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Physical Activity, Stress, and Metabolic Risk Score in 8- to 18-Year-Old Boys

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Background: We examined whether physical activity modifies the relationship between stress and the metabolic risk score in 8- to 18-year-old males (n = 37). ***Methods:*** Physical activity (PA) and television (TV)/videogame (VG) use were assessed via accelerometer and questionnaire, respectively. Stress was determined from self-report measures. A metabolic risk score (MRS) was created by summing age-standardized residuals for waist circumference, mean arterial pressure, glycosylated hemoglobin, and high-density lipoprotein cholesterol. ***Results:*** Correlations between PA and MRS were low ($r < -.13$), and TV and VG were moderately associated with MRS ($r = .39$ and .43, respectively). Correlations between stress-related variables and MRS ranged from $r = .19$ to .64. After partitioning by PA, significant correlations were observed in the low PA group between school- and sports-related self-esteem and anxiety with the MRS. ***Conclusions:*** The results provide suggestive evidence that PA might modify the relationship between stress and MRS in male adolescents.

Keywords: exercise, anxiety, fitness, obesity, children

Currently, an estimated 16.5% of US children and adolescents 6 to 19 years of age are obese, and an additional 15% are overweight, which represents a 3-fold increase over the past few decades.[1] These figures warrant attention because childhood obesity is adversely associated with cardiovascular disease (CVD) risk factors.[2-4] In addition to the immediate consequences, childhood obesity often tracks into adulthood[5] and has been linked to CVD morbidities in adulthood (coronary artery calcification,[6] dyslipidemia and hypertension,[7,8] and carotid artery intima-media thickness[9]) and CVD mortality.[10]

As mentioned, obesity, and more specifically abdominal or visceral obesity, is associated with elevated blood pressure (BP), an adverse blood lipid profile, and insulin resistance. The co-occurrence of these traits has been termed *the metabolic syndrome*.[11] According to the most recent National Health and Nutrition Examina-

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tion Survey (NHANES, 1999 to 2000), the prevalence of the metabolic syndrome is 25% among US adults[12] and 6.4% among US adolescents.[13] Furthermore, about 43% of US adolescents possess at least 1 characteristic of the metabolic syndrome, and 17% have 2 or more characteristics.[14,15]

Given the increased prevalence of pediatric obesity and the metabolic syndrome, there has been great interest in preventing these conditions during childhood and adolescence with considerable focus on diet and physical activity.[16] However, epidemiological studies indicate that physical activity and diet only explain a small-to-modest amount of the total variance in the adiposity–metabolic syndrome phenotype. Thus, there is reason to consider other possible contributing factors to obesity and the metabolic syndrome among youths. One intriguing hypothesis is related to the chronic activation of the hypothalamic-pituitary-adrenal (HPA) axis caused by various emotional, environmental, and physical stressors that can create a state of hypercortisolaemia.[17-20] Chronically elevated levels of cortisol result in an up-regulation of lipoprotein lipase and subsequent storage of fat, specifically in the viscera.[19] In addition, increased cortisol levels negatively affect insulin sensitivity.[18] Although the relationships between stress-related cortisol secretion and markers of the metabolic syndrome have been demonstrated in adults,[21-25] little evidence is available in children.[26] Likewise, few studies have examined the relationship between physical activity and stress-related variables (ie, perceived stress, anxiety, depression, self-esteem, etc) in children and adolescents. In general, an inverse relationship has been demonstrated between physical activity and stress-related measures.[27] Parfitt and Eston[28] recently found that habitual physical activity was negatively related to anxiety and depression (r = –.48 and –.60, respectively) and positively associated with global self-esteem (r = .66) in children. A recent study also found that physical activity buffered the associations between chronic stress and adiposity.[29] However, both stress and physical activity were self-reported. In addition, this study only examined the stress–physical activity interaction with adiposity. This relationship has yet to be established with the metabolic syndrome, a more comprehensive expression of overall metabolic health.

The purpose of this study was to examine if physical activity modifies the association between measures of stress (various self-report measures) and the components of the metabolic syndrome in adolescent males. We hypothesized that the correlation between stress and the metabolic syndrome would be stronger among subjects with lower levels of physical activity compared with those with higher levels of physical activity.

