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**METHOD**

# Relationship Between Isometric Hip Torque With Three Kinematic Tests in Soccer Players

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**Introduction:** Hip muscle strength has a good component to improve the execution of movement preventing excessive knee movements, such as dynamic valgus, which is a factor related to ACL injuries, however, the relationship between isometric torque and dynamic valgus is not yet well established. Functional tests that resemble sports have been used for movement analysis and possible injury minimizing factor.
**Objectives:** To compare the knee medialization peak in three kinematic tests with different demands, and its correlation with the isometric torque of the abductors and hip extensors.
**Methods:** The isometric torque was collected by the Lafayette hand dynamometer. Two-dimensional kinematics were used to evaluate three functional tests of different requirements, Single Limb Squat, Lateral Step Down Test and Single Leg Drop Landing Tests. For comparison between values we used the Student T test and for correlation the Spearman test, with $p < 0.05$.
**Results:** No significant differences were found between the three right kinematic tests, different from the left. And no relationship was established between the isometric hip torque and none of the three kinematic tests.
**Conclusion:** There is no correlation between the dynamic knee valgus peak during different tests. It is concluded that the isometric torque test does not seem to be as sensitive when related to functional tests, but it has good applicability for comparing strength between limbs.

**Keywords:** Hip; muscle; strength; dynamic knee valgus; isometric torque

## Introduction

Excessive dislocation to the knee medial line in the transverse and frontal planes is called valgus and, when it is in motion, it is denominated dynamic valgus (Powers. 2010). Dynamic valgus has been studied mainly because it is a predictor (Alentorn et al. 2009) of one of the injuries responsible for demanding longer recovery time in sport, the anterior cruciate ligament (ACL) injury (Kyritsis et al. 2015) since the main mechanisms of this injury are the increase in amplitude in knee valgus during the landing of a jump and/or during activities involving deceleration and changes in direction (Cochrane et al. 2007).

Dynamic knee valgus usually occurs in association with femoral adduction and medial rotation, together with tibial medial rotation, often related to possible imbalances of more proximal segments, such as trunk and hip (Powers. 2010). These imbalances may be caused by weakness of muscle groups such as the rotators and abductors, but there are still doubts about the correlations between isometric hip contractions and knee valgus (Bittencourt et al. 2012; Hollman et al. 2009; Thijs et al. 2007; Dimattia et al. 2005; Willson et al. 2006).

This concern about the correct movement pattern has made two-dimensional (2D) kinematics a great ally of sports medicine clinics, as it is an accessible assessment, with quantifiable results and minimal risk (Burnham et al. 2016). And even though it is not a substitute for the three-dimensional gold standard (3D) that allows movement analysis in three different planes (sagittal, frontal and transverse), 2D analysis has shown reliability for pelvis and knee kinematic quantifications for healthy individuals (Olson et al. 2011).

For performance analysis of professional athletes, there are functional tests that resemble their daily practice, studies with equipment affordable to all clubs is a major current concern. Squats and single-legged landings are present in the daily lives of all soccer athletes implicitly changing direction (Cochrane et al. 2007), post-head landing (Grassi et al. 2017). Movements that require the action of many muscles including abductors (Han et al. 2017) and hip extensors (Bittencourt et al. 2012, Hollman et al. 2013), related to movement correction such as dynamic valgus (Baldon et al. 2011).

No studies are found that evaluate the medialization peak in athletes in different kinematic tests according to a systematic review of Medline, Lilacs, Cochrane using the keywords medialization, peak, athletes, kinematic and tests, which would be very important in order to improve the evaluations to minimize injuries. It is thought that the medialization peak should not vary between different tests (Pappas et al. 2007) and is also related to the performance of muscles located in the hip.

Thus, the present study aimed to analyze the knee medialization peak in the frontal plane in three kinematic tests of progressive difficulties; and to correlate each with the isometric torque of abductors and hip extensors.

## Methodology

The present study was cross-sectional, analytical, in which 19 professional soccer players (holders and reserves) were recruited for convenience. All signed a free and informed consent form. The current research was approved by the Ethics and Research Committee of the Federal University of Triangulo Mineiro, with advice number 2.347.067 (**Figure 1**).

