Irish Journal of Medical Science (1971 -) (2023) 192:685–691
https://doi.org/10.1007/s11845-022-03010-0

ORIGINAL ARTICLE

Comparison of hip abductor and adductor muscle performance between healthy and osteitis pubis professional footballers

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Received: 3 February 2022 / Accepted: 5 April 2022 / Published online: 14 April 2022

Abstract

Objective The study aimed to compare the concentric and eccentric muscle performance of the hip abductor and adductor muscles at a high angular velocity in football players with osteitis pubis and healthy players.

Methods A total number of 32 male football players with osteitis pubis and 20 healthy footballers were tested using an isokinetic dynamometer at a speed of 180°/s. Hip abductor and adductor peak torque/body weight, time to peak torque, acceleration, and deceleration times produced during concentric and eccentric muscle contraction modes were measured using a Biodex dynamometer.

Results Football players with osteitis pubis demonstrated a significantly higher time to peak torque, acceleration, and deceleration times ($p < 0.05$); however, when compared to healthy athletes, there was no significant change in muscle strength.

Conclusion The present study showed that football players with osteitis pubis had a reduction in neuromuscular reaction. Therefore, the reaction time of these muscles is critical, and the reduction could result in magnified stresses and/or poorly distributed loads across the musculotendinous structure of the anterior pelvis, which presumably could lead to the development of osteitis pubis. Incorporate findings of the current study in clinical practice could afford critical information when evaluating the hip muscles in football players with osteitis pubis, for pre-screening, enhancing the rehabilitation programs, and guiding the decision of returning to sports after injury.

Keywords Football players · Hip muscles · Muscle performance · Neuromuscular control · Osteitis pubis

Introduction

Osteitis pubis (OP) refers to a syndrome characterized by an aching inflammatory disorder of the pubic bone and the neighboring soft structures resulting from repetitive tensions on the external fascia and subsequently the joint, leading to a displacement microtrauma [1, 2]. Additionally, the term "osteitis pubis" could interchangeably be used as an expression to define the syndrome of workout-related groin pain or adductor pain [3]. Among sports injuries, OP is a widespread disorder with an incidence of 0.5–6.2% in the athletic population with an average recovery time of approximately 9.6 months [1, 4–6]. Although OP may be associated with several physical activities, players of sports like football, ice hockey, or rugby are at a higher threat of injury [7, 8]. More specifically, the OP accounts for 5–13% of all athletic injuries in football players [9].

Muscle imbalance has been proposed to play a critical role in developing OP in football players [10, 11]. The deficiency in muscle force in one or more muscle groups surrounding the hip joint could disturb the normal distribution of mechanical forces around the joint. Consequently, this could negatively influence the optimal muscle performance and function of the hip joint [12]. Therefore, measuring muscle performance is of great value for returning to sports with normal physical activity after injury. The ubiquitous measure of strength obtained from isokinetic dynamometer testing is the peak torque (PT) [13]. Although other parameters like speed and acceleration are fundamental factors for motor function, they are poorly explored. Indeed, the time to generate force or the maximum rate of force production is

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essential in the majority of sports [14]. However, it has been suggested that assessments of muscle imbalance are not only limited to the strength [15, 16]; they may also involve non-traditional parameters that are capable of adding information on injury prevention and treatment.

Acceleration time (AT), deceleration time (DT), and time to peak torque (TPT) are some of these non-traditional parameters obtained from isokinetic testing. Such parameters could provide extremely valuable information linked to the efficient capability of the lower extremity neuromuscular system next to an injury [17]. For example, muscle reaction time variables (AT and TPT) are considered essential elements in the protection against injury episodes in the joints, especially in the sports [18]. Moreover, the non-traditional parameters could aid in the clinical decision-making and implementation of specific rehabilitation protocols in order to optimize the treatment outcomes, especially in sports activities that use a chain of limb acceleration and deceleration movements [19, 20]. Such movements are accomplished not only through concentric muscle action, but also through eccentric activation which is essential for performing numerous basic skills in football, such as cutting, kicking, and jumping [21].

