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Effects of an eccentric training programme on hamstring strain injuries in women football players

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Summary

Study aim: to test the hypothesis that an eccentric training programme applied on women football players would reduce the hamstring injury rate by improving thigh muscle balance and, particularly, hamstring strength.
Material and methods: three football teams were recruited for this randomised controlled trial. They played in the first and second divisions in Spain. Players were randomised within clubs either to the intervention (eccentric exercises, $n = 22$) or control (control exercises, $n = 21$) groups, and randomisation was stratified according to previous history of thigh strains. The eccentric programme was divided into 3 phases, and each phase was composed of 7 weeks. Compliance level and all injuries were recorded throughout the season as well as training and game exposure times. Muscle strength and power of the lower extremities and flexibility of the hamstrings and lower back were measured before and after the intervention.
Results: the risk for sustaining a hamstring strain (RSHS) was reduced by 81%. However, differences were not significant due to the low number of subjects (relative risk 0.19; 95% coefficient interval 0.02–1.50). The strength of the hamstrings decreased in both groups ($p < 0.05$), whereas sprint time was improved only in the intervention group ($p < 0.05$).
Conclusion: the present findings suggest that a simple program of eccentric exercise could reduce RSHS.

Keywords: Hamstring strain – Randomised controlled trial – Eccentric training programme – Injury prevention – Football

Introduction

Hamstring muscle strains are common injuries in sports involving high intensity actions such as football and Australian Rules football [12, 27, 36]. A high prevalence of hamstring strains has been reported in men's elite-level football, accounting for 12% of total injuries [12, 36], which is higher than in earlier studies [24]. This indicates that hamstring injury incidence has increased over time since modern football involves in more matches and more aggressive play than previously [2]. Additionally, the rate of recurrence for hamstring strain is higher than for other injuries, accentuating the need for prevention [36]. Despite the growing popularity of women's football and the increasing number of female players, there has been little research on female football injuries. Most of the research has focused on the rate and aetiology of knee injuries, while hamstring strain injuries have not been particularly examined. Nonetheless, epidemiological studies showed that muscle strains and thigh injuries are also common injuries in women football players [11, 19].

The risk factors for sustaining hamstring strains (RSHS) are muscle fatigue, muscle imbalances, muscle weakness, lack of flexibility, previous injuries and insufficient warm up [9]. Muscle unilateral imbalances (concerning agonist and antagonist muscles of the same thigh) and muscle bilateral imbalances (concerning the same muscles of the right and left thighs) have been the most-studied risk factors in the literature. Muscle imbalances are discovered through isokinetic testing and are usually described by hamstring/quadriceps unilateral ratio (H/Q)

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and by left hamstring/right hamstring bilateral ratio (H_{left}/H_{right}). It has been shown that an improvement in H/Q ratio and H_{left}/H_{right} ratio decreases RSHS injury [10]. Due to the physical demands of the sport, football players tend to have more developed quadriceps than hamstrings [34]. Therefore, H/Q ratios are at times lower than the 0.60, or 60%, recommended value [8, 31], which increases RSHS injury. In regards to gender differences, [16] demonstrated significantly different changes in H/Q ratio with increased isokinetic velocity between males and females. At slower testing velocities, no differences in isokinetic H/Q ratio were observed, while with increased angular velocities, approaching those that occur during sports activities, significantly greater H/Q ratios were observed in male than female athletes. Thus, females with low H/Q ratios may be at increased risk of hamstring strains [8].

Several studies have showed that eccentric resistance training may be an important preventive factor. Eccentric training of the hamstring muscles reduces the hamstring strain injury rate primarily by correcting the balance between the quadriceps and hamstring muscle groups [2, 10]. It is well known that eccentric muscle actions generate greater force at a lower activation level, which requires less metabolic cost and exposes muscles to more severe damage than concentric actions do [18]. However, muscle damage is not necessarily a negative response. In fact, it should be perceived as a protective muscle adaptation and a stimulus for beneficial musculo-tendon responses [18, 23]. This protective adaptation within the muscle is known as repeated bout effect (RBE). Even though the exact mechanisms of this adaptation are not well defined, it seems to involve a series of neural, mechanical and cellular adaptations [23]. To our knowledge, two randomised control trials (RCT) have been undertaken in men athletes to determine the effectiveness of eccentric hamstring training [2, 14]. In both studies, it was concluded that when the compliance level was high, eccentric hamstring training decreased RSHS injury. In the first study, the prevention programme involved the use of specific equipment, limiting the applicability of the program to amateur levels of sport. In the second study, however, Nordic Hamstring (NH) exercise was performed. This exercise does not require any expensive equipment. Additionally, it has been shown that NH improves hamstring strength and produces a shift in the optimum angle for hamstring torque generation, decreasing RSHS injury [5, 7, 14, 25].

Prevention programmes for hamstring strain injuries have never been applied in women football players. Thus, the main goal of the present RCT is to evaluate the effectiveness of an eccentric training programme (ETP) for preventing hamstring strain injuries in women football players. We hypothesized that players from the intervention group would improve their muscle balance in the thigh and, subsequently, would sustain fewer hamstring strain injuries.

