Effects of a program of eccentric exercises on hamstrings in youth soccer players

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Summary

Objective: To determine the effects of a 6-week eccentric exercise program on the active knee extension range of motion in young soccer players.
Material and method: Randomized controlled trial. The sample was constituted by 37 youth players (18 control group and 19 experimental) of male sex between 14 and 16 years belonging to the under-15 and under-16 categories of a sports club in the Talca city, Chile. All the players were evaluated in a pre-intervention session (S0) by measuring the active knee extension range of motion in the dominant leg (DL) and non-dominant leg (NDL) with the Active Knee Extension (AKE) test using an electrogoniometer. The experimental group was subjected to eccentric exercises of the hamstring muscle 3 times a week for a period of 6 weeks. The intervention sessions were carried out prior to the usual training of the players. Both groups were reevaluated in 4 sessions: third (S1), sixth (S2), ninth (S3) and twelfth week (S4).
Results: In the control group there were no gains in the active knee extension range of motion, while in the soccer players who underwent eccentric exercise, a gain of 11.4 ° was observed for the DL and 7.8 ° for the NDL. In this group, significant changes occurred at S1 ($p = 0.005$) in PD and PND ($p = 0.008$); S2 in PD ($p <0.001$) and PND ($p = 0.006$); and S3 in the PD ($p = 0.004$).
Conclusion: A progressive training of eccentric exercises of 6 weeks on the hamstring musculature generates positive changes in the active knee extension range of motion, reducing the shortening of this muscle group, mainly, in the dominant leg. The effects are maintained until the third week after the intervention.

Key words:
Eccentric contraction exercises. Hamstrings tightness. Soccer. Sports.

Efectos de un programa de ejercicios excéntricos sobre la musculatura isquiotibial en futbolistas jóvenes

Resumen

Objetivo: Determinar los efectos de un programa de ejercicios excéntricos de 6 semanas de duración sobre el rango de extensión activa de rodilla en futbolistas juveniles.
Material y método: Ensayo clínico aleatorizado y controlado de corte longitudinal. La muestra fue constituida por 37 futbolistas juveniles (18 grupo control y 19 experimental) de sexo masculino entre 14 y 16 años pertenecientes a las categorías sub-15 y sub-16 de un club deportivo de la ciudad de Talca, Chile. Todos los jugadores fueron evaluados en una sesión preintervención (S0) midiendo el rango de extensión activa de rodilla en la pierna dominante (PD) y no dominante (PND) con el test *Active Knee Extension* (AKE) utilizando un electrogoniómetro. El grupo experimental fue sometido a ejercicios excéntricos de la musculatura isquiotibial 3 veces a la semana por un periodo de 6 semanas. Las sesiones de intervención se llevaron a cabo previo al entrenamiento habitual de los futbolistas. Ambos grupos fueron reevaluados en 4 sesiones: tercera (S1), sexta (S2), novena (S3) y duodécima semana (S4).
Resultados: En el grupo control no se observan ganancias en el rango de extensión activa de rodilla, mientras que en los futbolistas que fueron sometidos a 6 semanas de ejercicio excéntrico se observa una ganancia del rango de movimiento de 11,4° para la PD y de 7,8° para la PND. En este grupo los cambios significativos se produjeron a la S1 ($p = 0,005$) en PD y PND ($p = 0,008$); S2 en PD ($p < 0,001$) y PND ($p = 0,006$); y S3 en la PD ($p = 0,004$).
Conclusión: Un entrenamiento progresivo de ejercicios excéntricos de 6 semanas sobre la musculatura isquiotibial genera cambios positivos en el rango de extensión activa de rodilla, disminuyendo el acortamiento de este grupo muscular, principalmente, en la pierna dominante. Los efectos se mantienen hasta la tercera semana una vez finalizada la intervención.

Palabras clave:
Ejercicios de contracción excéntrica. Acortamiento de isquiotibiales. Fútbol. Deportes.

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Introduction

Soccer players are constantly exposed to the risk of sustaining musculoskeletal injuries, with the lower extremity being more affected than the upper one[1]. Greater injury incidence has been reported for youth soccer players than for professionals during training sessions, the most common being of muscular origin[2].

Hamstring injuries are as high as 37%[3], accounting for between 12 to 16% of the total number of soccer-related injuries[4]. Current investigations indicate that approximately 12% of the total of a competition season is lost due to injuries sustained by soccer players[5]. It has also been reported that between 12% to 30% of players suffered re-injury within the first 2 months of returning to sport, which has led to great concern among the leading elite soccer organisations[5]. In this context, it has been reported that hamstring injuries have a high re-injury rate following a return to sports training, reaching 12%[4].

