Original Paper DOI: 10.5604/20831862.1077554 Biol. Sport 2013;30:281-288

THE EFFECTS OF INJURY PREVENTION WARM-UP PROGRAMMES ON KNEE STRENGTH IN MALE SOCCER PLAYERS

Accepted for publication 26.05.2013

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ABSTRACT: The study investigates the effects of the 11+ and HarmoKnee injury prevention programmes on knee strength in male soccer players. Under-21-year-old players (n=36) were divided equally into: the 11+, HarmoKnee and control groups. The programmes were performed for 24 sessions (20-25 min each). The hamstrings and quadriceps strength were measured bilaterally at $60°\cdot s^{-1}$, $180°\cdot s^{-1}$ and $300°\cdot s^{-1}$. The concentric quadriceps peak torque (PT) of the 11+ increased by 27.7% at $300°\cdot s^{-1}$ in the dominant leg ($p<0.05$). The concentric quadriceps PT of HarmoKnee increased by 36.6%, 36.2% and 28% in the dominant leg, and by 31.3%, 31.7% and 20.05% at $60°\cdot s^{-1}$, $180°\cdot s^{-1}$ and $300°\cdot s^{-1}$ in the non-dominant leg respectively. In the 11+ group the concentric hamstring PT increased by 22%, 21.4% and 22.1% at $60°\cdot s^{-1}$, $180°\cdot s^{-1}$ and $300°\cdot s^{-1}$, respectively in the dominant leg, and by 22.3%, and 15.7% at $60°\cdot s^{-1}$ and $180°\cdot s^{-1}$, in the non-dominant leg. In the HarmoKnee group the hamstrings in the dominant leg showed an increase in PT by 32.5%, 31.3% and 14.3% at $60°\cdot s^{-1}$, $180°\cdot s^{-1}$ and $300°\cdot s^{-1}$, and in the non-dominant leg hamstrings PT increased by 21.1% and 19.3% at $60°\cdot s^{-1}$ and $180°\cdot s^{-1}$ respectively. The concentric hamstrings strength was significantly different between the 11+ and control groups in the dominant ($p=0.01$) and non-dominant legs ($p=0.02$). The HarmoKnee programme enhanced the concentric strength of quadriceps. The 11+ and HarmoKnee programmes are useful warm-up protocols for improving concentric hamstring strength in young professional male soccer players. The 11+ programme is more advantageous for its greater concentric hamstring strength improvement compared to the HarmoKnee programme.

KEY WORDS: the 11+, HarmoKnee, knee, professional soccer player, isokinetic strength

INTRODUCTION

Soccer is one of the most commonly played sports in the world with 265 million male and female players or 4% of the world's population that is actively involved in the game of soccer [1]. It is a contact sport and challenges physical fitness by requiring a variety of skills at different intensities [28]. Unfortunately, the game is also associated with a high risk of injuries in the lower extremities, which results in significant costs for the public health system and may even cause long-term disability for the injured player [33,40].

A study has described incidence rates of soccer injuries among young athletes ranging from 2.3 to 6.4 injuries per 1000 athlete-exposure hours [33]. Serious knee injuries, such as anterior cruciate ligament injuries, are of particular concern in team sports. Consequently, there is every reason to emphasize the prevention of knee injuries in soccer, and to develop and implement prevention programmes for young players as early in their career as possible [38].

There are two major categories of risk factors: intrinsic athlete related and extrinsic environment related. An important point is that the risk factors can also be divided into modifiable and non-modifiable factors. Although non-modifiable risk factors such as gender and age may be of interest, it is necessary to investigate the factors which are potentially modifiable through intervention programmes, such as strength, balance, and flexibility [3]. One of the factors that is very important in knee injuries and lower body injuries is strength of the muscles surrounding the knee. The essential functions of these muscles are to protect, support and stabilize joints of the skeletal system. Inadequate strength of these muscles is associated with injuries [4,23]. Therefore, strength enhancement is one of the most important intrinsic factors in preventing injuries as well as re-injuries especially in the lower body [4,23]. Isokinetic testing enables precise muscle strength assessment in athletes, which could in turn be used in injury prevention programmes [12,13].