Material and methods

Study design and participants

A RCT study design was used for the present study. Both subjects and medical staff were blinded to the study. Subjects of the study were recruited through a convenience sampling from three different football teams of Gipuzkoa (Basque Country, Spain). The teams were Añorga K.K.E. (AN), Oiartzun K.E. (OI) and Real Sociedad de Fútbol S.A.D. (RS). AN and OI played in the second national division of Spain, whereas RS played in the first national division. To be included in the study, players had to play in either of the teams selected for the study and sign the informed consent. Players were excluded from the study if they were injured or sick. Randomisation was stratified by a past history of thigh strain (last two seasons) to ensure an even spread of players with a past history of injury across intervention group (IG) and control group (CG). The study was approved by the Ethical Committee of Clinical Research of Gipuzkoa's Health, and the players were treated based on the ethical principles of the Declaration of Helsinki.

Procedures

Player's baseline information form: The players completed a baseline questionnaire prior to randomisation. The information captured through the questionnaire included age, sport history, medical history, past history of thigh strain, regular playing position, level of competition and preferred leg for kicking.

Measurements: Leg extension and leg flexion exercises, flexibility test and vertical jumps were performed at the gym, whereas sprint time was measured at the pitch. Pre-intervention measurements were done during the preseason phase and the beginning of the competition phase (August–September), while post-intervention measurements were done in the end of the competition phase (April–May). The same protocol was used for both pre – and post-intervention measurements. All players performed a standardized warm up for 15 minutes. After the warm up the players underwent five repetition maximum (5RM) tests (Technogym leg extension and flexion machines. Vantaa, Finland). The 5RM loads and the position of each player (seat and legs handle) were noted to ensure same conditions for following measurements.

Loads were set separately for right and left leg extensions as well as right and leg flexions. After 5RM, the players performed one leg extension maximal voluntary contraction (MVC) and one leg flexion MVC with each leg. The mean force of leg extension MVC (right quadriceps F_{mean}, RQ F_{mean}; left quadriceps F_{mean}, LQ F_{mean}) and leg flexion MVC (right hamstring F_{mean}, RH F_{mean}; left hamstring F_{mean}, LH F_{mean}) were taken into account.

MVCs were recorded by the FITRODyne dynamometer (Bratislava, Slovakia), which consists of 2 functional components, a sensor and an electronic unit. The sensor unit contains a precise analogue velocity sensor and an infrared impulse sensor. Both machines are mechanically coupled with the reel. While pulling the tether out of the reel, this rotates and velocity produces a measurement. The other end of the tether is connected to the weights of the weight exercise machine. After each repetition a summary of mean and peak data can be found in digital form. A repeatability test was done a half year earlier demonstrating that RH F_{mean}, LH F_{mean}, RQ F_{mean} and LQ F_{mean} were reliable variables according to the statistical method of agreement [3].

After MVCs, the players performed the sit-and-reach test (box for sit-and-reach test). Each player performed this test twice, and the best value was taken into account. After a break of 10 minutes, the players did 5 squat jumps (SJ) and 5 countermovement jumps (CMJ) (Newtest force platform, Oulu, Finland). For SJ, players were asked to keep their hands on their waists, to flex their knees to an angle of 90º, to count three in that position and to jump as high as possible. For CMJ, however, they were only asked to flex their knees and to jump as high as possible. The best and the worst values of each jump were ignored, and the mean of the remaining 3 jumps was registered for both SJ and CMJ [4]. Finally, players were taken to the pitch and their sprint time was measured (Newtest photoelectric cells, Oulu, Finland). Three photoelectric cells were placed on the pitch: the first one at 0 m, the second one at 5 m and the last one at 15 m. Each player performed 2 sprints, and the best times for 5 m and 15 m were recorded (S5m and S15 m).

Training programme: Players classified into the IG performed an eccentric training programme (ETP) for 21 weeks. The main goal of this programme was to strengthen hamstring muscles and, therefore, to improve muscle balance at the thigh level. They performed two exercises: Nordic Hamstring (NH) and eccentric band exercise (EBE). Players in the CG performed another set of exercises. These exercises included frontal leg swings (FLS), side leg swings (SLS) and multiple jumping (MJ). CG was subject to a double objective: on the one hand they aimed to blind IG, and on the other hand they aimed to match the load and training time to IG in order to avoid differences between groups. Both prevention programmes were performed in the beginning of training sessions. They were divided into three different phases (Table 1). The aim of the periodization was to maintain training effects throughout the whole season.

