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Concurrent Validity and Reliability of the Vertical Jump and Standing Broad Jump Tests in Youth

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Muscular power is an important component of fitness with implications for bone health, explosiveness in movements, and predicting long-term health outcomes. However, the literature is scarce concerning commonly used muscular power field tests among youth, including vertical jump (VJ) and standing broad jump (SBJ). PURPOSE**:** To investigate the relationship between VJ and SBJ. METHODS**:** Approximately 540 students (9-14 years of age) in grades 4-8 participated in the testing of the VJ and SBJ. Pearson correlations were used to evaluate relationships between jump variables and intra-class correlations (ICC) were used to examine the consistency of the relationship between the VJ and SBJ. RESULTS**:** VJ had a positive and moderately-highly correlated relationship with SBJ ($r = 0.74$, $p < 0.05$). ICC analyses demonstrated VJ had poor consistency (ICC = 0.36, $p < 0.05$) with SBJ. Regression analyses showed an r^2 of 0.549 when predicting VJ from SBJ. The r^2 was 0.576 when sex, age, and BMI percentile were utilized as covariates, all $p < 0.05$. CONCLUSIONS**:** Pearson correlations show the VJ has a positive and moderate-highly correlated relationship with SBJ. Age was statistically significant in our regression model but had minimal (1 cm.) impact on VJ. While each are used as field assessments of lower body power in youth, each contributes unique variance during assessment. Further investigation is needed to better determine this unexplained variance.

KEYWORDS: Vertical Jump, Standing Broad Jump, youth, reliability, consistency, validity.

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I.F.

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CHAPTER I: INTRODUCTION

Each year, in schools across the United States, a large number of physical educators carry out fitness assessments. The majority of these assessments are from the FitnessGram testing battery and are administered to evaluate physical activity levels, fitness, and further determine how to better support physical health for millions of students (Plowman et al., 2006; Welk, 2017). For decades, FitnessGram assessments have evaluated the fitness components of aerobic capacity, body composition, muscular strength and endurance, and flexibility (Plowman et al., 2006). Each component of fitness has specific field-assessments (e.g. the PACER test or one-mile-run evaluate aerobic capacity). However, a standardized field-assessment for the component of muscular power has yet to be agreed upon.

While the vertical jump (VJ) and standing broad jump (SBJ) are different movements, both are assumed to assess lower-body muscular power and would likely share variance when compared to a laboratory or clinical assessment. In 2010, a review was conducted to further understand the criterion-related validity of field tests performed in youth and adolescents (Castro-Pinero et al., 2010). The review included a study with children ages 7-12 who performed the VJ and SBJ with a one repetition maximum (1RM) of the leg press as the criterion outcome (Milliken et al., 2008). With BMI (Body Mass Index) accounted for, the SBJ and VJ accounted for 44.4% and 40.8% of variation in the leg press 1RM, respectively. This was the only lower body muscular power test referenced in the review with the authors concluding that, due to a lack of available literature, there is limited evidence that the VJ and SBJ tests are entirely representative of the assessment of lower body explosiveness in youth (Castro-Pinero et al., 2010). A recent study, consisting of young participants (10-18 years), demonstrated that VJ power (represented via force plate) could be accurately predicted from VJ height and body mass

(Mahar et al., 2022). Thus, in a sample of youth, power could be predicted from a participant's mass and VJ performance.

Load-bearing activities are crucial for increasing bone strength (Benedetti et al., 2018; Chevalley & Rizzoli, 2022; Rizzoli et al., 2010). Furthermore, the demographic for the FitnessGram assessments, ranging from youth in grades 3-12, are at an important age for maximizing their bone mineral density (BMD). Peak BMD is built during youth-young adulthood and will regress during the natural aging process (Adams et al., 2016; Loud & Gordon, 2006). Muscular power is predictive of bone strength in youth and could be a crucial measurement for determining if a student has sufficient bone density levels (Janz et al., 2022). Also, poor muscular power may indicate the need for further risk assessment to determine future risk of diseases during the aging process, such as osteoporosis.

Field tests, like VJ and SBJ seem to be related to estimating muscular power (Markovic et al., 2004). A study was conducted to evaluate these jumps in male youth (ages 6-15 years) athletes from a wide variety of sport backgrounds (Gillen et al., 2018). The authors found that the SBJ and VJ were highly reliable in estimating muscular power. However, the authors also indicated that performing the SBJ and VJ in the same battery may be redundant due to their similar results of reliability and could potentially harm an athlete's performance due to fatigue (Gillen et al., 2018). The currently available literature is limited in the field assessment of muscular power for youth of all backgrounds (e.g., athletes and non-athletes, normal weight and overweight, etc.). In this study, we aim to investigate the convergent validity and consistency of the VJ and SBJ field tests of muscular power in a sample of approximately 540 students ages 9-14 years old. Further, we hope to provide physical educators and researchers with data that can potentially save time and resources during assessment.

