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The influence of quadriceps and hamstring strength on balance performance

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Abstract

Background and Study Aim	Muscular strength and balance are important components of athletic performance, and the muscles around the knee (Quadriceps and Hamstrings) provide joint stability when the knee is in motion. The aim of this study was to analyze the correlation between quadriceps/hamstring (H/Q) muscle strength, Hamstring/Quadriceps (H/Q) strength ratio and balance performance.
Material and Methods	Ten male volunteers with an average age of 21.60±2.11 years, height 176.40±4.67 cm, and body weight 76.50±8.85 kg, who were students of the Faculty of Sports Sciences. Performance tests included dynamic and static balance using the Biodex Balance System and isokinetic strength using the Cybex Humac NORM®.
Results	Statistically significant ($p<0.05$) results in dynamic balance scores were found in the correlation of H/Q ratio and overall stability index (OSI) in the left leg (r =-0.645), and in the correlation of peak torque hamstring and anterior-posterior stability index (APSI) in the right leg (r =0.671). Statistically significant ($p<0.05$) results in static balance scores were found in the correlations of peak torque quadriceps with OSI (r=-0.760) and anterior-posterior stability index (APSI) (r=-0.650) in the right leg. No statistically significant results were found for the left leg in the static balance scores.
Conclusions	As a result of the study, the relationship between quadriceps and hamstring strength and H/Q ratios and balance performance without ignoring the fact that balance is a complex feature involving the visual, vestibular, and proprioceptive systems. It can be said that muscle strength is an important factor in balance performance based on our study and other sources.

Keywords: dynamic balance, H/Q ratio, static balance

Introduction

Balance, as a basic function in daily human life and sports activities, is the process of maintaining the position of the body's center of gravity vertically above the base of support. In other words, it is the ability to maintain the body center pressure necessary to maintain the position of the body center in space within the base of support. Or to maintain movement against internal and external perturbations in a compliant and controlled state [1, 2]. Human beings rely on three sensory systems to perceive their place in space and to maintain their body position. Balance is achieved through the same systems. These are the visual, vestibular and proprioceptive systems [3]. In addition, anthropometric characteristics, such as height, weight, body composition, base of support, length, and weight of each limb can mechanically influence the balance of individuals [4, 5].

Two types of balance play an important role in the acquisition of motor skills: "Static balance", defined as the ability to maintain different positions created by adjusting the line of gravity and the width of the support surface at a stable level of support and without the need for any external force [6, 7]. "Dynamic balance", defined as the ability to maintain or restore balance throughout the movement by neutralizing the external forces acting on the body [8, 9].

Muscular strength and balance are important components of athletic performance, especially in young athletes, and a strong relationship exists between them [10]. Experimental methods proven to improve balance ability include knee proprioception, increased knee extensor and flexor muscle strength, and improved stretch rate in the flexor muscles [11, 12]. The muscles around the knee provide joint stability when the knee is in motion. These muscles are known as the quadriceps group in the front and the hamstring group in the back. The hamstring muscle group, which consists of the biceps femoris, semitendinosus, and semimembranosus muscles, is of primary importance for running, walking, turning, stabilizing the knee, and controlling trunk movements. The quadriceps femoris, which is a combination of the anterior muscle group vastus lateralis, rectus lateralis, vastus medialis, and vastus intermedius muscles, is of primary importance for

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jumping, balance, and kicking movements [13, 14].

The Hamstring/Quadriceps (H/Q) strength ratio is used to examine the similarity of moment-velocity patterns between the hamstrings and quadriceps, and to assess the functional adequacy and muscle balance of the knee. Various combinations of contraction types (concentric, eccentric, and isometric), angular velocities, and torque types (peak or angle-specific torque) can be used to calculate the Hamstring/Quadriceps (H/Q) ratio. Traditional ratios are computed using same type of torque values for each antagonist muscle group. The concentric hamstring torque divided by the concentric quadriceps torque is the conventional H/Q force ratio. The norm for the functional ratio also varies with test angular speed and is about 0.79 at $60°.s^{-1}$ [15].