The players were evaluated within one week during the pre-season, separated by simple draw, in five evaluation days, which between 13h and 15h in the fourth week of the pre-season, in a heated room at the Analysis and Human Movement Laboratory (LAHM) of the Federal University of Triangulo Mineiro.

## Lower limb kinematics

For the kinematic tests, a Canon Rebel T5 frequência de aquisição 50/60 Hz, previously positioned to the volunteer, three meters and 75 cm from the ground was used. Before the tests, all tests were demonstrated and verbal guidance was given regarding the depth and speed of the tests, without specifying the hip and knee direction. Previously, tests were familiarized, the suggested clothing and initial and final positioning of

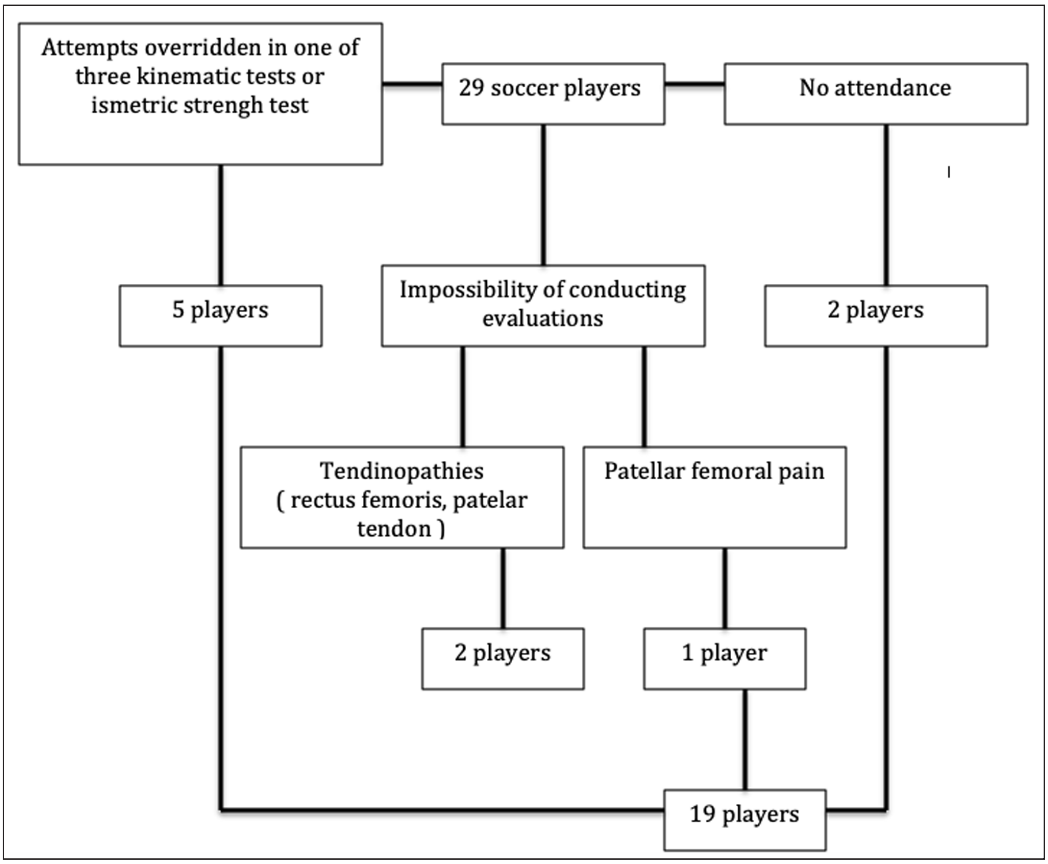


**Figure 1:** Player recruitment flowchart.

each test are shown in **Figure 2**. Any imbalance that caused a fall or support on the contralateral foot floor or hand on the floor would invalidate the attempt (Almeida et al. 2016). All participants performed three trials of each test (Lateral Step Down) (Rabin et al. 2010; Rabin et al. 2016), Single Leg Drop Landing (Pappas et al. 2007) and Single Limb Squat (Powers. 2010; Hollman et al. 2013) (**Figure 2**).