Few studies that examined the OP conditions were limited to assessing the PT values of hip musculatures during the concentric contraction at a moderate angular velocity [10, 22], or restricted to the eccentric PT of the hip adductor without referring to the hip abductor muscles or non-traditional performance parameters [11]. Other literature explored the effect of precise treatment protocols on the OP conditions [7, 9, 23, 24]. Additionally, there are no reports investigating the muscle performance parameters of the hip muscles during concentric and eccentric muscle contractions. Because of the importance of prevention and treatment strategies in football practice, it is plausible to consider that adding the AT, DT and TPT variables in the isokinetic evaluation of football players can provide a new perspective for recognizing the muscular imbalances and differences in strength between healthy and who suffering from OP. Therefore, the purpose of this study was to compare the hip abductor and adductor muscle performance parameters during concentric and eccentric modes of contractions at an angular velocity of 180°/s in OP football players with healthy players. We hypothesised that there would be muscle imbalance between groups.

Materials and methods

Design

This is a cross-sectional study.

Sample characteristics

A group of thirty-two male football players diagnosed with OP was assessed in this study. Depending on a priori power analysis (G*power software), the number of participants was meticulously chosen to ensure that type I error does not exceed 0.05 and type II error does not exceed 0.20. This statistical power analysis specified that a total of 30 subjects would be enough to establish a power of 0.95 with a large effect size of 0.7. This sample size is also confirmed with a similar sample size documented in the previous studies [10, 11]. The participants were accepted to take part in the current study after a referral from an orthopaedist or a sports medicine specialist with a diagnosis of the current OP condition. This was followed by a clinical test to affirm the participant's diagnosis. The test is considered positive if the participant experiences pain in the pubic bone while performing isometric adduction both in the back lying position and back lying with flexed hip at 60° (squeeze test), and tender pubic symphysis to palpation. A matched group of twenty healthy footballers with the same anthropometric data was tested. The participants of the healthy group were not permitted to participate in the study in case of a history of the lower extremity, back, or abdominal surgery. Before the study began, ethical approval was obtained, and each participant signed a consent form for participation and publication of results. The Institutional Human Research Ethical Committee granted ethics approval for this study (ethics approval no: P.T.REC/012/002933).

Measuring devices

The Biodex System 3 isokinetic dynamometer was used to measure the hip abductor and adductor peak torque/body weight (PT/BW), AT, DT, and TPT produced during concentric and eccentric muscle contraction modes (Biodex Medical Systems, Shirley, NY, USA). The dynamometer quantifies the internal torque generated by a group of muscles while maintaining the tested segment at a constant angular velocity (180°/s) and movement range. Before each measurement session, the Biodex dynamometer was calibrated.

Procedure

Each subject was instructed to dress his comfortable sportswear after acquiring their participation agreement. This was followed by a clear simple illustration of the testing procedures using a visual video record. Before the actual testing, participants were given a 10-min warm-up stretching session. The tests for the hip abductor and adductor muscles groups were performed in a random arrangement to avoid the dependent ordering effect. A rest time of 5 min was allowed between

Table 1 Demographic data for healthy and osteitis pubis groups (mean ± SD)

Groups	Healthy athlete group ($n = 20$)	Osteitis pubis group ($n = 32$)	p value
Age (years)	19.78 ± 2.52	19.57 ± 1.46	0.62
Weight (kg)	69.90 ± 8.22	70.56 ± 6.48	0.65
Height (cm)	176.50 ± 3.50	175.56 ± 5.53	0.34
Body mass index (kg/m^2)	22.37 ± 1.84	22.88 ± 1.56	0.14

$^*p < 0.05$

each group of muscle tests to avoid muscle fatigue. The isokinetic concentric and eccentric modes for abduction/adduction were performed at speed of 180°/s which has been adopted for football players in previous literature [25, 26], and supported by isokinetic manual guidelines. The testing procedure consists of two sets of five repetitions each [27], with a 2-min rest period between sets. Gravity automatic correction was used to compensate for the effect of gravity in all tested muscles.

