Adrian Douglas Lloyd. RELATIONSHIPS AMONG MEASURES OF STRENGTH AND POWER AND HEALTH OUTCOMES IN YOUTH. (Under the direction of Dr. Matthew T. Mahar) Department of Kinesiology, August 2014.

Abstract

The interest in musculoskeletal fitness and its overall impact on health has been increasing in the last decade. The Institute of Medicine (2012) report called for the addition of several muscular fitness tests to national surveys of youth health-related physical fitness and to fitness test batteries in schools and other educational settings. **Purpose:** The purpose of this study was to examine the relationships among various muscular fitness tests and health outcomes in youth. **Methods:** Participants included 49 boys and girls aged 9 to 14 years. A series of muscular fitness tests and tests of health outcomes were completed in two test sessions. Muscular fitness tests included the standing long jump, vertical jump, upper body power throw, total body power throw, and handgrip strength. Handgrip strength was expressed in absolute terms and allometrically scaled to a power of 0.67. The health outcomes examined were aerobic capacity, body composition, systolic blood pressure (SBP), diastolic blood pressure (DBP), and physical activity. Aerobic capacity (VO_{2max}) was directly measured during a maximal treadmill test. Body composition (percent fat) was assessed with the BODPOD. Blood pressure was measured via auscultation after 5 minutes of seated rest. Physical activity was quantified as minutes of moderate-to-vigorous physical activity (MVPA) from 7-day accelerometer measurement. Bivariate correlations were calculated to examine the relationships among fitness tests of strength and power and health outcomes. To control for the impact of body mass index (BMI) and age, partial correlations were calculated among fitness tests and health outcomes controlling for BMI z-score and age. To examine relationships among fitness tests and health outcomes from a criterion-referenced perspective, participants were categorized into both the aerobic capacity

and body composition Healthy Fitness Zone (HFZ) and Needs Improvement Zone (NIZ) as defined by FitnessGram®. Effect size (*ES*) estimates were calculated with Cohen's delta to examine the size of the difference between the HFZ and NIZ groups on the fitness test variables. **Results:** SBP and VO_{2max} were moderately correlated with several fitness tests, including total body power throw (*r* = .37, -.28), upper body power throw (*r* = .33, -.31), and dominant (*r* = .44, -.33) and nondominant handgrip strength (*r* = .37, -.34). Percent fat was moderately correlated with the standing long jump (*r* = -.45) and vertical jump (*r* = -.50). The correlation between percent fat and handgrip strength was close to zero when handgrip strength was expressed in absolute terms. Moderate correlations were found between percent fat and handgrip strength when handgrip strength was allometrically scaled for body mass (*r* = -.50 and -.48). When partial correlations controlling for BMI z-score and age were calculated, generally a similar pattern of correlations was found, except that the partial correlations among SBP and the throwing tests and absolute handgrip strength were lower than the bivariate correlations. When the HFZ was defined with aerobic capacity standards, the HFZ group did better on the standing long jump than the NIZ group (*ES* = 0.45). However, medium effect sizes demonstrated that the NIZ group did better than the HFZ group on total body power throw (*ES* = -0.42), upper body power throw (*ES* = -0.59), and absolute handgrip strength (*ES* = -0.48, -0.39). Differences in the vertical jump and allometrically scaled handgrip strength favored the HFZ group over the NIZ group, but these differences were generally small (range of *ES* = 0.16 to .32). When the HFZ was defined with body composition standards, effect size estimates revealed large differences between the HFZ and NIZ groups favoring the HFZ group for standing long jump (*ES* = 0.84), vertical jump (*ES* = 1.06), and allometrically scaled handgrip strength (*ES* = 1.30, 1.42). Small to medium effect sizes were found for total body power throw (*ES* = 0.26), upper body power throw (*ES* = 0.19),

and absolute handgrip strength (*ES* = 0.36, 0.43) favoring the HFZ group over the NIZ group. **Conclusion:** Results demonstrated moderate levels of norm-referenced and criterion-referenced evidence that the tests of musculoskeletal fitness used in the current study are health-related. However, findings also indicated that the significant relationships between these musculoskeletal fitness tests and health outcomes are highly influenced by body composition.

Relationships among Measures of Strength and Power and Health Outcomes in Youth

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RELATIONSHIPS AMONG MEASURES OF STRENGTH AND POWER

AND HEALTH OUTCOMES IN YOUTH

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Introduction

Youth physical fitness testing has a rich history in the United States. This history can date back to1885 at the consummation of the American Alliance for Health, Physical Education, and Recreation (AAHPER) (Plowman et al., 2006). In 1954 a major impetus for physical fitness testing occurred when Kraus and Hirshland (1954) reported that American youth had worse muscular fitness than European youth. Shortly after the results of the Kraus and Hirshland report, Executive Order 10673 was released creating the President's Council on Youth Fitness (Morrow et al., 2009). In the near future the first national youth fitness test, the AAHPER Youth Fitness Test, was established (Franks et al., 1988).

Since the AAPHER Youth Fitness Test was established in 1957 numerous developments in fitness assessment have surfaced including the development and implementation of new fitness tests. The current national youth fitness test is the FitnessGram® (Plowman et al., 2013). The FitnessGram includes the following test items: push-up, curl-up, trunk lift, shoulder stretch, back-saver sit and reach, PACER test, modified pull-up, skinfolds, and body mass index. Many of these tests have been associated with the FitnessGram for over 20 years (Institute of Medicine, 2012). Recently the Institute of Medicine (IOM) released a report that recommended new additions to youth fitness tests. The IOM report reviewed a plethora of studies that measured various fitness test items and their relationships to health outcomes. Components of fitness examined were body composition, cardiorespiratory endurance, musculoskeletal fitness, and flexibility (IOM, 2012).

One conclusion drawn from the IOM report was that sufficient evidence is available to demonstrate a relationship between musculoskeletal fitness and health. This conclusion, however, is drawn primarily from the research findings in adults, with less evidence available in

youth. The IOM report concluded that no high quality evidence supports a relationship between any single musculoskeletal fitness test and health in youth. However, the IOM report recommends inclusion of the standing long jump and handgrip strength test in national health surveys as well as in educational settings.

The IOM report reviewed numerous studies that examined the relationship between muscular fitness test scores and metabolic health. Ruiz et al. (2008) found moderate correlations in 13-18.5 year olds between a muscular strength score and three inflammatory proteins, C-reactive protein (r = .32), complement factor C3 (r = .32), and complement factor C4 (r = .45). The muscular strength score was calculated from the standardized scores of handgrip strength and standing long jump. Artero et al. (2007) reported a positive association (value of correlation was not provided) between muscular fitness and a lipid-metabolic index (a combination of triglycerides, LDL-C, HDL-C, and glucose concentrations) in 15.2 (± 1.4) year old females. Garcia-Artero et al. (2007) represented muscular fitness by a combination of handgrip strength, standing long jump, and bent arm hang scores. Artero et al. (2013) reported a negative correlation between standing long jump (r = -.38) and inflammatory scores in 14.9 ± 1.2 year olds. The inflammatory score was the total of the z-scores for the following inflammatory markers: C-reactive protein, complement factor C3, complement factor C4, leptin, and white blood cells. Artero et al. (2013) also found a negative relationship between a muscular fitness score (r = -.38) and an inflammatory score. The muscular fitness score was the sum of the standardized z-scores for handgrip strength and standing long jump.

Steene-Johannessen et al. (2009) found that the standing long jump had significant, yet low, correlations with a homeostasis model assessment (r = -.16), HDL (r = .06), and

triglycerides (r = -.09) in 1,891 youth aged 9 and 15 years. Steene-Johannessen et al. also found that the standing long jump was significantly correlated (r = -.20) with a metabolic index consisting of combined z-scores for homeostasis model, waist circumference, triglycerides, HDL, and systolic blood pressure. Artero et al. (2011) reported correlations between the standing long jump and multiple metabolic risk factors including waist circumference (r = -.32), HOMA (r = -.17), and total cholesterol (r = -.10) in 12.5 to 17.5 year olds. Artero et al. found that the standing long jump had a significant, yet low, correlation (r = -.24) with total metabolic risk score (calculated as the sum of the standardized z-scores of systolic blood pressure, homeostasis model, and total cholesterol). A total muscular fitness score was created from the z-scores for the standing long jump and handgrip strength. This total muscular fitness score was significantly related to waist circumference (r = -.49), systolic blood pressure (r = -.10), homeostasis model assessment (r = - .23), triglycerides (r = -.11), total cholesterol (r = -.12), and total metabolic risk score (r = - .33).

Magnussen et al. (2012) appear to be the only researchers that used allometric parameters for normalizing the standing long jump for body mass. Magnussen et al. used the standing long jump to measure muscular power and split the cohort into five groups based on performance. Group one had the highest performance and group five had the lowest performance. Magnussen et al. demonstrated that the highest fit group had significantly lower standardized cardiovascular disease risk factor values compared to all four other groups. Cardiovascular disease risk factors included: non-HDL-C, HDL-C, total cholesterol, triglycerides, systolic blood pressure, diastolic blood pressure, mean arterial pressure, waist circumference, and body mass index.

Considerable research has also linked muscular strength and power to body composition (Beunen et al., 1983; Brunet et al., 2006; Liao et al., 2013). Brunet et al. (2006) found that in first

(r = -.16), second (r = -.25), and fourth grade boys (r = -.39) standing long jump was significantly correlated with waist circumference. Similar correlations were found between the standing long jump and waist circumference in second grade (r = -.25) and fourth grade (r = -.39) girls. Beunen et al. (1983) found that amongst over 20,000 participants aged 12-20 years, vertical jump was significantly correlated with body fatness within the range of r = -.18 to r = -.37. Beunen et al. also found that body fatness was significantly correlated with bent arm hang within the range of r = -.18 to r = -.37. Minck et al. (2007) reported correlations between body fatness and muscular fitness tests, including the arm pull and standing high jump. Correlations between body fatness and arm pull were r = -.21 for males and r = -.20 for females. Correlations between body fatness and the standing high jump were r = -.11 for males and r = -.21 for females. Rodriguez et al. (2011) found that after following a cohort of six year olds for nine years certain fitness test were able to predict body fatness. The coefficients reported were significant, yet low, for the flexed arm hang (r = -.06), standing long jump (r = -.07), and sit ups (r = -.04).

In summary, research linking youth muscular fitness tests and health outcomes is limited. The standing long jump, used as a measure of lower body muscular power, was shown to have significant, but low to moderate, correlations with several health markers (Artero et al., 2011, 2013; Ortega et al., 2005; Steene-Johannessen et al., 2009). Several researchers developed muscular fitness scores based on mulitple fitness tests (primarily the standing long jump and handgrip strength) and reported slightly higher correlations with health markers (Artero et al., 2011; Martinez-Gomez et al., 2012; Ruiz et al., 2008) than was found between standing long jump and health markers. Significant and low to moderate correlations have also been reported between fitness tests of muscular power (e.g., standing long jump, vertical jump) and body

composition variables (e.g., body fatness, waist circumference, body mass index [BMI]) (Beunen et al., 1983; Brunet et al., 2006; Liao et al., 2013; Minck et al., 2000; Moliner-Urdiales et al., 2011). Although Magnussen et al. (2012) adjusted the standing long jump for body composition using allometric scaling, the impact of body composition on the relationships between youth fitness tests and health markers has not been thoroughly considered. The IOM (2012) report recommended that additional research examining the relationships between specific musculoskeletal fitness tests and health outcomes in youth is needed.

Purpose Statement

The purpose of this study was to examine the relationships among fitness tests of strength and power and health outcomes in youth. Health outcomes examined in this study included aerobic fitness, blood pressure, physical activity levels, and body composition. In addition, the relationships between fitness tests and health outcomes were examined after adjustment for body composition.

Research Hypotheses

It was hypothesized that:

1. Correlations among youth fitness tests of strength and power and health outcomes in youth will be significant and of moderate strength.

2. After adjustment for body composition, correlations among fitness tests of strength and power and health outcomes in youth will be attenuated.

Definitions of Terms

BODPOD – The BODPOD is an air displacement plethysmography system used to measure body composition.

Functional Power – Functional power was defined as the ability to produce maximal muscle force during a field test of explosive body movement (e.g., standing long jump) in which a time factor is not directly assessed.

Health outcomes – Health outcomes are traits that reflect specific parameters of health. For this study, healthy outcomes will be aerobic fitness, body composition, physical activity level, and blood pressure.

Muscular power – Muscular power was defined as the maximal force exerted by muscles with near maximal velocity. Lower body muscular power was assessed in the current study by the standing long jump and vertical jump tests. Upper body muscular power was assessed by the upper body (seated) medicine ball throw. Whole body muscular power was assessed by the total body medicine ball throw.

Muscular Endurance – Muscular endurance was defined as the ability of a muscle or group of muscles to perform repeated contractions against a constant external load for an extended period (Institute of Medicine, 2012).

Muscular Strength – Muscular strength was defined as the ability of skeletal muscle (single or group) to produce measurable force, torque, or moment about a single or multiple joints, typically during a single maximal voluntary contraction and under a defined set of controlled conditions (Institute of Medicine, 2012). The measure of muscular strength used in the current study was handgrip strength.

Partial Correlation – A partial correlation represents the degree of association between two variables with the effects of other variables removed.

VO_{2max} – VO_{2max} is the rate of oxygen consumption during maximal exercise and indicates one's capacity for oxygen transport and utilization. VO_{2max} is the criterion measure of aerobic fitness

(American College of Sports Medicine, 2000). Aerobic fitness was assessed in this study by a maximal treadmill test using the COSMED portable metabolic system.

Delimitations

The study included the following delimitations:

1. All participants were between 9 and 14 years of age.
2. Muscular power was assessed via field-based measures that do not have a specific measurement of time, although all field-based measures of muscular power are made with explosive movements.
3. Muscular strength was assessed with the handgrip dynamometer test.

