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Title: Intra and inter-tester reliability of a novel device to assess gluteal muscle strength in professional football players

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ABSTRACT

The aim of this study is to investigate inter-tester and intra-tester reliability of a novel clam test (CLAMT) for the measurement of gluteal muscle strength and to detect possible differences between CLAMT values in football players with and without a history of groin injuries. Twenty male football players participated in the test-retest and sixty-two male professional football players participated in the case-control study. Hip abductor maximal muscle strength was evaluated either using CLAMT or in a supine position with the hip in a neutral pose. For CLAMT, intraclass correlation coefficient (ICC) for inter-tester-intra-day reliability was 0.80 (95% CI:0.60–0.90), with a standard error of measurement of 34.2N. The intra-tester-intra-day ICC was 0.92 (95% CI:0.87–0.95), with a standard error of measurement of 23.6N. The inter-week ICC was 0.96 (95% CI:0.92–

0.98), with a standard error of measurement of 18.9N. CLAMT showed lower (but not significant) strength values in football players with a history of groin injuries to non-injured players. CLAMT showed *good* to *excellent* levels of reliability, intraday and inter-week, with low standard errors of measurement while it was effective (*possible*) to identify residual weakness in players with previous groin injuries.

Keywords: Risk factor; a; groin injury; hip abduction; soccer, athlete.

INTRODUCTION

Despite the popularity and overall benefits of continuous football (soccer) practice (e.g., cardiovascular function) (Beato et al., 2017; Oja et al., 2015), football is also identified as a team sport with a high incidence of injury in both male (Herrero et al., 2014; Moreno-Pérez et al., 2020) and female players (Del Coso et al., 2018). The high physical demands of this sport (Gualtieri et al., 2020), especially the ones imposed on the muscles and tendon structures, lead players to sustain an average of 0.60–0.70 non-contact injuries per match (Junge & Dvořák, 2015). Furthermore, groin injury and groin pain is one of the most common complaints in football, ranging from 7% to 18% of the total injuries (Mosler et al., 2018; Waldén et al., 2015). Due to the frequent and long-lasting nature of groin injuries in football and the economic impact these injuries have on football teams (Ekstrand, 2013; Hallén & Ekstrand, 2014), the use of prevention strategies to reduce the likelihood of groin injuries might suppose an extraordinary benefit. Thus, the use of precise and sensitive tests to identify football players with the higher risk of groin injury and the concomitant development of preventive strategies in the routine practice of football might be the optimal scenario to reduce likelihood of groin injury in football (Hölmich, 2015; Whittaker et al., 2015).

Sports therapists routinely assess gluteus medius muscle strength to evaluate its capacity to accomplish the demands required for team sports movements (Graham et al., 2011; Morrissey et al., 2012). The gluteus medius is considered the primary pelvic stabilizer and it has an essential function in the maintenance of the normal patterns of the pelvis and the lower limbs during exercise (Boudreau et al., 2009). A weakness of the gluteus medius muscle can lead to increased likelihood of sport injury (Powers, 2010), for instance the gluteus medius muscle is highly activated during non-anticipated actions of landing and changes in direction (Meinerz et al., 2015) which are related to a greater probability of anterior cruciate ligament rupture (Cortes et al., 2011). Therefore, gluteus medius muscle strength might play a critical role for the development of several types of football injuries, since its weakness may increase the likelihood of groin pain, as well as other injuries of the lower limbs (Graham et al., 2011). Moreover, previous evidence has revealed that suboptimal gluteus medius muscle activation might be a discriminative parameter to differentiate between players with and without history of groin injury (Morrissey et al., 2012). Thus, the assessment of hip abductor muscle strength, which is a potential risk factor for groin injury, may be an important component to introduce into testing procedures.

The most common test for assessing muscle medius strength involves an isometric contraction of hip abductor muscles using a hand-held dynamometer in different positions such as uniplanar side-lying (Bolgla et al., 2011; Widler et al., 2009), standing position (Widler et al., 2009), and supine position (Moreno-Pérez et al., 2017; Thorborg et al., 2010; Tyler et al., 2001; Widler et al., 2009). This type of testing to assess gluteus medius strength is considered practical because of its low cost, high applicability, and good reliability (Moreno-Pérez et al., 2017; Thorborg et al., 2010; Tyler et al., 2001). Some authors observed that, in a supine body position, there was a high activation in the gluteal medius muscle (Bolgla & Uhl, 2005), together with a high stability to assess gluteus medius force production (Thorborg et al., 2011). However, more recent investigations have found that, when participants are side-lying and executing a clam-type muscle contraction, the activity of the gluteus maximus and gluteus medius was higher than the activity of tensor fascia lata muscle (Selkowitz et al., 2013). The limited involvement of the tensor fascia lata is an important factor because its excessive activation during testing of hip abductor strength may be counterproductive as it induces an excessive internal hip rotation. Consequently, based on such evidence, it would appear to be more appropriate developing a method to assess isometric gluteal strength while minimizing recruitment of the tensor fascia lata, particularly for football players. However, this novel approach that includes measurement of gluteus medius muscle strength with a clam exercise (CLAMT) has not undergone previous scientific verification and the analysis of its reliability is critical for its implementation in athletes and in the clinical setting.

