Range of Motion and Injury Occurrence in Elite Spanish Soccer Academies. Not Only a Hamstring Shortening—Related Problem

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Abstract

Sanz, A, Pablos, C, Ballester, R, Sanchez-Alarcos, JV, and Huertas, F. Range of motion and injury occurrence in elite Spanish soccer academies. Not only a hamstring shortening—related problem. *J Strength Cond Res* 34(7): 1924–1932, 2020—Age-related development of range of motion (ROM) during an active hip flexion (active straight leg raise) and its relationship with hamstring injury occurrence were examined in 1657 young male soccer players (9–18 years of age). Age-related differences in ROM showed a significant decrease from U9 to U11 ($p = 0.001$), from U11 to U13 ($p < 0.005$), and from U9 to U13 ($p < 0.001$), whereas ROM increased from U13 to U15 and from U13 to U18 (both p's < 0.001). Interestingly, younger and older players reached similar ROM values (U9–U18, $p = 0.87$). Higher ROM was found in dominant than nondominant leg in all age groups (all ps < 0.001). No differences related to playing position were found on ROM (all ps > 0.478). During the follow-up period (11 months) 97 hamstring injuries were reported showing higher rates in the older age groups ($p < 0.001$) and outfield players ($p < 0.001$). Remarkably, no differences in ROM average were found between injured players and noninjured players ($p = 0.152$). Our results suggest that ROM during hip flexion does not only depend on the hamstrings shortening but also on the variables related to joint stability, motor control, and hip flexor muscle weakness. Sport scientists in youth sport soccer academies should develop age-specific screening and action plans to develop strength, motor control, and flexibility to optimize ROM and reduce injuries from the grassroots stages.

Key Words: extensibility, flexibility, adolescence

Introduction

The development of physical fitness (strength, endurance, speed, and flexibility) in young soccer players has been extensively studied (28). The methodology of fitness training should be adapted to players' developmental stage and their playing position (24,29). This issue is especially relevant in top-club soccer academies where training process optimization is a key factor for obtaining the highest performance and reduce injuries. Among the physical abilities required in soccer, the necessary range of motion (ROM) of the lower limb joints is very relevant, as it has been associated with the performance of some specific soccer skills (17) and the prevention of lower-body muscle injuries (6), particularly in the hamstrings muscles (49).

According to a Union of European Football Associations (UEFA) report (13), hamstring injuries accounted for 70% of injuries in the lower body and 12% of the total rate, standing out as the most common muscle injury in soccer with a high percentage of relapse (50). Despite of data from many studies having supported the effectiveness of diverse injury prevention programs, the incidence of hamstring injuries has increased annually by 4% since 2001 in professional male soccer players (14), with an augmented risk of injury as the age of the player increases (21).

Hamstring injuries are less prevalent in young soccer players than adults. However, probably due to early specialization (greater demand of competitiveness and an increase in the volume and intensity of training), an increased risk of injuries in the lower extremities (5), especially in the hamstring, has been shown in grassroots football, with peaks at the age of 15 and 17 years (47).

The skeletally immature athlete is involved in a process of epiphysis construction, ossification, and development of support structures (15). At this stage of growth and development, a vigorous eccentric contraction at the myotendinous junction of the hamstrings (very common in sports involving high-speed sprinting and changes of direction) could provoke a hamstring injury and even a traumatic avulsion of the ischial apophysis (18).

Raya et al. (40) showed during one season that hamstrings were the muscle group with the most injury incidence, with higher prevalence in older than in younger players. Similarly, an epidemiological study of thigh muscle injuries in young soccer players (8) observed that although the frequency of hamstring injuries was not related to age, the severity of the injuries was greater as the players grew. In the same line, Valle et al. (47) analyzed hamstring injuries in 1,157 young athletes (6–18 y.o.) belonging to different team sports. In this study, it was observed that hamstrings represented the muscle group with the highest injury incidence (close to quadriceps), specially the semitendinosus and the semimembranosus muscles.

In soccer players, hamstring flexibility is often measured to determine the risk of incurring a hamstring injury (12,42,49). Different studies have shown that poor values of ROM and muscular tightness are 2 of the main intrinsic factors associated with hamstring injury risk (21,49). However, other studies have

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Journal of Strength and Conditioning Research 34(7)/1924–1932

found no relationship between hamstring flexibility and injury incidence neither in adults (12) nor in youth soccer players (42).

Part of the controversy found between the results of different studies could be explained by factors related to the internal and external validity of diverse flexibility testing methods. Therefore, further research using more functional protocols to measure active ROM is needed, not only in the adult population (49) but also for youth athletes during their earlier developmental stages.