Limitations

The study is limited by the following:

1. Participants may not have provided a maximal effort on all fitness tests. Verbal encouragement and appropriate instructions and demonstrations were provided for all tests.
2. Participants may not have exhibited a high level of compliance with wearing the accelerometers to assess physical activity. A minimum of three days of wear time was accepted as compliant for this study.

Significance of the Study

The Institute of Medicine (2012) report recommended the addition of the handgrip strength and standing long jump in future youth fitness test batteries. This recommendation was made in light of the report also claiming that further research should examine the relationships among muscular strength and power tests and health outcomes. This study responds to the Institute of Medicine (IOM) recommendation regarding further research. The study will also examine how the correlations among muscular fitness tests and health outcomes changes when

controlling for body mass. This is significant because many of the studies examined in the IOM report did not adjust for the impact of body mass on the correlations.

Review of Literature

History of Physical Fitness Testing

Physical fitness testing in the United States has a rich history. It dates back to the establishment of the American Alliance for Health, Physical Education and Recreation in 1885 (Plowman et al. 2006). In the early 1900s Sargent Dudley developed a vertical jump test used to measure fitness and health (Institute of Medicine [IOM], 2012). Shortly after that, the Playground Association of America Athletic Badge Test was created for boys in 1913 and girls in 1916 (IOM, 2012**).** The heightened awareness of physical fitness was stimulated by the wartime era **(**IOM, 2012).

Perhaps the most decisive event that dramatically increased the emphasis of youth fitness was the Kraus and Hirshland reports published in 1953 and 1954. These reports revealed that American youth had less muscular fitness than European youth (Kraus et al., 1954). This publication occurred only a decade after World War II and one year after the Korean War. This spurred president Dwight D. Eisenhower to enact Executive Order 10673 in 1956. This Executive Order called for the creation of the President's Council on Youth Fitness (Morrow et al., 2009). The increased research during that time period produced the first national youth fitness test. This test was called the Youth Fitness Test and was established in 1957 by the American Alliance for Health, Physical Education and Recreation (AAHPER) (Franks et al., 1988). The test items included the straight leg sit-ups, standing long jump, pull-ups, modified pull-ups (girls), 50-yard sprint, shuttle run, 600-yard run-walk, softball throw, and optional aquatic tests (Morrow et al., 2009).

In 1973 the Texas Governor's Commission Physical Fitness Test was developed (Morrow et al., 2009). In the development of this test the authors separated the fitness

measurements into two distinct groups, labeled physical fitness or motor ability. This idea, including already heightened awareness of health-related fitness components, helped to set the stage for the revamping of the previous Youth Fitness Test (Morrow et al., 2009). Therefore, in 1976 AAPHER made adjustments to the Youth Fitness Test to account for more functional and physical health measurements (Plowman et al., 2006). In 1980, AAPHERD came out with a fitness test called the American Alliance for Health, Physical Education, Recreation and Dance (AAHPERD) Health-related Physical Fitness Test. This test included items that measured aerobic fitness, body composition, abdominal function, and low back-hamstring function (Morrow et al., 2009).

The 1980s was filled with a consistent debate to identify the correct way to measure and evaluate fitness. The two major groups in the debate were the President's Council on Youth Fitness and AAPHERD. In 1987, the President's Council eventually developed its own test battery, called the President's Challenge. One year later AAPHERD came out with a fitness test named Physical Best (Franks et al., 1988). In 1987, a new test called the FitnessGram was published by the Institute for Aerobics Research (Franks et al., 1988). The FitnessGram is an educational fitness assessment and reporting software system that has dramatically grown since its inception in 1987 (Plowman et al., 2006). The FitnessGram is now recognized as the official national youth fitness test.

The 2012 Institute of Medicine report evaluated various fitness test items and their relationships to health. They reviewed a plethora of scientific articles and recommended individual fitness test items that should be tested in youth fitness tests. Among the recommendations was that fitness test items that measure musculoskeletal fitness should be included in youth fitness tests. The standing long jump and handgrip strength were specifically

recommended for inclusion in national youth fitness surveys and in fitness tests for educational settings. However, the report stated that no clear evidence has emerged to support the relationship between any single musculoskeletal fitness test item and health outcome. Therefore, further investigation of the relationships between musculoskeletal fitness test items and health outcomes was recommended. The recommendation to further investigate the relationships between musculoskeletal fitness items and health outcomes was the catalyst for the current thesis.

Defining Power

Power is defined as work divided by time. Power is the rate of work done over the course of time (Gray et al., 1962). Power assessments, following the definition of work/time, must be expressed in a unit that is equivalent to work per unit of time. Common units to express power are Joules per second (watts), horsepower, and foot-pounds per second (Sapega et al., 1983). Researchers have used several laboratory-based instruments to measure power. These instruments include isokinetic dynamometers, force platforms, and high speed motion analysis (Sapega et al., 1983; Smith et al., 2010).

It is not feasible to assess power via such laboratory-based instruments in field settings, such as schools. Instead, a field-based concept of power is used. Sapega et al. (1983) described field-based power tests as fast, forceful performance tasks, such as the standing long jump and vertical jump. While these tests do not strictly measure power as work/time, they are still widely-used in the field and assumed to provide a measure of power because they are fast, forceful performance tasks. Several authors have used field-based power measurements, but may report that they are measuring a characteristic different that power. For instance, the standing long jump has been reported to measure power (Magnussen et al., 2012), lower body explosive strength

(Artero et al., 2011), and lower body strength (Ruiz, 2008). For the purpose of this literature review, field-based power items are considered a measure power regardless of what the authors terms the outcome.

The most widely-used field-based test of power is the standing long jump (Artero et al., 2011; Brunet et al., 2006; Liao et al., 2013; Magnussen et al., 2012; Martinez-Gomez et al., 2012; Ortega et al., 2005; Ruiz et al., 2008). Other field-based measurements of power include the vertical jump (Beunen et al. 1983, Minck et al. 2000, Moliner-Urdiales et al. 2011) and the 5-yard sprint and 10-yard sprint (Considine et al., 1973).

Resistance Training in Adults

Several researchers have reported a relationship between muscle fitness and health parameters in adults (Fitzergerald et al., 2004; Jurca et al., 2005, Ullrich et al., 1987;). The 2011 American College of Sports Medicine position stand on exercise prescription was drafted to give scientific evidence-based recommendations for healthy adults. The authors of the position stand devoted a section on muscular fitness citing over 20 studies that identified the health benefits of resistance training (Garber et al., 2011).

Fitzgerald et al. (2004) studied the relationship between all-cause mortality and muscular fitness in 9,105 subjects aged 20-82 years. Muscular fitness was measured via one repetition maximal bench and leg press tests and a one minute sit-up test. Tertiles were developed for each test. Zero was designated as the lowest tertile and two was designated as the highest tertile. The scores for each test were combined to create a muscular fitness index that ranged from 0 to 6. Low, moderate, and high muscular fitness groups were formed. Proportional hazards analyses were conducted.

After controlling for age and sex, results revealed that compared to the low muscular fitness group, participants in the moderate fitness group had a 44% reduction in relative risk of all-cause mortality. The high muscular fitness group had a 35% reduction in relative risk of all-cause mortality compared to the low muscular fitness group after controlling for age and sex. Fitzergerald et al. (2004) further controlled for BMI, cardiorespiratory fitness, health status, total cholesterol, resting systolic blood pressure, smoking status, and baseline examination year. While controlling for multiple variables moderate and high muscular fitness groups still had a 36% and 20% reduction in all-cause mortality compared to the low muscular fitness group, respectively. The authors concluded that their results supported that increased muscular fitness was associated with lower all-cause mortality rates.

Jurca et al. (2005) examined the relationship between muscular strength and metabolic syndrome in 3,233 men aged 20-80 years. Muscular strength was measured through a one repetition maximum of the supine bench press and seated leg press. A muscular strength score was formulated by combing the two maximum tests and dividing by body weight. Age specific quartiles were set up and used in the analyses (20-29, 30-39, 40-49, 50-59, and 60+ years). Cardiorespiratory fitness was measured through a maximal treadmill test using a modified Balke protocol. Cox regression was used to compute hazard ratios.

Results revealed that participants in the highest strength category had a 34% lower risk of developing metabolic syndrome than subjects in the lowest strength category, while controlling for smoking status, alcohol intake, number of metabolic syndrome risk factors at baseline, family history of diabetes, hypertension, and premature coronary disease. After further adjusting for aerobic fitness, the high strength group had a 24% lower risk of developing metabolic syndrome compared to the low strength group. However, this difference was not significant.

Participants were divided into two different groups based on BMI level. There was a normal weight group (BMI < 25) and a combined group of overweight and obese individuals (BMI ≥ 25). Within both groups, muscular strength was inversely related to metabolic syndrome incidence. Within the normal weight group the high strength group had a 44% lower chance of developing metabolic syndrome compared to the low strength group. The same pattern was found in the overweight and obese group with the high strength group having a 39% lower chance of developing metabolic syndrome compared to the low strength group. When evaluated within separate age categories significant linear trends that demonstrated a decrease in metabolic risk as muscular fitness increased were seen for ages 20-39 years, 40-49 years, and 50+ years. Jurca et al. (2005) concluded that muscular strength was inversely related to metabolic syndrome risk after adjusting for various confounding variables.

Ullrich et al. (1987) studied the relationship between a muscular resistance training program and various health outcome variables in 25 male participants aged 18-35 years. Participants were divided into four separate groups during the eight week intervention, including endurance training, strength I training, strength II training, or explosive training groups. Groups differed on the number of repetitions, sets, and loads they had to complete for their training program. Body fat was determined through hydrostatic weighing and maximal oxygen consumption (VO_{2max}) was measured using a modified Balke protocol. Muscle mass was also measured using the arm circumference and triceps skinfold measurement. Blood samples were taken to assess cholesterol and triglycerides.

The results at the end of the intervention revealed several key findings. Total cholesterol decreased significantly from 192 mg/dL at baseline to 186 mg/dL for all groups (results were not reported separately for each group). LDL-cholesterol decreased significantly by 8%, and HDL

increased by 14%. Muscle mass increased by 4.6 kg and percent fat decreased significantly from 14.0% to 12.7%. Maximal oxygen consumption also increased by 3.8 $mL \cdot kg \cdot min^{-1}$. The authors concluded that the eight week intervention assisted in improving lipid levels, aerobic conditioning, and muscle mass while decreasing fat mass.

Muscular Power and Health

Power and Metabolic Risk Factors

Ruiz et al. (2008) examined the relationship between physical fitness and various markers of health in 416 subjects aged 13-18.5 years who participated in the Food and Assessment of Nutritional Status of Spanish Adolescents (ANEVA study). Measurements included a complete set of inflammatory proteins, muscle strength, and cardiorespiratory fitness measurements. Upper body strength was assessed via handgrip strength and lower body strength was assessed via standing long jump. The muscular strength score was the mean of the standardized scores of the standing long jump and the handgrip strength test. The standardized scores were calculated separately for boys and girls for each age group (13, 14, 15, 16, and 17-18.5 years). The PACER test was used to estimate aerobic fitness.

Results showed that the PACER test was significantly correlated to handgrip strength (r = .15) and standing long jump performance (r = .75). The PACER test scores were not significantly related to any inflammatory protein. C-reactive protein (r = .32), complement factor C3 (r = .32), and complement factor C4 (r = .45) were three of the five inflammatory markers significantly related to the standardized muscular strength score after controlling for sex, age, pubertal status, weight, height, socioeconomic status, and aerobic fitness. Ruiz et al (2008) divided subjects into two groups according to BMI: nonoverweight and overweight adolescents. Results revealed no significant correlations between any inflammatory protein and muscular

fitness in the nonoverweight group. In the overweight group, C-reactive protein (r = .44) and prealbumin (r = .33) were significantly correlated with muscular fitness.

Ruiz et al. (2008) did not specifically state that they were measuring power in this study. However, a major component of their muscular strength score was the standing long jump. The standing long jump has been used consistently as a measure of lower body power (Beunen et al., 1983; Brunet et al., 2006; Kontulainen et al., 2002). Therefore, a relationship could exist between muscular power and improved inflammation responses. Ruiz et al. concluded that muscular fitness is significantly correlated with inflammatory responses in adolescents and could help distinguish more at risk subjects in the overweight category.

Garcia-Artero et al. (2007) used the same overarching ANEVA study data to complete further analysis of relationships between physical fitness and health markers. The purpose of this study was to evaluate the relationship between physical activity and physical fitness in relation to lipid and metabolic profiles. Four-hundred and sixty participants with a mean age of 15.2 (± 1.4) years were evaluated. Physical activity was measured with the Yesterday Activity Checklist. The results from this questionnaire were used to calculate a total MET index. Muscular strength and aerobic fitness comprised the physical fitness component. The Course-Navette 20-meter shuttle run test was used to assess aerobic fitness and muscular strength included a combined index score of the standing long jump, hand grip dynamometry test, and the bent arm hang. Each variable of the muscular strength test was modified by dividing the observed score by the maximum value of the variable. The maximum value of each variable is defined by the highest possible score on the EUROFIT test battery. The transformed scores for each test were averaged to create the general strength index. A metabolic cardiovascular risk index was calculated from the measures of triglycerides, LDL-C, HDL-C, and glucose concentrations. Each value was

standardized separately for boys and girls from sample data. The HDL-C standardized variable was multiplied by -1 because of its inverse effect on cardiovascular risk. The total of each of the four standardized values made up the metabolic profile.

Results demonstrated no relationship between the physical activity index and the metabolic index. Garcia-Artero et al. (2007) did not report the correlation for this relationship. After controlling for age, maturational development, physical activity, and muscular strength, aerobic fitness was significantly related to the metabolic index in males. Therefore, in males higher aerobic fitness was associated with an improved lipid-metabolic index. Correlation data were not provided in the article to support this relationship. For females, muscular strength was positively associated with the lipid-metabolic index, after controlling for sex, age, maturational development, and aerobic fitness. Correlation data were not provided in the article to support this relationship either. When aerobic fitness and muscular strength were combined in the same analyses the results showed that a high level of muscular strength was linked to a low metabolic risk at any level of aerobic fitness, regardless of sex. Analysis also revealed that muscular strength had a low, but significant relationship with aerobic fitness in males (r = .26) and females (r = .29).