The relationship between lower limb muscle strength and balance tests was reported in only a few articles, and most studies evaluated only the improvement in balance performance. Therefore, this study analyzed the correlation among different test methods for knee joint muscle strength, H/Q strength ratio, and balance performance.

Material and Methods

Participants

Ten male who were students of the Faculty of Sports Sciences, do not have any health problems, regularly practiced sports and had an amateur sports background, volunteers (average age of 21.60 ± 2.11 years, height 176.40±4.67 cm, and body weight 76.50±8.85 kg) participated in the study. The research was approved by Selçuk University Clinical Research Ethics Committee (Decision No: 33, Date: 04/03/2019).

Research Design

Prior to testing, participants were given an approximately 15min. standardized warm-up that included light cycling and dynamic stretching. All performance tests were completed on one occasion by participants. Tests included dynamic balance, static balance, and isokinetic strength, respectively. Some restrictions and rules have been applied to reduce external factors. All participants were asked to refrain from exercising on the test day and one week before [16]. The balance tests were performed barefoot for each leg [17], and performed between 12:00-17:00 hours to eliminate diurnal fluctuations in postural control [18]. Balance and isokinetic strength data were collected by the main researcher who was experienced at. All tests were performed at the Kinanthropometry Laboratory and Performance Laboratory of Selçuk University, Faculty of Sports Sciences.

Isokinetic Strength Measurement

The isokinetic strength measurements of the knee were performed by an isokinetic dynamometer (Cybex NORM®, Humac, CA, USA). Participants were seated on the isokinetic dynamometer according to the placement protocol. The participants were instructed to complete a ROM from 90° to 0°. The point of the beginning was 90° of flexion, then moving into extension.

After familiarization, each participant was asked to perform as hard and fast as possible for five repetitions at a speed of $60°.s^{-1}$ for knee extension (Quadriceps) and knee flexion (Hamstrings) muscular strength assessment for each leg. The isokinetic strength data were automatically recorded by the device as peak strength in newton meters (Nm) [9, 19].

Hamstring/Quadriceps Muscles Strength Ratio

The conventional H/Q muscle ratio was calculated according to its formal definition by dividing the maximal isokinetic hamstring (knee flexor) strength by the maximal quadriceps (knee extensor) strength for a given contraction mode and joint angular velocity.

Balance Performance Test

Balance measurements were performed using the Biodex Balance Systems (Biodex Medical Systems, Shirley, NY, USA), which has a circular platform that is free to move in the anterior–posterior and medial–lateral axes simultaneously. The Biodex Balance System (BBS) allows up to 20° of foot platform tilt, which allows the ankle joint mechanoreceptors to be maximally stimulated. The BBS measures, in degrees, the tilt about each axis during dynamic conditions and calculates a medial–lateral stability index (MLSI), anterior–posterior stability index (APSI), and overall stability index (OSI). These indexes represent fluctuations around a zero-point established prior to testing when the platform is stable. High scores on these indexes indicate poor balance, while scores close to zero indicate good balance. The platform is either stationary or has mobility levels 1-12. Level 12 is the most stable state of the platform, whereas Level 1 is the most active [20, 21].

Dynamic Balance Test

After the participants stepped barefoot on the device with platform stability set to level 6, foot angle and heel position were recorded according to the placement of the foot. For 20 seconds, they tried to stay balanced with one foot on the movable platform with their hands crossed at chest level. At the end of the test, medial-lateral, anterior-posterior, and overall stability scores were recorded.

Static Balance Test

After the participants stepped barefoot on the device platform, the foot angle and heel position were recorded according to foot placement. For 20 seconds, they tried to stay balanced with one foot on the stable platform with their hands crossed at chest level. At the end of the test, medial-lateral, anterior-posterior, and overall stability scores were recorded.

Statistical Analysis

The data obtained in the study were summarized using the arithmetic mean (x̄) and standard deviation (SD) from the descriptive statistics. Kolmogorow-Smirnov (K-S) test, one of the normality tests, was applied to the obtained data and it was determined that the data were not normally distributed. The Bivariate Correlations Pearson correlation test was applied to determine the relationship between balance performance values and isokinetic knee (right-left) strength (60°.s^{-1}). All statistical values were evaluated at 95% confidence intervals, and the significance was set at $p<0.05$.

