

PHYSICAL ACTIVITY AND FITNESS: MODERATORS OF THE STRESS-METABOLIC
SYNDROME RELATIONSHIP?

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ABSTRACT

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Childhood obesity and metabolic syndrome are viewed as critical public health concerns and efforts to attenuate these conditions have focused primarily on two behavioral factors, diet and physical activity. Recent research has shifted toward viewing these conditions as a result of the interactions between many antecedents that can influence the balance of energy intake and expenditure. One intriguing line of research implicates perturbations in the stress response system and the putative role that dysregulation may have on the development of obesity and metabolic syndrome. Researchers have observed relationships similar to those found in the adult literature when examining the links between health and a number of ‘stress-related’ variables in youth. An increased focus on psychosocial health determinants of metabolic health such as stress is of particular interest, given the favorable relationship between physical activity and/or fitness and stress. This apparent beneficial relationship between physical activity and stress has led researchers to examine whether physical activity may have a moderating effect (i.e., effect modification) on the stress-metabolic syndrome relationship. Literature addressing this potential effect modification is sparse but promising.

This dissertation aimed to examine further the relationship between psychosocial health and metabolic health and investigate the potential moderation physical activity and health-related fitness may have on this relationship. We examined perceived stress, problem-focused coping levels, metabolic syndrome-related variables, physical activity levels, and health-related fitness variables in 126 middle school students in the 2010-2011 school year. Participants approximated

the 75th percentile for BMI and gender differences were observed when examining systolic blood pressure, physical activity level as estimated by questionnaire, vigorous physical activity as estimated by accelerometer, and perceived stress. Results showed little influence of perceived stress or problem-focused coping associated with metabolic health as determined by a metabolic syndrome composite score and BMI. Likewise, a moderating influence of physical activity or fitness was not observed.

Results of this study suggest physical activity, stress, and problem-focused coping have little influence on the metabolic syndrome composite score or BMI in this sample. Although we did not observe our hypothesized relationships, the line of inquiry examining a moderating influence of physical activity and fitness on this relationship holds merit and should not be abandoned. Our study highlights the need for continued methodological refinement, particularly regarding assessment of psychosocial health indicators in this age group. A critical step in elucidating the relationship between stress and health in youth requires identification and concise descriptions of indices of psychosocial health that are most relevant to metabolic health. Identification of modifiable variables with influence that transcends multiple putative contributors to energy imbalance is particularly critical in children and adolescents where behaviors and attitudes are still developing and timely interventions could translate into long-term, positive health outcomes in adulthood.

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“A positive attitude may not solve all your problems, but it will annoy enough people to make it worth the effort.” --Herm Albright I have been fortunate to carry this sentiment as my motto and creed throughout my academic career. The upkeep of a positive attitude is a seemingly impossible task at times and would not have been accomplished without the support of some very special people. Without question, my committee members are among the most supportive people with whom I have ever had the good fortune of working. Their ability to challenge me in such a way that encouraged my soul and cultivated my desire to learn is a characteristic I hope to model with my own students. Jim and Karin deserve distinct recognition for their efforts. From catching spelling errors to providing the tissues for an emotional crisis, you have supported me and I thank you so much for all you have done. Jo Ann Janes will always have a special place in my heart. I am so fortunate to have had you in my corner and I will be forever grateful.

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CHAPTER 1

INTRODUCTION

In its most basic sense, obesity is a pathological excess of adiposity that is the result of energy intake chronically exceeding energy expenditure (1). Approximately one-third of U.S. children and adolescents (ages 6-19 years) are overweight or obese (2). Given its high prevalence and the potential implications for so many other facets of life, the obesity epidemic is viewed as a critical public health concern. Childhood obesity and the co-occurrence of elevated blood pressure, an adverse blood lipid profile, and insulin resistance is commonly referred to as the metabolic syndrome (3). Research efforts on metabolic syndrome have focused primarily on two behavioral factors, diet and physical activity, which is evident by their inclusion in recent major public health campaigns (4, 5). More recently, however, research has begun to shift towards viewing the condition as a result of many antecedents that influence the balance of energy intake and expenditure.

One intriguing line of research implicates perturbations in the stress response system and the putative role that dysregulation may have on the development of obesity and metabolic syndrome. This relationship is well established in the adult literature (6-9), and is receiving increased attention in pediatric work. Identifying an operational and methodological definition robust enough to capture the ubiquitous nature of stress has been difficult in adults, as noted in a recent review by Holmes et al (10). When considering the rapid transition in all areas of development during adolescence, which is also recognized as a stressor (11), it is not surprising that investigators who examine the stress-obesity relationship in youth have also encountered difficulty defining stress. Researchers have observed relationships similar to those found in the adult literature when examining the links between health and a number of 'stress-related' variables such as adrenocortical activity and cortisol levels (12-15), teasing (16, 17), quality of

life (18), depression (19), chronic stress (20), self-esteem (17), and trait-anxiety (17). Further, Lazarus suggests that upon recognition of a stimulus, or stressor, there is an appraisal process which influences the coping behaviors and stress response (21). This tightly linked relationship between stress and coping has been neglected in health-related research. An individual's perception of available coping resources and his/her ability to deal with any given challenge, ultimately dictate the way by which an individual experiences stress (21). Lazarus (22) has identified eight general coping resources (confrontive or problem-focused, distancing, self-controlling, seeking social support, accepting responsibility, escape or avoidance, playful problem-solving, and positive reappraisal) which have not been thoroughly examined in youth. Adolescence is a particularly important time period for examination of coping responses because this is a time when adult behavior patterns are still forming. Additional research is needed to identify if examination of relationships between coping resources and/or behaviors and health outcomes is a viable avenue for exploration in pediatric research.

An increased focus on mental health determinants such as stress is warranted given the marked increase of psychotropic medication prescription and physicians office visits for the treatment of emotional and behavioral problems in youth (23, 24), particularly when considering the favorable relationship between physical activity and/or fitness and stress. Although this is a relatively new line of research, results generally show an inverse relationship between physical activity and/or fitness and stress-related variables (19, 25-30). Likewise, Motl et al. used latent class modeling to examine patterns of *change* in physical activity and depressive symptoms over a two year period. Results from this study suggest that the secular decline in physical activity is inversely associated with increases in reported depressive symptoms (31).

This apparent beneficial relationship between physical activity and stress has led researchers to examine whether physical activity may have a moderating effect (i.e., effect modification) on the stress-metabolic syndrome relationship. Literature addressing this potential effect modification is sparse but promising. Previous work by our lab (17) and others (20) has suggested that physical activity appears to buffer the relationship between stress and metabolic syndrome and/or obesity. This relationship requires confirmation in a larger, diverse sample.

Likewise, the influence of fitness on the stress-metabolic syndrome relationship also requires additional investigation. Previously, Holmes and colleagues (10) discussed the rationale for examining physical activity as a moderator of this deleterious relationship as being grounded in the notion that a bout of exercise (structured and purposeful physical activity) can be a stressor and, as such, it can engage most of the same biological pathways as psychosocial stress (i.e., sympatho-adreano-medullary (SAM) axis, hypothalamic pituitary adrenal (HPA) axis, and cardiovascular system). Similarly, Sothmann et al. (32) concluded that a bout of exercise that is sufficient to elicit an improvement in aerobic fitness typically elicits a stress response as well. Thus, the working assumption is that exercise can produce beneficial adaptations in the stress pathways while avoiding harmful effects on health. In turn, these exercise-induced adaptations are expected to manifest themselves as responses to psychosocial stressors that are modified in a way that entails reduced potential for harm. This rationale is referred to in the literature as the "cross-stressor adaptation hypothesis" (32, 33).

Most studies investigating the cross-stressor adaptation hypothesis have utilized cardiorespiratory response measures (e.g., heart rate, blood pressure) and laboratory stressors (e.g., mental arithmetic, Stroop word-color conflict task, hand or foot cold pressor task). Most of these studies are also cross-sectional. Study results have been summarized in a series of recent

meta-analyses with limited conclusions (27-29). Sothmann expresses it best in a recent update of the status of the cross-stressor adaptation hypothesis, "The few studies conducted to date with humans suggest that, while exercise training for three to four months may increase key physiological measures of fitness, it generally has not induced changes in stress reactivity as indicated by neuroendocrine measures where a short-term psychosocial challenge is the precipitating factor" (33). Sothmann added that "it is theoretically reasonable to postulate that ... a beneficial effect should be present, but the experimental approaches to date have offered limited confirming data in the human" (33).

As we continue to refine our methodological approach to studying the cross-stressor adaptation hypothesis, it is important to consider the relationship between stress and fitness from pediatric perspective. The premise of the cross-stressor adaptation hypothesis relies on training responses that can be attained from physical activity, which are well-established in adults but less clear in children. While the relationship between fitness (aerobic or health-related) and stress has received very little attention in pediatric literature (34), it is a critical step in the investigation of the cross-stressor adaptation hypothesis in youth.

The adult literature suggests that aerobic fitness may have an attenuating effect of 15-25% on heart rate and blood pressure reactivity (28). This translates into a modest influence in adults (a reduction of approximately 2 beats per minute in heart rate and almost 4 mm Hg in systolic blood pressure). When we consider the impact of this potential attenuation throughout the lifespan, the significance of exploring the fitness-stress relationship becomes clear.

The overall purpose of this dissertation was to examine the relationship between stress and metabolic syndrome, and the moderating effect of physical activity and health-related fitness on this relationship. There were seven major research aims and hypotheses.

Aim 1: To describe sources of psychosocial stress, problem-focused coping resources, metabolic syndrome-related variables, physical activity, and health-related fitness in a sample of middle school students.

Hypothesis: This is not a hypothesis driven aim but is required for completion of Aims 2 through 7.

Variables to be assessed in the total sample are: sources of psychosocial stress (as estimated by the sum of the ten Adolescent Stress Questionnaire subscales), problem-focused coping resources, metabolic syndrome-related variables (i.e., metabolic syndrome composite score, which is comprised of waist circumference, mean arterial pressure, fasting triglycerides, high density lipoprotein cholesterol, and fasting glucose, and body mass index), physical activity (via questionnaire and activity monitor), and health related fitness (i.e., aerobic fitness, muscular strength and endurance, flexibility, and body composition).

Statistical Analysis: To assess Aim One, descriptive statistics will be calculated for each variable.

Aim 2: To examine the relationships between stress (as estimated by the sum of the ten Adolescent Stress Questionnaire subscales) and metabolic syndrome related variables.

Hypothesis: There will be a positive relationship between stress and metabolic syndrome related variables.

Statistical Analysis: To assess Aim Two, linear regression analysis will be used to determine the relationships between stress (as estimated by the sum of the ten Adolescent Stress Questionnaire subscales) and metabolic syndrome-related variables, controlling for chronological age, and gender.

Aim 3: To examine the relationships between coping resources and metabolic syndrome related variables.

Hypothesis: There will be an inverse relationship between (problem-focused) coping resources and metabolic syndrome related variables.

Statistical Analysis: To assess Aim Three, linear regression analysis will be used to determine the relationships between (problem-focused) coping resources and metabolic syndrome-related variables, controlling for chronological age, and gender.

Aim 4: To examine the moderating influence of physical activity on the relationship between stress (as estimated by the sum of the ten Adolescent Stress Questionnaire subscales) and metabolic syndrome related variables.

Hypothesis: Physical activity will modify (attenuate) the relationship between stress and metabolic syndrome related variables.

Statistical Analysis: Regression analysis will be used to assess Aim Four. An interaction term between stress and physical activity will be created to determine the moderating influence of physical activity, controlling for chronological age, and gender.

Aim 5: To examine the moderating influence of physical activity on the relationship between coping resources and metabolic syndrome related variables.

Hypothesis: Physical activity will modify (enhance) the relationship between problem-focused coping strategies and metabolic syndrome related variables.

Statistical Analysis: Regression analysis will be used to assess Aim Five. An interaction term between coping resources and physical activity will be created to determine the moderating potential of physical activity, controlling for chronological age, and gender.

Aim 6: To examine the moderating influence of health related fitness on the relationship between stress (as estimated by the sum of the ten Adolescent Stress Questionnaire subscales) and metabolic syndrome related variables.

Hypothesis: Health related fitness will modify (attenuate) the relationship between stress and metabolic syndrome related variables.

Statistical Analysis: Regression analysis will be used to assess Aim Six. An interaction term between stress and health related fitness will be created to determine the moderating influence of health related fitness, controlling for chronological age, and gender.

Aim 7: To examine the moderating influence of health related fitness on the relationship between coping resources and metabolic syndrome related variables.

Hypothesis: Health related fitness will modify (enhance) the relationship between (problem-focused) coping strategies and metabolic syndrome related variables.

Statistical Analysis: Regression analysis will be used to assess Aim Seven. An interaction term between coping resources and health related fitness will be created to determine the moderating influence of health related fitness, controlling for chronological age, and gender.

This dissertation will be organized as an introduction (Chapter 1), comprehensive review of literature (Chapter 2) followed by a detailed account of the research methods used in this study (Chapter 3). Chapter 4 will discuss the results as they relate to the aims and Chapter 5 will provide discussion and conclusions as well as directions of future research. Results from this investigation will provide a better understanding of the etiological sequelae of obesity and metabolic syndrome, which, in turn, can be used to better formulate prevention and treatment strategies by providing effective coping skills through positive healthy habits.

CHAPTER 2

REVIEW OF LITERATURE

INTRODUCTION

This review will explore the complex relationships between obesity and related co-morbidities during childhood and adulthood as well as the relationship between physical activity and aerobic fitness and their influence on these conditions. Additionally, this review will examine the postulated influence of stress in the etiology of obesity. Perturbations in stress response and the function of the hypothalamic-pituitary-adrenal (HPA) and sympathetic adrenomedullary (SAM) axes have been implicated as contributing factors in the development of obesity and this review will examine the possibility that physical activity and fitness may have a moderating influence on the relationship between stress and obesity and related metabolic disorders.

OBESITY/METABOLIC SYNDROME

Overweight and obesity.

The Centers for Disease Control recently began using the terms “overweight” and “obese” (formerly, “at risk for overweight” and “overweight”) to identify weight status in children and adolescents ($\geq 85^{\text{th}}$ percentile and $\geq 95^{\text{th}}$ percentile, respectively) (35, 36). These classifications are age- and sex-specific and have been derived from national growth data (37). The most recent estimates of overweight and obesity among U.S. children and adolescents (ages 6-19 years) is approximately 34.7% (2). Another classification method developed by the International Task Force on Childhood Obesity, utilizes a statistical technique which back-

extrapolate from the adult cut-points (i.e., BMI of 25 kg/m² and 30 kg/m²) to establish age- and sex-specific cut-points for classifying children as overweight or obese (38).

Metabolic Syndrome.

Childhood obesity is associated with several adverse physiological states such as early maturation, orthopedic issues, sleep apnea, and polycystic ovary disease, among others (39). Furthermore, obese children are at greater risk for cardiovascular disease (CVD) risk factors, such as insulin resistance, hypertension, and dyslipidemia (40-44). This nebulous of co-morbidities (abdominal obesity, insulin resistance, elevated triglycerides, and low high-density lipoprotein cholesterol) constitute a condition that is referred to as the metabolic syndrome. Although definitive classification criteria for children and adolescents have not yet been established, some authors have adapted adult criteria of these five key components for use in pediatrics. Using various age-adjusted NCEP criteria, metabolic syndrome among adolescents (ages 12-19 years) is estimated between 4.2-9.2% and two thirds of US adolescents have at least one metabolic abnormality (45-47). When examining overweight/obese adolescents specifically, thirty percent have metabolic syndrome (47). Metabolic syndrome in adolescence affects more males than females (6.1% vs. 2.1%, respectively) (46) and varies by ethnicity. Metabolic syndrome is more prevalent in Mexican-American, followed by non-Hispanic white adolescents compared with non-Hispanic blacks (12.9%, 10.9% vs. 2.5%, respectively) (47).

Metabolic syndrome diagnosis was designed to complement the classic Framingham risk score used to estimate short-term risk (10-year) in adults which tends to underestimate the importance of obesity in CVD risk (48). Obesity is considered to be the proximal causal factor in development of metabolic syndrome (48, 49). Likewise, some researchers suggest that

impaired insulin function (50), sometimes described in combination with metabolic sensitivity (51), is also a key precipitate of metabolic syndrome diagnosis. These attributes often overlap and are well established as contributors in the development of the two other components of the syndrome; atherogenic dyslipidemia and hypertension (48-50, 52).

In addition to physiological outcomes, Dietz (39) notes adverse psychosocial consequences as the most prevalent morbidity associated with obesity. Childhood obesity is associated with increased emotional distress (53) and one mechanism for this is observed through teasing and/or bullying. Obese children are more likely to be teased and/or bullied compared to their normal weight peers (54). Likewise, childhood obesity is also associated with a decrease in quality of life (QOL) during this time period (18). Schwimmer et al. (18) showed a significantly lower QOL in obese children and adolescents compared to normal-weight children. Furthermore, the QOL in obese subjects was comparable to that of children and adolescents who had been diagnosed with cancer.