Markers were positioned bilaterally over: Antero Superior Iliac Spine (EIAS), patella midpoint and tibial tuberosity. Due to the amount of tests and differences between the placement of markers (Pappas et al. 2007; Almeida et al. 2016; Rabin et al. 2010; Rabin et al. 2016; Gwynne et al. 2014), for measuring the peak of knee medialization a line was drawn over the markers following the static assessment of valgus the Q angle (Almeida, 2016). To measure the medialization peak of the knee in the frontal plane, the video editing program, Kinovea version 0.28.26, was used, with the angle considered for the alignment of the lower limb measured from the EIAS, the midpoint of the patella and the tibial tuberosity.

## Single Limb Squat Test

The Single Limb Squat Test, or Single Leg Squat, was performed on the ground with the foot centered in a cross design drawn on the floor. The test consists of a squat on a single limb and the task execution time of five seconds total, being the first second to remove one leg from the floor, the next two seconds to the descent (eccentric phase) and two more seconds. to return to the starting position (concentric phase), measured using a stopwatch (Gwynne et al. 2014).

## Lateral Step Down Test

The Lateral Step Down Test consists of a single lower limb squat over a step (15 centimeters), so that the contralateral limb is suspended in the air laterally to the stepped limb, so the supported limb performs a squat and the contralateral limb descends towards the ground until there is a touch of the heel, soon after the volunteer makes the movement return to the initial position (Rabin et al. 2016). Similar to the previous test, the time was timed, and the execution time was five seconds (Almeida, 2016).

## Single Leg Drop Landing Test

The Single Leg Drop Landing Test was performed on a 40 cm high, 60 wide and 40 deep wooden platform, and adjusted to the comfortable distance for each participant. The test consisted of an anterior step of the box sequenced from a unipodal landing with the foot not resting on the platform. The participant was positioned in unipodal support with one of the lower limbs on platform and the other limb was positioned in the air anterior to the supported, and thus, landed on the previously free member in the air. To validate the attempt, the landing should be on a demarcated cross on the ground and held for two seconds (Pappas et al. 2007). The initial values of unipodal support were always analyzed in the attempts before or after the test, since for the landing limb used only in unipodal support, in the attempt that the landing will be performed by the contralateral limb (**Figure 2**).

## Isometric torque

Isometric torque was assessed using the Muscle Tester Lafayette Manual (Lafayette, Instrument Co, USA). Belts were used to stabilize the hip and torso, and also to stabilize the dynamometer, thus eliminating the bias of the force exerted by the evaluator (Gwynne et al. 2014). Before the start of the test, maximum


**Figure 2: A.** Single Limb Squat Test **B.** Side Step Down Test **C.** Single Leg Drop Landing Test. Source: the authors.

isometric contraction of the abductor and hip extensor muscles was requested for familiarization with the procedures and equipment. After this process, the participants performed three maximum isometric contractions lasting five seconds, considering the average of the three for analysis, with rest of 30 seconds. For data analysis, the force (N), generated by the device, was calculated from the lever arm (Nm) and divided by the body mass (kg) multiplied by 100 (Torque [Nm] ÷ Weight [kg]) × 100). The lever arm was calculated from the measurement between the greater trochanter and the lateral malleolus of each of the players, due to the difference in height of the individuals.

The position for performing hip abductor torque was performed with a volunteer in the lateral decubitus position, the limb assessed at 20° of abduction, 10° of extension and neutral rotation of the hip, with the knee extended. The unevaluated limb was positioned at 90° of hip and knee flexion. The dynamometer was positioned above the lateral malleolus (Pappas et al. 2007). The position for performing the torque of the hip extensors was performed in the prone position, with a tested limb 20° hip extension, knee flexed at 90° and the dynamometer positioned above the popliteal fossa (Hollman et al. 2013). Both members tested were passively placed in position by another evaluator, who measured the angles from a manual goniometer, after assuming the position the last velcro belt was positioned to eliminate the force bias exercised by the evaluator with the dynamometer.