Results

Descriptive statistics of quadriceps and hamstring strength, H/Q ratio, range of motion, and dynamic/static balance performance of the participants for both legs are shown in Table 1.

The only statistically significant value in the 60°.s^{-1} isokinetic dynamometer measurements and dynamic balance scores in the left leg was r =-0.645 in the H/Q ratio and overall stability correlation. The only statistically significant value in the 60°.s^{-1} isokinetic dynamometer measurements and dynamic balance scores in the right leg was r =0.671 in peak torque hamstring and anterior-posterior stability correlation (Table 2).

No statistically significant results were found in the left leg 60°.s^{-1} isokinetic dynamometer

Table 1. Dynamic and Static Balance and Isokinetic Measurement results of legs. (Values are the means ± standard deviations).

Values	Left Leg	Right Leg
Isokinetic 60°.s^{-1}	**x̄±SD**	**x̄±SD**
Peak Torque Quadriceps (Nm)	233.70±29.69	240.30±28.70
Peak Torque Hamstring (Nm)	122.00±16.21	121.30±18.93
Range of Motion Quadriceps (°)	3.40±2.84	4.30±4.45
Range of Motion Hamstring (°)	88.80±6.91	93.70±7.38
Peak Torque H/Q (%)	52.70±6.96	51.00±8.92
Dynamic Balance		
Overall Stability Index Scores	2.28±0.52	2.33±0.43
Anterior-Posterior Stability Index Scores	1.60±0.57	1.47±0.37
Medial-Lateral Stability Index Scores	1.49±0.26	1.39±0.36
Static Balance		
Overall Stability Index Scores	2.26±0.62	2.46±0.67
Anterior-Posterior Stability Index Scores	1.50±0.56	1.73±0.64
Medial-Lateral Stability Index Scores	1.40±0.35	1.27±0.26

Nm: newton meter, °: degree, H: hamstring, Q: quadriceps

Table 2. Strength and balance correlations.

Values		Dynamic Balance						Static Balance					
		Left Leg			Right Leg			Left Leg			Right Leg		
60°.s-1		OSI	APSI	MLSI	OSI	APSI	MLSI	OSI	APSI	MLSI	OSI	APSI	MLSI
Peak Torque Quadriceps	r	0.348	0.009	-0.023	-0.089	0.253	-0.148	-0.469	-0.476	-0.342	-0.760	-0.650	-0.724
	p	0.325	0.981	0.949	0.807	0.480	0.682	0.172	0.164	0.334	0.011*	0.042*	0.018
Peak Torque Hamstring	r	-0.274	0.010	-0.175	0.247	0.671	0.438	-0.394	-0.322	-0.337	-0.072	0.204	-0.052
	p	0.444	0.979	0.629	0.491	0.034*	0.205	0.259	0.364	0.341	0.842	0.572	0.887
H/Q Ratio	r	-0.645	0.020	-0.112	0.218	0.406	0.431	0.076	0.165	0.014	0.409	0.578	0.432
	p	0.044*	0.957	0.758	0.546	0.245	0.214	0.834	0.649	0.970	0.241	0.080	0.213

The asterisks denote significant differences: *= p<0.05

OSI: Overall Stability Index, APSI: Anterior/Posterior Stability Index, MLSI: Medial/Lateral Stability Index measurements or static balance scores. Statistically significant values in the right leg $60^{o/s}$ isokinetic dynamometer measurements and static balance scores were r =-0.760 and r =-0.650 in peak torque quadriceps and overall stability and anterior-posterior stability correlations, respectively. (Table 2).