The participants were tested in the standing position since it was the most functional position; however, it was linked with less stabilization. The participant was positioned in the standing position facing away from the dynamometer, with the dynamometer's axis aligned with the anterior superior iliac spine [10]. The typical hip range for hip abduction/adduction was 65° (20° adduction to 45° abduction). Maximum concentric voluntary efforts were measured when participants are requested to do two sets; each includes five repetitions of hip abduction–adduction at an angular velocity of 180°/s in the concentric contraction mode [27]. Similarly, maximum eccentric voluntary efforts will be measured from hip muscles at the same angular velocity. The highest hip abductors and adductors concentric and eccentric PT values were normalized to the participant's body weight (PT/BW, expressed in Nm/kg) in an attempt to minimize the between-subject variation in the raw scores of the tested muscles. All participants were motivated to utilize their highest effort through all tests. To assess muscular performance, the evaluated parameters were AT, DT, and TPT.

Statistical analysis

The assumptions of parametric statistical tests were first verified using Q-Q plot estimation and the Shapiro–Wilk test for normality for all variables. All data were found to meet the parametric testing assumptions. After that, anthropometric data (age, weight, height, and BMI) of healthy and OP football players were compared using a one-way analysis of variance (ANOVA). For the examined parameters, a two-way multivariate analysis of variance (two-way MANOVA) was used with a significance level of $p < 0.05$ for all statistical tests. The statistical analysis was carried out with Statistical Package for the Social Sciences (SPSS) (version 26.0 for Windows; SPSS Inc, Chicago, IL).

Results

Table 1 displays the demographic information of the healthy and OP football players who participated. Tables 2 and 3 demonstrate the PT/BW and muscular performance parameters for the hip abductor and adductor muscle groups during concentric and eccentric contractions in both groups.

Hip abductor muscles

Considering the AT and TPT variables, there was a statistically significant interaction effect ($p < 0.05$) between the two groups and the contraction modes. The Scheffe post hoc test revealed that there was a marked increase in AT ($p < 0.05$) and TPT ($p < 0.05$) in OP athletes, but no significant difference in PT/BW and DT between OP and healthy athletes ($p > 0.05$) for both modes of contraction. The percent of the variation in reaction time parameters between healthy and osteitis pubis athletes during concentric and eccentric abductor muscle contractions is shown in Fig. 1.

Table 2 The concentric and eccentric isokinetic peak torque/body weight (Nm/kg) values of hip abductor muscles at 180°/s in healthy and football players suffering from osteitis pubis (mean ± SD)

Test statistics	Hip abductors					
	Concentric			Eccentric		
	Healthy athletes	Osteitis pubis athletes	p value	Healthy athletes	Osteitis pubis athletes	p value
PT/BW (%)	1.33 ± 0.18	1.16 ± 0.39	0.167	1.69 ± 0.17	1.70 ± 0.16	0.917
AT	70.00 ± 11.55	116.25 ± 21.34	0.000*	109.23 ± 21.39	185.71 ± 19.10	0.000*
DT	80.00 ± 5.77	80.00 ± 5.35	1.000	74.62 ± 11.27	77.14 ± 8.25	0.450
TPT	262.86 ± 31.47	290.00 ± 39.28	0.336	187.69 ± 43.04	288.57 ± 73.99	0.000*

$^*p < 0.05$; *PT/BW*, peak torque/body weight (in %); *AT*, acceleration time (in milliseconds); *DT*, acceleration time (in milliseconds); *TPT*, time to peak torque (in milliseconds)