Therefore, the aims of the present study were: (1) to investigate the inter- and intra-tester reliability of CLAMT for the measurement of gluteus medius muscle strength to determine its reliability; (2) to determine possible differences between the CLAMT and hip abduction strength measurement in a supine position in football players with and without a history of groin injuries as a method to determine the ability of each strength test to discriminate players with a higher risk of groin injury. This latter objective is based in the high contribution of the existence of a previous groin injury, together with reduced hip abduction strength, on the risk of groin injury in sport, particularly in the higher-level of play (Whittaker et al., 2015). Then, the capacity of detecting hip abductor weakness in players with previous groin injuries might be key to ascertain the likelihood of suffering a recurrent groin injury.

METHODS

Participants

Twenty male football players (mean ± standard deviation [SD]; age: 20.9 ± 2.5 years; body mass: 73.7 ± 6.9 kg; height: 180.0 ± 5.1 cm) participated in the test-retest reliability of CLAMT. The sample size power was evaluated using G*power (software version 3.1, Düsseldorf, Germany) and results indicated that a total sample of 17 participants would be required to detect a *large* correlation ($r = 0.60$) with 80% power and an alpha of 5%. In addition, 62 professional football players (from two football teams participating in the second division of Spanish football) underwent hip abductor strength measurements with the CLAMT and with a comparable test in the supine position. Based on the Consensus Statement on Epidemiological Studies of medical conditions in football defined by Fuller et al. (2006), these professional players were divided into two groups: 13 football players with a history of groin injury in the past 12 months (GI group; 23.5 ± 5.4 years; 71.2 ± 6.8 kg; 1.79 ± 0.1 m), and 49 football players without any history of groin injury (NGI group; age: 23.4 ± 4.9 years; body mass: 74.4 ± 7.2 kg; height: 1.79 ± 0.1 m) to produce a case-control research design. As part of the inclusion criteria in the present study, players were required to avoid reporting their history of orthopaedic problems in the three months prior to the test session that prevented football practice, or the presence of delayed-onset muscle soreness during the testing session. Participants were not taking any type of medication nor pain reliever related to muscle treatment at the time of the present study. Prior to the start of this investigation, all players were fully informed about the testing procedures, and written informed consent was obtained. This investigation was performed in accordance with the latest version of the Declaration of Helsinki 2013 and was approved by the local Ethics Review Committee (code: DPC.VMP.01.18).

Procedures

Data were recorded prior to the beginning of a training session during the pre-season period. Tests were performed in specific clinical areas at the football clubs. All assessments were conducted by one senior sports physiotherapist with 19 years of clinical experience (tester #1) and another physiotherapist with 8 years of clinical experience (tester #2). The two testers performed their assessment under blind conditions on separate occasions and they did not interexchange any type of information after the measurements. At the beginning of each testing session, participants performed a standardized warm-up: jogging (light intensity [10–12, Bog-scale 6–20]) and static stretching exercises of the lower limbs. Specifically, participants performed two repetitions of seven different unassisted and static stretching exercises, holding the stretch position for 30 s.

Football players recruited for the reliability test (n = 20) visited the testing facility on three separate occasions at the same time of day to avoid circadian variability (10:00 am). All measurements were carried out in a room with fixed ambient temperature (22º C) and only in the presence of the testers to assure a quiet environment. On the first day, one week prior to reliability testing, all football players were familiarized with the procedures to reduce the influence of the learning effect on the results of the study. On this day, player's body mass and body height were measured, and an *ad-hoc* survey was conducted to assess players' training routines and medical history. The second testing session was used to measure intra- and inter-tester isometric CLAMT reliability and to collect data on hip abductor strength measured in a supine position. First, tester #1 performed three measurements in each side with at least a 30-s rest between measurements. After 10 minutes of recovery, tester #2 performed the same protocol. After 30 minutes of recovery, tester #1 performed the second set of measurement. The order of the sides was randomly assigned, and it was counterbalanced for intra and inter-day measurements. Finally, the third session was carried out one week apart to measure the intra-tester reliability of isometric CLAMT.