Injuries and exposure time: Players had a personal file in which they registered the time they trained in each session and the time they played in each game throughout the season. Additionally, each player was in charge of filling out a form every time she got injured in order to define the localization, the type, the gravity, the mechanism and the cause of the injury as well as the part of the body affected, the diagnoses of the doctor and whether it was a recurrent injury or not. Any physical complaint sustained by a player resulting from a football match or football training was considered an injury [13]. The injury had to result in a player being unable to take part in a future football training or match play [13]. Injuries unrelated to football competition or training, and other physical complaints such as diseases and mental illnesses, were reported separately from the incidence of physical complaints [13]. All injuries were defined by the medical staff of each team. However, when the injury concerned the thigh, all players went to the facilities of RS and were examined by the same doctor; there a clinical assessment and an ultrasound examination were conducted on the players. All the injuries were classified based on Orchard's OSICS 10 classification (The Orchard Sports Injury Classification System Version 10) [29].

Compliance level: In AN, the coach was in charge of guiding the exercises for CG and IG, whereas in OI and RS, the physical trainer guided them. They were told that delayed onset muscle soreness (DOMS) during the first one to two weeks of training would be expected. Physical trainers from RS and OI and the coach from AN had to complete a control sheet after every time they guided the exercises. Thus, it was possible to know which players performed the prevention programme in each session and calculate the total compliance. First of all, the total amount of players in each club was multiplied by the total amount of training sessions (IG: 22 players × 42 sessions = 924 cases

Table 1. Periodization of eccentric training programme (ETP)

	IG		CG		
	EBE	NH	SLS	MJ	FLS
Phase 1 (9 Nov–27 Dec)	5 reps/12 s each	1 set/5 reps	1set/10 reps	1 set/5 reps 10m	1set/20reps
Phase 2 (4 Jan–21 Feb)	5 reps/20 s each	1 set/5 reps	3set/15 reps	1 set/7 reps 12m	3set/15 reps
Phase 3 (22 Feb–9 April)	5 reps/15 s each	1 set/5 reps	3set/15 reps	1 set/6 reps 12m	3set/15 reps

* NH: Nordic Hamstring; EBE: eccentric band exercise; SLS: side leg swing; MJ: multiple jumping; FLS: frontal leg swing.

and CG: 21 players × 42 sessions = 882 cases). Then the total amount of players that were absent in those sessions was subtracted (IG: 924 cases − 187 cases = 737 cases and CG: 882 − 215 = 667). The percentages for each group were then obtained. The compliance level for IG was 80%, and the compliance level for CG was 76%. When the evaluation of the exercises was 2 or lower (poor and very poor, respectively), the session was not taken into consideration. Unusable data happened twice in the OI team and four times in AN due to the bad weather.

Statistical analysis

Statistical analysis was performed using SPSS version 15 software. ANOVA for repeated measures [Group (CG, IG) × Team (RS, OI, AN) × Time (pre-intervention, post-intervention)] was used for means comparisons for anthropometrical data as well as power and flexibility data. The Bonferroni test was utilised for post-hoc pairwise-comparisons. Descriptive and comparative analyses were used to present data concerning injury rate and characteristics. The χ^2 test was used to investigate differences, and statistical significance was accepted at $p < 0.05$. Mann-Whitney, Kruskal-Wallis and Wilcoxon signed-rank non-parametric tests were used to analyse non-normally distributed data. The evaluation tool for RCTs (Critical Appraisal Skills Programme Español, CASPe) was used to determine the absolute risk of IG (AR intervention) and CG (AR control), relative risk (RR), relative risk reduction (RRR) and their confidence intervals (CI).

Results

Fifty-five players were assessed for eligibility. However, 48 players were finally randomised into the intervention (IG) and control groups (CG), and in the end, the data of 43 players were analysed (21 in CG and 22 in IG) (Fig. 1). Table 2 summarises the profile of players in each study group. One hamstring strain occurred among the 22 players who performed ETP during the intervention time, whereas 5 hamstring strains occurred among the 21 players who did not perform ETP (Table 3). The absolute risk (AR) of sustaining a hamstring strain among players from IG was 1/22 = 0.045 (4.5%), whereas the absolute risk

