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Dynamometer Resistance Pad Position Influences Knee Strength and Hamstring/Quadriceps Ratio in Professional Basketball Players: Retrospective Observational Study

Raúl Coto Martín [1,2], María Jesús Martínez Beltrán [1,2,*], Néstor Pérez Mallada [1,2], Lucía Cuéllar Marín [1,2], Oscar Otín Arroyo [3], Pablo José Borrás Luján [3] and Juan Manuel Arribas-Marín [1,2]

[1] San Juan de Dios Foundation, 28016 Madrid, Spain; rcoto@comillas.edu (R.C.M.); nestor.perez@comillas.edu (N.P.M.); lcuellar@comillas.edu (L.C.M.); juanmarribas@comillas.edu (J.M.A.-M.)
[2] Health Sciences Department, San Juan de Dios School of Nursing and Physical Therapy, Comillas Pontifical University, 28350 Madrid, Spain
[3] Club Estudiantes de Baloncesto, 28006 Madrid, Spain; o.otin@clubestudiantes.com (O.O.A.); pborras@clubestudiantes.com (P.J.B.L.)
* Correspondence: mjesus.martinez@comillas.edu

Abstract: Some knee strength measuring devices have an anterior cushioning area but relies on a belt for the posterior pad adjustment, creating an uneven force distribution. This study analyzed whether the distal pad position affects knee strength measurements. Eleven professional basketball players participated in this study, with a total of 22 knees evaluated. Knee flexion and extension dynamometric measurements were performed at different angular velocities: 30°/s, 120°/s, and 240°/s. For each angular velocity, two measurements were performed with varying positions of the measuring tool pad at the anterior and posterior aspects (AA and PA). The hamstring/quadriceps (H/Q) ratio was calculated by dividing the hamstring musculature's maximum peak strength by the quadricep musculature's maximum peak strength at each measurement. The knee work was extracted from the device after finishing the measurements. Significant differences were found between measurement positions in the knee flexion force at 30°/s ($p < 0.001$) and 120°/s ($p = 0.027$). No differences were found for the extension forces. As for the H/Q ratio, significant differences were found between positions at 30°/s ($p < 0.001$). Furthermore, significant differences between positions were found for the knee work at 120°/s ($p = 0.019$). These findings suggest that the positioning of the pad on the leg directly influences knee flexor strength measurements, which in turn impacts critical parameters, such as the H/Q ratio and knee work. Given the importance of these variables in injury prevention, particularly for conditions such as anterior cruciate ligament (ACL) injuries, ensuring precise and reliable measurement methods is essential. We recommend using the PA position because it increases knee flexion strength values, potentially leading to more accurate assessments of the muscle function and balance.

Keywords: anterior cruciate ligament injury; strength ratio; hamstrings; isokinetic; measurement position

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1. Introduction

The force that a muscle group can generate can indicate an athlete's physical condition and, in turn, serves as a criterion for returning to competition after an injury. The quadriceps and hamstring muscle strength provide information about the athlete's function [1]. High levels of strength in the knee flexor/extensor musculature may prevent lower limb injuries in the athlete population, specifically anterior cruciate ligament (ACL) injuries [2], since the strength relationship between the quadriceps and the hamstring musculature is considered a relevant factor in knee stability [3–5]. It is important to highlight that the assessment of knee strength is critical in both sports medicine and rehabilitation settings, where accurate measurements of muscle function are essential to evaluate the effectiveness of interventions and prevent injuries. Therefore, alterations in this musculature may increase the risk of lower limb injuries [1].

It is estimated that among the sports population there is one ACL injury for every 3500 athletes. The sports with the highest incidence of ACL injury are basketball and soccer. Additionally, in men's sports, there are a greater number of cases of ACL injuries due to direct trauma, unlike in women's sports, where a greater number of non-contact ACL injuries occur [6]. Notably, ACL injuries (by direct or indirect mechanisms) occur three to six times more frequently in female athletes than in male athletes [7]. One study even reported an incidence up to ten times higher in female athletes [8].

The dynamometer is considered the gold standard tool for measuring muscle strength [2]. This device analyzes the athlete's performance and evaluates medical or physiotherapy interventions and/or injury processes [8]. Different options are used to assess the strength ratio of the knee flexor/extensor musculature. The most common is the conventional hamstring/quadriceps (H/Q) ratio [3]. The conventional ratio is between 0.52 and 0.67 and positively correlates with the test's angular velocity. There is also the functional ratio, which has values around 0.79 at low speeds (60°/s) and can exceed the value of 1.00 at high speeds (240°/s) [9]. While a conventional H/Q ratio of less than 0.47 indicates an imbalance of strength and, therefore, an increased risk of lower limb injury [10], there is no consensus on the H/Q ratio at which point the risk of injury increases [4].