Kirkendall et al. [21] reported that a warm-up programme has been effective at preventing common injuries in soccer. Two widely used injury prevention programmes incorporated in warm-ups in soccer are the 11+ and HarmoKnee programmes [19, 34]. The FIFA Medical and Research Centre (F-MARC) developed, in cooperation with the Oslo Sports Trauma & Research Center and the Santa Monica Orthopedics & Sports Medicine Center, the 11+ injury prevention programme for soccer players. The 11+ programme, which is an advanced version of the 11, was shown to reduce the prevalence of knee injuries in female soccer players (33 injured players compared to 47 in the intervention group and control group, respectively) [34]. Recently Kiani et al. [19] proposed another warm-up programme for female soccer players which showed 77% reduction in knee injury incidence [19].

Recently, studies reported positive effects of the 11+ and HarmoKnee programmes on balance and proprioception risk factors [7] and influence of the 11+ on improvement of static and dynamic balance [36] on soccer players. Another investigation using the 11+ programme showed that female soccer players with high adherence in the supervised 11+ group had 57% lower injury risk compared to the players with low adherence [37]. Several studies have successfully incorporated one or more exercise components, including plyometric, balance, proprioceptive, strength, running and cutting movement patterns, to prevent injuries in female soccer players [14, 16, 24-27], but, unfortunately only a few are related to male soccer players [1, 4, 9]. Ironically, 90% of registered players are men and also the greater number of soccer players are young soccer players, who constitute 54.7% of all registered male players [1]. Hence it is important to provide some information on the effect of an exercise programme on the strength affecting knee injuries among young male professional soccer players. We attempted to elucidate the difference in strength gain between the two programmes following an 8-week training period. The aim of this study was to investigate the effects of eight-week 11+ and HarmoKnee injury prevention training programmes on the strength of the quadriceps and hamstrings in professional male soccer players.

MATERIALS AND METHODS

Participants. Thirty-six young (between 17 and 20 years), male professional soccer players with at least five years' experience of playing soccer at professional level with regular training and without history of major lower limb injury or disease participated in this study. Three top professional teams (according to their match outcome) were selected for the present study. The clubs had almost daily training and played one match per week in a season. Descriptive data for participants were age: mean 18.9 ±1.4 years, weight 73.6± 6.3 kg; height 181.3± 5.5 cm. The study was approved by the ethical committee of the Institute of Research Management and Monitoring, University of Malaya and the Sports Centre Research Committee in accordance with the Declaration of Helsinki. All the participants were informed orally about the procedures they would undergo and their written consent was taken. Moreover, we also obtained written informed consent from coaches, as caretakers, on behalf of the minors involved in this study.

Procedure

The coaches and team managers from three professional teams were invited to a four-hour instruction course which aimed to introduce the intervention programmes (at the mid-season of 2011). Three under-21 professional soccer teams participated in this study. The players from one team were randomly selected and assigned to one of the intervention programmes. Each subject performed only one of the selected warm-up programmes. The groups were matched during pre-test using the knee strength measurements. One-way ANOVA did not show significant difference in pre-test between the 11+, HarmoKnee and control groups at all angular velocities of quadriceps and hamstrings strength ($p>0.05$).

All players attended a workshop to discuss the prescribed proper ways to carry out the exercises, prior to starting the intervention programmes. Players were instructed on how to perform the exercises correctly. All the training sessions were supervised by the same researcher to ensure their compliance with the programmes. Verbal encouragement was given throughout the training period to help the subjects concentrate on the quality of their movements. They also participated in a familiarization session on how to use the isokinetic machine. During the familiarization sessions, the subjects were fitted on the isokinetic system for a knee extension and flexion protocol. The settings were recorded to ensure the same positioning for all experimental tests. The trials were monitored for smooth motion during the data collection and where necessary corrected to ensure that they were fully familiar with the tests. All subjects participated in common training and were encouraged not to engage in other physical activities.

TABLE 1. THE FIFA 11+ INJURY PREVENTION WARM-UP PROGRAMME

Exercise	Duration
Part 1: Running	8 minutes
Straight ahead, hip out, hip in, circling partner, shoulder contact, quick forward & backwards (6 running items, each item 2 sets)	
Part 2: strength, plyometric and balance	10 minutes
The bench: Static, alternate legs and one leg lift and hold (3 items, each item 3 sets)	
Sideways bench: Static, raise & lower hip, with leg lift (3 items, 3 sets on each side)	
Hamstring: Beginner (3-5 repetition, 1 set), intermediate (7-10 repetition, 1 set), advanced (12-15 repetition, 1 set). (3 items)	
Single-leg stance: Hold the ball, throw the ball to a partner, test your partner (3 items, each item 2 sets)	
Squats: With toe raise, walking lunges, one-leg squats (3 items, each item 2 sets)	
Jumping: Vertical jumps, lateral jumps, box jumps (3 items, each item 2 sets)	
Part 3: running exercise	2 minutes
Across the pitch, bounding, plant & cut (3 items, each item 2 sets)	