CHAPTER II: METHODS

Participants

The participants included approximately 540 students from a local school district in grades 4-8 (ages 9-14) that were currently enrolled in physical education classes. The state in which data collection occurred mandates physical education five days per week, allowing for the majority of school students to be eligible for data collection. The data was collected within the gymnasiums of an elementary (4^{th}-5^{th} grade) and a junior high school (6^{th}-8^{th} grade). Exclusion criteria included students who were issued medical exemptions from physical education classes, those who had sustained an injury that would prevent participation, or students missing on the day of the assessments. Testing took place during the participants' normal physical education class hours. A separate test administrator, that was not their primary physical education teacher, conducted the assessments. Informed consent and assent was provided by parents/guardians and youth, respectively. All procedures and protocol were approved by the Illinois State University Institutional Review Board.

Procedures

Participants had their height and mass measured via stadiometer-scale (Seca, Hamburg, Germany). Body mass index (BMI) was calculated with age- and sex-specific percentiles based on the Centers for Disease Control and Prevention growth charts (Kuczmarski et al., 2002). Eligible participants completed two field tests of muscular power; the SBJ and VJ (with a countermovement). The VJ was measured via Vertec (Sports Imports, Ohio, USA). The Vertec vertical jump height measuring apparatus consists of a solid metal base, telescoping upright and colored vanes spaced 1/2" apart that rotate when touched. The VJ was performed on a hard surface/mat. All subjects started with feet parallel, approximately shoulder width apart, and toes under the Vertec device. The test administrator instructed the student to jump as high as possible, reaching (and touching) the Vertec device with one of their outstretched hands. A maximum of three jump attempts was allotted. The highest jump was recorded as the final score for each test.

The SBJ was performed on a hard surface/mat with all participants standing with feet parallel, approximately shoulder width apart, and toes on the starting line. The test administrator instructed the participant to jump forward as far as possible, landing with both feet and without their hands or any other part of their body touching the ground. The measurement was recorded measuring from the back of the heel to the starting line. A maximum of three jump attempts was allotted, with the longest jump recorded as the final score.

Statistical Analysis

Descriptive statistics (including sex, age, height, weight, and BMI) were calculated. The sample was split into groups based on sex. To compare descriptive statistics for boys and girls, independent samples t-tests and chi-square tests of independence were used. To determine the relationship between each muscular power test, correlation and consistency measurements were performed. We carried out both Pearson's and Spearman's correlations to determine the relationship between the continuous metric and ranked scores. Consistency was determined by computing an intraclass correlation coefficient ($ICC_{3,1}$; two-way mixed, single measure for consistency).

To further investigate the relationship between VJ and SBJ, we completed two linear regression analyses. The first regression model included only SBJ as the independent variable, predicting VJ performance. The second model introduced the co-variates of sex, age, and BMI percentile to determine if these variables influenced the relationship between VJ and SBJ.

Retrospective data were exported from EXCEL (Microsoft) and analyzed in IBM SPSS statistics version 27.

CHAPTER III: RESULTS

Descriptive statistics of the participants are presented in Table 1. In our sample, boys and girls were similar in age, weight, height, and BMI status. In general, boys scored higher in the VJ and SBJ. Table 2 represents correlation data for each test performed. We found that the VJ had a statistically significant, positive, and moderate-high correlation with the SBJ ($r = 0.741$, $r_s = 0.706$, $p < 0.05$). For reliability, intra-class correlation values (ICC) indicated VJ/SBJ had poor consistency (ICC = 0.369, $p < 0.05$).

Regression models predicting VJ from SBJ and r^2 values are presented in Table 3. Model 1 predicted VJ from SBJ and resulted in a moderate correlation ($r^2 = 0.549$, $p < 0.05$). Model 2 predicted VJ from SBJ controlling for sex, age, and BMI percentile which resulted in a moderate correlation ($r^2 = 0.576$, $p < 0.05$). Scatter plots representing regression models of the entire sample, boys, and girls are presented in Figures 1, 2, and 3 respectively.

CHAPTER IV: DISCUSSION

The goal of the current study was to assess the relationship between the VJ and the SBJ in youth. We focused on the consistency and convergent validity of the SBJ and VJ, with an emphasis on assessing shared variance between these movements. We found that VJ was positively and moderately-highly correlated with SBJ ($r = 0.741$). However, when assessing consistency with an ICC, the two tests had poor reliability. These values indicate that while both movements are closely associated with each other, unique variances remain between the two. Further, regression models predicting VJ from SBJ found that sex, age, and BMI percentile were not meaningful determinants of the relationship between the two power variables. While age was a statistically significant covariate in our regression model, the impact was minimal with each increasing year of age equating to a one-centimeter increase in SBJ performance. Thus, the unique variance between the two field measures of power cannot be explained by sex, age, or BMI.

We found that while there is a relationship between the VJ and SBJ as assessments of muscular power, that relationship is not greatly influenced by sex, age, or BMI percentile. As stated, age was statistically significant in our regression model, but the impact was minimal, with each increasing year of age only predicting a one-centimeter change in VJ. Similarly, Mahar et al. predicted VJ power, assessed via mechanography, from VJ height, body mass, age, and sex in a sample of 10-18 year olds (Mahar et al., 2022). While the authors found that VJ height and body mass were accurate predictors of VJ power, age and sex did not meaningfully change the model (Mahar et al., 2022). Milliken et al. found that BMI and SBJ and BMI and VJ were significant predictors of leg press one-repetition-maximum (1RM) performance, though age and gender were not significant predictors (Milliken et al., 2008). While BMI was a significant predictor in the Milliken et al. study, it was not in the current study. However, leg press is a non-weight bearing test (and VJ and SBJ are not), which is likely the reason BMI was a stronger predictor. An individual must produce the force necessary to move their body mass when performing the VJ or SBJ, while the leg press only demands the participant to move the weight applied on the machine. Overall, none of the available co-variates in the current study were capable of explaining additional variance between VJ and SBJ in this sample of youth.