The football players recruited for the case-control research (n = 62), visited the testing facility twice: one for familiarization and recording of players' training routines and medical history; another for the measurement of CLAMT and hip abductor strength, measured in a supine position. All injuries were meticulously diagnosed and recorded throughout the previous competitive season by the medical staff of the football teams using a paper player-injury audit questionnaire, following the recommendations of the Medical Assessment and Research Centre (F-MARC) sponsored by the Federation Internationale de Football Association (Fuller et al., 2006).

Measurements

Questionnaire to selectively collect groin injuries

Player-injury audit questionnaires were used to record injuries. Injuries were then catalogued according to the injury classification system developed by the F-MARC (Fuller et al., 2006). Specifically, any physical complaint sustained by a player that resulted from a football match or training, was considered as an injury (Fuller et al., 2006). From the total of injuries, we selected only groin injuries, defined as complaints located in the groin area which prevented a player from taking full part in training and match play activities. To consider a groin injury, the physical feeling of discomfort in the groin area had to remain for a period longer than 24 hours (starting at the midnight of the day of the injury (Murphy et al., 2012). Regarding injury severity, it was defined as the number of days that elapsed from the date of injury to the date of the player's return to full participation in team training and availability for match selection (Fuller et al., 2006). Finally, the questionnaire also included sections to classify if the injury occurred during match or training exposure, the time of exercise until the injury and the type of football-specific action that leaded to the injury.

CLAMT for the assessment of isometric gluteal medius muscle strength

For this test, players laid on a physiotherapy table on the opposite side to the extremity to be tested. Both extremities were flexed to 45º at the hip and to 90º at the knee with the tested limb on top of the opposite one from 30º hip abduction and with a support between the legs. The correct position of each limb prior to the measurement was certified with a simple long-arm goniometer (Orthopaedic Equipment Co., Bourbon, IN, USA). Players were not allowed to use the upper extremities for trunk stabilization during the measurements. In this position, the weight of the tested extremity was consistently assessed to allow correction of maximal voluntary contraction strength values by separating the knees, without the feet losing contact, and pushing against a fixed dynamometer. The dynamometer (Nicholas Manual Muscle Tester, Lafayette Indiana Instruments, USA) was fixed to a horizontal steel bar (Figure 1) and placed 5 cm proximal to the knee joint, located exactly at the most prominent point of the lateral femoral condyle. Prior to testing the handheld dynamometer was calibrated. Peak force was measured as Newton (N), but it was normalized by body mass for the comparison of injured and non-injured players. Three maximum effort trials for each side (e.g., dominant and non-dominant) were performed, with at least a 30-s resting period between trials. The attempt with the highest peak force of the three trials was used as the strength outcome measure for this test. The dominant leg was determined according to Thorborg et al. (2011), who defined the dominant leg as the preferred leg for kicking a ball.

******Insert Figure 1 here******

Hip abductor strength in a supine position for the assessment of isometric gluteal medius muscle strength

To measure hip abductor isometric strength, we followed the procedures previously described by Thorborg et al. (2010). Briefly, participants were comfortably placed in the supine position on a stretcher with the hip in a neutral pose. They were told to stabilize themselves by holding onto the sides of the stretcher. On command, the examiner applied resistance in a fixed position (5 cm proximally to the proximal edge of the lateral malleolus) and participants exerted a 5-s maximum voluntary contraction trying to abduce the limb against the dynamometer. The measurement was performed three times in dominant and non-dominant sides (Thorborg et al., 2010). A portable handheld dynamometer (Nicholas Manual Muscle Tester, Lafayette Indiana Instruments, USA) was used to obtain strength values and there was a 30-s rest period between measurements. The intra-class correlation coefficient for this test ranged from 0.83 to 0.96 (V. Moreno-Pérez et al., 2017).