The warm-up programmes

The 11+ consists of three parts, beginning with running exercises (part I), followed by six exercises to develop strength, balance, muscle control and core stability (part II), and ending with advanced running exercises (part III). The different levels of difficulty would improve the programme's efficiency and enable coaches and players to individually adapt to the programme. The 11+ takes approximately 20-25 minutes to complete and replaced the usual warm-up before general training. All exercises (27 exercises) focus on core stability, neuromuscular control, eccentric hamstrings strength and agility (Table 1) [34]. These exercises were performed three times per week as a warm-up programme.

The aim of the HarmoKnee prevention programme is to increase overall awareness of injury risk, to provide a structured warm-up protocol, and to increase strength, which may improve movement patterns and reduce knee injuries (Table 2). The training protocol consists of five parts: warm-up, muscle activation, balance, strength, and core stability. Total programme duration was 20 to 25 minutes [19]. Similar to the 11+, the HarmoKnee was also performed three times per week as warm-up before the general training.

Control group

For comparison, the control group was asked to continue with their regular team training and warm-up such as running across the pitch and static stretching. In addition, before the commencement of the study, the control group was promised that they would receive the intervention programme 8 weeks later.

TABLE 2. THE HARMOKNEE INJURY PREVENTION WARM-UP PROGRAMME

Exercise	Duration
Warm-up	≥10 min
Jogging (≥4-6 min), Backward jogging on the toes (Approximately 1 min), High-knee skipping (Approximately 30 s), Defensive pressure technique (Approximately 30 s), One and one (≥2min)	
Muscle activation	Approx. 2 min
Activation of calf muscles, quadriceps muscles, hamstring muscles, hip flexor muscles, groin muscles, hip and lower back muscles (6 item, each item 4 s for each leg/side)	
Balance	Approx. 2 min
Forward and backward double leg jumps, Lateral single leg jumps, Forward and backward single leg jumps, Double leg jump with or without ball (optional), (4 items, each item approximately 30 s)	
Strength	Approx. 4 min
Walking lunges in place, Hamstring curl (in pairs), Single-knee squat with toe raises (3 item, each item Approximately 1 min)	
Core stability	Approx. 3 min
Sit-ups, Plank on elbows and toes, Bridging (3 items, each item approximately 1 min)	

Isokinetic test

A Biodex Isokinetic Dynamometer (Biodex 3, 20 Ramsay Rode, Shirley, New York, USA) was used to assess the hamstring and quadriceps strength of the subjects. The Biodex System 3 has been shown to be a reliable instrument with high ICC (intra class correlation coefficient) values (>0.90) for collecting isokinetic net peak torque data in humans [8, 32]. All tests were carried out between 8 am and 11 am. Before each testing session, the gravity correction method of the dynamometer was chosen in accordance with the manufacturer's recommendations. The subjects performed a general cardiovascular warm-up for at least 5 min on a Monark cycle ergometer at a moderate pace (50-100 W) followed by 10 minutes of dynamic stretching (such as walking lunges, squats, and heel-toe walks) concentrating on the lower body [13, 30].