Long-term consequences of childhood obesity.

While the immediate effects of childhood obesity are significant, tracking these effects into adulthood poses an additional public health concern. Several longitudinal studies have demonstrated the relationship between high levels of fatness during childhood and adolescence and subsequent development of various CVD morbidities as well as mortality.

Childhood obesity tends to persist through adolescence and into adulthood (55-57). The child-adult relationship is modest ($r \approx 0.30$) and strengthened when the initial assessment is taken at a later age ($r = 0.46-0.91$ and $0.60-0.78$ for adolescent boys and girls, respectively) (55). The

degree of obesity also influences the persistence into adulthood as children or adolescents at a higher BMI percentile are more likely to be obese as adults (56-59).

In addition to adult obesity, the literature demonstrates very clearly that childhood obesity increases risk for other components of the metabolic syndrome in adulthood (i.e., hypertension (60-63), dyslipidemia (61-63), insulin resistance (64, 65)), poor vascular health (66, 67), and CVD and all-cause mortality (65, 68). Likewise, childhood obesity also increases the risk for metabolic syndrome as an adult (69-71). Because metabolic syndrome is a progressive condition and typically does not manifest clinically until later in life, some authors have created composite risk scores in order to examine to what extent the clustering of characteristics associated with metabolic syndrome track into adulthood. Although time to follow-up is relatively short in most studies (8-12 years), the available literature consistently reports moderate tracking of clustered risk factors (42, 72-75). Authors of the Princeton Lipid Research Follow-up Study recently published a twenty-five year follow-up which examined metabolic syndrome diagnosis during childhood (using NCEP criteria) and adult disease (76). Results from this study showed that children diagnosed with metabolic syndrome as children are 6.2 times (95% CI, 2.8-13.8) more likely to have metabolic syndrome as adults (76). When compared to their healthy counterparts, those with metabolic syndrome during childhood were 14.6 times (95% CI, 4.8-45.3) more likely to develop incident CVD (76). The same group also examined the sensitivity of pediatric metabolic syndrome which showed that examination of individual components are less sensitive for predicting adult metabolic syndrome compared to examination of all five components (77). Furthermore, it may be that different combinations of risk factors may predict risk specific to the degree of adult obesity, as was found by a recent follow-up of the Bogalusa Heart Study (78). In normal weight adults, abnormal metabolic risk profiles were

associated with higher low density lipoprotein cholesterol and insulin levels during childhood. Contrastingly, abnormal metabolic risk profiles in obese adults were associated with higher mean arterial pressure and glucose levels during childhood (78).

Risk factors during childhood persist through adolescence and predict risk in adulthood. Further, examination of the clustering of risk factors suggest that the aggregated risk tends to track stronger than individual risk factors (79). Thus, examination of metabolic syndrome is warranted in pediatrics even in the absence of a standard definition of the condition in this age group.

PHYSICAL ACTIVITY, FITNESS, AND THEIR RELATIONSHIP WITH PEDIATRIC OBESITY/METABOLIC SYNDROME

Physical activity

Physical activity is defined as “any bodily movement produced by skeletal muscles that results in an increase in energy expenditure above resting rate” (80). This broad definition allows the researcher a considerable amount of latitude in the description and categorization of physical activity. Physical activity can be weight-bearing, non-weight-bearing, occupational, leisure-time, continuous, intermittent, organized or non-organized. Physical activity can also be (and is most commonly) categorized by the type, frequency, duration, and intensity of the activity. The multi-factorial nature of physical activity makes precise and accurate assessment problematic. Several techniques (e.g., surveys and questionnaires, pedometers, accelerometers) are commonly used to assess physical activity; however, a detailed account of each of these methods is beyond the scope of this review (see *Medicine and Science in Sports and Exercise*, (29) 6S). Several excellent reviews are available that examine the relative precision and

practicality of assessment tools that are available for children (81-83). Likewise, an entire issue of the journal *Research Quarterly for Exercise and Sport*, (vol. 71, issue 2) has been devoted to articles dealing with the reliability and validity of various assessment tools in a number of subpopulations.

Intensity of physical activity receives a great deal of attention, as it is most applicable to health-related research. The descriptive terms "very light," "light," "moderate," "hard," "very hard," and "maximal" have been matched to a relative percentage of maximal aerobic capacity or assigned a metabolic equivalent (MET) value as a means of standardizing the classification of physical activity (84). This classification system is used as the basis for recommendations designed to improve or maintain health and cardiorespiratory (aerobic) fitness.

In 2005, results were published from an expert panel that was assembled to evaluate the available evidence and determine physical activity recommendations to improve health and behavioral outcomes (30). The panel concluded that children and adolescents should participate in at least sixty minutes of moderate to vigorous physical activity daily (30). Since then, the U.S. Department of Health and Human Services has published the *2008 Physical Activity Guidelines for Americans*, which provides more detailed recommendations for all age groups (85). Current recommendations for children and adolescents require school-aged youth to participate in at least sixty minutes of physical activity daily (85). It is recommended that the majority of that sixty minutes be spent participating in activities that are of moderate-to-vigorous intensity and aerobic. Furthermore, the recommendations suggest that at least three of the days should be at a vigorous intensity. Muscle- and bone-strengthening activities should also be incorporated as part of the sixty minutes of activity at least three days each week (85). Approximately 34.7% of high school-aged youth meet the recommendation of sixty minutes of physical activity per day (86).

As mentioned previously, accurate measurement of physical activity is challenging. Welk, Corbin, and Dale (87) noted that the assessment techniques must be sensitive enough to capture the short, intermittent bouts of activity characteristic of the physical activity behaviors of children, which is a difficult task even when using a more objective measure (e.g., accelerometer). Accelerometers detect and quantify motion in units of ‘counts’ by determining the amount of disruption of a signal within the monitor during a specified interval of time. The counts are summarized for each interval and reflect the total amount of activity that occurred during the interval. This summary can obfuscate short bouts of vigorous activity that are alternated with bouts of rest (87). Furthermore, MET-specific cut-points are often applied to the counts in each interval of time to determine the amount of time spent in various intensities. MET values are not very well established in children (88), and when those cut-points are used to identify participation in adequate levels of physical activity (>60 minutes MVPA/day), the error of the estimate is exacerbated even further.

Aerobic Fitness

While physical activity refers to a behavior, physical fitness refers to a set of physiological attributes and is categorized as either health- or skill-related (89). Skill-related fitness is comprised of agility, balance, coordination, power, reaction time, and speed and are related to performance of motor skills associated with athletic ability (89). Health-related fitness consists of body composition, aerobic fitness, flexibility, muscular endurance, and strength (89). Given the well-established connection with health outcomes in adult literature, aerobic fitness receives considerable attention relative to the other components.

Aerobic fitness is a physiological characteristic that reflects the maximal amount of oxygen that can be utilized (VO_2max) (80). VO_2max , assessed using indirect calorimetry on either a treadmill or cycle ergometer, is the criterion measure of aerobic fitness and is typically expressed in absolute terms or relative to body weight (L/min and ml/kg/min, respectively). Field assessments of aerobic capacity consist of distance or timed runs (e.g., 1-mile run, 12-minute run) or submaximal heart rate measures to predict VO_2max and generally can be used with reasonable confidence of the validity of the estimate (90). Aerobic capacity remains relatively stable throughout childhood and adolescence in boys at approximately 52 ml/kg/min in boys. Aerobic capacity remains relatively stable in girls at approximately 45 ml/kg/min until age 12 when it begins to decline (91).

Physical activity-aerobic fitness relationship

Intuition would suggest that more active individuals would have higher fitness and that the relationship between physical activity and aerobic fitness would be relatively strong, as is the case in adults (92). This relationship is considerably more evanescent in children and adolescents, and was examined thoroughly following the 1993 International Consensus Conference on Physical Activity Guidelines for Adolescents in a review by Morrow and Freedson (93). In light of this excellent review, a summary of the rationale substantiating the modest relationship between aerobic fitness and physical activity will be provided here.

The apparently high levels and modest trainability of aerobic fitness in children and adolescents are noteworthy contributors to the modest relationship between physical activity and aerobic fitness in this age group. As mentioned previously, aerobic fitness remains relatively stable through adolescence, particularly in boys. This stability appears to also apply regardless of

physical activity participation. Rowland examined the effects of prolonged inactivity on aerobic fitness in a small group of children who had been confined to bed rest for nine weeks (94). Immediately following bed rest, VO_2 was approximately 37.2 ml/kg/min. Testing was repeated monthly for the next four months and again at six and nine months and VO_2 increased at each successive test until leveling off at the third month (43.1 ml/kg/min). The difference between initial and testing at the third month can be considered an estimate of the loss due to bed rest (~13%) (94). Because normal variation in physical activity does not match these extremes, these findings suggest that habitual physical activity has little influence on aerobic capacity in young people. This is in concordance with a meta-analysis by Payne and Morrow (95) that suggests the trainability of aerobic fitness in prepubertal children and adolescents is very modest (~5%). However, some evidence is available that suggests a more pronounced training effect can be observed in sedentary pubertal children and adolescents (96). Morrow and Freedson concluded that the modest association between physical activity is conceivably explained by the high levels of aerobic fitness combined with the inherent error associated with physical activity assessment in youth and probable lack of a true association (93).

Physical activity, fitness, and components of the metabolic syndrome.

Several excellent reviews have examined the association between physical activity, aerobic training and/or fitness and individual components of the metabolic syndrome or clustered CVD risk factors (97-104) and, therefore, will only be briefly summarized here.

Some population-based research has suggested that lower physical activity levels are modestly related to greater BMI and overweight status in children and adolescents (105-107). Studies examining the relationship of sedentary pursuits and adiposity provide a stronger

association (106-110), but should also be interpreted with some caution. Time spent pursuing sedentary behaviors does not necessarily displace time that would otherwise be spent in physical activity (111) and can be the reflection of productive sedentary behaviors (e.g., reading, homework) which are associated with greater physical activity (112).

The relationship between physical activity and other traditional CVD risk factors (i.e., blood pressure, blood lipids, and insulin resistance) has received limited attention in youth. Aerobic training has mixed results: lowering blood pressure in normotensive and hypertensive children (113) and normotensive adolescents (114, 115), but appears to modestly decrease blood pressure in hypertensive (114, 115) and/or obese (116) adolescents. Physically active children tend to have more favorable lipid profiles compared to sedentary children (98, 117, 118). Likewise, aerobic activity and exercise training are also associated with more favorable lipid profiles (117-119). Research examining the relationship between physical activity and/or aerobic fitness and blood glucose or insulin function in children and adolescents generally suggests that more active children have lower fasting insulin and aerobic training can result in reduction in insulin levels (120-122). Furthermore, aerobic fitness appears to be an independent predictor of insulin resistance in middle school-aged youth (123).

Physical activity, fitness, and clustered metabolic risk.

Given the lack of consensus regarding the cut-points of individual risk factors for metabolic syndrome classification in youth and because metabolic syndrome does not typically manifest clinically until later in life, studying the relationships between physical activity, aerobic fitness, and metabolic syndrome in this age group is a somewhat cantankerous endeavor. Some researchers have developed various composite scores to represent metabolic syndrome risk (124-

126). These methods create a continuous variable, which lends itself well to examining associations between the severity of the metabolic syndrome with other variables. Examination of objectively measured physical activity and aerobic fitness as independent influences is limited, but generally suggest that both variables are inversely associated with clustered risk factors in youth (127) and that fitness partially mediates the relationship between physical activity and clustered risk (128).

Only a handful of studies have examined objectively measured physical activity with a clustering of risk factors in youth. A study examining Hispanic youth found the number of risk factors to be inversely related to total physical activity measured by accelerometry (129). Furthermore, the number of five-minute bouts of moderate-to-vigorous activity was also inversely related to the number of risk factors (129). The European Youth Heart Study (EYHS) showed an inverse graded relationship between quintiles of objectively measured physical activity and clustered metabolic risk (130). Additional analysis of the Danish arm of the study, found that this inverse relationship was maintained even after adjusting for aerobic fitness (125). Ekelund examined the various sub-components of physical activity (i.e., time spent in low, moderate, vigorous, and total physical activity) in this group and observed a stronger association for total physical activity compared to moderate-to-vigorous (131). Rizzo et al. (132) found similar results in a smaller group of 15-yr-old Swedish girls, but the relationship was attenuated after adjustment for fatness and aerobic fitness. The EYHS has been equally instrumental in elucidating the inverse association between aerobic fitness and clustered risk factors. When separated in to quartiles of aerobic fitness, the least fit were significantly more likely to have clustered risk factor profiles compared to the most fit (OR= 15.8 and 10.4 for boys and girls, respectively) (121). Likewise, this inverse relationship held when fitness was examined as a

continuous variable (133) and regardless of fatness (131). Similar associations have been observed in other American (134-137), French Canadian (138), and Australian samples (139).

AN ALTERNATIVE HYPOTHESIS

Dysregulation of the stress response

Several authors have postulated relationships among variables in the outer valence shells that may contribute to the central energy imbalance concept. Studies of factors such as infections, epigenetics, maternal age, assortive mating, sleep debt, endocrine disrupting chemicals, pharmaceutical induced weight gain, decreased variability in ambient temperatures, greater fecundity in people with greater adiposity, and intrauterine environment have found varying levels of support for their relation to obesity and/or the metabolic syndrome in adults (140) and children (141). While the relative importance of these factors is yet to be established, dysregulated stress response function has been related consistently to obesity in both adults and children and will be further examined here.

Stress and coping

Stress is a ubiquitous term used to describe a physiological response to various environmental, physical, and emotional stimuli. Our current understanding of stress stems from Hans Selye's notion of a "general adaptation syndrome" (142). According to Selye's description, the syndrome, progresses in three stages, including an initial alarm reaction, a stage of resistance, and, if the damage continues, exhaustion and death and manifests as a result of exposure to damaging stimuli as diverse as cold, injury, transsection of the spinal cord, excessive exercise, or intoxication. Enlargement of the adrenal glands, involution of the thymus and lymph nodes, and

ulceration of the stomach were characteristic of the process. Selye is responsible for assigning to it the meaning stress now has in the biomedical literature. The exact definition evolved over a period of decades. For example, "we may define stress as the state manifested by a specific syndrome which consists of all the nonspecifically induced changes within a biologic system" (143) or, "stress is the nonspecific response of the body to any demand made upon it" (144). Much of Selye's work on stress was devoted to the search for the so-called "first mediator," a substance which he believed was the single common signal for the initiation of the stress response to various stimuli. Several substances suspected to be the "first mediator(s)" were examined and eliminated as candidates (e.g., epinephrine, norepinephrine, acetylcholine, histamine). Selye did not give serious consideration to the role of psychological factors until shortly before his death (145). It is important to point out that Selye's first observation of psychological influence came rather early, albeit as an incidental side note: "even mere emotional stress, for instance, that caused by immobilizing an animal on a board, proved to be a suitable routine procedure for the production of a severe alarm reaction" (146).

This observation became the starting point for critics of Selye's concept of stress. Richard Lazarus (22) focused on the fact that the magnitude of human stress responses is typically not proportional to the degree of objective danger. Thus, he rejected the idea of stress as a passive response and instead proposed that the key in the stress process is the subjective appraisal of threat. This appraisal is a cognitive inferential process about the meaning of the stimulus and its implications for the well-being and the goals of the individual, influenced jointly by the individual's psychological makeup (e.g., knowledge and beliefs) on the one hand and the situation on the other. This concept gradually matured into one of the most influential cognitive theories of stress, coping, and emotion (21, 22).

John Mason also influenced our present conceptualization of stress and focused his critique of Selye's view of stress on the notion of a chemical "first mediator" and the fundamental tenet of non-specificity (147-150). Mason agreed with Lazarus in assigning a central role to psychological processes; he suggested that the first mediator "may simply be the psychological apparatus involved in emotional or arousal reactions to threatening or unpleasant factors in the life situation as a whole" (147). Mason was a pioneer in broadening the scope of investigations beyond morphological changes in organs and tissues and beyond focusing on a single hormone or a single endocrine system. Instead, he systematically recorded changes across multiple endocrine systems in response to multiple challenges, including those of a psychological nature. Mason concluded that there was evidence of patterning and specificity: "The picture emerging so far from our study of multihormonal patterns, in fact, is one suggesting that such patterns are organized in a rather specific or selective manner, depending upon the particular stimulus under study, and probably in relation to the complex interdependencies in hormonal actions at the metabolic level" (149).