Methods

Subjects

Thirty-eight boys, ages 8 to 18 years, participated in the current study. Because of noncompliance with the physical activity assessment of 1 subject, 37 subjects were included in the analysis. All subjects signed assent forms, and parental consent was obtained before data collection. This study was approved by the university Institutional Review Board.

General Procedures

The study protocol was reviewed with the subject on arrival to the laboratory. The test session included an explanation of the physical activity monitors and assessment of CVD risk factors. In addition, the subject received instruction on questionnaires aimed at assessing perceived stress, anxiety, depression, self-esteem, weight-related and general appearance-related teasing, and media time. A detailed description of each of these measures is provided below. Subject demographics and anthropometric data were assessed following the explanation of the study protocol. The subject was then seated for 5 to 10 minutes before the measurement of resting BP, blood lipids, and glycosylated hemoglobin (HbA1c).

Assessment of Stress

Self-Report Measures of Stress. Because *stress* is a ubiquitous term and is difficult to qualify with a single measure, the following surveys were used in an attempt to capture the various aspects of stress.

Physical Appearance Related Teasing Scale (PARTS). PARTS was used to determine weight- and size-related and general appearance-related teasing by peers.[30] The PARTS questionnaire consists of 2 scales with a total of 18 questions. The questions were changed from past to present tense to make the questionnaire age appropriate. Examples of questions include, "Do you ever feel as though your peers are staring at you because you are overweight?" and "Do kids ever call you funny looking?" Subjects responded on a 5-point Likert scale from *never* (1) to *frequently* (5). The internal consistency coefficient for the weight- and size-related scale is .91, and the test–retest reliability is .86. The internal consistency coefficient for the general appearance-related scale is .71, and the test–retest reliability is .87.[30]

Perceived Stress Scale (PSS). The PSS is a global measure of stress and was used to determine the subjects' overall perception of stress in their lives over the last month.[31] An example of a question is, "In the last month, how often have you been upset because of something that happened unexpectedly?" The coefficient alpha reliability ranged from .84 to .86 in 3 separate examinations.[31]

Children's Depression Inventory (CDI). Depressive characteristics were examined using the CDI.[32] This instrument consists of 27 items assessing affective, cognitive, and behavioral symptoms of depression. Subjects were asked to choose the sentence that best describes them for the past 2 weeks (eg, "I am sad once in a while." "I am sad many times." "I am sad all of the time."). Reliability coefficients for this instrument range from .71 to .89.[32]

State-Trait Anxiety Inventory for Children (STAI-C). The STAI-C[33] was used to assess symptoms of trait anxiety. This measure consists of 20 statements such as, "I worry about making mistakes . . ." which subjects might respond to by choosing "hardly ever," "sometimes," or "often." The coefficient alpha reliability for the STAI-C for boys is .78.[33]

Self-Esteem Questionnaire (SEQ). The SEQ[34] is composed of 6 subscales with a total of 42 statements. The SEQ was used to determine subjects' global feelings of self-worth, as well as perceptions of influential factors (peers, school, and family). Examples of questions include, "I am as popular with kids my own age as I want to be," and "I am happy about the way I look." Subjects could respond by choosing "strongly disagree," "disagree," "agree," and "strongly agree." Coefficient alphas for each of the subscales range from .81 to .91 and .81 to .92 in 2 separate examinations of internal consistency.[34]

Physical Activity and Media Time. The Manufacturing Technology, Inc (MTI) uniaxial accelerometer (Shalimar, FL) was used to assess habitual physical activity. The MTI is a small, lightweight unit with a time-sampling mechanism that is designed to detect acceleration ranging in magnitude from 0.05 to 2.00 G with frequency response from 0.25 to 2.50 Hz. The filtered acceleration signal is digitized and the magnitude summed over a user-specified epoch interval. At the end of each epoch, the summed value is stored in memory, and the integrator is reset. One-minute epochs were used in this study. The unit was attached to a belt and worn at the midaxillary line at the hip. The instrument was explained to the subject and worn for 4 days during the subsequent week (3 weekdays and 1 weekend day). The accelerometers were returned via mail in a standard, padded envelope. The Freedson age-specific MET equation[35] [$MET = 2.757 + (0.0015 \times counts/min) - (0.08957 \times age (y)) - (0.000038 \times counts/min \times age (y))$] was used to convert accelerometer counts to a metabolic equivalent. According to the Freedson protocol, moderate-to-vigorous physical activity (MVPA) was classified as being >3 METs.

