RELATION BETWEEN ANTHROPOMETRIC DATA AND PERFORMANCE OF LOWER LIMB IN SQUAT JUMP

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In this study, the total peak of joints' torque, work, and the maximum jump height were measured in ten physically active male subjects performing the squat jump (SJ), and squat jump with arm swing (SJA). Accordingly, arm swing caused an increment in the heights of squat jump ($p<0.001$).The results revealed relationships between body mass and height with the total peak of joints' torque ($0.58<r<0.68$ and $0.68<r<0.70$ respectively) and work ($0.54<r<0.59$ and $0.69<r<0.68$ respectively) which were comparable for jumps. There was no significant relationship between body fat percentage and lower limb performances.

KEY WORDS: Body mass, height, work, torque, vertical jump.

INTRODUCTION: There are several parameters contributing to vertical jump performance. In addition to gender, age, level of physical activity and jump technique, body size factors have also associated with vertical jump performance (Jaric, 2003; Markovic and Jaric, 2004). This significant has been supported by studies revealing that the maximum height of vertical jump could be a measure of lower output characteristics affected by anthropometric parameters (Markovic and Jaric, 2007; Nedeljkovic et al., 2009). The effect of these parameters such as body mass, height, and body fat percentage, has yet to be properly quantified. Although body mass has been investigated in some previous studies (Markovic et al., 2014; Samozino et al., 2008;), other factors such as height and body fat percentage have been studied negligibly. It was indicated that increased body fat percentage reduces the jump height in countermovement jump (CJ), although, the discussed effect may not be strong enough (Davis, 2003). Studying the muscle strength and the performance of various movements using geometric similarity revealed that muscle strength should increase with body volume at a lower rate than body mass (Batterham and George, 1997). However, in more complex movements such as vertical jump, theoretical prediction is not straightforward caused by the various parameters integrated with body size factors (Jaric, 2003). In a recent research, the relationships between body mass and power output during squat jump (SJ) and CJ have been examined (Markovic et al., 2014). They concluded that body mass confounds the power-performance relationship obtained from maximum vertical jumps. It was also stated that when controlled for body mass, the maximum power output of lower extremity consistently shows a stronger relationship with the maximum height achieved than average power output.The lower extremities output in vertical jump plays the main characteristic in athletes' achievement (Ostojic et al., 2006; Vuk et al., 2012) while its relationship with anthropometric data was investigated rarely. The purpose of this study, therefore, was to determine how anthropometric data viz., body mass, height, and body fat percentage, affect lower limb torque and work during the squat jump, in order to provide a comprehensive implementation of motor control, performance evaluation, ergonomics, rehabilitation and injury prevention used by professional athletes, athletic trainers, and physical therapists. The main hypothesis associated with this study was that the anthropometric data influence the lower limb performances of subjects during squat jumping in the vertical direction.

METHODS: Following approval by the Ethic Committee of Musculoskeletal Research Center of Isfahan University of Medical Sciences, ten physically active male individuals (mean (S.D.): age = 22.3 (2.4) years; height = 175.6 (4.7) cm; mass = 66.2 (8.5) kg; percent of body fat = 13.1 (4.2) percent) were enrolled on a voluntary basis and provided informed consent.

Mass and percent of body fat were measured by Omron BF511 using BIA method (Bioelectrical Impedance Analysis). Two types of vertical jump have been considered in this study. Each task was performed five times with right and five with left leg on the force platform (5060, Kistler, Switzerland). One minute of rest between each jump was considered. These two jump tasks were: squat jump (SJ) and squat jump with arm swing (SJA). Before the main jump tasks, participants performed a few practice jumps. Experiments were repeated in case of losing balance or violating the jump protocol. The highest jump was considered for further analysis. In SJA, subjects were requested to swing their arms at a self-preferred style after the start command has been given. For SJ, participants were instructed to keep their hands on the pelvis arch with their thumbs located in a belt around the waist. SJA and SJ started from the knee with the approximately 90 degrees, in order to make sure that each subject started the jump from the same altitude in each trial. Subjects remained unmoved in the squat situation for a period of 5 seconds and then attempted to jump without any furthermore downward movement. The jump movement time was specified from the beginning of changes in GRF until it became zero. A marker-based motion capture system (Proreflex, Qualysis, Savedalen, Sweden) with 34 reflecting skin markers were used on both sides of the body to trace the body movements. Also, four rigid plastic cluster containing four markers on each cluster were placed on shin and thigh for tracking the segment's movements. Data were collected at 100 Hz and filtered by using a low-pass fourth-order zero-lag Butterworth filter with cut-off frequency of 10 Hz, while the force was collected at 1000 Hz. Visual 3D (C-Motion, Inc., Germantown, MD) was used to model body movements with respect to X-coordinate (Lateral). Joint work was determined as the integrating of joint power with respect to time. All the joint parameters were calculated considering the mean value of the right and left limbs. The obtained results were averaged over all ten participants. Descriptive statistics were calculated as the mean and SD. An ANOVA with repeated measurement (Bonferroni) tests and linear regression models were performed. A value of $p<0.05$ was used to demonstrate statistical significance.