Most of the studies on this topic have found higher values of hamstring flexibility in older subjects (35), but they have been conducted using the "sit and reach test." This test has been criticized for being highly influenced by anthropometric factors and for lacking specificity in differentiating the extensibility of the lumbo-pelvic musculature (34). By contrast, Rolls and George (42) showed a reduction in hamstring extensibility by age using the AKE (active knee extension) test, the SKE (sitting AKE) test, the PSLR (passive straight leg raise) test, and the PKE (passive knee extension) test. Nonetheless, other studies have used a more functional soccer-specific test, the "active straight leg raise test" (ASLR) (27,30). Results have shown that the older the age of the athlete, the higher degrees of active flexion ROM. However, these studies were conducted using a reduced sample size which therefore limited the interpretation and generalization of the findings. Therefore, scientific evidence has shown controversial findings about the relationship between the extensibility and growth, suggesting the need of adding more pieces of evidence with larger samples of subjects and more functional tests.

Considering that ASLR actions are typical in many functional and athletic situations, we consider that the ASLR test could be one of the most appropriate assessment procedures for measuring active ROM. The result of this test does not only depend on hamstring extensibility and eccentric antagonist action but also on hip flexor and knee extensor muscles (strength agonist action) (33). An adequate and coordinated activation pattern of these neuromuscular factors make possible to reach an active ROM. Therefore, the ASLR test seems to be a useful tool to study the presence of alterations in movement patterns that could cause injuries in the hamstrings muscles.

Through this study, we aim to provide evidence regarding differences in hip flexion ROM in different age groups (8–18 y. o.), while taking the playing position and the dominant lower limb laterality into research consideration. Moreover, differences in hip flexion ROM between injured and noninjured players will be analyzed.

Methods

Experimental Approach to the Problem

The present prospective study used a cross-sectional design to compare the hip flexion ROM of young soccer players, at different age categories, according to their playing position and lower limb dominance. Moreover, we have conducted a detailed descriptive and comparative analysis of hamstring injuries during the entire regular season, considering variables such as age, playing position, and injury type. Finally, we compared hip flexion ROM differences between players suffering hamstring muscle injuries and players without hamstring muscle injuries.

Subjects

One thousand six hundred fifty-seven young male soccer players (mean ± *SD*; age: mean 12.58 ± 2.65 years, range from 7.88 to 18.79 years) from 122 teams belonging to the football academies of the 5 best soccer clubs in the Valencia region (Spain) were divided up and classified according to their age category (U9, U11, U13, U15, and U18, Table 1). A self-report was used to confirm that all subjects were free from any injury in the lower extremities for at least 2 months before the testing period. The collected data were reviewed and confirmed by the coach and medical staff of each team. Participation in the study was voluntary, but due that the most of subjects were under the age of 18, all subjects and their parents or legal guardians were properly informed of the risks and benefits of the study before any data collection and signed an institutionally approved informed consent document. The study's procedures were approved by the Ethics Committee of the Catholic University of Valencia (2017-2018-08) and in accordance with the Declaration of Helsinki.

Procedures

Maximum active ROM during hip flexion was measured for the dominant and nondominant leg at the beginning of the regular competitive season (October–November). Age, limb dominance (defined as the predominant foot used for kicking a ball in a penalty kick), and playing position were registered in a team document completed by the head coach of each participating team. During the regular competitive season (October–June), data pertaining to hamstring injuries were registered prospectively by the coach, physiotherapist, or medical physician of each corresponding team/club.

Hip Flexion Range of Motion Assessment: Active Straight Leg Raise Test. One of the main purposes of the ASLR test is to measure hamstring tightness (34) and active hip mobility while simultaneously looking at core stability and motor control of the trunk while maintaining a stable pelvis (23). Testing was performed in the first training session of the microcycle, located at least 48 hours later than previous training session or competition match. All subjects were cited 30 minutes before the training session and were assessed in the medical area of their club's training facilities between 5:00 and 8:00 PM under similar temperature conditions, ranging from 16 to 23° C. Following the

Table 1
Distribution of the sample of subjects by the age group and playing position.

Age	Teams (*n* = 122)	GK (*n* = 166)	DEF (*n* = 584)	MID (*n* = 356)	FOR (*n* = 551)
U9 (*n* = 334)	29	37	130	63	104
U11 (*n* = 384)	34	47	132	73	132
U13 (*n* = 408)	26	29	143	96	140
U15 (*n* = 342)	20	31	114	82	115
U18 (*n* = 189)	13	22	65	42	60

DEF = defenders; FOR = forwards; GK = goalkeepers; MID = midfielders.

