Atwood et al. (2017) *Int J Res Ex Phys*. 13(1):48-58.

Sponsored by:
Exercise and Sport Science Program
Western State Colorado University

International Journal of Research in Exercise Physiology

Original Research Article

Ratio of Hamstring to Quadriceps Strength in Female Collegiate Basketball Players in Relation to the Performance of 10 Meter Sprint and Vertical Jump: A Pilot Study

Christopher P. Atwood[1], Kaylee L. Biba[1], Haley L. Collum[1], Connor J. Olson[1], Amanda J. Pavlicek[1], Nicholas M. Beltz[1]

[1]Department of Kinesiology, University of Wisconsin - Eau Claire, Eau Claire, Wisconsin, USA

Abstract

Introduction: The conventional hamstring to quadriceps (H:Q) ratio is derived from concentric peak torque of the hamstring during flexion versus the concentric peak torque of the quadriceps during extension. The H:Q ratio is often used in sport performance and rehabilitation to measure strength properties of the muscles and to detect muscle imbalances. Researchers have identified H:Q ratios that can increase the risk of lower extremity injuries, such as anterior cruciate ligament (ACL) and hamstring injuries. Recently, research has begun to examine the relationship between vertical jump measures and sprint speed over 10, 20, and 40 meters (m) in professional basketball players. Therefore, the purpose of this study is to examine the relationship between isokinetic strength (H:Q isokinetic ratio) and selected performance metrics associated with competitive basketball (10 m sprint and countermovement jump). **Methods:** Eight subjects were selected from a NCAA Division III intercollegiate women's basketball program (mean ± SD: age, height, weight, years played = 20.10 years ± 1.13 years, 1.74 m ± 0.10 m, 75.49 kg ± 15.27 kg, and 11.06 years ± 2.34, respectively). They completed one session containing the following assessments: vertical jump, 10 m sprint, and lower extremity isokinetic dynamometry. **Results:** The mean and standard deviations for the performance tests include vertical jump at 0.30 ± 0.06 m and 10 m sprint at 1.83 ± 0.17 sec. The average H:Q ratio was 59.83 ± 9.42 for all speeds. No correlations were found to be significant. However, 10 m sprint was found to be positively correlated and vertical jump to be negatively correlated with H:Q ratio. **Conclusion:** In this study there was a positive correlation found between H:Q ratios and sprinting while a negative correlation was found with jumping. Apart from these findings, the results suggested that using isokinetic testing is not a recommended method to evaluate athletic performance in Division III female collegiate basketball players.

Key Words: Isokinetic, Maximal Exercise Testing, Muscle Imbalance

INTRODUCTION

Basketball athletes are required to perform short bouts of sprinting interspersed with vertical jumping throughout practice and competition. These movements involve both concentric and eccentric movement in the lower extremities, which may result in upwards of 46 vertical jumps per game[1]. Currently, studies have shown that these biomechanical movements have one of the highest incident rates of anterior cruciate ligament (ACL) injuries for female athletes. However, few studies have been performed on the relationship between these movements and athletic performance[2, 3].
Isokinetic methods are used to assess muscular strength ratios and peak muscular torque in separate muscle groups under controlled conditions[4]. Isokinetic muscular contraction is the velocity of a movement, which is controlled and held constant by a device[5]. The resistance of the device is equal to the applied muscular torque over the range of movement; therefore, muscular force can be measured[6]. The conventional hamstring to quadriceps (H:Q) ratio is derived from concentric peak torque of the hamstring during flexion versus the concentric peak torque of the quadriceps during extension[7]. The H:Q ratio is then used in sport performance and rehabilitation to measure strength properties of the muscles and to detect muscular imbalances[8, 9].