Each subject was seated on the chair and assumed his most comfortable position to perform the best tests. Then the subject was secured with snug straps across the shoulder, chest and hip. The cuff of the dynamometer's lever arm was attached proximally to the malleoli of the ankle. Dynamometer orientation was fixed at 90° and tilted at 0°, while the seat orientation was fixed at 90° and the seatback tilted at 70°-85°. The lateral epicondyle of the knee was visually aligned with the dynamometer rotational axis. Device set-up and subject positioning were as per the manufacturer's guidelines, which were also similar to previous studies [4, 5, 18]. All the seating positions of the subjects were recorded carefully and repeated during post-test. The subjects were instructed to complete 3 trials: two sub-maximal efforts and one maximal effort on the isokinetic machine. Then they performed concentric knee extension and flexion 3 times at each selected angular velocity with 5-s rest intervals in between. They were also given a 1-min rest between different angular velocities and a 3-min break when the machine setting was changed for the opposite leg. The order of testing was randomized for the dominant and non-dominant legs. Encouragement by verbal coaching and visual feedback was given to all subjects. The isokinetic measurement was standardized according to the Biodex manufacturer's manual, and similar to previous studies [20, 30]. All isokinetic contractions were performed on the dynamometer at the speed of $60°\cdot s^{-1}$ (slow velocity), $180°\cdot s^{-1}$ (medium velocity) and $300°\cdot s^{-1}$ (high velocity), through a knee range of motion of 0° (flexed) to 90° (full extension). These testing speeds are widely used for isokinetic muscle strength assessment in soccer players [10]. Selecting low ($60°\cdot s^{-1}$), medium ($180°\cdot s^{-1}$) and high ($300°\cdot s^{-1}$) isokinetic testing speeds is essential for optimal strength evaluation in bilateral mode, given that in slow muscle action the vast majority of motor units are recruited, while faster testing velocities enrich the force-velocity spectrum of the acting muscles [10]. For assessment of hamstring and quadriceps strength, the tests were performed twice. The pre-testing was conducted one week prior to the first day of training and the post-test was recorded eight weeks after the pre-test (three days after the final training session). All tests were conducted in the same order for each player at pre- and post-tests [30, 35]. Isokinetic testing was performed by a member of the research team who was blinded to each subject's intervention group. The net peak torque values were recorded and used for data analysis.

Statistical analysis

To compare the strength between times (pre-test, post-test), groups (11+, HarmoKnee, control groups) and velocities ($60°\cdot s^{-1}$, $180°\cdot s^{-1}$, $300°\cdot s^{-1}$) the 2 ×3 ×3 (time vs group vs velocities) repeated measures mixed ANOVA was used separately for the dominant and non-dominant leg as described by Holcomb et al. [17]. To compare eccentric strength of hamstring and quadriceps muscles between time (pre-test, post-test) and group (11+, HarmoKnee, control groups) a mixed ANOVA method was used. Bonferroni corrections for multiple comparisons were used to adjust for potential inflation of alpha. The Kolmogorov-Smirnov (KS) test was employed for assessing normality of the distribution of scores ($p>0.05$). Furthermore, Levene's test was employed for assessing homogeneity of variance among groups ($p>0.05$). The effect sizes of each variable were tested using partial eta (η) squared (0.01=small effect, 0.06=medium effect, and 0.14=large effect) [6,28]. Significance was accepted at the 95% confidence level for all statistical parameters ($p<0.05$).

RESULTS

Comparison of net peak torque in the quadriceps muscle. The means of quadriceps' net peak torques in pre-test and post-test are presented in Table 3. For quadriceps muscle the mixed ANOVA showed a significant main effect between time in the dominant leg ($F_{1,33}=13.28$, $p<0.001$) and non-dominant leg ($F_{1,33}=7.03$, $p=0.012$). The partial eta squared statistic indicated a large effect size in the dominant (0.29) and non-dominant (0.18) legs. In the 11+ group, the net peak torques increased significantly ($p<0.05$) by 27.7% at $300°\cdot s^{-1}$ in the dominant leg. In the HarmoKnee group the Bonferroni post-hoc test showed significant increases in the dominant leg ($P<0.05$) by 36.6%, 36.2% and 28% at $60°\cdot s^{-1}$, $180°\cdot s^{-1}$ and $300°\cdot s^{-1}$ respectively and in the non-dominant leg by 31.3%, 31.7% and 20.05% at $60°\cdot s^{-1}$, $180°\cdot s^{-1}$ and $300°\cdot s^{-1}$, respectively. In the control group, the Bonferroni post-hoc test did not show any significant difference between pre- and post-tests at all angular velocities in both legs ($p>0.05$).

Comparison of net peak torque in the hamstring muscle

The means of hamstrings' net peak torque in pre- and post-tests are presented in Table 3. The mixed ANOVA showed a significant main effect between time in the dominant leg ($F_{1,33}=15.97$, $p<0.001$) and non-dominant leg ($F_{1,33}=11.49$, $p=0.002$). The effect size

TABLE 3. ISOKINETIC PT IN THE QUADRICEPS AND HAMSTRING MUSCLES (VALUES ARE MEAN ± SD) AND PERCENTAGE CHANGE (Δ) [VALUES ARE MEAN (95%CI)] FROM PRE- TO POST-TIME POINTS

