack, 2003) and are significantly less likely to be considered as a friend by their peers in comparison to average weight adolescents.

Moreover, obese adolescents typically report experiencing greater verbal and physical victimization than their average weight peers (Zeller & Modi, 2009; Janssen, Craig, Boyce, & Pickett, 2004; Pearce, Boergers, & Prinstein, 2002; Crick & Grotpeter, 1995; Storch, Milsom, DeBraganza, Lewin, Geffken, & Silverstein, 2007). For example, Janssen and colleagues (2004) showed that obese youth were more likely to be victims of aggression than their average weight peers. Specifically, they found significant relationships for relational (e.g., withdrawing friendship or spreading rumors or lies) and overt (e.g., name-calling or teasing or hitting, kicking, or pushing) victimization (Janssen et al., 2004).

In addition, obese adolescents seeking weight loss treatment often report that they receive negative or little social support (Zeller & Modi, 2006), which in one study, predicted weight gain at two-year follow-up (Epstein, Wisniewski, & Wing, 1994). However, success in weight management programs is related to fewer social problems and greater perceived social competence (Myers, Raynor, & Epstein, 1998).

School functioning. Most of the literature examining adolescents' academic performance outcomes (e.g., GPA) and degree of adiposity suggests they are unrelated after adjusting for race/ethnicity, sex, and parental level of education (Cottrell, Northrup, & Wittberg, 2007; Huang, Goran, & Spruijt-Metz, 2006; Datar, Sturm, & Magnabosco, 2004; Judge & Jahns, 2007). However, there is evidence that obese children are more negatively affected by psychosocial influences than their average weight peers as perceived by their teachers (Judge & Jahns, 2007). Further, other factors such as depressed mood, anxiety, or stress might indirectly affect perceptions of academic functioning due to their influence on attention and concentration (e.g., paying attention in class; Huang, Goran, & Spruijt-Metz, 2006).

Demographic differences in HRQoL. Some studies suggest that there may be demographic differences (race, sex, age) in perceptions of HRQoL among obese children and adolescents (Swallen et al., 2005; Fallon, Tanofsky-Kraff, Norman, McDuffie, Taylor, Cohen, & Young-Hyman, 2005). Yet, few studies have examined the relationship among these variables (Swallen et al., 2005). In the studies that do exist, researchers generally conclude that:

1) Caucasians report lower HRQoL than African Americans (Fallon et al., 2005; White, O'Neil, & Kolotkin, 2004)
2) Caucasians also report lower physical functioning compared to African Americans, which may be partially explained by African American preferences for larger body types and higher tolerance for increased weight (Padgett & Biro, 2003)
3) Girls perceive greater impairments in HRQoL than boys (Strauss, 2000)
4) Younger adolescents (ages 12 to 14) report lower HRQoL than older adolescents (Swallen et al., 2005)

In sum, more research is needed to understand how demographics might explain differences in perceptions of HRQoL in obese adolescents. Current studies are limited by cross-sectional designs, small sample sizes, and largely child (rather than adolescent), Caucasian, and female samples. Thus, it is unclear how minorities and boys, in particular, might experience their condition (Wardle & Cooke, 2005; Cohane & Pope, 2001).

Global Self-esteem

Self-esteem, one's personal judgment of worthiness, reflects dimensions of the self in relation to social, family, and school domains (Coopersmith, 1967). In particular, most studies have shown that severe obesity is associated with low self-esteem (Israel & Ivanova, 2002; Strauss, 2000), and weight-related stigma experienced by obese adolescents seems to play a role (Swallen et al., 2005; Israel & Ivanova, 2002; Carpenter et al., 2003).

However, the relationship is not clear cut. It appears that the operationalization of self-esteem—global or domain-specific—might affect this relationship (Zeller & Modi, 2009). Given the literature that points to the effects of weight-related stigma and body dissatisfaction on self-esteem (Pesa, Syre, & Jones, 2000), it is not too surprising that when specific domains of self-esteem such as physical appearance or athletic competence are measured individually, obese children almost always report lower self-esteem than their average weight peers (Kimm, Barton, Berhane, Ross, Payne, & Schreiber, 1997; Braet & VanStrien, 1997; French, Perry, Leon, & Fulkerson, 1996; Campbell & Hausenblas, 2009).

Demographic differences in self-esteem. Furthermore, self-esteem appears to vary by age, race, and sex. Specifically, obese adolescents tend to rate their self-esteem lower than younger children (French, Story, & Perry, 1995), particularly as they go through puberty (Israel & Ivanova, 2002; Stradmeijer, Bosch, Koops, & Seidell, 2000). Some researchers also suggest that obesity-related stigma might be higher for girls than boys (Brownell, 1991; Swallen et al., 2005) because girls often report higher depression and lower self-esteem in comparison to average weight peers, and boys, regardless of their weight, often report similar levels of self-esteem and depression (Swallen et al., 2005; Erickson, Robinson, Haydel, & Killem, 2000; Strauss, 2000). Many researchers believe these findings are a function of body dissatisfaction, which is more pronounced in girls, thus, affecting self-esteem (Manus & Killeen, 1995; Pesa, Syre, & Jones, 2000).

However, this might not always be the case. For example, one prospective study showed that chronic obesity was associated with depression in Caucasian boys (ages 9 to 16) but not in girls (Mustillo, Worthman, Erkanli, Keeler, Angold, & Costello, 2003). Thus, it should be noted that the relationship among psychosocial sequelae is less clear in males, particularly adolescents, because most studies include only females or a small number of male participants (Cohane & Pope, 2001; Wardle & Cooke, 2005).

Thus, based on the literature to date, there is more compelling evidence that Caucasian and Hispanic youth, particularly girls, have lower self-esteem than African American peers in both childhood and adolescence (Strauss, 2000; Zeller & Modi, 2009; Campbell & Hausenblas, 2009; Neff, Sargent, McKeown, Jackson, & Valois, 1997; Faith, Manibay, Kavitz, Griffith, & Allison, 1998; Swallen et al., 2005). One explanation for demographic differences in self-esteem is that African Americans generally accept a larger body type than Caucasians (Fallon et al., 2005).

Self-reported Physical Activity

Self-reported physical activity is related to both psychosocial and metabolic outcomes in obesity. Specifically, decreased activity and increased sedentary behaviors negatively impact adolescents' well-being (Ferron, Narring, Cauderay, & Michaud, 1999; Kirkcaldy, Shepard, & Siefen, 2002; Page & Tucker, 1994), QoL (physical activity measured by accelerometers; Shoup, Gattshall, Dandamudi, & Estabrooks, 2008) and metabolic profiles (Dunstan, Salmon, Owen, Armstrong, Zimmet, Welborn, & Cameron et al., 2005; Healy, Dunstan, Salmon, Shaw, Zimmet, & Owen, 2008).

Gray and colleagues (2008) studied adolescents' perceived barriers to physical activity and found that higher peer victimization (e.g., relational and overt) and depressive symptoms, in particular, predicted barriers (e.g., self-consciousness, social stigmatization, physical discomfort) to activity. Moreover, the total number of perceived physical activity barriers from five domains (body-related, access to resources, social, fitness, and convenience) mediated the relationships between peer victimization, depressive symptoms, and physical activity. The authors concluded that peer victimization makes children feel uncomfortable and self-conscious about being in situations where they might be excluded from physical activities, leading them to avoid activity altogether (Gray, Janicke, Ingerski, & Silverstein, 2008).

Other studies have also linked perceived levels of physical activity to emotional functioning. For example, Steptoe and Butler (1996) found that adolescents' self-reported physical activity was related to emotional well-being. Those who participated in non-vigorous, recreational activities reported greater psychological and somatic symptoms than their active peers. However, those who engaged in vigorous physical activity had the highest emotional well-being.

Similarly, adolescents who perceive themselves as athletic also report better functioning. For example, according to a national survey of 10,000 adolescents aged 15-20, those classified as athletes (e.g., reported participating in sports daily or 2-3 times per week and belonging to a fitness club) endorsed fewer somatic complaints, had greater confidence in future health, and had less depression and anxiety compared to those classified as non-athletes (e.g., engaged in sports' activities once per week or never). Further, those with the highest levels of activity also had the greatest well-being. In addition, amount of time spent participating in sports' activities was related to perceived locus of control regarding health (Ferron et al., 1999).

Clinical and Metabolic Indicators

Body mass index (BMI). Overweight and obesity are defined according to BMI, which is the most frequently used outcome in obesity research**.** It reflects the proportion of excess body fat, corresponding to an individual's height and weight. Children with a BMI between the 85th and 95th percentile are considered overweight (BMI = 25 to 29.9 kg/m^2; Helmrath, Brandt, & Inge, 2006), those with BMIs greater than the 95th (BMI = 30 kg/m^2 or greater) percentile are considered clinically obese, and severe obesity is defined as having a BMI greater than or equal to 40 kg/m^2. Overweight adolescents are at risk for secondary complications such as hypertension and dyslipidemia (Barlow & Dietz, 1998), while older adolescents with BMIs greater than the 95th percentile tend to have elevated blood pressure and lipid profiles, which increase their risk for obesity-related diseases and mortality (Barlow & Dietz, 1998; Helmrath, Brandt, & Inge, 2006).

Blood pressure. Obesity is the primary cause of clinical hypertension in children and adolescents and occurs 10 times more often in obese rather than average weight children (Must, 1999; Sorof, Poffenbarger, Franco, Bernard, & Portman, 2002). In addition, 30% of those who are overweight have elevated systolic or diastolic blood pressures (BPs), and systolic blood pressure is positively related to skinfold thickness and waist-to-hip ratio (Lurbe & Redon, 2001). Further, high blood pressure in adolescence is a main predictor of later health problems such as CVD (Meredith & Dwyer, 1991; Freedman, Dietz, Srinivasan, & Berenson, 1999).

Even in the absence of hypertension, obese adolescents are still at increased risk for developing it. This may be because obesity seems to heighten autonomic nervous system activity, which has been linked to higher blood pressures (Sorof et al., 2002). This activity can increase stroke volume and cardiac output, which over time can lead to cardiovascular changes, including systolic and diastolic dysfunction (Peavy, 2009).

Cholesterol. Cholesterol, a type of lipid, is produced in the liver and is responsible for cell repair and hormone production. Additionally, intake of dietary saturated fat stimulates production of cholesterol and triglycerides, which are carried throughout the bloodstream and made available to cells via lipoproteins (e.g., LDL and HDL). Specifically, LDLs transport cholesterol and contribute to plaque buildup on the artery walls, which restricts blood flow to and from the heart. HDLs ("good cholesterol") remove cholesterol from the bloodstream. In adolescent obesity, high cholesterol is often characterized by elevated LDL cholesterol and triglycerides and low HDL cholesterol (Dietz, 1998), all of which are risk factors for CVD.

Triglycerides and serum cholesterol. Cardiac risk factors are commonly experienced by obese adolescents, including atherogenic dyslipidemia (decreased HDL cholesterol), elevated triglycerides (high LDL cholesterol), and hypertension. Fifty percent of overweight adolescents have at least one risk factor for developing CVD, and

20% have two risk factors (Freedman, Khan, Dietz, Srinivasan, & Berenson, 2001). In fact, the presence of multiple risk factors, including obesity, is further associated with atherosclerosis (Berenson, Srinivasan, Bao, Newman, Tracy, & Wattigney, 1998; Srinivasan, Bao, Wattigney, & Berenson, 1996).

Insulin and glucose. Many factors contribute to variability in insulin sensitivity including diet and amount of physical activity (Grundy, 2000). Hyperglycemia typically occurs after several years of insulin resistance (Weiss, Taksali, Tamborlane, Burgert, Savoye, & Caprio, 2005; Uwaifo, Fallon, Chin, Elberg, Parikh, & Yanovski, 2002), but impaired glucose tolerance may still be present in obese youth (Sinha et al., 2002).

Measuring insulin resistance, particularly in populations most at-risk for developing diabetes and other metabolic abnormalities, is necessary to understand its progression and symptoms that might interfere with functioning. For example, if left untreated, chronic obesity can lead to endocrine malfunction due to a reduced sensitivity to insulin. This is typically associated with the onset of T2DM, which has increased 10-fold between 1982 and 1992 (Pinhas-Hamiel, Dolan, Daniels, Standiford, Khonry, & Zeitler, 1996). Over 90% of these adolescents had a BMI greater than the 90^{th} percentile**,** and about one-fifth of new diagnoses affect pubertal children (Pinhas-Hamiel et al., 1996). Thus, it is particularly important to identify differences in metabolic patterns to develop prevention strategies and appropriate interventions (Conwell, Trost, Brown, & Batch, 2004).

Relationship Between Psychosocial and Metabolic Functioning

Most researchers agree that obesity is triggered by a complex interaction of biopsychosocial factors (Rosmond, Dallman, & Björntorp, 1998; Björntorp, 2001; Golden, 2007; Grundy, 2000; Weinsier, Hunter, Heini, Goran, & Sell, 1998; Bradford, 2009; Helmrath, Brandt, & Inge, 2006). Biology includes genetics, medical comorbidities, and metabolism while psychological factors might include lifestyle (e.g., excess caloric intake and decreased physical activity), motivation to change, perceived stress, mood, and self-esteem. Typical social influences attributed to obesity are socioeconomic status (SES), peer relationships, and family environment.

In health psychology research, the primary model used to conceptualize these complex interactions is the biopsychosocial model (Engel, 1977; Molinari, Bellardita, & Compare, 2006 in Molinari, Compare, & Parati, 2006). This paradigm incorporates information from other sciences into a behavioral theory of disease development. Based on this theory, psychological factors such as stress and negative emotional states act either indirectly by affecting behavior (e.g., favoring unhealthy lifestyles, non-adherence to treatment) or directly on metabolic factors through a number of pathophysiological mechanisms that are not fully understood (Compare, Gondoni, & Molinari, 2006; Molinari, Bellardita, & Compare, 2006 in Molinari, Compare, & Parati, 2006; Björntorp, 2001; Golden, 2007). This uncertainty exists for several reasons, mainly due to individual variation (e.g., genetics, personality; Rosmond, Dallman, & Björntorp, 1998).

However, it appears that the major pathophysiological mechanisms thought to mediate psychological relationships and metabolic dysfunction are often cited as pathways to cardiovascular disease (CVD); these include, but are not limited to, heightened sympathetic nervous system (SNS) activity and alterations in neuroendocrine regulation (Rutledge, 2006). It seems that psychosocial functioning might be partially explained via elevated activity of the HPA axis, which is the result of perceived stress. The neuroendocrine-autonomic stress reaction is probably followed by metabolic abnormalities from repeated activation of the HPA axis and elevation of blood pressure via a parallel activation of the SNS (Golden, 2007; Kiecolt-Glaser, McGuire, Robles, & Glaser, 2002).

Clear evidence for these pathways has been shown, which links chronic stress and its physiological response to disease processes. Therefore, it seems reasonable that patients who are obese might be at even greater risk for psychosocial and metabolic disturbances due to the indirect (and often negative) effects that obesity has on behavior (diet, physical activity) and self-perceptions and its direct physiological effects (heightened SNS activity).

Thus, for the purposes of this study, two of the main biopsychosocial theories that relate psychosocial functioning (e.g., perceived, chronic stress, depressed mood) to risk factors for metabolic dysfunction were reviewed. These include: dysregulation of the SNS/hypothalamic-pituitary-adrenal (HPA) axis and inflammation/immunological dysregulation, both of which overlap considerably and have been investigated in obese populations (Björntorp, 2001; Lumeng & Saltiel, 2011).

Hypothalamic-pituitary-adrenal (HPA) axis and autonomic nervous system (SNS) dysregulation. One theory linking psychosocial and metabolic pathways is through SNS and HPA axis dysregulation. Specifically, stress activates the SNS or “fight or flight" response and the hypothalamic-pituitary-adrenocortical (HPA) axis. Collectively, this activation stimulates the release of cortisol, a counter-regulatory hormone, and increases production of catecholamines (epinephrine and norepinephrine) and inflammatory markers (e.g., excess cytokines; Hjemdahl, 2002). While release of these hormones (cortisol and other adrenal steroids) is beneficial for short-term stress relief and maintenance of blood pressure (Peavy, 2009), chronic HPA and SNS activation appear to be involved in the pathophysiology of CVD. Repeated stimulation of these systems might be related to metabolic disturbances including insulin resistance, dyslipidemia, and hypertension (Björntorp, 2001; Grundy, 2000) for some individuals, which can increase one's predisposition to future diseases such as diabetes. Recent research has further indicated that even subclinical levels of hypercortisolism can lead to adverse metabolic consequences.

In addition, abnormal hormone concentrations (Stunkard, Faith, & Allison, 2003; McElroy, Kotwal, Malhotra, Nelson, Keck, & Nemeroff, 2004) can increase susceptibility to depression (Miller & O'Callaghan, 2002; Ahlberg et al., 2002) and other physical problems (Williams, Jacka, Pasco, Dodd, & Berk, 2006). This is because in depressed patients, SNS dysregulation also exists, placing them at higher risk for diseases such as CAD (Carroll, Curtis, & Mendels, 1976; Gerken & Holsboer, 1986; Golden, 2007; Carney, Freedland, & Veith, 2005; Björntorp, 2001).

Inflammation and immunological dysregulation. The second theory involves the role that negative emotions have on inflammatory processes and immunological responses. Specifically, negative emotions such as depression and anxiety can lead to immune system alterations through increased production of proinflammatory cytokines (Kiecolt-Glaser et al., 2002; Markowitz, Friedman, & Arent, 2008). Elevated levels of these immune system mediators can also activate the HPA axis. Thus, it is not surprising that chronic, heightened activity (via the stress-related response) changes cardiovascular function and intermediary metabolism. It also inhibits immune-mediated inflammation, increasing susceptibility toward illnesses (Chrousos, 1995). Initial support for these findings has been shown in antidepressant medication effects, which reduce certain proinflammatory cytokines (Basterzi, Aydemir, Kisa, Aksaray, Tuzer, Yazici, & Goka, 2005).

The current study. Currently, it is unclear how adolescents who are obese experience their condition and potential susceptibility to future disease. Given the literature supporting a link between psychological and physiological processes, the proposed study examined psychosocial data in combination with metabolic factors and physical activity to determine whether certain individuals experience worse functioning, which could be, in part, a result of weight-related stressors (e.g., depressed mood, weight stigmatization; Dietz, 1998; Goodman & Whitaker, 2002), which can further contribute to metabolic abnormalities (Ahlberg et al., 2002; Goodman & Whitaker, 2002).