Table 3 The concentric and eccentric isokinetic peak torque/body weight (Nm/kg) values of hip adductor muscles at 180°/s in healthy and football players suffering from osteitis pubis (mean ± SD)

Test statistics	Hip adductors					
	Concentric			Eccentric		
	Healthy athletes	Osteitis pubis athletes	*p* value	Healthy athletes	Osteitis pubis athletes	*p* value
PT/BW (%)	1.12 ± 0.12	1.30 ± 0.38	0.156	1.38 ± 0.16	1.46 ± 0.21	0.394
AT	110.00 ± 16.73	154.55 ± 27.69	0.000*	130.83 ± 19.75	225.00 ± 20.97	0.000*
DT	98.33 ± 18.35	216.36 ± 30.75	0.000*	110.00 ± 12.06	188.13 ± 21.67	0.000*
TPT	368.33 ± 69.69	300.91 ± 39.61	0.200	338.33 ± 55.19	330.00 ± 89.29	0.831

[*]$p < 0.05$; *PT/BW*, peak torque/body weight (in %); *AT*, acceleration time (in milliseconds); *DT*, acceleration time (in milliseconds); *TPT*, time to peak torque (in milliseconds)

Hip adductor muscles

On the AT and DT variables, there was a statistically significant interaction effect ($p < 0.05$) between both groups and contraction modes. The simple main effect indicated that OP athletes experienced greater AT and DT in eccentric mode and greater AT in concentric mode than the healthy group ($p < 0.05$). However, there was no significant difference in PT/BW and TPT between OP and healthy athletes for both modes of contractions ($p > 0.05$). The percent of the variation in reaction time parameters between healthy and osteitis pubis athletes during concentric and eccentric adductor muscle contractions is shown in Fig. 2.

Discussion and implications

The current study compared the performance parameters of the hip abductor and adductor muscles during concentric and eccentric modes of contraction at an angular velocity of 180°/s in OP football players to that of healthy players, taking into account traditional (PT/BW) and additional variables (AT, DT, and TPT). In summary, our findings showed that OP athletes' concentric and eccentric hip abductors had higher AT and TPT than healthy athletes. In terms of concentric and eccentric hip adductors, our findings revealed that OP athletes had higher AT and DT (reaching longer reaction times) than healthy athletes. However, there was no significant difference in PT/BW between the groups for either muscle. As a result, our hypothesis that there would be muscle imbalance between groups is supported by these findings. Up to the authors' knowledge, there are no comprehensive datasets that compare the muscle performance parameters of hip abductors and adductors in healthy and OP football players. As a result, this is the first study to conduct this comparison.

PT/BW results of the current study could be attributed to the homogeneous groups that have been tested in which all participants of the study have similar body physique and performed the same type of sport and training loads and they even competed at the same age level, youth level. The findings of the current study were consistent with the outcomes presented by Mohammad et al. [10] who found no significant difference in PT/BW values between the OP and

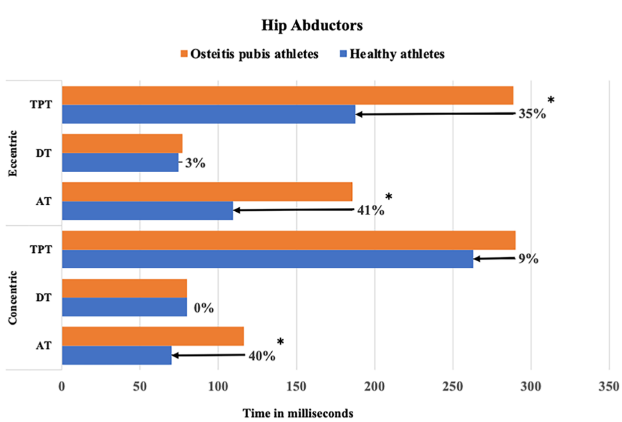

Fig. 1 The percent of the variation in reaction time parameters between healthy and osteitis pubis athletes during concentric and eccentric abductor muscle contractions (*$p < 0.05$)