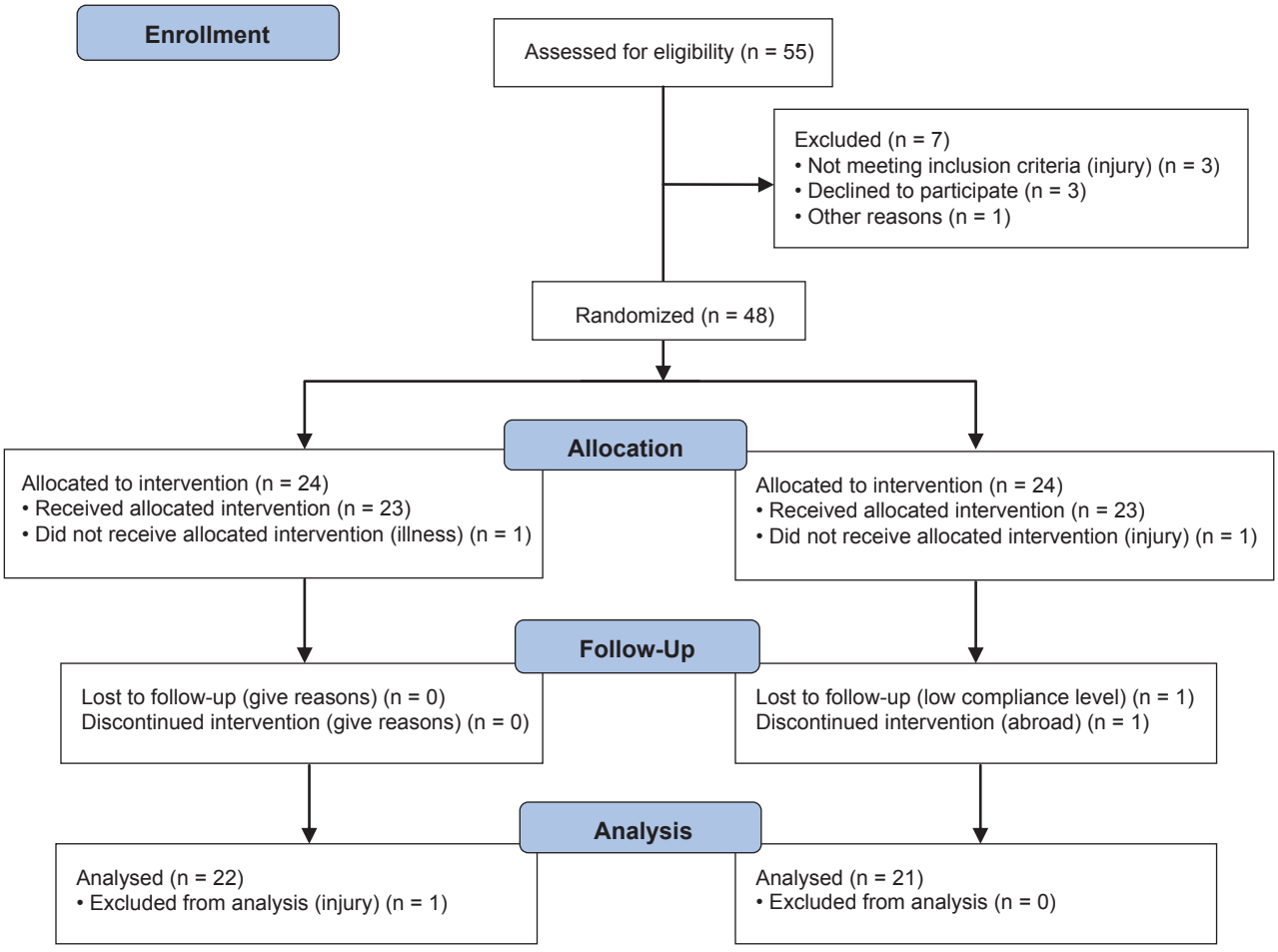


Fig. 1. Flow diagram of the progress through the phases of this RCT (enrollment, intervention allocation, follow-up, and data analysis) based on the CONSORT statement 2010 (Moher et al. 2001; Schulz et al. 2010)

Table 2. Characteristics of the subjects at the beginning of the study (mean and SD)

	Teams					
	RS (n = 17)		AN (n = 13)		OI (n = 13)	
Age (years)	23	(4)	19	(2)	22	(3)
Height (m)	1.65	(0.06)	1.64	(0.05)	1.65	(0.04)
Body mass (kg)	61.4	(4.7)	65.4	(6.8)	63.1	(6.1)
BMI (kg/m^2)	22.49	(1.24)	24.25	(2.13)	23.13	(2.13)
% BF	17.8	(3.2)	20.3	(1.8)	18.4	(3.6)

* RS: Real Sociedad de Fútbol S.A.D; AN: Añorga K.K.E; OI: Oiartzun K.E.

Table 3. Data concerning all hamstring strain injuries sustained by players throughout the season

Code	Group	Month	Grade	Mechanism	Time	Recovery	Severity
RS8	Intervention	August	Grade II	Trauma	Training	30 days	Severe
RS10	Intervention	September	Grade II	Trauma	Training	13 days	Moderate
RS11	Control	October	Grade I	Trauma	Game	28 days	Severe
RS11	Control	December	Grade II	Trauma	Game	70 days	Severe
RS15	Control	November	Grade I	Overuse	Game	6 days	Mild
RS15	Control	April	Grade I	Trauma	Training	16 days	Moderate
AN5	Intervention	February	Grade I	Overuse	Training	6 days	Mild
AN11	Control	May	Grade I	Trauma	Game	10 days	Moderate
OI15	Control	January	Grade I	Trauma	Game	9 days	Moderate

* Shaded areas correspond to hamstring strains sustained during and after the intervention (November-May).

(AR) of getting a hamstring strain among players from CG was 5/21 = 0.238 (23.8%). RRR shows that ETP reduced RSHS by 81%.