Statistical analysis

All reliability analyses were performed using a specific spreadsheet for consecutive pairs of trials, which is available at www.sportsci.org. The intra-class coefficient correlation (ICC) was calculated (with the respective 95% confidence interval [CI]), using the two-way mixed effects ICC (3,1) for intra-tester measurements, and the two-way random effects ICC (2,1) for inter-tester measurements. ICC values were interpreted as *poor (< 0.50), moderate* (0.50-0.79), *good* (0.79−0.90), and *excellent* (> 0.90). An ICC higher than 0.75 was used as the cut-off value to catalogue the CLAMT as a reliable test (Koo & Li, 2016). Standard error of measurement (SEM) in absolute values (in N) and expressed as a coefficient of variation (%SEM) were calculated to determine the magnitude of the variability between test-retest. A cut-off value of %SEM < 10% was used to consider a the CLAMT as a test with low error (Cormack et al., 2008). The minimal detectable change (MDC) was calculated using the following formula: $MDC = SEM \cdot \sqrt{2} \cdot 1.96$ (Nevill & Atkinson, 1997). The comparison of strengths in the different tests between injured and non-injured players was performed through magnitude-based inference using 90% CI (Hopkins et al., 2009) and null hypothesis test ($p < 0.05$). The quantitative chance effect was assessed qualitatively as follows: < 1%, *almost certainly not*; > 1–5%, *very unlikely*; > 5–25%, *unlikely*; > 25–75%, *possible*; > 75–95%, *likely*; > 95–99*%, very likely*; and > 99%, *almost certain*. Effect size (ES) was interpreted by Cohen's scale as *trivial* (< 0.2), *small* (0.2–0.59), *moderate* (0.6–1.19), *large* (1.2–2.0), and *very large* (> 2.0). In addition, Pearson's product moment correlation coefficients (r) were computed to assess relationships between strength values in the CLAMT and hip abduction strength in supine position.

RESULTS

Data on the reliability for the measurements of the gluteal medius muscle strength (CLAMT) are presented in Table 1. Intra-tester reliability (both intra-day and inter-week) showed *good* to *excellent* scores (ICC ranging from 0.86 to 0.96), with a % SEM between 4.0% and 7.9%. For the inter-tester analysis, the CLAMT showed a *moderate* to *good* reliability, with an ICC ranging from 0.73 to 0.80 and a %SE below 8.0%.

******Insert Table 1 here******

In the case-control analysis, 13 out of 62 football players sustained a groin injury in the prior 12 months to the measurement of gluteus medius muscle strength. All injuries were classified as adductor longus muscle strains by the medical staff of the team. From the total, 38.4% occurred during match exposure (63.0 ± 19.9 minutes of playing since the start of the game) and 61.6% during training sessions (with an average of 49.5 ± 16.1 minutes of playing since the start of the training session). The time needed for full return to training was on average 17.2 ± 9.4 days. Most injuries (69.2%) were non-contact injuries: from these, 50% were reported after an explosive change of direction, 37.5% after a movement to reach the ball that required an unusual lower limb abduction and 12.5% after a jumping action). The remaining injuries (30.7%) were reported after game actions that included kicking the ball and thus, then they were catalogued as with indirect contact.

The comparison of strength values between injured and non-injured players for both the CLAMT and abduction in supine position tests is shown in Table 2. Furthermore, the comparison between injured and non-injured limbs within the sample of injured players is shown in Table 3. Injured players *possibly* had lower strength values in the CLAMT. In contrast, injured players showed slightly higher strength values in the abduction test performed in supine position. When comparing injured vs. non-injured limbs in the injured players, the CLAMT displayed *possible* (but not significant) differences, while the abduction test performed in supine position showed unclear differences.

******Insert Table 2 here******

******Insert Table 3 here******

Pearson's correlation coefficients in injured and non-injured players were both *large* to *very large* between dominant and non-dominant legs within the same test: CLAMT (r = 0.839–0.848; $p < 0.05$) and abduction test performed in supine position (r = 0.651–0.822; $p < 0.01$). However, non-significant ($p > 0.05$) correlations were found between the two tests, independent of the group analysed (Table 4).

******Insert Table 4 here******

DISCUSSION

The aim of the present study was to investigate the inter- and intra-tester reliability of a novel CLAMT test to assess isometric muscle strength of gluteus medius muscle in male professional football players. A second purpose was to determine differences between the CLAMT and other test with a similar purpose, but performed in a supine position, to determine hip abductor weakness in professional football players with a history of groin injury. Overall, the present study reports *good* to *excellent* levels of intra-tester reliability (intra-day and inter-week) and a *moderate* to *good* inter-tester reliability of the novel CLAMT for the measurement of isometric gluteal medius strength. Another important aspect of this test is the high precision of measurements as determined by the MDC and SEM values. In the present study, the CLAMT showed an MDC of 52.3–94.9 N, which allows for the detection of relatively small strength changes associated to muscle weakness which might be useful for the detection of a predisposition to groin injury in football players. Specifically, the present study suggests that the CLAMT might be able (*possible*) to detect gluteus medius weakness in professional football players with a history of GI as compared with NGI players (Table 2). In addition, CLAMT was more effective than a similar gluteus medius muscle strength test performed in supine position to differentiate between the injured leg and the control/non-injured leg in players with groin injury (Table 3). Based on our results, we suggest that the CLAMT is a reliable tool to assess gluteus medius muscle strength. Due to its high applicability and low cost, it can be used in a clinical setting to detect muscle weakness that might predispose to a groin injury in football, especially in the higher-level of play. However, it is recommended that the same tester perform this assessment to increase the accuracy of the measurement obtained.

