

The Relationship between Isokinetic Knee Strength and Squat Jump Performance

Cigdem Bulgan

*Halic University, School of Physical Education and Sport, 34330, Istanbul, Turkey
E-mail: cigdembulgan@gmail.com*

KEYWORDS Dynamometer. Explosive Power. Hamstring/Quadriceps Muscles. Peak Power. Vertical Jump

ABSTRACT The aim of this paper was to investigate the relationship between isokinetic strength of knee flexion/extension muscles and squat jump performance. Twenty-two students (age 23.13 ± 3.28 yrs; height 180.59 ± 7.87 cm; body mass 75.27 ± 7.39 kg) from the School of Physical Education and Sport Department, participated in this study. The subjects performed the squat jumping (SJ) test and their jump height was measured by using MyoTest Pro2. Biodex System 4 was used for determination of isokinetic knee strength. After a Pearson Correlation analysis in SPSS 22.0, there were significant correlations between maximum jump speed, maximum jump height and right/left extensor muscles of the Peak Torque/Body Weight at $60^\circ \cdot s^{-1}$ and $180^\circ \cdot s^{-1}$. The significant relationship between the average power that produced at $60^\circ \cdot s^{-1}$ and maximum power, maximum eccentric and concentric contractions were found ($p < 0.05$). The paper shows that knee flexor muscles have more roles in jumping performance and effected to jumping height.

INTRODUCTION

The vertical jump test can be used in a different fields as a functional test to measure power output of the legs (Suchomel et al. 2015). Vertical jump have been partly applied for measuring height and centre of mass velocity as access to muscular coordination and physical fitness capacity in athletes (Houel et al. 2011). Maximal jumping performance is associated with higher levels of speed, strength and power (Harrison et al. 2013). Since vertical jumping is a multi-joint activity which involves the simultaneous activity of various muscles, the examination of the relationship between muscle strength of muscles across the hip, knee and ankle and vertical jump performance is worthwhile (Tsiokanos et al. 2002). Vanezis and Lees (2005) demonstrated that the strength contribution related to vertical jump ability from the ankle, knee and hip were 28, 29 and 43 percent respectively. It is suggested that the muscle strength characteristics of

the lower limbs, rather than jumping technique, are the main determinants of vertical jump performance (Harrison et al. 2013) and muscular strength is strongly correlated to jumping (Suchomel et al. 2016).

Lately, in the area of power and strength evaluation new data have been suffixed, using integrated tests, concerning maximum isokinetic strength and vertical jumping tests. Isokinetic tests are open kinetic chain activities and they involve the evaluation of an isolated active muscle group through one leg movement, with limitations of the joint angular velocity (Koutsioras et al. 2009). Isokinetic dynamometers are extensively used to evaluate muscular strength of lower leg muscles, in the form of maximal torque output exerted by isolated muscle groups around the hip, the knee and ankle joints at various angular velocities. The objective assessment of muscle function using isokinetic measurements allows the production of comparable and reproducible results (Tsiokanos et al. 2002).

The squat jump can be used as the most basic functional statement of explosive muscle strength, that it requires just concentric activation. It can be perform for the capacity of explosive muscle strength (Earp et al. 2010). Previous studies have investigated the relationship between vertical jump height and isokinetic strength of the lower limbs (Byrne and Eston 2002; Chang et al. 2015; Gantiraga et al. 2006; Harrison et al. 2013). However, research has evaluated the re-

Address for correspondence:

Cigdem Bulgan
Halic University,
Department of Physical Education and Sport,
TSYD Campus, Levent Caddesi No.51,
34330 Besiktas, Istanbul
Telephone: +902126321888
Mobile: +905535388959
Fax: +902122740403
E-mail: <cigdembulgan@gmail.com>,
<cigdembulgan@halic.edu.tr>

relationship between isokinetic testing and vertical jump tests among athletes. The aim of this paper was to investigate the relationship between isokinetic strength of knee flexion/extension muscles (quadriceps/hamstring) and squat jump performance for physical education and sport students.

METHODOLOGY

Participants

Twenty-two students (age 23.13 ± 3.28 yrs; height 180.59 ± 7.87 cm and body mass 75.27 ± 7.39 kg) from Halic University, School of Physical Education and Sport Department, participated to this study. The participants had not had any lower extremity injuries before. The study was conducted consistent with the recommendations of the Declaration of Helsinki. Written consent was obtained from all the students. Students performed the tests in 2014-2015 spring semester season and visited laboratory on two separate days.

