THE RELATIONSHIP BETWEEN UPPER ARM ANTHROPOMETRICAL MEASURES AND VERTICAL JUMP DISPLACEMENT

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ABSTRACT

Int J Exerc Sci 1(1) : 22-29, 2008. The purpose of this study was to determine if upper body segment length or mass contributes to vertical jump (VJ) displacement. Seventeen men (n=9) and women (n=8) who were active recreationally participated in this investigation. Subjects performed VJ for maximal displacement, and skeletal length measurements of the humerus (acromion following the lateral lip to the greater tuberosity), ulna (olecranon to the ulnar styloid process), and hand (lunate to distal end of third phalanx) were obtained by palpation of boney landmarks and a standard tape measure. Pearson Product Moment Correlation Coefficients were used to compare the data with statistical significance accepted at the p=0.05 level. Length of the ulna was the only upper body limb measurement that was significantly correlated with the vertical jump (P = 0.04). As the regression equation to predict VJ from ulnar length was not significant, it appears that neither intrinsic upper arm skeletal length nor arm segment mass is a strong predictor of VJ displacement.

KEY WORDS: Skeletal measurements, functional testing, body segment length

INTRODUCTION

The vertical jump (VJ) test is a common functional measure of an athlete's current and potential level of athletic performance (3, 4, 6, 10). Several studies have documented the influence of VJ displacement on the playing status, level of play, and position in college athletics (3, 4, 10). As a result, coaches and athletes are interested in the improvement of VJ displacement in sports, which require vertical jumping. The VJ is a multijoint action that requires substantial muscular effort from primarily the ankle, knee, and hip joints (13). If the factors that predict VJ displacement are clearly identified, then targeted training programs may be investigated to determine the most effective program (4). Many studies have attempted to determine the factors that influence vertical jump displacement (2-4, 7, 8, 10, 11, 15, 18, 20). Despite the efforts of many investigators, a strong prediction model for VJ displacement has not been identified (4). Previous studies have focused on trainable variables, such as muscular strength, flexibility, balance, body weight, and composition, as well as jumping technique (1-4, 10, 11, 15, 18, 20).

To date there have been very few studies that have examined the influence of non-trainable variables such as the length of individual body segments in predicting VJ displacement. Body segment length has been measured in previous investigations by identification of boney landmarks via palpation (9). Davis et al. (6) assessed measurements of the trunk, tibia, femur, and foot to determine if segmental skeletal length contributed to vertical jump displacement in recreational athletes. The results of the investigation revealed that VJ displacement could not be predicted by skeletal length measures.

During a VJ, muscle force production primarily from the back extensors, gluteus maximus, quadriceps, gastrocnemius, and soleus results in a powerful ground reaction force that propels the body upward against gravity. While the lower leg muscles are necessary for force production, execution of a vertical jump is enhanced with an arm swing. Harman et al. found that take-off velocity during a vertical jump was approximately 10% higher while a jump is performed with the arms compared to when the arms are restricted (11). The arms can be used while jumping to create a rotary force, or torque (T), which is the product of force (F) and the perpendicular distance from the line of axis to the axis of rotation (d). Factors that beneficially affect this arm torque during the execution of a vertical jump could theoretically improve the height of the jump. As in any lever system, the length of the lever arm affects joint torque, with longer lever arms possessing the ability to impart greater force (14). Therefore, it was theorized that longer upper arm segments may lead to greater production of propulsive force and have a beneficial influence on vertical jump. Additionally, since T = F*d, with F being product of mass times acceleration, segment mass may also have an effect on VJ. It was theorized that an increased segment mass would have a direct effect on both force and torque, and result in a beneficial effect on VJ. The purpose of this study was to determine if either upper body segment length (humerus, ulna, and hand) or mass is a predictor of vertical jump displacement in recreational individuals.

METHOD

Participants

Seventeen men (*n* = 9) and women (*n* = 8) who were active recreationally volunteered to participate in this study (age: men 22±1 years, women 22±1 years). Recreational involvement was defined as any individual who participated in nonprofessional or noncollegiate athletics three or more times per week. Descriptive statistics including means and standard deviations are listed in Table 1. This investigation was approved by the university Institutional Review Board for Human Subjects and all subjects completed and signed a written informed consent detailing the purpose and risk of the study before testing began.

Table 1. Descriptive statistics for participants (n=17).