The ICC analyses indicated poor consistency between the VJ and SBJ in the current study. Previous research aimed to investigate the VJ and SBJ as tests of muscular power in a sample of 85 students, with an average age around 19 years (Glencross, 1966). The results of this study found that although the VJ and SBJ are similar, about half of the variance between each test is specific variance (Glencross, 1966). Further, it is noted that while muscular power is one component of that variance, jumping ability also appeared to be an important component (Glencross, 1966). Similarly, prior research has indicated the SBJ and VJ do not utilize hip, knee, and ankle musculature to the same extent during each movement (Robertson & Fleming, 1987). Thus, perhaps jumping ability is related to an individual's ability to recruit the musculature necessary to perform the VJ or SBJ adequately. However, we did not assess jumping ability or specific muscle activation in the current study. In a similar study, VJ, SBJ, and sprint tests were assessed by Boone et al. to determine if there was overlap between each of the movements (Boone et al., 2021). The results showed that, while outcome scores were related, no relationships were found between the kinetics of each test and agreement was poor across performance tests (Boone et al., 2021). If jumping ability was related to the ability to recruit the necessary musculature, it seems there would be significant variance between recruitment for each movement. Thus, while sex, age, and BMI may not account for high amounts of variance in these movements, future literature should seek to indicate and further define jumping ability or assess muscle activation to better understand what influences VJ and SBJ performance.

Our results indicated that VJ and SBJ are moderately-strongly correlated. Another study, albeit not in youth, indicated similar relationships between the two jumps. Previously, the SBJ and VJ were assessed in male and female law enforcement recruits with an average age of about 27 years (Lockie et al., 2022). In this study, the SBJ and VJ had a moderate correlation ($r = 0.665$) within all recruits which is relatively similar with the results of our study ($r = 0.741$). The authors noted that due to the degree of coordination required for these tests, recruits with less experience in these movements may have higher variability between each test which could lead to differing values in correlation or reliability testing procedures (Lockie et al., 2022). Thus, the authors recommend practice repetitions for participants prior to testing, as familiarity with these movements could assist in the consistency and reliability of measurements taken. In our study, participants were given verbal instructions on how to perform each movement, as well as multiple trials with the best performance being listed as the result. This was done to familiarize each participant with the movement being performed and decrease volatility between each measurement. However, even with verbal instruction and multiple trials, variance is still present between these movements. While instruction and familiarity are likely not equivalent, our findings reflect that this variance is likely present even with practice attempts of both jumps.

Along with the validity of these tests, the consistency of the VJ and SBJ must also be assessed within the literature. A study examining a variety of fitness tests, including the SBJ and VJ, on European adolescents was conducted to determine the reliability of each test (Ortega et al., 2008). The authors found that there was no learning/mental or fatigue/physical effect for any of the fitness tests when repeated. These results further indicated that sex did not play a role in determining the strength of reliability (Ortega et al., 2008). These results are reflected in a separate study with a sample of 373 Scottish youth soccer players (Dugdale et al., 2019). The sample in this study participated in field-based fitness batteries that included the SBJ and VJ. The resulting data indicated that the majority of these tests proved to be reliable measures of physical performance, including the VJ and SBJ (Dugdale et al., 2019). Further, it has been shown that reliability values may improve with age when performance testing with youth participants. In a sample of athletes aged 10-16 years from a variety of sports backgrounds, reliability values for weighted vertical jump tests improved drastically from age 10 to age 11 and by ages 15-16 the participants reached the same levels measured in adults (Viitasalo, 1988).

As indicated, performance on the field tests could be influenced by familiarity with the movements. In the current study, participants were informed on how to perform each movement and given three trials to perform each movement before a final measurement was taken. One study investigated whether warming up prior to the performance of the SBJ was a determinant for successful SBJ performance outcomes (Koch et al., 2003). In this study, thirty-two trained and untrained men and women were assigned to a high force warm up group, a high power warm up group, a static stretching warm up group, or a no activity warm up group that served as a control. The authors found that none of the warm-up groups produced any meaningful effect on SBJ performance. Further, the authors indicated that the resulting data suggests maximal strength of the participant may be the primary predictor of SBJ performance (Koch et al., 2003). Thus, while familiarity may certainly affect performance, a warm-up routine of the SBJ may prove redundant when attempting to achieve maximal performance values.

There are limitations present within our study. There is a lack of standardization for these movements, specifically the VJ. For example, some administrators may prefer VJ be performed with a counter-movement, others may prefer it to be done without a counter-movement. Therefore, depending on the movement used, it can be difficult to make comparisons between similar jumps in other studies. Additionally, we chose to focus on assessing the covariates of sex, age, and BMI percentile to determine their influence on the relationship between VJ and SBJ. Due to time constraints, there were variables we were not able to investigate as covariates. Perhaps covariates such as short distance, explosive sprint performances could offer additional insight. Although previous research has indicated that sprint test and jump test results do not agree well, perhaps a different outcome is possible with youth. The unknown variance between these movements may lie in variables we were unable to explore in the current study. We believe a strength of our study to be the sample size of youth participants. As mentioned, the available literature on muscular power assessments within youth is limited. Our sample of around 540 youth participants taking part in muscular power assessments helps to broaden the data available to researchers and health educators.