To the best of the authors' knowledge, this is the first study analysing the reliability of the CLAMT in a sample of male football players. The reliability results of the present work agree with a previous study carried out in 49 physically active women using a test with a similar objective (Almeida et al., 2017). Although both studies show *good* to *excellent* levels of intra-tester reliability, they cannot be compared due to the differences in testing measurements and the differences in the sample under investigation.

In the study carried out by Almeida et al. (2017), subjects were told to start the isometric action from a position of 20º hip abduction, while in the present study, the football players started from 30º hip abduction, with a support between the legs, and pushed against a fixed instrument (Figure 1). This methodology was chosen to facilitate the stabilization of participants in the present study. Although both tests present a high reliability, further research is needed to elucidate the most appropriate testing procedure for the assessment of gluteal strength.

The present study found statistically significant correlations for the CLAMT strength values between lower limbs (e.g., dominant and non-dominant; Table 4); however, no significant correlations were found between the CLAMT and the measurement of hip abduction strength in a supine position. According to these results, it seems that two tests do not measure the same muscle intervention, since players showed a higher strength score (49.4%) in the CLAMT as compared with the supine-position testing. Traditionally, the supine position has been used for the evaluation of the adduction-abduction strength ratio (Moreno-Pérez et al., 2017; Thorborg et al., 2010; Tyler et al., 2001), and could explain the extended utilization of this assessment. However, the present results are in accordance with those of Widler et al. (2009) whom found a lower strength value (30%) for a maximal voluntary contraction in the unilateral abduction strength in supine position as compared with the side-lying test. Overall, these outcomes would support the use of lateral decubitus position when testing hip abduction strength. According to the above-mentioned study, the differences in the two tests used in the current investigation can be explained by the different positions used during tests: Widler et al. (2009) observed that the supine position demonstrated a lower electromyographic activity of the gluteus medius as compared with the activity registered using a side-lying position. This difference could be attributed to poor body stabilization during the supine position that might hinder the obtaining of maximal values of strength abduction. In addition, the supine position to evaluate gluteus medius muscle strength would require a higher abdominal muscle activation as compared with the lateral position, being the latter a more stable position since the body is supported by the stretcher.

Another important and possible justification for the present results may be associated with movements performed. While the CLAMT allows for a three-dimensional evaluation of gluteal muscle strength, the supine position for abduction testing can only register a uniplanar action of these muscles (Almeida et al., 2017). Moreover, it is also plausible that the side-lying position is a condition where hip flexors (i.e., psoas, sartorius, and tensor fascia lata muscles) are less involved in the contraction. This fact, together with a clearer effect of gravity against abduction when lying in a lateral position, may facilitate the activation of the gluteus medius during the CLAMT. This idea is strongly supported by Selkowitz et al. (2013), who demonstrated that "clam" muscle contraction (lateral decubitus position with the lower limbs in 45° hip flexion and 90° knee flexion) produced the greatest electromyographic activation of the gluteus medius muscle in relation to the tensor fascia lata in 11 different exercises.

Weakness of the hip muscles has been associated with chronic hip joint pain (Harris-Hayes et al., 2014; Mastenbrook et al., 2017); however, to the best of our knowledge, no study has assessed the status of gluteal medius muscle strength in football players with a history of groin injury. Interestingly, our study registered a possible (but not significant) reduction in the CLAMT in the injured players for both the comparison with non-injured players and for the non-injured limb (Table 2 and 3, respectively). However, no significant differences were found in these comparisons with a similar testing performed in supine position. The differences among the results may be due to the different positions used, as authors have previously argued. A decrease in hip strength would affect the ability to maintain normal movement patterns of the pelvis and lower limbs when executing sports skills, such as landing, changes of direction and kicking, as previously observed (Masuda et al., 2005), resulting in an increased susceptibility to groin injuries. Based on the above-mentioned data, the CLAMT can be considered a useful measurement for the detection of gluteal strength deficits in football players.

