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ORIGINAL ARTICLE

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The Effect of Concurrent Ankle and Hip Positions on Hamstring Function in Athletes

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ABSTRACT

Background. Previous studies have suggested that ankle position and hip position can influence hamstring strength, but none have considered the influence of both joint positions at the same time. **Objectives.** This study aimed to investigate the effect of ankle and hip position on peak torque (PT), normalized PT (NPT), angle of PT (APT), and surface electromyographic (SEMG) activity during isokinetic knee flexion. **Methods.** In this within-subject study design, thirteen physically active men in a single session performed three maximal isokinetic unilateral knee flexion repetitions in four different ankle and hip positions: sitting with dorsal/plantar flexion and supine with dorsal/plantar flexion at two angular velocities of 60 and 180°/s on the isokinetic dynamometer. The individual SEMG activity of the gastrocnemius (GL), biceps femoris (BFl), and semitendinosus (ST) muscles was detected using a wireless SEMG system. **Results.** Ankle and hip positions had a significant impact on the PT, NPT, and APT ($p < 0.05$), but did not affect SEMG activity of BFl, ST, and GL muscles for both angular velocities ($p > 0.109$). Specifically, the flexed hip and dorsiflexed ankle provided the greatest torque production, while the extended hip and plantarflexed ankle led to a decrease in hamstring torque production. An increase in angular velocity also led to an increase in APT. **Conclusion.** Both hip and ankle positions have a significant impact on the PT, NPT, and APT, but not on BFl, ST, and GL activation during maximal knee flexion, for both angular velocities, 60 and 180°/s.

KEYWORDS: ***Joints, Hamstring Muscles, Isometric Contraction, Torque, Electromyography.***

INTRODUCTION

A hamstring is a muscle group composed of four muscle bellies (i.e., the semimembranosus (SM), the semitendinosus (ST), and the long (BFl) and short heads of biceps femoris (BFs)). This muscle complex is often classified as biarticular muscles (ST, SM, and BFl) or monoarticular muscles (BFs) according to the number of joints they act upon (1). Therefore, it is responsible for both knee flexion and hip extension plays an important role in activities such as walking, running, or jumping (2), and requires substantial strength and power (3). Further, coactivation of the hamstrings during quadriceps contraction provides greater knee stability through joint compression, and counteraction of the anterior shear induced by the pull of the quadriceps on the tibia (4) and acts as the primary anterior cruciate ligament (ACL) agonist (5).

Hamstring tightness or lower strength and its lower activity, imbalance, inhibition, or a low hamstring-to-quadriceps strength ratio are the main factors leading to hip, knee, and hamstring injuries (6) and are risk factors for secondary ACL injury (7, 8). Therefore, numerous active and passive training methods are used to enhance

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the performance and to prevent hamstring injuries (9–11). However, while these methods can be effective, two strategies often are overlooked: active insufficiency and passive tension (12).

The active insufficiency of a muscle that crosses two or more joints occurs when the muscle produces simultaneous movement at all the joints it crosses and reaches such a shortened position that it no longer can develop effective tension (13). In other words, active insufficiency occurs when a multi-joint muscle shortens over both joints simultaneously, and hence, creates so much slack, that muscle tension is almost completely lost. The reason for this is that the sarcomeres are already shortened, cross-bridges of myosin filaments have attracted actin filament as much as they could, so there are no more binding sites of actin filament for the myosin filament to attach to shorten the muscle even more (12). For example, gastrocnemius medialis and lateralis (GL) cross the knee and ankle and they are primary plantar flexors, but also help to perform knee flexion. Active insufficiency occurs when performing plantarflexion in knee flexed position (12), or during knee flexion in a plantarflexed position. On the other hand, passive tension is achieved when a biarticular muscle is elongated at one joint while producing motion or force at the other joint (14). Simplified, passive tension refers to the force that is recorded when the muscle is stretched without activation (15). That produces a favorable length–tension relationship and therefore maximizes the capacity of a muscle to produce force (e.g., knee flexion in a hip-flexed position) (12).

Some previous studies have suggested the ankle (16) or hip position (17, 18) as a factor that may affect the hamstring strengthening exercise, but neither has considered them both at the same time. Observing the effect of the position of only one of the joints does not provide a complete picture of the relationship between muscle length, force, and activation. During daily and sports activities such as walking, running, sitting down, or kicking, the hip and knee joint angles change simultaneously. Because of this, the muscle's operating length range undergoes a continuous shift from one combination of hip and knee joint positions to another. Consequently, conclusions about hamstring function derived from one movement pattern may not have the same impact in other exercise conditions, which may lead to erroneous conclusions about the optimal exercise stimulus to develop hamstring muscle function (15). Thus, different combinations of hip and knee joint positions can result in different, but also the same hamstring length, so it is important to determine whether they affect the production of torque during hamstring contraction. Furthermore, it is important that during activities such as sprinting, the muscles should generally work at approximately optimal length, just as strength exercises performed at optimal length could provide higher torques. Therefore, it is necessary to investigate and better understand the role of the combined impact of ankle and hip position on hamstring strength training and injury prevention.

Another feature that can affect the production of force is the angular velocity. The two velocities most commonly used during isokinetic testing procedures are 60 and 180°/s (19), which have been suggested to reveal the maximal capacities of the muscles to produce force (18). It is known that higher force outputs can be achieved at lower angular velocities (20), however, it is not known how the force relations of different hip and ankle positions behave at different angular velocities.

Therefore, further studies are needed to investigate the effectiveness of knee flexion exercises taking into consideration the ankle and hip positions, as well as movement velocities. This study aims to examine the impact of ankle and hip positions on knee flexor muscle strength and to evaluate and compare the muscular activation of the BFl, ST, and GL muscles during maximal isokinetic knee flexion.