While previous studies have explored the relationship between muscle strength and injury risk, little attention has been given to the impact of measurement protocols, such as the positioning of the dynamometer pads, on the accuracy of these assessments. The measurement protocol for obtaining hamstring and quadricep strength values is established in angular velocities between 30°/s and 360°/s, with the patient in a seated position with the hip flexion between 80° and 100° [11]. The knee's range of motion goes from full extension (0°) to 90° flexion [2,10,12]. The axis of the dynamometer should always be aligned with the axis of the motion of the knee joint (i.e., external femoral condyle) [2,12,13]. It has been reported that a misalignment, with a difference of 6 to 12 cm between the two structures, causes muscle strength alterations of up to 14% [14]. Fixation straps are placed on the trunk, hip, and thigh to attenuate compensatory movements with the body [2,4]. The placement of straps increases the fixed points for generating muscle strength, with increases of 5.84% in the knee flexor strength and 1.59% in the extensor strength [15]. Some authors seem to agree on the placement of the distal tibial fixation (pad against which the subject will perform the force) between 2 and 3 cm above the malleolus [2–4,12]. However, it has been found that lower strength values are obtained with a more proximal pad, with 24 cm of lever arm from the lateral condyle [15]. Despite the widespread use of dynamometers, there is limited research on how variations in the position of the measurement pad, whether anterior or posterior, affect knee strength outcomes, particularly in athletes. This gap in the literature highlights the need for studies that investigate the effect of pad positioning on the accuracy and consistency of knee strength measurements.

Some devices, such as the Byodex 3, utilize distal fixation, where the force is exerted against a pad at the anterior and posterior parts, as shown in the study by Perkins and Canavan [10]. Other devices, such as the Isomed 2000 [12], the PRIMUS RS [8], and the HUMAC NORM [5], only have cushioned areas in the anterior part of the fixation, and the posterior part simply has a belt to adjust the pad. Consequently, the support surface on which the anterior aspect of the leg has to exert the knee extension force on the device differs from the one on which the posterior aspect has to exert the flexion force.

In the 1940s, Dr. Herman Kabat described proprioceptive neuromuscular facilitation as a set of methods to promote neuromuscular response by stimulating receptors [16]. This method uses the body’s receptors (including skin pressure and tactile exteroceptors) to inhibit or facilitate muscle contraction [17]. Visual, auditory, somatosensory, and proprioceptive information are necessary to plan a movement. If the brain receives sufficient afferents, the movement will be more coordinated. Therefore, a deficit of the above information may cause functional alterations [18]. In addition, a larger fixed point to exert force will increase the force generated [15].

Therefore, when measuring with the pad placed on the anterior aspect of the leg, theoretically, the quadricep musculature will be capable of generating a greater force than the hamstring musculature because it has a larger contact surface and, therefore, will receive a greater tactile and pressure stimulus and have a greater fixed point of support. As a result, it is plausible that the muscular force generated could vary depending on where we place the pad (anterior or posterior aspect of the leg).

Thus, the main objective of this study is to analyze whether the position of the pad in distal fixation influences knee flexion/extension strength values, addressing the gap in the existing literature and providing valuable insights into the optimization of dynamometer use in sports and rehabilitation settings.

It is hypothesized that the position of the pad in distal fixation (anterior versus posterior) significantly affects knee flexion and extension strength measurements, with the posterior pad position resulting in higher knee flexion strength values compared to the anterior pad position.

2. Materials and Methods

2.1. Experimental Design

A retrospective observational study was conducted, and data were collected from clinical reports of biomechanical tests performed on professional basketball players for injury prevention purposes. The sample was defined by including reports from players who were medically discharged at the time of the measurement. Specific inclusion criteria were players with no previous knee injuries, while exclusion criteria consisted of reports from players who were on medical leave at the time of measurement or had a history of knee injuries. Participants were selected using a purposive sampling method to ensure the inclusion of relevant cases for the study’s objectives.

Informed consent was obtained prior to data collection. This study was conducted in accordance with the ethical principles for medical research involving human subjects outlined in the Declaration of Helsinki (1964) and its most recent update in 2013 (Brazil). Additionally, the principles of the Taipei Declaration were considered regarding the use of databases. This study received approval from the Clinical Research Ethics Committee of Hospital San Carlos in Madrid, Spain, under approval number C.P-C.I. 23/704-E in December 2023.