recommendations established by Muyor and Arrabal (33) and to avoid any fatigue effect, warm-up was not performed before the testing. The subject lied down in a supine position on the physiotherapy table with both lower extremities extended, with both hands placed on the chest. The location of virtual markers to determine the hip joint angle during data analyses was done by the examiner's palpation of the subject's greater trochanter. After the location, the examiner placed the index finger over this anatomical point for 3 seconds while the subject executed a slow hip flexion movement. This procedure was repeated previously to the ASLR test in both right and left legs. After that, from this position, the examiner (located on the opposite side to the camera) fixed the leg not involved with one hand and placed the other hand under the lumbar spine to detect the posterior pelvic tilt (retroversion) (34). Then, the subject was asked to actively and slowly flex the contralateral hip with the leg totally extended for approximately 3 seconds with the ankle in a relaxed position to minimize the influence of the gastrocnemius muscles (3), while the opposite knee remained extended (Figure 1). The final position was determined when the athlete reported tension in the hamstring and was unable to continue the lift or at the moment the examiner felt that the pelvis started to tilt posteriorly (palpable onset). The subjects were encouraged to hold this static maximum ROM position during 3 seconds. Two ASLR tests were performed for each leg, with 10 seconds of resting intervals between them. The procedure was simultaneously recorded with a stationary (tripod set) high-speed digital video camera (Sony HXRNX5U NXCAM; Sony, Corp., Minato, Tokyo, Japan) at 240 fps (4). The camera was located in parallel to the sagittal plane at a distance of approximately 3 meters from the edge of the examination table, in a position that allowed the hip and ankle joints to be centered in the filming scene. The camera lens and table surface were adjusted to have the same distance from the floor. The focal length of the lens was adjusted so that the hip joint, the thigh, and ankle of the raised leg could be viewed to coincide with a previously published procedure (31).

Measuring Range of Motion Using the Kinovea Method. The camera recordings were subsequently analyzed using open-license video analysis software (Kinovea 0.8.15 for Windows), and the procedure was conducted in accordance with a previously published modus operandi (31). Following the criteria indicated by Grigg et al. (19), we determined the ROM using virtual markers located on the greater trochanter of the femur (axis of rotation) and on the peroneal malleolus (see procedure described in the previous section). One arm of the angle was aligned from the axis of rotation to the peroneal malleolus, and the other one was aligned parallel to the table surface (Figure 1). Because the objective was to detect the greatest angle of hip flexion (sustained static position) to facilitate the treatment of the images and the calculation of the angles, we used Kinovea to reduce the frequency of the video sample rate from the originally 240 to 60 fps (each frame is about 16 ms). Afterward, a full-leg and hip angle raise was visually determined, frame by frame, until the greatest distance was achieved and maintained, for at least 10 frames (160 ms). At that point, the frame was frozen, and the angle tool was used to determine ROM.

The highest value obtained from the 2 tests in each limb was annotated to statistical analysis. Six observers were trained for 2 weeks (two 2-hour sessions per week) to determine precisely the

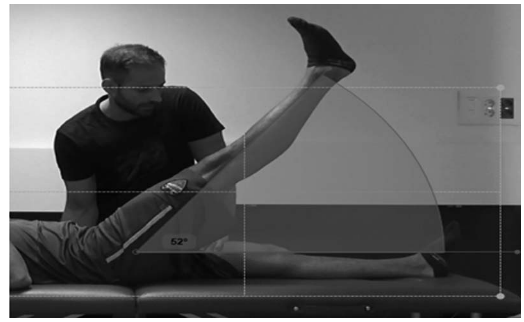

Figure 1. Experimental procedures for measuring the range of motion during the ASLR test. Range of motion was calculated using Kinovea software. ASLR = active straight leg raise.

anatomical reference point and markerless movement analysis using Kinovea software. The intraclass correlation coefficients (ICCs) were calculated for interrater reliability (44), showing very high values (ICC = 0.994; 95% confidence interval [CI] = 0.991–0.999). Absolute differences between the 6 observers ranged from 0.65 to 4.7° ($\bar{X}$ = 2°).

Assessment of Hamstring Injuries During the Season. According to Ekstrand et al. (14), a recordable hamstring injury was defined as a traumatic distraction or overuse injury to the hamstring muscle group (the musculotendinous complex of biceps femoris, semitendinosus, and semimembranosus), including both first-time and recurrent injuries. Each injury/discomfort in the players' hamstrings was diagnosed and validated through clinical judgment by the club's medical staff according to the consensus statement established by Fuller et al. (16), this being, "*Any physical complaint sustained by a player affecting the posterior side of the leg that results from a match or training session, irrespective of the need for medical attention or time lost from sports activities*." All injury characteristics were initially registered by team coaches in detail on an annotation form designed for this study. This survey was designed considering previous recommendations established by Askling et al. (2) and adding some items according to the suggestions obtained from different coaches, physiotherapists, or doctors from the clubs participating in the study. Finally, the survey also included data gathering about the nature of the hamstring injury (muscle overload, muscle contracture, muscle strain, or muscle rupture), along with the player position (goalkeeper, defender, midfielder, or forward) and age group. Player injuries were prospectively collected from October 2016 to the end of June 2017, inclusive.

Statistical Analyses

The Kolmogorov-Smirnov test was used for each variable showing that data were normally distributed. Dependent 2-sample *t*-tests were used to analyze ROM differences between the dominant leg and nondominant leg. Differences in hip flexion ROM by age groups and the by playing position were assessed using 1-way analysis of variances (ANOVAs). One-sample chi-square tests (χ^2) were used to investigate differences in hamstring injury distribution by age, playing position, and nature of injury. Independent 2-sample *t*-test analysis compared the hip flexion ROM in players who were injured against those who were not injured. To be able to achieve this, considering the size of the sample and the low number of players injured, a stratified random sampling with proportional affixation at the U15 and U18 groups (with the highest incidence of injury) was used.