MATERIALS AND METHODS

Design. A within-subjects study design (repeated measures design) was used during a single testing session at the Laboratory for Motor Control and Performance at the University of Zagreb, Faculty of Kinesiology.

Peak torque (PT), normalized peak torque to body mass (NPT; a ratio displayed as a percentage of the maximum torque produced to the subject’s body mass), angle of peak torque (APT), and maximal normalized surface electromyographic (SEMG) muscle activation were compared during knee flexion between four different joint positions and under two angular velocities.

The experimental procedures were approved by the local institutional review board (Ethics Committee of University of Zagreb, Faculty of

Kinesiology; Decision number: 84/2020) and were under the Declaration of Helsinki.

Participants. Thirteen young adults (18-25 years) with a physical activity level 6 on the Tegner Activity Scale volunteered in the study. The Tegner Activity Scale is formed by a scoring system of 0-10 points for daily and sporting activities, graded from 0 points when an activity has been stopped because of injury or dysfunction up to 10 points for those undertaking professional sport at an elite level (21). The sample size was estimated using G*Power software (ver. 3.0.10., Franz Faul, Universität Kiel, Germany) using an a priori test with a significance level of 0.05, an effect size of 0.50 and 0.80 statistical power using the F test, ANOVA: Repeated measures, within the factor statistical test. Although the results of the power analysis showed that this study would require 10 participants, we conservatively recruited 13.

Several inclusion criteria were used during the recruitment process: individuals aged between 18 and 25 years and voluntary participation in the study; performing regular physical activity, with at least one year of experience in strength training; who considered their knee function normal without any history of knee surgery or recent knee injuries. Exclusion criteria included neural, muscular, skeletal, or connective tissue injuries during the last 12 months in the area of the back, hips, and legs. This information was obtained by questioning each participant during the initial visit to the laboratory.

Participants were introduced to the goals and potential risks of the research before signing an institutionally approved informed consent document to participate in the study.

Instruments and Procedures. To evaluate the research question, analysis of the dominant leg (the one with which participant kicks the ball) knee flexion on the isokinetic dynamometer (System 4, Biodex Corporation, Shirley, New York, USA) was used to determine dynamic changes elicited under two different angular velocities (60 and 180°/s) by different ankle and hip joint positions: hip flexion with dorsiflexion (HFDF), hip flexion with plantar flexion (HFPF), hip extension with dorsiflexion (HEDF) and hip extension with plantar flexion (HEPF) (Figure 1).

Also, the SEMG analysis (DELSYS® Trigno Wireless EMG System; Massachusetts, USA) was performed to determine the differences in the activation of certain muscles between the mentioned hip and ankle joint positions.

After brief information on the objectives of the research and the measurement procedure, the placement of wireless EMG electrodes was started by an experienced examiner with more than three years of EMG testing. The testing was preceded by a standardized dynamic 3-minute warm-up consisting of various track-and-field drills (e.g., jogging, skipping, dynamic stretches), after which the participants performed 10 squats and 10 lunges.

The electrodes were placed on the dominant leg on three knee flexor muscles: the long head of biceps femoris (BFl), semitendinosus (ST), and lateral gastrocnemius (GL). The positions of the electrodes on the muscles were determined according to the European recommendations for surface electromyography (SENIAM - Surface Electromyography for the Non-Invasive Assessment of Muscles) (22). The skin surface at each site was shaved and cleansed with alcohol to remove dead surface tissues and oil that might reduce conductivity. Electrodes were secured with a microporous patch and an elastic synthetic bandage mesh.

Thereafter, the participants performed 5-second maximal voluntary isometric contractions (MVC) against external resistance for SEMG normalization as follows: plantar flexion in plantar flexion ankle position with 10° knee flexion (attempting to push the door frame using only ankle joint) for the GL, and knee flexion in a sitting position on isokinetic dynamometer, with the knee flexed at 45˚and ankle in neutral position for the BFl and ST. The knee angle was determined according to the previous study of Higashihara et al. (2010), showing the highest knee flexion torque of the BF and ST at 45˚of knee flexion during MVC and a similar SEMG activity (23). Raw signals were bandpass filtered, enveloped, and low pass filtered using EMGworks Analysis software (Delsys Inc.). Both the bandpass (20 Hz and 450 Hz) and low pass (10 Hz) filters were second-order Butterworth filters applied in both direct and reverse signal directions to avoid phase distortions, therefore being 0-phase, fourth-order filters. Processed SEMG signals from each muscle were normalized across all trials with the corresponding RMS values of each MVC. Consequently, the EMG amplitude was expressed as a percentage of the

MVC for each muscle. During all MVC trials, loud verbal encouragement was provided.

The participant was strapped into the chair of the isokinetic dynamometer, with the seat back positioned at either 90° (hip flexion position) or 180° (hip extension position). The lateral femoral condyle was used as an anatomical reference to the axis of rotation. The length of the lever arm was individually determined, and the resistance pad was placed proximally to the medial malleolus. Gravity correction was applied following direct measurements of the mass of the lower limb-lever arm system at 30° knee extension. The range of motion covered the interval from 10° to 90°, where 0° equals full knee extension.

Participants performed three maximal concentric-concentric knee extension-flexion with a dominant leg at an angular velocity of 60 and 180°/s with pronounced plantar and dorsal ankle joint positions in sitting and supine positions. The order of hip and ankle position and angular velocity were randomized between participants. A 45-second rest interval between each condition was sufficient for participants to rest and resume testing as fatigue did not affect the continuation of the protocol. Before measuring each condition, participants performed two submaximal trials.