Summary

Adolescent obesity is a chronic disease and has immediate mental health consequences in addition to long-term medical complications (Zametkin, Koon, Klein, & Munson, 2004). As a result, interventions have been designed to control concomitant diseases and minimize adverse psychosocial effects by reducing weight. Much of the literature indicates that severely obese adolescents in weight loss treatment experience worse psychosocial and metabolic functioning than their average weight peers. However, studies still report a range of functioning across patient populations. In light of these findings, a recent body of literature has called upon behavioral researchers to use alternative methods to identify "vulnerable subgroups" in obese populations (Wardle & Cooke, 2005) to inform the development of more appropriate treatments (Lanza Savage, & Birch, 2009; Sullivan et al., 2001). More importantly, advances in statistical methods allow us to identify individual's perspectives and experience of their condition across domains of psychosocial and physiological functioning (Kudel et al., 2006). While these methods have been used only sparsely, the results offer compelling insight into the phenomenological world of patients with a variety of conditions.

To wit, no studies have attempted to model patterns of behavior in a sample of severely obese adolescents. Thus, the current study aimed to: 1) determine whether self-report data could be organized into a meaningful typology, and 2) identify whether adolescents' perceived psychosocial functioning was related to demographics, physical activity, and obesity-related metabolic factors. The specific hypotheses are described below.

Hypotheses. The current study combined latent profile analysis (LPA; Gibson, 1959) and regression modeling. It was hypothesized that: 1) Meaningful subgroups of overweight and obese adolescents can be identified based on self-reported psychosocial data (HRQoL-4 domains and global self-esteem), and 2) If the groupings exist, group membership will be related to demographic, physical activity, and metabolic factors.

Method

Description of Intervention

Teaching, Encouragement, Exercise, Nutrition, Support (TEENS) Healthy Weight Management Program

The TEENS program is a two-year, interdisciplinary clinical research trial funded by Virginia Premier Health Plan, Incorporated, to treat obese, ethnically diverse adolescents (aged 11 to 18) in central Virginia. TEENS provides supervised exercise and nutrition education along with behavioral support (e.g., individual and group counseling) to increase physical activity, improve dietary intake, improve psychosocial and metabolic functioning, and ultimately, decrease BMI (Kirk, Zeller, Claytor, Santangelo, Khoury, & Daniels, 2005; Schroeder, Browne, & McComiskey, 2010). It is implemented in three phases, where Phase I = baseline, initial 6-months; Phase 2 = maintenance of weight loss (6-months), and Phase 3 = the final 12-months. The TEENS' study was approved by Virginia Commonwealth University's (VCU) Institutional Review Board (IRB).

Participants

Adolescents in this study included those with complete baseline, psychosocial data who were between 11 to 18 years and >85th percentile for BMI for age and sex (Kuczmarski, Ogden, Guo, Grummer-Strawn, Flegal, Mei, & Wei et al., 2000). Each adolescent was also required to have at least one consenting adult who agreed to attend program meetings (e.g., nutrition education and behavioral support follow-up appointments). At the initial baseline visit, all adolescents and their guardians completed a detailed consent process, approved by VCU's IRB, which explained study requirements.

Participants were referred to the TEENS' program primarily by local school nurses or primary care physicians (PCPs) who were given information about the study; others were self-referred via word-of-mouth. Adolescents were not enrolled if they: 1) lived in a residence beyond a 30-mile radius of downtown Richmond, Virginia, 2) could not understand program instructions due to a mental disability, 3) could not exercise due to a physical disability or underlying medical condition, 4) had been diagnosed with a severe mental illness or a current eating disorder, or 5) did not have a PCP to coordinate care.

Procedure

This study is a secondary data analysis of baseline data from TEENS' participants. The baseline assessments included collection of medical and self-report data. Adolescents also answered questions regarding demographics. The baseline assessments took place between 2004 and are still ongoing; however, various protocols have been instituted.

During the baseline medical visit, adolescents completed laboratory work (basic hematology/chemistry and a comprehensive metabolic panel), and their BMI, weight, height, waist, hips, vitals, and resting electrocardiogram (ECG) were obtained at VCU's General Clinical Research Center (GCRC).

Baseline psychosocial data were gathered when the adolescent and his or her parent/guardian met with a supervised doctoral-level psychology student. During the visit, the student administered a series of self-report questionnaires, three of which were included in this study.

Baseline physical activity data were obtained when the adolescent and his or her guardian met with a graduate student and/or faculty member of VCU's Division of Health and Human Performance. At this time, the physical activity questionnaire (7-Day Physical Activity Recall; Sallis, Haskell, Wood, Fortmann, Rogers, Blair, & Paffenbarger, 1985) was completed.

Measures

Demographics questions. (See Appendix A). Adolescents answered demographic questions regarding their sex, age, and race/ethnic identity.

Clinical measures. The clinical data used for this study included 1) BMI (an indicator of body fatness; CDC, 2012), which was determined using participants' height and weight and measured to the nearest 0.1 cm/0.1 kg (BMI = weight (kg)/height $(m)^2$), 2) BMI *z*-scores (determined using the Epi Info software program), 3) blood pressure (systolic and diastolic), 4) serum cholesterol values (triglyceride levels, high-density lipoprotein [HDL], low-density lipoprotein [LDL], and total cholesterol [TC]), and 5) metabolic indicators (glucose and insulin levels). BMI (kg/m^2) and BMI *z*-score were both used because, although highly correlated with one another (Cole, Faith, Pietrobelli, & Heo, 2005), each may contribute unique information. For example, some studies suggest that in youth, BMI *z*-score is ideal for assessing adiposity at a single time point whereas BMI (kg/m^2) might better capture change in adiposity over time (Cole et al., 2005). Thus, both were included to make sure that no important information was lost.

Blood pressure readings were taken using an automated device (Dynamap Pro 100, General Electric) after participants sat quietly for five minutes. Prior to August 3, 2006, only one blood pressure reading was taken. After this date, the average of three measurements was included for all participants. For consistency, the current study examined only the first blood pressure reading taken for each participant.

Total cholesterol (TC), triglycerides, and HDL cholesterol were calculated using a Roche automated clinical chemistry analyzer. LDL cholesterol was calculated by the Friedewald equation (LDL = TC – HDL – [Triglycerides/5]; Wickham, Stern, Evans, Bryan, Moskowitz, Clore, & Laver, 2009).

Metabolic testing included collection of fasting (no food consumed for at least 12 hours prior to testing) blood samples of plasma glucose, insulin, and lipids and were taken at three time points (baseline, 6 months, and 12 months). Specific values for glucose and insulin were calculated using glucose oxidase methodology (YSI 2300 Stat Plus Glucose Analyzer Yellow Springs Instruments [YSI]). Insulin resistance was estimated from the homeostasis model of insulin resistance or HOMA-IR (Wickham et al., 2009), which is calculated as the product of the fasting plasma insulin level (in microunits per milliliter) and the fasting plasma glucose level (in millimoles per liter) divided by 22.5. Lower HOMA-IR values indicated higher insulin sensitivity, whereas higher values indicated lower insulin sensitivity (Weiss et al., 2005).

HOMA-IR was used primarily in this study over other methods (oral glucose tolerance tests; OGTTs) because participants had fewer missing data for these values. In addition, this measure has been shown to correlate well with other measures of insulin resistance (clamp techniques; Uwaifo et al., 2002; Gungor, Saad, Janosky, & Arslanian, 2004), and recent studies suggest that it is highly sensitive at detecting impaired glucose tolerance (IGT) for adolescents with severe obesity (Weigensberg, Ball, Shaibi, Cruz, & Goran, 2005; Sinha et al., 2002; Greig, Hyman, Wallach, Hildebrandt, & Rapaport, 2011). Third, OGTTs are costly, labor intensive, and their use varies widely between research and clinical settings, making it difficult to determine the meaningfulness of such findings.

For example, in research studies, OGTTs often point to insulin resistance and impaired IGT, suggesting a progression to T2DM (Sinha et al., 2002; Weiss et al, 2005). However, in clinical settings, OGTTs are typically discouraged unless youth are determined to be at high risk for glucose intolerance and even what constitutes high risk in many cases is not well-defined (Kaufman, 2005).

Lastly, it should be noted that adolescents in this study were not excluded if they were determined to have T2DM (defined by a fasting glucose ≥ 126 mg/dL by the American Diabetes Association [ADA]; Lee, Okumura, Davis, Herman, & Gurney, 2006) because it was believed that this information would be helpful in determining whether those with worse scores on self-report data also had poorer metabolic functioning compared to other adolescents. Further, according to the above criteria, only two participants had T2DM, so excluding them from the analyses would have little impact on the results.

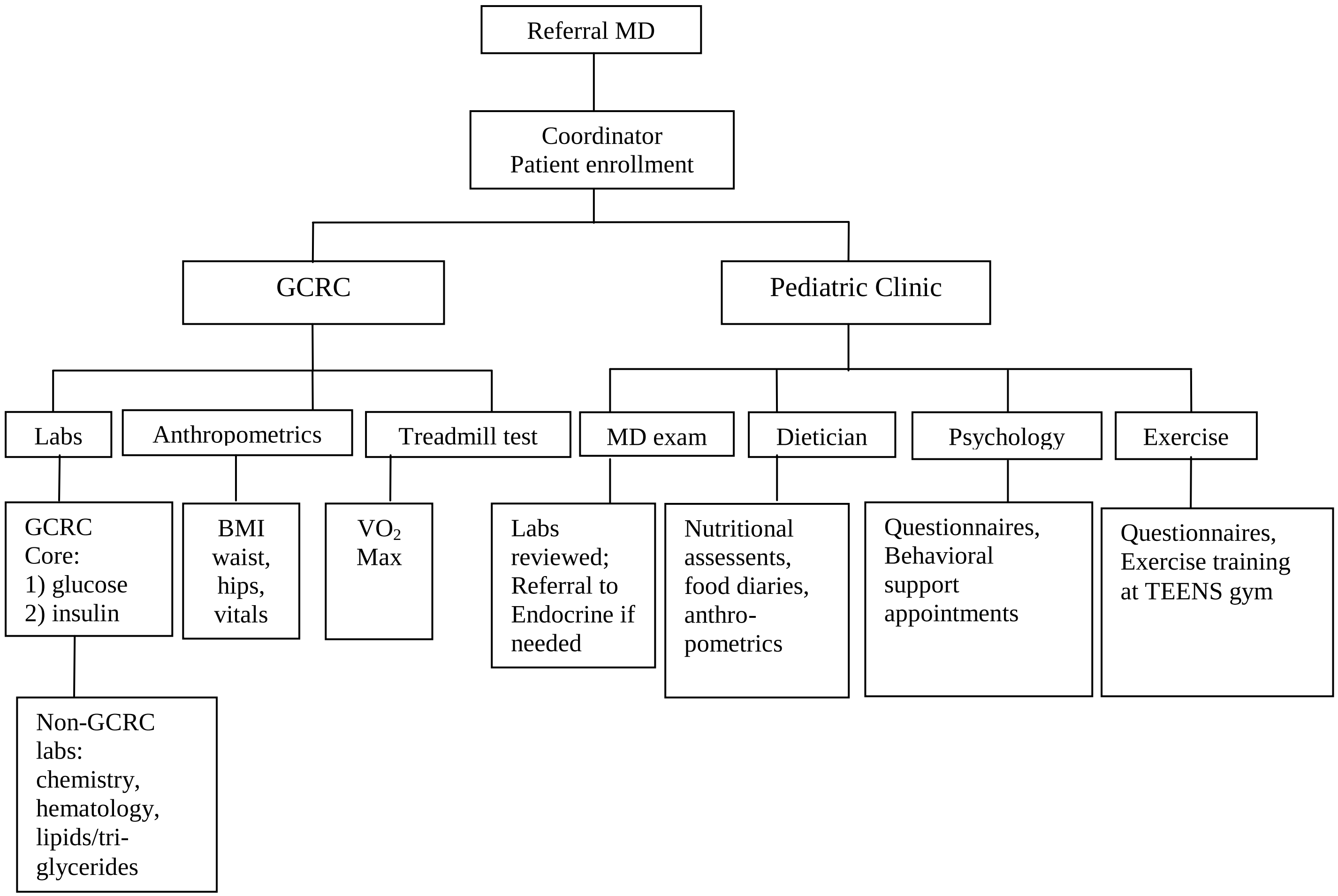

Figure 1. Program overview with breakdown of responsibilities for all study phases.
Note: Figure modified from the research synopsis of Laver et al, 2005, Understanding the barriers in treatment of obesity in adolescents 11-18 in Central Virginia; GCRC = General Clinical Research Center

Self-report measures. Self-reported exercise was assessed by adolescents' response to "How often do you exercise (for at least 30 minutes, without stopping; Appendix B, question #6), for moderate to high intensity activities, including rollerblading, dancing, bike riding, running, jump-rope, walking, playing basketball?" Responses were based on a four-point Likert-type scale from "Never" to "More than 3 times per week."

7-Day Physical Activity Recall (PAR). (See Appendix E). The PAR (Sallis et al., 1985) requires the respondent to report the amount of time spent sleeping and in moderate, hard, and very hard activities in 10 minute intervals over seven days. For purposes of the current study, physical activity scores were totaled according to reported minutes of moderate, hard, and very hard activity. Consistent with standard scoring procedures, time spent exercising in each category was rounded to the nearest .25 hours (Sallis, McKenzie, & Alcaraz, 1993). Prior research with the PAR has shown good same-day reliabilities (.86) across standardized administration protocols (Gross, Sallis, Buono, Roby, & Nelson, 1990). Furthermore, the PAR has adequate temporal stability (.77) in adolescents (Sallis, Buono, Roby, Micale, & Nelson, 1993).

Health-Related Quality of Life (HRQoL). (See Appendix C). The Pediatric Health-Related Quality of Life (PedsQL 4.0) Inventory is a self-report measure containing 23 items and is used to assess four domains of HRQoL: physical (8 items), emotional (5 items), social (5 items), and school functioning (5 items; Varni et al., 2003). Physical functioning includes aspects such as fitness and pain while emotional functioning assesses symptoms such as depression and anxiety. Social functioning includes aspects related to interpersonal relationships, particularly with peers, and school functioning addresses difficulties related to academics (e.g., attention problems and school absences).

Adolescents were asked to rate each symptom on a five-point Likert scale ranging from 0 (“It is never a problem”) to 4 (“It is almost always a problem”). Items were reverse-scored and linearly transformed (0 = 100 to 4 = 0), such that higher scores indicated better functioning and HRQoL (Stern, Mazzeo, Gerke, Porter, Bean, & Laver, 2007; Pinhas-Hamiel et al., 2006).

The PedsQL 4.0 has been used extensively with both healthy children and adolescents (ages 2 to 18) and those with chronic illnesses and is effective at discerning the two perspectives (Varni, Seid, & Kurtin, 2001). For example, it is often used to assess domains of functioning in obese adolescents seeking weight loss treatment (Schwimmer, Burwinkle, & Varni, 2003). Moreover, the PedsQL 4.0 has been validated and used with ethnically diverse adolescent populations (Varni, Limbers, & Burwinkle, 2007). Internal consistency for all four HRQoL dimensions was previously found to be .91 in this same sample of obese adolescents (Stern et al., 2007), and other studies with obese children report similar reliability estimates (e.g., Cronbach’s alpha = .86; Varni, Limbers, & Burwinkle, 2007).

Global Self-esteem. Global self-esteem was measured using the Coopersmith Self-Esteem Inventory (SEI; Coopersmith, 1981; Appendix D), a 25-item self-report measure. Adolescents chose from a 0/1, dichotomous response format, indicating whether the item was “Like Me” or “Unlike Me.” Respondents were given one-point for each item they endorsed that indicated the presence of high self-esteem. Example items included "I am a lot of fun to be with," "I have a low opinion of myself," and "I often get discouraged with what I am doing." The SEI has been previously used with obese adolescents (Stern et al., 2007) and demonstrated good reliability (Cronbach's alpha = .83).

***Post hoc self-report measure*.**

Depressed mood. The Children's Depression Inventory (CDI; Kovacs, 1985; Appendix F) is a 27-item questionnaire that assesses depressed mood in children and adolescents. Each item has three statements that are graded in severity and assigned values from 0 to 2. A total score (range = 0 to 54) is computed, where higher scores indicate more severe depressive symptoms. Prior studies have found the psychometric properties of the CDI to be adequate (Devine, Kempton, & Forehand, 1994); however, others have noted several methodological limitations (Garcia, Aluja, & Barrio, 2008). Most notable is an unstable factor structure (anywhere from 2 to 8; Garcia, Aluja, & Barrio, 2008; Craighead, Smucker, Craighead, & Ilardi, 1998). In the current study, Cronbach's alpha was 0.84.

Data Analyses

Analyses were divided into three parts: 1) preliminary analyses, 2) classification methodology, which involves using latent profile analysis (LPA; Gibson, 1959) to empirically identify latent subgroups, and 3) regression analyses, which were used to determine whether there was an association between the latent subgroup to which a teen was classified and their clinical and exercise data.

Preliminary analyses. First, means, standard deviations (SDs), and normality statistics (skewness, kurtosis) were calculated for the four subscales of the HRQoL (PedsQL4.0), the total score of the global self-esteem measure (Coopersmith SEI), the total score of the physical activity recall (PAR; moderate and vigourous physical activity), and clinical data (systolic and diastolic blood pressure, triglyceride concentrations, and glucose/insulin levels). Then, reliability (Cronbach's alphas) and convergent validity were assessed for the self-report data.

Convergent validity was assessed by comparing correlations between the PedsQL subscales and the Coopersmith SEI total score. Both measures were thought to represent the latent construct and were expected to correlate at least moderately well and in the expected (positive) direction. Lastly, Pearson correlations were used to determine the associations among self-report, exercise, and clinical data. At this time, the single item question, "How often do you exercise (for at least 30 minutes, without stopping; Appendix B) was correlated with both time spent in moderate intensity physical activity and vigorous (hard + very hard activities) physical activity from the PAR. It was determined apriori that if these measures were highly correlated, then only the single item question would be used in the regression analyses. However, if moderate to low correlations were observed, both measures would be included.

In this study, no corrections were made to adjust for multiple comparisons (the likelihood of producing Type 1 error) in the correlation matrix because these analyses were: 1) only conducted to identify potential (expected) relationships in the data, and 2) the results of the table had no bearing on the LPA analysis or subsequent analyses (linear regressions and ordinal regression models).