Similar to the study by Ruiz et al. (2008), Garcia-Artero et al. (2007) did not specifically measure muscular power. In both studies, the standing long jump was used as a major component of the muscular strength assessment. Therefore, because the authors considered the standing long jump to be a measure of a muscular power, they concluded that a relationship may exist between muscular power, cardiovascular health, and improved lipid profile indexes (Garcia-Artero et al., 2007).

Artero et al. (2013) further examined the relationship between inflammatory biomarkers and muscular fitness in adolescents. Participants in the Artero et al. study consisted of 639 adolescents with a mean age of 14.9 ± 1.2 years. The inflammatory markers of C-reactive protein, complement factor C3, complement factor C4, leptin, and white blood cells were analyzed via blood sample. Each marker was standardized separately for boys and girls and by 1-year age groups. The standardized scores were then totaled to achieve the inflammatory score. Muscular fitness was assessed using the total standardized scores of the handgrip strength and standing long jump for each sex and 1-year age groups. Aerobic fitness was also assessed via the PACER.

Partial correlations showed standing long jump (r = -.32), aerobic fitness (r = -.31), and total muscular fitness score (r = -.38) had similar levels of association with inflammatory scores after controlling for age, sex, pubertal state, and center. Four quartiles were developed for muscular fitness. Quartile one was the least fit and quartile four was most fit. Analysis revealed that there was a significant difference in inflammatory score between quartile one and quartile four.

Multiple regression revealed a significant moderate predictive value of muscular fitness and inflammatory score (β = -0.39*)* after controlling for age, sex, pubertal state, and center. A similar value was revealed after additionally controlling for aerobic fitness. However, once the homeostasis model assessment and four skinfolds were controlled, a nonsignificant and weak relationship between muscular fitness and inflammatory score resulted (β = -0.08). Participants were then split into non-overweight or overweight groups. Within the overweight group, those with low muscular fitness had significantly higher inflammatory scores than those with high muscular fitness. No other group comparisons were statistically significant.

Artero et al. (2013) concluded that muscular fitness is related to inflammatory biomarkers in adolescents. However, this relationship was only found in the overweight group of this study. Analysis from the overweight group which revealed a significant difference in inflammatory score between low muscular fitness and high muscular fitness showed that muscular fitness could help identify which obese individuals are more at risk for poor inflammatory scores.

Steene-Johannessen et al. (2009) studied the independent associations of muscle fitness and aerobic fitness with clustered metabolic risk in 1,851 youth aged 9 and 15 years. Muscle fitness was defined through a combination scoring index. The combination score consisted of handgrip strength, standing broad jump, sit-up test, and the endurance of the trunk extensor muscles. Test results were standardized and the combined standardized scores provided the muscle fitness index. Aerobic fitness was tested through a progressive cycle test to exhaustion using an electronically braked cycle ergometer. Metabolic index was calculated as the combination of standardized scores from the following variables: homeostasis model assessment (HOMA), waist circumference, triglycerides, HDL count, and systolic blood pressure.

Steene-Johannessen et al. (2009) analyzed the partial correlations of muscle fitness and aerobic fitness with individual cardiovascular disease risk factors. The standing long jump had significant, yet low, relationships with HOMA (r = -.16), waist circumference (r = -.30), HDL (r = .06), triglycerides (r = -.09), and total metabolic index (r = -.20). The predictive value of total muscular fitness for metabolic risk was moderate (β = -0.32); when adjusted for aerobic fitness the value decreased (β = -0.11).

Participants were split into one of four quartiles for both aerobic and muscle fitness. Quartile 1 was the lowest fit group and Quartile 4 was the highest fit group. Quartiles were set up for each age and sex. For each set of quartiles a main effect was seen for increased metabolic risk

in the low muscle fitness group. Therefore, participants in the lowest quartile of muscle fitness had significantly poorer metabolic risk scores compared to the other three groups. Further analysis revealed that the odds ratio for having metabolic risk was 7.2 in the least fit quartile compared with the most fit quartile. After adjusting for aerobic fitness the odds ratio was 1.7.

Steene-Johannessen et al. (2009) further analyzed the relationship between muscle fitness and metabolic risk while attempting to control for body weight. Participants were split into overweight and normal weight categories. Within each weight class, participants were divided into one of three groups based on muscular fitness (low, moderate, and high). Within both weight categories, significant differences were seen in metabolic risk scores between the low muscular fitness group to the high muscular fitness group. Numeric data were not provided for this analysis.

Steene-Johannessen et al. (2009) concluded that muscle fitness was inversely associated with clustered metabolic risk. Clustered risk was higher in the least muscular fit group compared to the most muscular fit group regardless of weight.

Artero et al. (2011) studied the relationship between muscular and aerobic fitness with metabolic risk in 709 adolescents aged 12.5-17.5 years. Muscular fitness was measured through combining the one year age and sex specific standardized scores of the standing long jump and handgrip strength. Metabolic components measured were waist circumference, systolic blood pressure, homeostasis model assessment, triglycerides, and total cholesterol. A metabolic risk score was the summation of one year age and sex specific standardized scores of systolic blood pressure, homeostasis model assessment, and total cholesterol.

Partial correlation showed that standing long jump was lowly, yet significantly related to waist circumference (r = -.32), HOMA (r = -.17), total cholesterol (r = -.10), and total metabolic

risk score (r = -.24). The total muscular fitness score was significantly related to waist circumference (r = -.49), systolic blood pressure (r = -.10), homeostasis model assessment (r = -.23), triglycerides (r = -.11), total cholesterol (r = -.12), and total metabolic risk score (r = - .33).

Participants were split into four separate groups: boys < 14.5 years, boys > 14.5 years, girls < 14.5 years, girls > 14.5 years. Each group was further divided into four muscular fitness quartiles. Quartile one was the lowest fit, while quartile four was the highest fit. ANCOVA analysis found main effects for each muscular fitness score across the quartiles in all sex and age groups. Post hoc tests revealed that participants in the lowest fitness quartile had a significantly higher metabolic risk compared to participants in quartiles two, three, and four.

Standardized regression coefficients were calculated after controlling for age, sex, pubertal status, and center. Muscular fitness showed a low, but significant beta value (β = -0.33) after controlling for age, sex, pubertal status, and center. Muscular fitness also showed a low, but significant beta value (β = -0.25), even after adjusting for aerobic fitness. Odds ratios were calculated after participants were split into four different muscular fitness quartiles. Quartile one was the least fit quartile and quartile four was the most fit quartile. The odds ratio (OR = 8.3) for metabolic risk in the lowest fit quartile was significant when compared to quartile four after controlling for age, sex, pubertal status, and center. After further controlling for aerobic fitness the odds ratio for metabolic risk was still significant (OR = 5.3) for quartile one compared to quartile four.

Artero et al. (2011) further studied the metabolic risk while accounting for weight. Participants were split into a nonoverweight group and an overweight group. Within each group four muscular fitness quartiles were created, quartile one was the least fit quartile and quartile four was the most fit quartile. Analysis showed that in the nonoverweight group, metabolic risk

score was significantly different between quartile one and quartiles three and four. In the overweight group, metabolic risk score was significantly different between quartile one and quartile two.

Artero et al. (2011) concluded that muscular fitness is related to metabolic risk independent of aerobic fitness. Artero et al. also explained that the relationship seems to be an exponential relationship rather than a linear one because the greatest difference in metabolic risk came between the lowest fit group and the other three groups. They concluded that muscular fitness could help to determine the increased metabolic risk within an overweight population.

Magnussen et al. (2012) examined the relationship between muscular power and cardiovascular disease risk in 600 nine year olds, 562 twelve year olds, and 480 fifteen year olds. Muscular power was tested via standing long jump and was normalized for childhood body mass according to allometric parameters (Jaric et al., 2005). Cardiovascular disease risk factors were measured independently including: non-HDL-C, HDL-C, total cholesterol, triglycerides, systolic blood pressure, diastolic blood pressure, mean arterial pressure (1/3SBP + 2/3 DBP), waist circumference, and body mass index. A clustered cardiovascular disease risk score was computed as the sum of the age- and sex-specific z scores of non-HDL-C, HDL-C (multiplied by -1), triglycerides, mean arterial pressure, and waist circumference divided by five.

Participants were split into five quintiles based on muscular power performance. The 1st quintile had the lowest power performance and the 5th quintile had the highest power performance. Analysis showed that compared to quintile one (r = .33), quintile two (r = .08), three (r = -.05), four (r = -.17), and five (r = -.20) all had significantly lower standardized cardiovascular disease risk factor values. Systolic blood pressure, diastolic blood pressure, and mean arterial pressure all decreased as muscular power increased across quintiles. HDL-C

increased as muscular power increased from quintile one to quintile five. After adjusting for BMI, muscular power was no longer associated with HDL-C.

Magnussen et al. (2012) examined the relationship between muscular power, aerobic fitness (1.6 km run time), and cardiovascular disease risk factor. Muscular power was moderately related to aerobic fitness (r = .35). Muscular power and aerobic fitness were independently shown to significantly predict clustered cardiovascular disease risk. Also the interaction of muscular power and aerobic fitness significantly predicted clustered cardiovascular disease risk. Muscular power was significantly correlated with clustered CVD risk in each aerobic fitness category (low, moderate, and high), but values for the correlations were not given. Magnussen et al. concluded that muscular power was inversely related to clustered CVD risk and muscular power may provide protection against clustered CVD risk regardless of aerobic fitness.

Adiponectin and leptin are adipocytokine proteins that seem to contribute to the development of cardiovascular disease and type 2 diabetes (Morales et al., 2004; Yoshinaga et al., 2008). Martinez-Gomez et al. (2011) examined the relationship between independent and joint relationships of physical activity, aerobic fitness, and muscular fitness with adiponectin and leptin levels in 198 subjects aged 13-17 years. Physical activity was measured via accelerometer for seven consecutive days, aerobic fitness was measured via PACER, and muscular fitness was measured via handgrip strength and standing long jump. The muscular fitness score was the mean of the handgrip strength and standing long jump standardized scores.

Physical activity data were used to create two groups (low or high) based on whether participants accumulated at least 60 minutes of moderate to vigorous physical activity in a day or not. Participants were divided into low or high aerobic fitness groups based on the FitnessGram-ActivityGram criterion-referenced standards for VO_2max. If participants were placed into all

three high fitness groups (physical activity, aerobic fitness, and muscular fitness), then they were categorized as healthy. If participants were placed into two of the three groups, then they were categorized as medium-healthy. If participants were placed into one or zero high fitness groups, then they were categorized as unhealthy. Adiponectin and leptin values were analyzed via blood sample. Insulin resistance was also measured through the homeostasis model assessment.

Several analyses were conducted. Aerobic fitness, after controlling for age, sex, and pubertal status, was positively correlated with muscular fitness (r = .43). Cardiorespiratory fitness was significantly correlated with adiponectin (r = .37) and leptin (r = .81). Muscular fitness was also significantly correlated with adiponectin (r = .37) and leptin (r = .82). Multiple regression analysis showed that participants in the high aerobic group and high muscular fitness group had significantly lower values of adiponectin and leptin than the low aerobic and low muscular fitness group (exact values were not reported). Further analysis revealed that the healthy group (participants who scored high on each test), had significantly lower values of adiponectin and leptin compared to the medium-healthy or unhealthy groups. Results revealed that standing long jump, as a single predictor and combined with other fitness components, significantly correlated with adiponectin and leptin levels (Martinez-Gomez et al., 2012).

Ortega et al. (2005) provided normative values for physical fitness tests in 2,859 Spanish adolescents aged 13-18.5 years. They presented various relationships that linked physical fitness with future cardiovascular disease risks. Physical fitness was tested through a modified version of the EUROFIT which included: the sit and reach, handgrip, standing long jump, bent arm hang, 4 x 10 m shuttle run, and the 20 m shuttle run. Participants were then placed into a non-risk or at-risk group for future cardiovascular disease risks based on aerobic capacity cut points as defined by the FitnessGram test administration manual published in 1999. Seventeen percent of

participants were categorized into the at-risk group. The at-risk group and the non-risk group were compared on the youth fitness tests. For both males and females a significant difference was seen between at-risk and non-risk groups on the bent arm hang, standing long jump, and agility tests (data were not provided).

Jimenez-Pavon et al. (2012) studied the relationships between muscular strength and markers of insulin resistance after controlling for total and central body fat in 1,089 subjects aged 12.5-17.5 years. Muscular strength was assessed via standing long jump for the lower body and via handgrip strength for the upper body. Handgrip strength was analyzed as an absolute measure and also relative to body weight. Various health measurements were evaluated including insulin, glucose, waist circumference, skinfold thickness, BMI, homeostasis model assessment (HOMA), and quantitative insulin sensitivity check index.

Partial correlations between health outcomes and performance measures controlling for pubertal status were calculated. Standing long jump was significantly correlated with insulin (r = -.16), HOMA (r = -.16), glucose (r = -.10), quantitative insulin sensitivity (r = .15), waist circumference (r = -.16). skinfold thickness (r = -.43), and BMI (r = -.17). Handgrip strength expressed relative to body weight was significantly correlated with insulin (r = -.25), HOMA (r = -.24), quantitative insulin sensitivity (r = .23), waist circumference (r = -.50), skinfold thickness (r = .59), and BMI (r = -.53).