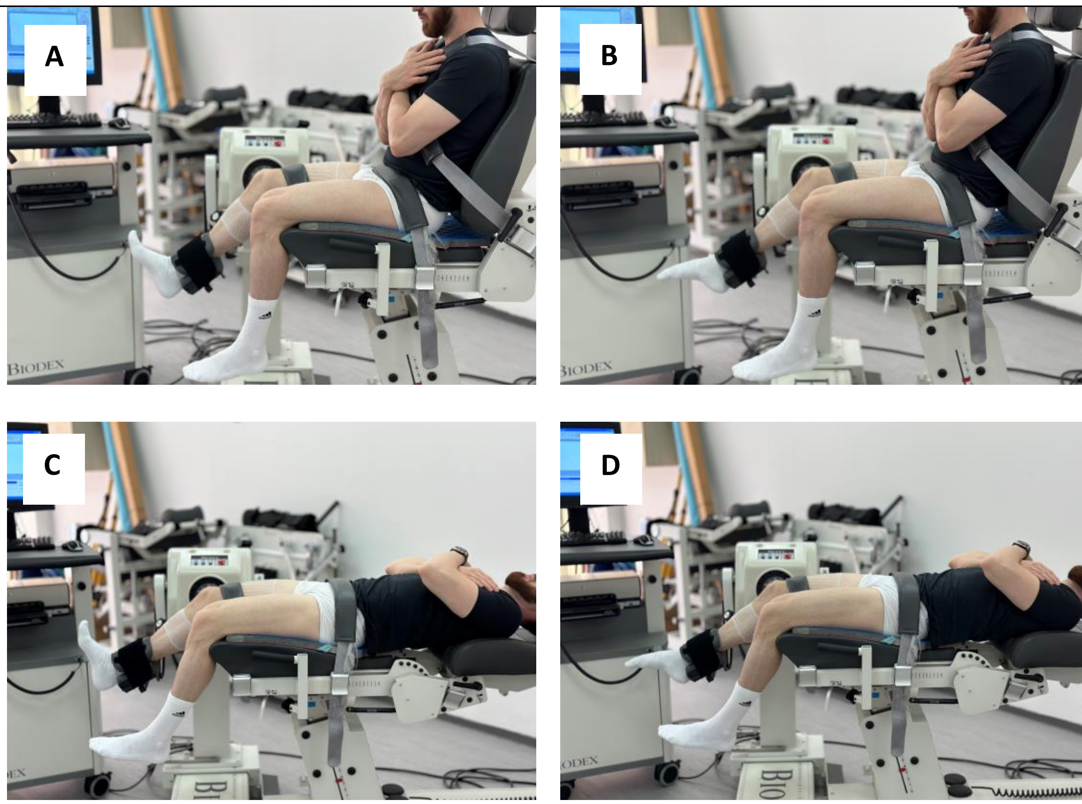

Figure 1. Testing knee flexion on the isokinetic dynamometer under four joint positions: (A) hip flexion with dorsiflexion (HFDF); (B) hip flexion with plantar flexion (HFPF); (C) hip extension with dorsiflexion (HEDF); and (D) hip extension with plantar flexion (HEPF).

Statistical analysis. SEMG analysis was performed in EMGworks Analysis (ver. 4.7.3.0., Delsys Inc.). The obtained data were processed in the SPSS program (ver. 24, 64 Bit, IBM, United States). Descriptive statistics were calculated for all variables as mean (M) and standard deviation (SD).

The statistical significance of differences in the strength and maximum electrical muscle activation amplitudes in different hip and ankle positions were determined by univariate analysis of variance for repeated measures (ANOVA) for both angular velocities. The normality of the distribution of the variables was determined using the Shapiro-Wilk test. In the case of violations of sphericity determined by the Mauchly test, a Greenhouse-Geisser correction was used. For post hoc comparisons between the hip and ankle positions, Bonferroni tests were performed. Peak torque percentage change (i.e., percentage increase; %) was calculated according to the formula: ((PT2 – PT1) / PT1) × 100. The level of statistical significance was set at $p < 0.05$ for all analyses.

RESULTS

The participants had a mean age of 19.9 ± 1.1 years, a mean body height of 178.4 ± 5.9 cm, and a mean body mass of 78.2 ± 10.9 kg. They all completed the test, but some of them had a negligible loss of SEMG signal.

Peak Torque, Normalized Peak Torque, and Angle of Peak Torque at 60 and 180°/s. Means and standard deviations of PT and NPT at different hip-ankle positions for 60 and 180°/s, APT, and percentage change (percentage increase over HEPF; %) are shown in Figure 2. The Shapiro-Wilk distribution normality test showed that the results were normally distributed in all variables ($p > 0.094$).

The ANOVA results showed a significant difference in PT and NPT between hip-ankle positions at 60 and 180°/s ($p < 0.001$) and between APT ($p < 0.05$) (Figure 2). Bonferroni post-hoc tests revealed that the hip flexion with dorsiflexion (HFDF) scored significantly higher in PT and NPT than the hip flexion with plantar flexion (HFPF), hip extension with dorsiflexion (HEDF) and hip extension with plantar flexion (HEPF) for both angular velocities ($p < 0.05$).

Bonferroni post-hoc comparison showed that the differences obtained in the APT were found only between the two hip positions at 60°/s ($p < 0.027$), while the difference at 180°/s was found only between the HFDF and HEPF ($p = 0.014$).

Electromyography Results - Performance at 60 and 180°/s. Means and standard deviations, as well as differences between values of maximum amplitudes of electrical muscle activation in different hip-ankle positions for 60 and 180°/s, are shown in Table 1. The results were normally distributed in all variables ($p > 0.052$).

There is no significant difference in SEMG activities for all muscles and angular velocities ($p > 0.109$) (Table 1).