It appears that stressors at each level of intensity or severity, have distinct and replicable "signatures" in the patterning of not only hormone levels but also the activity of brain regulatory centers (151, 152). However, the "signature" of different psychosocial stressors or emotional states is less understood. The question of whether particular types of stressful situations or emotions are linked to particular patterns of neuroendocrine responses remains unanswered. To better understand this relationship, we must consider the relationships between affective states and the activation of the hypothalamic pituitary adrenocortical (HPA) and sympathetic adrenomedullary (SAM) axes.

This multi-dimensional concept of affect is consistent with a framework proposed

independently by two researchers for the specificity of endocrine responses to stress, Marianne Frankenhaeuser and James Henry. Frankenhaeuser's work focused on human occupational health psychology, whereas Henry's work was with animals and focused on adaptation to stress and the mechanisms of cardiovascular disease (CVD). Their models suggest that the HPA axis and cortisol are sensitive to differences along the affective valence dimension (pleasure versus displeasure), whereas the SAM axis is primarily sensitive to differences along the activation dimension. According to Frankenhaeuser, (153) "epinephrine is a general (non-specific) indicator of mental arousal, increasing regardless of whether the affect is positive or negative." In contrast, "cortisol generally increases in negative affective states only". Henry's model was summarized as: "One system [HPA] responds with distress and with euphoria in situations associated respectively with loss of control and with success; the other [SAM], which is activated by situations demanding effort, decreases its response when relaxation predominates" (154). Frankenhaeuser (153, 155) noted further that the cortisol response should be expected to be stronger when displeasure is combined with low activation (as in exhaustion or boredom) than when displeasure is combined with high activation (as in fear or tension). Frankenhaeuser offered the examples of depressed patients, prisoners awaiting trial, or people who lost jobs for the former and people under pressure to produce in low-control, coercive jobs for the latter. On the other hand, although Frankenhaeuser (155) noted that "the pattern of [epinephrine] and [norepinephrine] secretion from the adrenal medulla tends to be rather similar, irrespective of the quality or nature of the emotional experience," Henry (156, 157) maintained that epinephrine is primarily associated with fear, whereas norepinephrine is primarily associated with anger. Today, the model proposed by Frankenhaeuser and Henry is commonly used as the conceptual basis for investigations focusing on HPA and SAM responses to psychosocial stressors (158).

This conceptual framework has important implications for researchers interested in studying the dynamics of the HPA and SAM axes in response to psychosocial stressors. For example, if the primary target of investigation is the HPA response, the experimental situation should involve negative affect, which can be accomplished with tasks that allow little or no chance for the participants to successfully meet the given performance goal and combine such elements as social evaluation, loss of control, and a sense of helplessness (159, 160). However, if the primary target of investigation is the SAM response, the experimental situation should mainly involve high levels of activation and effort (ideally, uncontaminated by physical effort). Such tasks should be as engaging and engrossing as possible, challenging but also offering a reasonable chance of success (so that they do not elicit a consistently positive or a consistently negative outcome).

Linking stress to pathophysiology

Traditionally, researchers have examined the amplitude of the stress response (e.g., the elevation of heart rate or hormone levels), assuming that it is the magnitude of the stress response that is the "toxic element" or the aspect of the response most closely associated with stress-related pathologies. However, if one considers the totality of the stress response, it is apparent that the amplitude of the response is only one way to define it and, in many cases, it might not have the most meaningful implications for health. The impact on the body could be determined by several other criteria. McEwen (161) uses the concept of allostatic load, the wear and tear of the body that occurs as a result of repeated cycles of adapting to internal and external demands, to illustrate what these other forms might be. McEwen suggests that the normal course of events in the process of "allostasis" (i.e., adapting to changing demands) consists of an

appropriately sized stress response of the SAM and HPA axes to help us deal with the demand, immediately followed by a rapid deactivation and return to baseline. This is what "normally happens when the danger is past, the infection is contained, the living environment is improved, or the speech has been given" (161). However, there are at least four other scenarios, each could exacerbate the allostatic load. These include (a) repeated activations with excessive frequency, (b) failure to habituate (i.e., show a gradually attenuating response to a familiar stressor), (c) delayed and slow recovery and return to baseline, and (d) failure of a system to respond, resulting in compensatory or unregulated activation of other systems. Essentially relaying a similar message, Chrousos and Gold (162) have focused on the "chronicity" and "excessiveness" of the stress response as its most pathogenic elements:

Generally, the stress response is meant to be acute or at least of a limited duration.

The time-limited nature of this process renders its accompanying anti-anabolic, catabolic, and immunosuppressive effects temporarily beneficial and of no adverse consequences. *Chronicity* and *excessiveness* of stress system activation, on the other hand, would lead to the syndromal state that Selye described in 1936.(162)

Stress, Obesity, and the Metabolic Syndrome: Possible Mechanisms

Hypercortisolemia has frequently been associated with adiposity, particularly visceral adiposity (12, 163, 164). Visceral fat accumulation can be viewed as a pathological adaptation to stress (165) as it is particularly sensitive to cortisol, perhaps due to the high density and apparent sensitivity of glucocorticoid receptors in this region. Hypercortisolaemia creates favorable conditions for increased lipoprotein lipase (LPL) and hormone sensitive lipase (HSL) activity,

the chief enzymes involved in the conversion of triglycerides to free fatty acids in circulation, and intracellularly, respectively. LPL is responsible for increasing the amount of triglycerides at the adipocyte (166) and because insulin resistance often manifests concurrently with visceral adiposity, the increased circulating insulin exerts antilipolytic effects and decreased lipid mobilization (166). Likewise, cortisol appears to have a stimulatory effect on LPL activity when insulin is present (167). Chronic hypersecretion of cortisol may lead to impaired feedback and resistance, which is similar to the situation with insulin resistance. HSL imparts its most deleterious effect in the development of atherosclerotic plaque. Atherogenesis involves the uptake of lipoproteins by macrophages, which in turn leads to cellular accumulation of cholesterol and formation of foam cells or fatty streaks (168). This process may be exacerbated in persons with a dysregulated or hyperactive stress response given that glucocorticoids stimulate the esterification of sterols in smooth muscle (169). Complementary to the dysregulation of the HPA axis, the SAM axis also plays a role in the pathogenesis of metabolic syndrome, particularly with regard to visceral obesity. Obese individuals with dysregulated HPA axis also have increased SAM activity, suggesting that stress great enough to promote visceral obesity may be in the causal pathway (170). Additionally, visceral obesity is associated with a greater basal SAM activity compared to peripheral obesity or subcutaneous abdominal obesity (164). The presence of hypertension within the metabolic syndrome symptomatology appears to intensify further sympathetic reactivity compared to non-hypertensive metabolic syndrome diagnosis (171). Although the relationships between stress and markers of the metabolic syndrome have been well demonstrated in adults (163, 172-175), little evidence is available in children (13, 14, 176). Additional research is necessary to confirm if the adult hypothesis may also be applicable to youth.

PHYSICAL ACTIVITY, EXERCISE, AND STRESS

The cross-stressor adaptation hypothesis questions if the adaptations to one kind of stressor (i.e., exercise or physical activity) are applicable when subjected to other sources of stress and the generalized system is activated (33). Sothmann et al. (32) conducted an extensive review and concluded that an acute bout of exercise sufficient to elicit an improvement in aerobic fitness generally can also elicit a stress response. Sothmann et al. also suggest that hormones secreted by the HPA and SAM systems are generally lower at the same exercise load after only a few weeks of training. Likewise, training results in increased production and storage of epinephrine and norepinephrine and subsequent increased responsiveness to maximal exercise (32). Sothmann et al. concluded that exercise training provides a beneficial adaptation to the threshold and also the magnitude to which the stress response is activated during exercise bouts.

Evidence regarding the applicability of an exercise-stress-training effect on non-exercise stressors is less clear. Several adult studies have examined stress response and aerobic fitness or activity, and results have been summarized in three separate meta-analyses (27-29). Given the methodological immaturity of this line of research, these adult investigations are far from conclusive, but do provide evidence that aerobic physical activity and fitness impart physiological benefits beyond metabolic health improvements.

Very few studies have examined the relationship between physical activity and stress-related variables (i.e., perceived stress, anxiety, depression, self-esteem, etc.) in children and adolescents. The majority of available literature has focused on habitual physical activity or exercise bouts without a specific focus on activity that would influence aerobic fitness. Because these studies apparently have not focused specifically on resistance or strength training, it is reasonable to assume that the physical activity examined was, at least to some degree, aerobic.

Brown et al. (25) found that as exercise frequency increased, the relationship between stress and disease decreased. Furthermore, Strauss et al. (26) demonstrated significantly lower self-esteem in the areas of behavior, happiness, intellectual, and popularity aspects in 9 to 16 year old adolescents who were less active. Parfitt and Eston (19) found recently that habitual physical activity was negatively related to anxiety and depression ($r = -0.48$ and -0.60 , respectively,) and positively associated with global self-esteem ($r = 0.66$) in children. Likewise, Motl et al. (31) used latent class modeling to examine patterns of change in physical activity and depressive symptoms over a two year period. Results from this study suggest that the secular decline in physical activity is inversely associated with increases in reported depressive symptoms. These studies provide preliminary evidence to confirm the inverse relationship between stress and physical activity.

An exercise training study by Norris et al. (177) provides some experimental evidence for the inverse relationship between stress and fitness in youth. Norris and colleagues (177) compared the influence of three different training regimes (low intensity, high intensity, and flexibility) and a control group on psychological stress in a group of adolescents ($N=60$). The training protocol lasted ten weeks. The high ($n=14$) and low ($n=15$) intensity groups exercised at 70-75% and 50-60%, respectively, of their age-predicted heart rate max for 25-30 minutes, twice per week. The flexibility group ($n=15$) participated in stretching exercises, accompanied by music. Stress was assessed using Cohen's Perceived Stress scale and anxiety was assessed using the Multiple Affect Adjective Checklist. Results showed that the high intensity group was the only one to show fitness improvements. Furthermore, this group reported less perceived stress than the other groups after training ($p<0.05$) and less anxiety than the moderate intensity group after training ($p<0.05$) (177).

High aerobic fitness may also modify the relationship between stress and disease. Only one study to date has examined fitness as a moderator between stress and disease in youth. Guskowska (34) examined health-related fitness using the International Test of Physical Fitness, as opposed to examining aerobic fitness exclusively. This study utilized an inventory developed by the author to quantify the number of stressful events experienced by the participants in the previous two weeks. Likewise, health status and major life events and daily hassles as a source of stress perceived by adolescents were also assessed by taking an inventory of the somatic complaints reported in the previous two weeks and an overall rating of health. When examining this health rating as an outcome variable, a significant main effect for stress level ($F_{(1,250)} = 8.39, p < 0.0001$) and gender ($F_{(1,250)} = 9.97, p < 0.0001$) was observed, suggesting self-rated health was better in those who were less stressed and in boys compared to girls. Also in this model, an interaction between physical fitness and gender was reported by the authors ($F_{(1,250)} = 4.88, p = 0.03$), where boys with higher fitness exhibited higher ratings of health. No differences were observed in girls. The authors interpreted this significant interaction as physical fitness acting as a resource in boys that improves mood, psychological well-being, and subjective health (34). This study provides some preliminary evidence of the effect modifying potential of physical fitness. Because aerobic fitness is considered the most viable in terms of warding poor metabolic health, this relationship requires additional examination with particular emphasis on aerobic fitness and aerobic activities.

Discrepancy in the literature regarding the applicability of an exercise-stress-training effect on non-exercise stressors may be due to the high individual variability in the perception and appraisal of the stressor (178). Lazarus (22) suggests that the perception and appraisal of a stressor is based on previous experiences and encounters with similar stressors and dictates the

stress response and subsequent coping mechanism employed. It may be that exercise and physical activity serve as coping resources by providing an escape from a stressful condition. This notion aligns with Dienstbier's (1979) concept of "physiological toughness," which suggests that exercise provides a rapid and robust sympathetic nervous system and catecholamine "pulse" that helps the individual cope effectively and efficiently with the challenge at hand, a low basal rate and a muted HPA axis response, and a quick return to baseline. Of note in this model is that the magnitude of the SAM reactivity is considered beneficial rather than maladaptive and having relatively little pathogenic potential, which has been the focus of most research on the exercise-stress relationship. Consistent with McEwen's (1998) notion of allostatic load, Dienstbier believes an inadequate initial response, a slow, protracted, or incomplete recovery, and the inability to habituate across multiple exposures to the same stressor have the greatest pathogenic potential. According to Dienstbier, the "obvious avenue toward "toughening" is a program of aerobic exercise,"(1979) which he contends can bring about most of the adaptations considered critical in this model.

Lazarus (1993) has identified eight general coping resources which have not been examined thoroughly in youth. Very little work has explored the coping resources employed by children and adolescents. Additional research is needed to identify if exercise and physical activity are coping strategies used by this age group and, if so, what the implications on health outcomes such as metabolic syndrome might be.

PHYSICAL ACTIVITY, STRESS, AND THE METABOLIC SYNDROME

Some researchers have begun to examine variables that could potentially modify the stress-obesity/metabolic syndrome relationship in youth. Physical activity has been shown to modify the relationship between stress and obesity (20) and a metabolic syndrome composite score (17). This line of research is relatively new, and researchers have not investigated the possibility that it may have been the aerobic benefit achieved by the physical activity that was the modifying influence. Yin and colleagues (20) examined the relationship of personal and community stress and physical activity with adiposity in 303 individuals, aged 12 and 24 years. Physical activity was assessed via self-report as the number of days per week during which physical activity was sufficient to work up a sweat and stress was assessed using the Adolescent Resource Challenge Scale. Adiposity was assessed as waist circumference, sum of three skinfolds, and BMI. After controlling for possible confounders, personal stress was associated with the body mass index but not with physical activity. Further the interaction of both personal and community stress with physical activity significantly predicted adiposity measures. These interaction terms accounted for 2- 3% of the variance in adiposity measures, with the total models accounting for no more than 15% and 22%.

More convincing evidence for the positive influence of aerobic activity is observed in the study by Holmes et al. (17) In this study, physical activity was assessed via accelerometry as minutes per day of moderate-to-vigorous physical activity. In this study, school- and sports-related self-esteem (negatively), as well as trait-anxiety (positively) were significantly associated with the metabolic risk score ($r = -0.64, -0.53, 0.53$, respectively) in the low physical activity group. Conversely, none of the stress variables were associated with the metabolic risk score in the high physical activity group (17). These preliminary studies suggest that aerobic physical

activity may exert its beneficial effects not only by raising energy expenditure but also by attenuating the relationship of psychosocial stress to obesity and the metabolic syndrome.

SUMMARY AND CONCLUSIONS

The irrefutable consequences of childhood obesity and metabolic syndrome make disentangling the causal pathways involved in the etiology of these conditions a high-priority issue for the public health community. This review examined the relationships between obesity and related co-morbidities during childhood and adulthood as well as the relationship between physical activity and aerobic fitness. Further, this review explored the labyrinthine relationships that exist between these variables and entertained the notion that multiple antecedents influence each other and contribute to the development of obesity and metabolic syndrome. Understanding the variegated relationships between the factors that influence either side of the energy balance equation is critical for effective prevention and treatment strategies. Future research should continue to explore variables that augment the traditional concept of energy balance. Focus should be directed to behaviors with influence that transcends multiple putative contributors to obesity.

Examining the role of stress as a significant antecedent of these conditions is important given the cyclic potential of this relationship, particularly in children. Obese children are more likely to be teased or bullied (180, 181). Consequently, these children may experience more frequent activation of the stress response and possibly a greater volume of stress. Identifying and employing coping strategies through physical activity have the potential to improve the perception and appraisal of stressful conditions while simultaneously promoting healthy metabolic function. This is particularly important in adolescents where behaviors and attitudes

are still developing and timely interventions could translate into long-term, positive health outcomes in adulthood.

CHAPTER 3

RESEARCH METHODS

We examined middle school students (grades 7-8) who were enrolled in physical education in the fall/spring of 2010/11 in a public school district in close proximity to Michigan State University. All students (n=200) enrolled in physical education in the first and second semester were invited to participate in the study. An informational letter to obtain parental consent for participation in the study was sent home with students. Subject assent was obtained prior to data collection. This study was approved by the Michigan State University Institutional Review Board. The middle school setting was chosen for reasons of ease of facilitation. We established a rapport with the school previously during a three-year service project that involved similar testing.

General Procedures: The graduate student investigator (MH) reviewed procedures with all participants at the beginning of each data collection session. The initial assessment session included measures of anthropometry and resting blood pressure, and took place during physical education classes during a normal school day. Students also completed questionnaires designed to assess stress and coping resources. Participants completed all questionnaires during physical education class. A final evaluation consisted of a finger stick assessment of fasting lipids and glucose. Additionally, accelerometers were distributed in four major waves throughout the period of data collection, with the first wave distributed on the first day of the initial assessment. A detailed description of each measure is provided below.