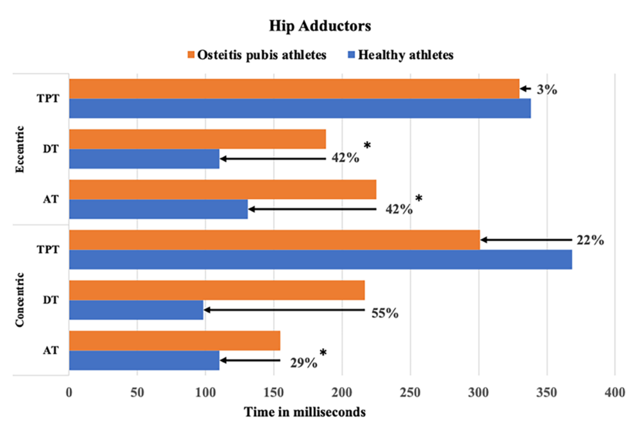

Fig. 2 The percent of the variation in reaction time parameters between healthy and osteitis pubis athletes during concentric and eccentric adductor muscle contractions (*$p < 0.05$)

healthy groups while testing the hip adductor and abductor muscles in concentric mode. Several studies examined abduction strength and found no difference between the hip/groin pain group and the controls during the isometric [28], or concentric and eccentric modes of contractions [11], but the bounded arguments suggested that reduced hip adduction strength during isokinetic testing was a risk element for groin injury [29]. As a result of the consistency in muscle strength (PT/BW), this parameter cannot be considered an appropriate predictor for assessing muscle imbalance. Furthermore, sports movements involve a series of accelerating and decelerating limb movements performed by concentric, eccentric, and static muscular contractions [17]. Therefore, understanding test parameters like acceleration and deceleration rates following isokinetic testing is critical and helps in clinical decision-making that boosts post-injury recovery and aids in the recurrence prevention [30].

To the finest of our readings, the current study is the prime attempt to understand the neuromuscular function of hip abductor and adductor muscles in football players with and without OP. In comparison to OP athletes, healthy athletes had lower AT and TPT of the hip abductors and lower AT and DT of the adductors. Compared to healthy athletes, the AT values of the OP were dramatically increased by 40% and 41%, respectively, during concentric and eccentric contraction of the abductor muscles. Similarly, the AT values of the OP were considerably augmented by 29% and 42%, respectively, compared to healthy athletes' concentric and eccentric adductor muscles. Considering the DT values, the concentric and eccentric adductor muscles of healthy athletes significantly increased by 55% and 42%, respectively, and the TPT of eccentric abductor muscles increased by 35% when compared to the OP group. These results could be attributed to the fact that the efficient kicking action requires great acceleration and high recruitment speed in addition to force [31], which would explain the shorter reaction time found in both muscles in healthy athletes, and the delayed neuromuscular control of both muscles in OP athletes, regardless the mode of contraction.

Although there is a paucity of studies available for comparison with the current results, a better understanding of the normal actions of the muscles around the hip joint may interpret the development of OP. This can be elucidated by the co-activation of muscles during the kicking action to start and maintain the movement concentrically by the agonist muscles and to slow down and stop the agonist movement eccentrically by the antagonist muscles [32]. The hip abductors, for example, contract concentrically to abduct the hip during the backswing phase [33], while the hip adductors act in an eccentric manner to regulate the hip abduction movement caused by pelvic rotation and outward leg swing [34]. During the follow-through phase of kicking, the hip abductors contract eccentrically to abduct and medially rotate the hip [35], while the kicking limb's adductors become more activated [36]. Additionally, the hip flexion position achieved through the kicking task naturally enhances the adductor muscles' ability to generate extension torque, thereby supporting the main hip extensors [37]. Consequently, during kicking activity, the limb is quickly accelerated from a position of extension (leg behind) into a position of flexion (leg in-front) all while bringing the leg across the body (adducting). This particular motion needs a proper neuromuscular response from both adductor and abductor muscles, and any substantial increase may reflect a slowness in the neuromuscular reaction of these muscles. Therefore, the reaction time of these muscles is essential, and any slowness of the neuromuscular response could result in magnified effort and/or poorly distributed loads across the musculotendinous structure of the anterior pelvis, which possibly could lead to the development of OP.