Table 1. Surface EMG muscle activation (% MVC) at 60 and 180°/s angular velocities during isokinetic knee flexion (Mean ± Standard Deviation)

	60°/s				
	HFDF	**HFPF**	**HEDF**	**HEPF**	**p**
GL (% MVC)	84.21 ± 25.74	117.67 ± 48.80	88.24 ± 24.64	113.26 ± 41.44	0.109
BFl (% MVC)	119.00 ± 38.88	118.83 ± 38.84	126.17 ± 47.03	128.87 ± 45.88	0.254
ST (% MVC)	108.02 ± 67.39	100.38 ± 47.99	110.39 ± 65.46	111.80 ± 56.96	0.785
	180°/s				
	HFDF	**HFPF**	**HEDF**	**HEPF**	**p**
GL (% MVC)	90.49 ± 27.55	110.80 ± 20.08	120.08 ± 55.24	122.37 ± 40.33	0.171
BFl (% MVC)	120.42 ± 50.70	127.61 ± 64.50	126.34 ± 45.40	125.23 ± 47.20	0.937
ST (% MVC)	84.61 ± 57.49	90.40 ± 61.24	89.67 ± 53.83	104.96 ± 76.46	0.168

BFl: biceps femoris long head. GL: gastrocnemius. ST: semitendinosus. HEDF: hip extension with dorsiflexion. HEPF: hip extension with plantar flexion. HFDF: hip flexion with dorsiflexion. HFPF: hip flexion with plantarflexion.

DISCUSSION

The first main finding of the present study indicates that both ankle and hip positions have a significant impact on the magnitude of torque production during maximal knee flexion, regardless of body size. Specifically, the highest PT and NPT were produced in the hip flexed position with dorsal flexion, then in the hip flexed position with plantar flexion, followed by the hip extension with dorsal flexion, while the lowest peak torque was produced in the hip extension with plantar flexion, all for both angular velocities, 60 and 180°/s, with greater torque found at the slower velocity for all hip-ankle positions.

The second main finding is that both ankle and hip position, as well as angular velocity, have a significant impact on the angle of PT, which was expected and supported by previous reports (24). The PT of isokinetic knee flexion at 60°/s occurred between 25 and 41°. Specifically, in HEDF and HEPF position was around 25°, in HFPF was around 31°, and in HFDF was around 41° knee angle. As angular velocity increased to 180°/s, the PT shifted to between 40 and 62°.

Specifically, in HEPF position was around 40°, in HEDF was around 52°, in HFPF was around 59°, and in HFDF was around 62°.

And the third main finding is that there are no statistically significant differences in muscle activation in different hip-ankle positions of BFl, ST, and GL muscles for both angular velocities, but it should be noted that there is a clear trend of their activation at both velocities. It is seen that the GL, which is primarily a plantar flexor, was more active in the position of plantar flexion in both hip positions.

This is, to our knowledge, the first paper in which the influence of both hip and ankle positions on knee flexor muscle strength is investigated simultaneously with monitoring of muscle activation at two angular velocities. Several previous studies aimed to determine the optimal ankle position for hamstring strengthening (16, 25, 26), or the role of hip position on knee flexion strength (17, 27, 28). Our findings suggest that both ankle and hip positions affect the torque-producing capability of the knee flexors. Specifically, significant differences of 8.89 and 13.81% PT increase were noted with the hip in a flexed position when the ankle was dorsiflexed from the plantarflexed position at both 60 and 180°/s, respectively, and significant differences of 10.88 and 11.42% PT increase with hip in the extended position when the ankle was dorsiflexed at both 60 and 180°/s, respectively.

Our results are similar to those of Miller, Catlaw and Confessore (1997), who reported significant differences in knee flexor PT at both 60 and 180°/s and greatest PT with ankle dorsiflexion, and to those of Croce, Miller and St Pierre (2000), who found that maximum knee joint flexion moment was observed when the ankle joint was fixed in dorsiflexion rather than being fixed in the plantar flexion at both 60 and 180°/s (29). Kim, Cha, and Fell (2016) investigated the influence of two different active ankle positions during training on the strengths of knee flexors and concluded that active ankle dorsiflexion position during knee isokinetic concentric exercise increases knee flexor strength more than training with the ankle-fixed at plantar flexion.

The results of our study demonstrated that hamstring peak torque values were influenced also by hip position. Hamstring peak torque values were significantly higher in the flexed than in the extended position for both tested velocities. Specifically, significant differences of 43.17 and 40.88% PT increase were noted with the ankle in dorsiflexed position when the hip was flexed from the extended position at both 60 and 180°/s, respectively, and significant differences of 45.79 and 37.93% PT increase with plantarflexed ankle when the hip was flexed at both 60 and 180°/s, respectively. These results are consistent with the findings of Bohannon, Gajdosik, and LeVeau (1986) as well as Worrell, Perrin, and Denegar (1989) and Deighan et al. (2012) who found that participants produced significantly greater knee flexion torque when sitting upright compared with when semireclined or supine, without considering the ankle position.

This research clearly shows that the force produced by a muscle depends on its length, which is greatly influenced by changes in joint angles. As with any bi-articular muscle, both joints affect its length-tension curve (30), thereby producing favorable and unfavorable joint angle combinations. Based on our results, it looks like the optimal position for the hamstrings to generate the greatest knee flexion PT is the 90° hip position with a dorsiflexed ankle (HFDF). One of the mechanisms for these observed increases in hamstring torque production is related to the effectiveness of the contractile element of the muscle (sliding filament model), i.e., length-tension relationship which describes an optimal length at which a muscle can develop maximal force (31). In this model, there is an optimal position at which maximum overlap between the thick and thin filaments occurs which results in the production of maximum tension. Specifically, in the HFDF position the hamstrings and gastrocnemius are stretched creating passive tension which is more optimal for actin-myosin cross-bridging, which further results in the greatest torque production capacity (18). Lengths shorter or longer than this optimal length accommodate fewer actin-myosin bonds and therefore decrease the tension produced.

