UDC 796.431.012.11:572.087.1-057.875
Research Article

THE ASSOCIATIONS BETWEEN COUNTERMOVEMENT VERTICAL JUMP DISPLACEMENT AND ANTHROPOMETRIC MEASURES IN COLLEGE AGED STUDENTS

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Abstract

Objectives: To determine the associations between vertical jump height and anthropometric characteristics in non-athlete college students. *Participants:* College students (n = 170) aged 19.1 ± 1.6 years participated in a study measuring countermovement vertical jumps and several anthropometric variables. *Outcome measures:* Anthropometric variables were recorded: age, height, body weight, body mass index, body fat percentage, fat free mass, and body surface area. Vertical jump was assessed using a VERTEC jump system. *Results:* Vertical jump height was significantly different between gender and group classification by body fat ($p < .001$). Body fat percentage displayed strong negative correlations ($r = -.624$, $p < .001$) and fat-free mass displayed strong positive ($r = .667$, $p < .001$) correlations with vertical jump for all the subjects. Both of these findings were consistent across group categorizations (body fat percent and body mass index) with body fat percent yielding the strongest correlations with jump performance. *Conclusion:* This study suggests body fat percentage and fat-free mass have strong associations with vertical jump height in non-athlete college aged students.

Keywords: Body composition, Jump displacement, Body fat percent, Fat-free mass

Introduction

Vertical jump is a movement where individuals jump vertically with the end goal of creating the greatest displacement between their feet and the ground. Jump performance is measured by the vertical displacement of the centre of mass between when one is standing on the ground and while at the apex of the jump (Bobbet & Van Soest, 1994). Vertical jump was first described in 1921 (Sargent, 1921) and is a fundamental activity for many athletic physical activity patterns. Health care professionals, athletic coaches and strength and conditioning trainers incorporate vertical jump as an objective functional movement in their training paradigms (Waggener et al., 2002). Vertical jump is an accepted measureable functional movement of an athlete's ability for physical performance (Barker et al., 1993; Davis et al., 2003; Fry et al., 1991; Carlock et al., 2004; Black et al., 1994; Kraska et al., 2009; and Markovic et al., 2007). Two of the most common jumps used are the squat jump (SJ) and the countermovement jump (CMJ). The CMJ has been demonstrated to have a high correlation with lower limb explosive power (Markovic et al., 2007) and is a reliable and valid field test for estimation of power. The CMJ consists of an initial downward movement (countermovement) that ends with a squat position, followed by an immediate and forceful hip, knee and ankle extension that propels the athlete upward, resulting in takeoff (Reiser et al., 2006). The propulsion phase begins when the concentric contraction follows the eccentric contraction (Reiser et al., 2006; Li-I et al., 2002). The change in movement position, from the eccentric to the concentric contractions, allows for the generation of maximal velocity for the take-off phase. The SJ consists of hip, knee, and ankle extension and also results in takeoff, but the movement begins from a static position and does not provide the same jump height

(Bobbert et al., 2005; Bobbert et al. 1996). The performance of the athlete in the vertical jump is closely related to biomechanics and velocity, force, acceleration, momentum and are the biomechanical principles involved in any type of vertical jump (Bobbert et al., 2005; Reiser et al., 2006). Besides mechanical principles, research has also examined individualistic factors which may have the greatest prediction for vertical jump performance. The majority of the previous studies have focused on modifiable variables in athletes, such as muscle strength, muscle size, segmental measures, flexibility, balance, body composition, and jumping technique (Carlock et al., 2004; Markovic et al., 2007; Reeves et al., 2006; Ashley et al., 1994; Barker et al., 1993; Black et al., 1994; Harmen et al., 1990; Saha et al., 2015). Aside from these published studies, body composition and anthropometrics have been shown to play a role in vertical jump performance. Numerous researchers have conducted studies on anthropometric and body composition variables (Aslan et al., 2001; Davis et al., 2003; Wyon et al., 2006; Reeves et al., 2006; Markovic et al., 2007), however, almost all of the published research has been conducted on athletes or recreational athletes of varying ages. Therefore the purpose of this study was to determine the association of anthropometric characteristics on vertical jump displacement in non-athlete college students.