Linear regression analyses were used to examine the relationships between the muscular fitness tests and health markers. Model I controlled for pubertal status, country, and BMI. For males, regression analyses demonstrated significant relationships between handgrip strength expressed relative to body weight and HOMA (β = -0.10), and insulin (β = -0.21), and between absolute handgrip strength and HOMA (β = -0.14). In males, standing long jump significantly

predicted insulin, HOMA, and quantitative insulin sensitivity check index while controlling for pubertal status, country, and either BMI, waist circumference, or skinfold thickness. For males, beta values for the relationships between standing long jump and insulin and HOMA ranged from β = -0.17 to β = -0.19. Beta values for the relationship between standing long jump and quantitative insulin sensitivity check index ranged from β = .17 to β = .18. For females, standing long jump was only significantly predictive of HOMA (β = -0.11). For females, handgrip strength was not significantly associated with insulin, HOMA, or quantitative insulin sensitivity check index.

Jimenez-Pavon et al. (2012) controlled for weight by multiplying the standing long jump score by weight. The data were not provided, but Jimenez-Pavon et al. reported that multiplying the standing long jump scores by weight did not change the results compared to using the raw standing long jump score. When Jimenez-Pavon et al. controlled for aerobic fitness, the significant relationships between muscular fitness and health markers became non-significant in females.

Jimenez-Pavon et al. (2012) concluded that for females lower body muscular fitness was associated with markers of insulin resistance after controlling for various confounding variables. However, these relationships were not significant after controlling for aerobic fitness. Upper body strength in males was negatively associated with markers of insulin sensitivity after controlling for BMI or waist circumference, but not skinfold thickness.

Martinez-Gomez et al. (2012) studied the relationship between objectively measured and self-reported physical activity and fitness and inflammatory markers in 1,025 subjects aged 12.5 to 17.5 years. Physical activity was objectively measured with accelerometers using 15 second epochs. Physical activity was also self-reported by participants using the International Physical

Activity Questionnaire for Adolescents. Aerobic fitness was objectively measured using the 20 meter shuttle-run test. Muscular fitness was objectively assessed from the average of standardized scores from the handgrip strength and standing long jump. Motor fitness was objectively assessed using the 4 × 10 shuttle-run test. An overall fitness score was calculated taking the average z-scores from aerobic, muscular, and motor fitness tests. Aerobic, muscular, and motor fitness were also self-reported using a four question system found in the International Fitness Scale. Blood samples were taken to examine levels of C-reactive protein, complement factor 3, complement factor 4, interleukin-6, and tumor necrosis factor.

Partial correlations revealed low, yet significant relationships between various variables after controlling for age, sex, and city. Objectively measured muscular fitness, measured by handgrip strength and standing long jump, was significantly correlated with overall objectively measured physical activity (r = .10), objectively measured vigorous physical activity (r = .17), and objectively measured moderate-to-vigorous physical activity (r = .08). Self-reported muscular fitness was not significantly correlated with any objective measure of physical activity. Overall fitness was significantly correlated with objective measurements of overall physical activity (r = .13), vigorous physical activity (r = .16), and moderate-to-vigorous physical activity (r = .13).

Regression analysis showed that objectively measured muscular fitness had low, but significant predictive values for C-reactive protein (β = -0.18), complement factor 3 (β = -0.26), and complement factor 4 (β = -0.17). There were no significant predictors for any inflammatory proteins from self-reported muscular fitness. Objectively measured overall fitness had low, but significant predictive value for C-reactive protein (β = -0.22), complement factor 3 (β = -0.35), and complement factor 4 (β = -0.29).

Martinez-Gomez et al. (2012) concluded that objectively measured overall fitness was inversely related to three of the five inflammatory markers measured. Results also showed that objectively measured muscular fitness was significantly related to three of the five inflammatory markers measured.

Power and Body Fatness/Body Composition

The Quebec in Forme project was designed to help promote healthy lifestyles for children with low socioeconomic statuses. A total of 1,140 subjects in first, second, or fourth grade were involved with the intervention. Within the intervention various anthropometric and fitness measurements were assessed including: BMI, waist circumference, standing long jump, speed shuttle run, and a 1-minute speed sit-ups test. From these results Brunet, Chaput, and Tremblay (2006) evaluated the relationship among anthropometric measurements and fitness measurements.

The correlations for boys between waist circumference and standing long jump increased as grade level increased from first (r = -.16), second (r = -.25), to fourth grade (r = -.39). The same pattern was found in the girls. The authors reported the following: first grade (no significant relationship [NS]), second grade (r = -.25), and fourth grade (r = -.39). For males associations were found between BMI and standing long jump in the first (no significant relationship [NS] second (r = -.27), and fourth grade (r = -.40). The common knowledge that heavier children may not be able to jump as far as leaner children cannot be ignored. Brunet et al. (2006) did not control for body weight when evaluating the relationship between standing long jump and BMI or waist circumference. Future studies will hopefully identify this deficiency and seek to correct it. However, the study by Brunet et al. does add to the literature by at least providing evidence that the link between jumping capacity and weight does exist. However,

because differences in weight were not controlled, the findings of the Brunet et al. study must be interpreted with caution.

Liao et al. (2013) investigated the relationship between fitness tests and BMI in 13,500 Taiwanese students ranging from 10-18 years of age. Subjects were placed in one of three groups: non-overweight (BMI $\leq 84^{th}$ percentile), overweight (85^{th} percentile $\leq$ BMI $\leq 94^{th}$ percentile), and obese (BMI $\geq 95^{th}$ percentile). Within each category participants were further split into five quintiles ranging from Quintile 1 (least fit) to Quintile 5 (most fit) for each fitness test. The fitness tests conducted were the modified sit-and-reach test, bent-leg sit-up test, standing long jump, and a run/walk test.

The results for both boys and girls revealed significant, but weak, correlations among BMI and sit-and-reach, bent leg sit-up, and the standing long jump ranging from .08 to -.10. The relationships between BMI and running performance appeared stronger with values ranging from .17 to .39. Analysis of quintiles done with a chi-square test revealed significant increases in the prevalence of overweight and obesity in the least fit quartile compared to the most fit quartile within three of the four fitness parameters (bent-leg sit-up, standing long jump, and run/walk test). Further analysis showed the adjusted odds of being overweight and obese were higher in the least fit quartiles for both the standing long jump (OR = 3.66) and the run/walk test (OR = 5.40).

Liao et al. (2013) provided evidence of the negative relationships among aerobic fitness, lower body power, and obesity risk. The negative relationship found between standing long jump and obesity could be due to insufficient lower body explosive strength inhibiting one's ability to participate in physical activity, as suggested by Liao et al. This conclusion should be interpreted

with caution, as the common explanation that body weight causes heavier children to not jump as far as leaner children, rather than a lack of leg strength, should be considered.

Beunen et al. (1983) examined the relationship between body fatness and motor fitness through the Leuven Growth Study of Belgian Boys, Beunen et al. which studied 21,174 male subjects aged 12-20 years. Participants underwent various anthropometric measurements, including body fatness via four site skinfold. Numerous motor fitness tests were conducted, including the arm pull, vertical jump, leg lifts, and bent arm hang. Many different correlations were reported and they reported in ranges. Among the most significant findings were the inverse relationships among the motor fitness tests involving the body being supported off the ground and body fatness. The strongest correlations observed, although still only moderate in strength, were between body fatness and the bent arm hang (r = -.18 to -.37) and between the vertical jump and body fatness (r = -.18 to -.37). The correlations previously listed were partial correlations reported in age-specific ranges. With height and weight held constant, the arm pull and vertical jump had the strongest relationships with body fatness (r = - .28 to .40). Beunen et al. concluded that fatness is associated with motor performance, defined partially by a power assessment.

In the Amsterdam Growth and Health project, Minck et al. (2007) examined the relationship between fitness tests and health markers while correcting for weight. The purpose of this study was to examine the relationships between body fatness and physical fitness, and to also examine the effect that physical activity may have on these relationships. One hundred and eighty-one participants ranging from 13-27 years of age were studied. Numerous tests were used to measure physical fitness including: flexed arm hang, arm pull, vertical jump, 10 leg lifts, 10 times 5-m sprint, plate tapping, and sit and reach. Physical activity was assessed with an

interview questionnaire and body fatness was measured through a four-site skinfold measurement of biceps, triceps, subscapular, and suprailiac sites. The relationships were evaluated with three types of regression analyses. The first analysis examined the univariate relationship between each fitness item and body fatness. The second analysis examined the same relationship after correcting for physical activity level. The last analysis corrected for physical activity, body weight, and height.

The first analysis showed that for both males and females arm pull (r = -.21, r = -.20, respectively), vertical jump (r = -.11, r = -.21), and maximal oxygen uptake (r = -.29, r = -.23) were significantly and inversely related to body fatness. Similar relationships with body fatness were found when the analysis controlled for physical activity for males and females with the arm pull (r = -.19, r = -.20), standing high jump (r = -.10, r = -.19), and maximal oxygen uptake (r = -.27, r = -.20). The last analysis which controlled for physical activity, body weight, and height, showed the greatest association between body fatness and physical fitness for males in the arm pull (r = .-23), vertical jump (r = -.32), and maximal oxygen uptake (r = -.44). The same analysis found that for females the standing long jump (r = -.38) and maximal oxygen uptake (r = -.40) were significantly related to body fatness. These findings suggest that low, yet significant relationships, exist between the fitness tests (arm pull, vertical jump, and maximal oxygen uptake) and body fatness. Specifically, concerning the vertical jump, for both males and females the highest relationship between body fatness and jumping ability was the one that controlled for height and weight. Not controlling for height and weight was the pertinent factor that the Brunet et al. (2006) study lacked in linking jumping ability to the health marker of body composition.

Rodriguez et al. (2011) studied the relationship between physical fitness and body fatness over nine years. Five hundred and eighteen six year old participants were monitored. Body fat

was measured via skinfolds and various fitness tests were administered, including: 60 second sit-ups, flexed arm hang, standing long jump, 50 m dash, 10 m shuttle run, sit-and-reach, and 20 m PACER run. Measurements were taken at the ages of six, seven, eight, nine, and 15 years.

Regression coefficients were established to show the significant, yet low, predictive value of each fitness test for body fatness including: flexed arm hang (R = -.06), standing long jump (R = -.07), sit ups (R = -.04), 50 m dash (R = 0.96), and PACER (R = -.08). The significant, yet low, correlation between standing long jump and body fat led Rodriguez et al. (2011) to include muscular strength (defined partly by standing long jump in their study) as a target fitness component when working with youth. This conclusion should be observed in light of the extremely low regression coefficient for standing long jump when predicting body fat (R = -.07).

Urdiales et al. (2009) analyzed the relationship between fitness and fatness in 363 teenagers aged 12.5-17.5 years. Fitness was divided into aerobic, agility, and muscle fitness. The muscle fitness to fatness relationship will be discussed here. Muscle fitness was measured via handgrip strength for the upper body and standing broad jump and vertical jump for lower body strength. Fatness was measured through DXA, BodPod, and the sum of skinfolds. Physical activity was controlled when fitness and fatness were correlated. Physical activity was measured with 15 second epochs with an accelerometer over at least three days.

Results were analyzed separately for boys and girls. Significant correlations were found between each strength test and each measure of fatness for both boys and girls. Values ranged from low to moderate associations (r = .24 to .58). The highest correlations for females were between the vertical jump and DXA (r = .56), vertical jump and BODPOD (r = .54), and vertical jump and skinfolds (r = .54). Slightly lower correlations were found for females for the standing long jump and DXA (r = .46), BODPOD (r = .44), and skinfolds (r = .32). The highest

correlations for males were found between vertical jump and DXA (r = .52), BODPOD (r = .56), and skinfolds (r = .58). Standing long jump had slightly lower correlations with DXA (r = .48), BODPOD (r = .52), and skinfolds (r = .54) for males as well. The handgrip strength had the lowest correlations with the DXA, BODPOD, and skinfolds.

When Beta values were calculated the handgrip strength test had a positive relationship with fatness, and the jump tests had a negative relationship with fatness. Moliner-Urdiales et al. (2011) speculated that this positive relationship could be due to an individual with excess fat tissue having extra lean tissue to support the fat tissue, but this relationship deserves further study.

Power and Physical Activity

Blaues et al. (2011) investigated the relationship between performance on fitness tests and physical activity in 214 children aged 6 to 12 years. Physical activity consisted of physical activity level (time spent in different physical activity intensities) and physical activity patterns (numbers of bouts of physical activity). Physical activity was measured using a uniaxial accelerometer over seven consecutive days. A physical activity bout consisted of at least 5 seconds of activity. Fitness test measurements were taken from the European Physical Fitness Test battery: standing long jump, 10 × 5 meter shuttle run, sit-and-reach, handgrip, number of sit ups in 30 seconds, and the 20 meter shuttle run. Waist-to-hip ratio and percent body fat were also calculated.

The only significant relationship found was between body fatness and physical activity level in boys. Moderate negative relationships were found between body fat and vigorous physical activity (r = - .38) and very high physical activity (r = -.35). A moderate positive relationship was found between body fat and light physical activity (r = .28). No significant

relationships were found between physical activity and physical performance on any fitness test. Blaues et al. (2011) concluded that spontaneous physical activity of subjects within this study did not induce enough of a stimulus to increase fitness test performance.

Martinez-Gomez et al. (2012) examined the relationship between physical activity and muscular fitness in 2,400 participants aged 13-16 years. Physical activity was measured over seven days using the ActiGraph GT1M accelerometer. Strength was measured via muscular index. The muscular index included handgrip strength, 60 second abdominal test, and the standing long jump. The handgrip strength test score was the average of each hand and the hand-dynamometer was adjusted for gender and hand size (Ruiz et al., 2008). The muscular index score was the summation of the standardized scores from each test. The PACER test was used to assess aerobic fitness.

Aerobic fitness was significantly correlated with standing long jump (r = .48) and with the total muscle fitness score (r = .35). Vigorous activity was the only category of physical activity which was significantly related to muscle fitness (β = .13), after adjusting for gender, age, pubertal status, BMI, and aerobic fitness. Participants were split into three groups of low, middle, and high levels of vigorous activity. ANCOVA results revealed significant differences between muscle fitness in the lowest vigorous activity group compared to the highest vigorous activity group.