This justification is supported by Fricker [38] who proposed a possible mechanism for developing OP through increased shearing forces on the symphysis pubis produced by the accumulation of repetitive minor stresses or due to imbalanced pelvic musculature pulling on the joint. In the same context, several studies indicated that a reduction in muscular reaction time plays a vital role in minimizing subsequent musculoskeletal injuries, particularly in the knee [39] and ankle [40] joints. It was reported that in cases of abrupt movements, the muscles should rapidly contract to stabilize the joint, and the delay in this neuromuscular recruitment would make the joint more susceptible to injury [40]. As football is a sport with great physical contact, jumps, and sudden changes in direction [41], the delay in muscle reaction time could increase the risk of joint injuries in this sport. As a result, we assume that the neuromuscular regulation, as presented by time to peak torque, acceleration, and deceleration times, may be declined in OP athletes due to signal deficiency and reflexive motor coordination of abnormal mechanoreceptors caused by excessive loads on the injured structure. This assumption is supported by Duchateau and Enoka [42] who proposed that the increased feedback from peripheral sensory receptors during eccentric contractions seems to be reduced by central and peripheral mediated presynaptic inhibition signals of Ia afferents, which could explain the reduction of voluntary activation during peak eccentric contractions to avoid tissue injury.

Conclusion

This is the prime study to present the concept of exploring the muscle performance parameters for the hip abductor and adductor in football players with OP. The neuromuscular control of both hip abductors and adductors was diminished in OP; however, muscle strength remained unchanged. The neuromuscular system monitors and regulates the ongoing changes in limb acceleration which is very critical in football, particularly during the kicking task. Therefore, this integration is accomplished through the integration of afferent neurologic inputs and the capacity to create changes in the efferent output, which generates a muscular reaction. Thus, the neurophysiological integrity of the muscle is important in the evaluation of contractile tissue; however, interpretation of traditional isokinetic testing data (i.e., PT/BW) may not effectively assess normal muscular performance. Accordingly, clinicians and therapists should evaluate the reaction time parameters for the hip muscles, preferably AT, and should implement strength training that is aimed at restoring neuromuscular control during the management protocols for OP football players.

Acknowledgements The authors extend their appreciation to the Deputyship for Research & Innovation, the Ministry of Education in Saudi Arabia, for funding this research work through the project number (IFP-2020-27).

Author contribution Conception and design: W Mohammad and W Elsais; material preparation, data collection, and analysis: W Mohammad and W Elsais. The first draft of the manuscript: W Mohammad and W Elsais. All authors commented on previous versions of the manuscript. All authors read and approved the final manuscript.

Funding This work was supported by Deputyship for Research & Innovation, the Ministry of Education in Saudi Arabia (grant number IFP-2020–27).

Declarations

Ethics approval This study was performed in line with the principles of the Declaration of Helsinki. Approval was granted by the Ethics Committee of Cairo University (ethics approval no: P.T.REC/012/002933). Informed consent was obtained from each patient before taking part.

Consent to participate Paper submitted with consent participation of patients.

Consent for publication Paper submitted for publication with consent knowledge of co-authors.

Conflict of interest The authors declare no competing interests.