Methods

Participants

Two hundred and ten subjects were asked to participate in this study and one hundred seventy subjects agreed to take part in this research project. Forty subjects did not want to participate due to time constraints. Subjects were taking part in a bi-yearly voluntary fitness testing project conducted by the Exercise and Sport Science department. Wall vertical jump assessment was part of the fitness testing protocol. Students were also asked if they would like to volunteer at this station to perform a vertical jump on the VERTEC jump system. Students were excluded if they were classified as a collegiate athlete who had previous training on the VERTEC jump system. This research project was approved by the Institutional Review Board for Human subjects and all subjects completed and signed a written consent detailing the purpose and risk of the study before testing began.

Protocol

Anthropometric measures

Subject's height was assessed using standard stadiometer and anthropometric measures were collected using a Tanita bioimpedance scale model t-444 (Tanita Coporation of America, Arlington Heights, IL). Body mass index was calculated as: BMI = weight (kg)/height (cm)^2. The Mostellar formula (Mostellar, 1987) was used to calculate body surface area (BSA = $0.016667 \times W^{0.5} \times H^{0.5}$). Subjects were classified by gender, BMI, underweight/normal (<25 kg/m^2) and overweight (>25 kg/m^2) and by body fat percentage (Fitness men 6-17%, women 14-24%, acceptable men 17-25%, women 24-31%, and obese men <25%, women <32%).

Vertical jump

Vertical jump assessment was conducted using a Vertec vertical jump tower (Sports Imports, Hillard, OH). Subjects were instructed on how to perform a countermovement jump (CMJ) for the three phases of the movement: countermovement, propulsion and take-off. The countermovement phase starts in a standing position and begins with downward movement by flexing the knees and hips to a comfortable position. The propulsion phase starts when the hips and knees are extended in a high velocity and the subject then leaps off the floor (take-off phase) and reaching with their preferred hand to touch the displacement markers. The subjects were asked to perform five standing squat repetitions for a warmup and then two practice jumps at a moderate velocity to practice the movement pattern. For the Vertec jump system subjects positioned themselves below and one step behind the markers to allow for their arm swing to reach the markers. They were allowed one practice jump and then performed two maximal velocity jumps and both measures were recorded. The subjects maximal jump displacement was recorded as the maximal jump height for each test and their best achieved jump was used for statistical analysis.

Statistical Analysis

Three separate one-way ANOVA was used to assess significant anthropometric differences between gender, body mass index classification, and body fat percent classification. Statistical significance was accepted at the $p \leq .05$ level. Bivariate Pearson correlations were evaluated using SPSS 21.0 for Windows (SPSS Inc., Chicago, IL). Statistical significance was accepted at the $p \leq .05$ level.

Results

Anthropometric measures

One hundred seventy subjects (117 male, 53 female) agreed to participate in this research project. Average age was 19.1 ± 1.6 years old for all subjects and there was significant difference between males (19.3 ± 1.8) and females (18.6 ± 1.2), p = .013. The male subjects were also taller in stature in centimeters (male 178.8 ± 7.9, female 164.6 ± 7.1) and there was a significant difference between the groups' height (p < .001). Table 1 displays the demographical data by subject classification. The male subjects displayed significant differences for weight, fat percentage, fat mass (FM), fat free mass (FFM) and body surface area (BSA) (all significant, p < .001), body mass index (BMI) was not significant between the gender groups (p = .130). Classification by BMI demonstrated that the overweight subjects, had significantly higher values for all anthropometric variables (p < .001) compared to the normal weight subjects (see Table 1). Classification by body fat percentage confirmed significant differences between the overweight and acceptable groups for all variables (p < .001) except for FFM (p = .568). Similar findings were observed between the overweight and acceptable groups (p < .001, FFM p = .207) and the fitness and acceptable groups (p < .001, FFM p = .299).

Table 1. Demographic / anthropometric statistics

	Weight (cm)	BMI	Fat Mass %	Fat mass	Fat free mass	BSA
All subjects	70.7 ±12.5	23.4 ± 3.3	18.9 ± 8.8	26.7 ± 15.4	126 ± 24.6	1.84 ± .20
Gender						
Male	75.9 ± 11.4*	23.6 ± 3.5	14.4 ± 6.6*	25.1 ± 14.2*	141 ± 14.2*	1.93 ± .16*
Female	62.2 ± 9.2	22.8 ± 2.9	26.7 ± 6.6	37.3 ± 14.4	99 ± 7.5	1.68 ± .15
BMI						
Normal weight	65.6 ± 9.6*	21.6 ± 2.1*	16.6 ± 8.1*	23.9 ± 11.8*	120 ± 22.2*	1.77 ± .17*
Overweight	82.2 ± 10.8	27.2 ± 2.1	23.9 ± 8.5	42.8 ± 14.8	138 ± 27.3	1.99 ± .17
Body fat						
Fitness	65.7 ± 10.5†	20.9 ± 2.3†	10.8 ± 4.2†	15.5 ± 5.6†	129 ± 21.9	1.78 ± .18†
Acceptable	72.1 ± 12.7‡	24.2 ± 2.3‡	22.1 ± 5.3‡	34.2 ± 6.8‡	124 ± 27.6	1.85 ± .21‡
Overweight	81.4 ± 9.6	27.5 ± 3.3	32.4 ± 4.8	57.9 ± 8.7	121 ± 19.8	1.96 ± 1.4