Power and Quality of Life

Morales et al. (2013) investigated the relationships between health-related quality of life (HRQL), BMI, aerobic fitness, and musculoskeletal fitness in 1,158 children aged 8-11 years. HRQL was measured through the KIDSCREEN-52 questionnaire and aerobic fitness was tested via the PACER. Musculoskeletal fitness was measured through a musculoskeletal fitness index

for each specific age and sex. The index consisted of the sum of standardized scores for each age and sex of the handgrip test score expressed relative to body weight and standing long jump score. Participants were then divided into three separate categories for both aerobic fitness and musculoskeletal fitness. The categories were based on percentile rank for each test and were as follows: poor (< 25^{th} percentile), satisfactory (25^{th}-75^{th} percentile), and good (> 75^{th} percentile).

ANCOVA was used to test differences in the mean scores on HRQL. Results revealed that boys who were in the higher aerobic fitness categories had higher scores in physical well-being and social support segments of HRQL compared to the lower aerobic fitness groups. Data showed that boys in the poor category scored a mean score of 51.2 in the physical well-being subscale and 52.4 in the social support subscale of the HRQL, compared to a score of 57.0 and 57.6, respectively, for the good fitness category. Girls who were in the good aerobic fitness category had a physical well-being mean of 57 compared to 51.2 in the poor aerobic fitness group. Regarding social support, girls in the good aerobic fitness group averaged 57.6 compared to a 52.4 score for the poor aerobic fitness group.

For boys, significant differences were found between participants in the good vs. the poor muscular fitness groups for physical well-being, social support, and social acceptance. The biggest difference between the good muscular fitness and poor muscular fitness group was in the category of social support (a difference of 6.0 points).

Morales et al. (2013) used multiple regressions to examine the value of BMI, aerobic fitness, and musculoskeletal fitness for predicting HRQL. After controlling for age and jointly combining all three factors aerobic fitness was significantly related to physical well-being (β = 0.12), psychological well-being (β = 0.11), moods and emotions (β = 0.14), self-perception (β = 0.11), social groups (β = 0.14), school environment (β = 0.11), social acceptance (β = 0.17), and

financial resources (β = 0.11) in girls. For boys, aerobic fitness was only significantly associated with social groups (β = 0.11). Musculoskeletal fitness seemed to have a much greater impact on predicting HRQL for boys than girls, as the musculoskeletal index significantly predicted physical well-being (β = 0.19), self-perception (β = 0.12), autonomy (β = 0.13), social support (β = 0.22), and financial resources (β = 0.02). For girls, the musculoskeletal fitness index significantly predicted physical well-being (β = 0.19).

Results from the study by Morales et al. (2013) seem to show that a relationship may exist between musculoskeletal fitness and HRQL. Morales et al. used the standing long jump as part of a measure of musculoskeletal fitness. It would seem plausible to then link this measure of power to HRQL. These relationships, once again, have to be considered with caution as weight was not controlled for during the analysis.

Intervention Studies Evaluating the Relationships among Measures of Power and Various Health Markers

Numerous intervention studies have tried to identify links between muscle fitness and positive health outcomes (Heinonen et al., 2000; Ingle et al., 2006; Kontulainen et al., 2002). From these studies, the relationships between the fitness measurement of power and various health markers could be examined. For example, Kontulainen et al. (2002) examined the effects of a jumping intervention on bone development in growing females. Sixty-four participants with a mean age of 12.8 ± 1.5 years were placed in the training group and 62 girls with a mean age of 12.2 ± 1.6 made up the control group. A pretest was conducted to measure the participants' bone mineral density (BMD) at the lumbar spine and proximal femur locations. Participants also underwent various performance tests, such as the leg press to measure maximal isometric strength, a shuttle run to measure agility, and the standing long jump to assess muscular power.

The training offered two step aerobics classes for 50 minutes a week lasting for 9 months. The number of jumps within a class gradually increased as time went on. After the 9-month training program, participants were brought in for a follow-up evaluation in which they underwent the same tests given before the training.

A multivariate regression analysis was used to examine the relationship between participation in training and bone mineral density. This relationship was established after controlling for the effects or various confounding variables, such as growth, nutrition, pubertal development, and physical activity. The results showed a 4.9% increase in bone mineral density within the lumbar spine of the training group compared to the control group. The training group also had a significant increase of 6.4% in the standing long jump (Kontulainen et al., 2002). The relationship here could be rather important in that only the standing long jump, not the leg extension test nor the shuttle run test, reflected increases in lumbar bone mineral density after training.

Heinonen et al. (2000) investigated the relationship between bone mineral growth and jump training in girls. The training group and control group consisted of 73 girls and 64 girls, respectively. The two groups were further divided into two groups of premenarcheal or postmenarcheal based on several characteristics, one of which was the Tanner five-stage assessment. The intervention was a 9 month program in which 50 minute step aerobics sessions were offered twice a week. Pretest and posttest measures consisted of various bone density measurements via dual-energy X-ray absorptiometry (DXA). Fitness tests were also measured pretest and posttest, including isometric leg press, standing long jump, sit-ups, and shuttle run.

The results showed that premenarcheal girls in the training group increased significantly more than participants in control group at the lumbar spine (8.6% vs. 5.3%) and femoral neck

(9.3% vs. 5.3%). However, no significant differences were found at the trochanter (9.7% vs. 6.9%), tibial midshaft (0% vs. 0%), tibial CoA (6.0% vs. 4.4%), or tibial BSI (9.6% vs. 7.5%). Postmenarcheal girls showed no significant difference between the training group and control group with bone mineral density improvements at any bone site. The fitness tests revealed that, compared to the control group, premenarcheal girls in the training group significantly increased their performance in the shuttle run (3% vs. 0%) and standing long jump (7% vs. 1%). Postmenarcheal girls in the training group significantly increased their scores compared to the control group for the sit-up test (18% vs. 12%) and the standing long jump (7% vs. 2%). Heinonen et al. (2000) provided limited support for the relationship between lower body power and bone health. The premenarcheal girls training group increased both bone mineral density and standing long jump performance. However, the postmenarcheal groups did not significantly increase in bone mineral density, but did increase significantly in the standing long jump.

Ingle, Sleap, and Tolfrey (2006) examined the potential link between power assessments and decreases in lean body mass and body fatness. A complex training program incorporating both plyometrics and resistance training was used over a course of 12 months. The authors assessed the effects of the training program on various performance markers in males aged 11 to 12 years. The intervention group consisted of 33 participants and the control group consisted of 21 participants.

Three measurement periods were used to assess percent body fat, lean body mass, and performance on various tests including: Wingate anaerobic test, standing long jump test, vertical jump test, basketball chest pass, and 40 m-sprint test. The first measurement period was during the pretest. The second measurement period was after the intervention. The third measurement came after a 12-week detraining period in which the intervention group did not participate in the

training. Results revealed that the intervention group lost 6% of their body fat over the course of the 24-week study. Performance measurement results of the intervention group revealed a statistically significant increase in vertical jump (0.9 cm) and basketball chest pass (80 cm) (Ingle et al., 2006). These tests are measures of lower body and upper body power, respectively. Therefore the association between increased power performance and improved body composition could be plausible.

Summary

Physical fitness testing has a significant history in the United States. The most recent development is the official implementation of the FitnessGram as the national youth fitness test. The 2012 Institute of Medicine report evaluated various fitness test components as they related to health outcomes in hopes to recommend possible improvements to youth fitness testing. Studies that examined the relationship between muscular fitness and health outcomes were examined the Institute of Medicine report. The report called for the implementation of the standing long jump in national youth fitness tests as a measure of muscular fitness. However, further research was needed to analyze the relationships among muscular fitness and health outcomes.

In this review of literature numerous studies were examined to help understand the relationships between muscular fitness, with an emphasis on muscular power, and health outcomes in youth. The literature revealed that muscular fitness has been linked to healthier metabolic profiles in youth including: healthier inflammatory responses (Martinez-Gomez et al., 2012; Ruiz et al., 2008), improved lipid profile indexes (Artero et al., 2013; Garcia-Artero et al., 2007), decreased metabolic disease risk (Artero et al., 2011; Steene-Johannessen et al., 2009), decreased clustered cardiovascular disease risk (Magnussen et al., 2012; Ortega et al., 2005), and improved insulin sensitivity (Jimenez-Pavon et al., 2012).

In addition to its relationship with metabolic health, muscular fitness has also been linked to improved body composition among youth (Beunen et al., 1983; Brunet et al., 2007; Liao et al., 2013; Rodriguez et al., 2011; Urdiales et al., 2009). Muscular fitness has also been positively correlated to physical activity in youth (Martinez-Gomez et al., 2012) and quality of life (Morales et al., 2013).

The Institute of Medicine (2012) recommended that future research focus on the relationships among measures of muscular fitness and health outcomes in youth. Specifically, the IOM report noted the importance of identifying which individual tests could be used to predict health outcomes. Numerous studies have reported relationships between a muscle fitness index score, consisting of several tests, and health outcomes. The purpose of this study is to evaluate the relationship between muscular fitness tests of power and health outcomes in youth.

Methods

Participants

Twenty-two girls and 27 boys aged 9 to 14 years were recruited through the East Carolina University listserve. Participants were paid $20 for participation in the study and the parent or guardian received $5.

The study was reviewed and approved by the Institutional Review Board of East Carolina University. Written assent was obtained from the participant and consent was received from the participant's parent or guardian.

Procedures & Measurements

Summary of Procedures. Testing took place in two separate sessions. The following measures were taken at the first session: resting heart rate, blood pressure, height, body mass, physical activity questionnaires, body composition via BODPOD and skinfolds, total body medicine ball throw, upper body medicine ball throw, vertical jump, standing long jump, and handgrip strength. The same measures were taken on the second day of testing, except for the anthropometric measurements. Also, at the end of the testing days either the PACER test or a maximal treadmill test was administered.

Resting heart rate. Resting heart rate was measured for 60 seconds with a Polar heart rate monitor after 5 minutes of seated rest.

Blood Pressure. Blood pressure was measured manually after participants rested for at least 5 minutes. Blood pressure was assessed with the participant seated and left arm resting on a table. Two blood pressure measurements were conducted with at least 1 minute between measures.

Height. Height was measured with a stand-alone stadiometer (SECA Corporation, Hanover, MD) to the nearest 0.1 cm. Participants stood straight up with their shoes off and heels together and were to take a deep breath and hold their breath during the measurement.

Body Mass. Body mass was measured with an electronic scale (COSMED, Concord, CA) to the nearest 0.1 kg during the BODPOD procedure.

Bod Pod Test. Before completing the BODPOD test participants changed into compression shorts or bathing suit and were instructed to remove jewelry, shoes, eye glasses, and socks. Participants also wore a swim cap during the test.

Before the BODPOD test, the system was warmed-up and calibrated. The participant's information was then entered into the system including: date of birth, gender, height, and ethnicity. Participants then entered the BODPOD and their thoracic gas volumes (TGV) was measured. Five trials were attempted. If TGV was not obtained after five trials, then TGV was predicted by the software.

Skinfolds. Skinfolds were measured two times at the triceps and calf sites of the right arm and leg with Lange (Cambridge, MD) calipers. The calf skinfold was measured on the inside of the right leg at the level of maximal calf girth. The right foot was placed flat on a crate so that the knee was bent at approximately 90°. The triceps skinfold was measured on the back of the right arm over the triceps muscle, midway between the elbow and the acromion process of the scapula.

Physical Activity Measurement. Physical activity was measured using a GT3X accelerometer. Participants were asked to wear the accelerometer for seven days and were instructed to put the accelerometer on immediately after getting up out of bed and to take it off

right before they went to bed. Epochs were set at 5 seconds and Evenson et al. (2008) cut points were used to categorize time spent at various intensities.

Total Body Medicine Ball Throw. Participants were asked to throw a 4-pound medicine ball as far forward as possible. They were instructed that the trajectory of the ball would make a difference in the distance it would travel. Participants were told to not throw the ball straight up or straight out, but up and out at the same time. Participants started with their toes behind a line and squatted with the medicine ball held at chest height with hands slightly behind the ball. From the squat position participants then thrust their hips into extension and drove their arms forward and up to throw the ball as far as possible. Participants were given two or three practice trials and a visual demonstration was provided. After the practice trials, three test trials were administered. Distance of the throw was measured with a tape measure.

***Upper Body Medicine Ball Throw*.** The upper body medicine ball throw was tested with participants seated on the ground with their back and head against a wall and feet spread shoulder width apart with legs straight. Participants were instructed to hold the 4-pound medicine ball at chest height with hands behind the back of the ball. Participants thrust the ball forward and were instructed to maintain contact between their back and the wall. Two or three practice trials were provided before three test trials were recorded.

***Vertical Jump*.** The vertical jump was tested with the Vertec (Power Systems, Knoxville, TN). Participants were instructed to reach up as far as possible on the Vertec and displace the highest plank they could. The standing reach was recorded. Participants were then instructed and given a visual demonstration on executing the vertical jump. Participants were told to squat down and swing their arms back and then straighten up their legs, bring their hands forward and

up and jump as high as they could to displace the highest plank on the Vertec. Two practice jumps were allowed and then three test trials were recorded.

A field test for the vertical jump was also conducted in which participants put a sticker as far up the wall as possible while standing. Participants were instructed to use the same form previously described to jump up and place a sticker on the wall as far up as possible. Three trials for this test were recorded.

***Standing Long Jump*.** Participants stood with their toes behind a starting line. They were instructed to bend their knees, swing their arms back, and then straighten their legs and bring their arms forward and jump horizontally as far as possible. A visual demonstration was provided and participants were allowed two or three practice attempts. Three test trials were then recorded. Jump distance was measured to the nearest quarter inch from the heel that landed closest to the starting line.