The second mechanism that could favor greater force production is passive tension. However, since passive tension was not directly measured, we can only assume that the passive tissues generated the most significant force in the initial phase of the HFDF position, i.e., while the knee was extended (32). The increased torque in lengthened muscle could be explained by the non-contractile component of the muscle, i.e., connective tissue sleeves which, when stretched, produce passive tension that adds to the active tension generated by muscle contraction. At shorter lengths, these passive elements are slack and their contribution to tension gradually decreases as the amount of slack increases (32). Therefore, the flexed hip position with dorsiflexed ankle is preferable for strengthening the hamstrings (26), but when the isolation of the hamstrings is wanted, it is recommended to train in the HFPF position to reduce the impact of the gastrocnemius muscle.

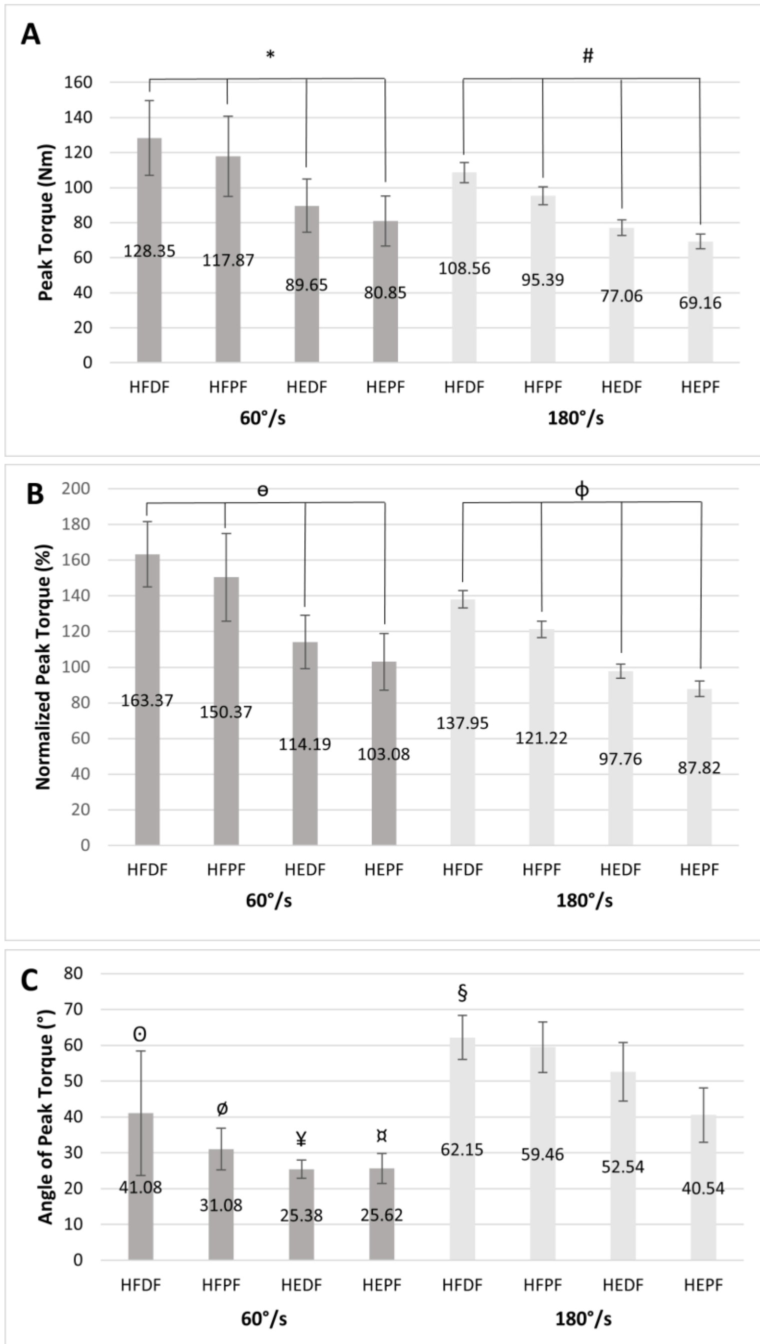

Figure 2. Means (bars), standard deviations (error bars), statistical differences between hip and ankle positions: (A) Peak Torque; (B) Normalized Peak Torque; and (C) the Angle of Peak Torque; for 60 and 180°/s angular velocities. Note: *, #, ɵ, and ϕ = significantly different from all other positions at $p < 0.001$. Ѳ = HFDF significantly different from HEDF ($p = 0.025$) and HEPF ($p = 0.027$). ø = HFPF significantly different from HEDF ($p = 0.004$) and HEPF ($p = 0.015$). ¥ = HEDF significantly different from HFDF ($p = 0.025$) and HFPF ($p = 0.004$). ¤ = HEPF significantly different from HFDF ($p = 0.027$) and HFPF ($p = 0.015$). § = HFDF significantly different from HEPF ($p = 0.014$). Abbreviations: HFDF, hip flexion with dorsiflexion; HFPF, hip flexion with plantar flexion; HEDF, hip extension with dorsiflexion; HEPF, hip extension with plantar flexion.

Further, we have noticed that the hamstring joint PT decreased almost linearly from the HFDF joint combination, through the HFPF and HEDF, to the HEPF combination. The effect of active insufficiency was most pronounced when the hamstrings and gastrocnemius muscles were simultaneously shortened at both joints. With the hip extended and the ankle in plantar flexion, the biarticular hamstrings were shortened at the proximal end, and the gastrocnemius at the distal end, so the actin-myosin cross-bridging does not occur as efficiently. Their further shortening, caused by an increase in the knee flexion angle, greatly reduced the efficiency of muscle contraction, thus producing the smallest PT (32).

In the HFPF position, the length of the gastrocnemius is shortened and actively insufficient to generate torque of the knee flexion (26). However, higher knee flexion PT in HFPF than in HEDF position, where the length of the hamstrings is shortened, confirms that hamstrings play a more significant role than the gastrocnemius in knee flexion force production.