Previously, researchers have identified H:Q ratios that can increase the risk of lower extremity injuries, such as ACL and hamstring injuries. It has been found that H:Q ratios less than 0.60 (60.0%) for 60 degrees per second (deg·sec^{-1}) may increase the risk for injury[10, 11]. If the hamstrings are significantly weaker than the quadriceps, the muscular system in place for protection is less than efficient[12]. Women are also significantly more likely than men who participate in the same sport to suffer from a knee injury[13]. Females have increased anteversion, Q angle, excessive tibial torsion, and subtalar pronation, as well as greater joint laxity which could account for the increased prevalence of injury[12]. Understandably, there is a high prevalence of research on H:Q ratio in female athletes as it pertains to injury. Regarding H:Q and performance, a study examined H:Q ratios in elite, subelite, and amateur soccer players. They found that a higher H:Q ratio was associated with improved performance in short distance sprint tests, but they found no difference in the vertical jump[14].
The relationship between strength and speed has been studied for years. Past research examined the relationship between vertical jump measures and sprint speed over 10, 20, and 40 meters (m) in professional basketball players. Their results showed a considerable variation within the factors that contribute to performance. However, the study did not include any laboratory strength measurements[15].

Basketball players perform counter movement jumps (CMJ) throughout practices and games. In a CMJ, the subject starts in a fully upright position, initiates a downward movement, then immediately transitions to the upward movement to complete the jump[16]. Utilizing this type of jump, an assessment was done regarding the relationship between isokinetic knee strength in elite young female basketball athletes and vertical jump performance. The group found moderate to high positive correlations (the highest at $r = 0.88$, $P < 0.001$) between the isokinetic measures and the vertical jump height[17].

Few studies exist in the literature that focus on the relationship between isokinetic strength and athletic performance in collegiate female basketball players. Therefore, a relationship may exist between isokinetic testing variables, specifically H:Q, and the performance demands associated with competitive basketball. Thus, the purpose of this study is to examine the relationship between isokinetic strength (H:Q isokinetic ratio) and selected performance metrics associated with competitive basketball (10 m sprint and CMJ). Correlations will be made between H:Q ratios, 10 m sprint, and CMJ aiming to discover whether there is an ideal H:Q ratio that can predict female basketball sport performance. From the current literature, it is hypothesized that a greater H:Q ratio will predict better performance in both sprint times and vertical jump.

METHODS

Subjects

Eight subjects (mean ± SD age, height, weight, years playing organized basketball: 20.10 ± 1.13 years, 1.74 ± 0.10 m, 75.49 ± 15.27 kilograms (kg), 11.06 ± 2.34 years, respectively) were selected from a NCAA Division III intercollegiate women's basketball program on a volunteer basis with the stipulation of requiring at least one year of experience on the college team. Informed consent was obtained prior to testing and the study protocol was approved by the Institutional Review Board.

Procedures

Warm up

Prior to testing, participants completed a three minute warm up on a cycle ergometer (SCIFIT ISO 1000, SCIFIT, Tulsa, Oklahoma, United States). Before starting, a proper bike fit was found by using a goniometer (Orthopedic Equipment Company CAT 238, OEC Medical Systems, Salt Lake City, Utah, United States) to ensure that when one leg was at the bottom of pedal stroke, the knee was bent at between 25 and 35 degrees. Additionally, the ball of their foot was to be in the middle of the pedal. During the warm-up the bike resistance was set at 50 watts and the participants were instructed to keep their revolutions per minute above 70. Throughout the warm-up, participants were asked questions regarding past competitive basketball experience, collegiate basketball experience, past injuries, and preseason workout.

Vertical Jump

The vertical jump test was performed on the Kistler Quattro Jump (type 9290BD SN 4395898, Kistler Instrument Corp., Amherst, New York, United States) utilizing Kistler MARS (measurement, analysis, and reporting software, Kistler Instrument Corp., Amherst, New York, United States). The force plate was calibrated to the manufacturer's standards. The CMJ was performed by starting in a fully upright position, initiating a downward movement, then immediately transitioning to the upward movement to complete the jump[16]. The first test completed by the participants was the CMJ. Initially, the participants were read a summary of the test they would be performing. A CMJ was defined and demonstrated by the researcher. Participants were notified that they would be performing three separate trials with a 60 second rest break in between each jump. The participants' information was entered into the MARS software. Their weight was measured utilizing the force plate. The force plate was zeroed and the participants began the test. After each jump the participant stepped off the plate while the data was gathered and the plate was zeroed. They were given a 60 second rest break before repeating the procedure. The highest jump as measured by the flight time was utilized for statistical analysis.

10 M Sprint

The 10 m sprint test was performed in a gymnasium with a synthetic floor. Hand timing was used in place of a timing gate system due to previous research showing the flaws of machines mistaking forward anticipatory lean of the sprinter as starting of the test[18].