Classification methodology. Total scores for adolescents' responses from the four subscales of the PedsQL 4.0 (physical, emotional, social, and school functioning) and the Coopersmith SEI were analyzed using LPA. This approach assumes that participants' responses on a series of self-report items reflect the latent, intangible construct and are not based on anything directly observable such as clinical or demographic data (Lubke & Muthén, 2005; Lanza, Savage, & Birch, 2009). It is assumed for the current study that the latent variable, "life satisfaction" (a term developed for this project reflecting both HRQoL and self-esteem, together), is conceptualized as a latent variable with a finite number of levels, likely less than 5.

Description of mixture modeling (MM). LPA is a form of MM, which is a multivariate, psychometric technique used to identify unobserved groupings or "mixtures" of participants based exclusively on their responses to self-report data (Lubke & Muthén, 2005; Bauer & Curran, 2004). MM was chosen for this study; however, K-means cluster analysis (referred to as cluster analysis from this point forward) can also be used for the purposes of grouping individuals. Thus, in this section, the assumptions of MM are described, including how parameters are derived (which requires a brief discussion of the estimator), the process of determining the appropriate model, other advantages of the approach, and in the final section, a comparison between MM and cluster analysis is made.

MM is a psychometric method that is becoming increasingly used to group participants (Collins & Lanza, 2010). It makes a number of critical assumptions that are essential to understand the data that are produced. The reasons it was chosen as the primary methodology for this study are described in detail below and include:

1) Its ability to capture unobserved heterogeneity. A response on a self-report measure is a behavioral manifestation of a latent variable, which cannot be directly measured and is not a result of demographic differences (sex, age, etc.; Lubke & Muthén, 2005; Muthén & Muthén, 1998-2010; Lanza, Savage, & Birch, 2009; Lanza & Collins, 2006; Collins & Lanza, 2010).

2) The latent variable is discrete rather than continuous because it is based on another interpretation of the correlation coefficient, which reflects discrete groups characterized by different mean levels on the observed variables (Bauer & Curran, 2004). Thus, the latent variable has either a nominal or an ordinal scale. If it is nominal, the groupings are distinct and not directly comparable, for example, apples and oranges. If the latent variable has an ordinal scale, however, the groups can be ranked, for example, as high, medium, and low (Kudel et al., 2006; Bauer & Curran, 2004).

3) The sample drawn is a mixture of latent distributions (Magidson &Vermunt, 2002; Collins & Lanza, 2010; Bauer & Curran, 2004). In other words, the sample of obese adolescents enrolled in this study is derived from a population composed of smaller, clearly defined sub-populations that can be identified by analyzing participants' self-report data.

4) Observed relationships are conditional on (only related through) the latent variable (e.g., the between-class component of the model; Bauer & Curran, 2004), which is the assumption of local independence (Vermunt, 2008; Muthén & Muthén, 1998-2010). It is solely responsible for all responses on, in this case, the self-report measures. Therefore, the similarity of responses of participants from the same group and their dissimilar responses to those in other groups is caused by the latent variable and nothing else (Lanza, Savage, & Birch, 2009; Collins & Lanza, 2010). This is possible because the procedure identifies and eliminates measurement error (Lubke & Muthén, 2005; Muthén & Muthén, 1998-2010). Residual variability within a class, reflecting only random measurement error, would be uncorrelated (independent) by definition.

5) MM makes more appropriate statistical assumptions. MM, like other model-based psychometric approaches (structural equation modeling, item response theory), estimates both latent variable error (the error associated with each latent class) and measurement error (error that is independent of the latent variable indicators; Muthén, 2002; Collins & Lanza, 2010; Vermunt, 2011) compared to other approaches (e.g., cluster analysis) which do not separate that information.

The analysis also requires a maximum-likelihood estimator with an expectation-maximization algorithm (MLE-EM), an iterative estimator that is the default approach for most, if not all, statistical packages that employ MM, including Mplus which was used for this study (Muthén & Muthén, 2010). Estimators are employed in a large number of statistical procedures; however, they generally work behind the scenes. For example, the values derived from a regression in SPSS are based on the least squares estimator

(Marquardt, 1963). The underlying mathematical process is quite complex and well-described in many papers and chapters (McLachlan & Peel, 2000; Gibson, 1959; Goodman, 1974a, 1974b; Dempster, Laird, & Rubin, 1977; Agresti, 1990; Cohen & Cohen, 2003); however, a non-technical definition is provided in the following paragraph.

The MLE-EM estimator randomly selects parameters, fits them to the data, and generates loglikelihood values to quantify the probability of a good fit. Then, using a principled search algorithm, another set of values, which are more likely to derive parameters that best represent the data, are identified. A loglikelihood value is derived for that comparison too. Then, the loglikelihood values from the first and second iterations are compared, with the change in loglikelihood values becoming smaller over successive iterations (Collins & Lanza, 2010). This process continues until a convergence criterion is met, which is either the absolute difference between two loglikelihood values (an absolute value of .0000001; the default in Mplus), indicating that the parameters identified by the procedure correspond to the highest peak in the likelihood function, which indicates that, contingent on the data, the most likely solution was identified (Collins & Lanza, 2010). If that criterion is not met and the maximum number of iterations (500; the Mplus default that was used in this study) is reached, then the process ends, indicating an optimal solution could not be achieved.

It is also possible for the estimator to converge at an inappropriate solution, a local maxima, in which the estimation procedure converges and produces parameters that are, in fact, not the optimal solution. Thus, a two-step estimation process is used to flag such instances. In the first step, the estimation procedure described in the preceding paragraph is run at least 10 times (Collins & Lanza, 2010; Muthén & Muthén, 1998-2010). For this study, it was run 50 times. Then, in the final step of the estimation process, the final loglikelihood values from the 10 iterations from step one are compared, the two highest values are identified, and then using the same stopping procedure, final parameters are derived. A solution was not considered valid if: 1) the 500 iteration limit was reached and the lowest absolute loglikelihood difference was greater than .0000001, or 2) in the first step of the iteration procedure, the highest loglikelihood value was not replicated in a majority, if not all, of the 10 iterations; this is an indication the estimator could not identify the best solution.

Selecting the best solution. To identify the optimal number of groups or points on the latent scale requires one to test several potential solutions and then use a range of fit criteria to identify the one that best reflects the data. The fit criteria fall into two general groups, non-statistical and statistical. The first group is the most important and consists of substantive theory and parsimony and requires a thoughtful interpretation of the data and relevant literature. It also requires one to consider each solution and compare it to what is already known about the phenomena. The second, model parsimony (Kudel et al., 2006; Burnham & Anderson, 2002), requires that the solution with the simplest description of the data be selected. For example, Kudel et al. (2006) analyzed self-reported quality of life data from patients with Human immunodeficiency virus (HIV) and selected a 4-class solution because the 5-group solution was essentially one of the groups from the 4-class solution, split into two, which did not enhance understanding of the phenomena.

In the current study, three fit statistics and three "diagnostics" were used to identify the optimal model. In addition, theory and model parsimony were used to guide model selection.

Fit statistics. Fit statistics are used as an indicator of how well the data, overall, represent the model. The Bayesian Information Criterion (BIC; Schwarz, 1978), the Lo-Mendell-Rubin (LMR) likelihood ratio test (LRT), and the Lo-Mendel-Rubin-adjusted likelihood ratio test (LMR-adjusted; Lo, Mendell, & Rubin, 2001) were used for the purposes of the current project.

BIC. The BIC is used to assess the relative fit of a model with *k* classes (where *k* = the number of classes in the model) to competing models (*k* minus 1 class and *k* plus 1 class; Muthén, 2004; Beets & Foley, 2010). Specifically, it is a log-likelihood statistic that accounts for sample size and penalizes model complexity (e.g., models with more parameters increase error; the penalty is the log of *n* times the number of parameters estimated [Lanza & Collins, 2006; Schwarz, 1978]). These penalty terms resolve over-fitting (the modeling of random error instead of the underlying relationship), which can occur during the ML estimation procedure when parameters are added (Schwarz, 1978; Pek, Sterba, Kok, & Bauer, 2009). A model that is over-fit would have little to no predictive utility. Because BIC is a penalized fit statistic, lower values are preferred (Schwarz, 1978; Lubke & Muthén, 2005).

The Lo-Mendell-Rubin (LMR) likelihood ratio test (LRT). The purpose of using a LRT is to compare the fit of two consecutive models (*k* minus 1 vs. *k* class model, where *k* = the number of classes in the model; Lo, Mendell, & Rubin, 2001). It is a chi-square test that summarizes the discrepancy between the observed data and the expected values (Collins & Lanza, 2010), making it possible to determine whether the null hypothesis should be rejected (Cox & Hinkley, 1974; Casella & Berger, 2002). A significantly higher LRT statistic indicates that the observed model has a statistically better fit than the preceding model with fewer classes. In other words, if a 6-class model has a significantly higher LRT than the 5-class model, it is most likely preferable (Cox & Hinkley, 1974; Casella & Berger, 2002; Collins & Lanza, 2010; Lubke & Muthén, 2005; Feldman, Masyn, & Conger, 2009).

LMR-adjusted LRT. Muthén and Muthén (2010) note that there was an error in the original study in which the LRT was developed, thus, the adjusted fit index reflects this change. It works in the same manner as the original LRT test.

Diagnostics. The diagnostics are not accepted fit statistics, per se, but they were used because a good fitting model can sometimes yield odd or inappropriate values. There are no clear standards with regard to what constitutes good or poor values; thus, if such values are present, then judgment is used to determine whether a solution should be discarded in favor of another.

Classification certainty. Classification probabilities or posterior probabilities indicate the probability to which the respondent was correctly classified to a group. Not surprisingly, the metric ranges from 0 to 1 (Collins & Lanza, 2010), where higher values indicate greater classification certainty, good homogeneity, and better latent class separation (Collins & Lanza, 2010). This approach is Bayesian (e.g., Bayes' theorem; Collins & Lanza, 2010). Specifically, Bayes' equation is used to obtain a vector of posterior probabilities, which reflect each person's response pattern for a latent class solution (Collins & Lanza, 2010). Mplus summarizes these response patterns to compute the average posterior probability to guide class selection (Collins & Lanza, 2010). Although there is no accepted minimum cut-off for the average posterior probability, values greater than .80 are generally preferred (Collins & Lanza, 2010; Kudel et al., 2006).

***Item response probabilities and class membership probabilities*.** Class membership probabilities and item-response probabilities were also derived. Item response probabilities represent the likelihood of different responses to the items, conditional on latent class membership (Lanza, Savage, & Birch, 2009; Muthén & Muthén, 1998-2007; Collins & Lanza, 2010; Nylund, Asparouhov, & Muthén, 2007).

Class membership probabilities (also called latent class prevalences based on posterior probabilities) estimate the *proportion* of a population expected to belong to each latent class (Collins & Lanza, 2010; Lanza, Savage, & Birch, 2009). Thus, these probabilities sum to one (Lanza, Savage, & Birch, 2009). In Mplus, these values are derived by fitting the LPA model with a pre-defined solution (the number of subgroups to be identified) and the estimator; the Maximum Likelihood estimator with an Expectation-Maximization (EM) algorithm. This procedure maximizes the likelihood function (e.g., the theoretical minimum of the log-likelihood values; Collins & Lanza, 2010) thereby identifying the most probable solution given the data (Vermunt & Magidson, 2002; Vermunt, 2011). Participants are then assigned to one of the classes based on their highest probability of membership (Vermunt, 2011). For example, in a 3-group solution, the likelihood of belonging to each of the classes might be .85, .10, and .05, respectively. Thus, the participant would be grouped into the first class. This classification, thus, informs post hoc analyses, which compare classes to decide whether an additional class is informative (Lubke & Muthén, 2005).

MM versus cluster analysis. There are other approaches that can be used to group participants based on participants' self-report questionnaires; the most well-known is cluster analysis. Cluster analysis does not assume that responses reflect an underlying latent variable. Rather, classification is based purely on statistical approaches that attempt to minimize within-group variability while maximizing between-group variability (Lubke & Muthén, 2005). Further, it does not require an estimator. In programs such as SPSS, the approach can be used in one of two ways. In the first, the built in algorithm produces the ideal classification, while in the second, a solution is chosen a priori (1-class, 2-class, etc.), and similar to mixture modeling, the solution is derived. However, this approach does not readily produce fit indices, thus, it is impossible from a statistical perspective to compare each solution. Yet, perhaps the most important reason for selecting MM for this study is that direct comparison of cluster analysis and MM under a variety of conditions has found that the latter is more likely to accurately classify respondents (Magidson & Vermunt, 2002; Lanza, Savage, & Birch, 2009).

Summary. In sum, parameter estimation in LPA uses an iterative approach, where a model is selected (e.g., a 2-class model, etc.). In the actual analysis, successive sets of parameter estimates are tried using an ML estimator with an EM algorithm until the most likely solution, based on a range of criteria, is identified.

Regression analyses. Once the ideal solution was identified, 14 linear regressions were conducted to determine whether the group with the best overall self-reported functioning, as determined by the researcher, was significantly different from the other groups on a range of clinical and exercise measures related to obesity including systolic and diastolic blood pressure, serum cholesterol (TC, HDL, LDL, and triglycerides), fasting glucose levels, BMI, self-reported physical activity, and the CDI total score.

To conduct these analyses required that group classification be dummy coded using a system that one can find in any basic statistics textbook. Specifically, k-1 variables were created, with k being number of groups identified in the MM procedure. Thus, if three groups were found to be the optimal MM solution, then for the regression analyses, two variables were created. In the first variable, called 2 vs. everyone, those in the 2nd best functioning group were coded as a 1, while everyone else was coded as 0. In the 2nd variable created for the regression analyses (called 3 vs. everyone), participants categorized into the 3rd group were assigned a 1 while all others were given a 0.

Post hoc ordinal regression analyses. The regression analyses identified six variables that were significant predictors of class membership. Two of the variables were measures of blood pressure (diastolic and systolic), and two were demographic variables (race and sex). Three variables were self-report measures. Two of these assessed self-reported physical activity (PA self-report [question # 6 from Appendix B] and PAR-vigorous physical activity), and the other was a total score on the measure of depressed mood (CDI – total score). The final measure was the BMI z-score.

Based on these findings, another series of analyses were conducted to ascertain the association of these variables in relation to class when they were included in the model. In this instance, an ordinal regression was used. The DV was class membership (HF=0, MF=1, LF=2). All of the variables, however, could not be included as IVs because two pairs, diastolic and systolic blood pressure, and self-reported vigorous exercise and PA self-report were highly correlated. Therefore, four sets of regressions were conducted so that the associations of each combination of these variables could be determined in relation to the others.

The regressions were conducted with the assumption that the critical variables that could differentiate the LF group from the others were the two blood pressure variables, the two self-reported exercise items, and the total score of the measure of depressed mood. Thus, the demographic variables and the BMI *z*-score are present in all of the analyses, but the other variables were entered in different sequences to explicate the critical associations to possibly provide information that could be used to theorize why patients in the LF group are significantly worse than the referent group in these areas. Therefore, six distinct regressions were modeled. They are presented in the order in which they were conducted.

1) Demographic variables, BMI *z*-score, and a blood pressure variable (diastolic or systolic) were included

2) The four variables were retained from the previous analyses and a self-reported exercise variable (PAR-vigorous or PA self-report) was included
3) The five variables from the previous analysis were retained, and the total depressed mood score was included
4) This analysis was conducted to determine the relationship of the self-reported exercise item without a blood pressure variable being present. Thus, the demographic and BMI *z*-score and the self-reported exercise variable (vigorous-PAR or PA self-report) were included
5) The four variables from the preceding analysis were retained, and the total depressed mood score was included
6) This analysis was conducted to determine the relationship between all the variables without self-reported exercise

Lastly, it should be noted that Mplus uses an approximation of R^2 values for ordinal regressions. A simple R^2 value cannot be used in ordinal regression models because they split the variance of the IV into categories. Thus, a series of "pseudo R^2" statistics are used to estimate the variance explained by the IV (Ombui, Geofrey, & Gichuhi, 2011). While these values are not R^2, they are seen as an approximation of R^2 and thus, reported as such in the results.

Results

Preliminary Analyses

Demographics. A total of 423 adolescents between the ages of 11 to 18 completed the baseline initial assessment; however, only those who met inclusion criteria for the current study were those with complete baseline psychosocial data (*n* = 248). Most were female (68%) and African American (73%; Table 1). The average age was 13.9 years (*SD* = 1.8), and the mean BMI for the total sample (*M* = 38.0; *SD* = 7.3; range = 92 to 100) was in the 99th percentile (Table 1), reflecting severe obesity.

Descriptive statistics.

***Self-report measures*.** The average total scores on the PedsQL 4.0 ranged from 65.83 to 75.07 (Table 2), and the mean score on the Coopersmith SEI was 67.40 (*SD*=19.98; Table 2). Findings are comparable to other studies with obese adolescents and those undergoing treatment for cancer (Williams et al., 2005; Schwimmer et al., 2003). However, in this sample, mean global self-esteem was lower than adolescents being treated for cancer (Cantrell & Lupinacci, 2004).

For the CDI, the average total score for depressed mood was 9.55 (*SD* = 6.63; Table 2). This score is slightly lower in comparison to other samples of severely obese adolescents (Erermis et al., 2004).

The majority of adolescents (*n* = 99, 40%) self-reported participating in moderate to high intensity physical activity between one to three times per week (*M* = 2.79; *SD* = .98), as indicated by the single item question, "How often do you exercise for at least 30 minutes without stopping?" This was followed by 65 participants (26%) and 53 (21%) participants that engaged in at least 30 minutes of physical activity more than three times per week and once per week, respectively (Table 1). However, few adolescents reported that they never exercise (*n* = 27, 11%).

Table 1.

Participant Demographics

Variable	*n* (%)	*M*	*SD*
Child Sex			
Male	79 (32%)	--	--
Female	169 (68%)	--	--
Child Race/Ethnicity			
Caucasian	50 (20%)	--	--
African American	182 (73%)	--	--
Other	16 (7%)	--	--
Child age (in years)		13.9	1.8
Child Body Mass Index (BMI)		38	7.3
BMI percentile		99	.96
BMI *Z* score		2.5	.28
Child Exercise Frequency/week			
Never	27 (11%)	--	--
Once per week	53 (21%)	--	--
1 – 3 times/week	99 (40%)	--	--
More than 3 times/week	65 (26%)	--	--

Note: $N = 248$

Table 2.