Clinicians should be aware that the position of the patient's hip and ankle could significantly affect the strength of the hamstrings: the same result will not be obtained if the patient is sitting, or lying down, where an extended hip can mask the true strength of the hamstrings; Equally, the result will depend on whether the patient holds the foot in plantar flexion or dorsiflexion, in which the gastrocnemius has a large influence on force production (15). Further, acute injuries during sprinting mainly involve BFl and are attributed to high peak hip extension and knee flexion forces (33) or the sudden activation of the hamstrings while lengthening (34, 35). Furthermore, recent reviews have concluded that improvements in hamstring muscle strength, flexibility, and activation during activity vary between exercises (36, 37). As different combinations of hip and ankle positions, as well as different angular velocities, affect the change in APT, it is possible to assume that strength training using different hip and ankle angles, that is, with different hamstring lengths, would lead to specific results in terms of expanding the muscle operating range, functional adaptations, and injury propensity. In other words, the relationship between joint angular position and PT provides information about the effect of muscle length on force capacity; so, we can assume that different hip and ankle positions through different exercises could affect different components of the hamstrings.

Certain study limitations should also be mentioned. Although normalization using maximal voluntary isometric muscle contraction has provided representative measures of muscle activation during clinical exercises including isokinetic exercises (38), the EMG signals in some positions of all muscles were larger than MVC, which is following previous research (39–41). One possible reason is that certain positions in dynamic conditions are more suitable for producing maximum force than measured positions of isometric muscle contraction (42). Some research has found that the EMG levels change with muscle length (43), while other studies indicate that joint angle has little effect on maximum EMG levels (44) or that there is no consistent pattern of change in the EMG levels with joint angle (32). However, as we only wanted to compare SEMG amplitudes between different positions, the way the signal is normalized does not affect these relationships.

The other limitation is that the isokinetic dynamometer allows movement at a given angular velocity, which is not specific to natural human movement. The main problem with isokinetic devices relates to their usefulness as a training method to increase sports performance, as well as their usefulness in rehabilitation. The problem is that in the natural movements of the human body, the angular velocity is not constant throughout the range of motion of the joint, but the muscle follows a stretch-shortening cycle in which the phase of eccentric stretching of the muscle-tendon unit is followed by concentric contraction and the angular velocity changes along with the change in the joint angle (45). Nevertheless, Biodex is sensitive enough to find differences in PT between different hip-ankle positions during maximal knee flexion.

CONCLUSION

Based on the results of this study, it can be concluded that both hip position and ankle position have a significant impact on the magnitude of torque production during maximal knee flexion, regardless of body size, all for both angular velocities, 60 and 180°/s, with greater torque found at the slower velocity for all hip-ankle positions. Also, both ankle and hip position, as well as angular velocity, have a significant impact on the angle of peak torque, but not on BFl, ST, and GL muscle activation.

APPLICABLE REMARKS

- The highest knee flexion torque can be produced in a flexed hip position with a dorsiflexed ankle, while the smallest torque is produced in a flexed hip position with a plantar flexed ankle.
- The isolation of the hamstrings can be achieved by reducing the influence of the gastrocnemius by placing the ankle in a plantar flexion position.

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AUTHORS' CONTRIBUTIONS

Study concept and design: S. Vuk. Acquisition of data: S. Vuk, K. Pentek. Analysis and interpretation of data: S. Vuk, K. Pentek, B. Damjan. Drafting the manuscript: K. Pentek, B. Damjan. Critical revision of the manuscript for important intellectual content: S. Vuk. Statistical analysis: K. Pentek. Administrative, technical, and material support: S. Vuk, B. Damjan. Study supervision: S. Vuk.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

REFERENCES

1. Guruhan S, Kafa N, Ecemis ZB, Guzel NA. Muscle Activation Differences During Eccentric Hamstring Exercises. Sports Health. 2021 Mar 1;13(2):181–6. [doi:10.1177/1941738120938649] [PMid:32857686]
2. Schoenfeld BJ. Squatting Kinematics and Kinetics and Their Application to Exercise Performance. J Strength Cond Res [Internet]. 2010 Dec;24(12):3497–506. [doi:10.1519/JSC.0b013e3181bac2d7] [PMid:20182386]
3. Schoenfeld BJ, Contreras B, Tiryaki-Sonmez G, Wilson JM, Kolber MJ, Peterson MD. Regional Differences in Muscle Activation During Hamstrings Exercise. J Strength Cond Res [Internet]. 2015 Jan;29(1):159–64. [doi:10.1519/JSC.0000000000000598] [PMid:24978835]
4. Aagaard P, Simonsen EB, Andersen JL, Magnusson SP, Bojsen-Møller F, Dyhre-Poulsen P. Antagonist muscle coactivation during isokinetic knee extension. Scand J Med Sci Sports [Internet]. 2000 Apr;10(2):58–67. [doi:10.1034/j.1600-0838.2000.010002058.x] [PMid:10755275]
5. Mall NA, Chalmers PN, Moric M, Tanaka MJ, Cole BJ, Bach BR, et al. Incidence and Trends of Anterior Cruciate Ligament Reconstruction in the United States. Am J Sports Med [Internet]. 2014 Oct 1;42(10):2363–70. [doi:10.1177/0363546514542796] [PMid:25086064]
6. Hegyi A, Péter A, Finni T, Cronin NJ. Region-dependent hamstrings activity in Nordic hamstring exercise and stiff-leg deadlift defined with high-density electromyography. Scand J Med Sci Sports [Internet]. 2018 Mar 1;28(3):992–1000. [doi:10.1111/sms.13016] [PMid:29143379]
7. Ardern CL, Webster KE, Taylor NF, Feller JA. Return to the Preinjury Level of Competitive Sport After Anterior Cruciate Ligament Reconstruction Surgery. Am J Sports Med [Internet]. 2011 Mar 23;39(3):538–43. [doi:10.1177/0363546510384798] [PMid:21098818]
8. Wiggins AJ, Grandhi RK, Schneider DK, Stanfield D, Webster KE, Myer GD. Risk of Secondary Injury in Younger Athletes After Anterior Cruciate Ligament Reconstruction. Am J Sports Med [Internet]. 2016 Jul 15;44(7):1861–76. [doi:10.1177/0363546515621554] [PMid:26772611]
9. Pickering Rodriguez EC, Watsford ML, Bower RG, Murphy AJ. The relationship between lower body stiffness and injury incidence in female netballers. Sports Biomech [Internet]. 2017 Jul 3;16(3):361–73. [doi:10.1080/14763141.2017.1319970] [PMid:28553879]
10. Serpell BG, Ball NB, Scarvell JM, Smith PN. A review of models of vertical, leg, and knee stiffness in adults for running, jumping or hopping tasks. J Sports Sci [Internet]. 2012 Sep;30(13):1347–63. [doi:10.1080/02640414.2012.710755] [PMid:22845059]
11. Holcomb WR. Is Neuromuscular Electrical Stimulation an Effective Alternative to Resistance Training? National Strength and Conditioning Association. 2005;27(3):76–9. [doi:10.1519/00126548-200506000-00016]
12. Schoenfeld B. Accentuating Muscular Development Through Active Insufficiency and Passive Tension. Strength Cond J. 2002;24(4):20–2. [doi:10.1519/00126548-200208000-00006]
13. Clarkson HM. Musculoskeletal Assessment: Joint Motion and Muscle Testing. Third Edition. Philadelphia: Lippincott Williams & Wilkins; 2013.