Isokinetic strength measurement tests were carried out at the Biomechanics Laboratory of the San Juan de Dios School of Nursing and Physiotherapy, part of Comillas Pontifical University. At the beginning of the session, data on weight, height (later used to calculate body mass index—BMI), gender, playing position, and dominance were recorded.

2.2. Subjects

Twenty-two knees of professional basketball players were evaluated, of which sixteen belonged to males and six to females. The sample had a mean weight, height, and BMI of 88.09 ± 17.26 kg, 1.93 ± 0.17 m, and 23.35 ± 1.38, respectively.

The sample size was determined by analyzing means relative to a reference. An alpha risk of 0.05 and a beta risk of 0.20 were established. To define the standard deviation and the minimum detectable difference (set at 10% of the mean), data from the study by Risberg et al. [1] were used, specifically the maximum knee flexion strength in the dominant leg of soccer players (87.4 ± 13.6 N). An additional 10% was included to account for potential losses, leading to a final sample size of $n = 22$.

2.3. Measurements

Measurements were conducted using the PRIMUS RS dynamometer from BTE Technologies (Hanover, MD, USA), a validated and verified device [19]. The participants were placed in a seated position with the hip flexed at 110°. No support straps were placed on the trunk, hip, or thigh to avoid additional fixed support points other than the pad itself. The axis of the dynamometer was correctly aligned with the axis of motion of the knee joint. The pad was positioned with a 30 cm lever arm on all subjects. Six measurements were performed on each knee: three with the pad on the anterior aspect (AA) and three on the posterior aspect (PA) of the tibia (Figure 1). Measurements were performed at three different angular velocities: at 30°/s, three flexion/extension repetitions were performed; at 120°/s, five repetitions were performed; and at 180°/s, ten repetitions were performed. Before the measurements, ten submaximal repetitions at 180°/s were performed as a warm-up to familiarize the athletes with the device. A 2 min rest period was allowed between each measurement. The measurements were first taken with the pad on the AA position, followed by the PA position.

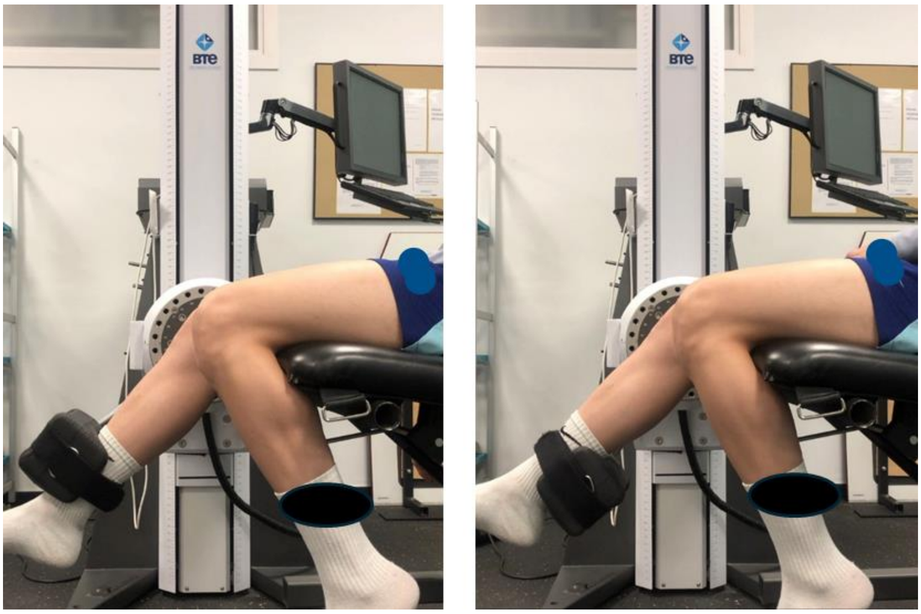

Figure 1. Measurement positions: anterior aspect (**left**) and posterior aspect (**right**).

The H/Q ratio was determined by dividing the hamstrings' maximum peak strength by the quadriceps' maximum peak strength for each measurement. Additionally, the value of the joint work was extracted from the device after finishing the measurements.

2.4. Statistical Analysis

Statistical analysis was conducted using SPSS® software (version 23; IBM Corp., Armonk, NY, USA). Given that the sample size was fewer than 30 participants, the results were presented as the median and interquartile range (Q1–Q3). Additionally, the mean and standard deviation (SD) are presented to allow for comparison and discussion with studies that report data in this manner. The Wilcoxon nonparametric test was used to analyze whether there are significant differences between the AA and PA positions ($n < 30$). A comparison was performed for each angular velocity in terms of peak knee flexion strength, peak knee extension strength, H/Q ratio, and joint work.