Procedures

Vertical Jumping Test

The subjects performed the squat jump (SJ) as vertical jumping test. 5 min jogging and 5 min dynamic stretching were applied for warm up before the test. SJ was performed from a squatting position with the knees flexed to approximately 90° and their hands were on the waist and jump height was measured by using MyoTest Pro2 v1.981.

The Myotest Pro2 system can be used to evaluate maximal height of subjects' centre of mass during a squat jump with acceptable accuracy and reliability (Houel et al. 2011). The Myotest Pro2 system which developed by Myotest SA (Swiss), includes a triaxial accelerometer (500 Hz) sensor. The equipment Myotest Pro2 was stabled vertically at the one side of athlete's belly, on the coxo-femoral joint in agreement with Myotest SA recommendations for every jump. Each player performed a special protocol in Myotest of three maximal squat jumps. The average jump was recorded for analysis.

Isokinetic Test

The isokinetic strength of the extensor and flexor muscles of the knee joints of both legs

was assessed by using isokinetic dynamometer (Biodex System 4 Pro™). The participants were warmed up in a stationary cycle ergometer for 5-10 min followed by 5 min of rest before test (Bingul 2015). After the warm-up exercise, each participant was tested in the seated position and fixed to the seat from their body, waist, and femur. The axis of rotation of the knees (lateral femoral epicondyle) was aligned with the mechanical axis of the dynamometer, and the resistance thigh pad was placed just proximal to the knee. Moreover, they held the handles of the seat on both sides to prevent the freeness of the arms and had support from the seat. Concentric/concentric peak torque of the Hamstring Muscles and Quadriceps Muscles of dominant and non-dominant leg of the participants was evaluated at angular velocities of $60^\circ \cdot s^{-1}$ and $180^\circ \cdot s^{-1}$. Before testing, the subjects were allowed 5 familiarization trials. Then, the subjects performed 5 maximal concentric knee extension-flexion at $60^\circ \cdot s^{-1}$, followed by 15 maximal concentric knee extension-flexion at $180^\circ \cdot s^{-1}$ for both legs. Subjects were allowed 3-min rest between each protocol. Isokinetic peak torque (PT), peak torque/body weight (PT/BW) of Hamstring and Quadriceps Muscles (N·m) were evaluated for each player.

Statistical Analysis

Statistical analysis was handled by using the Statistical package for Social Sciences 22.0 (SPSS. IBM, New York). The average and standard deviation (SD) of the data were calculated as descriptive statistics. Pearson Correlation analysis was used to determine the relationship between maximum isokinetic strength and jump performance. The level of significance was set at $p < 0.05$.

RESULTS

According to the isokinetic concentric and concentric test protocol results, the peak torque values for right and left legs, extensor and flexor muscles at $60^\circ \cdot s^{-1}$ were found 235.8 ± 57.55 N.m; 240.35 ± 54.80 N.m; 157.25 ± 63.99 N.m; 139.35 ± 30.47 N.m respectively. At $180^\circ \cdot s^{-1}$, they were 172.8 ± 69.86 N.m; 175.65 ± 56.92 N.m; 125.25 ± 49.56 N.m; 123.8 ± 32.10 N.m respectively. The mean squat jump height for participants was found 31 ± 5.79 cm. Additionally, mean values and standard deviations from peak torque/body weight and

squat jump performance variables from the tests can be seen in Tables 1 and 2.

Table 2: Squat jump performance results

Power Max. (W)	4062± 410.12
Max. Conc. F.(N)	2222.5± 86.97
Max. Eccen. F.(N)	1199± 87.68
Speed Max. (cm/s)	250.45± 22.98
Max. Height (cm)	31± 5.79

According to the statistical analysis, there were significant correlations between maximum jump speed, maximum jump height and right and

left extensor muscles of the Peak Torque/Body Weight at 60°·s⁻¹ and 180°·s⁻¹ (p<0.05) (Table 3.)

The significantly relationship between the average power that produced at 60°·s⁻¹ and maximum power, maximum eccentric and concentric contractions were found (p<0.05). At 180°·s⁻¹, almost all jumping variables were in the relation between average powers of isokinetic test result (Table 4.).