Means and Internal Consistency of Self-report Variables

	PedsQL-Physical	PedsQL-Emotional	PedsQL-Social	PedsQL-School	SEI	CDI
respondent						
Mean	75.07	65.83	71.59	67.40	67.40	9.55
SD	15.55	20.08	21.64	20.06	19.98	6.63
Range	57 - 99	57 - 74	65 - 79	60 - 72	12 - 100	0 - 32
Skewness	-.35	-.04	-.78	-.50	-.19	.76
Kurtosis	-.52	-.78	.34	-.03	-.65	.12
Cronbach's alpha	.75	.72	.80	.71	.81	.84

Note: PedsQL=Pediatric Health-Related Quality of Life (HRQoL) Measure with 4 Subscales: Physical, Emotional, Social, and School; SEI=Coopersmith Self-Esteem Inventory; CDI= Children's Depression Inventory (*n*=193); SD=Standard Deviation

According to the PAR, average time spent in moderate intensity physical activity was 1.84 hours per week; the mean time spent in vigorous physical activity was 1.24 hours during the week (Table 3). The single item question had a relatively low but significant correlation with both time spent in moderate intensity physical activity (r = .18, $p < .05$) and vigorous physical activity (r = .21, $p < .05$). For this reason (as noted in the Methods), all three measures were included in the regression analyses.

Skewness and kurtosis. All subscale scores in this study (except for the CDI total score, which was positively skewed) were negatively skewed indicating that most participants scored above the mean. Relative to a normal distribution, the physical subscale of the PedsQL 4.0 demonstrated moderate, negatively skewed values indicating modestly higher levels of perceived physical HRQoL. The emotional subscale revealed lower, negatively skewed values suggesting that most adolescents rate their emotional functioning at generally high levels. For the PedsQL 4.0 school and social functioning subscales, both demonstrated moderately high to highly negatively skewed values, respectively. This finding indicates that many adolescents in the sample are reporting higher levels of functioning in these domains relative to other areas. The SEI showed low, negatively skewed values, suggesting that most adolescents tend to endorse higher levels of global self-esteem. Furthermore, examining the peaked/flatness of the distribution as reflected by the kurtosis of the variables indicate that the data are normally distributed (Table 2).

Reliability. Each of the scales and subscales included in the current study had an internal consistency at or above, .70, the standard cut-off score (Cronbach, 1951; Table 2) and is similar to those with obesity and other chronic health conditions (Varni, Limbers, & Burwinkle, 2007; Bastiaansen, Koot, Bongers, Varni, &Verhulst, 2004). Reliability estimates found in this study for global self-esteem, as measured by the Coopersmith SEI, were also comparable to those in other pediatric samples (Van Tuinen &Ramanaiah, 1979; Ahmed, Valliant, & Swindle, 1985).

Validity. Convergent validity was assessed by comparing correlations between the PedsQL subscales and the Coopersmith SEI total score. In this sample, all PedsQL subscales and the SEI correlated moderately well and in the expected (positive) direction (e.g., higher perceived HRQoL was related to higher global self-esteem; Table 4).

Metabolic indicators. Compared to healthy child norms, mean values for measures of metabolic functioning in this sample were high; however, they did not reach levels characteristic of a metabolic syndrome (Wickham et al., 2009). The means, also reported in Table 3, were as follows: TC (*M* = 163.54 mg/dL, *SD* = 27.75; range = 107-237), LDL-C (*M* = 100.25 mg/dL, *SD* = 23.62; range = 49-176), HDL-C (*M* = 43.82 mg/dL, *SD* = 10.23; range = 24-92), triglycerides (*M* = 97.28, *SD* = 52.21; range = 34-402), fasting glucose (*M* = 85.02 mg/dL, *SD* = 9.03; range = 65-141), and fasting insulin (*M* = 21.04 μU/dL, *SD* = 21.53; range = 1-258). The average systolic blood pressure was 127.95 (*SD* = 14.71, range = 83-176), and the average diastolic blood pressure was 70.23 mg/dL (*SD* = 10.53; range = 42-168). Baseline triglycerides, fasting insulin, and HOMA-IR were not normally distributed in this population.

It should be noted that the average fasting glucose for the sample did not meet criteria for the metabolic syndrome (greater or equal to 100 mg/dL); however, mean fasting insulin was considered abnormal (e.g., greater than 15 μU/dL; Wickham et al., 2009), thus, elevating HOMA-IR values (*M* = 4.22, *SD* = 3.10; range = .23-.25). HDL-C levels (*M* = 43.82 mg/dL, *SD* = 10.23; range = 24-92) also approached the cut-off score for the metabolic syndrome (e.g., less than or equal to 40 mg/dL; Wickham et al., 2009; Falkner & Daniels, 2004). Of particular interest to this study, the average systolic blood pressure was 127.95 (*SD* = 14.71, range = 83-176), which falls above the 90^{th} percentile, suggesting that some adolescents in this sample may have pre-hypertension or hypertension (Falkner & Daniels, 2004). Specifically, of the 226 adolescents with complete metabolic data, nearly 50% of them (*n* = 117) had average systolic blood

Table 3.

Descriptive Statistics for Clinical and Exercise Variables

	Mean	SD	Range
Body Mass Index (kg/m^2)	38.01	7.28	25 - 74
Body Mass Index (%)	99.09	1.04	92 - 100
Body Mass Index (*z*-score)	2.47	.51	1 - 3
Self-report exercise	2.79	.98	1 - 4
PAR - Moderate	1.84	2.52	0 – 16.5
PAR - Vigorous	1.24	2.24	0 – 15.75
Systolic BP (mmHg)	127.95	14.71	83 - 176
Diastolic BP (mmHg)	70.23	10.53	42 - 168
Triglycerides (mg/dL)	97.28	52.21	34 - 402
Total cholesterol (mg/dL)	163.54	27.75	107 - 237
HDL – C (mg/dL)	43.82	10.23	24 - 92
LDL – C (mg/dL)	100.25	23.62	49 - 176
Fasting glucose (mg/dL)	85.02	9.03	65 - 141
Fasting insulin (μU/dL)	21.04	21.53	1 - 258
HOMA-IR	4.22	3.10	.23 - 25

Note. n = 226; n = 197 for PAR data; SD = Standard Deviation; PAR = 7 Day Physical Activity Recall; PAR-Moderate = time spent in moderate physical activity; PAR-Vigorous = time spent in vigorous physical activity; BP = blood pressure; HDL-C = High-density lipoprotein cholesterol; LDL = Low-density lipoprotein cholesterol; HOMA-IR = Homeostasis model assessment of insulin resistance pressures above this cut-off. Average diastolic blood pressure (M = 70.23 mg/dL, SD = 10.53; range = 42-168), however, did not reach this threshold (e.g., values greater than or equal to 80 mg/dL).

Associations. Pearson-product correlation matrices (Table 4) indicated some moderately significant and clinically meaningful relationships among LPA variables and those included in regression analyses. In particular, the physical subscale of the PedsQL was positively correlated with frequency of self-reported exercise (r = .22, and p < .05), and vigorous activity (r = .17, p < .05), respectively. It was inversely related to systolic (r = -.15, p < .05) and diastolic (r = -.17, and p < .05) blood pressure and BMI (r = -.15, p <.05), indicating that increased weight and blood pressure are associated with lower levels of physical activity and perceived physical functioning. Adolescents who endorsed higher activity levels perceived greater physical functioning. As expected, systolic and diastolic blood pressure showed moderate correlations (r = .44, p < .05). Both systolic and diastolic blood pressures were also positively related to BMI (kg/m^2), BMI z-score, and age (Table 4). Other metabolic factors such as total cholesterol and triglycerides were moderately correlated (r = .37, p < .05); those with higher triglyceride levels also had lower HDL-C (r = -.36, p < .05) and higher LDL-C (r = .14, p < .05), as would be expected. There were no significant relationships between HOMA-IR and other factors.

Table 4.

Pearson-Product Moment Correlations for Measures Included in Latent Profile Analysis (LPA) and Items Used in Regression Analyses

Variable	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
LPA Measures																					
1. SEI-Total Score	--	**.41***	**.53***	**.49***	**.37***	-.09	-.13	-.04	-.06	-.03	-.04	.03	.12	.14	.13	.01	.01	-.01	-.02	-.05	**-.65***
2. PedsQL- Physical		--	**.53***	**.59***	**.37***	**-.15***	**-.17***	-.09	-.01	-.00	.03	-.09	**.22***	.13	**.17***	**-.15***	-.04	.03	-.08	-.03	**-.41***
3. PedsQL-Emotional			--	**.49***	**.37***	-.10	**-.19***	-.05	-.08	.01	-.08	-.08	.04	.06	.13	-.03	.03	-.05	.00	.12	**-.53***
4. PedsQL-Social				--	**.35***	-.07	-.05	-.08	-.10	.00	-.08	-.02	.11	.04	**.17***	-.01	-.06	**.16***	-.03	.03	**-.39***
5. PedsQL-School					--	**-.14***	**-.15***	-.07	-.06	.02	-.05	.08	.10	.12	.07	-.10	-.03	.09	-.05	-.04	**-.42***
Follow-Up Analyses																					
6. SystolicBP (mmHg)						--	**.44***	-.02	-.09	-.01	-.09	-.01	-.06	-.10	-.02	**.40***	**.39***	-.09	**.21***	-.01	**.16***
7. DiastolicBP (mmHg)							--	-.06	**-.16***	-.08	-.12	.08	-.03	-.04	-.10	**.25***	**.18***	.04	**.17***	.01	**.21***
8. Triglycerides (mg/dL)								--	**.37***	**-.36***	**.14***	.13	-.01	.00	-.06	-.08	.05	-.10	-.08	**-.13***	.03
9. TC-(mg/dL)									--	**.24***	**.91***	.06	**.13***	-.08	-.05	-.09	.01	**-.23***	-.10	**-.15***	-.09
10. HDL-C (mg/dL)										--	.01	-.11	.10	-.08	.01	-.01	-.08	.11	.02	-.08	-.11
11. LDL-C (mg/dL)											--	.06	.12	-.07	-.03	-.07	.02	**-.28***	-.08	-.08	-.07
12.HOMA-IR												--	-.08	-.04	-.15	.12	.13	.08	-.13	.06	.05
13. Self-report Ex													--	**.18***	**.21***	-.10	.06	**-.13***	.03	-.02	**-.26***
14. PAR-Moderate														--	.09	-.11	-.02	-.11	**-.16***	.09	-.09
15. PAR - Vigorous															--	-.04	.09	-.20*	-.04	.02	-.03
16. BMI (kg/m^2)																--	**.63***	.06	**.37***	.09	.13
17. BMI-*z* score																	--	**-.19***	-.01	.05	.10
18. Sex																		--	.09	.08	.01
19. Age																			--	**.64***	.07
20. Race																				--	.05
21. CDI																					--

Note. N = 248 for all measures included in LPA; N = 226 for items used in Follow-up Analyses; *** *p* < .05**; Pearson correlations. SEI = Coopersmith Self-Esteem Inventory; PedsQL=Pediatric Health-Related Quality of Life (HRQoL) Measure with 4 Subscales: Physical, Emotional, Social, and School; BP = Blood pressure; TC = Total cholesterol; HDL-C = High-density lipoprotein cholesterol; LDL = Low-density lipoprotein cholesterol; HOMA-IR = Homeostasis model assessment of insulin resistance; Self-report Ex = frequency of self-reported exercise per week; PAR = 7 Day Physical Activity Recall; PAR-Moderate = time spent in moderate physical activity; PAR-Vigorous = time spent in vigorous physical activity; BMI = Body Mass Index; CDI = Children's Depression Inventory

As expected, the CDI – total score was negatively associated with all subscales of the PedsQL and the total score for the SEI such that adolescents with higher levels of HRQoL and self-esteem had lower CDI scores. Higher self-reported physical activity was also related to lower levels of depressed mood ($r = -.26$, $p < .05$). Lastly, higher levels of depressed mood on the CDI were related to worse systolic ($r = .16$, $p < .05$) and diastolic ($r = .21$, $p < .05$) blood pressure.

Summary of descriptive statistics. In this study, adolescents (*n* = 248) who were predominantly minority (*n* = 182; 73%) and female (n = 169; 68%) with severe obesity (mean BMI = 99%) reported, on average, levels of HRQoL, global self-esteem, and metabolic functioning comparable to other studies of obese youth in treatment for weight loss. Each of the subscales of the PedsQL and SEI demonstrated adequate internal consistency and correlated at least moderately well and in the expected (positive) direction. Metabolic factors, specifically systolic and diastolic blood pressure, and physical activity variables (PAR – vigorous and PA self-report) were also related to PedsQL - physical functioning and to a measure of depressed mood.

Review of hypotheses. LPA was employed to obtain a typology of "life satisfaction" in an obese sample of participants enrolled in a healthy weight management trial. It was hypothesized that baseline self-report data (HRQoL and global self-esteem) could be sorted into a typology reflecting meaningful differences among severely obese adolescents. If these groupings were identified, it was believed that demographic, metabolic, and exercise data could be used to further explicate the groups.

Mixture Modeling: Latent profile analysis (LPA)

Accuracy of the analyses. A series of 7 latent variable models were derived and iteratively compared on the basis of parameter estimates and fit indices to determine the optimal number of classes derived from adolescents' self-reported HRQoL and self-esteem, as measured by the PedsQL and SEI, respectively. As shown in Table 5, each model terminated normally, and the majority of loglikelihood solutions were replicated across all solutions (1-Class to 7-Class), indicating that (probabilistically) the correct or "best" parameters were estimated for each solution. Thus, in the current analysis, it is unlikely that a solution based on statistical artifact was reached (Muthén & Muthén, 1998-2010, p. 414).

Fit indices. The fit indices for each of the models are listed in Table 6. The 3-class model demonstrates the best-fit solution according to the aforementioned fit statistics.

BIC. The 3-class typology has the lowest BIC, indicating that the relative fit of a model with 3 classes is preferred to competing models.

LMR-adjusted LRT. Also, when comparing the fit of two consecutive models (e.g., 3-classes versus 4-classes), the 3-class model had a significantly higher LRT statistic, indicating that the observed model has a statistically better fit and is likely the most preferable solution.

Table 5.

Final stage loglikelihood values at local maxima, seeds, and initial stage start numbers for each class solution

Log-likelihood	Seed	ISS	Log-likelihood	Seed	ISS	Log-likelihood	Seed	ISS
1-Class			2-Class			3-Class		
-5430.218*	341041	34	-5275.445*	259507	53	-5237.832*	848890	95
-5430.218*	603842	61	-5275.445*	573096	20	-5237.832*	608496	4
-5430.218*	392418	28	-5275.445*	unp	0	-5237.832*	247224	94
-5430.218*	565819	65	-5275.445*	314084	81	-5237.832*	462953	7
-5430.218*	608496	4	-5275.445*	422103	62	-5237.832*	783110	72
-5430.218*	846194	93	-5275.445*	565819	65	-5237.832*	481835	57
-5430.218*	253358	2	-5275.445*	136842	58	-5237.832*	422103	62
-5430.218*	76974	16	-5275.445*	637345	19	-5237.832*	391179	78
-5430.218*	unp	0	-5275.445*	120506	45	-5237.832*	992389	77
Start value did	nc	--	-5275.445*	848890	95	-5237.832*	471398	74
4-Class			5-Class			6-Class		
-5214.704*	372176	23	-5201.340*	754100	56	-5190.162*	61587	400
-5214.704*	761633	50	-5201.340*	372176	23	-5190.162*	821011	161
-5214.704*	76974	16	-5201.340*	650371	14	-5190.266	34346	330
-5214.704*	391179	78	-5201.340*	637345	19	-5190.266	105435	265
-5214.704*	915642	40	-5201.340*	131856	90	-5190.266	848890	95
-5214.704*	364676	27	-5201.340*	902278	21	-5190.266	30098	209
-5214.704*	405079	68	-5201.340*	533738	11	-5190.266	70118	104
-5214.704*	76337	76	-5201.340*	136842	58	-5190.266	970689	266
-5214.704*	136842	58	-5204.870	544048	87	-5190.273	46437	153
-5214.704*	422103	62	-5205.388	318230	46	-5190.273	27071	15
7-Class								
-5179.885*	561664	392						
-5179.885*	966014	37						
-5179.885*	802779	122						
-5180.232	345070	114						
-5180.684	260601	36						
-5180.699	268217	83						
-5180.699	97158	205						
-5180.699	285380	1						
-5180.699	928287	197						
-5180.956	127215	9						

Note. *Indicates the best (highest) loglikelihood values for each solution
ISS = Initial Stage Starts, unp = unperturbed, nc = did not converge

Table 6.

Fit Indices for the 3-Class LPA Model

	Fit Indices	
	BIC	LMR-adjusted (p-value)
LPA		
1-Class	10915.57	N/A
2-Class	10639.11	300.462 (p = 0.00)
3-Class*	**10596.96**	**73.020 (p = 0.00)**
4-Class	10607.94	21.447 (p = 0.70)
5-Class	10618.77	21.605 (p = 0.14)
6-Class	10641.88	22.957 (p = 0.42)
7-Class	10671.16	22.893 (p = 0.45)

Note. *Average Posterior Probability (range) is 0.778 – 0.832
BIC = Bayesian Information Criterion; LMR-adjusted =
Lo-Mendell-Rubin-adjusted likelihood ratio test

Classification rates.

Average posterior probability. The estimated probabilities for participants being correctly categorized in 1 of the 3 groups (the average posterior probability; Table 6) was also quite high (range = 0.78 to 0.83), indicating a high degree of certainty in classification and separation between the classes.

Item response probabilities and class membership probabilities. Similarly, based on a 3-class model, the estimated probability (based on item response and class membership probabilities) shows a high degree of certainty in classification. For example, the likelihood that participants who were categorized to the LF group actually belong to that group is 91% (Table 7). For the MF and HF groups, this probability is 88% and 92%, respectively.

Table 7.

Estimated (Average) Latent Class Probabilities for the 3-Class Solution

Latent Classes	LF	MF	HF
LF	0.911	0.089	0.000
MF	0.050	0.881	0.069
HF	0.000	0.082	0.918

Note. LF = Low Functioning group, MF = Moderate Functioning group, HF = High Functioning group

Model parsimony. The 3-class solution seemed to be the best and simplest explanation of the data. No information was added by increasing the number of classes from 3 to 4. Specifically, in the 4-class solution, the MF group was split into 2 groups; one group had only 10 patients, and the HF and LF groups were exactly the same.