The Friedmann nonparametric test was used to analyze whether there are statistically significant differences in knee extension and flexion strength between the different measured angular velocities (30, 120, and 240°/s). The comparison was performed for each measurement position (pad in AA and PA).

A significance level (p) of 0.05 was chosen for all statistical analyses. The effect size (d) was calculated by performing the appropriate parametric tests (i.e., Student's t-test for related samples and ANOVA for repeated measures).

3. Results

Regarding the maximum knee flexion strength at 30°/s, the median value was 25.36% lower with the AA pad position compared to the PA position ($p < 0.001$ and $d = -0.908$); at 120°/s this difference decreased 5.88%, and these differences are statistically significant ($p = 0.027$ and $d = -0.478$). No statistically significant differences were obtained in the other strength values measured between the different measurement positions ($p > 0.05$) (Table 1 and Figure 2).

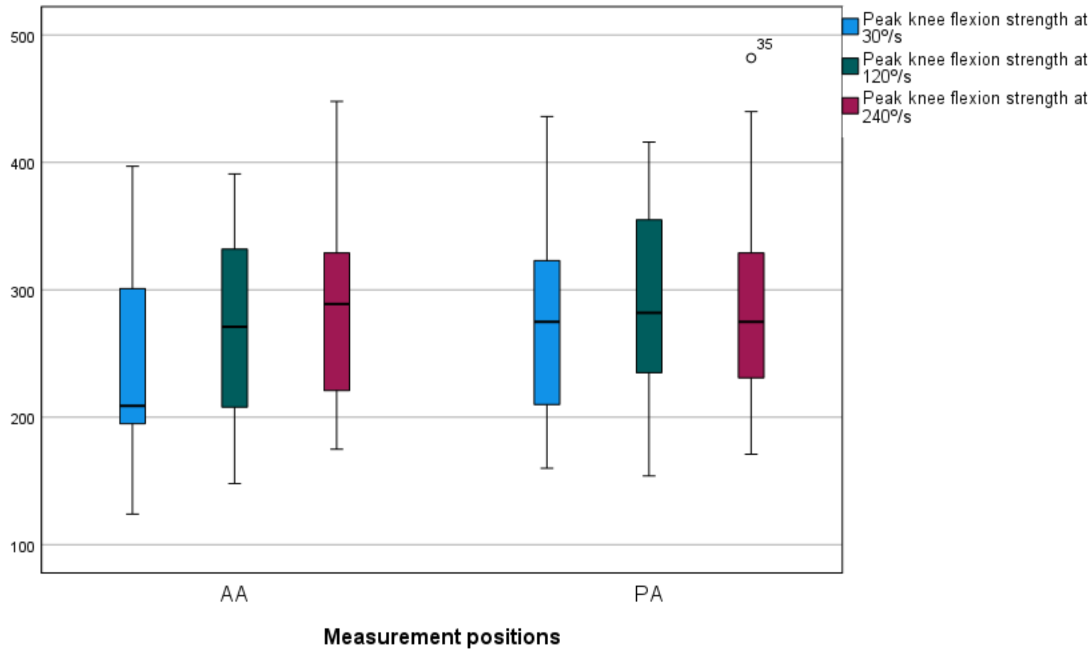

Figure 2. The box-and-whisker plot for the maximum knee flexion strength at 30°/s, 120°/s, and 240°/s in the anterior aspect (AA) and posterior aspect (PA) positions.

These changes affect the strength H/Q ratio. In this study, significant differences were obtained between the AA and PA positions ($p < 0.001$ and $d = -1.087$) in the H/Q ratio at 30°/s [0.554 (0.436–0.644) and 0.622 (0.52–0.712), respectively]. No statistically significant differences were found in the H/Q ratios at 120°/s nor 240°/s ($p > 0.005$) (Table 1 and Figure 3).