TV viewing and videogame playing time were assessed via questionnaire. The questionnaire asked participants to quantify average daily time spent watching TV and playing videogames during the week and on weekend days. Specifically, the questionnaires asked subjects to quantify the time they spent with each form of media from the time they woke up until lunchtime, from lunchtime until dinner, and from dinner until bedtime. Subjects were asked these questions for both schooldays and weekend days.

Body Size and Maturity Status. Stature and body mass were measured according to standard procedures.[36] Stature was measured with a wall-mounted, fixed stadiometer (Holtain Limited, United Kingdom) with the subject standing erect, without shoes, and with weight distributed evenly between both feet, heels together, arms relaxed at the sides, and the head in the Frankfort horizontal plane. Body mass was measured without shoes and excess clothing on a balance beam scale (Seca 770, Hamburg, Germany). Stature and body mass were used to calculate body mass index (BMI, kg/m^2). Because abdominal obesity is a key feature in the metabolic syndrome, waist circumference (WC) was assessed as a measure of central adiposity. WC was measured immediately above the iliac crest using a Gullick tape to the nearest 0.1 cm.

Because the age range of the subjects spans the period of puberty and numerous body size and physiological functions vary by pubertal status,[37] an indicator of biological maturity status was assessed via the maturity offset method. The maturity offset technique is a noninvasive method of indicating biological maturity and was calculated as outlined by Mirwald et al.[38] Anthropometric variables are used to calculate a value that is aligned to the estimated age of peak height velocity (eg, –1.5 years from peak height velocity, etc). This value was used as a covariate in the statistical analysis.

Assessment of CVD Risk Factors

Resting Blood Pressure. Resting systolic and diastolic BP was measured using an automated monitor (Critikon Dinamap) in accordance with standard recommendations.[39] Mean arterial pressure (MAP) was calculated as systolic BP – diastolic BP/3 + diastolic BP. Appropriate cuff size was determined by measuring the circumference of the right upper arm at its largest point. Three measurements were taken at 1-minute intervals, and the mean of the 3 values was used for data analysis.

Blood Cholesterol. A nonfasted blood sample was obtained by finger prick and collected in a 35 microliter capillary tube. Upon collection, samples were analyzed for total cholesterol (TC) and high-density lipoprotein cholesterol (HDL-C) by a portable cholesterol analyzer according to the protocol of the manufacturer (Cholestech LDX System, Hayward, CA). Because subjects were in a nonfasted state, triglycerides (TG) were not assessed. Blood sampling by finger prick was chosen for reasons of compliance and avoidance of undue stress. Intraclass reliability statistics yielded coefficients of variation ≤.03 for TC and HDL-C when testing high and low standards.

HbA1c. A second finger stick was taken to determine HbA1c. The concentration of HbA1c reflects blood glucose levels over the previous 2 to 3 months. The sample was collected in a 10 microliter pipette and analyzed by a desktop analyzer (Cholestech GDX, Hayward, CA) according to the protocol of the manufacturer. Previous studies have shown that the accuracy of the Cholestech GDX falls within the limits of the National Glycohemoglobin Standardization Program.[40]