	Age (years)	Height (cm)	Weight (kg)	BMI ($kg \cdot m^{-2}$)	Body Fat (%)
Mean	22	175.5	81.1	25.9	19.4
SD	1	9.1	13.5	1.4	8.0

Protocol

Anthropometrical Measures

Before vertical jump assessment, the participants were scheduled for collection of basic data. The initial assessments took place at the Kinesiology Laboratory at Southern Arkansas University. The first station was set up to determine body weight in pounds using a digital scale (Befour Inc., Saukville, WI). The second station determined the participant's height in inches using a standard scale (Healthometer Inc., Bridgeview, IL) with height attachment. The third station assessed body composition using Bioelectrical Impedance (Omroa Healthcare Inc., Vernon Hills, IL). At the final station body, segment length was assessed using a standard clinical tape measure.

Humerus Length: Humerus length was measured through palpation of the acromion and following from the lateral lip to the greater tuberosity, which is inferior to the acromion's internal edge (12). The examiner followed the length of the humerus to the lateral epicondyle to complete the measurement (Figure 1). Upper arm mass was estimated according to the following regression equation:
Y = -0.142 + 0.029 * (Body mass) (21).

Ulnar Length: To obtain the ulna measurement, the subject was asked to stand with the examiner at their side (12). The examiner then held the anterior lateral aspect of the arm and with the other hand around the biceps, abducted and extended the arm until the olecronon process was visible. The subject was then asked to flex the elbow 90 degrees. The measurement was then taken from the olecranon down the ulnar ridge to the ulnar styloid process (Figure 2). Forearm mass was estimated according to the following regression equation: Y = 0.165 + 0.0139 * (Body mass) (21).

Figure 1. Anthropometric measurement of the humerus, length was recorded as the distance from the greater tubercle to the lateral epicondyle.

Hand Length: The hand was measured palm up from the proximal palm at the lunate to the distal end of the third phalanx (12) (Figure 3). Hand mass was estimated according to the following regression equation: Y = 0.109 + 0.0046 * (Body mass) (21).

Figure 2. Anthropometric measurement of the ulna, length was recorded as the distance from the olecranon to the styloid process of the ulna.

Figure 3. Anthropometric measurement of the hand, length was recorded as the distance from the lunate to the distal end of the third phalanx.

Vertical Jump

The vertical jump assessment was conducted on a separate day using a Vertec vertical jump tower (Sports Imports, Hillard, OH). Prior to the VJ test, participants were warmed up by following an exercise leader through ten minutes of callisthenic-type stretching focusing on the legs, and low intensity cardiovascular activity (jogging, high knees, power skips). The standard vertical jump testing procedures were to have the participant (without taking a step) bend the knees and hips, flex the trunk, lower to a point that feels most comfortable, while at the same time moving arms back into hyperextension. Immediately after reaching this point, making sure not to pause between the flexion and extension phase, the subject jumped as high as possible reaching with dominant hand. The highest point the subject reached on the Vertec was recorded as the maximal jump. The subjects performed the jump three times with the best jump of the three recorded for statistical analysis.

Statistical Analyses

Bivariate correlations were evaluated using SPSS 13.0 for Windows (SPSS Inc., Chicago, IL). Linear regression and derivation of coefficients were also assessed using SPSS 13.0. Statistical significance was accepted at the P=0.05 level.

RESULTS

The mean group vertical jump displacement was 51.6±10.9 cm. Anthropometrical means and standard deviations are reported in Table 2.

Table 2. Anthropometric measurements of subjects (N = 17). Reported as mean±standard deviation.

	Length (cm)	Mass (kg)
Humerus	28.04±2.14	2.17±0.12
Ulna	30.69±2.06	1.27±0.06
Hand	18.55±1.11	0.48±0.02
Sum	77.28±4.34	3.91±0.20

A significant correlation was determined between ulnar segment and vertical jump (P = 0.04). No other significant correlations were evident for arm segment length or arm segment mass (see table 3). A regression equation was derived to predict vertical jump from ulnar length as follows: VJ (cm) = 3.038 * ulnar length (cm) – 16.286 (see Figure 5). However the coefficient for β was not significant (P = 0.33).