RESULTS: Table 1 shows SJ and SJA jump height (JH), the displacement of center of gravity (COG) from the standing position to the lowest position ($Depth_{COG}$), the total peak of lower joints' torque (T_{peak}), and the total peak of lower joints' work (W_{peak}). Results showed significant differences in the jump height, as well as W_{peak}. SJA jump height was 8.7cm higher than SJ (p<0.001). The total peak of joints' torque was greater in SJA than SJ (p<0.001). Total lower extremity work was greater in SJA than SJ (p<0.001) indicating arm swing influence in both squat jumps.

Table 1
Comparison between SJ and SJA. Values: mean (SD).

	SJ	SJA
JH (cm)	44.23(8.13)	52.94(8.33)
Depth $_{COG}$ (cm)	-19.02(3.02)	-18.84(3.71)
T_{peak} (N.m)	561.6(118.4)	603.6(124.7)
W_{peak} (J)	461.6(44.0)	499.4(46.7)

To illustrate the separate effect of each anthropometric data, Figure 1 represents the relations between output performances using the log-transformed variables, namely, the peak torque and work, with anthropometric data. Linear regression models also have been indicated.

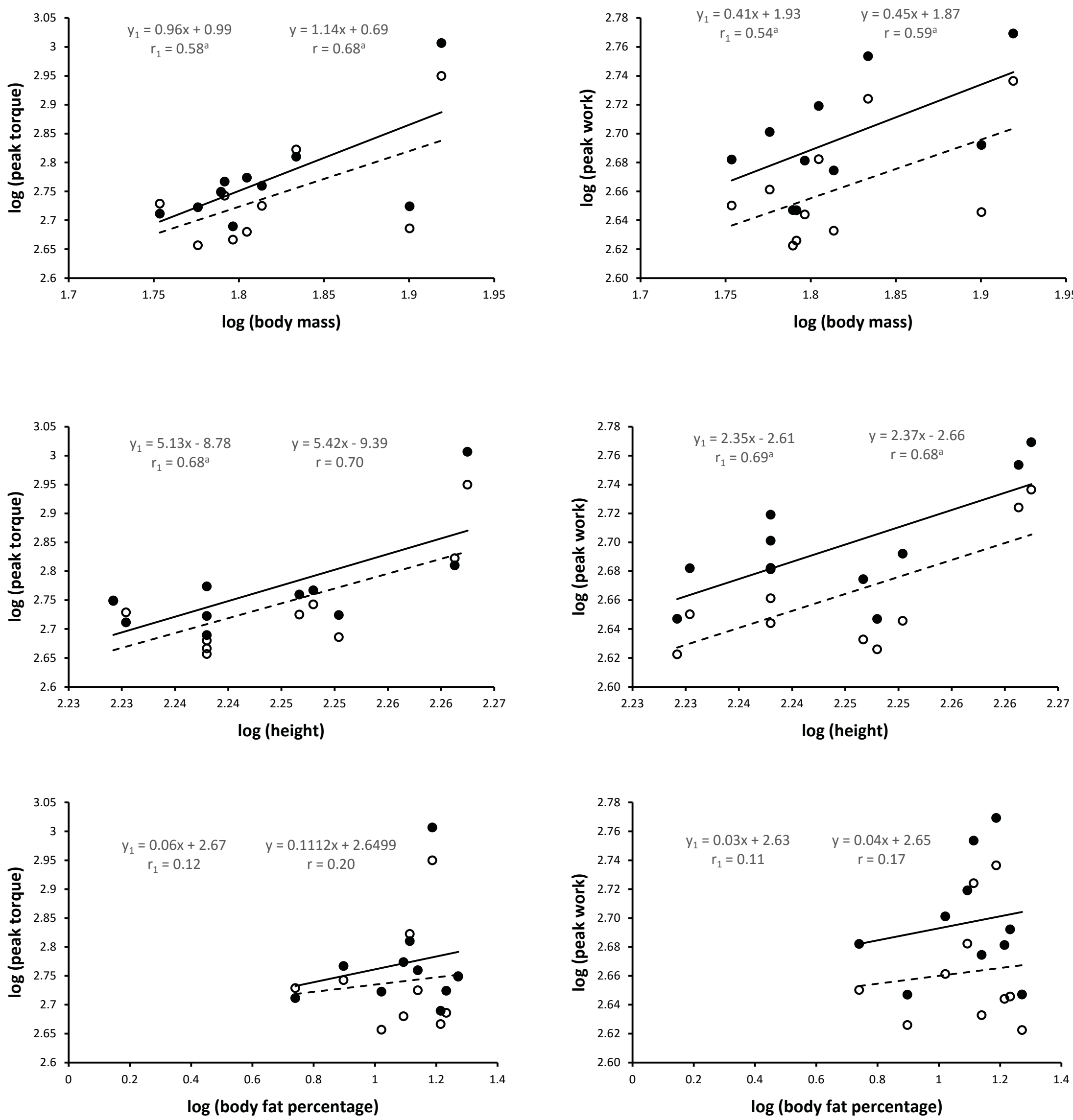

Figure 1: Log-transformed values of relationships between output performances and anthropometric parameters of SJ (dashed line, open symbols, y_1 and r_1) and SJA (solid line, closed symbols, y and r), [a]p<0.05.