We aimed to assess the convergent validity and consistency of the VJ and SBJ as field tests to estimate lower-body muscular power. We found that the VJ and SBJ were highly associated, but that the consistency between performance outcomes was poor. Further, we found predicting performance of the VJ from the SBJ was not meaningfully impacted when age, sex, or BMI percentile were used as covariates. Health educators who wish to assess muscular power within youth should note that, while the VJ and SBJ are correlated, assessment results may lack consistency within their sample if using both tests interchangeably. Further, if a Vertec is not financially feasible for test administrators, the SBJ is an adequate and practical assessment for muscular power in youth. Future research should seek to determine sources of shared and unique variance between the VJ and SBJ and how these tests can predict laboratory/clinical lower body power when used individually or in tandem.

Table 1. Descriptive statistics of sample

Variable	Boys (n = 292)	Girls (n = 245)
Age (years)	11.5 (1.5)	11.3 (1.4)
Height (cm)	154.1 (13.0)	151.5 (11.8)
Weight (kg)	51.9 (18.0)	51.5 (18.8)
BMI (kg/m^2)	21.3 (5.1)	21.9 (5.8)
Weight Status		
Normal Weight (%)	170 (58.2%)	139 (56.7%)
Overweight (%)	51 (17.5%)	48 (19.6%)
Obese (%)	71 (24.3%)	58 (23.7%)
Vertical Jump (cm)	37.9 (8.4)	34.5 (7.2)*
Standing Broad Jump (cm)	153.6 (30.44)	134.3 (26.5)*

Values are Mean (SD) or Count (%) weight status. Normal weight includes underweight.
*Indicates statistically significant difference between boys and girls ($p < 0.05$).

Table 2. Correlation coefficients between Vertical Jump and Standing Broad Jump

Correlation	Coefficient	95% CI
Pearson's *r*	0.741	(0.700, 0.777)
Spearman's *rho*	0.706	(0.660, 0.748)
Intra-class	0.369	(0.294, 0.440)

Sample size = 537, all correlations statistically significant ($p < 0.05$).

Table 3. Regression models predicting Vertical Jump from Standing Broad Jump

Correlation	Slope	95% CI	*p*-value	*y*-intercept
Model 1				
Standing Broad Jump (cm)	0.20	(0.18, 0.21)	< 0.001	7.74
Model 2				
Standing Broad Jump (cm)	0.18	(0.17, 0.20)	< 0.001	-1.16
Sex	-0.24	(-1.12, 0.71)	0.623	
Age (years)	0.99	(0.66, 1.33)	< 0.001	
Body Mass Index Percentile	-0.01	(-0.03, 0.01)	0.262	

Model 1 $r^2 = 0.549$, Model 2 $r^2 = 0.576$. Sample size = 537, Sex 0 = Girl, 1 = Boy. Both models are statistically significant predictors of vertical jump ($p < 0.05$).