While the results of the present study provide information regarding reliability and utility of the CLAMT to assess gluteus medius strength in professional football players, limitations of the study must be acknowledged. A major limitation of the present study is the retrospective nature of data collection related to the players with a previous history of groin injuries, which precludes determination of whether the gluteal weakness seen in the previously injured limb was one of the causes or the result of an injury. Similarly, a post-injury cross-sectional evaluation informed us about the hip abduction strength of athletes recovered from a groin injury in comparison to non-injured counterparts, which is a piece of valuable information, but it does not allow controlling of the post-injury rehabilitation programs undergone by the players after the groin injury, possibly affecting in part the outcomes of the present study.

CONCLUSION

The present study reports an *acceptable* reliability of a novel CLAMT test to assess gluteus medius muscle strength in professional football players. In addition, the current investigation also reports *possible* (but non-significant) weakness in hip abduction, measured with CLAMT, in professional football players with a history of groin injury. Based on our results, the use of prevention strategies for groin injury should include an analysis of gluteal muscle strength using the CLAMT protocol detailed in the present study (Figure 1). Players who have a history of groin injury in the past year may continue to have a strength deficit after the injury which might predispose to a recurrent injury. The measurement of gluteus medius strength with the CLAMT is a piece of valuable information for football players, athletic trainers, and clinicians for the design of optimal exercise protocols. Therefore, optimization of gluteal muscle strength is required and should be integrated into the players' training as a specific prevention related to groin injuries.

References

Almeida, G. P. L., Rodrigues, H. L. D. N., De Freitas, B. W., & De Paula Lima, P. O. (2017). Reliability and validity of the hip stability isometric test (HipSIT): A new method to assess hip posterolateral muscle strength. *Journal of Orthopaedic and Sports Physical Therapy*, *47*(12), 906–913. https://doi.org/10.2519/jospt.2017.7274

Beato, M., Coratella, G., Schena, F., & Impellizzeri, F. M. (2017). Effects of recreational football performed once a week (1 h per 12 weeks) on cardiovascular risk factors in middle-aged sedentary men. *Science and Medicine in Football*, *1*(2), 171–177. https://doi.org/10.1080/24733938.2017.1325966

Bolgla, L. A., Malone, T. R., Umberger, B. R., & Uhl, T. L. (2011). Comparison of hip and knee strength and neuromuscular activity in subjects with and without patellofemoral pain syndrome. *International Journal of Sports Physical Therapy*, *6*(4), 285–296.

Bolgla, L. A., & Uhl, T. L. (2005). Electromyographic analysis of hip rehabilitation exercises in a group of healthy subjects. *Journal of Orthopaedic and Sports Physical Therapy*, *35*(8), 487–494. https://doi.org/10.2519/jospt.2005.35.8.487

Boudreau, S. N., Dwyer, M. K., Mattacola, C. G., Lattermann, C., Uhl, T. L., & Mckeon, J. M. (2009). Hip-Muscle Activation During the Lunge, Single-Leg Squat, and Step-Up-and-Over Exercises. In *Journal of Sport Rehabilitation* (Vol. 18).

Cormack, S. J., Newton, R. U., McGuigan, M. R., & Doyle, T. L. A. (2008). Reliability of measures obtained during single and repeated countermovement jumps. *International Journal of Sports Physiology and Performance*, *3*(2), 131–144. https://doi.org/10.1123/ijspp.3.2.131

Cortes, N., Blount, E., Ringleb, S., & Onate, J. A. (2011). Soccer-specific video simulation for improving movement assessment. *Sports Biomechanics*, *10*(1), 22–34. https://doi.org/10.1080/14763141.2010.547591

Del Coso, J., Herrero, H., & Salinero, J. J. (2018). Injuries in Spanish female soccer players. *Journal of Sport and Health Science*, *7*(2), 183–190. https://doi.org/10.1016/j.jshs.2016.09.002

Ekstrand, J. (2013). Keeping your top players on the pitch: the key to football medicine at a professional level. *British Journal of Sports Medicine*, *47*(12), 723–724. https://doi.org/10.1136/bjsports-2013-092771

Fuller, C. W., Ekstrand, J., Junge, A., Andersen, T. E., Bahr, R., Dvorak, J., Hägglund, M., McCrory, P., & Meeuwisse, W. H. (2006). Consensus statement on injury definitions and data collection procedures in studies of football (soccer) injuries. *British Journal of Sports Medicine*, *40*(3), 193–201. https://doi.org/10.1136/bjsm.2005.025270

Graham, J., Morrissey, D., Small, C., Twycross-Lewis, R., & Woledge, R. (2011). Muscle Activation Patterns in Football Code athletes with chronic groin pain: a case control study. *British Journal of Sports Medicine*, *45*, 3–5.