Discussion

Our hypothesis was that there would be large correlations between indicators of balance and strength of the lower extremities. This hypothesis is based on the theory that similar neural mechanisms are involved in the control of balance and strength of the lower extremity. The results of this study can be outlined as follows: (a) in dynamic balance tests, statistically significant correlations were found between the hamstring and quadriceps ratio and Overall Stability Index in the left leg. Similar correlations were found between peak torque of knee flexors (Hamstring) and Anterior-Posterior Stability Index in the right leg; (b) No statistically significant results were found in the static balance test results for the left leg. Statistically significant correlations were found in the peak torque of the knee extensors (quadriceps), the overall stability index, and the anterior-posterior stability index in the right leg. As far as we know, only a few other studies have examined the relationship between static and dynamic balance, isokinetic muscle strength, and H/Q ratio. Thus, other balance and strength studies had to be consulted to discuss the current findings.

One of the studies examining the relationship between H/Q ratio and balance performance was conducted by Wang et al. [11] with 24 female participants aged 22.2±2.8 years. They reported that when the knee joint was located at 15°, the H/Q ratio was significantly correlated with medial-lateral stability index (MLSI) ($p<0.01$), and overall stability index (OSI) ($p<0.05$). When the knee joint was flexed at 45°, the H/Q ratio was significantly correlated with anterior-posterior stability index (APSI) and OSI ($p<0.01$). Similarly et al. [22] investigated whether there was a correlation between knee extensor and flexor isokinetic strength, injury risk, dynamic balance, and jump height in 22 female volleyball players. The results of this study showed that there was a significant correlation between OSI in both dominant and non-dominant legs in the H/Q ratio test performed at $60°.s^{-1}$.

Researchers such as Katayama et al. [23], McCurdy and Langford [24], Thorpe and Ebersole [25] show that lower extremity strength does not have an effect on balance performance. However, in addition to our study, researchers such as Wang et al. [11], Aka and Altundag [26], Ambegaonkar et al. [27] reveal the important relationship between lower extremity muscle strength and balance performance. Although the physiological basis of this relationship is not fully understood, it is likely to involve neural control of muscle contractions and the mechanics of the musculoskeletal system. What might explain some of the positive correlations found between measures of balance and knee extensor and flexor strength? First, the function of neural processes in course of postural control and strength output appears to be task specific, although similar neurophysiological mechanisms are engaged in the regularization of balance and strength [28, 29]. For example, during isometric dorsal and plantar flexion of the ankle are facilitated short-latency responses induced by transcranial magnetic stimulation [30]. However, these responses remained unchanged during the performance of a reactive balance task in studies examining spinal and corticospinal excitability during the performance of a strength or balance-related task [31]. Second, the literature has reported transfer effects of strength gains following balance training and strength gains following balance training, but the underlying adaptations are task specific [32, 33]. For example, Gruber, Gruber et al. [28] and Gruber et al. [29] examined the effects of four weeks of balance training compared to ballistic strength training on measures of strength using biomechanical and electrophysiological test equipment. After balance and ballistic strength training, the authors reported significant improvements in the maximal rate of force development.

The force required to maintain or regain balance is an important factor in balance performance [34]. There are several mechanisms by which muscle strength can affect balance performance. Strength can improve balance by increasing the stiffness of the body's support structures (muscles, tendons, and ligaments). Muscles work together in groups to provide support and stability to the body, and stronger muscles are better able to support body weight and maintain balance. In addition, stronger muscles can transmit larger signals to the central nervous system, which can increase the accuracy and speed of muscle activation in balance tasks. This may be due to the role of the central nervous system in coordinating muscle activity for balance control. This could improve the ability of stronger athletes to react quickly and maintain their balance in variable environments and improve balance by increasing sensory feedback from the feet and lower limbs to the brain [11, 34].

Conclusions

As a result of this study in dynamic balance tests, statistically significant correlations were found between the H/Q ratio and OSI in the left leg and between peak torque of the hamstring and anterior-posterior stability index (APSI) in the right leg. No statistically significant results were found in static balance tests in the left leg, while statistically significant correlations were found in peak torque of the quadriceps and OSI and APSI in the right leg. In conclusion, it can be said that muscle strength is an important factor in balance performance based on our study and other sources. However, it should not be ignored that balance is a complex feature involving visual, vestibular, and proprioceptive systems.

Note

This study was produced from the master thesis titled "The Effect of Quadriceps and Hamstring Strength on Balance Performance" published in 2019.

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