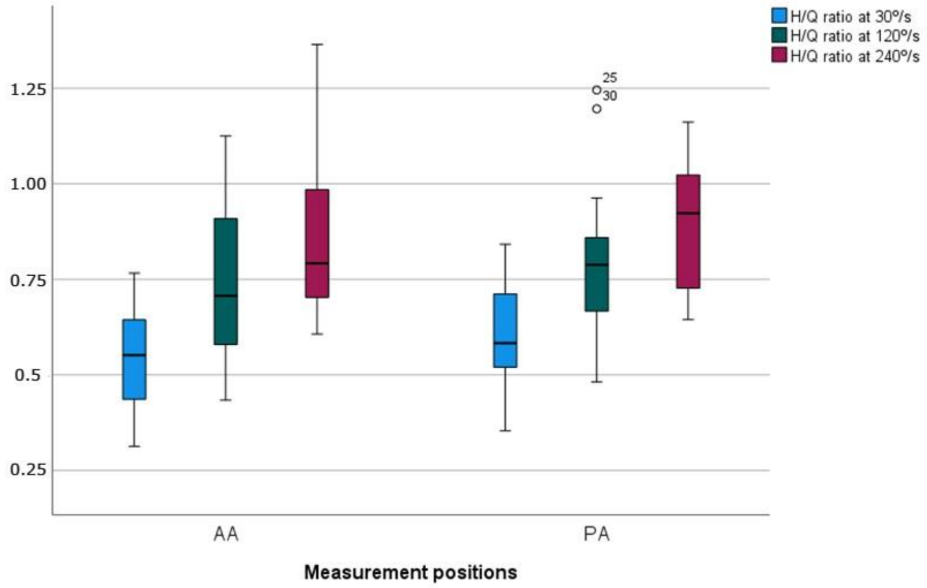

Figure 3. The box-and-whisker plot for the H/Q ratios at 30°/s, 120°/s, and 240°/s in the anterior aspect (AA) and posterior aspect (PA) positions.

Additionally, Table 1 shows the differences obtained between the AA and PA positions in terms of knee work. Statistically significant differences were found in terms of the work between the different AA and PA positions. The work performed in the PA position is 9% higher than in the AA position at 120°/s ($p = 0.019$ and $d = -0.518$). In the case of the work at 30°/s, despite not having statistically significant differences ($p > 0.05$; $d = -0.404$), there is a tendency at the clinical level to have a significant difference since more than 66% of the values obtained with the pad in the PA are above the mean value of the work in the AA (Figure 4).

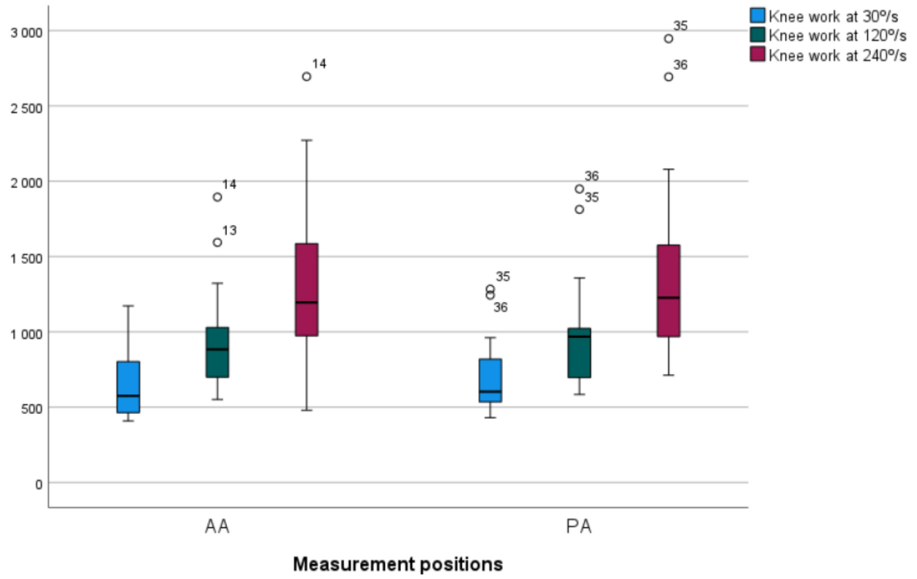

Figure 4. The box-and-whisker plot for knee work at 30°/s, 120°/s, and 240°/s in the anterior aspect (AA) and posterior aspect (PA) positions.

Finally, we analyzed the differences in the knee flexion–extension forces in the different pad positions between different angular velocities. In both positions, the knee extension force decreases as the angular velocity increases (Figure 5), with statistically significant differences ($p < 0.001$) and an effect size of 0.654 in the AA position and 0.699 in the PA position. However, the flexion force values increase as the speed increases when the pad is positioned in the AA (Figure 2), with an effect size of 0.281 and $p = 0.005$. No significant differences in the flexion force values ($p > 0.05$) were found with the pad in the PA (Table 2).