Anthropometry: Stature and body mass were measured according to standard procedures (182). Stature was measured with a portable stadiometer with the subject standing erect, without shoes, 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 assessed and body fatness was estimated using a foot-to-foot bioelectric impedance digital scale (Tanita Corporation, Tokyo, Japan). Given its non-invasive nature and feasibility, bioelectric impedance is commonly used as an indicator of body composition in youth (183, 184). Stature and body mass were used to calculate BMI as kg/m^2 . Because abdominal obesity is a key feature in the metabolic syndrome, waist circumference was assessed as a measure of central adiposity. Waist circumference was measured in duplicate immediately above the iliac crest (National Institutes of Health recommendation) to the nearest 0.1 cm using a Gulick tape. All anthropometry measures were assessed behind a privacy screen. All waist circumference measures were assessed by a single technician (MH). Measures of height and sitting height were assessed primarily by MH and two assistants (LH and AP) who underwent anthropometry training for other concurrent projects in our lab. Additionally, prior to each day of data collection for the present study, assistants reviewed measurement protocols, practiced, and confirmed their values were in agreement with those of MH.

Because the age range of the subjects spans the period of puberty and numerous body size and physiological functions and capacities vary by pubertal status (185), an indicator of biological maturity status was assessed (for potential analysis as a covariate) via the maturity offset method as outlined by Mirwald et al. (186). The maturity offset technique is a non-invasive method of indicating biological maturity. Anthropometric variables are used to create a value that is aligned to the estimated years away from peak height velocity (APHV) (e.g., -1.5 yrs, etc.).

Fitness Assessment: MH and research assistants helped the physical education instructor to facilitate fitness assessments using the FitnessGram test battery (187). FitnessGram protocol

requires assessment of cardio-respiratory fitness, muscular strength and endurance, flexibility, and body composition.

The Progressive Aerobic Cardiovascular Endurance Run (PACER 20-meter shuttle run) was used to determine cardio-respiratory fitness. A distance of 20 meters was measured on a gymnasium floor with lines marking each end. Each student ran back and forth to an audible cadence projected from a CD player. The prompts occur more rapidly as the test progresses and each 20-meter run counts as one lap. The test ends when participants are unable to maintain the proper cadence for two consecutive laps. Participants' scores were recorded as the number of laps completed during the test. Prior to testing, the PACER was explained and demonstrated by one of the investigators.

The curl-up test was used to assess abdominal strength and endurance. With knees bent at approximately 140°, heels flat on the floor, arms straight and parallel with the trunk, participants brought their upper bodies forward, curling up. One curl-up was defined as curling up from the start position and returning to the start position. Students were instructed to complete as many curl-ups as possible at a cadence of 20 per minute until they could no longer continue or had completed 81 curl-ups, which was the end of the recorded cadence.

Upper body strength and endurance were assessed using the 90° push-up test. Participants began in the prone position with hands placed under or slightly wider than the shoulders, legs straight and toes tucked under. Participants then pushed up until the arms were straight, while maintaining straight legs and back throughout the duration of the test. One 90° push-up was defined as lowering the body until the elbows were bent at a 90° angle and pushing back up until the arms were straight again. The test was scored as the number of 90° push-ups achieved before compromising form.

The sit and reach test was used to assess flexibility and required participants to sit on the floor with legs out straight in front and feet (shoes off) placed with the soles flat against the base of a sit and reach box. Arms were extended forward with the hands placed on top of each other. Participants were instructed to reach forward as far as possible without any jerky movements. Maximal flexibility was reported as inches reached.

FitnessGram utilizes criterion-referenced standards to dichotomize results of the testing into two categories, “healthy fitness zone” (HFZ) or “needs improvement” (187). For data analyses, fitness was examined as a) aerobic fitness (number of PACER laps completed) and b) dichotomously as a student being considered fit if s/he achieved the healthy fitness zone for aerobic fitness, body composition and one additional component (e.g., push-up, sit-ups, or sit-and-reach).

Blood pressure: An automated blood pressure cuff was used to collect systolic and diastolic blood pressures (SBP and DPB, respectively) in duplicate. SBP (mmHg) and DPB (mmHg) were used to calculate mean arterial pressure (MAP, mmHg): $(\text{systolic BP} - \text{diastolic BP}/3) + \text{diastolic BP}$. In order to insure resting values, subjects sat quietly for 5 minutes prior to assessment and this measure was taken prior to any other measures requiring physical exertion (188). An average of these measures was used for all calculations and analyses.

Physical activity: All participants were asked to complete the Physical Activity Questionnaire for Adolescents (PAQ-A) (189). PAQ-A is a self-administered 7-day recall tool that was designed to be completed in a classroom setting (189). The questionnaire consists of eight items that are scored on a 5-point scale and used to calculate a summary physical activity score, ranging 0-4. The summary physical activity score is calculated as the mean of these eight items and is considered a valid measure of general physical activity level (189).

Participants were also invited to wear the Sensewear Armband (SWA; BodyMedia, Pittsburgh, PA) as a second indicator of habitual free-living physical activity (190). The SWA is a wireless, non-invasive, multi-sensor activity monitor that is worn over the triceps muscle. The SWA monitor integrates data from five sensors including a bi-axial accelerometer, heat flux sensor, galvanic skin response (GSR) sensor, skin temperature sensor, and a near body ambient temperature sensor to estimate energy expenditure under free-living conditions. The heat-related sensors provide additional information about the energy cost of activity because periods of increased work are associated with increased heat production. The GSR sensor may also contribute to EE estimation because it detects changes in the skin's electrical properties due to sweat gland activity and psychological stimulus (periods of increased stimulus are associated with increased skin conductance). Direct contributions of heat indices and GSR in the prediction algorithms are not shared by the company but all five channels are used in estimations of EE (BodyMedia, personal communication). The SWA has been validated in young adults in standardized exercise sessions (191) and in children across a range of activities including: resting, coloring, playing computer games, walking on a treadmill (2, 2.5 and 3 mph) and stationary bicycling (192).

To ensure that the data reflected actual participant physical activity levels, detailed screening procedures were conducted to detect non-compliance with the protocol. Data for each day were examined to ensure that the device was worn for at least 480 minutes (8 hours). This is a typical protocol utilized when performing research with this age group (193-195). If compliance criteria were not achieved, then that particular day was excluded from the data analysis. Any participant with more than two missing weekdays or one missing weekend day was removed from analysis. Participants who missed more than two weekdays or one weekend

day were given the monitor a second time to obtain the missing days. We were able to obtain complete data on 7 of 15 repeat wearers. Data were examined using a t-test to ensure that participant physical activity did not differ between those who wore the monitor once or twice. The outputs from the device used for data analysis included minutes of moderate and vigorous physical activity per hour of wear time. These intensity levels were examined separately (i.e., MPA and VPA) and combined (i.e., MVPA) for descriptive purposes and combined for all statistical analyses.

Assessment of stress and coping resources: Because stress is an ubiquitous term and difficult to capture with a single indicator, we chose to use the Adolescent Stress Questionnaire (ASQ) (196) which is designed to assess ten dimensions of stress in adolescents: stress of home life, school performance, school attendance, romantic relationships, peer pressure, teacher interactions, future uncertainty, school and leisure time conflict, financial pressure, and emerging adult responsibility. The ASQ consists of 56 statements such as, “Disagreements between your parents” and “Peers hassling you about the way you look,” which subjects responded to using a 5-point Likert scale where 1 reflects “Not stressful at all.” and 5 indicates “Very stressful”. Alpha reliability coefficients for the dimensions of stress (stress of home life, school performance, school attendance, romantic relationships, peer pressure, teacher interactions, future uncertainty school and leisure time conflict, financial pressure, and emerging adult responsibility) have been demonstrated as $\alpha = 0.92, 0.88, 0.69, 0.86, 0.88, 0.87, 0.82, 0.86, 0.83,$ and 0.62, respectively for students aged 13-18 years in schools from diverse socio-economic conditions (196). The psychometric properties of the ASQ have been supported through concurrent validity analyses with anxiety, depression, and self-esteem as well as test-retest reliabilities for each of the dimensions of stress, ranging between 0.68 to 0.88 (196). Data can be

analyzed as individual scores for each subscale or totaled as an indicator of overall stress. The latter strategy was chosen for the present analysis and scores could range from 58-290 (196). Chronbach's alpha reliability coefficient was calculated for the total ASQ, because we chose to use the sum of all scales to represent stress in this sample ($\alpha = 0.96$).

Lazarus suggests that upon recognition of a stimulus, there is an appraisal process which individualizes the stress response and subsequently influences the coping response (21). To better explain the appraisal and coping processes of our subjects, we included the Ways of Coping Questionnaire (WCQ) (197, 198). A modified version has been used in this age group (199). The WCQ assesses five coping processes: problem-focused, wishful thinking, seeks social support, blamed self, and avoidance (alpha reliability coefficients are $\alpha = 0.82, 0.85, 0.75, 0.78$, and 0.74 , respectively in adults) (198). The WCQ requires the participant to recall his/her most stressful encounter in the previous week and consider that event as s/he answers a total of sixty-six questions such as "I criticized or lectured myself" and "I just concentrated on what I had to do next – the next step". Participants responded by recalling the stressful event and then indicating to what extent the statement was used by selecting "Does not apply or not used", "Used somewhat", "Used quite a bit", "Used a great deal" which corresponds with a 0-3 Likert scale. For present investigation, we chose to focus on the problem-focused scale as it has been the focus of similar investigations on coping strategies and health in this age group (200, 201). Chronbach's alpha reliability coefficient was only calculated for problem focused coping ($\alpha = 0.82$) in the present sample as it was the aspect of coping relevant to the aims of this study.

Assessment of additional metabolic syndrome variables: Subjects who consented to having additional metabolic syndrome variables assessed ($n=123$) via blood analysis were asked to abstain from eating breakfast on the day of assessment and reminder notes were sent home to

ensure a fasting sample. These variables included total cholesterol (TC, mg/dL), high density lipoprotein cholesterol (HDL-C, mg/dL), triglycerides (TG, mg/dL), and glucose (GLU, mg/dL). MH met students before school to collect a single finger stick blood draw and provide breakfast for participants. Blood sampling by finger stick (35 uL) was chosen for reasons of compliance and avoidance of undue stress for the study participant. Blood sample collection was conducted in accordance with the guidelines provided by the Michigan State University Office of Radiation, Chemical & Biological Safety (ORCBS) in order to minimize risk associated with blood borne pathogens. Upon collection, samples were analyzed using a portable analyzer according to the protocol of the manufacturer (Cholestech LDX System, Hayward, CA).

Derivation of the metabolic syndrome score. A composite risk factor, or metabolic syndrome score was derived by summing the age-standardized residuals (Z-scores) for GLU, MAP, HDL-C, TG and WC. These variables were chosen because they represent the same ones used in the adult clinical criteria and this variable has been used in recent work from our laboratory (17, 126, 202). Because the metabolic syndrome typically does not manifest until later in life and is a dichotomous variable, the use of a composite score is advantageous as it allows each subject to have a continuous value that is comparable to others in the study. A lower score is indicative of a better metabolic risk factor profile relative to the study sample.

Data Analysis: To assess Aim One, descriptive statistics were calculated for each variable for boys, girls, and the total sample. To assess Aim Two, linear regression analysis was used to determine the relationships between stress (as determined by the sum of the ten sub-scales of the Adolescent Stress Questionnaire) and metabolic syndrome related variables, controlling for chronological age, and gender. To assess Aim Three, linear regression analysis was used to determine the relationships between (problem-focused) coping resource and metabolic

syndrome-related variables, controlling for chronological age, and gender. Regression analyses were used to assess Aims Four and Five. Interaction terms between stress and physical activity and between coping resources and physical activity were created to determine the moderating influence of physical activity, controlling for maturity status, and gender. Regression analyses were used to assess Aims Six and Seven. Interaction terms between stress and health related fitness, and (problem-focused) coping resources and health related fitness were created to determine the moderating influence of health-related fitness, controlling for maturity status and gender.

Statistical power and sample size analyses. The ability to detect effect modification is considered the most power limited analysis (203). Therefore, power calculations were based on being able to evaluate Aims Four through Seven. With $\alpha = 0.05$ and power = 0.80, we assumed a minimum detectible effect size (MDES) of $F^2 = 0.067$. MDES was determined using previous research on this topic (17) and a statistical power and sample size calculator (204). For a medium effect size of $F^2 = 0.15$, 55 students are required for power = 0.80, $\alpha = 0.05$. For a small-to-moderate effect size of $F^2 = 0.07$, 115 students are required for power = 0.80, $\alpha = 0.05$.

CHAPTER 4

RESULTS

Participants

Consent was obtained from 136 of 200 (68%) middle school students. However, two students declined participation after consenting, and one moved prior to completion of data collection, reducing participant number to 133. In an effort to maintain a homogeneous sample, participants with preexisting conditions that might skew the results (e.g., insulin-dependent diabetes, Down Syndrome, etc.) were excluded from analyses ($n= 5$). Statistical criteria for outliers further reduced the sample, the details of which are discussed prior to discussion of the regression models. Final sample size was reduced to 126, which exceeded the minimum desired sample size according to power and sample size calculations sufficient to detect a small-moderate effect, determined a priori.

Key characteristics were selected to categorize those with incomplete data sets and then compared by category to assess the degree of attrition bias. Key characteristics included the presence of a metabolic syndrome score ($n= 11$ cases with missing data) and the presence of a physical activity assessment via SWA ($n= 14$ cases with missing data) (each coded yes or no). Independent variables assessed in each of these analyses were chosen because they are key variables that were collected in nearly all the sample (i.e., PAQ-A score, PACER laps, BMI, and stress). No statistically significant group differences between those with complete or incomplete metabolic syndrome score data sets were found when examining PAQ-A score ($t= 0.22$, $p= 0.82$), PACER laps ($t= -0.54$, $p= 0.59$), BMI ($t= 0.653$, $p=0.52$), and stress ($t= 0.14$, $p= 0.89$). Likewise, no statistically significant group differences between those with complete or incomplete physical activity assessment via SWA data sets were found when examining PAQ-A

score ($t = -1.29$, $p = 0.20$), PACER laps ($t = 1.72$, $p = 0.09$), BMI ($t = 0.20$, $p = 0.98$), and stress ($t = 0.96$, $p = 0.34$). These results suggest there was no statistically significant attrition bias for these variables.

Participant Characteristics

Participants were 7th and 8th grade students ($n = 126$, 55% male) from a local middle school. All study participants were enrolled in physical education class in the Fall 2010 and/or Spring 2011 semesters. The specific school was chosen for the study was based on its proximity to the investigators and a previously established collaborative relationship with the investigators. It should be noted that physical education is an elective course in this school district. The students at this school are primarily Caucasian (70%), with approximately 20% African-American, 5% Hispanic, and 5% Asian comprising the other ethnicities at the school. The middle school age range was chosen because this is a critical time of physical and emotional development that can lead to inappropriate behaviors and increased health risks. Participants in this study ranged in age between 12.2 and 15.5 years. Mean ages for boys and girls in this study were 13.5 and 13.3 years, respectively.

To address Aim 1, descriptive characteristics were calculated for all variables for boys, girls, and the total sample (Table 1a-c). Table 1a shows the results for anthropometric and metabolic data. Both boys and girls approximated the 50th percentile for height and the 75th percentiles for weight and BMI, respectively according to the 2000 CDC growth charts (205). Descriptive characteristics for boys and girls were similar, except boys were slightly older ($t = -2.08$, $p < .05$, $d = 0.62$) and taller ($t = -2.27$, $p < .05$, $d = 7.49$).

The majority of participants were average maturers and maturity status did not differ by gender (Table 1a). Likewise few variables of interest differed between early and late maturers. Late maturers completed more PACER laps compared to early maturers (65.8 vs. 39.7 laps, respectively) and did not perform as well on the sit-and-reach assessment (11.0 vs. 13.4 inches, respectively). Late maturers reported more physical activity via the PAQ-A (2.14 vs. 1.63, respectively). Additionally, late maturers exhibited a more favorable metabolic syndrome composite score than early maturers (-2.11 vs. 2.44, respectively), relative to the study sample.

There was very little gender difference among metabolic variables. Boys exhibited higher SBP compared to girls (113 mmHg vs. 109 mmHg, respectively; $t = -2.04$, $d = 12.32$ $p < 0.05$); however, no other gender differences were observed among the other metabolic variables. Mean values for blood pressure and blood lipids approximated the 50th to 75th percentiles, according to age- and gender-specific norms (188, 206). In a simple, exploratory search for potential outliers, we found four participants with triglyceride levels and two participants with SBP values greater than three standard deviations above the mean for each of those variables. However, when factored in as a component of the metabolic syndrome composite score, which was a primary outcome variable for this study, none of these participants met any criteria for outlier classification and, therefore, were not excluded.