Effect sizes were computed using Cohens's *d* for *t*-test analysis, Cramer's *V* for chi-square test, and partial eta-squared (η^2) for 1-way ANOVAs. Statistical significance was set at $p \leq 0.05$. Significant main effects were further analyzed by multiple independent- or paired-sample *t*-tests (depending on the analysis) and corrected by using the post hoc Bonferroni test for multiple comparisons, i.e., 0.05 divided by the number of comparisons. Results were reported as mean ± *SD* and 95% CI. All statistical analyses were analyzed using Statistica for Windows (version 8; StatSoft, Inc, Tulsa, OK).

Results

Active Straight Leg Raise Test Range of Motion

Descriptive values of ROM during hip flexion by age, playing position, and lower-limb dominance using the ASLR test are presented in Table 2. Dependent 2-sample T-test showed higher ROM values at the dominant (56.23 ± 8.60, 95% CI = 56.64–55.81) than nondominant leg (54.90 ± 8.61, 95% CI = 55.31–54.48) in all ages (t (1,656) = 11.32, $p < 0.001$, $d = 0.27$).

Analysis of variance revealed significant differences by the age group in ROM considering both legs (F (4, 1,652) = 12.152, $p < 0.001$, $\eta_p^2 = 0.029$) and contemplating dominant (F (4, 1,652) = 11.643, $p < 0.001$, $\eta_p^2 = 0.029$) and nondominant (F (4, 1,652) = 10.806, $p < 0.001$, $\eta_p^2 = 0.029$) independently. The independent *t*-test showed ROM decreasing from U9 to U13 ages (from U9 to U11, −1.89° (t (716) = 3.23, $p < 0.005$, $d = 0.23$), from U9 to U13, −3.66° (t (740) = 6.45, $p < 0.001$, $d = 0.45$), and from U11 to U13, −1.77° (t (790) = 3.11, $p < 0.005$, $d = 0.22$)). However, remarkably, this trend stopped starting right after the onset of the U13 ages, observing improvements in hip flexion ROM from U13 to U18 (from U13 to U15, +2.45° (t (748) = 4.11, $p < 0.001$, $d = 0.30$), from U13 to U18, +3.78° (t (595) = 5.09, $p < 0.001$, $d = 0.46$), and from U15 to U18, +1.32°, but not significant (t (529) = 1.66, $p = 0.096$)). Interestingly, there were no significant differences in ROM between the younger and older players (U9–U18, 0° (t (521) = 0.15, $p = 0.87$); U9–U15, 1.21° (t (674) = 1.99, $p = 0.04$); U11–U18, 2° (t (571) = 2.62, $p = 0.009$); or U11–U15, 0.56° (t (724) = 1.10, $p = 0.27$) (Figure 2).

No differences related to playing positions were found in ROM (considering both legs and contemplating their dominant and nondominant [all p's > 0.478]).

Hamstring Injuries' Occurrence

During the study period, 97 hamstring injuries were documented. Eight players reported 2 injuries, and 81 players reported 1 injury. Table 3 shows the distribution of hamstring injuries across the age group, playing position, and nature of injury. One-sample chi-square analyses showed that the age group modulated the prevalence of injuries (χ^2 (4) = 31.71, $p < 0.001$, $V = 0.28$), revealing that 66% of injuries were observed in older ages (U15 = 33% and U18 = 33%), although these age groups represented only 32% of the total sample of the study. The remaining 34% of injuries occurred in ages younger than 13 years of age (U9 = 4%, U11 = 12% and U13 = 18%),

Table 2
Subject's ROM in ASLR test by the age group, leg dominance, and playing position (Mean ± *SD*).*

Age	ASLR D (°)					ASLR ND (°)					Mean (°)
	All	GK	DEF	MID	FOR	All	GK	DEF	MID	FOR	All
U9	57.85 ± 8.03†	56.78 ± 9.10	57.78 ± 7.40	58.03 ± 7.56	58.21 ± 8.71	56.43 ± 7.88†	56.08 ± 8.12	56.23 ± 6.87	57.07 ± 7.79	56.43 ± 9.04	57.14 ± 8.19
U11	56.01 ± 8.40†	56.36 ± 9.65	55.58 ± 8	56.12 ± 8.64	56.27 ± 8.27	54.49 ± 8.44†	55.06 ± 8.23	54.23 ± 8.67	55.04 ± 8.61	54.24 ± 8.26	55.25 ± 8.26
U13	54.05 ± 8.14†	54.13 ± 9.36	52.88 ± 8	53.25 ± 7.95	55.77 ± 7.93	52.90 ± 8.33†	53.89 ± 8.95	51.74 ± 8.01	51.93 ± 8.59	54.53 ± 8.14	53.47 ± 8.24
U15	56.60 ± 8.75†	56.58 ± 8.67	57.44 ± 9.03	56.60 ± 7.99	55.78 ± 9.05	55.25 ± 8.64†	55.74 ± 9.23	56.27 ± 9.36	55.32 ± 7.59	54.06 ± 8.40	55.93 ± 8.27
U18	57.82 ± 9.67†	59.5 ± 9.19	58.23 ± 8.76	56.97 ± 8.66	57.31 ± 11.43	56.69 ± 9.78†	59.63 ± 8.02	57.41 ± 8.98	54.37 ± 8.83	56.35 ± 11.5	57.25 ± 8.25
Total	56.23 ± 8.60†	56.52 ± 9.25	56.08 ± 8.39	55.89 ± 8.26	56.52 ± 8.85	54.90 ± 8.61†	55.81 ± 8.56	54.83 ± 8.53	54.55 ± 8.41	54.92 ± 8.83	55.57 ± 8.27