Isometric torque was evaluated using the Muscle Tester Lafayette Manual (Lafayette, Instrument Co, USA). Belts were used to stabilize the hip and trunk, and also to stabilize the dynamometer, thus eliminating the bias of the force exerted by the evaluator (Allison et al. 2016). Prior to the start of the test, maximal isometric contraction of the abductor and hip extensor muscles was requested to familiarize them with the procedures and equipment. After this process, the participants performed three maximum isometric contractions lasting five seconds, being considered the average of the three for analysis, with rest of 30 seconds. For data analysis, the force (N) generated by the device was calculated from the lever arm (Nm) and divided by the body mass (kg) multiplied by 100 (Torque [Nm] ÷ Weight [kg]) × 100).

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## Statistical analysis

Statistical analysis in SPSS version 15.0. For data normalization, the Shapiro Wilk test was used. A) to verify if there is a relationship between the isometric torque of hip extensors and abductors (right and left side) with dominance, the independent T test was used; B) for comparison between dominance and kinematic tests, the independent T test was also used. Only the values of the Lateral Step Down Test – initial left (LSDT-Ei), were not normal, so the Mam-Whithney test was applied for comparison; C) Pearson's correlation test was used to verify agreement between the final and initial values of each kinematic test; and lastly, D) to verify the correlation between isometric exchange and kinematic tests, the Spearman correlation was used. Significance value of $p < 0.05$.

## Outcomes

Between the final values of each test there was a significant weak positive correlation (0.465 sig. 0.045) between the values of Lateral Step Down Test (B) – final left (LSDT-Ef) and Single Limb Squat Test (A) – final left (SLST-Ef), and moderate (0.530 sig. 0.020) for Single Leg Drop Landing Test (C) (SLDLT-Ef) and Single Limb Squat Test (A) (SLDLT-Ef). Moderate correlation (0.693 sig. 0.001 and 0.664 sig. 0.002) was found between Single Leg Drop Landing Test (C) (SLDLT-Ei × SLST-Ei) and Single Limb Squat Test (A) (SLDLT-Di × SLST-Di), Left and Right values. respectively (**Table 1**).

There was no significant difference between isometric torque of dominant and non-dominant hip abductors and extensors. Only the Lateral Step Down Test (B) – Initial Right (LSDT-Di) and Single Limb Squat (A) – Initial Left (SLST-Ei) showed significant difference between dominant and non-dominant side.

## Discussion

The relationship between hip isometric torque and dynamic valgus is not yet well established in the literature. The results of the present article corroborate with other authors who found no correlation between isometric muscle activation of hip abductors during Step Down Test (Hollman et al. 2009) or Single Limb Squat Test

**Table 1:** Correlation between kinematic tests.

| | | Initial Left | | | Final Left | | | Initial Right | | | Final Right | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | **A** | **B** | **C** | **A** | **B** | **C** | **A** | **B** | **C** | **A** | **B** | **C** |
| **A** | Pearson's correlation | 1 | 0,245 | 0,69* | 1 | 0,46* | 0,53* | 1 | 0,291 | 0,66* | 1 | 0,179 | 0,453 |
| | Significance | | 0,313 | 0,001 | | 0,045 | 0,020 | | 0,095 | 0,002 | | 0,464 | 0,51 |
| **B** | Pearson's correlation | 0,245 | 1 | 0,136 | 0,46* | 1 | –0,01 | 0,291 | 1 | 0,394 | 0,179 | 1 | –0,01 |
| | Significance | 0313 | | 0,580 | 0,045 | | 0,981 | 0,095 | | 0,95 | 0,464 | | 0,984 |
| **C** | Pearson's correlation | 0,69* | 0,136 | 1 | 0,53* | –0,01 | 1 | 0,66* | 0,394 | 1 | 0,453 | –0,01 | 1 |
| | Significance | 0,001 | 0,580 | | 0,020 | 0,981 | | 0,002 | 0,95 | | 0,51 | 0,984 | |

(Thijs et al. 2007; Dimattia et al. 2005; Willson et al. 2006). It is suggested that the form of force analysis may be a factor that influences these results. The muscle strength torque analysis method, considered the gold standard, is isokinetic dynamometry, which demonstrated a good correlation between Single Limb Squat and the eccentric torque of abductors and external hip rotators, because the eccentric torque of these hip muscles is responsible for control of femoral adduction and medial rotation during support or movements on a single limb (Baldon et al. 2011).