Description of classes. The 3 class-solution is typified by a group with high HRQoL and self-esteem, a group with middle levels of HRQoL and self-esteem, and another with low HRQoL and self-esteem (Figure 5). This configuration indicates that the latent variable, “life satisfaction,” is discrete and is best conceptualized on an ordinal scale. This means that the typology can be clearly ordered, in this case, according to high, medium, and low functioning groups (Vermunt & Magidson, 2004).

Figures 2 through 5 show the scores for all the responses for participants classified to high-, moderate-, and low-functioning groups and the average scores for each group. Overall, participants' responses within groups are more alike than between-groups, but there is overlap. For example, there are participants with high self-esteem scores (e.g., SEI = 80) that were not categorized in the highest functioning group because their other scores were more representative of the moderate functioning group (PedsQL range: 57 - 76).

The means of the individual response patterns further differentiated the groups, and the classes are described in further detail below.

(1) ***Class 1***: This class (*n* = 72; 29%) is characterized as having the best overall functioning ("life satisfaction;" Table 8, Figure 3). Thus, it was designated as the high functioning (HF) class or group. Those in this class reported having the highest self-esteem (*M* = 78.9; *SD* = 12.3) and HRQoL on each of the 4 subscales compared to the other 2 classes. Scores for this group on the PedsQL subscales ranged from 30 to 100 and 44 to 100 for the SEI. In addition, this group had more females than males (72% vs. 28%) and the highest percentage of African Americans compared to the other groups (*n* = 59; 82%). Class 1 participants also had the lowest mean diastolic (*M* = 68.0; *SD* = 7.5) and systolic (*M* = 124.5; *SD* = 14.1) blood pressure and BMI (*M* = 37.1; *SD* = 7.2). With the exception of triglycerides and fasting glucose, they also had the best mean values on other clinical indicators of metabolic functioning (Table 8).

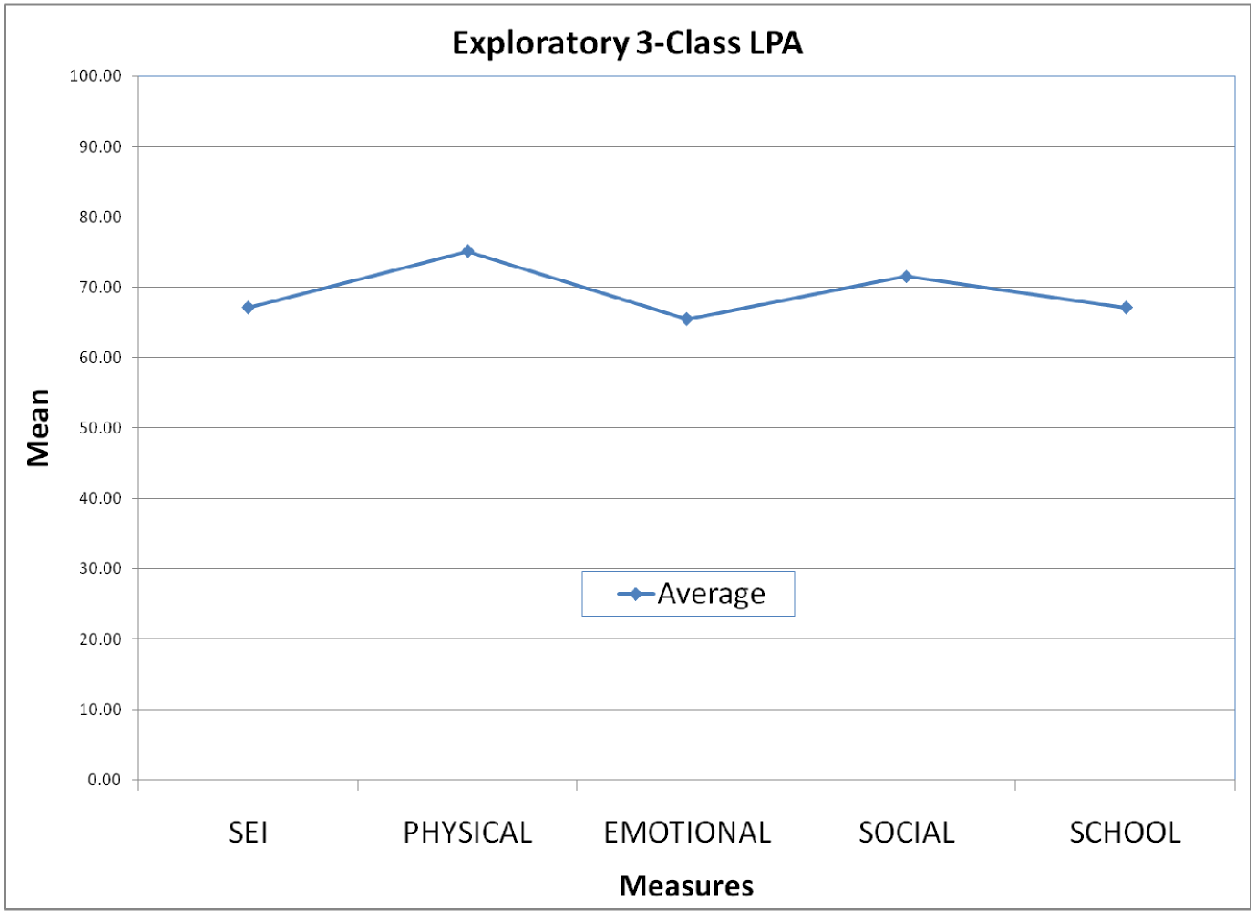

Figure 2. Average Scores on "Life Satisfaction"
Note. SEI = Coopersmith self-esteem inventory; Physical, Emotional, Social, and School = Each of the 4 subscales of the Pediatric health-related quality of life measure

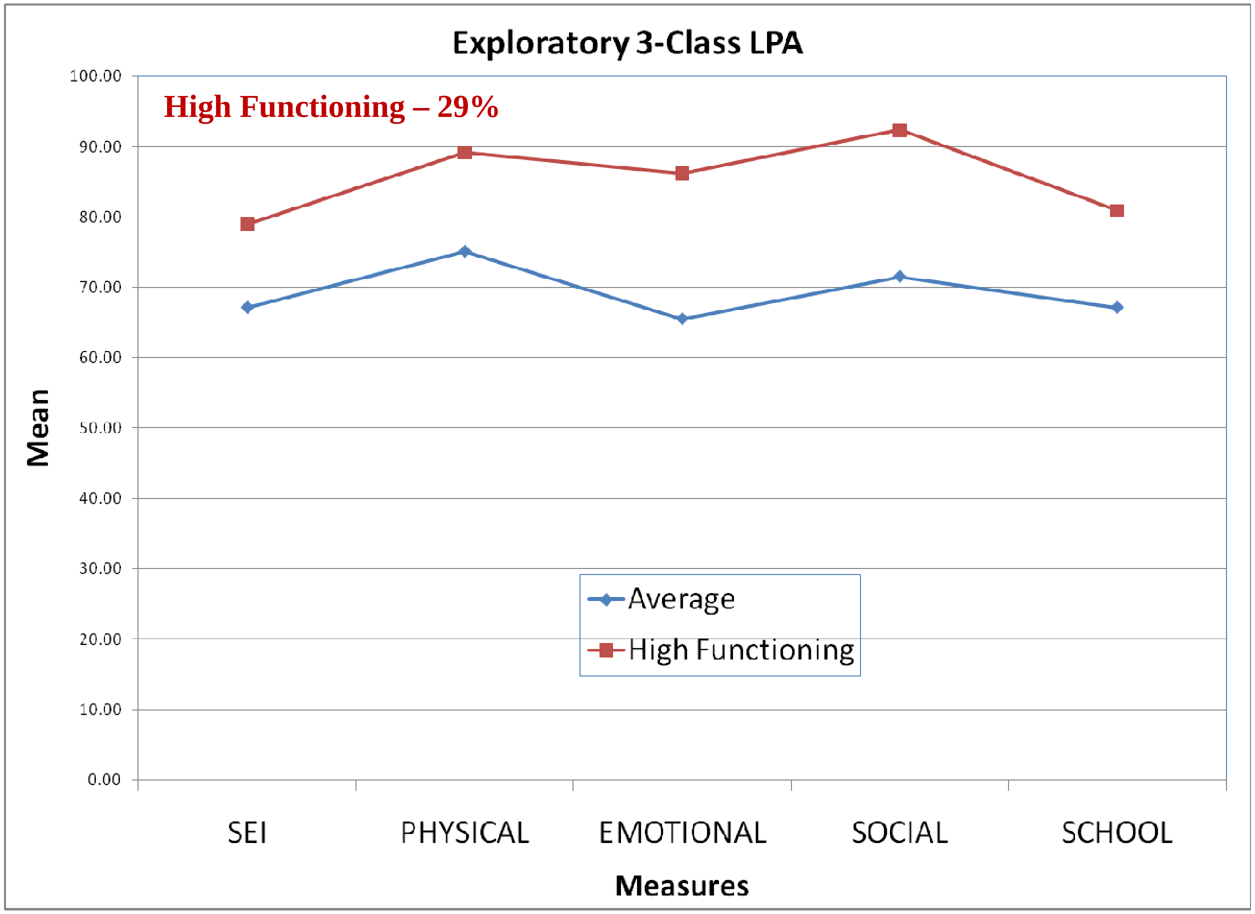

Figure 3. Responses of Class 1, the High Functioning Group
Note. SEI = Coopersmith self-esteem inventory; Physical, Emotional, Social, and School = Each of the 4 subscales of the Pediatric health-related quality of life measure

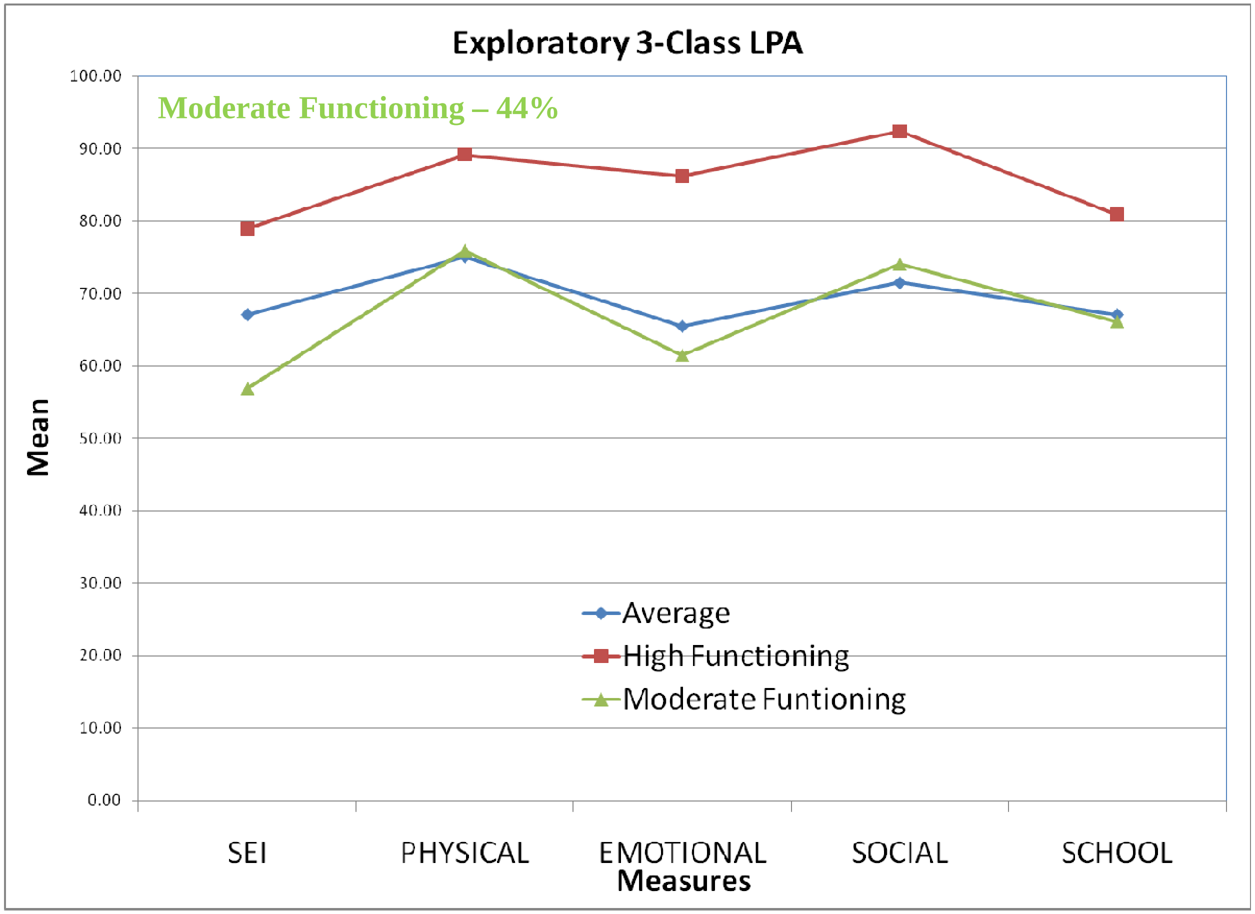

Figure 4. Responses of Class 2, the Moderate Functioning Group
Note. SEI = Coopersmith self-esteem inventory; Physical, Emotional, Social, and School = Each of the 4 subscales of the Pediatric health-related quality of life measure

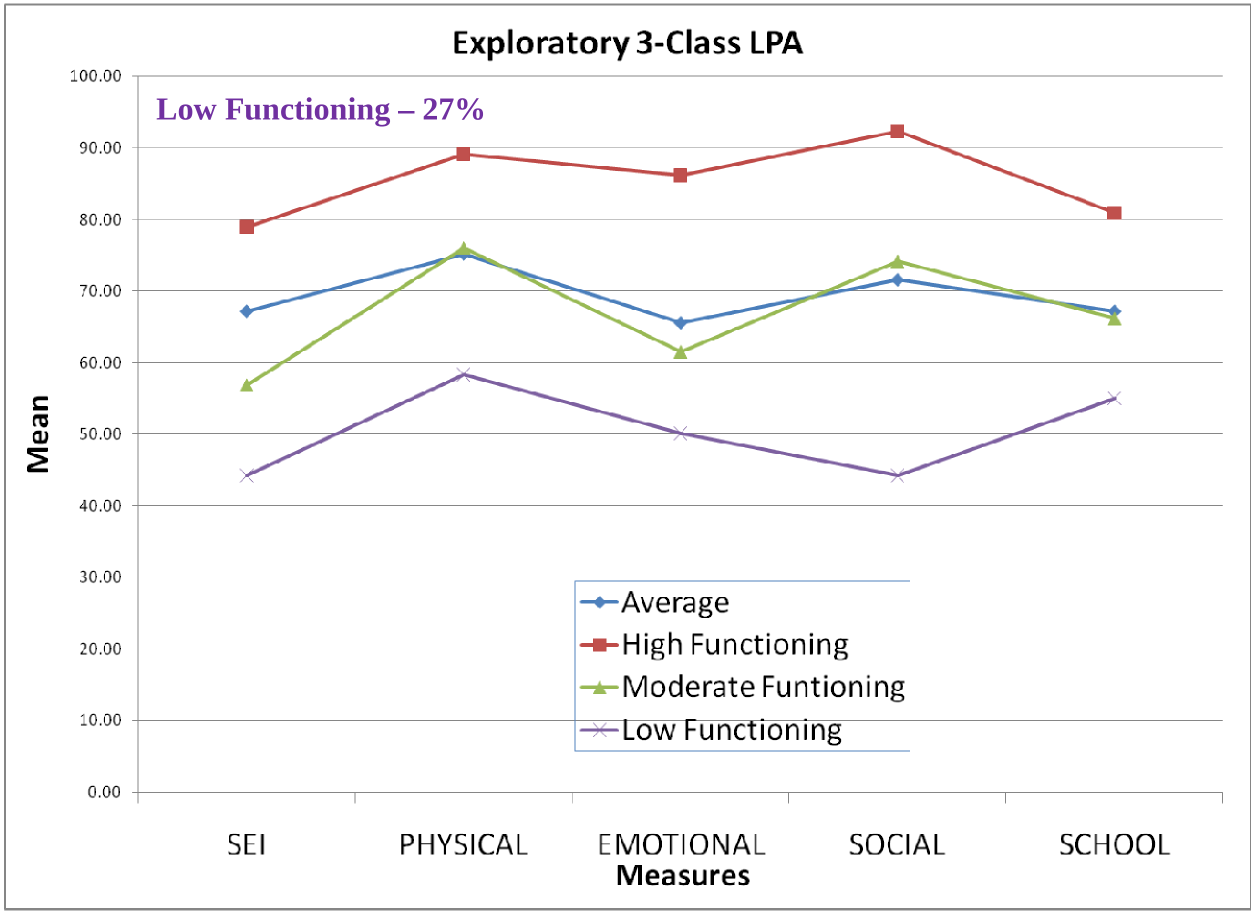

Figure 5. Responses of Class 3, the Low Functioning Group
Note. SEI = Coopersmith self-esteem inventory; Physical, Emotional, Social, and School = Each of the 4 subscales of the Pediatric health-related quality of life measure

Lastly, they endorsed the highest levels of physical activity (e.g., self-report, moderate, and vigorous; Table 8).

(2) ***Class 2***: This class, the largest of the 3 (*n* = 110; 44%) is distinguished by their moderate perceived "life satisfaction," and thus is called the "Moderate Functioning" group (MF) as assessed by the PedsQL measure and Coopersmith SEI (Figure 4). Scores ranged from 15 to 100 on the subscales of the PedsQL and 12 to 96 on the SEI. This group consists of mostly African Americans (*n* = 83; 76%) and females (*n* = 80; 73%). With the exception of triglycerides and fasting glucose levels, which were the best among the classes, their scores on all other clinical and physical activity measures fell between Class 1 and Class 3 (Table 8).

(3) ***Class 3***: This class's responses (*n* = 66; 27%) reflect the lowest perceived "life satisfaction" (LF group); adolescents in this category endorsed the lowest scores on HRQoL and self-esteem. Scores ranged from 0 to 90 on the PedsQL and 12 to 92 on the SEI. Particularly noteworthy is the fact that this group had the highest percentage of Caucasians (*n* = 21; 32%) and males (*n* = 29; 45%; Figure 5, Table 8). Other than HDL-C and fasting glucose, they had the worst mean scores for all clinical and physical activity measures.