*ASLR D = active straight leg rise dominant; ASLR ND = active straight leg rise nondominant; DEF = defenders; FOR = forwards; GK = goalkeepers; MID = midfielders; ROM = range of motion.
†Significant ($p < 0.001$) differences between the dominant and nondominant leg in each age group.

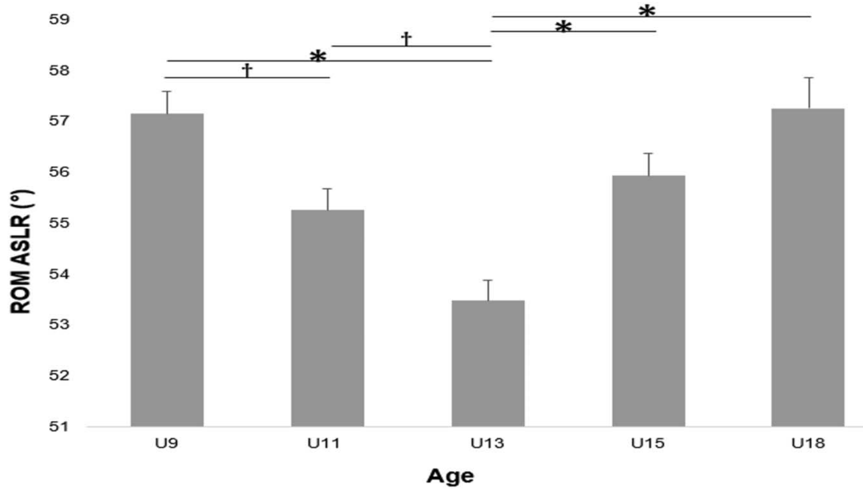

Figure 2. Mean ROM values in ASLR (obtained from dominant and nondominant leg) by the age group. Error bars represent *SE*. *Significant ($p < 0.001$), †significant ($p < 0.005$). ASLR = active straight leg raise; ROM = range of motion.

which represented 68% of the total sample of the study. The multiple comparison of frequency injuries among age groups was significant between the younger and older players (U9–U13 (χ^2 (1) = 8.09, $p < 0.005$, $V = 0.62$); U9–U15 (χ^2 (1) = 21.77, $p < 0.001$, $V = 0.77$); U9–U18 (χ^2 (1) = 21.77, $p < 0.001$, $V = 0.77$); U11–U15 (χ^2 (1) = 9, $p < 0.005$, $V = 0.45$); U11–U18 (χ^2 (1) = 9, $p < 0.005$, $V = 0.45$)).

On the other hand, chi-square analyses revealed that the observed frequency of injuries varied according to the playing position (χ^2 (3) = 33.94, $p < 0.001$, $V = 0.33$), showing that goalkeepers suffered significantly fewer hamstring injuries (2%) than outfield players (43% defender (χ^2 (1) = 36.36, $p < 0.001$, $V = 0.52$), 26% midfielder (χ^2 (1) = 19.59, $p < 0.001$, $V = 0.85$), and 29% forward (χ^2 (1) = 22.53, $p < 0.001$, $V = 0.5$). Regarding the distribution of injuries among outfield players, there was no significant difference between the observed and expected frequency (χ^2 (2) = 5.20, $p = 0.07$). Defender—forward (χ^2 (1) = 2.80, $p = 0.09$), defender—midfielder (χ^2 (1) = 4.31, $p = 0.03$), and midfielder—forward (χ^2 (1) = 0.16, $p = 0.68$). Concerning the nature of injury, our results revealed a differential distribution of the injuries (χ^2 (3) = 29.10, $p < 0.001$; $V = 0.32$), showing that the most recurrent injury was overload (48%), followed by strain (25%), contracture, and muscle rupture (both 15%).

Table 3

Distribution of hamstring injuries by age, playing position, and nature of injury.*

	Playing position			Nature of injury					
Age	GK	DEF	MID	FOR	OVER	CON	STR	RUP	
U9 (4)	4%	0	2	2	0	3	1	0	0
U11 (12)	12%	0	6	1	5	5	1	4	2
U13 (17)	18%	0	5	10	2	9	2	3	3
U15 (32)	33%	2	12	6	12	12	6	9	5
U18 (32)	33%	0	17	6	9	18	5	4	5
Total (n = 97)		2	42	25	28	47	15	20	15
		2%	43%	26%	29%	48%	15%	21%	15%

*CON = muscle contracture; DEF = defenders; FOR = forwards; GK = goalkeepers; MID = midfielders; OVER = muscle overload; RUP = muscle rupture; STR = muscle strain.