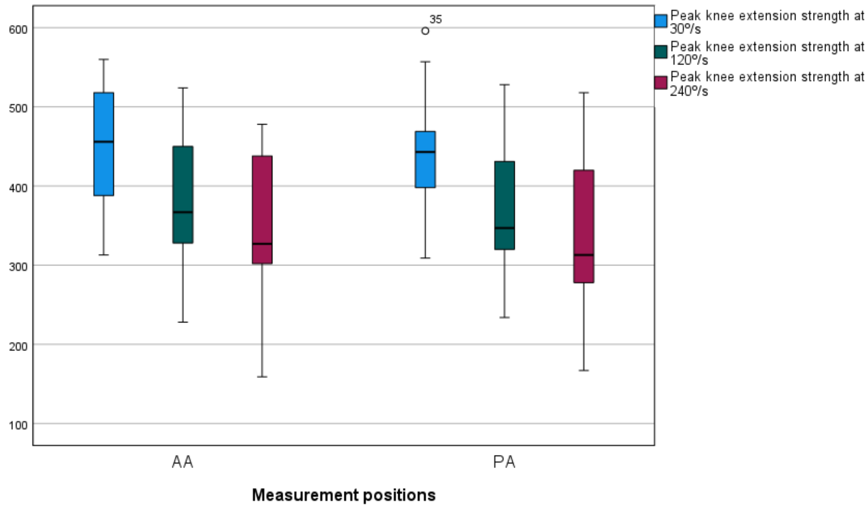

Figure 5. The box-and-whisker plot for the maximum knee extension strength at 30°/s, 120°/s, and 240°/s in the anterior aspect (AA) and posterior aspect (PA) positions.

Table 1. Statistical analysis of maximum knee flexion and extension strength, H/Q ratio, and knee work at 30°/s, 120°/s, and 240°/s between different pad placement positions (anterior and posterior aspects—AA and PA, respectively). Results are expressed in Newtons (N).

Variable [1]	Position	Mean (±SD)	Median	25th Percentile	75th Percentile	*p*-Value	Cohen *d*
Flexion peak strength at 30°/s	AA	244 ± 78	212	195	301	<0.001 *	−0.908
	PA	277 ± 78	284	210	323		
Flexion peak strength at 120°/s	AA	270 ± 70	272	208	332	0.027 *	−0.478
	PA	296 ± 82	289	235	355		
Flexion peak strength at 240°/s	AA	287 ± 76	289	221	329	0.602	−0.114
	PA	291 ± 86	275	231	329		
Extension peak strength at 30°/s	AA	449 ± 75	451	388	518	0.702	0.102
	PA	445 ± 71	445	398	469		
Extension peak strength at 120°/s	AA	375 ± 85	352	327	450	0.948	0.070
	PA	371 ± 82	349	320	431		
Extension peak strength at 240°/s	AA	350 ± 90	327	302	438	0.06	0.315
	PA	335 ± 98	313	278	420		
H/Q ratio at 30°/s	AA	0.54 ± 0.14	0.554	0.436	0.644	<0.001 *	−1.087
	PA	0.62 ± 0.12	0.622	0.52	0.712		
H/Q ratio at 120°/s	AA	0.75 ± 0.22	0.709	0.579	0.954	0.115	−0.338
	PA	0.81 ± 0.19	0.789	0.667	0.918		
H/Q ratio at 240°/s	AA	0.84 ± 0.2	0.792	0.703	0.985	0.181	−0.287
	PA	0.89 ± 0.17	0.923	0.727	1.023		
Work at 30°/s	AA	663 ± 224	581	464	832	0.074	−0.404
	PA	691 ± 240	621	536	844		

Work at 120°/s	AA	940 ± 339	886	700	1029	0.019 *	−0.518
	PA	990 ± 362	973	697	1034		
Work at 240°/s	AA	1323 ± 557	1195	974	1586	0.702	−0.287
	PA	1377 ± 607	1227	969	1576		

[1] Peak strength refers to the highest value recorded during the repetitions; * Significant differences ($p < 0.05$).

Table 2. Statistical analysis of maximum knee flexion and extension strength at different measurement velocities (30°/s, 120°/s, and 240°/s) in both placement positions (anterior and posterior aspects—AA and PA, respectively). Results are expressed in Newtons (N).