Gualtieri, A., Rampinini, E., Sassi, R., & Beato, M. (2020). Workload monitoring in top-level soccer players during congested fixture periods. *International Journal of Sports Medicine*, ahead of print. https://doi.org/10.1055/a-1171-1865

Hallén, A., & Ekstrand, J. (2014). Return to play following muscle injuries in professional footballers. *Journal of Sports Sciences*, *32*(13), 1229–1236. https://doi.org/10.1080/02640414.2014.905695

Harris-Hayes, M., Mueller, M. J., Sahrmann, S. A., Bloom, N. J., Steger-May, K., Clohisy, J. C., & Salsich, G. B. (2014). Persons with chronic hip joint pain exhibit reduced hip muscle strength. *Journal of Orthopaedic and Sports Physical Therapy*, *44*(11), 890–898. https://doi.org/10.2519/jospt.2014.5268

Herrero, H., Salinero, J. J., & Del Coso, J. (2014). Injuries among spanish male amateur soccer players: A retrospective population study. *American Journal of Sports Medicine*, *42*(1), 78–85. https://doi.org/10.1177/0363546513507767

Hölmich, P. (2015). Groin injuries in athletes - Development of clinical entities, treatment, and prevention. *Danish Medical Journal*, *62*(12).

Hopkins, W. G., Marshall, S. W., Batterham, A. M., & Hanin, J. (2009). Progressive statistics for studies in sports medicine and exercise science. *Medicine and Science in Sports and Exercise*, *41*(1), 3–13. https://doi.org/10.1249/MSS.0b013e31818cb278

Junge, A., & Dvořák, J. (2015). Football injuries during the 2014 FIFA World Cup. *British Journal of Sports Medicine*, *49*(9), 599–602. https://doi.org/10.1136/bjsports-2014-094469

Koo, T. K., & Li, M. Y. (2016). A Guideline of Selecting and Reporting Intraclass Correlation Coefficients for Reliability Research. *Journal of Chiropractic Medicine*, *15*(2), 155–163. https://doi.org/10.1016/j.jcm.2016.02.012

Mastenbrook, M. J., Commean, P. K., Hillen, T. J., Salsich, G. B., Meyer, G. A., Mueller, M. J., Clohisy, J. C., & Harris-Hayes, M. (2017). Hip abductor muscle volume and strength differences between women with chronic hip joint pain and asymptomatic controls. *Journal of Orthopaedic and Sports Physical Therapy*, *47*(12), 923–930. https://doi.org/10.2519/jospt.2017.7380

Masuda, K., Demura, N., Katsuta, S., & Yamanaka, K. (2005). Relationship between muscle strength in various isokinetic movements ... *Journal of Sports Medicine and Physical Fitness*, *45*(45), 44–52. https://doi.org/10.1016/j.jconhyd.2010.08.009

Meinerz, C. M., Malloy, P., Geiser, C. F., & Kipp, K. (2015). Anticipatory effects on lower extremity neuromechanics during a cutting task. *Journal of Athletic Training*, *50*(9), 905–913. https://doi.org/10.4085/1062-6050-50.8.02

Moreno-Pérez, V., Lopez-Valenciano, A., Barbado, D., Moreside, J., Elvira, J. L. L., & Vera-Garcia, F. J. (2017). Comparisons of hip strength and countermovement jump height in elite tennis players with and without acute history of groin injuries. *Musculoskeletal Science and Practice*, *29*, 144–149. https://doi.org/10.1016/j.msksp.2017.04.006

Moreno-Pérez, Victor, Soler, A., Ansa, A., López-Samanes, Á., Madruga-Parera, M., Beato, M., & Romero-Rodríguez, D. (2020). Acute and chronic effects of competition on ankle dorsiflexion ROM in professional football players. *European*

Journal of Sport Science, *20*(1), 51–60. https://doi.org/10.1080/17461391.2019.1611930

Morrissey, D., Graham, J., Screen, H., Sinha, A., Small, C., Twycross-Lewis, R., & Woledge, R. (2012). Coronal plane hip muscle activation in football code athletes with chronic adductor groin strain injury during standing hip flexion. *Manual Therapy*, *17*(2), 145–149. https://doi.org/10.1016/j.math.2011.12.003