Handgrip Strength. Handgrip strength was measured with both the JAMAR (Warrenville, IL) handgrip dynamometer and the CAMRY (Guangdong, China) handgrip dynamometer. The JAMAR and CAMRY dynamometers were fixed in the participants hand so that when the participant gripped the device the second joint of the pointer finger was at a 90° angle. The arm was bent creating a 90° angle at the elbow and tucked beside the body. The participant alternated trials between the dominant and non-dominant hand. The participant was encouraged to squeeze the dynamometer as hard as possible. Three test trials for each hand were recorded. The participant rotated trials from dominant to non-dominant hand with three test trials in each hand. The dynamometer grip width was adjusted to the same standards as followed for the JAMAR dynamometer.

Maximal Treadmill Test. The maximal treadmill test was administered on a Trackmaster treadmill (model TMX425C, Newton, KS). The testing protocol includes participants walking at an initial speed of 2.5 mph. At every one minute interval heart rate was recorded using a Polar heart rate monitor. Rating of perceived exertion (RPE) using the OMNI RPE scale was also recorded each minute (Utter et al., 2002). Speed was increased 0.5 mph each minute until 5 mph was reached. Speed was then maintained at 5 mph and treadmill grade was increased 3% each minute until the participant was unable to continue. VO_{2max} was considered maximal if two of the following characteristics were met: (a) signs of intense effort such as hyperpnea, facial flushing, grimacing, unsteady gait, and sweating; (b) heart rate at or above 90% of age-predicted maximal heart rate; (c) respiratory exchange ratio at or above 1.0. Once the test was terminated the participant was allowed to cool down. Participants received verbal encouragement throughout the test.

Statistical Analysis

Descriptive Analysis. Descriptive statistics were calculated for physical characteristics, fitness tests of strength and power, and health outcome measures.

Norm-referenced Test-retest Reliability. Reliabilities were estimated with an intraclass correlation using a one-way model for the following variables: standing long jump, vertical jump total body medicine ball throw, upper body medicine ball throw, and handgrip strength. Paired sample *t*-tests were used to examine differences between the first and second trial of each variable. Effect size (*ES*) was calculated using Cohen's delta as shown below.

ES = (Mean of 1st session – Mean of 2nd session) / (Mean of standard deviations of 1st and 2nd sessions)

***Relationships among Fitness Tests and Health Outcomes*.** Bivariate correlations were calculated to examine the relationships among fitness tests of strength and power (standing long jump, vertical jump, total body medicine ball throw, upper body medicine ball throw, handgrip strength) and health outcomes (blood pressure, VO_{2max}, physical activity level, and body composition). To examine the impact of body composition, partial correlations were calculated among fitness tests and health outcomes controlling for body mass and age. Partial correlations were also calculated controlling for body mass index (BMI) z-score and age.

Intercorrelations among fitness tests were also calculated. Of particular interest were correlations between standing long jump and vertical jump, total body medicine ball throw and upper body medicine ball throw, and left and right handgrip strength.

Criterion-referenced Evaluation. Participants were categorized into the aerobic capacity Healthy Fitness Zone (HFZ) and Needs Improvement Zone (NIZ) as defined by FitnessGram® (Meredith & Welk, 2010). Effect size estimates were calculated to examine the size of the difference between the HFZ and NIZ aerobic capacity groups on the fitness test variables (standing long jump, vertical jump, total body medicine ball throw, upper body medicine ball throw, and handgrip strength).

Participants were also categorized into the body composition HFZ and NIZ as defined by FitnessGram® (Meredith & Welk, 2010). Effect size estimates were calculated to examine the size of the difference between the HFZ and NIZ body composition groups on the fitness test variables (standing long jump, vertical jump, total body medicine ball throw, upper body medicine ball throw, and handgrip strength).

Results

Physical Characteristics

Physical descriptive statistics are shown in Table 1 for the 49 participants of the study. Twenty-two participants were female (45%) and 27 participants were male (55%). Sixteen participants were African American (33%), while the majority of the participants (65%) were Caucasian. Age ranged from 9 to 14 years. BMI values ranged from 12.7 to 38.3 $kg \cdot m^{-2}$.

Table 1
Physical Characteristics *(M ± SD)* of Sample (*N* = 49)

Variable	Total *Mean ± SD*	Boys *Mean ± SD*	Girls *Mean ± SD*
Age (years)	11.3 ± 1.8	11.4 ± 1.7	11.3 ± 1.9
Height (cm)	151.9 ± 13.2	153.3 ± 14.4	150.2 ± 11.7
Body mass (kg)	46.8 ± 16.4	50.2 ± 18.6	42.4 ± 12.0
BMI ($kg \cdot m^{-2}$)	19.8 ± 4.7	20.7 ± 5.4	18.6 ± 3.5

Note: BMI is body mass index.

Health Outcomes

Health outcomes are listed in Table 2. Compared to a nationally representative sample taken from National Health and Nutrition Examination Survey (NHANES) data, mean body fat was lower in participants in the current study (Laurson et al., 2011). Percent body fat ranged from 6.3% to 47.7%. Average percent body fat for boys was higher than the average percent fat for girls. Systolic and diastolic blood pressures were similar between boys and girls. Compared to physical activity assessed via accelerometry from NHANES data on 12- to 15-year-old participants (Troiano et al., 2008), males in the current study had similar levels of physical activity (42.1 minutes of MVPA in the current study vs. 45.3 minutes of MVPA in Troiano et al. study). Females in the current study were more active than females in the study by Troiano et al. (45.6 minutes of MVPA in the current study vs. 24.6 minutes of MVPA in Troiano et al. study).

Table 2
Health Outcomes (*M* ± *SD)* of Sample (*N* = 49)

Variable	Total *Mean* ± *SD*	Boys *Mean* ± *SD*	Girls *Mean* ± *SD*
Systolic Blood Pressure (mm Hg)	98.3 ± 9.7	98.0 ± 9.8	100.8 ± 14.4
Diastolic Blood Pressure (mmHg)	61.8 ± 8.7	62.5 ± 9.6	61.5 ± 8.1
VO_{2max} ($ml \cdot kg^{-1} \cdot min^{1}$)	37.3 ± 7.0	35.6 ± 10.7	39.2 ± 5.2
Body Fat (%)	24.5 ± 9.7	25.6 ± 8.0	23.2 ± 8.1
Physical Activity (min MVPA)	44.2 ± 19.5	42.1 ± 21.2	45.6 ± 18.0

Reliability of Blood Pressure Measurement and Fitness Tests

Table 3 presents the reliability of the blood pressure results and fitness tests. All fitness tests had a test-retest reliability estimate above $R \geq .97$. Reliability was lower for diastolic blood pressure and systolic blood pressure than for the other variables.

Table 3
Descriptive Statistics and Test-Retest Reliability (*M* ± *SD*) for Selected Variables (*N* = 49)

Variable	Day 1 (*Mean* ± *SD*)	Day 2 (*Mean* ± *SD*)	Reliability
Diastolic Blood Pressure (mm Hg)	62.1 ± 8.9	61.8 ± 8.7	.66
Systolic Blood Pressure (mm Hg)	99.3 ± 12.0	98.3 ± 9.7	.78
Standing Long Jump (in.)	54.6 ± 11.8	54.1 ± 12.7	.97
Vertical Jump (in.)	11.0 ± 4.1	11.0 ± 3.9	.97
Total Body Power Throw (in.)	183.6 ± 57.2	182.8 ± 58.3	.97
Upper Body Power Throw (in.)	134.1 ± 39.5	131.5 ± 39.5	.98
Handgrip (kg) – Dominant hand	23.4 ± 8.4	23.3 ± 8.2	.98
Handgrip (kg) – Nondominant hand	21.8 ± 8.4	21.4 ± 8.3	.98

Correlations among Health Outcomes and Fitness Tests

Table 4 presents correlations among fitness tests and health outcomes. Correlations ranged from low to moderate. Low correlations were found between the health outcomes of diastolic blood pressure and physical activity and all fitness tests. Systolic blood pressure and VO_{2max} were moderately correlated with several fitness tests, including total body power, upper body power, and dominant and nondominant handgrip strength. Percent body fat was moderately correlated with the standing long jump and vertical jump. The correlation between percent fat and handgrip strength was close to zero when handgrip strength was expressed in absolute terms. Moderate correlations were found between percent fat and handgrip strength when handgrip strength was allometrically scaled for body mass.

Table 4
Correlations among Health Outcomes and Fitness Tests

Variable	Diastolic Blood Pressure	Systolic Blood Pressure	VO_{2max} ($ml \cdot kg^{-1} \cdot min^{-1}$)	Body Fat (%)	Physical Activity (min MVPA)
Standing Long Jump	-.16	-.01	.18	-.45**	.16
Vertical Jump	-.25	.08	.04	-.50**	.06
Total Body Power Throw	-.19	.37**	-.28*	-.07	.12
Upper Body Power Throw	-.17	.33*	-.31*	-.04	.10
Handgrip (kg) – Dominant hand	.06	.44**	-.33*	-.03	-.07
Handgrip (kg) – Nondominant hand	.09	.37**	-.34*	-.03	.01
Handgrip ($kg \cdot mass^{-.67}$) – Dominant hand	.02	.14	.11	-.50**	-.13
Handgrip ($kg \cdot mass^{-.67}$) – Nondominant hand	.06	.06	.08	-.48**	.01

*$p < .05$, **$p < .01$

Partial Correlations among Health Outcomes and Fitness Tests Controlling for Age and Body Mass

Partial correlations, controlling for age and body mass, are presented in Table 5. Low correlations were found between all fitness tests and the health outcomes of systolic blood pressure, $VO_{2max,}$ and physical activity. Diastolic blood pressure was moderately negatively correlated with total body power and upper body power. Percent fat was moderately correlated with all fitness tests.

Table 5
Partial Correlations among Health Outcomes and Fitness Tests Controlling for Age and Body Mass

Variable	Diastolic Blood Pressure	Systolic Blood Pressure	VO_{2max} ($ml \cdot kg^{-1} \cdot min^{-1}$)	Body Fat (%)	Physical Activity (min MVPA)
Standing Long Jump	-.17	-.18	.19	-.45**	.25
Vertical Jump	-.28	-.04	.00	-.57**	.11
Total Body Power Throw	-.42**	-.08	.12	-.49**	.28
Upper Body Power Throw	-.42**	-.19	.07	-.46**	.23
Handgrip (kg) – Dominant hand	-.01	.00	.09	-.55**	-.05
Handgrip (kg) – Nondominant hand	.02	-.15	.15	-.60**	.08
Handgrip ($kg \cdot mass^{-.67}$) – Dominant hand	.07	.09	.07	-.54**	-.11
Handgrip ($kg \cdot mass^{-.67}$) – Nondominant hand	.09	-.09	.13	-.59**	.05

**$p < .01$

Partial Correlations among Health Outcomes and Fitness Tests Controlling for Age and BMI Z-score

Partial correlations, controlling for age and BMI z-scores, are presented in Table 6. The pattern of correlations was somewhat similar to the partial correlations with age and body mass

partialled out, with a few exceptions. The significant correlations between DBP and the total body power throw and upper body power throw were smaller when BMI z-scores were controlled than when body mass was controlled. In addition, the significant correlations between percent fat and total body power throw, upper body power throw, and absolute handgrip strength became low and nonsignificant when BMI z-scores were partialled out. The correlations between percent fat and standing long jump and vertical jump were similar with body mass or BMI z-scores partialled out.

Table 6
Partial Correlations among Health Outcomes and Fitness Tests Controlling for Age and BMI Z-score

Variable	Diastolic Blood Pressure	Systolic Blood Pressure	VO_{2max} ($ml \cdot kg^{-1} \cdot min^{-1}$)	Body Fat (%)	Physical Activity (min MVPA)
Standing Long Jump	-.20	-.27	.29	-.52**	.25
Vertical Jump	-.30*	-.10	.09	-.55**	.11
Total Body Power Throw	-.30*	.15	-.22	-.14	.25
Upper Body Power Throw	-.30*	.06	-.22	-.22	.21
Handgrip (kg) – Dominant hand	.09	.29*	-.35*	.01	-.03
Handgrip (kg) – Nondominant hand	.12	.19	-.33*	-.02	.07
Handgrip ($kg \cdot mass^{-.67}$) – Dominant hand	.05	.04	.04	-.36*	-.10
Handgrip ($kg \cdot mass^{-.67}$) – Nondominant hand	.09	-.06	.00	-.34*	.08

*$p < .05$, **$p < .01$

Intercorrelations among Fitness Tests

Table 7 presents the correlations among fitness tests. Correlations among all fitness tests ranged from .57 to .95 and were statistically significant. The correlation between the two fitness

tests designed to assess lower body power, standing long jump and vertical jump, was high (r = .84). The two throwing tests (upper body power throw and total body power throw) were also highly correlated with each other (r = .95). Absolute handgrip strength measured on the dominant and nondominant hands was highly correlated (r = .96). The correlations between absolute handgrip strength and allometrically scaled handgrip strength were moderately high (r = .76 and .79).

Table 7
Intercorrelations among Fitness Tests

Variable	Standing Long Jump	Vertical Jump	Total Body Power Throw	Upper Body Power Throw	Handgrip (kg) – Dominant hand	Handgrip (kg) – Nondominant hand	Handgrip ($kg \cdot mass^{-.67}$) – Dominant hand
Vertical Jump	.84**						
Total Body Power Throw	.71**	.74**					
Upper Body Power Throw	.71**	.75**	.95**				
Handgrip (kg) – Dominant Hand	.65**	.70**	.87**	.88**			
Handgrip (kg) – Nondominant hand	.61**	.66**	.85**	.86**	.96**		
Handgrip ($kg \cdot mass^{-.67}$) – Dominant hand	.71**	.79**	.58**	.57**	.76**	.69**	
Handgrip ($kg \cdot mass^{-.67}$) – Nondominant hand	.67**	.75**	.60**	.58**	.73**	.79**	.89**

**$p < .01$

Partial Correlations among Fitness Tests Controlling for Age and Body Mass

Table 8 displays the partial correlations among fitness tests, controlling for age and body mass. Partial correlations among all fitness tests were statistically significant and moderately or highly correlated. The partial correlation between the standing long jump and vertical jump was lower than the zero order correlation between these tests (r = .75 vs. r = .84). The partial correlation between the two throwing tests (upper body power throw and total body power throw) was high, although lower than the zero order correlation between these tests (r = .85 vs. r = .95).