There were no significant differences between IG and CG either in the beginning of the study or at the end of the study concerning muscle strength of the lower extremities. However, when looking at the differences between pre-intervention and post-intervention measurements, several significant changes were observed. RH F_{mean} and LH F_{mean} decreased significantly in IG (−65.4 N, $p < 0.001$ and −57.9 N, $p < 0.001$, respectively) and CG (−53.7 N, $p = 0.015$ and −46.7 N, $p = 0.009$, respectively) (Fig. 2a, b). The unilateral left and right leg ratios decreased in both IG and CG. However, the difference was only significant for the unilateral ratios of the left leg (IG −0.17, $p = 0.003$; CG −0.12, $p = 0.003$). IG and CG did not significantly

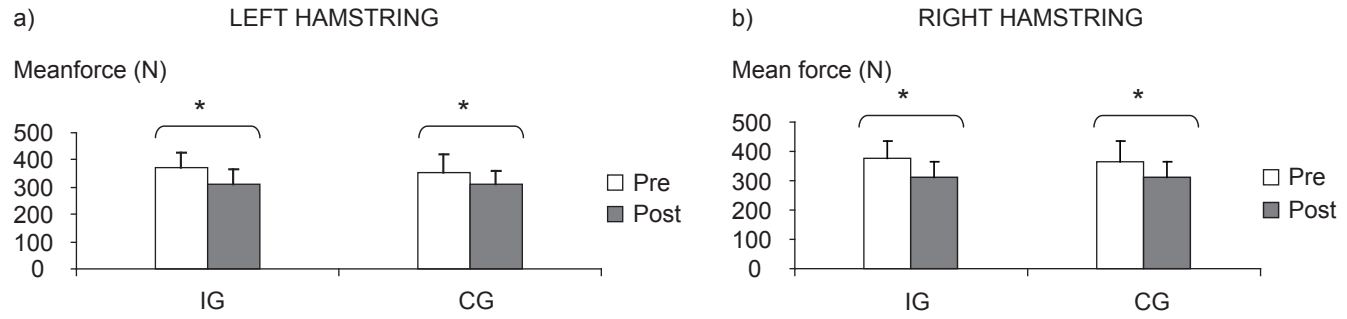


Fig 2. a) Changes in left hamstring mean force throughout the season for IG and CG. Changes were significant ($p < 0.05$) for both IG and CG; b) Changes in right hamstring mean force throughout the season for IG and CG. Changes were significant ($p < 0.05$) for both IG and CG

differ in the end of the study (Fig. 3a, b). Bilateral ratios and RQ F_{mean} and LQ F_{mean} values did not significantly change. However, it should be pointed out that while LQ F_{mean} increased for both groups (IG +24 N; CG +17 N), RQ F_{mean} decreased (IG −5 N; CG −5 N) (Fig. 4a, b), and subsequently, the changes of the bilateral quadriceps ratio (IG −0.04; CG −0.04) were higher than the respective changes of the hamstring ratio (IG −0.01; CG −0.02) (Fig. 5a, b).

At power production, there were no significant changes between pre – and post – measurement values of either IG and CG. Conversely, CMJ values after the intervention were significantly lower in IG (p = 0.043; baseline 35 ± 1 cm vs. post-intervention 33 ± 1 cm), while SJ values did not change. In regards to CG, there were no significant differences concerning pre – and post-measurement values of SJ and CMJ. Sprint time differed significantly between IG pre-measurement values (1080 ± 20 ms in S5 m

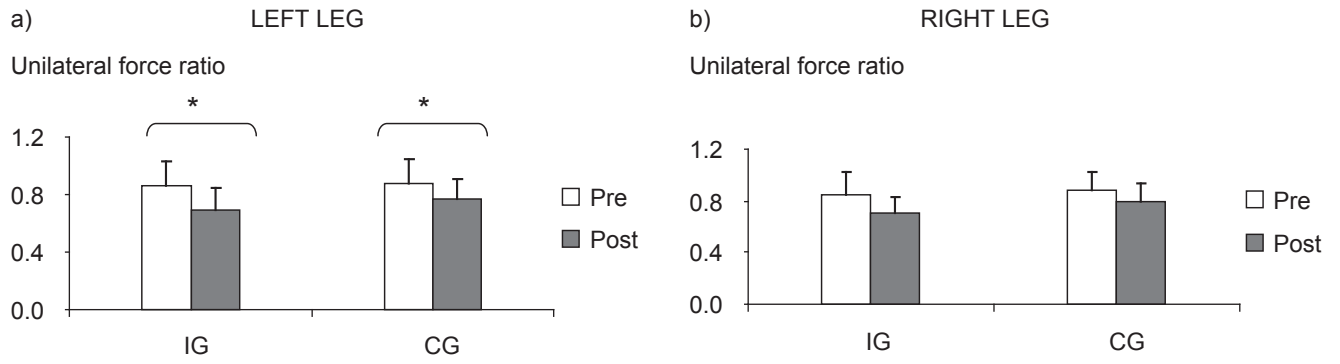


Fig 3. a) Changes in the unilateral ratio of the left leg throughout the season for IG and CG. Changes were significant ($p<0.05$) for both IG and CG; b) Changes in the unilateral ratio of the right leg throughout the season for IG and CG