In general, hamstring injuries primarily occur during sprinting, due to an intense and abrupt change from maximum eccentric contraction to concentric contraction during the deceleration of the knee extension6. This occurs in the final stage of the swing phase, causing a lengthening of the muscle structure associated with a load and/or contraction. The most-affected section corresponds to the biceps femoris long head, over the semitendinosus and semimembranosus muscles, due to the fact that their insertion points are the furthest away during the injury mechanism, with the myotendinous junction being the most common anatomical site of injury[6].

The risk of sustaining a hamstring injury is generally multifactorial, where it has been reported that some of the extrinsic factors are associated with training while other are directly associated with competition, however it is agreed that the most common factors are related to insufficient warm-up and muscle over-exertion[6,7]. On the other hand, intrinsic factors include muscle fatigue, decreased strength, agonist/antagonist strength imbalance and a lack of flexibility[6-8]. With regard to flexibility, its contribution to hamstring injuries is not clear, although it has been reported that shortened muscle-tendon units cause a delayed response in the adjacent muscles in the face of destabilizing situations, which could be associated with musculoskeletal injuries[9-11]. Specifically, with regard to hamstrings, the results were controversial and only some authors suggest a relationship between the lack of flexibility and the injury rate in soccer players during a normal season[12]. The differences in investigation findings could be attributed to the different evaluation methods used to measure hamstring flexibility. Hamstring flexibility tests include Straight-Leg-Raising (SLR), Sit and Reach (SR) and active knee extension (AKE). At present, the SLR is primarily intended for neurological evaluation, while the SR is considered unsuitable for hamstring evaluation due to the involvement of the lumbo-pelvic muscles in the test[13]. For its part, the AKE is an active mobility test that appears to be the most valid evaluation, give the fact that it can isolate the flexibility of the hamstring muscles[14]. This test measures the knee extension angle with a 90º hip flexion, with a system in which the femur is in the vertical position. Due to its validity and reliability, the test has been recommended as a good tool for assessing hamstring flexibility[14].

Eccentric contraction exercises could be a prevention mechanism for a range of soccer knee injuries. However, there is little information in the literature on the effects of these exercises on hamstring flexibility. It has been reported that eccentric exercises improve hamstring flexibility, increasing the active knee extension range by 1.67º in adolescents with hamstring shortening, after 6 weeks of rehabilitation, yet showing no differences with traditional muscle stretching techniques[15]. Moreover, it has been seen that the eccentric work of this muscle over a 6 week period, using the Nordic hamstring as the only exercise, improves the eccentric force of the muscle by 25 nm, optimising the kinematics with a more prolonged control in the Nordic hamstring fall of 5.6º and improved neuromuscular parameters during a motor task, increasing the electromyographic activity by 38%[16]. Increased flexibility in other muscle groups, such as the sural triceps, has been demonstrated following a program of eccentric exercise[17]. For their part, Ramirez-Campillo *et al.* (2015) applied a plyometric training protocol with an important eccentric component to a group of youth soccer players for six weeks, observing significant improvements in jump tests, agility, speed and flexibility of the lower extremity[18]. Although there are some investigations that suggest that eccentric exercise has positive effects on flexibility and other muscular parameters, the duration of this change over time has not been clearly described.

Therefore, the aim of this investigation was to determine the short and long term effect of a 6-week eccentric training program on the active knee extension range in youth soccer players.

Material and method

This is a randomised, controlled clinical trial. Simple random sampling was used to assign the participants to either an experimental group (n=19) or control group (n=18).

Participants

Of the 40 youth soccer players aged between 14 to 16 years, at a sports club in the city of Talca (Chile), 37 met the eligibility criteria described in Table 1. All participants were authorised by their legal guardians to participate in the investigation through informed consent approved by the ethics committee of the Santo Tomás University (Chile), observing the basic principles established in the Declaration of Helsinki.

Intervention

The investigation was conducted at the sports club's training field during the competitive period of the 2016 Clausura Tournament, comprising 15 dates with one match each weekend. Both groups (control and experimental) performed their normal soccer training for 5 days a week, consisting in warm-up, physical exercise, technical work, cool-down and stretches, in accordance with a program developed by the physical preparation team. The training sessions lasted 90 min. For 3

Table 1. Eligibility criteria of participants.