Range of Motion Differences Between Injured and NonInjured Players

To compare hip flexion ROM in players who were injured against those who were not injured, ROM from 57 injured players of the age groups with the highest incidence of injury (U15, $n = 342$, 30 injured, and U18, $n = 189$, 27 injured) were compared with the hip flexion ROM obtained from a random and stratified sample ($n = 57$) obtained from the noninjured players of these same age groups (U15, $n = 22$ and U18, $n = 35$). T-test analyses showed no statistically significant differences between groups in the mean ROM value, obtained from both legs (t (112) = 1.44, $p = 0.152$), or any statistically significant differences from each ROM value pertaining to the dominant leg (t (112) = 1.43, $p = 0.153$) and the nondominant (t (112) = 1.37, $p = 0.17$) (Table 4).

Discussion

To date, very scarce data have been collected concerning the evolution of the ROM throughout all the stages of the soccer training process. Some previous studies were conducted on age groups from 11 to 14 years of age (27,30), these having used small sample sizes which limited the interpretation and generalization of the findings. Along the same line, some previous studies also used questionable data collecting methods, such as the sit and reach test (35), which have also been questioned and criticized from a methodological point of view.

The results of this study conducted on 5 elite soccer academies have shown that age development modulates the ROM during hip flexion, in both the dominant and nondominant leg. Notably,

Table 4

Subject's ROM in ASLR by injury occurrence and leg dominance (mean ± *SD*).*

Leg	Injured ($n = 57$)	Noninjured ($n = 57$)
DL	60.1 ± 10.29	57.0 ± 12.15
NDL	59.1 ± 9.21	56.3 ± 11.98
MEAN	59.6 ± 9.49	56.7 ± 11.83

*ROM = range of motion; ASLR = active straight leg raise; DL = dominant leg; NDL = nondominant leg.

our results reported a change of trend in the U13 age group, showing a significant decrease in ROM from this 9- to 13-year-old age group (−3.66°). At this stage (U13), the trend is reversed, and the ROM starts to increase (+3.78° from U13 to U18).

Our findings could be explained by the evolutionary development of the different physical abilities of the young athlete, taking into consideration that the maximum growth peak for strength is experienced around 12–13 years of age (36). In this sense, Lloyd et al. (27) using the Functional Movement Screen test (FMS) determined that the post-peak height velocity groups (U16 and U18) were the ones that achieved the best scores in the different FMS tests. In the same vein, Marques et al. (30) reported the lowest ROM values for their youngest age group, in this case U15, compared to U16 and U18. These findings are in line with those observed in our study from the age ranges of U13 to U18. By contrast, Rolls and George (42) observed a decrease in hamstring flexibility in the oldest group of a reduced sample of players 9–19 years old (n = 93) using the AKE test, SKE test, PSLR test, and PKE test. The divergence with our findings could be accounted by factors related to the variability of the results due to a small sample size. It is important to note that these controversial results could be explained by the type of tests used and the muscles involved in the actions that determined the ROM, taking into consideration the active or passive engagement to achieve the maximum ROM and strength and motor control requirements of the ASLR test (22).

Considering hamstring extensibility as one of the modulating factors of ROM, similar results to those observed in our study have been described with players 10–22 years old, showing lower ROM values in players from the U12 age group than those players from younger and older groups (35). However, when comparing these results with ours, we must highlight that the test used in the aforementioned study was the Sit & Reach test. According to Muyor et al. (34), the values observed in this test are affected by the multisegmental mobility of the spine and pelvis. Furthermore, the authors recommended the ASLR test (used in our study) as an appropriate test for the assessment of hamstring flexibility in school-aged children.

It is important to note here that the ASLR test is more than a simple hamstring test. It is clear that the extensibility of the hamstring on the lifting will affect the ASLR test outcome, and also, the demands of certain levels of strength and activation on the flexor (psoas, anterior iliac, rectus femoris, and adductor longus) and stabilizer (gluteus medius, erector spinae, and abdominal muscles) hip musculature will be determinant. Thus, our pattern of results could be explained by the fact that the older groups (U15 and U18) are in a moment of special development of the strength capacity (the postpeak height velocity period) (27). This fact allows older players to achieve a greater activation of the agonist, subsequently increasing the ability to raise the thigh higher.

Other factors that may contribute to the interpretation of our results would be those related to motor control and intermuscular coordination between the agonist, antagonist, synergist, and fixator muscles of hip flexion with knee extension and maintaining the isometric position during the time required in the ASLR (23). Although the measurements were being taken, we observed the players' difficulties, especially in the younger age groups, in performing the straight leg raising movement and keeping the leg stable within the sagittal plane. Compensations with rotation (internal and external) and with hip abduction and adduction were observed. Although it would be interesting to perform further studies aiming to better know how the variables linked to control-stabilization of movement modulate the strength and ROM level at these ages, we consider that in the early stages of development (U13 and younger), the young athlete has not yet reached adequate proprioceptive capacities to maintain functional stability of the joint, unlike the older groups (U15 and U18), which due to a maturational development of stability and gained strength, would have already improved this capacity (30).