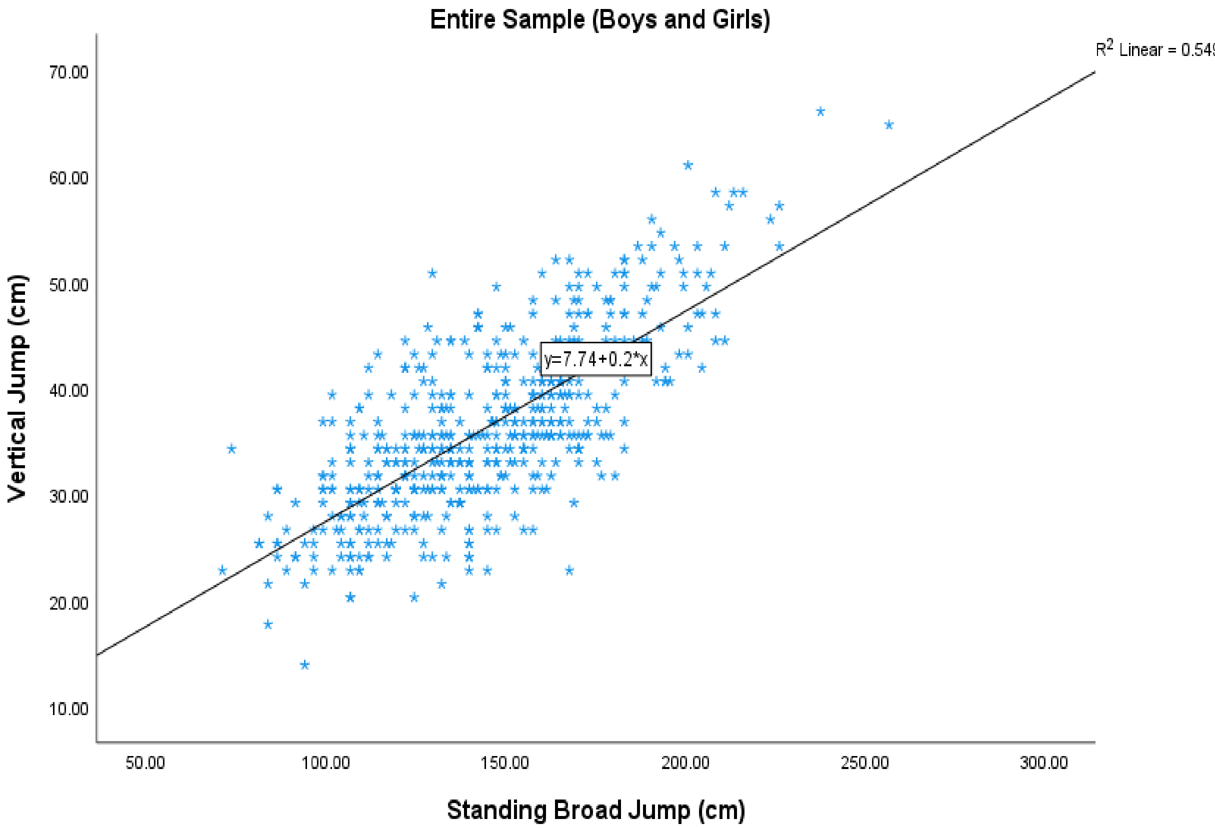

Figure 1. Regression Model of Standing Broad Jump and Vertical Jump scores for entire sample.

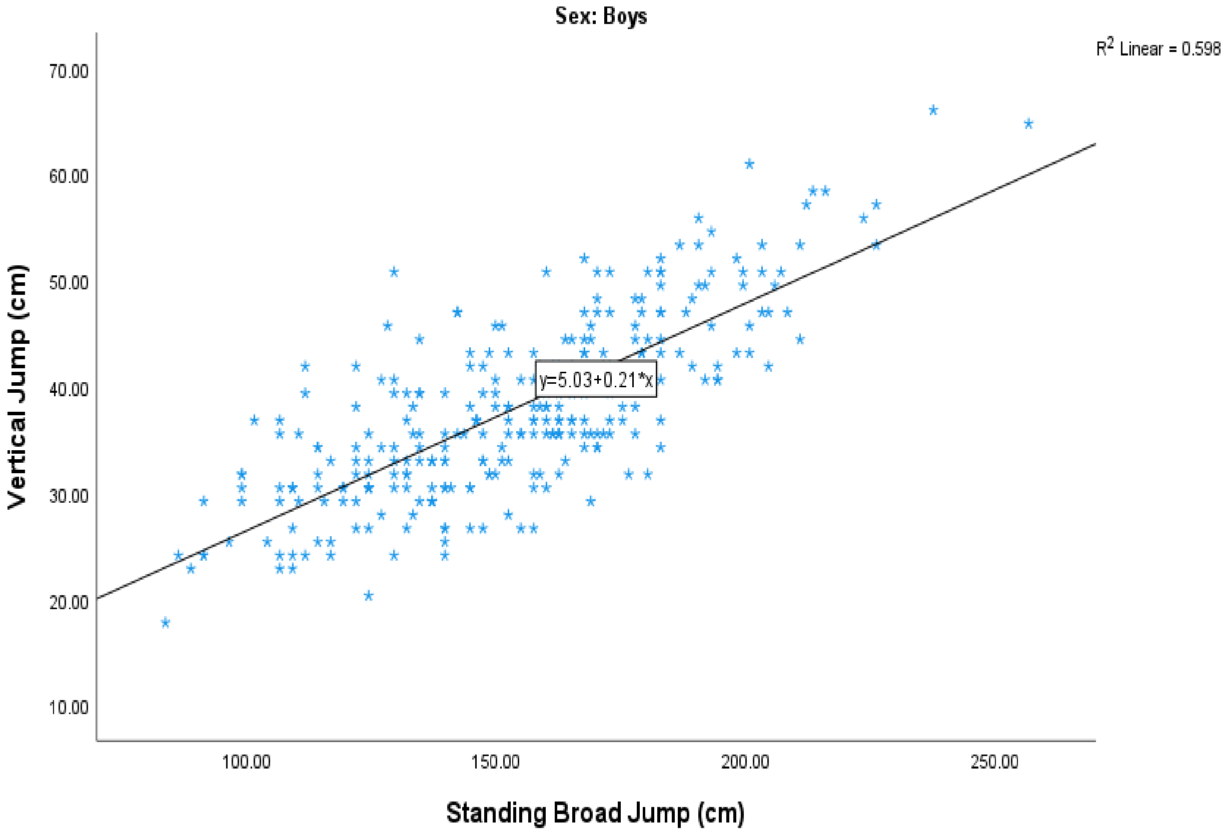

Figure 2. Regression Model of Standing Broad Jump and Vertical Jump scores for boys.