	Dominant			Non-dominant		
Peak Torque	Pre (Nm)	Post (Nm)	Δ% (95%CI)	Pre (Nm)	Post (Nm)	Δ% (95% CI)
The 11+						
Q_{Con} $60°\cdot s^{-1}$	217.5±43.8	240.1±49.2	22.6 (-5.2 to 50.4)	228.6±49.3	234.5±53.9	6 (-17.9 to 29.9)
Q_{Con} $180°\cdot s^{-1}$	144.8±34.4	165.4±31	20.6 (-4.1 to 45.3)	146.5±29	163.9±32.6	17.3 (-4.9 to 39.6)
Q_{Con} $300°\cdot s^{-1}$	97.3±30.8	125.1±22.5	27.7 (3.6 to 51.8)*	100.8±30.5	122.8±19.7	22 (-2.2 to 46.2)
H_{Con} $60°\cdot s^{-1}$	112.8±15.7	134.8±18.6	22 (9.5 to 34.5)*	109.7±16.9	132.0±20.6	22.3 (10.5 to 34.1)*
H_{Con} $180°\cdot s^{-1}$	78.2±21.3	99.7±15.1	21.4 (4.4 to 38.5)*	80.7±16.7	96.4±8.7	15.7 (6.2 to 25.2)*
H_{Con} $300°\cdot s^{-1}$	67.9±22.7	90.1±22.4	22.1 (5 to 39.2)*	74.7±25	89.9±17.9	15.2 (-3.3 to 33.8)
HarmoKnee						
Q_{Con} $60°\cdot s^{-1}$	189.4±40.9	226.1±48.5	36.6 (15.8 to 57.5)*	190.7±52.6	222±52.1	31.3 (11 to 51.6)*
Q_{Con} $180°\cdot s^{-1}$	115.1±31.4	151.3±27.5	36.2 (19.2 to 53.1)*	118.1±35.5	149.8±34.5	31.7 (13.4 to 50)*
Q_{Con} $300°\cdot s^{-1}$	87.4±27.5	115.4±22.6	28 (12.4 to 43.6)*	90.9±26.3	111±21	20.05 (8.1 to 32)*
H_{Con} $60°\cdot s^{-1}$	90.2±27.1	122.8±27.6	32.5 (13.8 to 51.3)*	90.3±26.9	111.5±27.7	21.1 (5.8 to 36.4)*
H_{Con} $180°\cdot s^{-1}$	58.6±23	90±25.8	31.3 (16.3 to 46.3)*	69.2±20.3	88.4±35.2	19.3 (1.6 to 36.9)*
H_{Con} $300°\cdot s^{-1}$	69.3±23.1	83.6±28.1	14.3 (1.7 to 26.9)*	70±20.1	80.3±18.9	10.3 (-0.2 to 20.8)
Control						
Q_{Con} $60°\cdot s^{-1}$	198.4±57	203.6±56.7	5.2 (-32.8 to 43.1)	208.7±46.3	194.8±39.7	-13.9 (-33.8 to 5.9)
Q_{Con} $180°\cdot s^{-1}$	127.6±43.8	130.4±37.3	2.8 (-19.2 to 24.8)	124.9±42.8	126.2±29	1.3 (-21.1 to 23.7)
Q_{Con} $300°\cdot s^{-1}$	94.9±34.8	98.9±22.2	4 (-19.2 to 27.2)	95.7±35	92.3±22.3	-3.5 (-25.2 to 18.2)
H_{Con} $60°\cdot s^{-1}$	97.3±33.8	103.7±34.1	6.3 (-15.1 to 27.7)	106.7±41.5	100.3±28	-6.4 (-25.6 to 12.8)
H_{Con} $180°\cdot s^{-1}$	59.5±28.8	61.6±18.9	2.05 (-23.3 to 27.4)	57±26.3	64.9±22.2	7.9 (-13.7 to 29.6)
H_{Con} $300°\cdot s^{-1}$	63±30.5	59.1±29	-3.9 (-29.1 to 21.3)	59 ±28	62.9±32.6	3.9 (-25.8 to 33.7)