Note: mean±SD; *p < =.05; †= significant difference between fitness and overweight groups p < =.05;
‡= significant difference between acceptable and overweight groups p < =.05.

Vertical jump Height

The average vertical jump height for all subjects was 47.38 ± 15.6 centimeters. A significant difference was observed for vertical jump height between males (56.6 ± 11.2) and females (32.1 ± 8.1), p < .001. No significant difference for vertical jump height was seen for the BMI grouping between the overweight/obese (47.9 ± 16.4) and normal subjects (46.2 ± 15.6), p = .501. A significant difference was observed between the fitness (53.2 ± 13.8) and acceptable groups (45.1 ± 15.8). Likewise there was a significant difference between the acceptable and overweight groups (37.7 ± 13.7, p = .042), and the fitness and overweight groups (p < .001).

Relationship between vertical jump and body composition

For all the subjects it was observed that FFM displayed the strongest positive correlation (p < .001) with vertical jump and fat mass percentage yielded the strongest negative correlation (p < .001), Table 2. No significant correlations were observed for any of the independent variables for the female subjects and males displayed a weak negative correlation for fat mass % (p < .05) and FM (p < .05). The normal weight subjects displayed the strongest positive correlation with FFM (p < .001) and BSA (p < .001). Conversely, the overweight subjects classified by BMI displayed a strong negative correlation with fat mass % (p < .001) and a strong positive correlation with FFM (p < .001). Subjects in the fitness group by body fatness presented strong to moderate positive correlations with FFM (p < .001) and BSA (p < .001). The acceptable group revealed the strongest correlations with fat mass % (p < .001) and

FFM ($p < .001$). Lastly, the overweight group displayed moderate positive correlation with FFM ($p < .001$) and a negative correlation with fat mass % ($p < .001$).

Table 2. Pearson coefficient (vertical jump centimeters).

	n	Weight	BMI	Fat%	FM	FFM	BSA
All subjects	170	.335*	-.035	-.624*	-.434*	.667*	.448*
Male	107	-.118	-.208	-.259**	.-275**	.056	-.063
Female	63	.-056	-.165	-.216	-.167	.170	-.006
Under weight	117	.540*	.046	-.611*	-.444*	.746*	.590*
Overweight	53	.420*	-.006	-.744*	-.573*	.724*	.472*
Fitness	68	.541*	.290	-.400*	-.102	.597*	.556*
Acceptable	80	.634*	.388*	-.780*	-.385*	.739*	.661*
Overweight	22	.460*	.084	-.632*	-.281	.612*	.561*

Note: *p < =.001; **p < =.05,

Discussion

The purpose of this study was to investigate the relationship between vertical jump performance and several anthropometric characteristics. The vertical jump is an important marker for the measurement and evaluation of lower extremity leg power in athletic groups (Fleck et al., 1985; Hakkinen, 1993; Markovic et al., 2007). Research has demonstrated that at individuals' age, the ability to generate explosive power decreases. One explanation for this decrease in power may be the increased amount of body fat. It has been demonstrated that the preservation of muscle power into late life can greatly decrease the risk for disability, falls, and enhance functional independence (Evans, 2000).

This study demonstrated that a significant correlation exists between vertical jump height and percent body fat, fat free body mass, body surface area and body weight (see Table 2). Vertical jump height was significantly different between males and females and body fat percentage and fat-free mass may have played the largest part in these findings. The male subjects displayed a significant greater quantity of fat free mass compared to the female subjects. These findings were also supported with significant differences between vertical jump height, when subjects were classified according to their body fat percentage.