Table 8
Partial Correlations among Fitness Tests Controlling for Age and Body Mass

Variable	Standing Long Jump	Vertical Jump	Total Body Power Throw	Upper Body Power Throw	Handgrip (kg) – Dominant hand	Handgrip (kg) – Nondominant hand	Handgrip ($kg \cdot mass^{-.67}$) – Dominant hand
Vertical Jump	.75**						
Total Body Power Throw	.71**	.77**					
Upper Body Power Throw	.73**	.83**	.85**				
Handgrip (kg) – Dominant hand	.64**	.77**	.60**	.60**			
Handgrip (kg) – Nondominant hand	.61**	.72**	.60**	.60**	.89**		
Handgrip ($kg \cdot mass^{-.67}$) – Dominant hand	.54**	.68**	.49**	.48**	.96**	.82**	
Handgrip ($kg \cdot mass^{-.67}$) – Nondominant hand	.54**	.66**	.53**	.51**	.87**	.97**	.86**

**$p < .01$

Criterion-referenced Test Results

Figures 1 and 2 display comparisons between participants categorized into the aerobic capacity Healthy Fitness Zone (HFZ) and Needs Improvement Zone (NIZ) as defined by FitnessGram® (Meredith & Welk, 2010). Effect size estimates to examine the size of the difference between the HFZ and NIZ groups demonstrated that the HFZ group did better on the standing long jump than the NIZ group. However, medium effect sizes demonstrated that the NIZ group did better than the HFZ group on total body power throw, upper body power throw, and absolute handgrip strength. Differences in the vertical jump and allometrically scaled handgrip strength favored the HFZ group over the NIZ group, but these differences were generally small.

Figures 3 and 4 display comparisons between participants categorized into the body composition Healthy Fitness Zone and Needs Improvement Zone as defined by FitnessGram® (Meredith & Welk, 2010). Effect size estimates revealed large differences between the HFZ and NIZ groups favoring the HFZ for standing long jump, vertical jump, and allometrically scaled handgrip strength. Small to medium effect sizes were found for total body power throw, upper body power throw, and absolute handgrip strength favoring the HFZ group over the NIZ group.

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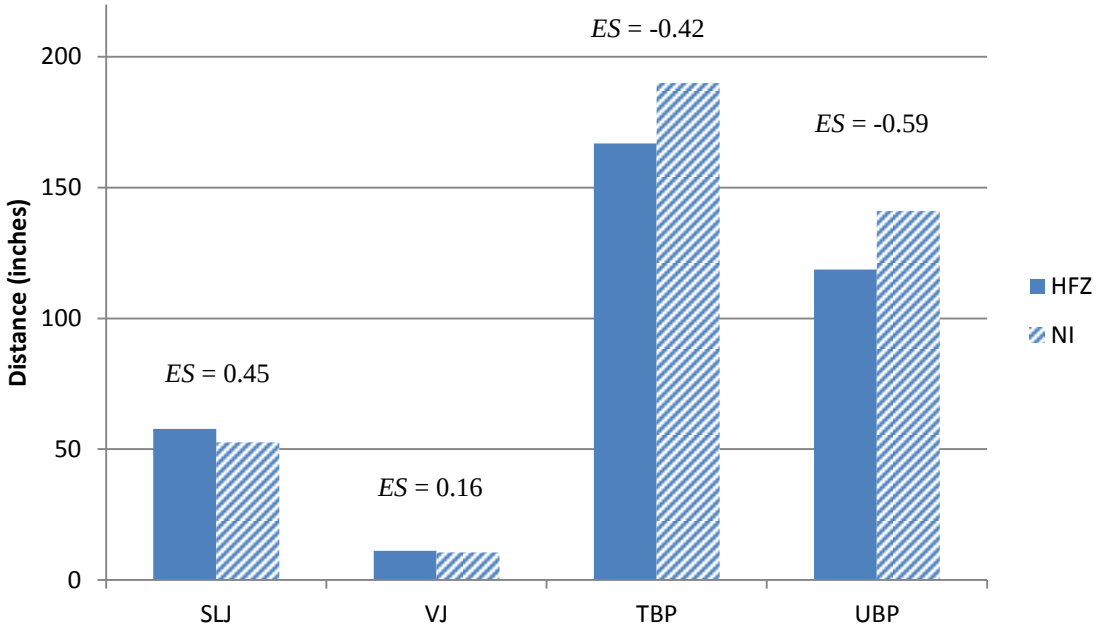

Figure 1
Comparison of Aerobic Capacity Healthy Fitness Zone groups using FitnessGram® Criterion-referenced Standards.
SLJ = Standing Long Jump, VJ = Vertical Jump, TBP = Total Body Power Throw, UBP = Upper Body Power Throw.

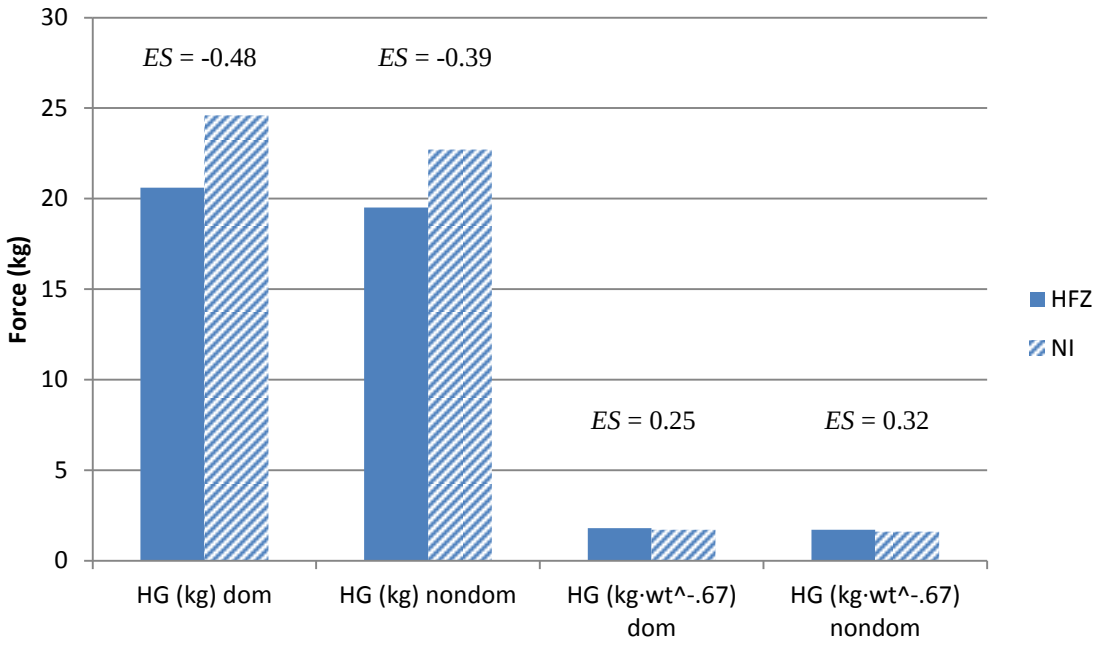

Figure 2
Comparison of Aerobic Capacity Healthy Fitness Zone groups using FitnessGram® Criterion-referenced Standards.
HG (kg) dom is absolute handgrip strength for the dominant hand, HG (kg) nondom is absolute handgrip strength for the nondominant hand, HG (kg·wt^-.67) dom is allometrically scaled handgrip strength for the dominant hand, HG (kg·wt^-.67) nondom is allometrically scaled handgrip strength for the nondominant hand.

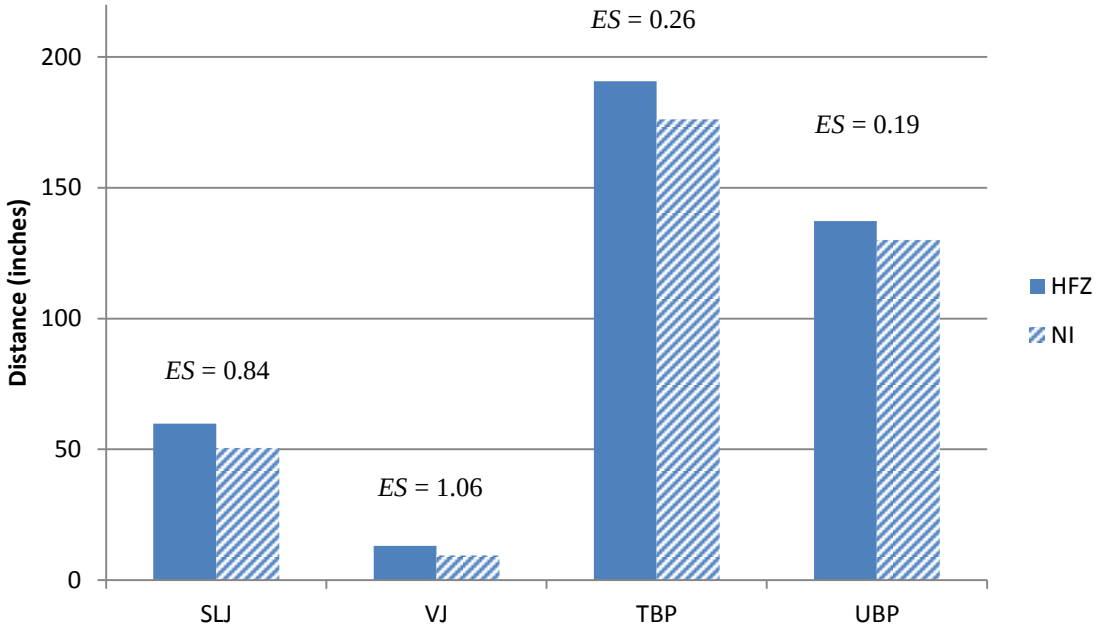

Figure 3
Comparison of Body Composition Healthy Fitness Zone groups using FitnessGram® Criterion-referenced Standards.
SLJ = Standing Long Jump, VJ = Vertical Jump, TBP = Total Body Power Throw, UBP = Upper Body Power Throw.

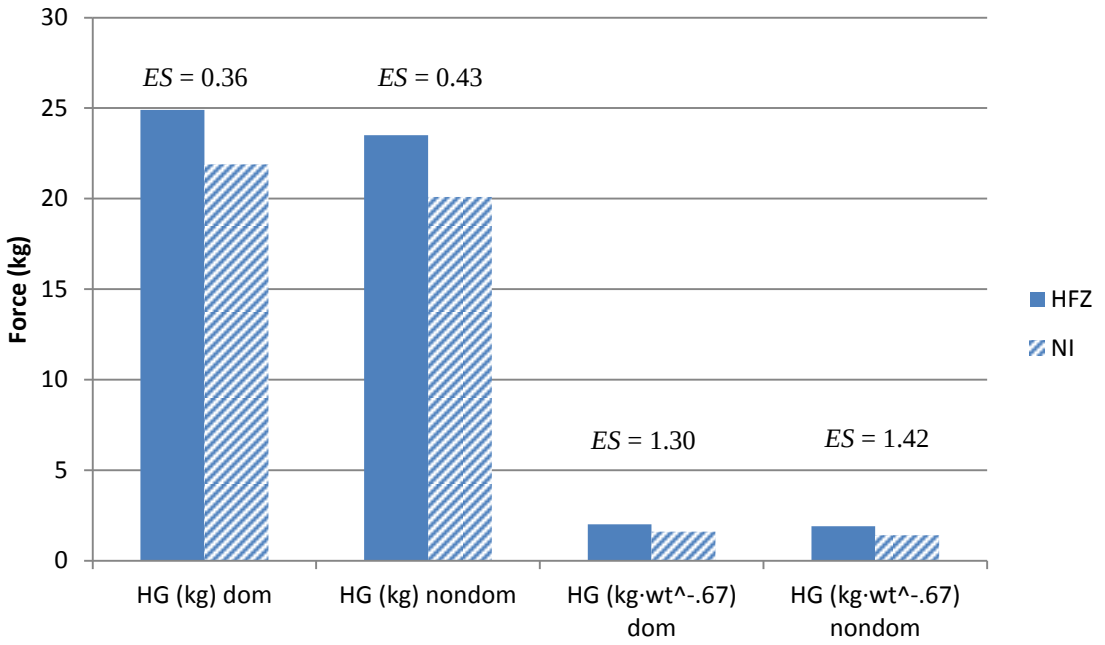

Figure 4
Comparison of Body Composition Healthy Fitness Zone groups using FitnessGram® Criterion-referenced Standards.
HG (kg) dom is absolute handgrip strength for the dominant hand, HG (kg) nondom is absolute handgrip strength for the nondominant hand, HG (kg·wt^-.67) dom is allometrically scaled handgrip strength for the dominant hand, HG (kg·wt^-.67) nondom is allometrically scaled handgrip strength for the nondominant hand.

Discussion

The current study was conducted in response to the Institute of Medicine (2012) recommendation for further investigation of the relationship between musculoskeletal fitness tests and health outcomes. Therefore, the primary purpose of the current study was to examine the relationship between specific musculoskeletal fitness tests and health outcomes in youth.

Several studies that evaluated relationships among musculoskeletal fitness tests and health outcomes used health markers derived from blood tests, such as C-reactive proteins, lipid metabolic indexes, inflammatory scores, cholesterol, triglycerides, and insulin measurements (Artero et al., 2011; Artero et al., 2013; Ortega et al., 2005; Ruiz et al., 2008; Steene-Johannessen et al., 2009). Fewer studies focused on field-based health outcome measures, such aerobic fitness, body composition, blood pressure, and physical activity levels (Beuenen et al., 1983; Martinez-Gomez et al., 2012; Minck et al., 2000). In the current study, relationships among various musculoskeletal fitness tests and health outcomes of aerobic fitness, body composition, blood pressure, and physical activity were investigated.