Variable [1]	Position	Angular Velocity	Mean (±SD)	Median	25th Percentile	75th Percentile	*p*-Value	Post hoc	*p*-Value	Cohen *d*
Flexion peak strength	AA	30°/s	244 ± 78	212	195	301	0.005 *	30–120	0.495	0.281
		120°/s	270 ± 70	272	208	332		120–240	0.192	
		240°/s	287 ± 76	289	221	329		240–30	0.004 *	
	PA	30°/s	277 ± 78	284	210	323	0.53	30–120	0.84	0.123
		120°/s	296 ± 82	289	235	355		120–240	1	
		240°/s	291 ± 86	275	231	329		240–30	1	
Extension peak strength	AA	30°/s	449 ± 75	451	388	518	<0.001 *	30–120	<0.001 *	0.654
		120°/s	375 ± 85	352	327	450		120–240	0.192	
		240°/s	350 ± 90	327	302	438		240–30	<0.001 *	
	PA	30°/s	445 ± 71	445	398	469	<0.001 *	30–120	0.002*	0.699
		120°/s	371 ± 82	349	320	431		120–240	0.135	
		240°/s	335 ± 98	313	278	420		240–30	<0.001 *	

[1] Peak strength refers to the highest value recorded during the repetitions; * Significant differences ($p < 0.05$).

4. Discussion

The results obtained in this study indicate that the isokinetic knee flexion strength values at low and medium angular velocities (30°/s and 120°/s) vary according to the position in which the fixation pad is placed on the leg. For example, when the pad is placed on an anterior aspect of the leg, the strength exerted by the hamstring musculature is lower than that exerted if the pad is placed posteriorly. In contrast, the strength values in the quadriceps are not altered. This discrepancy may be due to the patient not being strapped during flexion. As a result, there is no fixed point of support when the pad is placed in the AA position, and less strength is generated.

The aforementioned result coincides with the data obtained in the study by Otten et al. [15], who conclude that more force will be developed if the subject is strapped than if they are not (i.e., has more support points to exert force). By placing the pad in the PA position, the ischiocrural musculature has a fixed point where it can exert greater force. However, in our study, the difference in the strength between the AA and PA was 25.25%, much higher than the difference found in the study above between strapping and not strapping the patient in the thigh, pelvis, and trunk (5.84%). This result suggests that there may be other factors, in addition to fixed points of support, such as tactile and pressure stimuli, that facilitate neuromuscular activation and develop more strength, as Dr. Kabat stated in his method [16–18]. In the study by Nunes et al. [20], the authors found that the difference between having one more fixed point during the isokinetic knee test (hand grip or not) was 5.2% in the knee extension strength and 3% in the flexion strength. These differences are much smaller than in our study (a 25.25% difference in the flexion strength between the pad in AA and PA positions). Stumbo et al. [21] found no significant differences in the knee flexor strength between stabilizing by hand or not. Guenzkofer et al. [22] stated in their study that using any type of stabilizer increases the strength values in the knee flexion–extension regardless of its kind (e.g., hand grip, pelvic strap, or trunk strap).

At higher angular velocities, the maximal strength of the quadricep musculature decreases to a greater degree than the maximal strength of the ischiocrural musculature [23]. The attenuated loss of strength of the knee flexor musculature at high velocities, with respect to the extensor musculature, could indicate the high capacity that this muscle group has to provide for knee stability in rapid movements [24,25]. It could be concluded that an increase in the angular velocity affects the quadricep musculature more than the ischiocrural musculature [26]. The data obtained in the present study are related to the statements mentioned above if we focus on the extensor musculature. Interestingly, the hamstring strength increased when the pad was placed in the AA position, but no differences were detected with the pad positioned in the PA.

Comparisons with other studies regarding the strength data cannot be made. They would be methodologically incorrect because the lengths of the lever arm were not reported (in the present study, they are 30 cm), which would be methodologically incorrect. The force generated has a positive correlation with respect to the lever arm length; when one of the two variables increases, the other also increases [15]. Therefore, we focused on the H/Q ratios that were not influenced by the lever arm length.

In the study by Brígido-Fernández et al. [2], at low velocities (60°/s) the authors obtained a mean force ratio of 0.54 ± 0.07. In our study, at low velocities (30°/s), the mean force ratio was very similar (0.54 ± 0.14) at the AA position but significantly higher at the PA position (0.62 ± 0.12). At medium velocities (180°/s) in the study described above, an average H/Q ratio of 0.57 ± 0.09 was obtained, which is relatively lower than that obtained in our study at 120°/s, where a value for the H/Q ratio at the AA position of 0.75 ± 0.22 was obtained, with no significant differences with the PA position (0.80 ± 0.19). The same occurs at high velocities (240°/s) where a mean H/Q ratio of 0.62 ± 0.09 was obtained, much lower than that obtained in our study, as well as 0.84 ± 0.2 in the AA and 0.89 ± 0.17 in the PA with no significant differences between the two positions. It should be noted that in that study, professional female soccer players were measured, and professional male and female basketball players were measured in the present study.