DISCUSSION

Isokinetic muscle strength takes a significant role in different functional performance (Kout-

Table 1: Isokinetic test results of dominant and non-dominant legs

	60°·s ⁻¹		180°·s ⁻¹	
	PT/BW %	Avr. Power (W)	PT/BW %	Avr. Power (W)
Extension-Left	292.3± 56.56	153.15± 33.44	213.3± 61.94	321.9± 89.66
Extension-Right	286.7± 60.10	152.65± 31.74	209.45± 77.85	313.1± 101.11
Flexion- Left	169.5± 31.11	102± 16.26	150.5± 33.79	227.5± 41.15
Flexion- Right	190.6± 71.41	113.95± 40.80	151.85± 55.22	234.45± 77.85

Table 3: The correlation results between PT/BW and jumping performance variables

	Peak Torque/Body Weight % 60°·s ⁻¹	
	Extension-Right	Extension- Left
Speed Max (cm/s)	R=0.439, p=0.041	
Max. Height (cm)	R=0.480, p=0.24	R=0.426, p=0.048
	180°·s ⁻¹	
	Extension-Right	Extension- Left
Speed Max (cm/s)	R=0.582, p=0.004	R=0.529, p=0.011
Max. Height (cm)	R=0.534, p=0.011	R=0.600, p=0.003

p<0.05.

Table 4: The correlation results between average power and jumping performance variables

	Average Power (W) 60°·s ⁻¹			
	Extension-Right	Extension- Left	Flexion- Right	Flexion- Left
Power Max. (W)	R=0.449, p=0.036			R=0.482, p=0.023
Max. Conc. F.(N)			R=0.447 p=0.037	R=0.455, p=0.034
Max. Eccen. F.(N)	R=0.657, p=0.001	R=0.606, p=0.003		R=0.554, p=0.09
	180°·s ⁻¹			
	Extension-Right	Extension- Left	Flexion- Right	Flexion- Left
Power Max. (W)	R=0.704, p=0.000	R=0.665, p=0.001	R=0.653, p=0.001	R=0.558, p=0.007
Max. Conc. F.(N)	R=0.525, p=0.012	R=0.464, p=0.030	R=0.562, p=0.006	R=0.485, p=0.022
Max. Eccen. F.(N)	R=0.597, p=0.003	R=0.609, p=0.003	R=0.433, p=0.044	R=0.488, p=0.021
Speed Max. (cm/s)	R=0.471, p=0.027	R=0.500, p=0.018		
Max. Height (cm)		R=0.534, p=0.010		

p<0.05.

sioras et al. 2009). Jump height performance may be considered a partial predictor of knee strength (Boling et al. 2013). The main results of present study indicate the high relationship between isokinetic PT/BW at $60^{\circ}\cdot s^{-1}$ and $180^{\circ}\cdot s^{-1}$ and jump heights. Only knee isokinetic values were evaluated in this study. Studies showed correlation of jump height with knee extension is greater than hip extension. Knee extensor tendons and muscle are highly elastic and thereby able to generate additional force through elastic recoil (Harrison et al. 2013).

Many of the studies investigated the effect of isokinetic muscle strength on vertical jump performance as the current study (Cinar-Medeni et al. 2015; Chang et al. 2015; Menzel et al. 2013). Harrison et al. (2013) found a significant moderate positive correlation between the knee extensor peak torque and vertical jump height, also stronger correlations found at an angular velocity of $240^{\circ}\cdot s^{-1}$ ($R=0.609$) than at $120^{\circ}\cdot s^{-1}$ ($R=0.540$) in their study. Low to high significant positive correlations were detected between the isokinetic measures of the knee extensors and the vertical jump height. The highest one was found for the knee extensors peak torque at a velocity of $240^{\circ}\cdot s^{-1}$ ($R=0.88$, $p < 0.001$). The results accounted for an optimal velocity at which a strong relationship could be obtained between isokinetic knee extensors strength and vertical jump height (Rouis et al. 2015). The moderately strong relationship between higher normalised isokinetic strength values of the knee extensors and vertical jump height suggests that focusing on power training of the knee extensors may result in improved vertical jump performance and enhanced power outputs. The maximal knee velocity achieved in the dynamometer was correlated to vertical jump height and to the peak knee extensor torque measured at $240^{\circ}\cdot s^{-1}$ ($R=0.609$, $p=0.002$) (Koutsioras et al. 2009). Additionally, Chang et al. (2015) indicated that significant correlations existed between knee extension and vertical jump performance. They thought it may provide the mechanical insight regarding how vertical jump performance was related to lower extremity extensors. In current study, $60^{\circ}\cdot s^{-1}$ and $180^{\circ}\cdot s^{-1}$ protocols for knee joints were evaluated. According to this, a strong correlation was found at $180^{\circ}\cdot s^{-1}$ rather than at $60^{\circ}\cdot s^{-1}$. ($R=0.480$; 0.534) (Table 3). For the squat jumps, it appears that the jumping height had a moderate relationship with the hip and knee