DISCUSSION: The purpose of this study was to explore the relation between the lower limb joints' performance of squat jumps as depicted by the total peak of joints' torque and work, and the anthropometric parameters which were assessed through body mass, body height, and body fat. The jump height in SJA was 19.7% more than SJ ($p<0.001$). Moreover, the results mainly supported the hypothesis. To be specific, body mass has markedly influenced the peak torque and work output in two types of vertical jump so that its correlation with peak torque is considerable. For instance, by controlling the body mass, the correlation coefficient between jump height and output performances in SJA would increase from 0.47 to 0.70 for torque and from 0.58 to 0.78 for work. This significant relationship between body mass and output performances has been observed in previous studies which have indicated the particular relationship between power output and body mass (Markovic et al., 2014; Nedeljkovic et al., 2009). Another finding is related to the relationship between lower extremity output and height which shows the intense link for both peak torque and work. It should be noticed that having the strong regression coefficient for height ($0.68<r<0.70$) should not be interpreted as the absolute index of jump height superiority. In order to find the limitation of this relation, other studies with the vast variety of height should be carried out. Both jump show significant coefficient with the height which can be regardless of the technique used. Unexpectedly, body fat percentage did not show any significant relationship with the lower extremities peak output. One can conclude that this lack of significant relationship is due to the limited range of body fat percentage in participants. Since participants were selected from the physically active individuals, their body fat percentage was low leading to the limited range. The results could shed additional light on the jumping performance and role of body size parameters in the application of vertical jumps in routine training and testing procedures. Additionally, this relationship could be of considerable importance to determine if purposeful manipulation of the significant variables in a training program is helpful in enhancing vertical jump performance among specific athletic populations that require vertical jumping.Therefore, future research is needed to obtain the better perception of body size parameters, it is recommended that experiments should be repeated using a wider range of these factors, especially body fat percentage.

CONCLUSION: Applying a combination of kinematic and kinetic data, the jump height, the total peak of lower joints' torque and work were calculated. Using arm swing technique caused an enhancement in jump height. The role and the effect of anthropometric parameters on performance outcomes and the final output of jump which is jump height are investigated. Accordingly, the results supported the hypothesis that body mass, height and body fat percentage could influence the lower extremities performance output. Controlling the body mass affects the peak work enormously. On the contrary, the certain significant association was not observed between the body fat percentage and output performances, which may be related to the limited range of body fat. This finding could be of importance for realizing the role of body size factors in the application of squat jumps in jumping performance as well as testing procedures. Future research could address the body fat factor using the vast range of participants in addition to other body size factors including calf and thigh size, and the intra-participant correlation with body size factors.

REFERENCES:

Batterham, A.M. & George, K.P. (1997). Allometric modeling does not determine a dimensionless power function ratio for maximal muscular function. *Journal of Applied Physiology,* 83(6), 2158-66.

Davis, D.S., Briscoe, D.A., Markowski, C.T., Saville, S.E. & Taylor, C.J. (2003). Physical characteristics that predict vertical jump performance in recreational male athletes. *Physical Therapy in Sport,* 4(4), 167-74.

Jaric, S. (2003). Role of body size in the relation between muscle strength and movement performance. *Exercise and Sport Science Reviews,* 31(1), 8-12.

Markovic, G. & Jaric, S. (2004). Movement performance and body size: the relationship for different groups of tests. *European Journal of Applied Physiology*, 92(1-2), 139-49.

Markovic, G. & Jaric, S. (2007). Positive and negative loading and mechanical output in maximum vertical jumping. *Medicine and Science in Sports and Exercise,* 39(10), 1757-1764.

Markovic, S., Mirkov, D.M., Nedeljkovic, A. & Jaric, S. (2014). Body size and countermovement depth confound relationship between muscle power output and jumping performance. *Human Movement Science,* 33, 203-210.

Nedeljkovic, A., Mirkov, D.M., Bozic, P. & Jaric, S. (2009). Tests of muscle power output: the role of body size. *International Journal of Sports Medicine,* 30(02), 100-106.

Ostojic, S.M., Mazic, S. & Dikic, N. (2006). Profiling in basketball: physical and physiological characteristics of elite players. *The Journal of Strength & Conditioning Research*, 20(4) 740-744.

Samozino, P., Morin, J.B., Hintzy, F. & Belli, A. (2008). A simple method for measuring force, velocity and power output during squat jump. *Journal of Biomechanics,* 41(14), 2940-2945.

Vuk, S., Markovic, G. & Jaric, S. (2012). External loading and maximum dynamic output in vertical jumping: the role of training history. *Human Movement Science,* 31(1), 139-151.