Derivation of the Metabolic Risk Score. The metabolic risk score (MRS) was derived by first standardizing the individual MRS variables (WC, MAP, HbA1c, and HDL-C) by regressing them onto age to account for any age-related differences. The standardized HDL-C was multiplied by –1 because it is inversely related to metabolic risk. The standardized residuals (Z-scores) were summed to create the continuous MRS. These variables were chosen because they represent similar constructs used in the adult clinical criteria for the metabolic syndrome. We chose to include HDL-C as our sole indicator of dyslipidemia because samples were collected in the nonfasted state and measures of triglycerides would be inaccurate. Likewise, HbA1c was chosen for similar reasons, and fasting glucose is often normal in children, even those who are overweight. MAP was used because including both systolic and diastolic would load 2 blood pressure variables into the calculation, and MAP represents both SBP and DBP. Because the metabolic syndrome typically does not manifest until later in life and is a dichotomous variable, the use of a composite score allows each subject to have a continuous value. A lower score is indicative of a better metabolic risk factor profile. The MRS has been used in recent work from our laboratory[41] and others.[42]

Statistical Analysis

Descriptive statistics were calculated for all variables in the total sample and in the high and low physical activity (PA) groups. The low and high physical activity groups were determined based on a median split (77 minutes of MVPA). The associations between self-report measures of stress, physical activity/media time, and the MRS were examined by partial correlation, controlling for chronological age and maturity offset, in the total sample and in the low and high PA groups. All statistical analyses were conducted using SPSS version 12.0.

Results

Table 1 provides the descriptive statistics for the total sample and the low and high PA groups. In the total sample, mean height, weight, and BMI approximated the 50th percentile on the CDC growth chart.[43] Approximately 27% and 16% of the participants were overweight or obese, respectively, according to international cut points.[44] In addition to accumulating significantly less vigorous activity and MVPA, the participants in the low PA group were also significantly taller. Although not statistically significant, those in the low PA group were also noticeably older and heavier; had a higher BMI, WC, systolic BP, and MRS; and lower HDL-C than the participants in the high PA group. None of the stress-related measures differed between the 2 groups.

Table 2 shows partial correlations between PA and the MRS. Correlations were low ($r < -.13$) but in the expected direction (eg, inverse). TV and videogame playing were significantly related to the MRS ($r = .39$ and .43, respectively). Table 3 shows partial correlations between selected stress variables and the MRS. Of the self-reported markers of psychosocial stress, only school-related self-esteem ($r = -.46$, $P < .05$) and the general appearance scale of the PARTS ($r = -.36$, $P < .05$) were significantly related with the MRS. Of the remaining variables, the correlations of sports-related self-esteem and trait anxiety with the MRS approached significance ($P = .08$ and $P = .09$, respectively) and, therefore, were considered in subsequent analyses.

Table 4 shows partial correlations between selected markers of psychosocial stress and the MRS for the low and high PA groups. Both school- and sports-related self-esteem were significantly associated with the MRS ($r = -.64$ and $-.53$, respectively) in the low PA group. Trait anxiety was also significantly associated with the MRS in the low PA group ($r = .53$). In contrast, none of the stress variables were associated with the MRS in the high PA group. As an example, a pictorial representation of the relationship between anxiety and MRS is shown in Figure 1.

Discussion

In an attempt to explain some of the unaccounted variance of obesity and related metabolic disorders, an emerging research trend is the examination of variables acting within a system of complex interactions rather than in univariate relations. For example, previous research has examined the relationship between PA and the metabolic syndrome[45] and the relationship between PA and stress[28,29]; however, limited research has examined if PA modifies the relationship between stress and

Table 1 Physical Characteristics of the Sample—Mean (SD), Minimum–Maximum Values Are Provided for the Total Sample