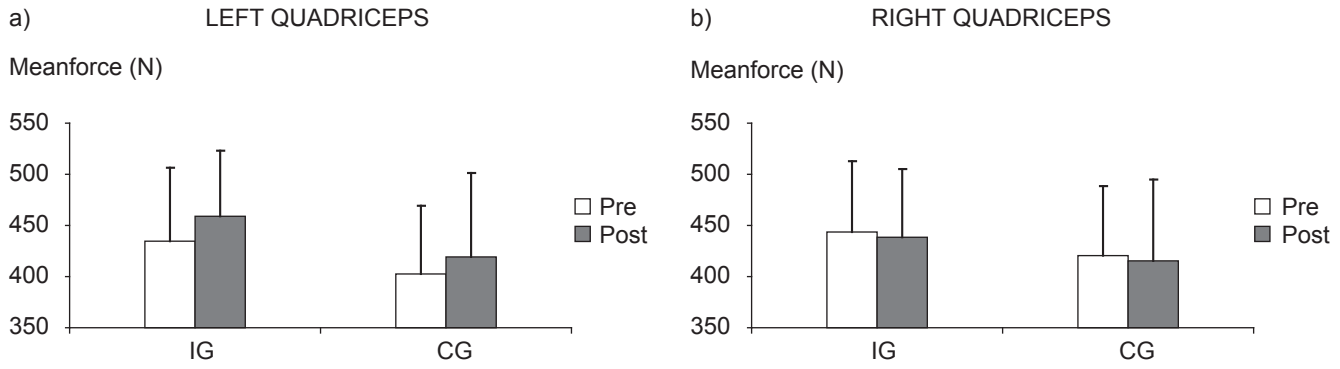


Fig 4. a) Changes in right quadriceps mean force throughout the season for IG and CG; b) Changes in left quadriceps mean force throughout the season for IG and CG

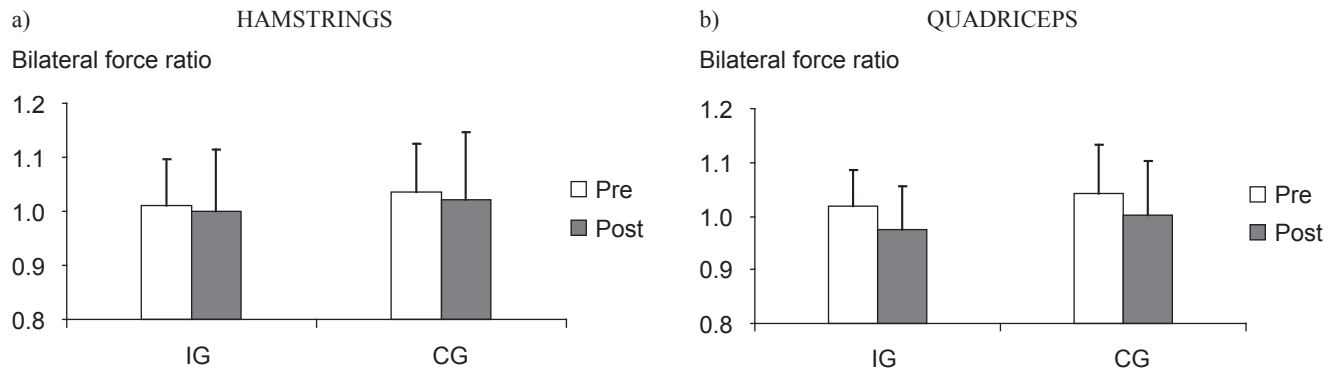


Fig 5. a) Changes in the bilateral hamstring ratio throughout the season for IG and CG; b) Changes in the bilateral quadriceps ratio throughout the season for IG and CG

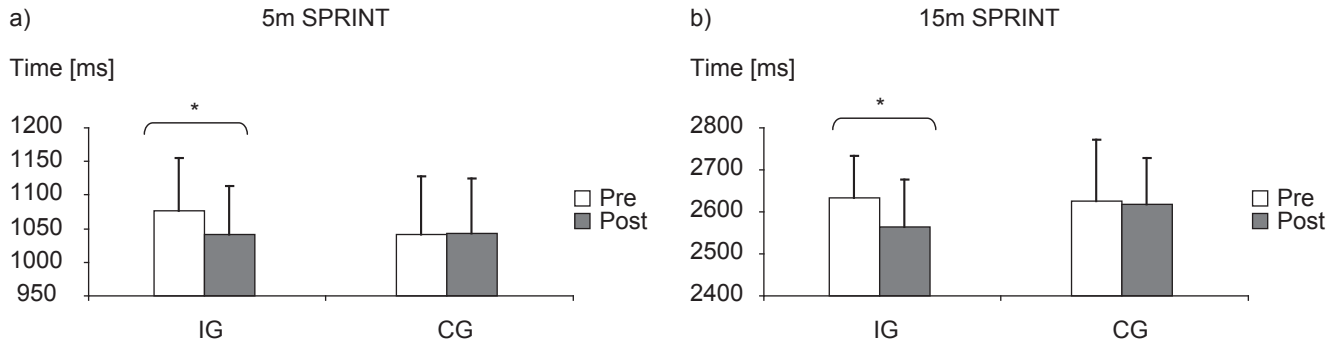


Fig 6. a) Changes in 5 m sprint time throughout the season for IG and CG. Changes were significant ($p<0.05$) for IG.; b) Changes in 15 m sprint time throughout the season for IG and CG. Changes were significant ($p<0.05$) for IG