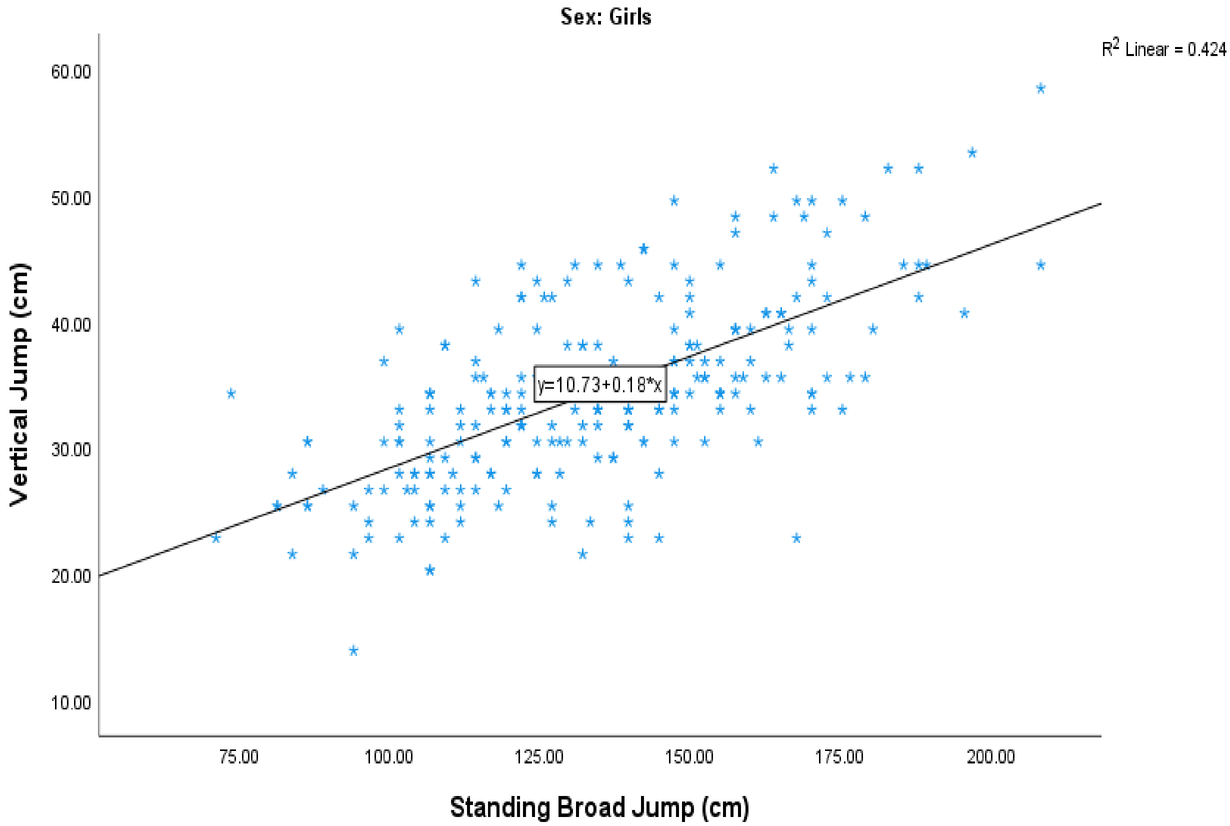

Figure 3. Regression Model of Standing Broad Jump and Vertical Jump scores for girls.

CHAPTER V: EXTENDED LITERATURE REVIEW

Estimating muscular power has many avenues of feasibility. The vertical jump (VJ), standing broad jump (SBJ) and countermovement jump (CMJ) are methods of estimating lower-body muscular power that are widely adopted. Certainly, each of these movements has a legitimate rationale for its utilization in estimating muscular power. What is not certain is whether utilizing each of these tests during assessments is reliable, valid, or even necessary at all to estimate muscular power. Therefore, a review of the literature is necessary to determine what extent each movement plays in assessing muscular power. Firstly, it is important to note what is determinant of a successful/powerful VJ, SBJ, or CMJ movement.

Previous research was conducted to assess the determinants of performing a high measuring vertical jump (Vanezis & Lees, 2005). The authors measured a sample of 50 male soccer players who performed the vertical jump that included a counter movement, denoted as the CMVJ. The sample was allowed to practice before testing with light exercise and stretching, and to practice the movement before assessment. The sample tested three times using an arm swing and three times without an arm swing with the arms held on the hips. The sample was divided into a group for the nine best performers of the CMVJ, denoted as the HIGH group. The sample was also divided into a group for the nine poorest performers of the CMVJ, denoted as the LOW group. The HIGH group was able to jump 11 cm higher than the LOW group in the arm swing condition and 9 cm higher without an arm swing. These results were assumed to be due to individual differences in the athletes' control of muscular contraction and the velocity at which they produce power. Anthropomorphic differences in the sample were ruled out due to the jump height difference being significantly greater than the mass difference between the samples. Therefore, the authors conclude that the performance difference in the samples was likely due to an increased possession of fast-twitch muscle fibers, which was not measured in the study. The authors also note that the fast-twitch fiber distribution could be due to genetics or prior training in the sample, but neither could be decisively concluded (Vanezis & Lees, 2005).

The results of this study seem to indicate that the differences in a high score and a low score seem to stem from individual muscular fiber distribution rather than form. It is important to note that the authors do not imply that form is irrelevant. Rather, it seems that if two athletes were to have perfect form the differences in muscular fiber type distribution would be a determinant for which athlete performs better. This is valuable data in this area of study, as it allows future assessments to potentially focus more on genetics rather than form. Further, it is important to note how we measure these movements.