The major findings from the current study were moderate negative correlations between aerobic fitness and musculoskeletal fitness tests of total body power throw, upper body power throw, and absolute handgrip strength. Positive moderate correlations were found between systolic blood pressure and musculoskeletal fitness tests of total body power, upper body power, and absolute handgrip strength. Negative moderate correlations were also found between percent fat and musculoskeletal fitness tests of standing long jump, vertical jump, and allometrically scaled handgrip strength.

Further analysis examined partial correlations among fitness test items and health outcomes while controlling for age and body mass and for age and BMI z-score. When

controlling for age and body mass, percent fat had a negative moderate correlation with all fitness tests. Diastolic blood pressure had negative moderate correlations with both the total body power throw and upper body power throw, after controlling for age and body mass.

In youth, BMI z-score may be a more appropriate variable than body mass to partial out if the intent it to control for differences in body composition. The main difference between the two partial correlation analyses (one with age and body mass controlled, and one with age and BMI z-score controlled) was that the correlations between percent fat and total body power throw, upper body power throw, and absolute handgrip strength were low and nonsignificant when BMI z-score was partialled out, but were moderate and significant when body mass was partialled out. This may suggest that BMI z-score did a better job of controlling for differences in body composition than did body mass. However, this pattern of correlations did not hold for the correlations between percent fat and standing long jump and vertical jump. The correlations between percent fat and the two jump tests (standing long jump and vertical jump) were moderate and negative, with body mass controlled and with BMI z-score controlled.

Few studies investigated relationships among aerobic fitness and musculoskeletal fitness tests. Garcia-Artero et al. (2007) reported low correlations (r = .26 for males and r = .29 for females) between muscular strength and aerobic fitness. Muscular strength was measured through a combined score index of bent arm-hang, standing long jump, and a handgrip dynamometry test. Aerobic fitness was quantified by the stage number during the PACER test. Martinez-Gomez et al. (2012) found a moderate correlation (r = .43) between aerobic fitness measured via the PACER and musculoskeletal fitness. Martinez-Gomez et al. defined musculoskeletal fitness as the mean of the handgrip strength and standing long jump standardized scores. In the current study, low negative correlations were found between aerobic

fitness and the total body power throw (r = -.29), upper body power throw (r = -.33), dominant handgrip strength (r = -.34), and nondominant handgrip strength (r = -.35). However, after controlling for age and body mass, these correlations were lower and not significant. Therefore, the relationships between aerobic fitness and musculoskeletal fitness tests may be explained simply by the body mass of the participant. The finding that the musculoskeletal fitness tests examined in this study are highly dependent on body mass should be considered carefully before including such tests in a national test battery, such as the FitnessGram.

Several other researchers have examined the relationships between body composition and physical fitness tests (Beunen et al., 1983; Brunet et al., 2006; Liao et al., 2013; Minck et al., 2000; Moliner-Urdiales et al., 2011). Beunen et al. (1983) reported a negative relationship between vertical jump and body fat measured via skinfolds using 12-20 year old males. The correlations ranged from r = -.28 to r = -.40, when controlling for height and body mass. Similar to the current study, Moliner-Urdiales et al. (2011) used the BODPOD system to measure body fat. They found a correlation of r = .52 between standing long jump and percent fat, after controlling for age, pubertal status, and physical activity. Also, after controlling for age, pubertal status, and physical activity a correlation of r = .56 was found between vertical jump and percent fat. Moliner-Urdiales et al. examined only males. In the present study, both males and females were evaluated and negative moderate correlations between body fat and the musculoskeletal fitness tests of standing long jump, vertical jump, and allometrically scaled handgrip strength were found. When controlling for age and body mass, negative moderate correlations were found between all fitness tests and percent fat. However, when controlling for age and BMI z-score, low and nonsignificant correlations were found between percent fat and the throwing tests and absolute handgrip strength.

Artero et al. (2011) studied the relationship between systolic blood pressure and various muscular fitness tests. Artero et al. found a low correlation (r = -.10) between systolic blood pressure and a muscular fitness test score. In the current study, moderate correlations were found between systolic blood pressure and total body power throw (r = .37), upper body power throw (r = .33), and absolute handgrip strength for both the dominant and nondominant hands (r = .44, r = .37). After controlling for age and body mass, each of the significant correlations between systolic blood pressure and fitness tests were attenuated. After controlling for age and body mass, moderate correlations were found between diastolic blood pressure and total body power throw (r = -.42) and upper body power throw (r = -.42). The moderate correlations between diastolic blood pressure and both throwing tests provides some evidence that these tests are health-related, supporting the recommendation of the IOM (2012) report to include musculoskeletal tests in national youth fitness tests.

Martinez-Gomez et al. (2012) found a low correlation between moderate to vigorous physical activity (MVPA) and a muscular fitness test score (r = .08). In the current study, no significant relationships between MVPA and muscular fitness tests were found. Several scenarios might explain the lack of correlation between physical activity and muscular fitness tests. It is possible that the measure of physical activity used in the present study does not represent the type of physical activity that might impact musculoskeletal fitness. Although the objective measurement of physical activity via accelerometry used in the current study is a widely-accepted measure of physical activity, tests such as the standing long jump, total body power throw, and handgrip strength may be influenced more by other factors than by minutes spent in MVPA.

In summary, moderate correlations between percent fat and musculoskeletal fitness tests provide some evidence that the fitness tests are health-related. However, because the partial correlations between health outcomes and fitness tests are lower than the corresponding zero order correlations, it is likely that performance on these fitness tests is highly affected by body mass. This finding must be considered when organizations decide which tests to include in their test batteries.

Criterion-referenced standards for body composition were used to categorize participants into two groups: Healthy Fitness Zone (HFZ) and Needs Improvement Zone (NIZ). The FitnessGram cut-points were used to distinguish the two groups. The analysis revealed that, when using the cut-points for body fat, the HFZ group scored significantly better on each muscular fitness test than the NIZ group. Effect sizes indicating large differences between the groups were found for the standing long jump (*ES* = 0.84), vertical jump (*ES* = 1.06), scaled handgrip strength for the dominant hand (*ES* = 1.30), and scaled handgrip strength for the nondominant hand (*ES* =1.40). Small to moderate effects sizes were found for the total body power throw (*ES* = 0.26), upper body power throw (*ES* = 0.19), absolute handgrip strength for the dominant hand (*ES* = 0.36), and absolute handgrip strength for the nondominant hand (*ES* = 0.43). The findings that participants in the HFZ scored better on all fitness tests provides some evidence that these fitness tests are health-related. That is, effect size estimates indicated that students with healthy levels of body fat scored better on average than students with unhealthy levels of body fat.

Criterion-referenced standards for aerobic fitness were also used to categorize participants into two groups: Healthy Fitness Zone (HFZ) and Needs Improvement Zone (NIZ). The HFZ group scored better than the NIZ group on several tests, including the standing long

jump (*ES* = 0.45), vertical jump (*ES* = 0.16), absolute handgrip strength for the dominant hand (*ES* = 0.25), and absolute handgrip strength for the nondominant hand (*ES* = 0.32). The NIZ group, however, scored better on the total body power throw (*ES* = -0.42), upper body power throw (*ES* = -0.59), scaled handgrip strength for the dominant hand (*ES* = -0.48), and scaled handgrip strength for the nondominant hand (*ES* = -0.39). In summary, these findings provide moderate evidence that these musculoskeletal fitness tests are health-related when considered in a criterion-referenced framework.

Analyses were also conducted to examine the intercorrelations among various musculoskeletal fitness tests. The vertical jump and standing long jump were highly correlated (*r* = .84). The total body power throw and upper body power throw tests also were highly correlated (*r* = .95). The correlations remained high when statistically controlling for age and body mass between the two jump tests (*r* = .75) and between the two throwing tests (*r* = .85). The high correlations between the standing long jump and vertical jump suggests that these two tests could be used interchangeably. If a teacher is already using one test, such as the vertical jump, then the standing long jump would not need to be added, or vice versa. The standing long jump was easier to measure than the vertical jump because no specialized equipment was needed to measure the distance of the jump. In addition, the vertical jump took longer to administer because of the need to evaluate standing reach and then to measure the highest peak of the jump. Based on unsystematic observation by the researchers, it appeared that participants enjoyed the total body power throw more than the upper body power throw. Participants may have enjoyed the total body power throw more because of the dynamic movement they had to complete in squatting and pressing the medicine ball. Participants also seemed to appreciate that they were able to throw the ball further during the total body power throw compared to the upper body

power throw. Importantly, the total body power throw was easier to administer than the upper body power throw. During the upper body power throw participants had to be cued several times to make sure their hips and back were touching the wall before the throw. It was also difficult for participants to keep their back against the wall while throwing. Numerous participants would lean forward during the upper body power throw, removing their back from the wall, and then throw the ball forward, necessitating additional trials with correct form. Therefore, based on the findings and observations from the current study, use of the total body power throw is recommended over use of the upper body power throw.

Limitations of our study included a sample that was slightly different than the nationally representative sample of NHANES. In the current study, males had a higher percent fat than females. This is contrary to the NHANES data in which females had greater percent fat, on average, than males (Laurson et al., 2011). The levels of percent fat in the current study could have been greatly influenced by the high percent fat of three male participants, each with a percent fat over 42%. The aerobic fitness levels of participants in the current study also differed from the aerobic fitness levels of participants in NHANES. In the current study, aerobic fitness was higher in females compared to males. The lower aerobic fitness found in males in the current study could have been driven by the very low VO_{2max} values obtained from two male participants ($\leq$ 21 $ml \cdot kg^{-1} \cdot min^{-1}$), coupled with high VO_{2max} values for two female participants ($\geq$ 48 $ml \cdot kg^{-1} \cdot min^{-1}$).

In conclusion, findings from the current study indicated moderate levels of norm-referenced and criterion-referenced evidence that the tests of musculoskeletal fitness used in the current study are health-related. However, findings also indicated that the significant relationships between these musculoskeletal fitness tests and health outcomes are highly

influenced by body composition. The finding that body mass has a strong influence on the standing long jump, vertical jump, and handgrip strength was not unexpected, but should be considered when determining if such tests should be added to national youth fitness testing batteries.

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Appendix A

IRB documentation

EAST CAROLINA UNIVERSITY
University & Medical Center Institutional Review Board Office
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Office **252-744-2914** · Fax **252-744-2284** · www.ecu.edu/irb

Notification of Amendment Approval

From: Biomedical IRB
To: Matthew Mahar
CC:
Date: 8/18/2014
Re: Ame4_UMCIRB 12-001355
UMCIRB 12-001355
Walking Test and Youth Fitness

Your Amendment has been reviewed and approved using expedited review for the period of 8/18/2014 to 8/17/2015. It was the determination of the UMCIRB Chairperson (or designee) that this revision does not impact the overall risk/benefit ratio of the study and is appropriate for the population and procedures proposed.

Please note that any further changes to this approved research may not be initiated without UMCIRB review except when necessary to eliminate an apparent immediate hazard to the participant. All unanticipated problems involving risks to participants and others must be promptly reported to the UMCIRB. A continuing or final review must be submitted to the UMCIRB prior to the date of study expiration. The investigator must adhere to all reporting requirements for this study.

Approved consent documents with the IRB approval date stamped on the document should be used to consent participants (consent documents with the IRB approval date stamp are found under the Documents tab in the study workspace).

The approval includes the following items:

Document	Description
Projected Enrollment Goal - Increased from 60 - 120	

The Chairperson (or designee) does not have a potential for conflict of interest on this study.

IRB00000705 East Carolina U IRB #1 (Biomedical) IORG0000418
IRB00001781 East Carolina U IRB #2 (Behavioral/SS) IORG0000418

Appendix B

Correlations among Health Outcomes and Fitness Tests For Females

Variable	Diastolic Blood Pressure	Systolic Blood Pressure	VO_{2max} ($ml \cdot kg^{-1} \cdot min^{-1}$)	Body Fat (%)	Physical Activity (min MVPA)
Standing Long Jump	.43*	.18	.22	-.40	-.01
Vertical Jump	.31	.15	.32	-.53*	-.14
Total Body Power Throw	.18	.50*	-.36	-.02	-.25
Upper Body Power Throw	.15	.53*	-.33	-.04	-.20
Handgrip (kg) – Dominant hand	.37	.43*	-.33	-.15	-.31
Handgrip (kg) – Nondominant hand	.28	.35	-.34	-.04	-.16
Handgrip ($kg \cdot weight^{-.67}$) – Dominant hand	.36	.10	.20	-.58**	-.28
Handgrip ($kg \cdot weight^{-.67}$) – Nondominant hand	.24	.07	.28	-.50*	-.06

*$p < .05$, **$p < .01$

Appendix C

Correlations among Health Outcomes and Fitness Tests For Males

Variable	Diastolic Blood Pressure	Systolic Blood Pressure	VO_{2max} ($ml \cdot kg^{-1} \cdot min^{-1}$)	Body Fat (%)	Physical Activity (min MVPA)
Standing Long Jump	-.43*	-.17	.23	-.51**	.26
Vertical Jump	-.48*	-.00	.01	-.52**	.17
Total Body Power Throw	-.30	.34	-.20	-.14	.31
Upper Body Power Throw	-.28	.26	-.27	-.09	.24
Handgrip (kg) – Dominant hand	-.05	.48*	-.32	-.02	.05
Handgrip (kg) – Nondominant hand	.06	.42*	-.31	-.07	.06
Handgrip ($kg \cdot weight^{-.67}$) – Dominant hand	-.21	.18	.06	-.48*	.02
Handgrip ($kg \cdot weight^{-.67}$) – Nondominant hand	-.01	.12	.03	-.50**	.05

*$p < .05$, **$p < .01$