Descriptive results for physical activity and health related fitness are shown in Table 1b. Analysis of PAQ-A data showed boys reported higher physical activity levels compared to girls (2.6 vs. 1.7, [out of 4] respectively; $t = -3.34$, $d = 0.72$, $p < 0.05$). Mean minutes of MVPA determined by the armband (SWA) exceeded the minimum recommendations (85) for both boys and girls and were nearly twice the national average (194), which may be reflective of our sample being drawn from students enrolled in physical education class. Gender differences were

not observed in MVPA as determined by the armband. However, when considering the components of MVPA, boys accumulated more VPA compared to girls (16.3 vs. 11.1 minutes respectively, $t = -2.03$, $d = 13.47$, $p < 0.05$).

Gender differences were present in some health-related components of fitness. Compared to girls, boys completed more PACER laps (67 vs. 44, respectively, $t = -6.46$, $d = 23.08$) and curl-ups (62 vs. 53, respectively; $t = -2.37$, $d = 22.51$, $p < 0.05$). However, girls performed better on the sit-and-reach test (13 vs. 11 inches, respectively; $t = 4.27$, $d = 3.06$, $p < 0.05$). On average, FitnessGram testing results were in the HFZ for all assessments. Likewise, the proportion of boys and girls in the present sample meeting the HFZ exceeded recently reported prevalences of Texas data in all variables except BMI in both boys and girls and push-ups in boys (207). Comparison of our results to those of Texas children is relevant, given that they are the only descriptive health related fitness data available which utilize the recently revised FitnessGram standards (207). Our subjects appear to be more fit compared to students from Texas, which may be reflective of our sample being drawn from students who elected to enroll in physical education class. When examining the psychosocial variables assessed in this study (Table 1c), girls reported higher stress ($t = 3.02$, $d = 40.38$, $p < 0.05$), but there was no difference in participant reported problem-focused coping scores.

Outlier screening

Before conducting any further analyses, data were screened for possible outliers. In accordance with procedures by Tabachnick and Fidell (203) one subject was excluded because the standardized residual for the primary outcome variables exceeded the acceptable range. After examination of Mahalanobis distances (203), one additional potential outlier was identified.

Outlier status was supported after additional examination of the Leverage value, which exceeded the acceptable level as determined by procedures according to Belsley, Kuh, and Welsch (208). To calculate the critical Leverage value, the following equation was used: Leverage (h): if $h > 2(k+1)/n$ (where k = # predictors). In all, these procedures resulted in the exclusion of two additional subjects, resulting in the final sample size of 126 participants.

Regression analyses

(Aims 2-3: Main Effects)

Multiple regression analysis was used to examine the relationship between stress and metabolic syndrome related variables (i.e., metabolic syndrome composite score, Table 2a, and BMI, Table 2b). Independent variables in these models included gender, APHV, and stress. Both models were significant ($p < 0.05$) with AVPH emerging as a significant predictor in both models ($\beta = 0.65$, $t = 9.28$, $p < 0.05$; and $\beta = 0.31$, $t = 3.56$, $p < 0.05$), for the metabolic syndrome composite score and BMI, respectively). Additionally, stress also emerged as a significant predictor of BMI ($\beta = 0.19$, $t = 2.09$, $p < 0.05$). Similarly, analyses examining problem-focused coping as a predictor of metabolic syndrome composite score or BMI were also both significant models with APHV emerging as a significant predictor ($\beta = 0.65$, $t = 9.26$, $p < 0.05$; and $\beta = 0.30$, $t = 3.37$, $p < 0.05$, for metabolic syndrome and BMI, respectively) (Tables 3a and b, respectively). Independent variables in these models included gender, APHV, and problem-focused coping.

Regression analyses

(Aims 4-5: Physical Activity as a Moderator)

Tables 4a and 4b show the results of regression analyses of the PAQ-A score and MVPA, respectively, and stress, on the metabolic syndrome composite score. Independent variables in these models included gender, APHV, physical activity (PAQ-A score and MVPA, respectively), stress, and a physical activity-stress interaction term. Both models significantly predicted metabolic syndrome composite score; however, the only significant predictor in either model was APHV ($\beta = 0.64$, $t = 8.97$, $p < 0.05$; and $\beta = 0.67$, $t = 9.01$, $p < 0.05$, for PAQ-A score and MVPA, respectively). Similar results were observed when examining the same independent variables (gender, APHV, physical activity via PAQ-A and MVPA, and stress) and BMI as the outcome variable (Tables 5a and 5b). Likewise, when including gender, APHV, physical activity (PAQ-A score and MVPA, respectively) and problem-focused coping as independent variables, significant relationships were observed when examining the metabolic syndrome composite score (Tables 6a and 6b) and BMI (Tables 7a and 7b) as outcome variables. In both of these models, APHV was the only significant predictor. ($\beta = 0.30$, $t = 3.44$, $p < 0.05$; and $\beta = 0.31$, $t = 3.34$, $p < 0.05$, for PAQ-A score and MVPA, respectively)

Regression analyses

(Aims 6-7: Health-Related Fitness as a Moderator)

Regression analysis was used to examine gender, APHV, aerobic fitness, and stress as predictors of the metabolic syndrome composite score yielded a significant model ($p < 0.05$). However, the only significant predictor was APHV ($\beta = 0.66$, $t = 9.37$, $p < 0.05$) (Table 8a). Likewise, multiple regression analysis of health-related fitness and stress on the metabolic syndrome composite score also yielded a significant model with APHV emerging as the only significant predictor ($\beta = 0.68$, $t = 9.45$, $p < 0.05$) (Table 8b). Table 9 shows the results of

regression analysis of aerobic fitness and stress on BMI. Gender, APHV, aerobic fitness, stress, and an interaction between aerobic fitness and stress were entered as independent variables in the model. This model was statistically significant ($p < 0.05$), however, the only significant predictors of BMI were gender ($\beta = 0.20$, $t = 2.16$, $p < 0.05$) and APHV ($\beta = 0.22$, $t = 2.77$, $p < 0.05$). In these models, neither stress nor fitness (aerobic and health-related) significantly influenced the metabolic syndrome composite score.

Regression analysis of aerobic fitness and problem-focused coping on the metabolic syndrome composite score was significant ($p < 0.05$) (Table 10a). In this model, gender, APHV, aerobic fitness, and problem-focused coping were examined as independent variables. The only significant predictor in this model was APHV ($\beta = 0.66$, $t = 9.28$, $p < 0.05$). Similarly, regression analysis of health-related fitness and problem-focused coping on the metabolic syndrome composite score also produced a significant model ($p < 0.05$) (Table 10b). Only APHV emerged as a significant predictor in this model ($\beta = 0.66$, $t = 9.28$, $p < 0.05$). Table 11 shows significant results of regression analysis examining the independent variables gender, APHV, aerobic fitness, problem-focused coping, and an interaction between aerobic fitness and problem-focused on BMI ($p < 0.05$). APHV ($\beta = 0.22$, $t = 2.64$, $p < 0.05$) and aerobic fitness as determined by PACER laps ($\beta = -0.53$, $t = -2.86$, $p < 0.05$) were significant predictors in this model. These results suggest that maturity status imparts a larger and more consistent influence metabolic syndrome related variables compared to the other variables examined.

Summary of Results

Our results suggest physical activity, stress, and problem-focused coping have little influence on the metabolic syndrome composite score or BMI in this sample. Maturity status

(i.e., APHV) was consistently observed as a significant predictor of metabolic syndrome related variables. The statistically significant influence of maturity status on our outcome variables is not surprising. Metabolic syndrome is a progressive condition development of which begins in early adolescence (69-71). Likewise, the influence of maturity status on BMI is also not surprising as increases in BMI are typical of normal growth and maturation. However, one main effects model showed stress to be a significant predictor of BMI in this sample (Table 2b). Likewise, individual models showed a main effect of physical activity (Table 7b) and aerobic fitness as determined by pacer laps (Table 11).

CHAPTER 5

DISCUSSION

Metabolic syndrome is a comprehensive indicator of health and, given the increasing prevalence in children and adolescents (45), is viewed as a serious public health concern. Considerable attention has focused primarily on two behavioral factors associated with metabolic syndrome, diet and physical activity energy expenditure. Because these two variables leave a considerable portion of the variance in the metabolic syndrome phenotype unexplained, investigation of the pathogenic potential of factors that extend beyond the traditional concept of energy imbalance has intensified. One intriguing line of research implicates perturbations in the stress response system and the putative role that dysregulation may have on the development of obesity and metabolic syndrome. This relationship has been well established in the adult literature (6-9), and is receiving increased attention in pediatric work (12-15). An increased focus on mental health determinants such as stress is warranted given the marked increase of psychotropic medication prescription and physicians' office visits for treatment of emotional and behavioral problems in youth (23, 24), particularly when considering the favorable relationship between physical activity and/or fitness and stress. Researchers have generally demonstrated an inverse relationship between physical activity and/or fitness and stress-related measures (27-30). Likewise, the relationship between stress and metabolic syndrome may be influenced by physical activity and/or fitness; however, literature addressing this potential effect modification is sparse but promising (17, 20). Physical activity and fitness may improve metabolic health by directly influencing risk factors associated with the metabolic syndrome, as well as providing a healthy coping resource that may serve to moderate the relationship between stress and poor metabolic health. Identifying these relationships is critical as we continue to refine and develop new

strategies for addressing childhood obesity by providing effective coping skills through positive health habits.

This dissertation had three major foci, 1) to describe metabolic syndrome-related variables, physical activity, health-related fitness, psychosocial stress, and problem-focused coping resources in a sample of middle-school students, 2) to examine the relationship between psychosocial health and metabolic syndrome related variables, and 3) to investigate the possible moderating effect of physical activity and health-related fitness on this relationship.

Participant Characteristics (Aim 1)

Participants were 7th and 8th grade students (n= 126) from a local middle school. All were enrolled in physical education class in the Fall 2010 and/or Spring 2011 semesters. The middle school age range was chosen because this is a critical time of physical and emotional development that can lead to inappropriate behaviors and increased health risks. The specific school chosen for the study was based on its proximity to the investigators and a previously established collaborative relationship with the investigators. Because of the close partnership between the physical education instructor and the investigators, the research project was carried out in a way that augmented many of the lessons taught during a normal school day. This unique collaboration allowed for ease of facilitation of the project and a longstanding welcome at the school.

Participants were of average height (50th percentile) and slightly above average weight and BMI (75th percentile) according to the CDC growth charts (205). Likewise, mean values of physiologic and metabolic characteristics (e.g., blood pressure, cholesterol, etc.) approximated

the 50th to 75th percentiles, according to age- and gender-specific norms (188, 206). Mean minutes of MVPA determined by the armband exceeded the minimum daily recommendations (85) and were nearly twice the national average (194). On average, FitnessGram testing results were in the HFZ for all assessments. Likewise, the proportion of boys and girls in the present sample meeting the HFZ exceeded recently reported prevalences of Texas youth in all variables except BMI in both boys and girls and push-ups in boys (207). Comparison of our results to those of Texas children is relevant, given that they are the only descriptive health-related fitness data available which utilize the recently revised FitnessGram standards (207). Our subjects appear to be more active compared to national samples and more fit compared to students from Texas. Overall, our study participants were metabolically healthy, active, and fit which may be reflective of our sample being drawn from students enrolled in physical education class.

Given the lack of consensus in methodology linking stress measures with poor metabolic health in youth, we chose to build upon previous work from our lab (17) that incorporated a broad-based approach to operationalize stress by assessing variables known to be related to the appraisal of the demands of daily life (e.g., trait-anxiety, depression, etc.) as well as variables that are known to affect the well-being of youth (e.g., self-esteem, appearance-related teasing, etc.). We sought to accomplish a similar broad-based approach, but do so using only two, more comprehensive assessment tools. The psychosocial variables assessed in this study were stress and problem-focus coping. We chose to measure stress as the sum of ten subscales (stress of home life, school performance, school attendance, romantic relationships, peer pressure, teacher interactions, future uncertainty, school and leisure time conflict, financial pressure, and emerging adult responsibility) that comprise the ASQ (196). The ten subscales meet the recommended criteria found in the psychology literature which suggests the assessment should capture stress

associated with family life and the participants' interaction with the environment in which they live (209). Similarly, the etiological significance of the stress appraisal process on health outcomes in children has also been noted as deserving additional attention (209). To address this knowledge gap, we used Lazarus and Folkman's Ways of Coping Questionnaire (WCQ) and we focused specifically on problem-focused coping (197-199). This focus was prompted by previous studies that have examined the relationship between problem-focused coping and health (200, 201).

Results from the present study showed greater reported stress in girls than boys which is typical of adolescents (210, 211) and adults (212, 213). Two studies to date have independently examined the validity of the ASQ (196, 214). The original validation study examined 1039 Australian boys and girls and used measures of anxiety, depression, and self-esteem as indicators of construct validity. ASQ scores were positively associated with anxiety and depression and negatively associated with self-esteem, suggesting the ASQ is a valid measure of stress (196). Likewise, demographic correlates of the ASQ showed reported stress was greater in girls than boys (196). The ASQ underwent a second validation when it was translated into a Norwegian version (ASQ-N) (214). Measures of anxiety and depression were positively associated with the ASQ-N and negatively associated with self-esteem in the Norwegian version (214). Further, the Norwegian version demonstrated similar gender differences as were observed in the original survey (214). Although there is no clear rationale for the gender differences, they are well recognized in the literature (196, 210-213). Further, these gender differences align with psychotropic medication prescription trends and physician office visits for the treatment of emotional problems in boys and girls (23, 24, 215). The similar gender patterning responses of

the current study provides some evidence of construct validity that the ASQ captured meaningful dimensions of stress in this sample.

Although gender differences in coping behaviors are not well-defined, the tendency to employ problem-focused coping strategies traditionally has been more apparent in males (216), which is in line with the notion that males are socialized to deal with adversities in a more action-oriented way (217). The role of socialization in the development of coping behaviors can be explained as social constraints differentially being presented to both genders that predisposes each gender to perceive and deal with adversity in a certain way (217). However, more recent investigations suggest that gender differences in coping strategies are becoming less significant as social roles continue to evolve (218, 219). In the present study, gender differences were not observed when examining problem-focused coping. Therefore, the results of the present study support literature suggesting gender differences may not be apparent in more contemporary assessments.

This dissertation was part of a larger research project in which resiliency was measured. In a separate analysis of these data, Holmes et al. (220) also did not observe gender differences when examining resiliency in this group. Resiliency is a measure of stress and coping ability (221) and is reflective of characteristics of those who thrive in the face of adversity. Resilient individuals are characterized as viewing stress as a challenge or an opportunity for improvement, having a greater tolerance to negative affect, and greater reliance on action-oriented approaches to problem solving (221). In the same report, Holmes et al. (220) note a significant positive correlation between problem-focused coping and resiliency. This relationship is consistent with literature regarding the link between coping strategies and resiliency (222) and provides some evidence of construct validity of the WCQ in the present analysis.

Psychosocial health and metabolic syndrome related variables (Aims 2-3)

As mentioned previously, it has been difficult to operationalize stress in a way that is methodologically feasible to examine relationships with health outcomes (10, 223). Stress is a ubiquitous term that includes identification of stressors, analysis of appraisal and subsequent employment of coping resources and reappraisal. Generally, the relationship between stress and health is examined using indicators of chronic stress or stress reactivity (see Holmes et al., for a review (10)). While the duration and frequency as well as the physiologic responses to a stressor are clearly important aspects of research examining the relationship between stress and metabolic health, this limited perspective does not capture the ubiquity of the stress concept. Further, the methodology used to examine these aspects varies across studies (see Holmes et al., for a review (10)). Investigations in youth provide an additional challenge when considering normal growth and maturation are recognized stressors (11). That is, when the speed and magnitude of these changes exceeds the adolescent's ability to cope, growth maturation and development can be an exacerbating influence that may confound the relationship between stress and metabolic health (11). Additional research is needed to elucidate the relationship between the stress and coping response and metabolic health in this age group. Particular attention should be directed towards the influence of growth and maturation on this relationship given its association with both variables.

Adult literature firmly establishes a relationship between stress, broadly defined as the adaptive responses that are the result of a disharmonious state when the threat to homeostasis exceeds a threshold (162), and poor metabolic health (6, 8, 10, 162). When this liberal definition

is applied to the pediatric literature, we can acknowledge an increased focus over the last decade when examining ‘stress-related’ variables such as physiologic markers (e.g., adrenocortical activity and cortisol levels (12-15, 224, 225) and cardiovascular reactivity (226)), chronic stress (20, 227), quality of life (18), and stress associated with home life (223, 228), depression (19, 225, 229-231), anxiety (17, 231), self-esteem (17, 230), and teasing (16, 17). The majority of literature in children and adolescents has been limited to examination of the relationship between these stress-related variables and BMI and has shown that the two are directly related. Although the majority of the evidence is restricted to BMI, the significance of examination of stress in youth is clear given the firmly established link between childhood BMI and adult obesity (56-59), hypertension (60-63), dyslipidemia (61-63), insulin resistance (64, 65), poor vascular health,(66, 67) and CVD and all-cause mortality (65, 68).