Currently, there is a lack of a gold standard for the analyzation of the VJ, CMJ, and SBJ. A systematic review conducted in 2010 agreed with the sentiment that there is a lack of standardization for how to assess Musculo-skeletal strength and lower body power (Castro-Pinero et al., 2010). In this review, 73 studies (50 of which were considered high quality) were assessed to determine criterion-related validity of field-based tests in youth and adolescents. The authors found that the specificity of muscular work performed, and different energy usage systems made it difficult to determine what method could be utilized as the gold standard (Castro-Pinero et al., 2010). The authors note that one-repetition max (1RM) tests have been used as gold standards in previous tests. Furthermore, the authors concluded that due to the limited literature it is difficult to determine if the SBJ and VJ are valid in their full assessment of lower-body explosive strength.

Because of the lack of a gold standard in youth and adolescents, it is imperative to search the literature for what others have determined to be valid assessments of lower body power, Musculo-skeletal fitness, or lower-body explosive strength. One study investigated three different methods of VJ analyzation against what some consider the criterion method of VJ measurement in the Vertical Jump Performance Test (VJPT) (Aragón, 2000). The different VJ analyzation techniques were tested for validity, accuracy, and reliability against VJPT. Two of the referenced techniques were based on vertical takeoff velocity (TOVEL) calculated from a force platform. The TOVEL methods included an equation that utilized TOVEL and body center of mass (BCOM) denoted as JUMP2. The second TOVEL equation utilized the force platform and video equipment used in the study without taking into account BCOM, denoted as JUMP3. The third method was based on time spent in the air, denoted as JUMPAIR. In this study, fifty-two physically active male college students performed five maximal vertical jumps with their hands on their hips. The study utilized the same performance, the same participants, and the same unit of measurement (millimeters) when comparing measurement methods. This allowed the study to evaluate concurrent validity, predictive validity, and accuracy quite easily as the best trial was used for each participant. The resulting data found that each method had excellent reliability and validity coefficients when referenced against VJPT (Aragón, 2000). JUMP2 was found to have the smallest average difference in jump height but also had a larger estimation error. JUMP2 was also found to underestimate actual jump height for some, while overestimating for others. JUMP3 and JUMPAIR were found to have larger averages differences from the criterion but were more stable, independent of the level of the results, and a had a smaller prediction error. The study notes that the JUMPAIR is considered an “incomplete measurement” as it does not account for BCOM prior to the performance of the VJ. Likewise, the study further notes that JUMP3 is not necessarily practical to implement due to using information from the force platform and video equipment, though it is conceptually sound

(Aragón, 2000). Still, this study is reflective of the validity, accuracy, and reliability of different forms of analyzing movements such as the VJ.

With the administration of these tests, there is little in terms of standard procedure for referencing results against a youth population. There also seems to be a lack of standardization for assessing VJ, SBJ and CMJ respectively. With this in mind, a meta-analysis of 117 studies that included the terms CMJ or squat jump (SJ) was conducted and targeted a population of adolescents defined as males and females ages 12-18 (Petrigna et al., 2019). The results of this meta-analysis determined that there seemed to be no universal description or standardized procedure for administering these tests. The authors also found that within the tests themselves, there were differences in the performance of the SJ and CMJ, the amount of jumps performed, and the tools used to measure the performance of the tests (Petrigna et al., 2019). This meta-analysis allows for a better understanding of the differences in how VJ is measured, assessed, and referenced across different administrators.

Another key aspect of studying the VJ, SBJ, and CMJ movements is to determine if they are reliable and valid measurements of muscular power in youth participants. Currently, the available literature on the reliability of VJ and CMJ measurement in youth is extremely limited. Administrators of the VJ and CMJ test may be unaware of what is the best practice to assess these movements, what tools to utilize for testing, and if similar tests are redundant in measuring their intended variable. A study sought to determine test-retest reliability for typical National Football League (NFL) combine tests with a sample of 69 youth male athletes (Gillen et al., 2018). Each participant was from a variety of sports backgrounds and were between 6-15 years of age. The combine included two attempts in standard NFL combine drills such as the 40-yard dash, VJ, SBJ etc. VJ performance was measured via Vertec and SBJ performance was measured via standard procedure on a turf field. The participants were allowed two attempts with at least thirty seconds of rest between each attempt. Reliability was determined via repeated-measures ANOVAs. The results for SBJ and VJ were promising in determining if they do in fact measure power, noting that the VJ and SBJ independently measured lower-body power performance (Gillen et al., 2018). The authors note that due to the high reliability in these tests, it may be redundant to perform both movements as it could unnecessarily fatigue the athlete. To further this point, the authors indicate that utilizing the simplest and fewest amount of tests that are reliable could improve performance during a combine due to a reduced workload for the athlete (Gillen et al., 2018). These results seemingly indicate that VJ and SBJ are reliable performance tests to estimate muscular power in participants. Future assessments to estimate muscular power may need to be studied further, as it could potentially be utilizing two forms of testing that are similar in the validity and reliability of testing the variable.