Table 8.

Sample Size and Means for the 3-Class Typology

	High Functioning Class 1	**Moderate Functioning** Class 2	**Low Functioning** Class 3
n (%)	72 (29)	110 (44)	66 (27)
Race = n (%)			
Caucasian	12 (17)	17 (16)	21 (32)
African Am.	59 (82)	83 (76)	40 (62)
Sex = n (%)			
Male	20 (28)	30 (27)	29 (45)
Female	52 (72)	80 (73)	37 (55)
Age = n (SD)	13.7 (1.9)	14.1 (1.8)	13.5 (1.7)
		Mean (SD)	
PedsQL – Physical	89.2 (8.9)	76.0 (11.0)	58.4 (10.8)
PedsQL - Emotional	86.2 (12.3)	61.5 (15.0)	50.1 (15.4)
PedsQL - Social	92.4 (7.8)	74.1 (11.8)	44.2 (15.7)
PedsQL - School	80.9 (16.7)	66.1 (17.5)	55.0 (18.6)
Self-esteem Inventory	78.9 (12.3)	56.8 (15.9)	44.2 (16.4)
Diastolic BP (mmHg)	68.0 (7.5)	70.5 (12.7)	72.0 (8.8)
Systolic BP (mmHg)	124.5 (14.1)	128.1(15.7)	131.2 (13.1)
Body Mass Index (kg/m^2)	37.1 (7.2)	38.1 (7.2)	38.9 (7.5)

Note. *N* = 248 for all measures included in LPA; *n* = 226 for metabolic items used in regression analyses; SD = Standard Deviation; PedsQL=Pediatric Health-Related Quality of Life (HRQoL) Measure with 4 Subscales: Physical, Emotional, Social, and School; BP = blood pressure

Table 8 Continued

Sample Size and Means for the 3-Class Typology

	High Functioning Class 1	**Moderate Functioning** Class 2	**Low Functioning** Class 3
n (%)	72 (29)	110 (44)	66 (27)
		Mean (SD)	
Body Mass Index (z-score)	2.5 (0.5)	2.5 (0.5)	2.5 (0.5)
Body Mass Index (%)	99.0 (1.3)	99.0 (1.1)	99.3 (0.7)
Self-report exercise	2.94 (.95)	2.81 (.99)	2.60 (.97)
PAR - Moderate	1.96 (2.27)	1.86 (2.59)	1.69 (2.69)
PAR - Vigorous	1.56 (2.43)	1.43 (2.53)	.57 (1.09)
Triglycerides	97.2 (49.8)	92.0 (44.0)	106.1 (65.3)
Total cholesterol (mg/dL)	161.6 (23.9)	163.3 (29.2)	166.0 (29.2)
HDL – C (mg/dL)	43.4 (9.2)	44.3 (10.7)	43.5 (10.5)
LDL – C (mg/dL)	98.7 (22.6)	100.6 (24.4)	101.3 (23.7)
Fasting glucose (mg/dL)	85.8 (7.2)	84.5 (10.2)	85.1 (8.6)
Fasting insulin (µU/L)	18.8 (11.9)	20.3 (15.8)	20.3 (12.4)
HOMA-IR	4.0 (2.6)	4.3 (3.6)	4.3 (2.8)
CDI	4.3 (3.8)	10.4 (6.6)	14.2 (5.0)

Note. N = 248 for all measures included in LPA; n = 226 for metabolic items used in regression analyses n = 197 for PAR data; PAR = 7 Day Physical Activity Recall; PAR-Moderate = time spent in moderate physical activity; PAR-Vigorous = time spent in vigorous physical activity; HDL-C = High-density lipoprotein cholesterol; LDL-C = Low-density lipoprotein cholesterol; HOMA-IR = Homeostasis model assessment of insulin resistance; CDI = Children's Depression Inventory

Demographic differences. To determine whether demographic differences (race and sex) between classes were statistically significant, chi-square tests were conducted. Sex, $\chi^2(2, N = 247) = 6.46$, $p = .04$, and race, $\chi^2(2, N = 247) = 7.99$, $p = .01$ differed across classes such that the LF group had a significantly higher proportion of males (45%) and Whites (32%) compared to the HF (referent) class. However, classes did not differ with respect to age. In the overall model, $F(2, 246) = .563$, $p = .57$; $R^2 = .01$, betas were not significant for the MF class ($\beta = .07$, $p = .33$) or LF class ($\beta = .06$, $p = .38$).

Regressions. Next, for the last set of analyses, 10 linear regression models were run using SPSS version 14.0 to determine whether class membership predicted metabolic functioning on clinical measures of BMI (kg/m^2), blood pressure (diastolic, systolic), glucose and insulin values, including HOMA-IR, cholesterol levels (HDL, LDL, and TC), and triglycerides. Then, three linear regressions were performed to examine the relationship between physical activity measures (self-reported exercise, moderate, and vigorous physical activity) and class membership. Lastly, the CDI – total score was used to determine its relationship to class membership. Because class (group) membership is nominal, the clinical and exercise variables were dummy coded, and Class 1 was set as the reference group because members' responses typified the best overall functioning (e.g., "life satisfaction").

Significant findings.

Metabolic factors. Of these regressions, 5 models were statistically significant (Table 8). Blood pressure was the only clinical measure associated with class membership; systolic blood pressure accounted for 3% of the variance ($\beta = .20$, $p = .04$),

Table 9.

Multivariate Relationships Between Classes and Other Measures

	Beta		
Measures	Class 2 **MF**	Class 3 **LF**	R^2
Body Mass Index (kg/m^2)	.06	.12	.01
Age (years)	.07	.07	.01
Self-report exercise	-.07	-.16*	.02$^+$
PAR - Moderate	-.02	-.05	.00
PAR - Vigorous	-.03	-.20*	.03$^+$
Systolic BP (mmHg)	.12	.20*	.03$^+$
Diastolic BP (mmHg)	.12	.17*	.02$^+$
Triglycerides (mg/dL)	-.05	.08	.01
Total Cholesterol (mg/dL)	.03	.07	.00
HDL – C (mg/dL)	.04	.00	.00
LDL – C (mg/dL)	.04	.05	.00
Fasting glucose (mg/dL)	-.07	-.03	.00
Fasting insulin (μU/L)	.05	.05	.00
HOMA-IR	.04	.05	.00
CDI	.46*	.65*	.32$^+$

Note: *n* = 226 (for metabolic data).Reference Class: Class 1 = High Functioning, **HF**
MF = Moderate Functioning; **LF** = Low Functioning
*Class significantly different from the reference group.
$^+$Multivariate statistic P < .05
PAR = 7 Day Physical Activity Recall; BP = Blood pressure; HDL-C = High-density lipoprotein cholesterol; LDL = Low-density lipoprotein cholesterol; HOMA-IR = Homeostasis model assessment of insulin resistance; CDI = Children's Depression Inventory

and diastolic blood pressure accounted for 2% of the variance (β = .17, *p* = .03). This means that membership in the LF group was significantly associated with worse blood pressures compared to Class 1, the referent class. Values for the MF group were not significantly different from Class 1 for systolic (β = .12, *p* = .12) or diastolic blood pressure (β = .12, *p* = .13). For diastolic blood pressure, the overall model was not significant when both classes (MF and LF) were compared to the referent class {$F(2, 225) = 2.404$, $p = .09$; $R^2 = .02$}; however, the LF group was still significantly different from the HF group as noted above. In this case, for a 1 standard deviation increase in scores among adolescents in this class, we would expect a .17 decrease in diastolic blood pressure. In other words, higher scores on "life satisfaction" indicate improvements in metabolic functioning. Thus, in this study, adolescents in the LF group had systolic readings {$F(2, 225) = 3.270$, $p = .04$; $R^2 = .03$} that were, on average, 6.7 points higher than in the referent class; their diastolic readings were 4 points higher.

Controlling for demographics (race, sex) and BMI. A separate analysis of race, sex, and BMI *z*-score was conducted to determine whether or not these variables confounded any significant relationships with blood pressure. Results showed that race was not a significant predictor of diastolic (β = .09, *p* = .18) or systolic (β= -.01, *p* = .87) blood pressure; neither was sex (diastolic, β = .09, *p* = .21; systolic, β = -.01, p = .93). Further, BMI *z*-score was a significant predictor of diastolic (β =.17, *p* = .01) and systolic (β = .38, *p* = .00) blood pressure, but in our analyses, the HF class did not significantly differ from the other 2 classes on BMI *z*-score such that $F(2, 225) = 1.091$, $p = .34$; $R^2 = .01$. Therefore, BMI was not related to class membership. Thus, after controlling for race, sex, and BMI *z*-score, adolescents classified to the LF group still had the worst BP readings (diastolic, $\beta = .19$, $p = .02$; systolic, $\beta = .17$, $p = .03$) compared to the HF group.

Physical activity variables. Exercise variables also predicted group membership. There was a significant difference between the HF (referent class) and LF classes on vigorous physical activity, $F(2, 193) = 3.192$, $p = .04$; $R^2 = .03$. Thus, vigorous physical activity on the PAR accounted for 3% of the variance in class membership such that respondents in the HF group engaged in nearly three times more vigorous activity (in minutes per week) than those in the LF group ($\beta = -.20$, $p = .02$). There was no difference between the HF and LF classes on moderate physical activity on the PAR such that $F(2, 193) = .157$, $p = .86$, $R^2 = .00$. Similar results were found for self-reported exercise. While the overall model was not significant, $F(2, 241) = 2.095$, $p = .13$; $R^2 = .02$, it was determined that the LF class significantly differed from the HF class ($\beta = -.16$, $p = .04$), indicating that overall, adolescents in the referent class engage in more self-reported physical activity.

Depressed mood. The CDI – total score, a measure of depressed mood, also significantly predicted group membership (2, 191) = 43.89, $p = .00$; $R^2 = .32$. Thus, depressed mood accounted for 32% of the variance in class membership. Specifically, MF group members reported levels of depressed mood that were significantly higher than the HF group ($\beta = .46$, $p = .00$); LF group members were also significantly more likely to report experiencing depressed mood ($\beta = .65$, $p = .00$) compared to the HF group.

Non-significant findings. The remaining metabolic indices including BMI, total cholesterol, LDL-C, HDL-C, triglycerides, glucose, insulin, and HOMA-IR values were not significantly related to class membership. As expected, average BMI (kg/m^2) was not related to class membership such that F (2, 225) = 1.091, p = .34; R^2 = .01, which is most likely due to its restricted (high) range. In other words, the best functioning (HF) class did not significantly differ from the MF (β = .07, p = .41) and LF classes (β =.11, p = .17) on average BMI (kg/m^2).

Second, class membership was not associated with total cholesterol levels, where F(2, 225) = .406, p = .67; R^2 = .00. Overall models for both LDL-C and HDL-C were also not significantly related to class membership. For LDL-C, F(2, 225) = .197, p = .82; R^2 = .00; for HDL-C, the F(2, 225) = .171, p = .84; R^2 = .00. Participants belonging to the MF (β = .04, p = .62) or LF (β = .05, p = .55) groups did not have LDL-C levels that were worse than those in the HF group. The same was true for HDL-C, where the MF (β = .04, p = .61) and LF (β = .00, p = .98) groups showed no differences compared to those in the referent class.

Third, class membership did not significantly predict triglyceride levels in the overall model, F(2, 225) = 1.396, p = .25; R^2 = .01, indicating no significant effects. The HF group could not be further differentiated from the MF (β = -.05, p = .54) or LF (β = .08, p = .34) group on this variable.

Fourth, class membership was not a significant predictor of baseline glucose, insulin values, or HOMA-IR. For glucose levels, F(2, 225) = .405, p = .67; R^2 = .00, there were no differences distinguishing the MF (β = -.07, p = .37) and LF (β = -.03, p = .67) groups from the referent class. Insulin and HOMA-IR regressions were also not significant meaning that the HF class does not significantly differ from the LF class on baseline insulin such that $F(2, 172) = .204$, $p = .82$; R2 = .00, or HOMA-IR values, where $F(2, 172) = .14$, $p = .87$; $R^2 = .00$.

Post hoc ordinal regression analyses. A series of regressions were conducted to better understand the relationships between variables demonstrating that participants in the LF group were significantly more impaired than the HF group. Since the pair of self-reported exercise variables (PAR-vigorous and single item exercise question [PA-self-report]) and blood pressure (diastolic and systolic) variables were correlated, only one from each pair was included in a set of regressions. Therefore, four sets of regressions were run and between four and six variables were included in each analysis. As mentioned in the Analysis section, each set included six regressions, in which the variables were entered in different sequences to explicate associations. Tables 10 to 13 include the results of these analyses. The general findings across the four sets of analyses, with some minor exceptions, are as follows:

1) The demographic variables were only significant in the presence of diastolic blood pressure
2) BMI *z*-score was not significant across any of the six analyses
3) Diastolic blood pressure was significant only when demographic variables were included and one instance in which self-reported exercise (PA self-report) was included
4) Self-reported vigorous exercise was significant in every regression in which the total CDI score was not included
5) The total CDI score was significant in each regression it was included

6) The presence of the CDI rendered blood pressure (diastolic and systolic) and self-reported exercise (PAR-vigorous and PA self-report) non-significant.
7) The R^2 of the models with the CDI were substantially higher (range= .353 - .357) than analyses in which it was not included (.077 - .099).

There were two exceptions. First, in only one set of the analyses (Table 10, Analysis 2) was blood pressure (diastolic) significant when self-reported exercise was included in the model. In the other, Table 11, Analysis 3; self-reported vigorous exercise was borderline significant after the total CDI score was included.

Overall, these patterns indicate that blood pressure and self-reported exercise were significant predictors of membership in the LF group but accounted for a relatively small proportion of the overall variance. However, when depressed mood was included, its presence rendered all of the other variables non-significant, thus, accounting for a much larger proportion of the variance.

In this section, the specific results are reported for the set of regressions that included diastolic blood pressure and self-reported (single item question) exercise (Table 10). Given that the findings are nearly identical for all of the other analyses that were conducted, they are not described in detail here but are included in Tables 11 to 13.

Analysis 1. Race and sex were positively associated with greater dysfunction. For a 1 unit increase in each of these two variables respectively, the expected ordered log odds increases by .394 and .348, as one moves to the next higher category of function. In other words, in general, African Americans and girls tend to be associated with membership groups with higher “life satisfaction.” Diastolic blood pressure was negatively associated with greater dysfunction. For a 1 unit decrease in diastolic blood pressure, the expected ordered log odds decreases by 0.017 as one moves to the next higher category of dysfunction. In other words, moving from the lowest functioning group to those with higher “life satisfaction,” diastolic blood pressure goes down.

Analysis 2. Sex and PA self-report were positively associated with greater dysfunction. For a 1 unit increase in these two variables respectively, the expected ordered log odds increases by .384 and .197 as you move to the next higher category of dysfunction. Thus, moving from groups with lower “life satisfaction” to those with higher “life satisfaction,” the respondents tend to be female and report engaging in more physical activity.

Diastolic blood pressure was negatively associated with greater dysfunction. For a 1 unit decrease in diastolic blood pressure, the expected ordered log odds decreases by 0.015 as you move to the next higher category of dysfunction. This is the same direction as analysis 1; diastolic blood pressure goes down moving from lower “life satisfaction” to groups with higher “life satisfaction.”

Analysis 3. Only the total score on the depressed mood scale was significant. In this case, for every 1 unit decrease in the score on this scale, the expected log odds decreases by 0.96 as you move to the next higher category of dysfunction. In other words, the total score on depressed mood goes down, indicating less depressed mood, moving from groups with lower “life satisfaction” to those with higher “life satisfaction.”

Analysis 4. Both sex and self-reported exercise were positively associated with greater function. Thus, for a 1 unit increase in these variables, the expected ordered log odds increases by .355 and .199, respectively, moving to the next higher category of the typology. Thus, participants are more likely to be female and report more exercise as one moves from lower “life satisfaction” to those with higher “life satisfaction.”

Analysis 5. Only the total score on the depressed mood scale was significant. In this case, for every 1 unit decrease in the score on this scale, the expected log odds decreases by 0.98 as you move to the next higher category of this typology. Similar to Analysis 3, the total score on the depressed mood scale goes down, indicating that as one moves to groups with greater “life satisfaction,” depressed mood decreases.

Analysis 6. Only the total score on the depressed mood scale was significant. In this case, for every 1 unit decrease in the score on this scale, the expected log odds decreases by 0.102 as one moves to the next higher category of this typology. Just like Analysis 3 and 5, the total score on the depressed mood scale goes down, indicating less depressed mood, as one moves from groups with less “life satisfaction” to those with greater “life satisfaction.”