In the systematic review carried out by Baroni et al. [27], the values of the H/Q ratios were as follows: 0.52 ± 0.08 at 30º/s, 0.65 ± 0.16 at 120º/s, and 0.80 ± 0.40 at 240º/s. These values are similar to those obtained at 30°/s and 240°/s in our study. In turn, this systematic review states that the cut-off point for the H/Q ratio should be 0.60. Below this value, the risk of suffering a knee joint injury increases. If we consider the value of 0.60, the values obtained in the present study at 30°/s would be within the safety range if we take the value of the PA position; however, if we consider the value of the AA position, we could conclude that there is a greater risk of knee injury. Therefore, it is necessary to determine the correct way to position the pad to detect possible injury risks more accurately. For ischiocrural muscle injuries, the cut-off point is set at 0.47 [28], although Dauty et al. [29] state that this point should not be taken as a reference since, in their study, only 2.7% of the athletes who sustained a muscle injury were below this value.

Grygorowicz et al. [30] determined that, in terms of the conventional ratio, taking a value of 0.658 as a cut-off point has a greater sensitivity (and therefore fewer false negatives) than a value of 0.47. However, taking 0.47 as the cut-off point has a higher specificity than taking a value of 0.658 (and therefore fewer false positives). Thus, it is difficult to determine what cut-off point to set. All these discrepancies may have something to do with the measurement protocol and positioning of the measuring tool, so it is essential to determine the correct approach.

In this sense, it is advisable to perform the measurements with the pad in the PA position since higher strength values are obtained in the hamstring muscles as well as a higher H/Q ratio because the quadricep strength does not vary with the change in position of the strap. By putting the pad in the AA position, the ratio values are lower, and there will be a greater number of patients who obtain values related to injury risk without having a real risk, which is simply a measurement error. This situation may be one of the problems for the current low injury prediction rate with the H/Q ratio value.

The athlete's competitive level should also be considered when interpreting the strength and H/Q ratio data. Carvalho et al. [31] evaluated first and second division Portuguese soccer players in their study. At low velocities (60°/s), the second division players had a lower concentric hamstring peak strength than the first division players (234 ± 37 vs. 258 ± 49, respectively) and a lower conventional H/Q ratio at 60°/s (0.59 ± 0.1 vs. 0.62 ± 0.1). With the data obtained in our study, we can establish that the strength value with the pad in AA position (244 ± 78) would be closer to the strength values of second division soccer players. However, if we take the strength data of the PA position (277 ± 78), it would be closer to the values of first division players. Although this statement has the limitation of the lever arm, as mentioned above, the present study's sample comprises basketball players. The same is true for the H/Q ratio at low velocities. The value of the ratio with the pad in the PA position (0.62 ± 0.12) is similar to the value of the ratio of first division soccer players, and the value of the AA ratio (0.54 ± 0.14) is more similar to the values of second division soccer players.

The values of the ratios obtained in the present study are lower at a low angular velocity, with 0.54 ± 0.14 and 0.62 ± 0.12 at 30°/s, and increase as the velocity increases, 0.75 ± 0.22 and 0.80 ± 0.19 at 120°/s and 0.84 ± 0.2 and 0.89 ± 0.17 at 240°/s. These data are in accordance with the study by Esmaeili et al. [32], in which the authors measured professional basketball players and observed that the H/Q ratio increases as the angular velocity of the test increases. However, they disagree with the study by Yoon et al. [33], in which no differences were found between the ratios at different angular velocities. It should be noted that the study was performed in a non-athlete population.

Finally, concerning the muscular work, in addition to a small amount of literature on the subject [2], the same occurs as with strength. Thus, we cannot compare studies because no study describes the length of the lever arm.

5. Conclusions

The pad's position on the leg for assessing the muscle strength at the knee joint influences the strength data of the knee flexor musculature obtained during the test. The same does not occur with the extensor musculature, in which no significant changes have been found between the different measurement positions. We recommend that the measurement be performed with the pad in the PA position to obtain greater hamstring strength data that corresponds to reality, identifies athletes with a real strength deficit, and better predict injuries.

In turn, studying the muscle forces, H/Q ratios, and total work performed is essential to assessing an athlete's functionality.

6. Limitations and Future Lines of Research

Despite calculating the sample size and carrying out the study with this sample, we believe the present study's sample is too small to extrapolate the results to the general population. Studies similar to the present one with a larger sample size are recommended.

The gender variable could have influenced the results. Future studies should focus on analyzing the data segmented by sex to better understand potential gender differences in the findings. Further research could investigate how gender-specific factors might affect the outcomes and whether interventions need to be tailored differently for male and female athletes.

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