In the present study we examined the stress-metabolic health relationship using a multi-dimensional indicator of perceived stress (i.e., ASQ). To examine metabolic health, we chose to look at the most common indicator, BMI, and a more robust indicator of metabolic health by using a metabolic syndrome composite score. The metabolic syndrome composite score allows each participant to have a continuous value that is comparable to the health of the rest of the sample. We hypothesized a positive relationship between reported stress and BMI or the metabolic syndrome composite score in our sample which would be consistent with research to date (12-20, 223-231). Our results indicated that none of our models demonstrated a significant relationship between any measure of psychosocial health with the metabolic syndrome composite score and only one model showed a significant relationship between stress and BMI, which is inconsistent with previous studies. The departure of our findings from the current trend may be due partially to the gender differences in reported stress. Girls in the present study

reported significantly more stress than boys. The ASQ is a relatively new assessment tool with the current version published in 2007 (196). Although the difference in perceived stress is expected (196, 212), it may be that the ASQ is an effective tool to demonstrate the relationship between stress and health in girls and not boys. Unfortunately, this sample is not powered to examine the research questions in this way. Additional research with sample sizes sufficient to examine gender differences is warranted to determine the efficacy of the ASQ in both genders.

The degree to which stress influences health in boys may be better captured by examining other stress-related variables rather than perceived stress. For example, personality traits such as trait-anxiety have previously been associated with higher BMI or adverse metabolic health (17, 231) and is commonly used as a measure of construct validity for stress survey tools, as was the case with the instrument used in this present study (196). Anxiety is a negative emotional state characterized by nervousness, worry, and apprehension and is often considered in two main facets, state- and trait-anxiety (232). State-anxiety refers to the transient, emotional state of nervousness, worry, and apprehension, whereas trait-anxiety refers to a behavioral disposition to perceive situations that are objectively not dangerous as threatening and respond with a disproportionate state-anxiety (232, 233). Individuals with high trait-anxiety are more likely to have a chronically activated stress response system, and thus may be more susceptible to the adverse effects of stress on certain diseases. Although trait-anxiety was related to the ASQ tool used in this study, it may be that examination of a propensity to be anxious may be more relevant to health-related research.

Aggression is another aspect of personality that deserves additional attention, particularly in boys. Trait aggressiveness is described as a propensity to engage in acts of aggression, a proneness to anger as well as to hold hostile beliefs about other people across situations (234,

235). American boys (aged 2-17) spend an average of thirteen hours per week playing video games (236). The bulk of video games being played by children and adolescents contain violent content (237) which is of particular concern given that the playing of violent video games has been shown to increase aggressive behaviors, thoughts, emotions and decrease prosocial behavior (238, 239). Aggression is linked with stress and the stress response in that the HPA axis plays a key regulatory role of aggressive behavior (240). Briefly, greater HPA activity, which is associated with greater arousal, is thought to be the underlying mechanism of sudden outbursts of aggression (241). Alternatively, lower HPA activity is also associated with aggression in that it is associated with hypoarousal that may result in more permanent changes in brain functions that are associated with violence (241). This perspective of the stress response and allostasis only partially describes possible adaptations as described by McEwen (161). McEwen suggests that the normal course of events in the process of "allostasis" (i.e., adapting to changing demands) consists of an appropriately sized stress response of the SAM and HPA axes to help us deal with the demand, immediately followed by a rapid deactivation and return to baseline (161). McEwen also describes other scenarios that could exacerbate the allostatic load including (a) repeated activations with excessive frequency, (b) failure to habituate (i.e., show a gradually attenuating response to a familiar stressor), (c) delayed and slow recovery and return to baseline, and (d) failure of a system to respond, resulting in compensatory or unregulated activation of other systems. Investigation into the role of aggression in these other allostatic scenarios could be a viable avenue for exploration as we continue to refine stress assessment methodology in children and adolescents.

The second indicator of psychosocial health assessed in this study was problem-focused coping which can be described as behavior aimed at solving the problem associated with a

stressor. We hypothesized that problem-focused coping would be associated with more favorable metabolic health in the present sample, as it has been consistently associated with better metabolic control in adolescents with Type I diabetes (209, 242). In the present study, we did not observe a significant relationship between problem-focused coping and metabolic health or BMI. This finding is consistent with findings from The Amsterdam Growth and Health Study (200). Participants in The Amsterdam Growth and Health Study were surveyed on their coping strategies and type A behavior twice in early adulthood (mean ages 21 and 27 years). Body fat (distribution via subscapular-triceps skinfold ratio and sum of four skinfolds) and a number of personality traits (e.g., inadequacy, dominance, etc.) were assessed six times between the ages of 13 and 27 years. Coping strategies (problem-focused or otherwise) were not related to fatness at any time point. However, associations between central fat distribution with type A behavior and some personality traits associated with type A behavior (e.g., dominance and rigidity) were observed (200).

The current study only examined one aspect of coping, problem-focused. Additional investigation is warranted to identify if any other coping strategies (i.e., distancing, self-controlling, seeking social support, accepting responsibility, escape or avoidance, playful problem-solving, and positive reappraisal) may influence metabolic health. One perspective in the literature describes these coping strategies as serving discrete functions and, in a given stressful situation, the behaviors of an individual serves multiple coping functions to attenuate distress (243). Because adolescence is a time when individuals experience many novel stressful situations, without established coping behaviors, future research endeavors may find it beneficial to examine coping from this more complex perspective. The survey tool designed to capture this

perspective is the A-COPE (243). The A-COPE integrates individual coping theory and family stress theory in a single tool to assess coping behaviors and style in adolescents (243).

Perhaps the method by which we cope with stress is not as influential on our metabolic health as is the overall product of the interaction between stress and our coping, or our resiliency. As previously mentioned, resiliency is a measure of stress and coping ability and is reflective of characteristics of those who thrive in the face of adversity (221). Little is known about the relationship between resiliency and metabolic health beyond what can be inferred from stress and coping literature. Examination of resiliency in future studies may provide a unique perspective as represents the outcome of the interaction between stress and coping and it warrants further investigation.

Moderating effect of physical activity and health-related fitness (Aims 4-7)

The evidence supporting the favorable relationship between physical activity or fitness and metabolic health is well established in youth (97-104). As mentioned previously, evidence linking ‘stress-related’ and poor metabolic health in youth has been increasing (12-20, 223-231). Further, the favorable relationship between psychosocial factors and physical activity is accepted by the scientific community as evidenced by the section devoted to this relationship in the 2005 Evidence Based Physical Activity Recommendations (30). These apparent univariate relationships have prompted some researchers to investigate how these three variables may be related within a system of complex interactions.

Literature addressing the moderating potential of physical activity and health-related fitness is sparse but promising (17, 20, 34). In 2005, Yin and colleagues (20) examined the relationship of personal and community stress and physical activity with adiposity in 303

individuals, aged 12 and 24 years. Physical activity was assessed via self-report as the number of days per week during which physical activity was sufficient to work up a sweat, and stress was assessed using the Adolescent Resource Challenge Scale. Adiposity was assessed as waist circumference, sum of three skinfolds, and BMI. After controlling for possible confounders, personal stress was associated with the body mass index but not with physical activity. Further, the interaction of both personal and community stress with physical activity significantly predicted adiposity measures. These interaction terms accounted for 2-3% of the variance in adiposity measures, with the total models accounting for 22% of the variance. The age range of this study includes the ages examined in this dissertation. However, the mean age of subjects in the Yin et al. study was 16.6 years (20), which is more than three years older than the mean age of students who participated in this dissertation. Perhaps the beneficial influence of physical activity and fitness may impart on the deleterious association between stress and metabolic health is better observed later in adolescence.

Additional evidence for the positive influence of physical activity is observed in the study by Holmes et al. (17). This study pursued a considerably different conceptual and methodological approach than the Yin study that allows evaluation of this issue from a different but complementary perspective. Rather than focusing only on adiposity, the authors chose to study the metabolic syndrome in the form of a composite score. Because it reflects a broader spectrum of risk factors, a metabolic syndrome composite score is presumably a more robust indicator of overall metabolic and cardiovascular health than any single measure of adiposity. Additionally, the authors acknowledge the issues of operationalizing stress in this age group by utilizing a broad-based approach to measuring stress. Key variables known to be related to the appraisal of the demands of daily life (i.e., perceived stress, anxiety, depression, self-esteem), as

well as variables known to influence the well-being of school-age youth (i.e., appearance-related teasing) were assessed using a number of self-report indices. In this study, physical activity was assessed via accelerometry as minutes per day of moderate-to-vigorous physical activity. In the Holmes et al. study, school- and sports-related self-esteem (negatively), as well as trait-anxiety (positively) were significantly associated with the metabolic risk score ($r = -0.64, -0.53, 0.53$, respectively) in the low physical activity group. Conversely, none of the stress variables were associated with the metabolic risk score in the high physical activity group, suggesting a moderating influence of increased physical activity (17). Although the sample in the Holmes et al. study was small ($n = 37$), it was apparently more unhealthy compared to the present sample. The present sample had a lower prevalence of overweight (38% vs. 43%), lower blood pressure (MAP, 77 mmHg vs. 87 mmHg), higher HDL cholesterol (50.8 vs. 44.4 mg/dL), and more active (85 vs. 78 minutes of MVPA/day) compared to the Holmes et. al study. One plausible explanation for the absence of significant associations between psychosocial and metabolic health as well as the absence of any moderating influence of physical activity and fitness in the present study could be participants' health. Study participants may have lacked sufficient variance in our indices of metabolic health such that a relationship with psychosocial variables could not be observed.

Fitness has also demonstrated some viability as a moderator on the stress-metabolic health relationship (34). Guskowska (34) examined health-related fitness in a group of Polish adolescents using the International Test of Physical Fitness and stress using an inventory developed by the author to quantify the number of stressful events experienced by the participants in the previous two weeks. Likewise, health status and major life events and daily hassles as a source of stress perceived by adolescents were also assessed by taking an inventory

of the somatic complaints reported in the previous two weeks and an overall rating of health. When examining this health rating as an outcome variable, a significant main effect for stress level ($F = 8.39$, $p < 0.0001$) and gender ($F = 9.97$, $p < 0.0001$) was observed, suggesting self-rated health was better in those who were less stressed and in boys compared to girls. Also in this model, an interaction between physical fitness and gender was reported by the authors ($F = 4.88$, $p = 0.03$), where boys with higher fitness exhibited higher ratings of health. No differences were observed in girls. The authors interpreted this significant interaction as physical fitness acting as a resource in boys that improves mood, psychological well-being, and subjective health (34).

The present study failed to show a relationship between psychosocial stress and coping and metabolic health and was also unable to observe an influence of physical activity or health-related fitness on the psychosocial-metabolic health relationship. We feel these results were not likely due to measurement error by the study technicians given their substantial training prior to data collection. However, any small amount of measurement error that may have occurred during data collection was not likely to differentially bias the results.

Although we did not observe our hypothesized relationships, the line of inquiry examining a moderating influence of physical activity and fitness on this relationship still holds merit and should not be abandoned. Additional work should focus on identifying indices of stress that might be most relevant to metabolic health among youth with particular attention to gender differences. Girls and boys report perception of stress at varying levels (196, 212) and it is likely tailoring assessment tools to address gender differences in stress may better illustrate the relationship between stress and health. Future researchers examining gender differences may find it beneficial to examine biomarkers such as cortisol as biological differences in gender may be more apparent when examining endocrinologic functions. However, obtaining a

comprehensive indicator of dysregulation of the stress as described by McEwen (161) requires multiple sampling over a specified time period, the methods and caveats of which are discussed in the Holmes et. al. (10).

Summary and Conclusions

This dissertation sought to expand the current body of knowledge regarding child and adolescent health by examining metabolic syndrome-related variables, physical activity, health-related fitness, psychosocial stress, and problem-focused coping resources and investigate the relationships that may exist between these variables in a sample of middle-school students. Results from the present investigation suggest physical activity and psychosocial variables (i.e., stress and problem-focused coping) imparted little influence on the metabolic syndrome composite score or BMI in this sample. The consistent, statistically significant influence of maturity status (i.e., APHV) on metabolic syndrome related variables yields little novel clinical significance. As noted earlier, metabolic syndrome is a progressive condition, the origins of which begin in adolescence and continue to adulthood (69-71). Similarly, increases in BMI are a part of normal growth and maturation, thus an influence of maturity status on BMI is not surprising. Given that maturity status was consistently a significant predictor of metabolic syndrome related variables in all of our models and the metabolic syndrome score was significantly different between early, average, and late maturers, it may be advantageous for researchers to examine possible differences in the strength of association between psychosocial and metabolic syndrome variables between maturity statuses. Although few significant relationships were observed, this study was an important step in our understanding of the complex system of interactions that relates psychosocial, physical, and metabolic health. Our

results suggest the need for continued methodological refinement, particularly regarding stress assessment in this age group. A critical step in elucidating the relationship between stress and health in youth requires identification and concise descriptions of indices of stress that are most relevant to metabolic health among youth. As previously mentioned, adolescence is a tumultuous time in life throughout all areas of development. Indicators of greater volumes of stress or ineffective practices in dealing with stress that have potential to be pathogenic over time must be examined through the course of adolescence and into adulthood to better understand their influence on metabolic health. Indicators of greater volumes of stress may be enhanced by indicators of personality traits that may be unique in certain groups (e.g., aggression in boys) as they may also identify opportunities for intervention (e.g., violence in video games). Likewise, indicators of ineffective practices in dealing with stress, or coping, may benefit from further examination of resiliency. Given that resiliency is the product of the interaction between stress and coping, examination of this variable may provide a more comprehensive indication of the influence stress has on health.

As we continue to investigate the etiological sequelae of obesity and metabolic syndrome, a multi-factorial perspective is essential to develop better-formulated prevention and treatment strategies. The possibility of improving metabolic health through physical activity may be twofold: 1) physical activity can directly influence the risk factors associated with the metabolic syndrome, and 2) physical activity may provide effective coping skills through positive healthy habits. This is particularly important in adolescents where behaviors and attitudes are still developing and timely interventions could translate into long-term, positive health outcomes in adulthood.

Table 1a. Anthropometric and metabolic descriptive characteristics of the sample.

	<u>Boys (n=69)</u>	<u>Girls (n=57)</u>	<u>Total (n=126)</u>
Anthropometric Variables			
Age (yrs)	13.5 (0.7)*	13.3 (0.6)	13.4 (0.6) 12.2-15.5
Ht (cm)	162.5 (8.3)*	159.6 (6.3)	161.2 (7.6) 139.2-184.2
Age at PHV (yrs)	12.4 (1.3)	12.1 (0.9)	12.3 (1.2) 8.7-15.33
Body mass (kg)	57.5 (14.7)	55.8 (13.2)	56.8 (14.0) 33.5-100.3
BMI (kg/m ²)	21.6 (4.3)	21.8 (4.5)	21.7 (4.4) 14.1-39.3
WC (cm)	73.5 (11.9)	73.5 (11.7)	73.5 (11.8) 55.2-113.1
Overweight	37.7%	38.6%	38.1%
Metabolic Variables			
SBP (mmHg)	113.6 (13.3)*	109.1 (11.0)	111.6 (12.5) 78-156
DBP (mmHg)	59.8 (6.7)	60.4 (5.3)	60.1 (6.1) 46-76
MAP (mmHg)	77.7 (8.0)	76.7 (6.1)	77.2 (7.2) 57-102
Glucose (mg/dL)	93.0 (9.0)	90.1 (9.6)	91.7 (9.3) 72-124
Total Cholesterol (mg/dL)	143.2 (24.4)	143.5 (25.2)	143.3 (24.7) 97-206
HDL Cholesterol (mg/dL)	51.3 (15.1)	50.3 (11.9)	50.8 (13.7) 22-97
Triglycerides (mg/dL)	92.6 (72.2)	101.8 (52.9)	96.9 (63.9) 45-412
Metabolic Syndrome Composite Score	0.39 (3.3)	-0.46 (2.6)	0.01 (3.0) -6.0-6.2

* $p < 0.05$ for gender difference

Values are mean (SD) and range values for boys, girls, and total sample. Due to non-participation of some subjects in the finger stick portion of the study, glucose, total cholesterol, HDL Cholesterol, Triglycerides, and the metabolic syndrome composite score have a slightly smaller sample size (n= 115, total; 62, boys; and 53, girls)

Ht, height; PHV, peak height velocity; BMI, body mass index; WC, waist circumference; SBP, systolic blood pressure; DBP, diastolic blood pressure; MAP, mean arterial pressure; HDL-C, high density lipoprotein cholesterol

Table 1b. Physical activity and health related fitness descriptive characteristics of the sample.