and 2638 ms ± 20 ms in S15 m) and IG post-measurement values (1037 ± 18 ms in S5 m and 2577 ± 26 ms in S15 m) ($p = 0.016$ and $p < 0.001$, respectively). Thus, there was an improvement in sprint time in both S5 m and S15 m. Changes in CG were not significant (Fig. 6a, b).

A significant difference was observed between IG and CG concerning the baseline and post-intervention values of hamstring and lower back flexibility. IG (pre 29.7 cm ± 1.8 cm; post 29.7 cm ± 1.6 cm) and CG (pre 23.1 cm ± 1.8 cm; post 22.5 cm ± 1.5 cm) differed by6.7 cm in sit-and-reach test performed for the measurements prior the intervention ($p = 0.013$) and by7.2 cm ($p = 0.003$) for the measurements performed after the intervention. However, there were no significant differences when comparing pre-measurement values to post-measurement values in any of the groups.

Discussion

The primary purpose of the present study was to reduce hamstring strain injury rate in women football players by performing an ETP composed of NH and EBE. The number of hamstring strains was lower during the intervention period (from November until May) in IG (1 hamstring strain out of 28 total injuries sustained in IG; 14%) than in CG (5 hamstring strain out of 23 total injuries sustained in CG; 3%). RRR showed that ETP reduced RSHS by 81%. However, RR's CI 95% (0.02–1.50) indicated that the treatments from this study were not significantly different as the dispersion was too high. Although RSHS was more notably decreased in the present study than in the study of Gabbe et al. (2006) (81% vs. 70%), the results in the present study were not statistically significant, while in the study of Gabbe et al. (2006) results happened to be significant. The reason for that is that in the present study only 43 players were analysed whereas 220 players were analysed in Gabbe et al.'s 2006 study. But, if the same RRR (81%) that was defined in the present study had been detected in 220 players, the results would suggest a higher significant difference (RR 5.02 and its CI 95% 2.01–12.56) and, in addition to that, the risk of getting a hamstring strain would be reduced in 402.1%. All these assumptions confirm that if the results are not significant in the present study, it is mainly because too few players were analysed. The main finding of the study is that even though the differences between groups were not significant due to the low number of subjects (n = 43), the intervention programme applied in the present RCT reduced RSHS injury by 81%.

The main hypothesis of the study was not proved. In order to reduce hamstring strain injuries, subjects that belonged to IG were meant to improve their bilateral and unilateral ratios and that did not happen. The hamstring bilateral and unilateral ratios were supposed to increase in IG mainly by an improvement in hamstrings strength due to ETP. However, both RH and LH strength were significantly reduced in both groups. More surprisingly, hamstring strength was reduced even more in IG than in CG. In similar studies that applied similar eccentric exercises, hamstring strength was improved [2, 25]. They applied more intense, shorter and frequent training programmes. Therefore, the most likely explanation for the decrease of hamstring strength is that the volume and intensity of ETP were not high enough to increase RH and LH strength. RQ and LQ did not significantly differ in any of the groups, and they behaved in the same way for both groups. LQ increased whereas RQ decreased during the season. The concomitant increase of LQ strength and decrease of LH resulted in a significantly lower left leg unilateral ratio at the end of the season for both groups. Conversely, RQ did not increase, and that is why the decrease in right leg unilateral ratio was not significant. The most likely reason for the increase in LQ strength is that the right leg was dominant for the majority of the players. Thus, the players used their left leg as a support in actions such as tackling, jumping and kicking. These explosive actions could be responsible for a higher increase in LQ strength. However,

in one study that analysed football players' strength profiles, the results suggested that no difference in musculature (in terms of muscle cross-sectional area and strength of knee flexors and extensors muscles, hip extensors and flexors muscles, and hip adductor and abductor muscles) was obvious among well-trained male football players, even between the dominant and non-dominant leg [21]. In football it is expected that players improve their strength of quadriceps and hamstring muscles throughout the season due to the training sessions and games. In this study, however, the strength after the season was lower than in the beginning of the season for almost all the cases. It is likely that players improved and peaked in their strength in the middle of the season (January-February-March) and that the strength had decreased already at the end of the season.