torques at $180^{\circ}\cdot s^{-1}$ they found $SJ=31.21\pm 4.32$ cm (Gonzalez-Rave et al. 2014). Tsiokanos et al. (2002) has found a moderate correlation between jump height and isokinetic hip extensor strength in footballers when measured at $60^{\circ}\cdot s^{-1}$ and $120^{\circ}\cdot s^{-1}$. They indicated that there was a significant positive relationship between jumping height and total work in hip and knee extensions ($p < 0.05$), whereas low correlation coefficients between isokinetic moment of the ankle plantar flexors and jumping performance were found ($p > 0.05$). For the squat jumps, it appears that the jumping height had a moderate relationship with the hip and knee torques at $180^{\circ}\cdot s^{-1}$ ($R=0.589$). The correlation coefficients between the squat jump work and the isokinetic parameters were higher, with the highest being observed between knee extension torque at $120^{\circ}\cdot s^{-1}$ ($R=0.81$) (Tsiokanos et al. 2002). Absolute quadriceps strength ($90^{\circ}\cdot s^{-1}$) ($R=0.573$) was related to vertical jump height and quadriceps endurance measures also had higher correlations ($R=0.708$). Absolute hamstring endurance was also related to vertical jump height in right limb ($R=0.634$) (Hrysomallis et al. 2002). Lehnert et al. (2013) indicated that the significance of the information acquired by measuring the strength of isokinetic extension of the knee joint to assess the jumping ability can change during the yearly training cycle. So they recommended to evaluate at $180^{\circ}\cdot s^{-1}$ and at higher velocities should be preferred. The strong relationship was found between isokinetic knee extension strength and maximum jump height at $60^{\circ}\cdot s^{-1}$ ($R=0.76$, $p=0.004$). However, the remaining measures of isokinetic strength were also significantly related to maximum jump height ($0.59 < R < 0.71$; $0.01 < p < 0.04$) (Tomioka et al. 2001).

CONCLUSION

In conclusion, keeping with biomechanical models of jumping indicating that the knee extensors play a significant role in shifting the force from the legs to the trunk. In squat jump performances, it is not possible to transfer potential energy from eccentric contraction to concentric contraction and however there is a possible situation occurs from isometric contraction to concentric contraction. For this reason, the study shows that knee extensor muscles have more roles in jumping performance and effected to jumping height.

RECOMMENDATIONS

Muscle structure can be used to predict jump performance for squat jump. Sport specificity should be a focus for coaches when prescribing exercises because of the roles of the quadriceps and hamstring muscles. For improved kinematic coordination, it is important to increased lower extremity muscle strength.

ACKNOWLEDGEMENTS

Many thanks to Dr. Turgay Turan and MSc. Mustafa Arslan Basar for their assistance with isokinetic strength.