Following the vertical jump test the participants were escorted into the gymnasium to perform a 10 m sprint. The participants were read a summary of the test they would be performing, and were encouraged to ask questions or clarify the directions at any time. Three timers were used for this test, one at the starting line, one at the finish line, and a break timer. This was done to maximize the accuracy of the test, knowing previous reports on sprint testing suggest that the error associated with short sprints (10 m) is about 2.0 % or 0.04 seconds[19]. The starting timer counted down, "3-2-1-GO" and both timers started their stopwatches. When the participant's body completely crossed the finish line the finish line timer said, "STOP" and both researchers stopped their stopwatches. During the 60 second break, which was timed by a third timer, the starting line and finish line timer came together and compared times. The average of both times were written down. After the three trials were completed the fastest average of the three was recorded. The fastest average sprint time was utilized for statistical analysis.

Isokinetic Machine

The isokinetic protocol was performed on the CSMi Humac NORM Testing and Rehabilitation System Model 770 isokinetic dynamometer (Computer Sports Medicine

Inc., Stoughton, Massachusetts, United States). Protocol was generated using guidelines from multiple studies analyzing rest time, repetitions, isokinetic speeds, and range of motion[4, 6, 20]. H:Q ratios were calculated by dividing each participant's concentric peak torque for the leg flexors by the concentric peak torque for the leg extensors for each maximal recorded trial within each subsequent speed.

All subjects were right foot dominant and were tested on the right leg with the isokinetic machine. Trunk flexion was set to 90 degrees and the chair was adjusted for easy access on a calibrated, gravity corrected isokinetic dynamometer. Participants were seated so that their proximal calf was 0.50 inches away from the end of the seat pad with a lumbar pad behind lower back. Non-testing limb was strapped at the thigh with the foot behind an ankle stabilizer, the chest was buckled and secured, and the hands were placed on handles. The chair was adjusted so the lateral epicondyle of the testing femur was aligned with the axis of rotation on the dynamometer head while the leg was at 90 degrees of flexion (with 0 degrees as full extension). The lever arm pad was positioned an inch above the lateral malleolus and secured with a strap. The testing leg was brought through range of motion to ensure there was no deviation besides parallel to the machine's axis and range of motion. If deviation was found, adjustments were made. The range of motion for the leg extension and flexion movements were set from 5 degrees to 90 degrees.

Prior to testing the protocol was read to the participant, ensured to push and pull to their maximum potential. The participant completed, for each isokinetic angular velocity (60, 90, 120 deg·sec^{-1}), three submaximal practice unrecorded trials, followed by 30 seconds of rest, then three maximal recorded trials, followed by 60 seconds of rest. H:Q torque ratios were recorded as percentages.

Statistical Analyses

All data were recorded and analyzed using IBM SPSS Statistics 24 (IBM Corporation, Armonk, New York, United States). Descriptive statistics calculated standard deviations and means for all dependent variables. Correlational statistics were calculated between H:Q ratio at 60 deg·sec^{-1}, 90 deg·sec^{-1}, and 120 deg·sec^{-1}, the best sprint time, and flight time for vertical jump height. For all statistical tests, significance was set at an alpha level of $p \leq 0.05$.

RESULTS

Participant characteristics are recorded in Table 1 and no participants dropped out during this study. The correlational analysis between H:Q ratio, 10 m sprint, and vertical jump at three angular velocities are displayed in Table 2. The mean and standard deviations for the performance tests include vertical jump at 0.30 ± 0.06 m and 10 m sprint at 1.83 ± 0.17 seconds. Figure 1 shows all correlational results evaluated with regression, coefficient of determination, and 95 percent confidence intervals. All three isokinetic speeds produced an average H:Q ratio was 59.83 ± 9.42. No correlations were found to be significant with the smallest p value = 0.32. However, H:Q ratio was found to be positively correlated with the vertical jump and negatively correlated with the 10 m sprint.

Table 1. Participant characteristics.

	Mean	Standard Deviation
Age (yrs)	20.10	±0.10
Height (m)	1.74	±0.10
Weight (kg)	75.49	±15.27
Competing (yrs)	11.06	±2.34
Competing on Collegiate Team (yrs)	2.88	±1.13

yrs = years; m = meters; kg = kilograms
Note. Values are presented in mean ± standard deviation for continuous variables.