The most striking result of the present study is that even though players from IG did not present any better hamstring strength, or unilateral and bilateral ratios, the decrease in RSHS injury in players from IG was 81%. This fact leads us to believe that something might have occurred or changed in IG players' muscles or neuromuscular system. These changes could have happened due to the effects caused by RBE. This phenomenon is defined as a protective adaptation induced by eccentric exercise that protects against damage [18, 23]. While the conditions required to induce a protective mechanism are fairly understood, the actual mechanism for RBE is not well known and several theories have been proposed. *The neural theory* states that when a second bout of maximal eccentric exercise is performed, the nervous system changes its pattern of activation by increasing the activation of slow motor units and by concomitantly decreasing the activation of fast units [6, 35]. Thus, if fewer fast twitches are activated, the probability of sustaining a muscle strain will be lower. However, this theory is still under discussion.

The cellular theory is based on a shift in muscle optimum length after eccentric exercise reported by several studies. At least three studies demonstrated changes in optimum length concerning hamstring muscles [5, 7, 17]. The first two studies used NH as eccentric exercise and reported similar shifts (7.7º and 6.3º) even though they used different exercise volumes. Brockett et al. (2001) used a very high exercise volume (2 bouts of 12 sets of 6 reps), whereas subjects in the study by Clark et al. (2005) performed 2–3 sets of 5–8 reps, and the protocol was repeated 1–3 times per week for 4 weeks. Kilgallon et al. (2007) used 3 weeks of eccentric resistance training and also demonstrated that the peak torque occurred at a more extended joint angle. The eccentric resistance training consisted of the stiff-legged dead lift (the eccentric stiff-legged dead lift is performed from a standing position, holding an Olympic bar, and lowering it onto the ground by flexing the hip joint) and the prone hamstring curl (performed using a prone leg curl machine). The increase in torque was seen on days 4 and 11 after the eccentric resistance training, but by day 18, it was no longer significant. Thus, it was concluded that frequent and repeated training sessions may be necessary to maintain a shift in the knee angle–torque relationship. In the present study, EBE and NH eccentric exercises were performed for 21 weeks. Even though the exercise volume was less than in the previous studies, they were performed for a longer period of time. Therefore, the theory of a rightward shift in muscle optimum length can be taken into consideration as a possible reason for the decrease in hamstring injury incidence in the present study. Note that it has been previously demonstrated that shorter optimum length place subjects at greater risk for sustaining a muscle strain [5, 28].

The *mechanical theory* has been related to a change in muscle stiffness. The belief is that eccentric exercise (6–8 weeks) leads to a greater passive stiffness or spring-like qualities at muscle level [20, 30]. Both tendon and collagen are structures capable of storing and releasing elastic strain energy, but these authors demonstrated that there is an active muscle spring as well. They speculate that titin could be a crucial element in this phenomenon. Sarcomeres that are exposed to greater strains may express titins with larger elastic segments. In fact, sprinters expressed a greater percentage of titin-1 isoforms than non-athletes [22]. It is possible that the titin is capable of storing and releasing elastic energy [18], and consequently, RSHS could be reduced. Note that during the swing phase of running, when hamstring muscles are active and stretched creating the potential circumstances for an injury to happen, they are also absorbing energy from the decelerating swing limb to be released during the ground phase [15, 18, 33].

None of the groups presented significant improvements in muscle strength- and power-related variables, with the exception of IG in S5 m and S15 m. Similar studies reported improvements in isometric and isokinetic hamstring strength, H/Q ratios, vertical jump and running maximal speed after performing similar eccentric exercise [1, 2, 7, 25]. However, training periods applied in these studies were not longer than 10 weeks, and in most of the cases, the load was progressively increased over time. In the present study, the training period was divided into 3 phases of 7 weeks each and the frequency and load decreased over time. The periodization of the training programme could explain the fact that only S5 m and S15 m were significantly improved.

The main objective of ETP applied in the recent study was to reduce the risk of sustaining a hamstring injury. Besides, before planning the training programme, it was set that ETP had to be easy for players and coaches to apply in order to obtain a high level of compliance, and it also had to keep the effects throughout the whole season. In fact,

similar studies [1, 14] reported a low compliance level as the main limitation. Therefore, avoiding low compliance was the objective in the first place.

Even though it seems that ETP was not sufficiently good training method, a high level of compliance was achieved, the risk of sustaining a hamstring injury was reduced by 81% and, finally, the sprint time of IG players was improved.

Conclusions

The result of the present study suggested that ETP composed of NH and EBE exercises, performed during 21 weeks with a decreasing volume and frequency over time, and completed by women football players, reduced RSHS by 81% and additionally improved the sprint time of the players ($p < 0.05$). The reason for reducing the risk of sustaining a hamstring strain was not defined in the recent study, but according to the literature, players could have developed an RBE protection mechanism. Once the efficacy of the ETP has now been confirmed, it would be possible to expand the ETP to other clubs with similar characteristics to the subjects in the study. But maybe it would not be worth it to employ the recent ETP in women at the amateur football level, since hamstring strain incidence in AN and OI was lower than in RS.

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