REFERENCES

- Bingul BM 2015. The optimal waiting time for hamstring peak power after a warm up program with static stretching. *Anthropologist*, 18(3): 777-781.
- Boling M, Padua D 2013. Relationship between hip strength and trunk, hip and knee kinematics during a jump-landing task in individuals with patellofemoral pain. *International Journal of Sports Physical Therapy*, 8(5): 661-669.
- Bryne C, Eston R 2002. The effect of exercise-induced muscle damage on isometric and dynamic knee extensor strength and vertical jump performance. *Journal of Sports Science*, 20: 417-425.
- Cinar-Medeni O, Colakoglu FF, Yuce K, Ipekoglu G, Baltaci G 2015. The relation of the knee muscle strength with performance tests in orienteering athletes. *Journal of Sports Medicine and Physical Fitness*, 2015 Dec 11.[Epub ahead of print].
- Chang E, Norcross MF, Johnson ST, Kitagawa T, Hoffman M 2015. Relationships between explosive and maximal triple extensor muscle performance and vertical jump height. *Journal of Strength Conditioning Research*, 29(2): 545-551.
- Earp JE, Kraemer WJ, Newton RU, Comstock BA, Fragala MS, Dunn-Lewis C, Solomon-Hill G, Penwell ZR, Powell MD, Volek JS, Denegar CR, Hakkinen K, Maresh CM 2010. Lower-body muscle structure and its role in jump performance during squat, counter-movement and depth drop jumps. *Journal of Strength and Conditioning Research*, 24(3): 722-729.
- Gantiara E, Katartzi E, Komsis G, Papadopoulos C 2006. Strength and vertical jumping performance characteristics in school-aged boys and girls. *Biology of Sports*, 23(4): 367-377.
- Gonzalez-Ravé JM, Juárez D, Rubio-Arias JA, Clemente-Suarez VJ, Martínez-Valencia MA, Abian-Vicen J 2014. Isokinetic leg strength and power in elite handball players. *Journal of Human Kinetics*, 41: 227-233.
- Harrison B, Firth W, Rogers S, Tipple J, Marsden J, Freeman JA, Hough AD, Shum GLK 2013. The relationship between isokinetic performance of hip and knee and jump performance in university rugby players. *Isokinetics and Exercise Science*, 21: 175-180.
- Houel N, Dinu D, Faury A, Seyfried D 2011. Accuracy and reliability of the Myotest Pro system to evaluate a squat jump. *Procedia Engineering*, 13: 434-438.
- Hrysmallis C, Koski C, McCoy M, Wrigley T 2002. Correlations between field and laboratory tests of strength, power and muscular endurance for elite Australian rules footballers. In: W Spinks, T Reilly, A Murphy (Eds.): *Science and Football IV*. Cambridge, London: Routledge, The University Press, pp. 81-85.
- Koutsioras Y, Tsiokanos A, Tsaopoulos D, Tsimeas P 2009. Isokinetic muscle strength and running long jump performance in young jumpers. *Biology of Exercises*, 5(2): 51-57.
- Lehnert M, Svoboda Z, Cuberek R 2013. The correlation between isokinetic strength of knee extensors and vertical jump performance in adolescent soccer players in an annual training cycle. *Acta Gymnica*, 43(1): 7-15.
- Menzel HJ, Chagas MH, Szmuchrowski LA, Araujo SR, de Andrade AG, de Jesus-Moraleida FR 2013. Analysis of lower limb asymmetries by isokinetic and vertical jump tests in soccer players. *Journal of Strength Conditioning Research*, 27(5): 1370-1377.
- Rouis M, Coudrat L, Jaafar H, Filliard JR, Vandewalle H, Barthelemy Y, Driss T 2015. Assessment of isokinetic knee strength in elite young female basketball players: Correlation with vertical jump. *The Journal of Sports Medicine and Physical Fitness*, 55(12): 1502-1508.
- Suchomel TJ, Lamont HS, Moir GL 2015. Understanding vertical jump potentiation: A deterministic model. *Sports Medicine*, 1-20. Doi:10.1007/s40279-015-0466-9.
- Suchomel TJ, Nimphius S, Stone MH 2016. The importance of muscular strength in athletic performance. *Sports Medicine*, 1-31. Doi: 10.1007/s40279-016-0486-0.
- Tomioka M, Owings TM, Grabiner MD 2001. Lower extremity strength and coordination are independent contributors to maximum vertical jump height. *Journal of Applied Biomechanics*, 17: 181-187.
- Tsiokanos A, Kellis E, Jamurtas A, Kellis S 2002. The relationship between jumping performance and isokinetic strength of hip and knee extensors and ankle plantar flexors. *Isokinetics and Exercise Science*, 10: 107-115.
- Vanezis A, Lees A 2005. A biomechanical analysis of good and poor performers of the vertical jump. *Ergonomics*, 48(11-14): 1594-1603.

Paper received for publication on January 2016
Paper accepted for publication on April 2016