Table 2. Test results of 3 speed isokinetic protocol measuring hamstring to quadriceps correlated to vertical jump and 10 meter sprint performance.

Isokinetic Speed	Average H:Q Ratio	Test	Correlation
60 deg·sec^{-1}	58.63	*Vertical Jump*	-0.29
		10 Meter Sprint	0.27
90 deg·sec^{-1}	57.38	*Vertical Jump*	-0.29
		10 Meter Sprint	0.40
120 deg·sec^{-1}	63.50	*Vertical Jump*	-0.35
		10 Meter Sprint	0.21

H:Q = hamstring to quadriceps torque ratio measured by isokinetic testing in percentages.
deg·sec^{-1} = range of leg motion in degrees per second.

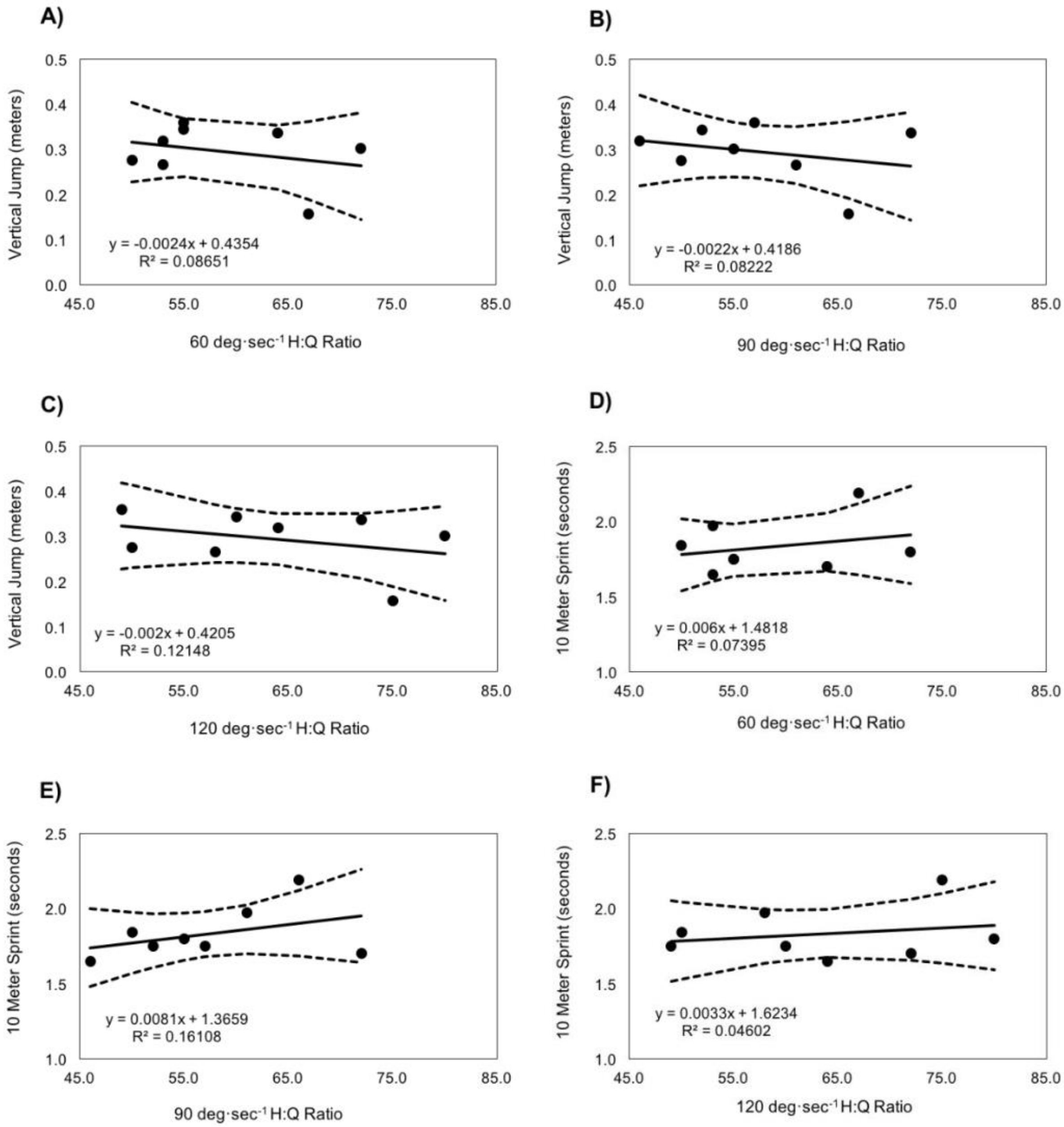

Figure 1. Relationship between vertical jump and (A) 60 deg·sec^{-1} H:Q, (B) 90 deg·sec^{-1} H:Q, and (C) 120 deg·sec^{-1} H:Q. Relationship between 10 meter sprint and (D) 60 deg·sec^{-1} H:Q, (E) 90 deg·sec^{-1} H:Q, and (F) 120 deg·sec^{-1} H:Q. Included solid regression line and equation, coefficient of determination, and dashed 95 percent interval confidence.

H:Q = hamstring to quadriceps torque ratio measured by isokinetic testing in percentages .

DISCUSSION

H:Q Ratio, Vertical Jump, and 10 m Sprint

The results of this study showed correlations of $r \leq 0.40$ between isokinetic strength and the performance measures of vertical jump and 10 m sprint in Division III collegiate women's basketball players. In our study the female basketball players had consistently stronger quadriceps than hamstrings. This is a typical muscular imbalance across all athletes and sports and is consistent with previous research[21].

In basketball, hamstrings play a prominent role in sprinting and the quadriceps play an important role in jumping. The balance between these muscles could explain why a positive correlation between H:Q ratios was found with sprinting while a negative correlation was found with jumping. For there to be a positive correlation in sprinting, the H:Q ratio increases (hamstring strength increases) as the sprinting time decreases. For there to be a negative correlation in jumping, the H:Q ratio decreases (quadriceps strength increases) as the jumping height increases. Like basketball, soccer also demonstrates this muscular trend. In a previous study, researchers looked at elite, subelite, and amateur French soccer players and found no correlation between isokinetic strength and anaerobic power performance[14]. This current research measured maximal strength of hamstrings and quadriceps similar to the study previously mentioned, thus this suggests that basketball performance is not determined by H:Q ratio. Therefore, the isokinetic machine may not be the best measure of maximal strength when looking at 10 m sprint and vertical jump.