References

1. Rodriguez, C, Miguel, A, Lima, H, Heinrichs, K (2001) Osteitis pubis syndrome in the professional soccer athlete: a case report. J Athl Train 36:437
2. Mandelbaum, B, Mora, SA (2005) Osteitis pubis. Oper Tech Sports Med 13:62–67
3. Brukner P (2012) Brukner & Khan's clinical sports medicine: McGraw-Hill North Ryde
4. Batt, ME, McSHANE, JM, Dillingham, MF (1995) Osteitis pubis in collegiate football players. Med Sci Sports Exerc 27:629–633
5. Johnson, R (2003) Osteitis pubis. Curr Sports Med Rep 2:98–102
6. Fricker PA, Taunton JE, Ammann W (1991) Osteitis pubis in athletes. Sports Med 12:266–279
7. Holt MA, Keene JS, Graf BK, Helwig DC (1995) Treatment of osteitis pubis in athletes: results of corticosteroid injections. Am J Sports Med 23:601–606
8. Pham DV, Scott KG (2007) Presentation of osteitis and osteomyelitis pubis as acute abdominal pain. Perm J 11:65
9. Ekstrand J, Ringborg S (2001) Surgery versus conservative treatment in soccer players with chronic groin pain: a prospective randomised study in soccer players. Eur J Sports Traumatol Relat Res (Testo stampato) 23:141–145
10. Mohammad WS, Abdelraouf OR, Elhafez SM, Abdel-Aziem AA, Nassif NS (2014) Isokinetic imbalance of hip muscles in soccer players with osteitis pubis. J Sports Sci 32:934–939
11. Mohammad WS, Elsais W (2018) Abdominal/adductor strength imbalance in soccer players with osteitis pubis. J Men's Health 14:e33–e40
12. Pontaga I (2003) Muscle strength imbalance in the hip joint caused by fast movements. Mech Compos Mater 39:365–368
13. Pelegrinelli AR, Guenka LC, Dias JM, Bela LFD, Silva MF, Moura FA, Brown LE, Cardoso JR (2018) Isokinetic muscle performance after anterior cruciate ligament reconstruction: A case-control study. Int J Sports Phys Ther 13:882
14. Chen W-L, Su F-C, Chou Y-L (1994) Significance of acceleration period in a dynamic strength testing study. J Orthop Sports Phys Ther 19:324–330
15. Cozette M, Leprêtre P-M, Doyle C, Weissland T (2019) Isokinetic strength ratios: Conventional methods, current limits and perspectives. Front Physiol 10:567
16. Schlumberger A, Laube W, Bruhn S, Herbeck B, Dahlinger M, Fenkart G, Schmidtbleicher D, Mayer F (2006) Muscle imbalances–fact or fiction? Isokinet Exerc Sci 14:3–11
17. Wilk KE, Romaniello WT, Soscia SM, Arrigo CA, Andrews JR (1994) The relationship between subjective knee scores, isokinetic testing, and functional testing in the ACL-reconstructed knee. J Orthop Sports Phys Ther 20:60–73
18. Maciel DG, Dantas GAF, Cerqueira MS, Barboza JAM, Caldas VVDA, de Barros ACM, Varela RR, Magalhães DH, de Brito Vieira WH (2020) Peak torque angle, acceleration time and time to peak torque as additional parameters extracted from isokinetic test in professional soccer players: a cross-sectional study. Sports Biomech 1–12
19. Brown LE, Whitehurst M, Gilbert R, Buchalter DN (1995) The effect of velocity and gender on load range during knee extension and flexion exercise on an isokinetic device. J Orthop Sports Phys Ther 21:107–112
20. Mazuquin B, Bela LD, Pelegrinelli A, Dias J, Carregaro R, Selfe J, Richards J, Brown L, Moura F, Cardoso J (2016) Torque-angle-velocity relationships and muscle performance of professional and youth soccer players. Int J Sports Med 37:992–996
21. Thorborg K, Petersen J, Magnusson SP, Hölmich P (2010) Clinical assessment of hip strength using a hand-held dynamometer is reliable. Scand J Med Sci Sports 20:493–501
22. Belhaj K, Meftah S, Mahir L, Lmidmani F, Elfatimi A (2016) Isokinetic imbalance of adductor–abductor hip muscles in professional soccer players with chronic adductor-related groin pain. Eur J Sport Sci 16:1226–1231
23. Biedert RM, Warnke K, Meyer S (2003) Symphysis syndrome in athletes: surgical treatment for chronic lower abdominal, groin, and adductor pain in athletes. Clin J Sport Med 13:278–284
24. McKim K, Taunton J (2001) The effectiveness of compression shorts in the treatment of athletes with osteitis pubis. New Zealand J Sports Med 29:70–73
25. Masuda K, Kikuhara N, Demura S, Katsuta S, Yamanaka K (2005) Relationship between muscle strength in various isokinetic