	<u>Boys (n=69)</u>	<u>Girls (n=57)</u>	<u>Total (n=126)</u>
Physical Activity			
PAQ-A score (0-4)	2.6 (0.8)*	1.7 (0.7)	2.0 (0.7)
MVPA (min/hr)	11.4 (5.2)*	8.9 (4.4)	10.3 (5.0) 0-265
Moderate PA (min/hr)	9.3 (4.1)*	7.5 (3.3)	8.5 (3.9) 1.5-19.9
Vigorous PA (min/hr)	2.1 (1.6)*	1.4 (1.7)	1.8 (1.7) 0.01-10.1
Health Related Fitness			
PACER (laps)	67 (27)*	44 (18)	55 (26) 6-118
Curl-ups	62 (24)*	53 (21)	58 (23) 2-81
Push-ups	16 (9)	14 (5)	15 (8) 0-50
Sit-and-Reach (in)	11 (3)*	13 (3)	12 (3) 4-22
Body Fat (%)	26.9 (12.5)	27.4 (8.3)	27.2 (10.8) 5.0-56.0

* $p < 0.05$ for gender difference

Values are mean (SD) and range values for boys, girls, and total sample. Due to non-participation of some subjects in portions of physical activity and fitness assessments sample size varies (n= 112-126 for the total sample; 62-69 for boys; and 50-57 for girls)

MVPA, moderate to vigorous physical activity

Table 1c. Psychosocial descriptive characteristics of the sample.

	Boys (n=69)	Girls (n=57)	Total (n=126)
Psychosocial Variables			
Total stress (58-290)	121.7 (34.2)*	144.1 (46.8)	131.8 (41.8) 58-258
Problem-focus coping (0-45)	18.5 (9.3)	17.7 (7.4)	18.1 (8.5) 0-45

* $p < 0.05$ for gender difference

Values are mean (SD) and range values for boys, girls, and total sample.

Table 2a. Multiple Regression of Stress on the Metabolic Syndrome Composite Score.

	B	β	<i>p</i>
Gender	0.20	0.03	0.64
APHV	2.97	0.65	0.0001*
Stress	-0.001	-0.02	0.82

F= 30.09*, $R^2 = 0.41$

* $p < 0.05$

APHV, years away from peak height velocity

Table 2b. Multiple Regression of Stress on BMI.

	B	β	<i>p</i>
Gender	-0.22	-0.03	0.78
APHV	2.05	0.31	0.001*
Stress	0.20	0.19	0.04*

F= 5.45*, $R^2 = 0.10$

* $p < 0.05$

APHV, years away from peak height velocity

Table 3a. Multiple Regression of Problem-focused Coping on the Metabolic Syndrome Composite Score.

	B	β	<i>p</i>
Gender	0.22	0.04	0.59
APHV	2.96	0.65	0.0001*
Problem-focused Coping	-0.002	-0.01	0.95

F= 30.07*, $R^2 = 0.41$

* $p < 0.05$

APHV, years away from peak height velocity

Table 3b. Multiple Regression of Problem-focused coping on BMI.

	B	β	<i>p</i>
Gender	-0.64	-0.07	0.41
APHV	1.98	0.30	0.001*
Problem-focused Coping	-0.003	-0.06	0.95
F= 3.85*, $R^2 = 0.06$			
* $p < 0.05$			

APHV, years away from peak height velocity

Table 4a. Multiple Regression of Physical Activity Questionnaire Score and Stress on the Metabolic Syndrome Composite Score.

	B	β	<i>p</i>
Gender	0.15	0.03	0.74
APHV	2.92	0.64	0.0001*
PAQ-A Score	-0.16	-0.04	0.86
Stress	-0.01	-0.09	0.67
PAQ-A Score x Stress	0.02	0.10	0.73
F= 17.14*, $R^2 = 0.39$			
* $p < 0.05$			

PAQ-A, Physical Activity Questionnaire for Adolescents; APHV, years away from peak height velocity

Table 4b. Multiple Regression of Moderate-to-Vigorous Physical Activity and Stress on the Metabolic Syndrome Composite Score.

	B	β	<i>p</i>
Gender	0.08	0.01	0.86
APHV	3.07	0.67	0.0001*
MVPA	0.13	0.22	0.17
Stress	0.01	0.09	0.41
MVPA x Stress	-0.001	-0.20	0.20

F= 18.49*, $R^2 = 0.45$

* $p < 0.05$

MVPA, Moderate-to-Vigorous Physical Activity; APHV, years away from peak height velocity

Table 5a. Multiple Regression of Physical Activity Questionnaire Score and Stress on Body Mass Index.

	B	β	<i>p</i>
Gender	-0.20	-0.02	0.81
APHV	2.03	0.30	0.001*
PAQ-A Score	2.05	0.35	0.22
Stress	0.05	0.45	0.08
PAQ-A Score x Stress	-0.01	-0.40	0.27

F= 3.39*, $R^2 = 0.09$

* $p < 0.05$

APHV, years away from peak height velocity

Table 5b. Multiple Regression of Moderate-to-Vigorous Physical Activity and Stress on Body Mass Index.

	B	β	<i>p</i>
Gender	0.11	0.01	0.90
APHV	2.12	0.31	0.001*
MVPA	-0.04	-0.04	0.85
Stress	0.03	0.24	0.08
MVPA x Stress	-0.001	-0.15	0.46

F= 3.78*, $R^2 = 0.11$

* $p < 0.05$

MVPA, Moderate-to-Vigorous Physical Activity; APHV, years away from peak height velocity

Table 6a. Multiple Regression of Physical Activity Questionnaire Score and Problem-focused Coping on Metabolic Syndrome Composite Score

	B	β	<i>p</i>
Gender	0.12	0.03	0.32
APHV	2.98	0.64	0.0001*
PAQ-A Score	-0.40	-0.10	0.52
Problem-focused Coping	-0.06	-0.17	0.38
PAQ-A Score x Problem-focused Coping	0.03	0.24	0.34

F= 17.39*, $R^2 = 0.40$

* $p < 0.05$

PAQ-A, Physical Activity Questionnaire for Adolescents; APHV, years away from peak height velocity

Table 6b. Multiple Regression of Moderate-to-Vigorous Physical Activity and Problem-focused Coping on Metabolic Syndrome Composite Score.

	B	β	<i>p</i>
Gender	0.10	0.02	0.83
APHV	3.09	0.67	0.0001*
MVPA	0.02	0.04	0.78
Problem-focused Coping	-0.004	-0.01	0.92
MVPA x Problem-focused Coping	0.00003	0.01	0.99

F= 17.88*, $R^2 = 0.44$

* $p < 0.05$

MVPA, Moderate-to-Vigorous Physical Activity; APHV, years away from peak height velocity

Table 7a. Multiple Regression of Physical Activity Questionnaire Score and Problem-focused Coping on Body Mass Index.

	B	β	<i>p</i>
Gender	-0.74	-0.09	0.37
APHV	1.97	0.29	0.002*
PAQ-A Score	0.23	0.04	0.85
Problem-focused Coping	-0.01	-0.02	0.94
PAQ-A Score x Problem-focused Coping	0.004	0.02	0.95

F= 2.20, $R^2 = 0.05$

* $p < 0.05$

PAQ-A, Physical Activity Questionnaire for Adolescents; APHV, years away from peak height velocity

Table 7b. Multiple Regression of Moderate-to-Vigorous Physical Activity and Problem-focused Coping on Body Mass Index.

	B	β	<i>p</i>
Gender	-0.32	-0.04	0.71
APHV	2.11	0.31	0.001*
MVPA	-0.36	-0.40	0.02*
Problem-focused Coping	-0.09	-0.17	0.23
MVPA x Problem-focused Coping	0.01	0.25	0.19

F= 3.37, $R^2 = 0.10$

* $p < 0.05$

MVPA, Moderate-to-Vigorous Physical Activity; APHV, years away from peak height velocity

Table 8a. Multiple Regression of Aerobic Fitness and Stress on the Metabolic Syndrome Composite Score.

	B	β	<i>p</i>
Gender	-0.20	-0.03	0.69
APHV	3.06	0.66	0.0001*
PACER laps	0.03	0.30	0.20
Stress	0.01	0.10	0.54
PACER laps x Stress	0.0001	-0.17	0.50

F= 4.02*, $R^2 = 0.12$

* $p < 0.05$

APHV, years away from peak height velocity

Table 8b. Multiple Regression of Health Related Fitness and Stress on the Metabolic Syndrome Composite Score.

	B	β	<i>p</i>
Gender	0.14	0.02	0.76
APHV	3.17	0.68	0.0001*
Health Related Fitness	2.23	0.37	0.12
Stress	0.004	0.06	0.50
Health Related Fitness x Stress	-0.01	-0.24	0.31

F= 18.71*, $R^2 = 0.42$

* $p < 0.05$

APHV, years away from peak height velocity

Table 9. Multiple Regression of Aerobic Fitness and Stress on Body Mass Index.

	B	β	<i>p</i>
Gender	1.76	0.20	0.03*
APHV	1.50	0.22	0.01*
PACER laps	-0.07	-0.44	0.11
Stress	0.02	0.15	0.40
PACER laps x Stress	0.0001	-0.04	0.88

F= 9.13*, $R^2 = 0.25$

* $p < 0.05$

APHV, years away from peak height velocity

Table 10a. Multiple Regression of Aerobic Fitness and Problem-focused Coping on Metabolic Syndrome Composite Score

	B	β	<i>p</i>
Gender	-0.24	-0.04	0.62
APHV	3.06	0.66	0.0001*
PACER laps	0.02	0.18	0.27
Problem-focused Coping	0.01	0.02	0.90
PACER laps x Problem-focused Coping	0.0001	0.001	0.84

F= 18.65*, $R^2 = 0.42$

* $p < 0.05$

APHV, years away from peak height velocity

Table 10b. Multiple Regression of Health Related Fitness and Problem-focused Coping on Metabolic Syndrome Composite Score.

	B	β	<i>p</i>
Gender	0.19	0.03	0.65
APHV	3.13	0.67	0.0001*
Health Related Fitness	1.15	0.19	0.25
Problem-focused Coping	0.01	0.02	0.81
Health Related Fitness x Problem-focused Coping	-0.02	-0.06	0.72

F= 18.38*, $R^2 = 0.42$

* $p < 0.05$

APHV, years away from peak height velocity

Table 11. Multiple Regression of Aerobic Fitness and Problem-focused Coping on Body Mass Index.

	B	β	<i>p</i>
Gender	1.54	0.18	0.06
APHV	1.46	0.22	0.01*
PACER laps	-0.09	-0.53*	0.01*
Problem-focused Coping	-0.02	-0.03	0.86
PACER laps x Problem-focused Coping	0.0001	0.05	0.83

F= 8.46*, $R^2 = 0.23$

* $p < 0.05$

APHV, years away from peak height velocity

APPENDICES

APPENDIX A

Permission



East Lansing Public Schools

Nurturing each student, educating all students, building world citizens

C.E. MacDonald Middle School
Learning for all...All for learning

Merem B. Frierson, Principal
John Atkinson, Associate Principal
Linda McDonald, Counselor

September 28, 2010

To Whom It May Concern,

This letter is to verify that I have given Megan Holmes permission to work with the Physical Education Department at MacDonald Middle School to conduct her research project. She will primarily be working with Terri Cregg, our lead instructor of that department.

Sincerely,

Merem B. Frierson
Principal

1601 Burcham Dr., East Lansing, MI 48823
(517) 333-7600, e-mail Frierson_MB@elps.us, fax (517) 333-5098

APPENDIX B

Consent Forms

Physical Activity and Fitness: Moderators of the Stress-Metabolic Syndrome Relationship?

Parental Consent

The purposes of this research study are to examine the relationship between stress and metabolic syndrome (cardiovascular disease risk factors) and determine the influence physical activity and fitness have on this relationship. Participating in this study involves your child's usual attendance to his/her physical education class, wearing of an activity monitor for one week, and early arrival to school one morning for a fasting finger stick (breakfast will be provided). All in-class assessments will require approximately 2 class periods. The finger stick will require approximately 30 minutes of time right before school begins. The activity monitor will need to be worn all day for one week. All measures will be spread out over the course of the semester.

- Your child will be completing the FitnessGram fitness testing as part of MacDonald Middle School's established curriculum. The FitnessGram testing that your child would normally do as part of regular PE class consists of the PACER (or beep) test for aerobic fitness, sit ups and push ups for muscular strength and endurance and the sit-and-reach for flexibility. We are asking permission to use this data and add to it by also measuring height, weight, sitting height (to estimate leg length), waist circumference, body composition using a portable bioelectrical body composition analyzer via Bioelectrical impedance analysis (BIA), and resting blood pressure. We will take 2 measures of resting blood pressure with an automated cuff (both on the same day) so that we can average them. The BIA machine measures ohms of resistance and reactance and we use this information to calculate percent body fat. These measures will all be done during PE class on a regular school day. There will be stations set up in the gym for each of these measurements through which your child will rotate.
- Your child will also be asked to complete three separate questionnaires about the sources of stress in his/her life and how s/he copes with it and one brief questionnaire about physical activity. These questionnaires will all be done during PE class on a separate, regular school day. On both of these days, study personnel will be present at PE class to help facilitate data collection and participate in the regularly scheduled PE activity following the completion of data collection.
- Your child will also be asked to wear an activity monitor for one week as an additional measure of physical activity. The monitor is worn on the arm (like an mp3 player) from the time your child gets up in the morning until the go to bed at night for seven days. The use of this monitor does not require your child to do anything out of the ordinary aside from wear the monitor. The monitor measures movement and provides a more detailed estimate of your child's daily physical activity. We will send additional information home when the monitors are distributed.
- The final component of the study is a check of your child's fasting blood lipids and sugar. We ask that your child not eat or drink anything before arriving to school on the morning of the finger stick. We will meet your child at the gym and collect a single drop of blood for on-the-spot analysis of blood lipids and glucose. Breakfast will be provided upon completion of the stick.

There is little known risk involved with participating in this study, aside from the known risk of injury associated with doing physical activities. However, risks from participating in this study are no greater than those associated with participation in a normal physical education class or normal play. The main source of discomfort in this study is associated with the finger stick for assessment of fasting blood glucose and lipids. In accordance with the Office of Radiation, Chemical & Biological Safety (ORCBS) guidelines, we will clean the finger with an alcohol wipe prior to the finger stick and place a bandage on it after the stick. Additionally, we will use a lancet that is designed to minimize discomfort associated with the finger stick (Ultrasoft Lancet, OneTouch, LifeScan Inc).

The direct benefits to your child for participating in this study are knowledge of his/her current height, weight, blood lipids, and blood sugar, all of which are important health indicators. Results from all assessments will be made available to parents/guardians upon request. If any abnormal findings are observed, parents/guardians will be notified immediately. In the future, adolescents will benefit from this study because the results will provide a better understanding of the development of obesity and metabolic syndrome, which, in turn, can be used to better formulate prevention and treatment strategies, by providing effective coping skills through positive healthy habits.

All students will receive a T-shirt for participating in any portion of the study. Additionally, students will receive small trinket incentives (e.g., Silly Bandz) or larger incentives (e.g. drawstring tote bag) for participating in each portion of the study on the day they participate. Your child's participation is voluntary, and s/he is free to withdraw at any time, without penalty. S/he may also refuse to participate in portions of the study without penalty. We will do everything possible to protect your child's privacy (to the maximum extent allowed by law) and will not include your child's name in any of the publications resulting from this study. All of your child's data will be kept in locked file cabinets or password-protected computer files. To further insure anonymity, your child will be assigned a participant identification number which will be associated with their data. A key linking your child's name with their identification number will be kept in a separate, password-protected file to which only the project investigators will have access. This key will be kept until all of the data has been collected and analyzed and then it will be destroyed. The only individuals who will have access to the data are the study investigators, and the MSU Institutional Review Board.

If your child is injured as a result of participation in this research project, Michigan State University will assist you in obtaining emergency care, if necessary, for your research related injuries. If you have insurance for medical care, your insurance carrier will be billed in the ordinary manner. As with any medical insurance, any costs that are not covered or in excess of what are paid by your insurance, including deductibles, will be your responsibility. The University's policy is not to provide financial compensation for lost wages, disability, pain or discomfort, unless required by law to do so. This does not mean that you are giving up any legal rights you may have. You may contact Jim Pivarnik, Principal Investigator, at (517) 353-3520 with any questions or to report an injury.