Although little research has been done on the correlation between hamstrings to quadriceps ratio as it pertains to athletic performance, Wislof found a strong correlation between maximal strength, sprinting, and jumping performance in elite soccer players[22]. In this study maximal strength was assessed using maximal squat strength of the athletes. Previous research indicates that the greatest muscular activation during a squat takes place in the quadriceps[23]. In this study the isokinetic machine took the ratio from the maximal torque of the quadriceps and hamstrings. Utilizing the one repetition maximum squat test instead of the isokinetic machine to assess lower body strength could explain the contrasting results.

As previously mentioned, short sprints and jumping are two main requirements for the sport of basketball. Combining H:Q ratio, sprinting, and jumping from previous research would allow researchers to assess its impact on athletic performance. Since basketball players jump 46 times per game on average and the court is only 28 by 15 m in dimensions, the assessments chosen were the best choice for this population[17]. In order to assess vertical jump, a CMJ was done on a force plate, which is similar to previous research and this assessment tool has been proven reliable[16, 24]. Past research found a small amount of error, 2.0 % or

0.04 seconds, associated with short sprints, making a 10 m sprint test appropriate[19]. This is to say the lack of significant correlations between H:Q ratio and the performance metrics is not due to lack of accuracy in assessments.

The assessments for this current study were chosen because of the high relevance to basketball. These biomechanical movements are often the cause of lower extremity injuries in this sport. These injuries such as ACL and hamstring injuries are the focus of the majority of H:Q ratio studies. It was found that five out of the eight participants in this study had an H:Q ratio less than 0.60 (60.0 %) for 60 deg·sec^{-1}. It is known that this muscular imbalance significantly increases the risk of lower extremity injuries. With the information provided during data collection three of the participants had already suffered from knee injuries. The muscular imbalances could explain the high prevalence of lower extremity injuries. This information could influence the exercises included in a pre-season workout. By focusing more on hamstring strength, it could decrease the risk of both hamstring and ACL injuries.