14. Tamaki H, Kitada K, Akamine T, Sakou T, Kurata H. Electromyogram patterns during plantarflexions at various angular velocities and knee angles in human triceps surae muscles. Eur J Appl Physiol [Internet]. 1996 Dec 1;75(1):1–6. [doi:10.1007/s004210050118] [PMid:9007450]
15. Kellis E, Blazevich AJ. Hamstrings force-length relationships and their implications for angle-specific joint torques: a narrative review. BMC Sports Sci Med Rehabil [Internet]. 2022 Sep 5;14(1):166. [doi:10.1186/s13102-022-00555-6] [PMid:36064431]
16. Miller JP, Catlaw K, Confessore R. Effect of Ankle Position on EMG Activity and Peak Torque of the Knee Extensors and Flexors during Isokinetic Testing. J Sport Rehabil [Internet]. 1997 Nov;6(4):335–42. [doi:10.1123/jsr.6.4.335]
17. Deighan MA, Serpell BG, Bitcon MJ, De Ste Croix M. Knee Joint Strength Ratios and Effects of Hip Position in Rugby Players. J Strength Cond Res [Internet]. 2012 Jul;26(7):1959–66. [doi:10.1519/JSC.0b013e318234eb46] [PMid:21912292]
18. Worrell TW, Perrin DH, Denegar CR. The Influence of Hip Position on Quadriceps and Hamstring Peak Torque and Reciprocal Muscle Group Ratio Values. Journal of Orthopaedic & Sports Physical Therapy [Internet]. 1989 Sep;11(3):104–7. [doi:10.2519/jospt.1989.11.3.104] [PMid:18796923]
19. Janicijevic D, García-Ramos A, Knezevic OM, Mirkov DM. Feasibility of the two-point method for assessing the force-velocity relationship during lower-body and upper-body isokinetic tests. J Sports Sci [Internet]. 2019 Oct 18;37(20):2396–402. [doi:10.1080/02640414.2019.1636523] [PMid:31256708]
20. Janicijevic D, Knezevic OM, Garcia-Ramos A, Cvetic D, Mirkov DM. Isokinetic Testing: Sensitivity of the Force-Velocity Relationship Assessed through the Two-Point Method to Discriminate between Muscle Groups and Participants' Physical Activity Levels. Int J Environ Res Public Health [Internet]. 2020 Nov 19;17(22):8570. [doi:10.3390/ijerph17228570] [PMid:33227905]
21. Briggs KK, Steadman JR, Hay CJ, Hines SL. Lysholm Score and Tegner Activity Level in Individuals with Normal Knees. Am J Sports Med [Internet]. 2009 May 23;37(5):898–901. [doi:10.1177/0363546508330149] [PMid:19307332]
22. Hermens HJ, Freriks B, Disselhorst-Klug C, Rau G. Development of recommendations for SEMG sensors and sensor placement procedures. Journal of Electromyography and Kinesiology [Internet]. 2000 Oct;10(5):361–74. [doi:10.1016/S1050-6411(00)00027-4] [PMid:11018445]
23. Higashihara A, Ono T, Kubota J, Okuwaki T, Fukubayashi T. Functional differences in the activity of the hamstring muscles with increasing running speed. J Sports Sci [Internet]. 2010 Aug;28(10):1085–92. [doi:10.1080/02640414.2010.494308] [PMid:20672221]
24. Onishi H, Yagi R, Oyama M, Akasaka K, Ihashi K, Handa Y. EMG-angle relationship of the hamstring muscles during maximum knee flexion. Journal of Electromyography and Kinesiology [Internet]. 2002 Oct;12(5):399–406. [doi:10.1016/S1050-6411(02)00033-0] [PMid:12223173]
25. Kim K, Cha YJ, Fell DW. Differential effects of ankle position on isokinetic knee extensor and flexor strength gains during strength training. Isokinet Exerc Sci [Internet]. 2016 Aug 22;24(3):195–9. [doi:10.3233/IES-160617]
26. Kim DH, Lee JH, Yu SM, An CM. The Effects of Ankle Position on Torque and Muscle Activity of the Knee Extensor During Maximal Isometric Contraction. J Sport Rehabil [Internet]. 2020 Jan 1;29(1):37–42. [doi:10.1123/jsr.2018-0145] [PMid:30526239]
27. Bohannon RW, Gajdosik RL, LeVeau BF. Isokinetic Knee Flexion and Extension Torque in the Upright Sitting and Semireclined Sitting Positions. Phys Ther [Internet]. 1986 Jul 1;66(7):1083–6. [doi:10.1093/ptj/66.7.1083] [PMid:3725894]
28. Zapparoli FY, Riberto M. Isokinetic Evaluation of the Hip Flexor and Extensor Muscles: A Systematic Review. J Sport Rehabil [Internet]. 2017 Nov 1;26(6):556–66. [doi:10.1123/jsr.2016-0036] [PMid:27992245]
29. Croce R V, Miller JP, St Pierre P. Effect of Ankle Position Fixation on Peak Torque and Electromyographic Activity of the Knee Flexors and Extensors. Electromyogr Clin Neurophysiol. 2000;40(6):365–73.
30. McGraw Hill. Brunnstrom's Clinical Kinesiology, 6e [Internet]. Houglum PA, Bertoti DB, editors. 2012 [cited 2023 Jun 11].