	Low PA (n = 18)	High PA (n = 19)	Total (n = 37)
Anthropometric variables			
age (y)	15.5 (2.1)	12.5 (2.4)	13.9 (2.7), 9.0–18.9
height (cm)	173.1 (8.1)[a]	157.9 (16.2)	165.3 (14.9), 136.7–189.6
estimated APHV (y)	14.7 (0.8)	14.3 (0.6)	14.5 (0.7), 13.1–16.5
body mass (kg)	73.2 (14.3)	54.1 (21.7)	63.4 (20.7), 27.1–111.1
body mass index (kg/m^2)	24.4 (4.5)	21.0 (5.1)	22.7 (5.1), 14.5–35.9
waist circumference (cm)	83.8 (13.6)	72.8 (16.0)	78.1 (15.7), 49.8–119.2
overweight/obese (%)	55.6%	31.6%	43%
Metabolic variables			
SBP (mmHg)	126.0 (10.0)	116.3 (10.3)	121.0 (11.1), 101–153
DBP (mmHg)	67.9 (3.8)	65.9 (3.7)	66.9 (3.8), 59–74
MAP (mmHg)	89.0 (4.1)	86.0 (4.1)	87.4 (4.3), 79–98
HbA1c (%)	5.4 (0.3)	5.5 (0.5)	5.5 (0.44), 4.9–7.4
HDL-C (mg/dL)	39.0 (10.8)	49.5 (12.4)	44.4 (12.6), 15–74
metabolic risk score	0.18 (2.7)	–0.11 (2.3)	0.03 (2.5), –3.6–7.0
Physical activity			
MVPA (min/d)	46.2 (15.9)[a]	109.7 (32.7)	78.8 (41.1), 22–205
vigorous PA (min/d)	5.1 (7.1)[a]	18.0 (17.1)	11.7 (14.6), 0–65
moderate PA (min/d)	41.2 (12.9)	91.7 (20.2)	67.1 (30.6), 21–140
total PA (counts/min)	374.7 (130.5)	629.7 (241.1)	505.7 (232.0), 234–1164
television (h/wk)	19.9 (12.7)	27.4 (19.7)	23.8 (16.9), 2–83
videogames (h/wk)	12.3 (23.0)	21.9 (24.9)	17.2 (24.2), 0–105
Selected stress variables			
SE–school	22.9 (6.2)	26.3 (3.9)	24.6 (5.4), 8–40
SE–sports	17.2 (3.6)	18.8 (3.7)	18.0 (3.7), 6–30
anxiety	31.2 (5.2)	31.7 (5.1)	31.4 (5.1), 20–60
PARTS–GA	32.7 (4.4)	34.1 (4.0)	33.4 (4.2), 6–36

Abbreviations: PA, physical activity; APHV, age at peak height velocity; SBP, systolic blood pressure; DBP, diastolic blood pressure; MAP, mean arterial pressure; HbA1c, glycosylated hemoglobin; HDL-C, high density lipoprotein cholesterol; MVPA, moderate-to-vigorous physical activity; SE, self-esteem; PARTS–GA, Physical Appearance Related Teasing Scale–general appearance.

[a] $P < .05$ for group difference.

Table 2 Partial Correlations, Controlling for Age and Maturity Offset, Between PA and the Metabolic Risk Score in Male Adolescents

Physical activity	*r*
MVPA (min/d)	–.13
Vigorous PA (min/d)	–.09
Moderate PA (min/d)	–.13
Total PA (counts/min)	–.07
Television (h/wk)	.34[a]
Videogames (h/wk)	.43[a]

Abbreviation: MVPA, moderate-to-vigorous physical activity; PA, physical activity.

[a] $P < .05$

Table 3 Partial Correlations, Controlling for Age and Maturity Offset, Between Selected Measures of Stress and the Metabolic Risk Score in Male Adolescents

Selected stress variables	*r*
Self-esteem–school	–.46[a]
Self-esteem–sports	–.31
Anxiety	.29
PARTS–GA	–.36[a]

Abbreviation: PARTS–GA, Physical Appearance Related Teasing Scale–general appearance.

[a] $P < .05$

Table 4 Partial Correlations, Controlling for Age and Maturity Offset, Between Stress Measures and the Metabolic Risk Score in Low and High Physical Activity Groups

	Low PA	High PA
Self-esteem–school	–.64[a]	–.41
Self-esteem–sports	–.53[a]	–.09
Anxiety	.53[a]	.07
PARTS–GA	–.39	–.48

Abbreviations: PA, physical activity; PARTS–GA, Physical Appearance Related Teasing Scale–general appearance.