Interestingly the strongest negative correlation was observed for body fat percentage (see Figure 1) and the strongest positive correlation with body fat-free mass (see Figure 2) for all subjects and grouping classification by BMI and body fat percentage. This study is in agreement with Davis et al. (2003), who found body fat percentage to be highly correlated with vertical jump performance. Of the variables tested in all subjects, fat-free mass and body fat percent elicited the highest correlations with jump performance. However, other studies have demonstrated no significant correlation between body fat percentage (Ashley et al., 1994; Misner et al., 1988), selected anthropometric variables (Ugarkovic et al., 2002), and vertical jump performance. This study also demonstrated similar results when subjects were examined for gender differences (see Table 2). Interestingly, when subjects were divided by gender the females displayed no significant correlations for any anthropometric variables while the men only yielded a weak negative correlation with fat percentage ($p < .05$) and fat free mass ($p < .05$), Table 2.

With respect to vertical jump performance and selected anthropometric measures, this study demonstrated that body composition and body size are moderate to strong predictors of vertical jump performance in untrained college students. Furthermore, when subjects were classified according to their body fat, vertical jump had a direct negative association with total percent body fat. These findings support previous research showing that as body fat percentage increases vertical jump performance decreases (Nahdiya et al., 2012; Davis et al., 2003). The significant difference in jump height in the overweight group supports our findings that body fat percentage may have the greatest association with lower leg power in college aged students. Studies have shown that a person's poorer performance on events that require the movement of a person's body weight through space can be attributed to a higher body fat percentage. This study confirmed these findings that in non-athletic college aged individuals who have a higher percentage of body fat there is a strong negative association with jump performance. While fat-free mass had strong positive correlations it was still interesting that across most subjects' groupings total body fat percentage revealed the strongest correlations with vertical jump height and subsequently their ability to generate lower leg explosive power.

A limitation for this study was that power quantification was not collected from the subjects. While vertical jump is a reflection of lower leg power generation it was not a main variable collected for this project due to time constraints.

Figure 1: Relationship between body fat percentage and vertical jump height in all subjects

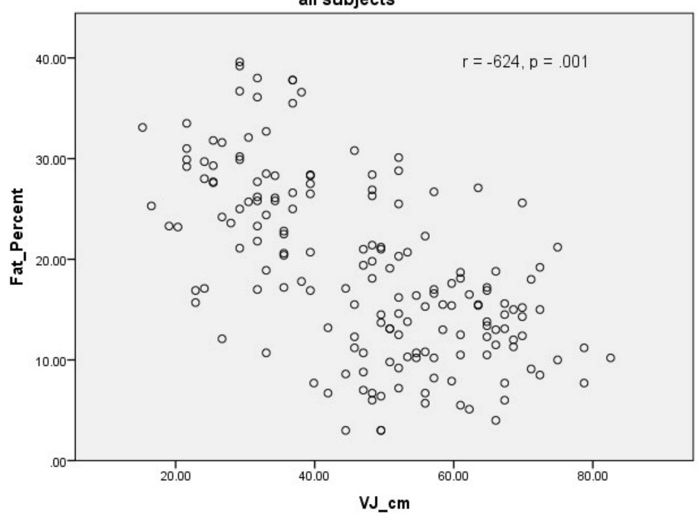
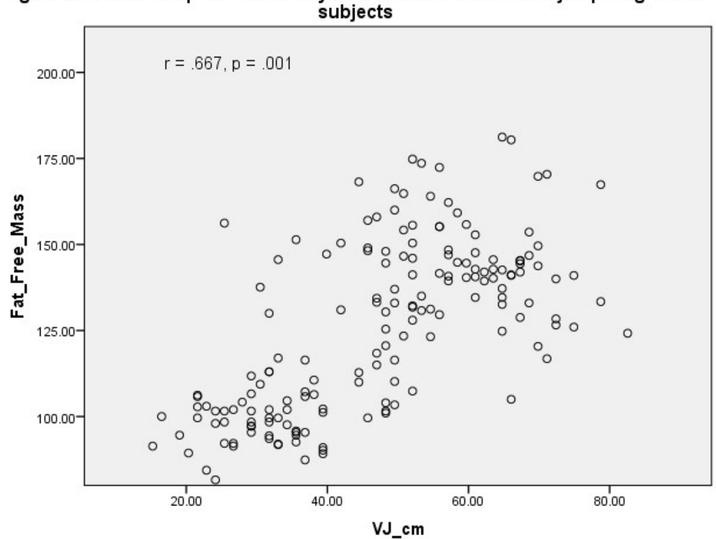


Figure 2: Relationship between body fat-free mass and vertical jump height in all subjects



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