The VJ and SBJ have been tested against each other in a plethora of studies. However, administrators may wish to understand whether sport specific jump tests are more reliable and better suited for their athletes compared to the VJ and SBJ. In one study, the CMJ and Abalkov Jump (AJ) were tested against sport-specific vertical jump tests to analyze and compare reliability values (Rodríguez-Rosell et al., 2017). The sample for this study consisted of teenage and adult soccer and basketball players. Each participant completed a CMJ and AJ as well as the sport-specific jumps in the run-up with two (2-LEGS) or one leg (1-LEG) vertical jump tests. The authors found that each jump test represented explosive power ability and each test yielded acceptable reliability within their sample. However, the AJ and CMJ tests were more reliable for the estimation of explosive force of the lower limbs in all age groups within their sample compared to the sport-specific jump tests (Rodríguez-Rosell et al., 2017).

In another study, the VJ and SBJ were researched to determine relationships between each assessment and if the results from each test were interchangeable (Lockie et al., 2022). This study included a sample of seventy-one males and twenty-three females from a law enforcement academy (LEA) with an average age of about 27 years old. VJ was assessed with a Vertec and SBJ was assessed via standard procedure with a line mark on the ground. The authors found that the VJ and SBJ were strongly correlated in their assessment of absolute height and distance respectively and notes that this is likely due to each test utilizing similar muscular recruitment to perform the task. However, they did note that relative VJ and SBJ did not differ between sexes or correlate and that it may be due to body mass rather than a difference between sexes (Lockie et al., 2022). The study also concluded that the SBJ may be a more feasible test to implement due to minimal equipment requirements.

Another study sought to determine the differences in VJ reliability between the Vertec vertical jump tool and mobile phone applications such as *My Jump* (Yingling et al., 2018). The authors found that in a sample of 135 healthy participants aged 18-39, the reliability values between the Vertec and *My Jump* mobile phone applications varied significantly based on CI values. These findings seem to indicate that while both forms of measurement are reliable, it is considered best to only assess jump height via either Vertec or the *My Jump* mobile application respectively (Yingling et al., 2018). These results could prove to be practical in a setting where a Vertec is not a financially feasible option and also indicates that mobile application capabilities have seemingly become more reliable as technological capabilities increase for testing purposes. However, it is important to note that there is still not a universal standardization of the VJ, CMJ, and SBJ measurement techniques when performed with a physical apparatus or mobile phone application. It could prove to be difficult to implement mobile phone applications nationwide if each app does not implement the same algorithms, technique instructions, and other forms of predictive technology to assist in accurate performance data.

It is important to note why educators and administrators would want to utilize these tests for youth. As previous studies have shown, it is feasible to utilize VJ as a predictor of bone strength or bone disease (Janz et al., 2022). Bone health is a key component of personal health. During the natural aging process, BMD (Bone Mineral Density) values will peak during youth and regress with age (Adams et al., 2016; Rizzoli et al., 2010). As BMD values decrease, the bone becomes frailer. This puts an individual at risk for diseases such as osteoporosis as well as an increased risk for bone fractures (Adams et al., 2016). Therefore, the best course of action for preventing the onset of disease, risk of fracture, and other bone-related ailments is to achieve as high a value of BMD as possible during youth (Rizzoli et al., 2010). This serves as a protective measure during the natural aging process, as when BMD values start to decrease, the individual will start with higher bone "storage" levels and thus have a reduced risk for bone disease. As it relates to testing VJ and SBJ in youth, it is important that administrators and educators are aware of the crucial window of opportunity that youth are in to develop high BMD values to set them up for healthy outcomes in life. Further, as shown in previous studies, VJ in particular is associated with bone strength and disease (Janz et al., 2022). If administrators of these tests are aware of the implications of how youth perform in these tests, they could potentially screen youth that are at a higher risk for bone disease from their test results and recommend them to the proper medical professionals for treatment or further risk assessment.

It has been shown that bone mass in adulthood is positively correlated with childhood activity and that exercise is associated with bone health in youth and adults (Loud & Gordon, 2006). Further, exercise participation during youth has been found to be significantly more osteogenic compared to exercise participation during adulthood (Turner & Robling, 2005). This reinforces the importance of relatively brief timeframe that youth have to develop peak BMD values, as the bone gains seen in adulthood are far less meaningful or may not be present at all in certain circumstances. Further, while all exercise should be recommended and encouraged, emphasis should be placed on load-bearing and dynamic exercises. These types of exercises have been shown to generate the stressors necessary to elicit osteogenic properties within bone (Turner & Robling, 2005). Certainly, any physical activity that involves dynamic loading would be beneficial. Such activities could range from simple activities such as jumping on a trampoline, to more structured activities such as resistance training with proper supervision. Participation in weight-bearing activity, as well as other variables such as Calcium and Vitamin D intake play a crucial role in developing bone strength (Rizzoli et al., 2010). Thus, administrators and health educators should inform youth on the importance of physical activity participation with an emphasis on dynamic load-bearing activity while recommending nutritional habits that support sufficient Vitamin D and Calcium consumption.

Summary

Estimating components of health and fitness is an important aspect of why health educators and administrators implement standardized testing in formats such as those found in FitnessGram assessments. While studies have shown the validity and consistency of VJ and SBJ as estimators of lower-body muscular power in adult samples, few have assessed these values for youth participants. The results of our study found that the VJ and SBJ are highly correlated with each other but have poor consistency. Further, our study found that when sex, age, and BMI percentile were controlled for, there was not a meaningful difference in performance outcomes. Thus, there is variance between the VJ and SBJ that this study was not able to account for.

Future literature should seek to further understand where this variance lies when assessing the VJ and SBJ for youth participants.

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