[a] $P < .05$ indicates correlational significance.

the metabolic syndrome in adolescents. The current study aimed to address this question in school-aged boys. To our knowledge, only 1 previous study[30] examined the relationship of self-reported personal and community stress and self-reported PA (assessed by the number of days per week that the respondents were active enough to "work up a sweat") with 3 measures of adiposity (WC, sum of 3 skinfolds [triceps, subscapula, suprailiac], and BMI) in three hundred and three 12- and 24-year-olds. Personal stress, but not PA, was significantly associated with BMI, after controlling for age, race, gender, socioeconomic status, and parental smoking. Moreso, the interaction of both personal and community stress with PA significantly predicted adiposity measures. It should be noted, however, that although statistically significant ($P < .05$), these interaction terms accounted for only 2% to 3% of the variance in adiposity measures, with the total models accounting for no more than 15% and 22%.

The current study followed a considerably different conceptual and methodological approach that should enable readers to evaluate this issue from 2 different but complementary perspectives. First, instead of focusing only on adiposity, we chose to study the metabolic syndrome. Because of the fact that it reflects a broader spectrum of risk factors, the MRS is presumably a more robust indicator of overall

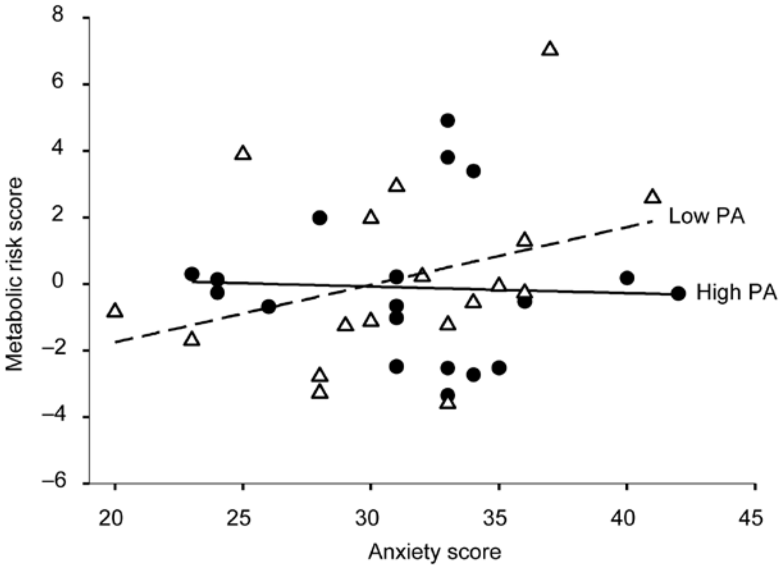

Figure 1 — Association between metabolic risk score and anxiety score in high and low physical activity groups. Solid line and circles represent the high physical activity group. Dashed line and triangles represent the low physical activity group.

metabolic and cardiovascular health than any single measure of adiposity. Second, given the lack of consensus in defining and operationalizing stress, as well as the absence of previous literature on the stress indices that might be most relevant to metabolic health among youth, we chose to adopt a broad-based approach to measuring stress. Thus, we thought it was important to assess a number of self-reported indices. We assessed both key variables known to be related to the appraisal of the demands of daily life (ie, perceived stress, anxiety, depression, self-esteem), as well as variables known to influence the well-being of school-age youth (ie, appearance-related teasing). The results from the current study are consistent with those found by Yin et al[29] and provide suggestive evidence that PA might modify the relationship between stress and the metabolic syndrome in 8- to 18-year-old boys. More specific, low PA appears to enable psychosocial variables to impact metabolic health, or higher levels of PA might buffer the association of anxiety with the metabolic syndrome.

Given its novelty, the current study can be considered, in several respects, as preliminary findings on this topic. This is particularly important in the case of the methods used to operationalize "stress." First, among the self-reported stress-related variables assessed, only anxiety (positively) and aspects of self-esteem (negatively) were found to be related to the MRS. In contrast, depression and perceived stress were not related to MRS in this small sample. Surprisingly, appearance-related teasing was found to have a modest but significant relationship with the MRS, but the correlation was in the opposite-than-predicted direction (ie, negative), albeit only in the whole sample and not among the low PA group. Presumably, this correlation might have been sample-specific and, therefore, unreliable. In our view, the challenge of identifying the stress marker or markers most closely related to the metabolic syndrome remains to be determined. For example, even though depression was unrelated to the MRS in the current investigation, it has previously been found to be related to BMI among school-age children.[46]