Regarding the observed asymmetries between the dominant and nondominant leg on ROM values (range from 0 to 27°, with an average of 1.33° and mean *SD* of 4.78°), our results are in line with those observed in previous studies using the ASLR test, such as Henderson et al. (21) (+3° in the dominant leg). These asymmetries could be associated with factors related to the greater frequency of repetition of the technical pass and striking movements by the dominant leg (10), which would imply greater development of strength at the hip flexors and knee extensors, united with the eccentric action of the hamstring musculature, whereas the nondominant leg has the main role of providing postural support.

In relation to this, it should be noted that the average error of interobserver measurement was 2°, similar magnitude to the difference between the ROM of the dominant leg vs. not dominant (Table 2). It should be noted that the strict procedure followed in the training of the evaluators guarantees the high level of reliability of the measure, and that the error detected in our study is similar or less than in previous studies that used direct measurements using goniometry (gold estandar), from 3 to 4° (39). In addition, this error of precision would affect equally in all subjects and experimental conditions, so we consider that it does not affect the validity and interpretation of the clinical relevance of the results obtained. Therefore, it is unlikely that these data are only attributable to the variability of the measurement and could represent clinically relevant differences, although in our study we cannot confirm it. In this way, the significant differences in ROM detected in our study can be related to increases in the risk of injury described in previous studies. Bradley and Portas (6) reported that players injured during the season showed lower values of ROM (about 3°) in flexor muscles of the knee than noninjured players. Similarly, Henderson et al. (21) observed that the active hip flexion ROM was higher on the dominant limb than the nondominant (3°). Results from this last study show that for every 1° decrease in the ASLR test, the odds of sustaining a hamstring injury increased ×1.29.

We suggest that as it has been performed in our study, the investigations conducted in this area cite the errors of inter observer and intraobserver measurement to be able to interpret the level of accuracy and clinical validity of the results obtained.

Finally, our results have shown an absence of significant ROM differences associated with specific player position. Conversely, in a study with 296 male subjects (from 10 to 13 years of age), Portes et al. (37) showed that there were higher flexibility values (sit and reach) in goalkeepers than in players from other positions. However, despite the limitations of the Sit & Reach test mentioned previously, these results are in line with those found in our U18 age group (a trend that did not reach significance, possibly due to the small number of players in this demarcation, 22 goalkeepers vs. 167 field players). These results could be determined by individualistic and specific training methods developed by goalkeepers, from an early age onwards, which require actions of great amplitude in different anatomical locations. On the other hand, Sporis et al. (45), through the ASLR test with the left leg, determined statistically significant differences between the midfielders and attackers (1.67°), giving relevance to this difference because the attackers perform a larger number of high-intensity sprints and perform more kicks than midfielders. In addition, they report a difference of +2° with the right leg in midfielders against the attackers and defenders. Authors attributed this difference to that the midfielders make the most changes of direction during a game.

During the study follow-up period, only 97 hamstring injuries were documented, showing a lower prevalence index than older professional soccer players (14,50). Regarding youth soccer, Raya et al. (40) recently described the incidence of muscle injuries over 1 complete regular season in a Spanish professional soccer academy, showing that hamstrings were the muscles with the highest incidence of injury at these earlier ages. Previously, Rolls and George (42) reported that 16 of 93 sample subjects (17%) experienced at least 1 hamstring muscle injury ($n = 20$ hamstring injuries) during 1 competitive season (10 months). The divergence with the lower injury rate observed in our study could be related to the fact that in our study, the preseason period was not included, being preseason a particular period with a higher prevalence of hamstring injuries (9). In addition, we must take into consideration that our study was conducted with a sample of subjects from the 5 best soccer academies in the region, which implies a higher qualified level required for all professionals (26) responsible for the design and supervision of the training process (Training Methodology Departments) as well as those professionals in charge of injury prevention and treatment (Health and Medical Departments).

Regarding the age distribution of injuries, our results showed that the older the age, the higher the incidence of hamstring injuries (U15 and U18 accumulated 66% of total injuries compared with only 16% in the U9 and U11 age groups). These results match with those observed by Rolls and George (42), showing the highest percentage of injuries in the U17–U19 ages and the lowest frequency in those younger than 9–10 years of age. Similarly, Raya et al. (40) recently replicated the observation of higher prevalence of injured hamstrings in older players (senior, U19, and U16) than in players at the younger stages. Our results are also supported by recent epidemiology studies determining age as a risk factor in children's soccer (43). The observed rising in frequency and severity of hamstring injuries with growth and maturation could be explained by endogenous factors such as the elastic, viscoelastic, and contractile properties of the tendinous and muscular tissues and structures (25). Other reasons may be due to the fact that at these older ages, players workout during longer training sessions (increased volume of soccer training) using higher workloads (5,41) and performing more running at very high speeds (20), which is the principal mechanism of harm in hamstring injuries (7). In addition, another very remarkable issue that could better support this pattern of results is the rise of premature sports specializations (38) and an insufficient or ineffective design of preventive programs to avoid injury at younger ages, which could cause problems to appear in higher categories (46).