Another justification for doubts regarding isometric torque and its relationship with dynamic valgus during kinematic tests, which may have influenced the results, are some differences in the use of different isometric torque assessment equipment: the Lafayette dynamometer (Burnham et al. 2016; Almeida et al. 2016; Allison et al. 2016) the dynamometer Handheld(Bittencourt et al. 2012; Hollman et al. 2009; Thijs et al. 2007; Willson et al. 2006) Microfet and the JTECH Commander Power Track II (Dimattia, et al. 2005) dynamometer, and an article correlating the results of various hand dynamometers is unknown. And the evaluation in different positions, with resistance close to the lateral malleolus in the supine (Allison et al. 2016) or lateral position (Almeida et al. 2016), or in lateral decubitus with resistance in the lateral region above the manual knee joint line (Hollman et al. 2009) and adapted to non-elastic braces (Bittencourt et al. 2012; Thijs et al. 2007; Dimattia et al. 2005; Willson et al. 2006; Burnham et al. 2016) results are influenced by gravity according to the change of position, and also by the lever arm. For the hip extensors torque, the pattern was more homogeneous (Thijs et al. 2007; Burnham et al. 2016).

Most of the studies cited were conducted with healthy or active individuals, few studies related to our findings were conducted in athletes (Bittencourt et al. 2012; Pappas et al. 2007). Our study obtained results contrary to those found by Bittencout et al (Bittencourt et al. 2012), in which the isometric torque of the hip abductor musculature was correlated with the dynamic knee valgus during the Single Limb Squat and Vertical Jump bipodal, suggesting to be the factor. However, this result is more sensitive, added to the lack of flexibility of the medial hip rotators and leg-to-foot alignment of these athletes. Thus, perhaps associated with other factors, isometric torque may still be a relevant factor in relation to kinematic tests in athletes.

Dynamic valgus during single leg squats is the most common misalignment in women (Boling et al. 2009). Thus, there is a predominance of studies in this population hindering homogeneity in the results of kinematic studies. Findings such as gluteus maximus recruitment have been related to the decrease in dynamic knee valgus in this population, for both Step Down (Hollman et al. 2009) and bipodal jump and landing tasks. Since the gluteus maximus is a powerful hip extensor and an important external hip rotator (Neumann et al. 2010), eccentric loading of this musculature may also be necessary to prevent dynamic valgus-related movements with femoral medial rotation (Hollman et al. 2009), suggesting that the isometric torque of the hip extensors, Without the rotational component, it may not be the most sensitive evaluation for the gluteus maximus, as was performed in our study.

In the present study in none of the three kinematic tests, the knee medialization peak correlated with the hip extensor and abductor muscle torque measurements. Corroborating other studies (Thijs et al. 2007; Burnham et al. 2016) that did not demonstrate this relationship between abductor and extensor torque during Single Limb Squat Test (Thijs et al. 2007) and Step Down Test (Burnham et al. 2016). They assumed that this could be related to lower limb kinematics not being performed on the ground and not evaluating the knee medialization peak. However, in the correlation of the knee medialization peak values in these two aforementioned tests a weak correlation was found for the left side (0.465 sig. 0.045) and no correlation for the right side and both sides when the Drop Landing Test was included. This may suggest that the tests are not similar despite assessing movement pattern. In addition, the Single Limb Squat Test and Drop Landing Test showed a moderate correlation for initial values on both sides (0.693 sig. 0.001 and 0.664 sig. 0.002) and final values for the left side (0.530 sig. 0.020), which may suggest that the platform may not be an influencing factor in the initial unipodal position prior to testing.