Inclusion criteria
- Male soccer players.
- Aged between 14 to 16 years.
- Shortening of hamstring muscles greater than 20º of the active knee extension range in at least one extremity.
- Approval of informed consent by the guardian.
Exclusion criteria
- Hamstring muscle tears, 2 months prior to the investigation.
- LL surgery, 6 months prior to the investigation.
- LL injuries requiring prolonged knee immobilization 1 month prior to the study.
- Musculoskeletal LL injury during the study, making it impossible to continue with the same.

LL: lower limb.

days a week (Monday, Wednesday and Friday), the experimental group was called 15 minutes before training and put through a program of eccentric hamstring exercises directed by a kinesiologist. Prior to this, a 1,000 m warm-up was made at a gentle jog (maximum level 4 according to the modified Borg scale). The design of the eccentric exercises was based on previous experience provided by the literature [6,19-21], with a rest of 1 minute between each set and applied for a 6-week period[15-17] (Table 2 and Figure 1).

Study variable

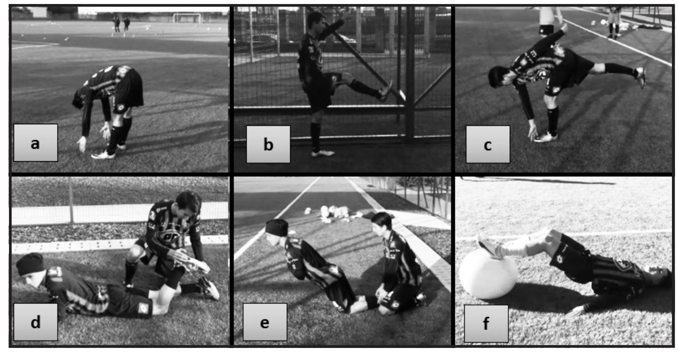
The 37 participants in the trial underwent the measurement of the degree of hamstring shortening through the active knee extension range of the AKE test[14] and measured with an electrogoniometer (Pasco®, Santiago, Chile) for the dominant leg (LD) and non-dominant leg (NDL), determined by the kicking leg. The measurement was taken with the subjects positioned in supine recumbency on a mattress with the hips

Table 2. Guideline for hamstring eccentric contraction exercises.

Week 1	Week 2	Week 3
Bipedal deadweight (3 x 10 rep)	Unipedal deadweight (3 x 8 rep)	Unipedal deadweight (3 x 12 rep)
Controlled kick (3 x 8 rep)	Controlled kick (3 x 12 rep)	Against manual resistance (3 x 8 rep)
Week 4	**Week 5**	**Week 6**
Against manual resistance (3 x 12 rep)	Nordic (3 x 8 rep)	Nordic (3 x 10 rep)
Nordic (3 x 6 rep)	Supine with ball Swiss ball bipedal (3 x 8 rep)	Supine with ball Swiss ball bipedal (3 x 12 rep)

Rep: repetitions

Figure 1. Eccentric hamstring exercises applied to the experimental group. a) bipedal deadweight. b) controlled kick, c) unipedal deadweight, d) against manual resistance, e) Nordic, f) supine with bipedal Swiss ball.



and knees bent at 90º, with the legs resting on a box with handles and a roll under the knees to maintain the femur vertical. The electrogoniometer was positioned with the fulcrum on the inter articular side of the knee, the fixed arm directed at the greater trochanter of the femur and the mobile arm at the lateral malleolus of the ankle, according to the criteria established by the *American Academy of Orthopaedic Surgeons* (AAOS). The measurements were taken over 5 sessions: pre-intervention (SO), third week (S1) sixth week (S2), ninth week (S3) and twelfth week (S4). S3 and S4 were made in the third and sixth post-intervention week respectively.

Statistical analysis

The GraphPadPrism 6.0 program was used for the statistical analysis. The average and standard deviation were considered to describe the general characteristics of the sample (age, weight, height and BMI). To describe the active knee extension range, the median, minimum and maximum values were used. The normality distribution and the homogeneity of variance were calculated using *the Shapiro-Wilk* and *Levenetests respectively. The Kruskall Wallis* nonparametric test was applied to determine differences in the active knee extension range, for the experimental group and the control group. *Dunn's post hoc* test was used to determine the differences between each of the measurements. For all the analyses, a significant value of 0.05 was considered.