Regarding the severity of the injuries, in the current study, muscle overload (48%) was by far the most commonly diagnosed injury, followed by strain (25%), contracture (15%), and muscle rupture (15%). Muscle rupture, considered the most serious injury in this study, occurred more frequently in U15 and U18 ages groups. Our results point in the same direction as previous studies showing that the proportion of severe injuries in hamstrings increases with the age of the player (8,40). Indeed, recent studies reported the most severe injury rate is at the U15 age group, an age period with rapid growth (41), when volume and intensity of training are increased, in comparison with younger age groups (38).

Concerning the incidence of hamstring injuries relative to the player's position in the field, we observed that goalkeepers sustained fewer hamstring injuries than outfield players. These results match those described by Woods et al. (50) who attributed this fact to the different patterns of motor actions and skills executed by the goalkeepers. Our descriptive results show that defenders suffered the most injuries and midfielders the least; whereas, conversely, Dauty et al. (11) observed that there were higher injury rates from midfielders than defenders in adult players. This difference with respect to our results may be due to the younger age groups of our sample.

Finally, our study explored the differences between hip flexion ROM in injured players compared with that of noninjured players. No significant differences in ROM between groups were found. We suggest that at least in young soccer players belonging to top-level academies, ROM during hip flexion does not seem to be an independent and consistent mediator in hamstring muscle injuries. This lack of statistical differences in ROM between the injured and the noninjured groups supports the results observed by Rolls and George (42). However, in this study, a tendency of a shorter hamstring amplitude in AKE (5.5–9.1°, respectively) and SKE (9.9–11.3°, respectively) was observed in injured athletes compared with noninjured athletes. However, the reduced number of subjects, the test used, and the fact that all the players belonged to a single soccer club may limit the extrapolation and the comparison of these results.

The absence of difference in ROM between the injured and the noninjured groups could also be supported by Arnason et al.'s findings (1), showing that at least in elite soccer players, a hamstring flexibility training program had no effect on the incidence of hamstring strains during 1 season. By contrast, Witvrouw et al. (49) analyzed the hamstring flexibility of 146 professional players during the preseason reporting that players who had suffered some injury in this muscle showed significantly lower values of hamstring flexibility. These controversial data require further research in this line, more precisely controlling the characteristics of the sample, the evaluation techniques, the relevance of strength and flexibility training loads, as well as other variables that affect hamstring injuries (21).

To conclude, we suggest that although hip flexion ROM is not significantly related to the injury rate of the hamstring, this is not a sufficient reason for disregarding the development of the different components of joint mobility (flexibility of the hip extensor musculature, flexor muscle strength, and motor control of muscles involved in synergies and stabilization). The intermittent nature of the actions that occur during a soccer match (high-intensity short sprints, with sudden turning and increasing or decreasing of speed, etc.) may lead to excessive muscle tightness (12), which may be an intrinsic risk factor in the prevalence of muscle injuries (7).

An early sport specialization and an insufficient or ineffective injury prevention program design may lead to the appearance of these problems at younger ages and could increase the incidence of medium- to long-term alterations in the rachis morphology (32).

Practical Applications

The present findings should encourage soccer coaches and sport scientists to implement, from the early stages onward, programs of preventive, compensatory, and neuromuscular awareness to develop optimal levels of motor control, strength, and extensibility. We suggest the inclusion of testing active hip flexion ROM of young soccer players, during preseason, to identify players with a low or decompensated active ROM and to prescribe an appropriate and individualized training program. It would be advisable that strength and conditioning coaches include routines of strengthening exercises of the hip flexors to prevent them from weakening and tasks demanding active extensibility of the posterior musculature of the leg to avoid excessive stiffness, during the grassroots stage, especially at the prepeak height velocity period age. On the other hand, because there is a greater incidence of hamstring injuries in older groups, it would be convenient for S&C trainers to prioritize prevention tasks during training sessions. Eccentric hamstring muscle training exercises combined with stretching seems to be a good option for preventing hamstring injuries in adult soccer players (1). These initiatives could help reduce the magnitude of lost ROM later ages, contributing to the reduction of risk factors and improving the development of the physical and technical—tactical abilities of the soccer player.

Acknowledgments

The authors acknowledge the soccer players who participated in this study. The authors thank Valencia Club de Fútbol, Villarreal Club de Fútbol, Levante Unión Deportiva, San José CF, and Alboraya Unión Deportiva for their support and collaboration in this study. The authors thank Dr. Daniel Sanabria from the University of Granada for his help with statistical analyses. Authors have no professional relationship with the clubs, companies, or manufacturers who will benefit from the results of this present research study.

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