A comparison study between dominant and non-dominant side in young soccer players showed differences between strength values of extensors, knee flexors, and hip abductors, as well as changes in direction in the cutting maneuver with the upper dominant side in all (Rouissi et al. 2016). In the present study, dominance was not a factor that interfered with the analysis of isometric torques of abductors and extensors in the comparison of sides. However, the players had higher valgus values in the non-dominant leg during the initial Step DownTest position, and the opposite during the initial position of the Single Limb Squat Test. However, during periods of greatest difficulty, the knee medialization peak, dominance was not an interfering factor.

In the study by Wilson & Davis (Willson et al. 2006), no changes in lower limb mechanics, hip strength, and abductor activation were found during three different tasks, Single Limb Squat, Running, and Single-legged Multiple Jumps in the control group, and the dynamic valgus remained very close during the progression of activities disagreeing with the results of the present study, where only in two tests, Step Down Test and Single Limb Squat Test for the left side there was a weak correlation (0.465 sig. 0.045). others do not have the same representativeness, and may conclude that different stimuli, such as descending a platform, squatting on a platform or squatting on the ground can influence the knee medialization peak. Few studies have attempted to compare kinematics in different tests (Earl et al. 2007; Souza et al. 2009).

In the comparison between the bipodal and unipodal landing kinematics, it was found that there is less knee flexion due to a compensatory mechanism to decrease the lever arm, more frequent activation of the rectus femoris and greater valgus misalignment of the knee (Pappas et al. 2007). This form of landing is one of the ACL injury mechanisms (Russell et al. 2006). And during changes of direction all body load is deposited on a single leg, and still having a rotational or laterality factor, depending on the direction in which the movement will be performed (reference). Thus, the application of different tests that reproduce sports movements during clinical application is necessary. And the literature still presents few studies comparing the results of different tests (Earl et al. 2007; Souza et al. 2009).

Unipodal kinematic analysis in different tests is necessary, especially in sports. A common injury in football is that of the ACL, which is mostly practiced by male players (Alentorn et al. 2009), which can cause major expenses for soccer teams (Gottlob et al. 1999), in addition to the long period of absence of injured athletes, and also with high chances of developing a new injury. or relapse if rehabilitation is not performed correctly (Kyritsis et al. 2015). Thus, functional tests are currently part of both pre-season evaluations as the present study proposed, and at the end of rehabilitation at the time called return to play (Kyritsis et al. 2015), such as muscle strength analysis. Force analyzes to verify homogeneity between sides are also of great importance. At present the muscle strength tests did not correlate with the knee medialization peak during the kinematic tests, but did not present differences in strength between the sides, perhaps a possible explanation for the homogeneity presented during the kinematic tests. As already mentioned, there are other forms of evaluation that were not related to the present tests evaluated in this population and may present different results from the current research. We suggest that further investigations be conducted with professional soccer players in search of tests that correlate for the variables strength and functional activity.

## Conclusion

The findings of the present study did not find major differences for peak knee medialization between three right-sided kinematic tests in professional soccer players during the pre-season. And there was no correlation between abductor and hip extensor isometric torque data. It is concluded that the isometric torque test does not seem to be as sensitive when related to functional tests, but it presents good applicability for strength comparison between limbs. The kinematic tests did not show a great correlation with each other, thus concluding that different activities may present different results regarding the dynamic valgus.

## Competing Interests

**DB completed paid consultancy work from CNPQ*, CAPES** and FAPEMIG*** as part of the data acquisition for this study. All other authors have no competing interests.**

***CNPQ** is National Council for Scientific and Technological Development is an entity linked to the Ministry of Science, Technology, Innovations and Communications to encourage research in Brazil.

****CAPES** is Coordination for the Improvement of Higher Education Personnel is a foundation linked to the Ministry of Education of Brazil that operates in the expansion and consolidation of stricto sensu postgraduate courses in all Brazilian state and *****FAPEMIG** is the agency that fosters scientific, technological and innovation development in Minas Gerais State. It is a foundation of the State Government, linked to the State Secretariat for Economic Development. Its mission is to induce and foster scientific and technological research and innovation for the development of the State of Minas Gerais State.

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