Table 10

Post Hoc Analyses 1

	Estimate	S.E.	Est./S.E.	Two-Tailed P-Value
		Analysis 1		
Race	0.39	0.18	2.23	0.03*
Sex	0.35	0.16	2.17	0.03*
BMI z-score	-0.07	0.15	-0.49	0.63
Diastolic BP	-0.02	0.01	-2.65	0.01**
				R^2=.08
		Analysis 2		
Race	0.35	0.18	1.90	0.06
Sex	0.39	0.17	2.33	0.02*
BMI z-score	-0.07	0.15	-0.46	0.64
Diastolic BP	-0.02	0.01	-2.22	0.03*
PA self-report	0.20	0.08	2.38	0.02*
				R^2=.09
		Analysis 3		
Race	0.36	0.24	1.48	0.14
Sex	0.31	0.20	1.59	0.11
BMI z-score	-0.14	0.19	-0.73	0.47
Diastolic BP	-0.01	0.01	-0.89	0.38
PA self-report	0.13	0.10	1.27	0.20
CDI	-0.10	0.01	-6.95	0.00***
				R^2=.36
		Analysis 4		
Race	0.31	0.18	1.72	0.09
Sex	0.36	0.17	2.16	0.03*
BMI z-score	-0.12	0.15	-0.80	0.42
PA self-report	0.20	0.08	2.46	0.01**
				R^2=.08
		Analysis 5		
Race	0.34	0.24	1.44	0.15
Sex	0.31	0.20	1.56	0.12
BMI z-score	-0.17	0.19	-0.89	0.38
PA self-report	0.13	0.10	1.26	0.21
CDI	-0.10	0.01	-7.26	0.00***
				R^2=.35
		Analysis 6		
Race	0.39	0.23	1.68	0.09
Sex	0.29	0.20	1.49	0.14
BMI z-score	-0.12	0.19	-0.64	0.52
Diastolic BP	-0.01	0.01	-0.95	0.34
CDI	-0.10	0.01	-8.07	0.00***
				R=0.36

Note. BMI = Body Mass Index, BP = blood pressure; PA self-report = physical activity, self-reported from single item question; CDI = Children's Depression Inventory; *p < .05, **p < .01, ***p < .001

Table 11

Post Hoc Analyses 2

	Estimate	S.E.	Est./S.E.	Two-Tailed P-Value
		Analysis 1		
Race	0.39	0.18	2.23	0.03*
Sex	0.35	0.16	2.17	0.03*
BMI z-score	-0.07	0.15	-0.49	0.63
Diastolic BP	-0.02	0.01	-2.65	0.01**
				R^2=.08
		Analysis 2		
Race	0.31	0.19	1.61	0.11
Sex	0.36	0.18	2.04	0.04*
BMI z-score	-0.06	0.16	-0.38	0.71
Diastolic BP	-0.01	0.01	-1.42	0.16
Vigor-PAR	0.10	0.04	2.30	0.02*
				R^2=.09
		Analysis 3		
Race	0.30	0.24	1.23	0.22
Sex	0.38	0.21	1.79	0.07
BMI z-score	-0.06	0.20	-0.32	0.75
Diastolic BP	-0.00	0.01	-0.34	0.74
Vigor-PAR	0.09	0.05	1.85	0.07
CDI	-0.10	0.01	-6.74	0.00***
				R^2=.36
		Analysis 4		
Race	0.29	0.19	1.49	0.14
Sex	0.35	0.18	2.00	0.05*
BMI z-score	-0.10	0.16	-0.63	0.53
Vigor-PAR	0.10	0.04	2.48	0.01**
				R^2=.08
		Analysis 5		
Race	0.29	0.24	1.21	0.23
Sex	0.38	0.21	1.82	0.07
BMI z-score	-0.08	0.20	-0.40	0.69
Vigor-PAR	0.10	0.05	1.96	0.05*
CDI	-0.10	0.01	-6.96	0.00***
				R^2=.36
		Analysis 6		
Race	0.39	0.23	1.68	0.09
Sex	0.29	0.20	1.49	0.14
BMI z-score	-0.12	0.19	-0.64	0.52
Diastolic BP	-0.01	0.01	-0.95	0.34
CDI	-0.10	0.01	-8.07	0.00***
				R^2=.36

Note. BMI = body mass index; Vigor-PAR = time spent in vigorous physical activity as measured by the Physical Activity Recall; CDI = Children's Depression Inventory; BP = blood pressure; *p < .05, **p < .01, ***p < .001

Table 12

Post Hoc Analyses 3

	Estimate	S.E.	Est./S.E.	Two-Tailed P-Value
		Analysis 1		
Race	0.36	0.18	2.02	0.04*
Sex	0.32	0.16	1.97	0.05*
BMI z-score	0.01	0.15	0.07	0.94
Systolic BP	-0.01	0.01	-2.17	0.03*
				R^2=0.08
		Analysis 2		
Race	0.31	0.18	1.72	0.09
Sex	0.35	0.17	2.14	0.03*
BMI z-score	-0.01	0.15	-0.06	0.95
Systolic BP	-0.01	0.01	-1.71	0.09
PA self-report	0.19	0.08	2.29	0.02*
				R^2=0.09
		Analysis 3		
Race	0.34	0.24	1.40	0.16
Sex	0.31	0.20	1.55	0.12
BMI z-score	-0.09	0.19	-0.47	0.64
Systolic BP	-0.01	0.01	-0.99	0.32
PA self-report	0.12	0.10	1.20	0.23
CDI	-0.10	0.01	-7.10	0.00***
				R^2=0.36
		Analysis 4		
Race	0.31	0.18	1.72	0.09
Sex	0.36	0.17	2.16	0.03
BMI z-score	-0.12	0.15	-0.80	0.42
PA self-report	0.20	0.08	2.46	0.01**
				R^2=0.08
		Analysis 5		
Race	0.34	0.24	1.44	0.15
Sex	0.31	0.20	1.56	0.12
BMI z-score	-0.17	0.19	-0.89	0.38
PA self-report	0.13	0.10	1.26	0.21
CDI	-0.10	0.01	-7.26	0.00***
				R^2=0.35
		Analysis 6		
Race	0.38	0.24	1.59	0.11
Sex	0.28	0.19	1.45	0.15
BMI z-score	-0.06	0.19	-0.32	0.75
Systolic BP	-0.01	0.01	-1.18	0.24
CDI	-0.10	0.01	-8.11	0.00***
				R^2=0.36

Note. BMI = Body Mass Index, BP = blood pressure; PA self-report = physical activity, self-reported from single item question; CDI = Children's Depression Inventory; *$p < .05$, **$p < .01$, ***$p < .001$

Table 13

Post Hoc Analyses 4

	Estimate	S.E.	Est./S.E.	Two-Tailed P-Value
		Analysis 1		
Race	0.36	0.18	2.02	0.04*
Sex	0.32	0.16	1.97	0.05*
BMI z-score	0.01	0.15	0.07	0.94
Systolic BP	-0.01	0.01	-2.17	0.03*
				R^2=0.08
		Analysis 2		
Race	0.29	0.19	1.50	0.13
Sex	0.35	0.18	1.96	0.05*
BMI z-score	-0.01	0.16	-0.08	0.94
Systolic BP	-0.01	0.01	-1.24	0.22
Vigor-PAR	0.10	0.04	2.40	0.02*
				R^2=0.09
		Analysis 3		
Race	0.29	0.25	1.19	0.23
Sex	0.38	0.21	1.81	0.07
BMI z-score	-0.03	0.21	-0.17	0.87
Systolic BP	-0.00	0.01	-0.52	0.60
Vigor-PAR	0.10	0.05	1.93	0.05*
CDI	-0.10	0.01	-6.83	0.00***
				R^2=0.36
		Analysis 4		
Race	0.29	0.19	1.49	0.14
Sex	0.35	0.18	1.99	0.05*
BMI z-score	-0.10	0.16	-0.63	0.53
Vigor-PAR	0.10	0.04	2.48	0.01**
				R^2=0.08
		Analysis 5		
Race	0.29	0.24	1.21	0.23
Sex	0.38	0.21	1.82	0.07
BMI z-score	-0.08	0.20	-0.40	0.69
Vigor-PAR	0.10	0.05	1.96	0.05*
CDI	-0.10	0.01	-6.96	0.00***
				R^2=0.36
		Analysis 6		
Race	0.38	0.24	1.59	0.11
Sex	0.28	0.19	1.45	0.15
BMI z-score	-0.06	0.19	-0.32	0.75
Systolic BP	-0.01	0.01	-1.18	0.24
CDI	-0.10	0.01	-8.11	0.00***
				R^2=0.36

Note. BMI = body mass index; Vigor-PAR = time spent in vigorous physical activity as measured by the Physical Activity Recall; CDI = Children's Depression Inventory; BP = blood pressure; *$p < .05$, **$p < .01$, ***$p < .001$

Discussion

Pediatric obesity has reached epidemic proportions across all ethnic and socioeconomic groups (Ogden et al., 2012, 2010), and the de facto assumption is that the population is homogeneous. While this approach has yielded important insights, testing this supposition could reveal important distinctions that could impact understanding of this group and how to treat people with this condition.

In this study, attempts were made to parse HRQoL and self-esteem data to determine whether groups can be detected and whether such a typology is meaningful. It was found that, in this sample, patients' responses can be divided into a 3-class typology characterized by high- (HF), medium- (MF), and low functioning (LF). Regression analyses showed that the LF group had a significantly higher proportion of Caucasians and males than the HF group. Further, when controlling for demographics and weight, the LF group had significantly worse systolic and diastolic blood pressure readings and lower self-reported physical activity and depressed mood compared to the referent (HF) group.

Interestingly, analyses testing the association with class membership and these variables (significant demographics, weight, blood pressure readings [diastolic or systolic], measures of self-reported exercise [PAR-vigorous and the PA self-report single item question] and depressed mood) when blood pressure and self-reported physical activity were included as independent variables (IVs) in the same regression, showed that blood pressure was no longer significant. Finally, when depressed mood was included, neither blood pressure (systolic or diastolic) nor self-reported physical activity remained significant.

These findings are perplexing, and there does not seem to be any analogue in the literature. After some consideration, it was hypothesized that:

1) Depressed mood and self-reported exercise both share common variance with blood pressure because in the presence of either of those variables, blood pressure was not significant.
2) Because blood pressure and self-reported exercise, both separately and together, are non-significant in the presence of depressed mood, then that variable may be the primary driver for both metabolic and self-reported dysfunction. Thus, patients in the LF group are significantly more depressed than those in the HF group, which is manifested in less self-reported exercise and worse blood pressure.

This possibility and its clinical implications are addressed in the following sections. Parallels are also made to current research findings in pediatric obesity as well as to the clinical research on depressed mood. Briefly discussed is the relationship between obesity and depressed mood with consideration given to the biobehavioral mechanisms that might explain this relationship. Lastly, the section concludes with a discussion of the strengths, limitations, and future directions of the study.

HRQoL and Self-esteem in Pediatric Obesity

First, it should be noted that the current study supports the well-established finding that, in general (when the sample is treated as homogeneous), obese youth perceive their HRQoL similarly to other samples of obese adolescents at baseline assessment (Schwimmer et al., 2003; Varni, Limbers, & Burwinkle, 2007). Compared to the literature, adolescents' average scores in this sample were lower than those reported in other studies of average-weight peers (Williams et al., 2005), those with cancer (Schwimmer et al., 2003), and adolescents with other chronic medical conditions (e.g., diabetes and End stage renal disease [ESRD], Varni, Seid, & Kurtin, 2001; Varni, Limbers, & Burwinkle, 2007). Mean SEI scores also approximated the sample to which the psychometric properties were analyzed (Coopersmith, 1981).

However, in this study, higher degrees of obesity, as measured by BMI, were not related to increased impairments in HRQoL and global self-esteem for all respondents. This is not surprising given the restricted range in BMI in this study. Interestingly, the act of empirically splitting the groups showed that those in the HF group reported levels of "life satisfaction" that were even higher than healthy populations (Varni et al., 2003) while those in the LF group had markedly impaired levels. Respondents classified to the MF group, the majority of adolescents (n = 110; 44%), endorsed similar HRQoL and self-esteem scores as other samples of obese youth (Varni, Limbers, & Burwinkle, 2007; Wardle & Cooke, 2005).

This typology, however, is only meaningful if it yields unique insight, but since this approach has not been used in this patient population, we examined relevant research to put the findings into context. Specifically, there appear to be a number of mechanisms—behavioral and physiological—that might explain poor self-reported health and high blood pressures in LF group members.

Class 3: The Low Functioning (LF) Group

It is believed that patients in the LF group are distinct from the other groups, and that depressed mood might be the primary driver of dysfunction. This finding appears to align with recent research indicating that obese Caucasians and males have higher levels of depressive disorders (Mustillo et al., 2003).

The Cognitive Model of Depression

There is evidence to support that depressed mood can be a primary driver for dysfunction for patients in the LF group. Using the cognitive model of depression, it is possible to understand how adolescents suffering with mood concerns might report dysfunction across all self-report measures, regardless of the content.

Much of the literature on depressed mood is based on the premise that thoughts or cognitions influence mood and behavior (Beck, 1995). Our experiences and how we perceive them (positively, negatively, or neutrally) lead to the formation of core beliefs and automatic thoughts about ourselves, others, and the world. Distressful symptoms occur as a result of one's negative beliefs/irrational (negatively skewed) thought patterns, which are often reinforced by maladaptive coping behaviors. For persons who are depressed, they are likely to feel worthless or unlovable, and these perceived defects are actually manifestations of negatively, biased thinking. Such faulty conclusions can lead individuals to feel worthless and insecure. For teenagers, in particular, they may feel misunderstood or avoid situations in order to escape possible hurt, pain, and loss from true threats to their self-esteem (Beck, Rush, Shaw, & Emery, 1979; Beck, 1988).

Negative, core beliefs tend to be long-standing as a result of schemas, which are relatively stable patterns of conceptualizing situations. People with depression typically attend more to negative information than positive or neutral. As such, their view of specific situations is distorted to fit particular schemas. The schemas that are activated determine how a person processes and affectively responds to situations. The more ingrained these thought patterns have become and the more severe the depression, the harder it is to view situations and thoughts objectively. In many cases, these hypervalent schemas lead to distortions of reality and systematic errors in thinking, which can lead to the development of negative ideas about many aspects of their lives (Rush & Nowels, 1994 in Wilkes, Belsher, Rush, & Frank, 1994). Cognitive theory further suggests that many symptoms of depression are maintained by this cognitive triad or one's negative view of the self, experiences, and the future. Thus, it is possible that class membership in the LF group reflects this negative thinking, which is permeating each domain of HRQoL, self-esteem, and adolescents' thoughts about their physical activity. The idea that depression can negatively skew self-report data has also been shown elsewhere in the literature.

For example, in a large, cross-sectional study of adults (N = 1024) with coronary artery disease (CAD), Ruo and colleagues (2003) found that outpatients with depressive symptoms on the Patient Health Questionnaire were more likely to report at least mild impairment in the following areas: symptom burden, physical limitation, and QoL; most rated their overall health as fair or poor. The authors concluded that patients' health status can be improved by assessing and treating depressive symptoms, which in turn, can improve health outcomes.

Social Implications

Second, as a result of negative thoughts resulting from their depressed schema, it is possible that those in the LF group misperceive their interactions and relationships with others, as evidenced in this study by their extremely low scores in the social domain of HRQoL. For example, with regard to peer relationships, if adolescents incorrectly think they are being rejected, they are likely to react with the same negative emotions that occur with actual rejection. If they falsely believe they are social outcasts, they may consequently feel lonely (Rush & Nowels, 1994 in Wilkes et al., 1994). They may also expect situations to turn out badly because they perceive themselves as inept or undesirable. Third, negatively biased thinking may further exacerbate the physical symptoms of depression. Apathy and low energy might result from adolescents' views that they are doomed to fail in all of their efforts (Rush & Nowels, 1994 in Wilkes et al., 1994).

Self-esteem

Low self-esteem is also a characteristic feature of depression (Beck, 1970), and in this study, adolescents' low scores on global self-esteem provide even more compelling evidence that depression may be driving their responses. Thus, it is possible that adolescents in the LF group who are depressed and/or prone to negative thinking view themselves as deficient in areas that reflect global self-esteem, including ability, performance, intelligence, health, strength, attractiveness, and popularity **(**Brown, McMahon, Biro, Crawford, Schreiber, & Similo et al., 1998; Beck, 1970). Although the extent to which those in the LF group experience depressed mood is unclear, it seems that negative thinking is influencing their self-perceptions.

Demographic Differences in Self-Report Measures

Research has consistently found that African American males and females (who comprised nearly 75% of the sample and the largest proportion of the HF group) are more accepting of larger body types and consider themselves to be more attractive and socially acceptable at higher BMIs than Caucasians (Desmond, Price, Hallinan, & Smith, 1989; Padgett & Biro, 2003; Pastore, Fisher, & Friedman, 1996; Faith et al., 1998; Strauss, 2000; Wardle & Cooke, 2005; Brown et al., 1998). For many African American adolescents, being heavy is not considered unattractive and does not adversely impact self-esteem (Kimm et al., 1997) or HRQoL (Swallen et al., 2005); however, it generally does for Caucasians (Strauss, 2000; Fallon et al., 2005). Similarly, perceptions of health status tend to be higher and less impaired in African Americans (Kolotkin, Crosby, & Williams, 2002).

Researchers have suggested that one mechanism by which obesity confers risk for depression is through body image dissatisfaction (BID; Friedman & Brownell, 1995). BID is linked to low self-esteem, which is related to depression (Markowitz, Friedman, & Arent, 2008). Given the confluence of these findings, it is possible that members of the LF group, consisting mostly of Caucasians and boys, are more pre-occupied with body image, such that the thin-ideal or athletic build is preferred. This preoccupation could reach levels of BID, which might be mediated by depressed mood.

Biobehavioral Mechanisms of Obesity and Depression

The finding that depressed mood might contribute to worse blood pressures is not surprising given the ample literature supporting a link between psychological and physiological functioning. Perhaps the best research explicating this relationship comes from work with patients with coronary artery disease (CAD). Patients with CAD have disproportionately higher rates of depression compared to the general population. As such, a number of biobehavioral mechanisms have been hypothesized to explain this relationship including, but not limited to, lifestyle factors (e.g., physical inactivity), hypertension, diabetes, insulin resistance, dysregulation of the autonomic nervous system and HPA axis, and alterations in immune responses, including inflammatory processes (Lett, Blumenthal, Babyak, Sherwood, Strauman, Robins, & Newman, 2004).

Direct physiological pathways.

Hypothalamic-pituitary-adrenal (HPA) axis and sympathetic nervous system (SNS) dysregulation. The HPA axis and the SNS connect the brain with the rest of the body, and both have centers that contain neurons (e.g., arginine-vasopressin [AVP]) and hormones such as corticotropin-releasing hormone (CRH) that innervate and stimulate each other (Chrousos & Gold, 1998). CRH, in particular, is responsible for activating the main noradrenergic centers of the brain (Leonard, 2005), thus, affecting baseline circadian rhythm and stress-related responses. For this reason, it has been called a "stress neurotransmitter" (Leonard, 2005, p. S302). Specifically, the secretion of the end-product of the HPA axis, cortisol, is kept by an elaborate feedback system, which, for most individuals, is normally regulated and stable (Chrousos & Gold, 1998).