Mosler, A. B., Weir, A., Eirale, C., Farooq, A., Thorborg, K., Whiteley, R. J., Hölmich, P., & Crossley, K. M. (2018). Epidemiology of time loss groin injuries in a men's professional football league: a 2-year prospective study of 17 clubs and 606 players. *British Journal of Sports Medicine*, *52*(5), 292–297. https://doi.org/10.1136/bjsports-2016-097277

Murphy, J. C., Gissane, C., & Blake, C. (2012). Injury in elite county-level hurling: A prospective study. In *British Journal of Sports Medicine* (Vol. 46, Issue 2, pp. 138–142). Br J Sports Med. https://doi.org/10.1136/bjsm.2010.072132

Nevill, A. M., & Atkinson, G. (1997). Assessing agreement between measurements recorded on a ratio scale in sports medicine and sports science. *British Journal of Sports Medicine*, *31*(4), 314–318. https://doi.org/10.1136/bjsm.31.4.314

Oja, P., Titze, S., Kokko, S., Kujala, U. M., Heinonen, A., Kelly, P., Koski, P., & Foster, C. (2015). Health benefits of different sport disciplines for adults: systematic review of observational and intervention studies with meta-analysis. *British Journal of Sports Medicine*, *49*(7), 434–440. https://doi.org/10.1136/bjsports-2014-093885

Powers, C. M. (2010). The influence of abnormal hip mechanics on knee injury: A biomechanical perspective. In *Journal of Orthopaedic and Sports Physical Therapy* (Vol. 40, Issue 2, pp. 42–51). Movement Science Media. https://doi.org/10.2519/jospt.2010.3337

Selkowitz, D. M., Beneck, G. J., & Powers, C. M. (2013). Which exercises target the gluteal muscles while minimizing activation of the tensor fascia lata? Electromyographic assessment using fine-wire electrodes. *Journal of Orthopaedic and Sports Physical Therapy*, *43*(2), 54–64. https://doi.org/10.2519/jospt.2013.4116

Thorborg, K., Couppé, C., Petersen, J., Magnusson, S. P., & Hölmich, P. (2011). Eccentric hip adduction and abduction strength in elite soccer players and matched controls: A cross-sectional study. *British Journal of Sports Medicine*. https://doi.org/10.1136/bjsm.2009.061762

Thorborg, K., Petersen, J., Magnusson, S. P., & Hölmich, P. (2010). Clinical assessment of hip strength using a hand-held dynamometer is reliable. *Scandinavian Journal of Medicine and Science in Sports*, *20*(3), 493–501. https://doi.org/10.1111/j.1600-0838.2009.00958.x

Tyler, T. F., Nicholas, S. J., Campbell, R. J., & McHugh, M. P. (2001). The Association of Hip Strength and Flexibility with the Incidence of Adductor Muscle Strains in Professional Ice Hockey Players . *The American Journal of Sports Medicine*, *29*(2), 124–128. https://doi.org/10.1177/03635465010290020301

Waldén, M., Hägglund, M., & Ekstrand, J. (2015). The epidemiology of groin injury in senior football: A systematic review of prospective studies. In *British Journal of Sports Medicine* (Vol. 49, Issue 12, pp. 792–797). BMJ Publishing Group. https://doi.org/10.1136/bjsports-2015-094705

Whittaker, J. L., Small, C., Maffey, L., & Emery, C. A. (2015). Risk factors for groin injury in sport: an updated systematic review. *British Journal of Sports Medicine*, *49*(12), 803–809. https://doi.org/10.1136/bjsports-2014-094287

Widler, K. S., Glatthorn, J. F., Bizzini, M., Impellizzeri, F. M., Munzinger, U., Leunig, M., & Maffiuletti, N. A. (2009). Assessment of hip abductor muscle strength. A validity and reliability study. *Journal of Bone and Joint Surgery - Series A*, *91*(11), 2666–2672. https://doi.org/10.2106/JBJS.H.01119

TABLES AND FIGURES LEGENDS

TABLES:

Table 1. Reliability scores for the CLAMT.

Table 2. Comparison of strength values in the different tests between injured and non-injured players.

Table 3. Comparison of strength values between injured and non-injured limb within the injured players.

Table 4. Bivariate correlations of the different measurements (CLAMT vs unilateral abduction in supine position hip strength) in the dominant and non-dominant legs.

FIGURE:

Figure 1. Testing for the measurement of abduction strength of gluteal muscles.