This consent form was approved by the Biomedical and Health Institutional Review Board (BIRB) at Michigan State University. Approved 12/15/10 – valid through 12/14/11. This version supersedes all previous versions. IRB# 10-1177.

If you have concerns or questions about this study, such as scientific issues, how to do any part of it, or to report an injury, please contact Jim Pivarnik, Principal Investigator, at (517) 353-3520, 27 IM Sports Circle Building, Michigan State University, East Lansing, MI 48824-1049, jimpiv@msu.edu; or Megan Holmes, Project Coordinator at (308) 641-3576, 27 IM Sports Circle Building, Michigan State University, East Lansing, MI 48824-1049, holmes58@msu.edu.

If you have questions or concerns about your role and rights as a research participant, would like to obtain information or offer input, or would like to register a complaint about this study, you may contact, anonymously if you wish, the Michigan State University's Human Research Protection Program at 517-355-2180, Fax 517-432-4503, or e-mail irb@msu.edu or regular mail at 207 Olds Hall, MSU, East Lansing, MI 48824.

Your signature below means that you voluntarily agree to allow your child to participate in this research study.

Name of parent/guardian

Signature of parent/guardian

Signature of Investigator

Date

Contact Information:

Home Phone: _____

Alternative/Cell Phone: _____

Address: _____

This consent form was approved by the Biomedical and Health Institutional Review Board (BIRB) at Michigan State University. Approved 12/15/10 – valid through 12/14/11. This version supersedes all previous versions. IRB# 10-1177.

Physical Activity and Fitness: Moderators of the Stress-Metabolic Syndrome Relationship?

Child Assent

Your parent or guardian has said it is okay for you to be in this research study. The project is about the relationship between stress and risk factors for cardiovascular disease and seeing how physical activity and fitness influence this relationship. We will be coming to visit you in PE class periodically through the semester. When we visit, you will be asked to do the following:

1. FitnessGram testing is part of PE class at MacDonald Middle School. FitnessGram tests include the PACER (or beep) test for aerobic fitness, sit ups and push ups for muscular strength and endurance and the sit-and-reach for flexibility. We are asking permission to use this information and add to it with the rest of the measures listed below.
2. We will measure your height, weight, sitting height (to estimate leg length), waist circumference, body composition, and resting blood pressure. We will measure body composition with a monitor that measures electrical conductivity. Then, we use this information to calculate body fat. We will be measuring your resting blood pressure twice with an automated cuff. You will also be asked to complete 3 separate questionnaires about the sources of stress in your life and how you cope, or deal with it as well as 1 short questionnaire about your physical activity. We will be doing all of these things during PE class on a couple days.
3. We also ask you to wear an activity monitor for a week. This monitor is worn on the arm (like an mp3 player) and lets us take a closer look at your physical activity. If you are asked to wear a monitor, we will explain how to wear it in PE class and send home some extra information at that time.
4. We will meet you before school for a finger stick check of your fasting blood lipids and sugar. Because we ask that you do not eat or drink anything before arriving to school that morning, we will provide breakfast after the finger stick.

Being in this project is up to you. You can choose to quit or stop at any time, and you can decide that you do not want to do some of the things that are part of the study. No one will be upset if you don't want to be in the project and you won't get in trouble. Only the people from MSU will see any of your information.

All students will receive a T-shirt for participating in any portion of the study. Additionally, you will receive small incentives (e.g., Silly Bandz) or larger incentives (e.g. drawstring tote bag) for participating in each portion of the study on the day you participate.

Your signature below means that you voluntarily agree to participate in this research study.

Name of participant

Signature of participant

Signature of Investigator

Date

This consent form was approved by the Biomedical and Health Institutional Review Board (BIRB) at Michigan State University.
Approved 12/15/10 – valid through 12/14/11. This version supersedes all previous versions. IRB# 10-1177.

APPENDIX C

Adolescent Stress Questionnaire (ASQ)

Adolescent Stress Questionnaire

Please read each item below and indicate, by using the following rating scale, to what extent each stressor has affected you in the past year.

1= Not at all stressful 2= A little stressful 3= Moderately stressful
4= Quite stressful 5=Very Stressful

- _____ 1. Arguments at home.
- _____ 2. Difficulty with some subjects.
- _____ 3. Going to school.
- _____ 4. Abiding by petty rules at home.
- _____ 5. Being ignored or rejected by the person you want to go out with.
- _____ 6. Breaking up with your boy/girl-friend.
- _____ 7. Lack of trust from adults.
- _____ 8. Pressure of study.
- _____ 9. Getting along with your boy/girl-friend.
- _____ 10. Not enough time for activities outside of school hours.
- _____ 11. Disagreements between you and your teachers.
- _____ 12. Having to take on new family responsibilities with growing older.
- _____ 13. Not enough money to buy the things you want.
- _____ 14. Concern about your future.
- _____ 15. Little or no control over your life.
- _____ 16. Making the relationship with your boy/girl-friend work.
- _____ 17. Work interfering with school and social activities.
- _____ 18. Having to make decisions about future work or education.
- _____ 19. Being judged by your friends.
- _____ 20. Changes in your physical appearance with growing up.
- _____ 21. Living at home.
- _____ 22. Having to concentrate too long during school hours.
- _____ 23. Having too much homework.
- _____ 24. Lack of respect from teachers.
- _____ 25. Employers expecting too much from you.
- _____ 26. Abiding by petty rules at school.
- _____ 27. Parents hassling you about the way you look.
- _____ 28. Getting up early in the morning to go to school.
- _____ 29. Disagreements between your parents.
- _____ 30. Having to take on new financial responsibilities with growing older.
- _____ 31. Not being listened to by teachers.
- _____ 32. Being hassled for not fitting in.
- _____ 33. Not being taken seriously by your parents.
- _____ 34. Not having enough time for your boy/girl-friend.
- _____ 35. Satisfaction with how you look.
- _____ 36. Teachers hassling you about the way you look.
- _____ 37. Pressure to make more money.
- _____ 38. Having to study things you are not interested in.
- _____ 39. Disagreements between you and your peers.
- _____ 40. Compulsory school attendance.

- 1= Not at all stressful 2= A little stressful 3= Moderately stressful**
4= Quite stressful 5=Very Stressful
- _____ 41. Keeping up with your schoolwork.
 - _____ 42. Lack of freedom.
 - _____ 43. Getting along with your teachers.
 - _____ 44. Not enough money to buy the things you need.
 - _____ 45. Peers hassling you about the way you look.
 - _____ 46. Disagreements between you and your mother.
 - _____ 47. Having to study things you do not understand.
 - _____ 48. Not having enough time for fun.
 - _____ 49. Putting pressure on yourself to meet your future goals.
 - _____ 50. Lack of understanding by your parents.
 - _____ 51. Teachers expecting too much from you.
 - _____ 52. Pressure to fit in with peers.
 - _____ 53. Parents expecting too much from you.
 - _____ 54. Not getting enough timely feedback on schoolwork.
 - _____ 55. Not getting enough time for leisure.
 - _____ 56. Disagreements between you and your father.
 - _____ 57. Lack of school resources.
 - _____ 58. Disagreements between you and your brothers and sisters.

APPENDIX D

Way of Coping Questionnaire (WCQ)

Ways of Coping

To respond to the statements in this questionnaire, you must have a specific stressful situation in mind. By stressful, we mean a situation that was difficult or troubling for you, either because you felt distressed about what happened, or because you had to use considerable effort to deal with the situation. Take a few moments and think about the most stressful situation you have experienced in the last week.

Was the situation about (Mark all that apply):

_____ School _____ Family _____ Social Relationships _____ Work
_____ Recreational Activity _____ Health _____ Financial _____ Other

Did the situation involve (Mark all that apply):

_____ Just You _____ Parents _____ Siblings _____ Other Relatives
_____ Peers _____ Friends _____ Boyfriend/Girlfriend _____ Teacher
_____ Coach _____ Boss _____ Adult Supervisor _____ Other

Please read each item below and indicate, by using the following rating scale, to what extent you used it in the situation you have just thought of and described.

0 = Not used 1 = Used somewhat 2 = Used quite a bit 3 = Used a great deal

- _____ 1. Just concentrated on what I had to do next – the next step.
- _____ 2. I tried to analyze the problem in order to understand it better.
- _____ 3. Turned to work or substitute activity to take my mind off things.
- _____ 4. I felt that time would make a difference – the only thing to do was to wait.
- _____ 5. Bargained or compromised to get something positive from the situation.
- _____ 6. I did something which I didn't think would work, but at least I was doing something.
- _____ 7. Tried to get the person responsible to change his or her mind.
- _____ 8. Talked to someone to find out more about the situation.
- _____ 9. Criticized or lectured myself.
- _____ 10. Tried not to burn my bridges, but leave things open somewhat.
- _____ 11. Hoped a miracle would happen.
- _____ 12. Went along with fate; sometimes I just have bad luck.
- _____ 13. Went on as if nothing had happened.
- _____ 14. I tried to keep my feelings to myself.
- _____ 15. Looked for the silver lining, so to speak; tried to look on the bright side of things.
- _____ 16. Slept more than usual.
- _____ 17. I expressed anger to the person(s) who caused the problem.
- _____ 18. Accepted sympathy and understanding from someone.
- _____ 19. I told myself things that helped me to feel better.
- _____ 20. I was inspired to do something creative.
- _____ 21. Tried to forget the whole thing.
- _____ 22. I got professional help.
- _____ 23. Changed or grew as a person in a good way.
- _____ 24. I waited to see what would happen.
- _____ 25. I apologized or did something to make up.

0 = Not used 1 = Used somewhat 2 = Used quite a bit 3 = Used a great deal

- _____ 26. I made a plan of action and followed it.
- _____ 27. I accepted the next best thing to what I wanted.
- _____ 28. I let my feelings out somehow.
- _____ 29. Realized I brought the problem on myself.
- _____ 30. I came out of the experience better than when I went in.
- _____ 31. Talked to someone who could do something concrete about the problem.
- _____ 32. Got away from it for a while; tried to rest or take a vacation.
- _____ 33. Tried to make myself feel better by eating, drinking, smoking, using drugs or medication, etc.
- _____ 34. Took a big chance or did something very risky.
- _____ 35. I tried not to act too hastily or follow my first hunch.
- _____ 36. Found new faith.
- _____ 37. Maintained my pride and kept a stiff upper lip.
- _____ 38. Rediscovered what is important in life.
- _____ 39. Changed something so things would turn out all right.
- _____ 40. Avoided being with people in general.
- _____ 41. Didn't let it get to me; refused to think too much about it.
- _____ 42. I asked a relative or friend I respected for advice.
- _____ 43. Kept others from knowing how bad things were.
- _____ 44. Made light of the situation; refused to get too serious about it.
- _____ 45. Talked to someone about how I was feeling.
- _____ 46. Stood my ground and fought for what I wanted.
- _____ 47. Took it out on other people.
- _____ 48. Drew on my past experiences; I was in a similar situation before.
- _____ 49. I knew what had to be done, so I doubled my efforts to make things work.
- _____ 50. Refused to believe that it had happened.
- _____ 51. I made a promise to myself that things would be different next time.
- _____ 52. Came up with a couple of different solutions to the problem.
- _____ 53. Accepted it, since nothing could be done.
- _____ 54. I tried to keep my feelings from interfering with other things too much.
- _____ 55. Wished that I could change what had happened or how I felt.
- _____ 56. I changed something about myself.
- _____ 57. I daydreamed or imagined a better time or place than the one I was in.
- _____ 58. Wished that the situation would go away or somehow be over with.
- _____ 59. Had fantasies or wishes about how things might turn out.
- _____ 60. I prayed.
- _____ 61. I prepared myself for the worst.
- _____ 62. I went over in my mind what I would say or do.
- _____ 63. I thought about how a person I admire would handle this situation and used that as a model.
- _____ 64. I tried to see things from the other person's point of view.
- _____ 65. I reminded myself how much worse things could be.
- _____ 66. I jogged or exercised.

APPENDIX E

Physical Activity Questionnaire for Adolescents (PAQ-A)

Physical Activity Questionnaire

Now, we would like to find out about your level of physical activity in the past week (last 7 days). Physical activity refers to sports or dance that make you sweat or make your legs feel tired, or games that make you breathe hard like tag, running, climbing, etc... There are no right or wrong answers. Please answer all the questions honestly and accurately.

- Physical activity in your spare time: have you done any of the following activities in the past 7 days (last week)? If yes, how many times? Circle the appropriate number of times you have completed each activity. Circle only one in each row.

Skipping	No	1-2	3-4	5-6	7+
Rowing/canoeing	No	1-2	3-4	5-6	7+
Rollerblading	No	1-2	3-4	5-6	7+
Tag	No	1-2	3-4	5-6	7+
Walking for exercise	No	1-2	3-4	5-6	7+
Bicycling	No	1-2	3-4	5-6	7+
Jogging or running	No	1-2	3-4	5-6	7+
Ice hockey	No	1-2	3-4	5-6	7+
Swimming	No	1-2	3-4	5-6	7+
Baseball, softball	No	1-2	3-4	5-6	7+
Dance	No	1-2	3-4	5-6	7+
Football	No	1-2	3-4	5-6	7+
Badminton	No	1-2	3-4	5-6	7+
Skateboarding	No	1-2	3-4	5-6	7+
Soccer	No	1-2	3-4	5-6	7+
Wrestling	No	1-2	3-4	5-6	7+
Volleyball	No	1-2	3-4	5-6	7+
Floor hockey	No	1-2	3-4	5-6	7+
Basketball	No	1-2	3-4	5-6	7+
Ice skating	No	1-2	3-4	5-6	7+
Cross-country skiing	No	1-2	3-4	5-6	7+
Other:_____	No	1-2	3-4	5-6	7+

- In the last 7 days, during physical education (PE) classes, how often were you very active (playing hard, running, jumping, throwing)? (check one only.)

I didn't do PE_____

 Hardly ever_____

 Sometimes_____

 Quite often_____

 Always_____

3. In the last 7 days, what did you normally do at *lunch* (besides eating)? (check one only.)

Sat down (talking, reading, doing school work)_____

Stood around or walked around_____

Ran or played a little bit_____

Ran around and played quite a bit_____

Ran and played hard most of the time_____

4. In the last 7 days, on how many days *right after school*, did you do sports, dance or play games in which you were very active? (check only one).

None_____

1 time last week_____

2 or 3 times last week_____

4 times last week_____

5 times last week_____

5. In the last 7 days, on how many *evenings* did you do sports, dance, or play games in which you were active? (check only one.)

None_____

1 time last week_____

2 or 3 times last week_____

4 times last week_____

5 times last week_____

6. During *the last weekend*, how many times did you do sports, dance, or play games in which you were very active? (check only one.)

None_____

1 time_____

2-3 times_____

4-5 times_____

6 or more times_____

7. Which *one* of the following describes you best for the last 7 days? Read *all five* statements before deciding on the *one* answer that best describes you. (check your answer.

_____ a. All or most of my free time was spent doing things that involve little physical effort.

_____ b. I sometimes (1-2 times last week) did physical things in my free time (such as played sports, went running, swimming, bike riding, did aerobics).

_____ c. I often (3-4 times last week) did physical things in my free time.

_____ d. I quite often (5-6 times last week) did physical things in my free time.

_____ e. I very often (7 or more times last week) did physical things in my free time.

8. Mark how often you did physical activity (like playing sports, games, doing dance, or any other physical activity) for each day last week. (circle only one for each day.)

Monday	None	Little bit	Medium	Often	Very Often
Tuesday	None	Little bit	Medium	Often	Very Often
Wednesday	None	Little bit	Medium	Often	Very Often
Thursday	None	Little bit	Medium	Often	Very Often
Friday	None	Little bit	Medium	Often	Very Often
Saturday	None	Little bit	Medium	Often	Very Often
Sunday	None	Little bit	Medium	Often	Very Often

9. Were you sick last week, or did anything prevent you from doing your normal physical activities? (check only one.)

Yes_____

No_____

If yes, what prevented you? _____

10. On a typical school day, how many total hours outside of school do you watch TV, view videos, work/play on the computer? (Check only one.)

- _____ a. I do not watch TV, view videos or use the computer on a typical day
- _____ b. less than 1 hour per day
- _____ c. 1 hour per day
- _____ d. 2 hours per day
- _____ e. 3 hours per day
- _____ f. 4 or more hours per day

APPENDIX F

Correlation Matrix

Correlation Matrix of Selected Variables of Interest

	PAQ-A	MVPA	Stress	Coping	MetScore	<u>BMI</u>
PAQ-A	+					
MVPA	0.10	+				
Stress	-0.06	-0.26*	+			
Coping	0.07	-0.13	0.10	+		
MetScore	0.06	0.14	-0.08	-0.05	+	
BMI	0.03	-0.17	0.16	-0.03	0.04	+

* $p < 0.05$

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