The consequences of acute stress and stimulation of the HPA axis are generally not problematic (the increase in glucocorticoids or cortisol is only transient); however, chronic hyperactivation of these systems can have damaging consequences to the body

(Leonard, 2005). This is because heightened secretion of adrenal glucocorticoids and continued activation of the central and peripheral sympathetic systems can lead to changes in the serotonergic system (Leonard, 2005). Such changes involving excess cortisol secretion have long been associated with depression, hypertension, visceral obesity, and the metabolic syndrome (Chrousos & Gold, 1998). This occurs because over time, the hypersecretion of glucocorticoids (including CRH) desensitizes central glucocorticoid receptors to the negative feedback inhibition of the HPA axis (by cortisol), which indirectly contributes to further activation of the HPA axis (Leonard, 2005). The rise in plasma cortisol concentration is accentuated by the release of AVP, and the simultaneous increase in pro-inflammatory cytokines that coincides with heightened stress further stimulates the HPA axis (secretion of glucocorticoids). It is believed that the co-occurring changes in both serotonergic and noradrenergic systems can also predispose individuals to depression (Leonard, 2005).

Despite this evidence, many cross-sectional and prospective studies have indicated that there is no relationship between depressive symptoms and resting blood pressure levels (Jones-Webb, Jacobs, Flack, & Liu, 1996); however, researchers believe that methodological differences across studies may explain this (Davidson, Jones, Dixon, & Markovitz, 2000). Other studies support that depressive symptoms predict later hypertension in young adults.

For example, in a large scale study of nearly 3,000 patients, long-term follow-up showed that depressive symptoms significantly predicted hypertension. Further, in another prospective study of CHD risk factors in young adults, participants with high depression scores on the Center for Epidemiological Studies – Depression Scale were at greater risk for hypertension compared to those with low depression scores (Davidson et al., 2000). Although the relationship between depression and hypertension was significant for African Americans but not Caucasians, the authors noted that there was insufficient power to detect interactions between race and sex for this group because few Caucasians had hypertension in this sample.

In sum, many studies have shown that depression is associated with HPA dysregulation (Ahlberg et al., 2002) and chronic elevations in cortisol (Hjemdahl, 2002; Björntorp, 2001; Grundy, 2000; Kiecolt-Glaser et al., 2002), which means that individuals who are depressed appear to have a heightened reactivity to stress and its response (Markowitz, Friedman, & Arent, 2008). Over time, elevated hormonal levels can promote weight gain (Björntorp, 2001), abdominal obesity, increased blood pressure, and elevated heart rate (Lett et al., 2004; Rosmond & Björntorp, 2000), which can eventually lead to hypertension and CAD (Davidson et al., 2000; Yeragani, 1995; Louis, Doyle, & Anavekar, 1975).

Inflammation and immunological dysregulation. As noted earlier, there is also evidence that inflammatory markers such as proinflammatory cytokines influence the development and maintenance of depression and obesity (Carney, Freedland, Miller, & Jaffe, 2002; Miller, Stetler, Carney, Freedland, & Banks, 2002).

For example, Ladwig and colleagues (2003) tested the associations between depressive mood, BMI, and C-reactive protein (CRP) levels in a population-based sample of 3,204 men aged 45-74 years. CRP, which is released by the body in response to acute injury, infection, or other inflammatory stimuli, is associated with coronary heart disease (CHD) in men (Mendall, Patel, & Ballam et al., 1996). The authors found that, among obese men, higher levels of depressed mood were associated with greater CRP levels, even after controlling for blood pressure, smoking status, and inactivity levels. There was no association between CRP and depressed mood in non-obese men. Thus, it may be that the relationship between obesity and atherosclerosis in men ultimately involves pathways that regulate mood and contribute to elevated CRP levels and chronic low-level inflammation (Faith, Calamaro, Dolan, & Pietrobelli, 2004; Ladwig, Marten-Mittag, Lowel, Doring, & Koenig, 2003).

Strengths of the Current Study

While research has begun to examine patterns of behavior in obese samples, to our knowledge, this study is the first to use latent variable modeling techniques in combination with metabolic data to understand adolescents' perception of obesity and its relationship to physical health. Previous research has shown that clinical measures are typically unrelated to psychosocial measures (e.g., Zeller, Roehrig, Modi, Daniels, & Inge, 2006), but this study (along with other studies, e.g., Kudel et al., 2006) indicates that this may be because of the assumptions about the patient population. Given the findings, we believe the approach used here yields a more detailed picture of patients enrolled in the study that would not have been achieved using traditional assumptions and statistical methods.

In general, mixture modeling also has a number of statistical advantages. It has become increasingly used to study complex constructs in the behavioral sciences, and more sophisticated estimators and fit indices have been developed to identify the model that best fits the data. Further, advances in software allow for many different types of outcomes and combinations to be analyzed (Ruscio & Ruscio, 2004; Lanza, Savage, & Birch, 2009).

Limitations of the Current Study

As with all research, some limitations exist. In this section, they are organized into three categories, including: 1) the LPA analyses, 2) secondary data analysis, and 3) self-report measures, in this case, global self-esteem and depressed mood.

LPA analyses. First, in LPA, respondents are assigned to groups as best as possible using substantive theory/parsimony and a series of fit indices; however, their assignment is not perfect. As such, there is still some variability within each group. As mentioned in the Results, some participants classified to the MF group, for example, might have had high scores on self-esteem that were similar to HF group members, but their other scores were more similar to MF group members. Therefore, they would likely have been classified to the MF group.

Second, the 3-class model identified is a function of the measures used. In this respect, if investigators were to use measures other than those included in the current study, they might find a different typology. Also, even if one were to use these exact measures in another study, the results might still be different as a function of the population and its sample size (Kudel et al., 2006; Turk, 2005). Thus, it is possible that having a larger sample could lead to, for example, a split in the MF group. And, lastly, the typology identified may not necessarily generalize to other samples of obese adolescents in weight loss treatment.

Third, there is no “gold standard” statistical indicator for identifying the optimal solution (Nylund, Asparouhov, & Muthén, 2007). While simulation studies suggest that BIC (used in this study) is superior to other information criterion statistics (Yang, 2006) such as Akaike’s Information Criterion (Akaike, 1987; Nylund, Asparouhov, & Muthén, 2007) in determining the number of classes (Nylund, Asparouhov, & Muthén, 2007), it is possible that the eventual identification of more optimal fit statistics may yield different insights.

Secondary data analysis. First, it should be noted that this was a secondary data analysis of cross-sectional data. In cross-sectional data analysis, it is impossible to differentiate cause and effect, thus, we cannot say that the typology identified in this study results from or definitively predicts specific variables or relationships. Second, our population may not be representative of other clinical samples of obese adolescents, which limits the generalizability of the findings.

Furthermore, the exclusion of certain variables in this data set limits our understanding of the relationship between self-report and metabolic data. For example, we lack information about cortisol levels, which may shed light on the impact that stress might have on members of the LF group. Also, in this study, we used subscale scores instead of individual items because of the sample size. A larger sample would permit the use of items, which may change the typology identified.

Also, blood pressure was determined from a single (first) measurement to maintain consistency. Therefore, this value might be slightly higher or lower than if using the average of three measurements. Fourth, the current study uses HOMA-IR to determine an estimate of insulin sensitivity. Some research has suggested that this method is less efficient at detecting changes in glucose tolerance compared to performing an oral glucose tolerance test (OGTT). However, results are somewhat mixed, and few studies, to date, have examined these variables in adolescents or in combination with self-report data.

Self-report measures. As with any self-report measure, there is the possibility that participants in the study may have under- or over-reported symptoms. For example, 11% (n = 27) of adolescents in this sample reported that they never engaged in physical activity. However, 26% (n = 65) of participants endorsed engaging in physical activity for 30 minutes, more than three times per week. Because these estimates are based on adolescents' perceptions of their activity levels, they may not be objectively accurate and are likely an over-estimation of activity levels.

In measuring global self-esteem with the SEI, it is traditionally associated with social desirability. Specifically, given its high face validity, there is a high correlation with social desirability. Therefore, it is possible that influences other than self-esteem contribute to SEI scores for each of the 3 classes (Blascovich & Tomaka in Robinson, Shaver, & Wrightsman, 1991).

Another problem concerns the CDI in this study, which has systematic missingness. In particular, the measure was not administered to the first 100 participants. Other psychometric limitations were noted in the Methods section.

Future Directions

Future analyses should consider alternative approaches to analyzing metabolic data and self-reported physical activity. This could provide different information about the groups. For example, some researchers calculate the mean arterial pressure (MAP) or pulse pressure to capture different aspects of blood pressure (BP). The MAP consists of three parameters (heart rate, stroke volume, and systemic vascular resistance) and is generally calculated as diastolic BP + (systolic BP – diastolic BP)/3. It is considered to be a steady component of BP. Pulse pressure (PP) accounts for the fluctuation in pressure values around the average BP and is often measured as systolic BP – diastolic BP (Salvi, 2012; Wildman, Mackey, Bostom, Thompson, & Sutton-Tyrrell, 2003). There is some evidence suggesting that these dimensions may provide a more accurate estimate of BP (Salvi, 2012); however, other studies indicate that the use of systolic and diastolic BPs are the best measurements for classifying individuals into disease categories (Pickering, Hall, Appel, Falkner, Graves, Hill, & Jones et al., 2005).

Another consideration for future analyses would be to test whether the distribution of metabolic variables is normal. If the data is not normal, then a procedure would be needed to correct for this. For example, one method might be to perform a log transformation of the metabolic variables that were not normally distributed to determine whether or not this procedure influences the results. It is possible that some of the findings may change (become either significant or non-significant) or that different associations may be found. Most studies that examine metabolic factors associated with obesity use log transformation before analyzing non-normal data (Di Bonito, Sanguigno, Di Fraia, Forziato, Boccia, Saitta, Iardino, & Capaldo, 2009; Wickham et al., 2009).

Physical activity variables could also be examined differently to determine their relationship to class membership. Some researchers have combined both moderate and vigorous physical activity (MVPA) and reported this total as MVPA per week (Evans, Bond, Wolfe, Meador, Herrick, Kellum, & Maher, 2007). Another option would be to use frequency and duration data for moderate and vigorous-intensity physical activities. Weighted MET minutes per week (MET min per week) can also be used and calculated as duration x frequency per week x MET intensity for each activity type (Marshall, Booth, & Bauman, 2005). Thus, MET data per week from each category can be summed to produce an overall estimate of physical activity.

Future research is also needed to determine whether the 3-class solution can be replicated, preferably with a larger sample size. If it is, then the next step would be to design interventions that are tailored to address the specific needs of the LF group. This is because research suggests that those with poor psychological functioning do not respond as well to standard interventions or do worse than their peers (Wardle & Cooke, 2005; Turk, 2005).

Clinical Implications. If the LF group is experiencing significantly greater depressed mood, it may require that they be treated differently than the other groups.

For example, this could translate to screening adolescents prior to enrollment to identify those with responses consistent to those in the LF group and then assigning them to an appropriate treatment that addresses both depressed mood and coping to reduce stress. For example, coping skills training (CST), which has been shown to be an effective method for treating patients with depressed mood (Kazdin & Weisz, 1998), can be used to modify depressive schemas/cognitive distortions and to develop coping skills with the goal of improving interpersonal relationships and problem-solving. Further, relaxation training (e.g., diaphragmatic breathing, Progressive Muscle Relaxation) can also be used to regulate mood and metabolic function by reducing stress and lowering oxygen consumption (Benson, 1993).

It would also be useful to test the validity of the model to determine whether the 3-class typology predicts outcomes such as adherence to prescribed treatments and BMI over time.

Treatment adherence. If depressed mood is the driver of dysfunction, then negative thoughts and attitudes associated with it can interfere with weight loss behaviors (Markowitz, Friedman, & Arent, 2008). For example, studies have shown that depression predicts poor adherence to prescribed treatment regimens (Davidson et al., 2000). In one study, DiMatteo and colleagues (2000) found that patients with depression were at twice the risk for non-adherence to treatments than those without depression (DiMatteo, Lepper, & Croghan, 2000). In particular, depression is associated with physical inactivity (Camacho, Roberts, Lazarus, Kaplan, & Cohen, 1991; Scully, Kremer, Meade, Graham, & Dudgeon, 1998; Gray et al., 2008).

Further, it might be helpful to know if class membership, specifically in the LF group, is related to degree of abdominal fat, as visceral adiposity could lead to greater dysregulation in the HPA axis, contributing to depressed mood (Shelton & Miller, 2010) and subsequent disease risk (Yudkin, Kumari, Humphries, & Mohamed-Ali, 2000). If this is the case, then interventions could specifically target weight loss in this area. In the long-term, it would also be important to test whether the classification system predicts future morbidity, as health status measures, in particular, have been shown to be stronger correlates of morbidity than clinical measures of disease (Ruo, Rumsfeld, Hlatky, Liu, Browner, & Whooley, 2003; Kaplan, 1988).

Lastly, recent research suggests that BMI is increasing among adolescent Caucasian boys but leveling off in other groups (Ogden et al., 2012). Our results may reflect this trend and point to the importance of studying males with severe obesity. To date, most obesity interventions include a female majority, which limits our understanding. It may also be helpful to look at additional criteria such as family history of disease to determine risk for poor functioning or comorbid illnesses such as diabetes (Greig et al., 2011).

Conclusion

Behavioral scientists have long preferred to conceptualize most patient populations as continuous rather than discrete. However, there is a growing recognition that there is a need to empirically evaluate whether this approach is accurate (Haslam & Kim, 2002). In this case, a more thorough investigation of psychological phenomena in severe obesity could only be accomplished by using empirical methods to identify population heterogeneity based on self-report data (Wardle & Cooke, 2005).

In this project, it was determined that “life satisfaction” (HRQoL and global self-esteem) is a complex construct in severe obesity, resulting in heterogeneous response profiles. In this sample, adolescents who reported distress in these areas had depressed mood which may affect metabolic functioning. Thus, it seems that in studies that assess psychosocial functioning, the most helpful information could be gained by exploring patterns of self-reported behavior across measures to identify individuals who fare better or worse in order to tailor interventions.

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Appendix A

Patient Demographics

Personal and Family Information

Subject Name: ______________________________ Date: ________________________

Parent of Legal Guardian Name: ___________________________________

Subject: Check the box for the racial or ethnic group which with you identify:

- ☐ White
- ☐ Black (includes Jamaican, Bahamanians and other Carribeans of African descent)
- ☐ Hispanic (includes persons of Mexican Puetro Rican, Central or South /American or other Spanish origin or culture)
- ☐ Asian (includes Pakistanis & Indians)
- ☐ Native American (includes Alaskans)
- ☐ Middle Eastern
- ☐ Pacific Islander
- ☐ Other (specify) __________________

Parent/Guardian: Check the box for the racial or ethnic group which with you identify:

- ☐ White
- ☐ Black (includes Jamaican, Bahamanians and other Carribeans of African descent)
- ☐ Hispanic (includes persons of Mexican Puetro Rican, Central or South /American or other Spanish origin or culture)
- ☐ Asian (includes Pakistanis & Indians)
- ☐ Native American (includes Alaskans)
- ☐ Middle Eastern
- ☐ Pacific Islander
- ☐ Other (specify) __________________
- ☐

Parents' Highest level of completed education:

- ☐ Less than high school diploma
- ☐ High School diploma
- ☐ Some college
- ☐ College degree
- ☐ Some graduate school
- ☐ Graduate degree

Family Income Level:

- ☐ Less than $10,000 per year
- ☐ $10,000 - $20,000 per year
- ☐ $20,000 - $30,000 per year
- ☐ $30,000 - $40.000 per year
- ☐ $40,000 - $50,000 per year
- ☐ More than $50,000 per year

Appendix B
Self-reported exercise – Question #6

Teens:
Please answer the following questions using the scales below. **Circle** the number that best describes what you think. Answer each question as honestly as you can. There are no right or wrong answers, just your answers. Thank you so much for your time.

1. I think I would look better if I lost weight.

Strongly agree	Agree	Somewhat Agree/Disagree	Disagree	Strongly Disagree
5	4	3	2	1

2. I worry that I will be overweight in the future.

Strongly agree	Agree	Somewhat Agree/Disagree	Disagree	Strongly Disagree
5	4	3	2	1

3. Have you ever tried losing weight? Yes No

4. Are you trying to lose weight now? Yes No

5. Has anyone in your family had (please circle all that apply)

diabetes?	Yes	No
heart disease?	Yes	No
high blood pressure?	Yes	No
high cholesterol?	Yes	No

6. How often do you exercise (for at least 30 minutes, without stop), including rollerblading, dancing, bike riding, running, jump-rope, walking, playing basketball?

Never once per week 1-3 times per week more than 3 times per week

7. What kind of exercise do you do? ____________________

8. Do you think your weight is a health problem?

Definitely Yes	Probably Yes	Somewhat Yes/No	Probably No	Definitely No
5	4	3	2	1

9. If members of my family are overweight, then I will probably be overweight.

Strongly agree	Agree	Somewhat Agree/Disagree	Disagree	Strongly Disagree
5	4	3	2	1

10. If I eat enough healthy food, it doesn't matter how much I weigh.

Strongly agree	Agree	Somewhat Agree/Disagree	Disagree	Strongly Disagree
5	4	3	2	1

11. As long as I am active, it doesn't matter how much I weigh.

Strongly agree	Agree	Somewhat Agree/Disagree	Disagree	Strongly Disagree
5	4	3	2	1

Form A

Appendix C

The Pediatric Quality of Life (PedsQL) Inventory Version 4.0 is protected by copyright, so it is not reproduced in this document.

Appendix D

The Coopersmith Self-Esteem Inventory (SEI) is protected by copyright, so it is not reproduced in this document.

Appendix E

The Seven-Day Physical Activity Recall (PAR) is protected by copyright, so it is not reproduced in this document.

Appendix F

The Children's Depression Inventory (CDI) is protected by copyright, so it is not reproduced in this document.

Vita

Cassie Sabrina Brode was born on September 3, 1980 in Winchester, VA. She graduated from Hood College in 2003 with a Bachelor of Arts in Psychology and Spanish.

She enrolled in Virginia Commonwealth University's (VCU) Counseling Psychology Program in the fall of 2005. In 2009, she received her Master of Sciences in Counseling Psychology.

Cassie came to VCU with an extensive knowledge of obesity-related research and clinical experience with this patient population. She also has significantly expanded her knowledge in both of these areas through her work in the Virginia Premier Health Plan-funded multidisciplinary trial, TEENS Healthy Weight Management Program and developed her own empirical research studies using TEENS data. Her research has deepened our understanding of how adolescents with severe obesity experience their condition and shed light on potential interventions needed to address the complex interaction of psychosocial and metabolic factors in this group.

Recently, Cassie completed her Clinical Psychology Internship in Integrated/Primary Care at Eastern Virginia Medical School in October 2011 and expects to graduate from VCU in 2012. She plans to continue working in the field of obesity and integrated care.