Results

Of the 37 players selected, 30 completed the study (15 from the experimental group and 15 from the control group). The baseline characteristics of the soccer players taking part in the investigation are given in Table 3. It should be pointed out that the footballers taking part in the test primarily demonstrated right-leg dominance (93.4% control group and 80% experimental group) and only a small proportion had left leg dominance (6.6% control group and 20% experimental group).

For the control group of youth soccer players that are part of the under 15 and 16 categories, no significant differences were observed in the active knee extension range measured with the AKE test during

Table 3. Baseline characteristics of the sample (mean and standard deviation).

Characteristic	Control (n=15) mean (SD)	Experimental (n=15) mean (SD)
Age (years)	15.00 (0.85)	15.07 (0.80)
Body weight (kg)	65.49 (7.18)	61.8 (4.75)
Bipedal height (m)	1.72 (0.06)	1.70 (0.06)
BMI (kg/m^2)	22.03 (1.45)	21.33 (1.49)

SD: standard deviation; BMI: body mass index; kg: kilograms; m: metres.

the intervention and follow-up for both the DL ($p = 0.314$) and the NDL ($p = 0.309$) (Table 4). For the experimental group, an increase in the active knee extension range was observed for the DL ($p = 0.0001$) and for the NDL ($p = 0.0014$). The *post hoc* test (*Dunn's* test) revealed the following significant differences for the DL: S0 vs S1 ($p = 0.005$), S0 *vs* S2 ($p < 0.001$), S0 *vs* S3 ($p = 0.004$), S2 *vs* S4 ($p = 0.001$). For the NDL, differences were found in the following comparisons: S0 *vs* S1 ($p = 0.008$), and S0 *vs* S2 ($p = 0.006$ (Table 4).

Discussion

The main finding of this investigation shows a positive effect of the eccentric contraction exercises on the muscle length of the hamstring group, as evidenced by an increase in the active knee extension range and quantified through the AKE test with electrogoniometry in youth soccer players (14-16 years) with muscle shortening. This increase in range was achieved following 6 weeks of progressive training with regard to volume, intensity and difficulty, with 3 sessions a week. These results are similar to those obtained by Brughelli *et al.* (2010), who, after an intervention period of 4 weeks, concluded that the eccentric contraction exercises managed to increase the knee range and to lengthen the hamstring muscle in professional male soccer players[20]. These results are similar to those reported by Mahieu *et al.* (2008) with a 6-week training session on calf muscles with 64 voluntary healthy subjects of both sexes and with an average age of 22 years[17]. Exercises of this type have been shown to generate changes in strength, kinematics and neuromuscular parameters in sedentary subjects[16], while in football it has been indicated as a good tool to prevent hamstring injuries[22,23].

The changes in the active knee extension range caused by eccentric exercise could be due to a change in the passive stiffness at the myotendinous junction[24]. It is put forward that increased actin and myosin cross-bridging causes an increase in the calcium ions present in the muscle fibres; these ions are related to the rupture of the muscle cell membrane[24,25]. The process to repair the micro-damage generated by eccentric exercise would cause a restructuring of the connective tissue, increasing the stiffness[24]. However, it is thought that, when the eccentric exercise is repeated for a minimum period of 6 weeks, the passive muscle-tendon stiffness decreases and transfers part of the mechanical restriction of the tendon to the muscle, increasing the series elastic components of the muscle and tendon, improving the muscle length[17,24,26]. Coincidentally, the principal active knee extension range changes in our study are observed in the sixth week of intervention.

It has been reported that an adequate muscle length is one of the principal factors that protect against soft tissue injuries, primarily strains that alter the integrity of the connective tissue and related vascular structures, leading to muscle fibre damage[26]. An optimal length of the hamstring muscles could maintain an adequate amount of sarcomere or contractile units, in parallel and in series, directly influencing the cross-sectional area and permitting a greater recruitment of fibres from this muscle group. This would permit an adequate length-tension relationship and an increase in the lever arm, favouring greater strength production[27,28].

Van Doormaal *et al.* (2017), reported that there was no relationship between the lack of flexibility and a risk of injury, measured with the *sit and reach test*[29]. However, it has been demonstrated that this test is unable to individualise the hamstring muscles from the lumbopelvic muscles[13]. For this reason, it was decided to use the AKE test in this study in order to indirectly assess the hamstring flexibility, due to the fact that, in soccer it has been demonstrated that an adequate assessment of flexibility could be a useful injury prediction tool and that even flexibility work could be an injury prevention strategy[30].