Table 3. Correlation statistics and significance for anthropometric variables with relationship to vertical jump displacement in subjects (N = 17).

	r	r^2	P
Humerus length	0.22	0.05	0.40
Ulna length	0.51	0.26	0.04*
Hand length	0.29	0.08	0.29
Sum length	0.42	0.17	0.10
Humerus mass	0.42	0.18	0.09
Ulna mass	0.42	0.18	0.09
Hand mass	0.42	0.18	0.09
Sum mass	0.42	0.18	0.09

DISCUSSION

Previous studies have attempted to determine predictors of VJ displacement basing them largely on variables that can be altered by training. The results of these studies revealed that VJ displacement is difficult to predict; however, two variables, power (1, 2, 7) and body composition (7, 15-19), appear to hold the greatest promise. To date few investigations have attempted to examine the importance of intrinsic (nontrainable) variables in the prediction of vertical jump displacement (6). Therefore, the present study attempted to identify the importance of intrinsic body segment length and mass variables in predicting VJ displacement.

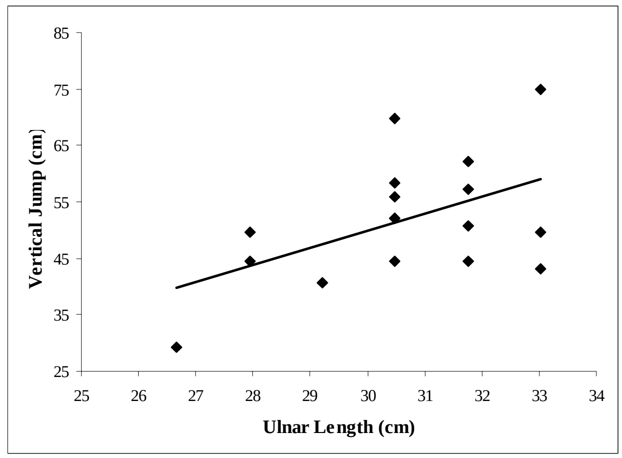

Figure 5. Correlation between length of the ulna and vertical jump (r= 0.51, P=0.04).

In the present study, although vertical jump and ulnar length were correlated, the prediction equation was not significant. In addition, there was no relationship between any other upper limb segment length or segment mass and vertical jump displacement. These findings are similar to the results reported for lower body segment length in that no body segment measurement produced a clear indicator of VJ displacement (6). Davies et al. found that the length of the foot ($p < 0.033$, R^2=0.08) in male recreational athletes was the only significant skeletal length predictor of VJ displacement (6). The sample size for men (n=55) was larger than women (n=23), which could account for the low variability among women. It was also possible that women use a different jumping strategy than men, which requires less ankle joint contribution. This possible difference in technique may place more emphasis on back, hip, and knee extension and less emphasis on ankle plantarflexion. It was hypothesized that for a given ground reaction force, the individual with the longer foot would generate more ankle torque due to the longer lever arm and additional propulsive force delivered in the vertical direction (6). In the present study it was hypothesized that the longer arm would create additional vertical acceleration through the longer lever arm generated by the arm swing. The relatively low predictions in both studies support the null hypothesis that intrinsic body segment length measures have very little influence on vertical jump displacement.

In this investigation, recreationally active was defined as any individual who participated in nonprofessional or noncollegiate athletics three or more times per week. The VJ displacement in this study was consistent with data presented in other investigations involving recreational individuals. In this investigation, the mean VJ displacement was 51.6 cm and included both male and female participants. Davis et al. (6) reported an average VJ displacement of 59.8 cm for male recreational athletes. Ashley and Weiss (2) reported a mean VJ displacement of 27.0 cm in college women. It should be noted that the vertical jump as measured by the Vertec is a learned skill (5), and it is probable that the participants in this study represented a heterogeneous group with some individuals being more trained in the skill of jumping and others being relatively novice at the skill. Future investigations should focus on using homogeneous groups of collegiate athletes, professional athletes or individuals who are specifically jump-trained to potentially yield more favorable results in correlating intrinsic measures as predictors of vertical jump displacement.

The validity of the measurement technique used in this investigation remains in question. The use of a tape measure and the palpation of boney landmarks by experienced testers has been used in previous investigations and has face validity (9). However, no attempt was made to assess criterion-related validity of this measurement technique compared to radiographic measurements. These factors should be taken into account if similar investigations are carried out in the future. As discussed earlier, participants in this investigation were a heterogeneous group with regards to the skill of vertical jumping. It is possible that individuals who are relatively untrained in the vertical jump may lose vertical displacement height with extraneous horizontal movement. As the horizontal displacement of participants upon returning to the ground was not recorded in the present study, the contribution of this possibility was not taken into account and should be controlled for in future investigations.