31. Herrel A, Meyers JJ, Timmermans JP, Nishikawa KC. Supercontracting muscle: producing tension over extreme muscle lengths. Journal of Experimental Biology [Internet]. 2002 Aug 1;205(15):2167–73. [doi:10.1242/jeb.205.15.2167] [PMid:12110650]
32. Mohamed O, Perry J, Hislop H. Relationship between wire EMG activity, muscle length, and torque of the hamstrings. Clinical Biomechanics [Internet]. 2002 Oct;17(8):569–79. [doi:10.1016/S0268-0033(02)00070-0] [PMid:12243716]
33. Liu Y, Sun Y, Zhu W, Yu J. The late swing and early stance of sprinting are most hazardous for hamstring injuries. J Sport Health Sci [Internet]. 2017 Jun 1;6(2):133–6. [doi:10.1016/j.jshs.2017.01.011] [PMid:30356597]
34. Chumanov ES, Schache AG, Heiderscheit BC, Thelen DG. Hamstrings are most susceptible to injury during the late swing phase of sprinting. Br J Sports Med [Internet]. 2012 Feb;46(2):90–90. [doi:10.1136/bjsports-2011-090176] [PMid:21727236]
35. Schache AG, Dorn TW, Blanch PD, Brown NAT, Pandy MG. Mechanics of the human hamstring muscles during sprinting. Med Sci Sports Exerc [Internet]. 2012 Apr;44(4):647–58. [doi:10.1249/MSS.0b013e318236a3d2] [PMid:21912301]
36. Bourne MN, Timmins RG, Opar DA, Pizzari T, Ruddy JD, Sims C, et al. An Evidence-Based Framework for Strengthening Exercises to Prevent Hamstring Injury. Sports Medicine [Internet]. 2018 Feb 7;48(2):251–67. [doi:10.1007/s40279-017-0796-x] [PMid:29116573]
37. Bourne MN, Williams MD, Opar DA, Al Najjar A, Kerr GK, Shield AJ. Impact of exercise selection on hamstring muscle activation. Br J Sports Med [Internet]. 2017 Jul 1;51(13):1021–8. [doi:10.1136/bjsports-2015-095739] [PMid:27467123]
38. Kellis E, Baltzopoulos V. The effects of normalization method on antagonistic activity patterns during eccentric and concentric isokinetic knee extension and flexion. Journal of Electromyography and Kinesiology [Internet]. 1996 Dec;6(4):235–45. [doi:10.1016/S1050-6411(96)00012-0] [PMid:20719680]
39. Ball N, Scurr J. Electromyography Normalization Methods for High-Velocity Muscle Actions: Review and Recommendations. J Appl Biomech [Internet]. 2013 Oct;29(5):600–8. [doi:10.1123/jab.29.5.600] [PMid:23270917]
40. Ball N, Scurr J. An assessment of the reliability and standardisation of tests used to elicit reference muscular actions for electromyographical normalisation. Journal of Electromyography and Kinesiology [Internet]. 2010 Feb;20(1):81–8. [doi:10.1016/j.jelekin.2008.09.004] [PMid:19027326]
41. Rouffet DM, Hautier CA. EMG normalization to study muscle activation in cycling. Journal of Electromyography and Kinesiology [Internet]. 2008 Oct;18(5):866–78. [doi:10.1016/j.jelekin.2007.03.008] [PMid:17507240]
42. Oliver GD, Dougherty CP. The Razor Curl: A Functional Approach to Hamstring Training. J Strength Cond Res [Internet]. 2009 Mar;23(2):401–5. [doi:10.1519/JSC.0b013e31818f08d0] [PMid:19204567]
43. Pincivero DM, Salfetnikov Y, Campy RM, Coelho AJ. Angle- and gender-specific quadriceps femoris muscle recruitment and knee extensor torque. J Biomech [Internet]. 2004 Nov;37(11):1689–97. [doi:10.1016/j.jbiomech.2004.02.005] [PMid:15388311]
44. Barr AE, Goldsheyder D, Özkaya N, Nordin M. Testing apparatus and experimental procedure for position specific normalization of electromyographic measurements of distal upper extremity musculature. Clinical Biomechanics [Internet]. 2001 Aug;16(7):576–85. [doi:10.1016/S0268-0033(01)00046-8] [PMid:11470299]
45. Kannus P. Isokinetic Evaluation of Muscular Performance. Int J Sports Med [Internet]. 1994 Jan 14;15(S 1):S11–8. [doi:10.1055/s-2007-1021104] [PMid:8157377]