H:Q Ratio Across Sports

A previous research study looking at elite adolescent jumpers and sprinters found absolute H:Q ratios of 0.75 (75.0 %) and 0.71 (71.0 %) respectively[25]. The ratios were obtained utilizing an isokinetic protocol measuring isokinetic peak torque of the leg extensors and flexors. Moving from track to basketball, professional basketball players have been found to have a H:Q ratio between 0.74 (74.0 %) and 0.79 (79.0 %)[26]. Looking at elite, subelite, and amateur French soccer players, researchers found that the Division I athletes had significantly stronger hamstrings and a greater H:Q ratio than amateur players. The average H:Q ratios for division I soccer players ranged from 0.70 - 0.80 (70.0% - 80.0%) across various angular velocities. For the amateur athletes the averages range from less than 0.50 - 0.80 (50.0% - 80.0%)[14]. The ratios of elite athletes across sports are fairly consistent in the research. The H:Q ratios obtained in this study were significantly lower than those of elite athletes. However, the ratios were in line with the H:Q ratios of the amateur French soccer players. This could indicate that H:Q ratios vary more across training levels than sports.

Limitations

The major limitation of this study was the small sample size. Eight participants were recruited from a Division III collegiate women's basketball team, defining our study as a pilot study. Prior research focuses heavily on elite athletes, whereas our study consisted of solely amateur athletes. The training programs and level of performance differ significantly between these two populations. This makes it difficult to generalize our findings and compare them with other populations. Although, the participants were instructed to give an all-out effort when performing each test, researchers can never be certain that the desired level of effort was given every time.

CONCLUSIONS

In basketball, both the quadriceps and the hamstrings play a prominent role in jumping and sprinting, respectively. In this study there was a positive correlation found between H:Q ratios and sprinting while a negative correlation was found with jumping. Apart from these findings, the results suggested that using isokinetic testing is not a recommended method to evaluate athletic performance in Division III female collegiate basketball players.

Although this study had no significant findings, there are some modifications to be addressed in future research to possibly find meaningful and applicable results for athletes. In the future, it will be important to obtain a larger and more diverse sample size, which would include athletes of both sexes, different sports, and training levels. In our study we performed a conventional H:Q ratio (concentric : concentric). In future studies it would be beneficial to perform a functional H:Q ratio (concentric : eccentric) (Jenkins, et al., 2013). With this information you could compare and contrast the two measures.

ACKNOWLEDGEMENTS

The authors acknowledge the study participants, faculty advisors, and the University of Wisconsin-Eau Claire for their time and contributions to the research.

ADDRESS FOR CORRESPONDENCE

Atwood, C. University of Wisconsin-Eau Claire, 105 Garfield Ave. Eau Claire, WI, 54701, USA; Phone: 952-250-3566; Email: atwoodcp@uwec.edu.

REFERENCES

1. McInnes SE, Carlson JS, Jones CJ, McKenna MJ. (1995). The physiological load imposed on basketball players during competition. *J Sports Sci*, *13*, 387-397.
2. Arendt E, Dick R. (1995). Knee injury patterns among men and women in collegiate basketball and soccer: NCAA data and review of literature. *Am J Sports Med, 23*, 694–701.
3. Hewett TE, Ford KR, Myer GD. (2006). Anterior cruciate ligament injuries in female athletes: Part 2, a meta-analysis of neuromuscular interventions aimed at injury prevention. *Am J Sports Med, 34*, 490–498.
4. Baltzopoulos V, Brodie D. (1989). Isokinetic Dynamometry. *Sports Med*, *8*(2), 101-116.
5. Thistle H, Hislop H, Moffroid M, Hofkosh J, Lowman E. (1967). Isokinetic contraction: a new concept of exercise. *Arch Phys Med Rehabil*, *48*, 279-262.
6. Ripamonti M, Ritz M, Rahmani A, Lemaire A. (2013). Agreement of three vs. eight isokinetic preset velocities to determine knee extensor torque- and power-velocity relationships. *Isokinet Exerc Sc*, *22*, 520-526.
7. Dvir Z, Egger G, Halperin N, Shklar A. (1989). Thigh muscle-activity and anterior cruciate ligament insufficiency. *Clin Biomech (Bristol, Avon), 4*, 87-91.
8. Aagaard P, Simonsen EB, Trolle M, Bangsbo J, Klausen K. (1995). Isokinetic hamstring/quadriceps strength ratio: Influence from joint angular velocity, gravity correction and contraction mode. *Acta Physiol Scand, 154*(4), 421-427.
9. Kannus P (1994). Isokinetic evaluation of muscular performance: Implications for Muscle testing and rehabilitation. *Int J Sports Med*, *15*, S11-S18.