To date, the study of VJ displacement has relied heavily on the assessment of isolated systems. The vertical jump is a complex task that requires the coordination of the nervous and musculoskeletal systems and is largely regulated by factors such as desire and motivation (6). In the human system, bones, muscles, ligaments, tendons, nerves, and emotions must interact together for optimal athletic performance (6). The results of this investigation identified that intrinsic nontrainable variables of the arm (ulna, humerus, and hand length) are not predictors of vertical jump displacement in recreationally active individuals. It is possible that muscle and specific fiber types around the joint affects the velocity of limb segments to a greater degree and could be a more capable predictor of VJ. Based on the results of this investigation, future studies should examine the interaction of more promising variables such as muscular strength and power, flexibility, balance, coordination, body weight and composition, and jumping technique.

REFERENCES

1. Aragon-Vargas LF, Gross MM. Kinesiological factors in vertical jump performance: Differences among individuals. J Appl Biomech 13: 24-44, 1997.

2. Ashley CD, Weiss LW. Vertical jump performance and selected physiological characteristics of women. J Strength Cond Res 8: 5-11, 1994.

3. Barker M, Wyatt TJ, Johnson RL, Stone MH, O'Bryant HS, Poe C, Kent M. Performance factors, psychological assessment, physical characteristics, and football playing ability. J Strength Cond Res 7: 224-233, 1993.

4. Black W, Roundy E. Comparisons of size, strength, speed, and power in NCAA Division 1-A football players. J Strength Cond Res 8: 80-85, 1994.

5. Burkett L N, Phillips WT, Ziuraitis J. The best warm-up for the vertical jump in college-age athletic men. J Strength Cond Res 19: 673-676, 2005.

6. Davis DS, Bosley EE, Gronell LC, Keeney SA, Rossetti AM, Mancinelli CA, Petronis JJ. The relationship of body segment length and vertical jump displacement in recreational athletes. J Strength Cond Res 20: 136-140, 2006.

7. Davis DS, Briscoe D, Markowski C, Saville S, Taylor C. Physical Characteristics that predict vertical jump performance in recreational male athletes. Phys Ther Sport 4: 167-174, 2003.

8. Dowling JJ, Vamos L. Identification of kinetic and temporal factors related to vertical jump performance. J Appl Biomech 9: 95-110, 1993.

9. Duyar I,Pelin C. Body height estimation based on tibia length in different stature groups. Am J Phys Antropol 122: 23-27, 2003.

10. Fry AC, Kraemer WJ. Physical performance characteristics of American collegiate football players. J Appl Sports Sci Res 5: 126-138, 1991.

11. Harman EA, Rosenstein MT, Frykman PN, Rosenstein RM. The effects of arm and countermovement on vertical jumping. Med Sci Sports Exerc 22: 825-833, 1990.

12. Hoppenfeld S. Physical examination of the spine and extremities. Appleton and Lange, East Norwalk, CT. 1976.

13. Lees A, Vanrenterghem J, Clercq DD. The maximal and submaximal vertical jump: implications for strength and conditioning. J Strength Cond Res 18: 787-791, 2004.

14. Levangie PK, Norkin CC. Basic concepts in biomechanics. In: Joint Structure and Function: A comprehensive Analysis (3rd Ed.). F.A. Davis Company, Philadelphia, PA. 2001.

15. Mcleod WD, Hunter SC, Etchison B. Performance measurement and percent body fat in the high school athlete. Am J Sports Med 11: 390-397, 1983.

16. Miller TA, Miller ED, Kinley KA, Congleton JJ, Clark MJ. The effects of training history, player position, and body composition on exercise performance in collegiate football players. J Strength Cond Res 16: 44-49, 2002.

17. Thomas TR, Zebas CJ, Bahrke MS, Araujo J, Etheridge GL. Physiological and psychological correlates of success in track and field athletes. Br J Sports Med 17: 102-109, 1983.

18. Ugarkovic D, Matavulj D, Kukolj M, Slobodan J. Standard anthropometric, body composition, and strength variables as predictors of jumping performance in elite junior athletes. J Strength Cond Res 16: 227-230, 2002.

19. Williford HN, Kirkpatrick J, Scharff-Olson M, Blessing DL, Wang NZ. Physical and performance characteristics of successful high school football players. Am J Sports Med 22: 859-863, 1994.

20. Young W, Wilson G, Byrne C. Relationship between strength qualities and performance in standing and run-up vertical jumps. J Sports Med Phys Fitness 39: 285-292, 1999.

21. Zatsiorsky VM, and Seluyanov VN. Mass-inertia characteristics of human body segments and their relationship with anthropometric parameters (in Russian). Voprosy Anthropologii (Probl Anthropol) 62: 91-103, 1979.