On the other hand, it was observed that, 6 weeks after intervention, the DL or kicking leg had a greater change in the AKER (11.4°) than the

Table 4. Values in degrees for the active knee extension range during the evaluation weeks.

Measurement sessions	Control (n=15) median (min-max)		Experimental (n=15) median (min-max)	
	DL	NDL	DL	NDL
S0	21.2 (16.8 - 44.7)	25.2 (18.2 - 44.7)	27.9 (21.1–37.3)	27.4 (17.5-44.1)
S1	24.7 (18.2 - 43.1)	28.7 (20.9 - 37.2)	20.2 (13.1-42.1)	19.9 (12.3-41.9)
S2	23.6 (17.9 - 36.4)	26.7 (19.9 - 37.9)	16.5 (13.9-23.4)	19.6 (10.3-24.8)
S3	23.9 (18.8 - 43.9)	28.1 (21.2 - 37.8)	20.1 (14.3-33.0)	21.2 (13.4-33.7)
S4	24.3 (17.6 - 38.1)	27.5 (20.8 - 38.4)	23.6 (19.3-33.2)	23.1 (17.9-36.4)

S0: Initial evaluation (pre-intervention); S1: evaluation third week (halfway through intervention); S2: evaluation sixth week (end of intervention); S3: evaluation ninth week (third week of monitoring); S4: evaluation twelfth week (sixth week of monitoring); Min: minimum value; max: maximum value; DL: dominant leg; NDL: non-dominant leg.

non-dominant leg (7.8°). Although it has been reported that the kicking leg is subject to a greater number of muscle injuries in soccer players[31], there is little evidence that compares the results of eccentric exercise between the DL and NDL. The results obtained in this investigation could be explained by the greater neuromuscular adaptation of the dominant leg, as it is constantly used.

In this investigation, the changes start to appear in both legs during the third week of intervention, and this coincides with the changes and architectural adaptations reported for hamstrings (primarily in the fascicle length) from that week onwards with eccentric exercises[32]. On the twelfth week of assessment, no differences were observed in either leg, in relation to the initial assessment, indicating that after 6 weeks of monitoring, during which the players continued with their training and sport competition as usual, the effects achieved in muscle length, caused by eccentric exercise in this study group, were lost. This is contrary to what is maintained by Brughelli *et al.* (2009), who indicates that the effects of eccentric exercise can be maintained for 23 weeks after intervention. However, his investigation was conducted on soccer players with a history of recurrent hamstring injuries and not on players with shortening[20]. Moreover, the activity of the soccer players during these 23 weeks is not sufficiently clear. On the other hand, this investigation specified that the players continued with their training sessions and normal competition matches during the 6 weeks following the intervention. Due to the differences of findings from one investigator to another, it would be interesting to determine the precise moment at which the beneficial effects of the eccentric contraction exercise disappear, an exercise which has been shown to be an active participant in the prevention of sport injuries[6]. This would make it possible to establish the frequency with which these exercises need to be performed in soccer training in order to avoid the shortening of the hamstring muscles, injuries and re-injuries. An investigation reported that a high-intensity plyometric training program performed twice a week could be implemented as a substitute for some exercises within regular soccer practice during the season, given the fact that it was determined that the inclusion of this type of exercises in youth soccer players improved explosive and strength performance in comparison with an isolated soccer training session[33]. Therefore, eccentric exercises could be beneficial not only in the rehabilitation of injured soccer players but also in the regular training of athletes as a method to prevent injuries and improve sport performance.

The limitations of this study include the fact that the sample only considers players from a specific soccer club and excludes the lack of complementary evaluations such as the measurement of the eccentric force through an isokinetic machine, which has been used in prior studies. Despite this, it is important to emphasise that this study was controlled and randomised, strengthening the methodological quality of the investigation.

In conclusion, a progressive intervention of eccentric exercises for the hamstring muscles for a period of 6 weeks, performed during the soccer competition season, generates positive changes in the active knee extension range in youth soccer players, reducing the hamstring shortening. These changes were principally evident in the kicking leg, where their effect was maintained for 3 weeks following the intervention. Due to the potential benefits of eccentric exercises on muscle length, it is recommended to include these exercises in the flexibility programs applied to soccer players. This could also reduce the risk of injury and enhance athletic performance.

Conflict of interest

The authors do not declare a conflict of interest.

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