The correlations between PA and the MRS were low in the current study ($r < -.13$) but were in the expected direction (ie, negative). This finding is consistent with previous research that indicates that PA explains only a small amount of the variance in individual components of the metabolic syndrome among children and adolescents.[45] However, TV and videogame playing time were significantly related with the MRS, which is also consistent with the literature. Previous research examining TV and other sedentary activities and adiposity provide convincing evidence to the role of physical inactivity/sedentary behavior in youth.[47-51] In a recent study by Heelan and Eisenmann,[52] sedentary activities were better correlates of adiposity for both boys and girls ($r = .31$ and .51, respectively) compared with PA variables. The present investigation furthers the current body of literature by establishing a relationship between sedentary behavior and the metabolic syndrome in youth.

Despite recent investigations in adults,[19,53] limited attention has been given to the association between stress and physical health status in children and adolescents. Most research has focused on the bivariate relationship between stress and body mass. Sjörberg and colleagues[46] found higher BMI to be associated with depression. A low quality of life (QOL) has also been observed among obese children and adolescents.[54] Furthermore, the QOL in obese youth was comparable to that of children and adolescents who had been diagnosed with cancer. QOL is a multidimensional construct that examines physical, emotional, social, and school functioning.[55] Each of these stress-related constructs has the potential to perturb HPA axis functioning and possibly affect markers of metabolic health in addition to weight status. In the current investigation, a variety of self-report measures were used to examine the association between stress and the metabolic syndrome. School-related self-esteem and teasing were significantly associated with the MRS. This finding might suggest that the stress associated with poor self-esteem, teasing, and anxiety is related to adverse health status in young people. Björntorp[19] suggests that because the HPA axis is perturbed in states of obesity and insulin resistance, poor metabolic health is driven by increased stress activation. In the current example, increased stress because of poor self-esteem and teasing might result in chronic hypersecretion of cortisol and subsequent metabolic syndrome. Given the dynamic nature of adolescence on psychosocial function, further research should examine this hypothesis.

Although there is a relationship between stress and the MRS, the unexplained variance suggests that other factors contribute to the metabolic syndrome. It was hypothesized that PA might buffer the relationship between stress and the MRS. The main finding in the current investigation provides preliminary, but suggestive, evidence to support this hypothesis. Although cross-sectional correlations do not confer causal inference, the results suggest that adequate MVPA is important for individuals with poor self-esteem and high anxiety to maintain metabolic health. Because the manifestation of the metabolic syndrome typically does not occur until later in life, the prevalence is relatively low among adolescents and does not accurately express the severity of the problem. The use of a composite score such as the one created here allows each subject to have a value relative to a more healthy or diseased status. Several studies have shown that the combined components of the metabolic syndrome track from adolescence into adulthood.[1,8,56] An additional strength of this study is the objective measurement of PA by accelerometry.

Although the findings are based on a small sample, this study is distinct in its conceptual design. This is the first study to examine the associations between PA, stress-related measures, and the metabolic syndrome in children and adolescents. Further research is needed in larger samples before conclusive evidence is drawn. The results from the current study show preliminary but suggestive evidence that PA buffers the relationship between stress and the metabolic syndrome. Viewed from a broad perspective, this study might serve to usher in a new era in which the problems of obesity and the metabolic syndrome are seen as precipitated by a multitude of interacting etiologic factors that go beyond PA and diet. The consideration of stress in addition to PA and diet for prevention and treatment strategies of childhood obesity and metabolic syndrome might prove beneficial in that stress can influence factors associated with the metabolic syndrome,[19] including obesity, and in turn, obesity has the propensity to influence stress levels via teasing and self-esteem.[54,57] Because of the reciprocal relationship between stress and metabolic disease, it might be illogical to consider these variables in a compartmentalized fashion. Ultimately, with a greater understanding of the intimate relationships between PA, stress, and the metabolic syndrome, the manner by which we address treatment and prevention of obesity and related diseases can be optimized.

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