10. Askling C, Karlsson J, Thorstensson A. (2013). Hamstring injury occurrence in elite soccer players after preseason strength training with eccentric overload. *Scand J Med Sci Sports, 13*(4), 244-250.
11. Croisier JL, Forthomme B, Namurois MH, Vanderthommen M, Crielaard JM. (2002). Hamstring muscle strain recurrence and strength performance disorders. *Am J Sports Med, 30*(2), 199-203.
12. Myer GD, Ford KR, Barber Foss KD, Liu C, Nick TG, Hewett TE. (2009). The relationship of hamstrings and quadriceps strength to anterior cruciate ligament injury in female athletes. *Clin J Sport Med, 19*(1), 3-8.
13. Wojtys EM, Huston LJ, Schock HJ, Boylan JP, Ashton-Miller JA. (2003). Gender differences in muscular protection of the knee in torsion in size-matched athletes. *J Bone Joint Surg Am, 85(*5), 782-789.
14. Cometti G, Maffiuletti NA, Pousson M, Chatard JC, Maffuli N. (2001). Isokinetic strength and anaerobic power of elite, subelite andamateur French soccer players. *Int J Sports Med, 22*(1), 45-51.
15. Shalfawi SA, Sabbah A, Kailani G, Tønnessen E, Enoksen E. (2011). The relationship between running speed and measures of vertical jump in professional basketball players: a field-test approach. *J Strength Cond Res, 25*(11), 3088-3092.
16. Van Hooren BAS, Zolotarjova J. (2017). The difference between countermovement and squat jump performances: a review of underlying mechanisms with practical applications. *J Strength Cond Res, 31*(7), 2011-2020.
17. 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. *Journal of Sports Medicine and Physical Fitness*, *55*(12), 1502-1508.
18. Duthie GM, Pyne DB, Ross AA, Livingstone SG, Hooper SL. (2006). The Reliability of Ten-Meter Sprint Time Using Different Starting Techniques. *J Strength Cond Res, 20*(2), 246-251.
19. Fitzsimons M, Dawhon B, Ward D, Wilkinson A. (1993). Cycling and running tests of repeated sprint ability. *Austral. J. Sports Med. 25*, 82-87.
20. Parcell AC, Sawyer RD, Tricoli VA, Chinevere T. D. (2002). Minimum rest period for strength recovery during a common isokinetic testing protocol. *Med Sci Sports Exerc, 34*(6), 1018-1022.
21. Aagaard P, Simonsen EB, Magnusson SP, Larsson B, Dyhre-Poulsen P. (1998). A new concept for isokinetic hamstring: quadriceps muscle strength ratio. *Am J Sports Med, 26*(2), 231-237.
22. Wisloff U. (2004). Strong correlation of maximal squat strength with sprint performance and vertical jump height in elite soccer players. *Br J Sports Med, 38*(3), 285-288.
23. Fauth ML, Garceau LR, Lutsch B, Gray A, Szalkowski C, Wurm B, Ebben WP. (2010). Hamstrings, quadriceps, and gluteal muscle activation during resistance training exercises. *SBS Proceedings, 28*, 1-4.
24. Buckthorpe M, Morris J, Folland JP. (2012). Validity of vertical jump measurement devices. *J Sports Sci, 30*(1), 63-69.
25. Housh TJ, Thorland WG, Tharp GD, Johnson GO, Cisar CJ. (1984). Isokinetic leg flexion and extension strength of elite adolescent female track and field athletes. *Res Q Exerc Sport*, *55*(4). 347-350.
26. Soslu R, Özkan A, Göktepe M. (2016) The relationship between anaerobic performances, muscle strength, hamstring/quadricep ratio, agility, sprint ability and vertical jump in professional basketball players. *JPES, 10*(2), 164-173.