movements and kick performance among soccer players. J Sports Med Phys Fitness 45:44
26. Masuda K, Kikuhara N, Takahashi H, Yamanaka K (2003) The relationship between muscle cross-sectional area and strength in various isokinetic movements among soccer players. J Sports Sci 21:851–858
27. Brown LE (2000) Isokinetics in human performance: Human Kinetics
28. Malliaras P, Hogan A, Nawrocki A, Crossley K, Schache A (2009) Hip flexibility and strength measures: reliability and association with athletic groin pain. Br J Sports Med 43:739–744
29. Kloskowska P, Morrissey D, Small C, Malliaras P, Barton C (2016) Movement patterns and muscular function before and after onset of sports-related groin pain: a systematic review with meta-analysis. Sports Med 46:1847–1867
30. Amaral GM, Marinho HV, Ocarino JM, Silva PL, Souza TRd, Fonseca ST (2014) Muscular performance characterization in athletes: a new perspective on isokinetic variables. Braz J Phys Ther 18:521–529
31. Scurr JC, Abbott V, Ball N (2011) Quadriceps EMG muscle activation during accurate soccer instep kicking. J Sports Sci 29:247–251
32. Scoville CR, Arciero RA, Taylor DC, Stoneman PD (1997) End range eccentric antagonist/concentric agonist strength ratios: a new perspective in shoulder strength assessment. J Orthop Sports Phys Ther 25:203–207
33. Nunome H, Lake M, Georgakis A, Stergioulas LK (2006) Impact phase kinematics of instep kicking in soccer. J Sports Sci 24:11–22
34. Nunome H, Asai T, Ikegami Y, Sakurai S (2002) Three-dimensional kinetic analysis of side-foot and instep soccer kicks. Med Sci Sports Exerc 34:2028–2036
35. Isokawa M (1988) A biomechanical analysis of the instepkick motion in soccer. In Science and Football 449
36. Brophy RH, Backus SI, Pansy BS, Lyman S, Williams RJ (2007) Lower extremity muscle activation and alignment during the soccer instep and side-foot kicks. J Orthop Sports Phys Ther 37:260–268
37. Neumann DA (2010) Kinesiology of the hip: a focus on muscular actions. J Orthop Sports Phys Ther 40:82–94
38. Fricker PA (1997) Osteitis pubis. Sports Med Arthrosc 5:305–312
39. Johnson AK, Palmieri-Smith RM, Lepley LK (2018) Contribution of neuromuscular factors to quadriceps asymmetry after anterior cruciate ligament reconstruction. J Athl Train 53:347–354
40. van Cingel RE, Kleinrensink G, Uitterlinden EJ, Rooijens PP, Mulde PG, Aufdemkampe G, Stoeckart R (2006) Repeated ankle sprains and delayed neuromuscular response: acceleration time parameters. J Orthop Sports Phys Ther 36:72–79
41. Zabka FF, Valente HG, Pacheco AM (2011) Isokinetic evaluation of knee extensor and flexor muscles in professional soccer players. Revista Brasileira de Medicina do Esporte 17:189–192
42. Duchateau J, Enoka RM (2008) Neural control of shortening and lengthening contractions: influence of task constraints. J Physiol 586:5853–5864