Note: Q=quadriceps muscles; H=hamstring muscles; con=concentric; Nm= Newton meter; °.s-1=degrees per second; pre= pre-test; post= post-test, CI= confidence interval; *=significant differences from pre- to post-time points ($p<0.05$)

analysis showed a large effect in the dominant (0.33) and non-dominant (0.26) legs. In the 11+ group the Bonferroni post-hoc test indicated significant differences ($p<0.05$) in the dominant leg, by 22%, 21.4% and 22.1% at $60°\cdot s^{-1}$, $180°\cdot s^{-1}$ and $300°\cdot s^{-1}$, and by 22.3%, and 15.7% at $60°\cdot s^{-1}$, and $180°\cdot s^{-1}$, in the non-dominant leg, respectively. In the HarmoKnee group the Bonferroni post-hoc test indicated significant increases in the dominant leg ($p<0.05$) by 32.5%, 31.3% and 14.3% at $60°\cdot s^{-1}$, $180°\cdot s^{-1}$ and $300°\cdot s^{-1}$ respectively, and in the non-dominant leg by 21.1%, and 19.3% at $60°\cdot s^{-1}$ and $180°\cdot s^{-1}$, respectively. The Bonferroni post-hoc test did not show any significant difference between pre- and post-tests at all angular velocities in both legs in the control group ($p>0.05$).

Comparison of strength between groups

For the quadriceps muscle, results did not show any significant main effect between groups in the dominant legs ($F_{2,33}=1.84$, $p=0.17$) or the non-dominant legs ($F_{2,33}=2.32$, $p=0.11$). For the hamstring muscles the repeated measures mixed ANOVA indicated a significant main effect between groups in the dominant leg ($F_{2,33}=4.92$, $p=0.01$) and non-dominant leg ($F_{2,33}=3.94$, $p=0.02$). The effect sizes were also large in dominant (0.23) and non-dominant (0.19) legs. The Bonferroni post-hoc test showed significant differences between the dominant ($p=0.01$) and non-dominant ($p=0.02$) legs of the 11+ and control groups.

Comparison of strength between angular velocities

A significant main effect in the quadriceps muscle between different angular velocities was observed in the dominant leg ($F_{2,32}=237.99$, $p<0.001$) and non-dominant leg ($F_{2,32}=166.80$, $p<0.001$). The effect size analysis showed a large effect in dominant (0.94) and non-dominant (0.91) legs. The results revealed a significant main effect in the hamstring strength between velocities in the dominant leg ($F_{2,32}=80.71$, $p<0.001$) and in the non-dominant leg ($F_{2,32}=106.7$, $p<0.001$). The partial eta squared showed a large effect size in the dominant (0.83) and non-dominant (0.76) legs.

Comparison of eccentric net peak torque

The means of hamstrings' and quadriceps' eccentric net peak torques in pre- and post-tests are presented in Table 4. No significant main effect was found in quadriceps strength in the dominant and non-dominant legs from pre- to post-tests and also between groups ($p>0.05$). The results did not show any significant main effect between time and group in the eccentric hamstring strength ($p>0.05$).

DISCUSSION

The present intervention study reports the effects of the 11+ and HarmoKnee injury prevention training programmes on the strength of the quadriceps and hamstrings in young professional male soccer players. The 11+ and HarmoKnee programmes are multifaceted soccer-specific prevention programmes that include core stability, balance, and neuromuscular control that promote proper motion patterns aimed to decrease lower body injuries [19, 34]. Within-group analysis revealed that HarmoKnee warm-up programmes enhanced the concentric strength of quadriceps at various isokinetic testing speeds tested, whereas the 11+ increased quadriceps strength just in the dominant leg at $300°\cdot s^{-1}$. It seems that the 11+ did not improve concentric quadriceps strength significantly. Conflicting results using the 11+ programme in non-professional male soccer players have been published by Brito et al. [4]. They reported that the 11+ improved net peak torque of knee extensors at $60°\cdot s^{-1}$ and $180°\cdot s^{-1}$ in the dominant leg of non-professional male soccer players [4]. These differences could be attributed to factors such as playing level of subjects. They employed non-professional male soccer players compared to professional players in this study. The quadriceps are maximally active during landing (deceleration and the control of knee flexion while working eccentrically) and during the take-off phase of the jump. Quick change of direction which is common in soccer requires eccentric quadriceps strength and a short amortization (plyometric) phase, i.e., fast transition from eccentric to

TABLE 4. ISOKINETIC ECCENTRIC PT IN THE HAMSTRING AND QUADRICPES MUSCLES (VALUES ARE MEAN ± SD) AND PERCENTAGE OF CHANGE (Δ) [VALUES ARE MEAN (95%CI)] FROM PRE-TO-POST TIME POINTS

	Dominant			Non-dominant		
Peak Torque	Pre (Nm)	Post (Nm)	Δ% (95%CI)	Pre (Nm)	Post (Nm)	Δ% (95% CI)
The 11+						
H $120°\cdot s^{-1}$	160.3 ± 8.2	152.8±12.1	-7.5(-16.7 to 1.7)	159.5±19.7	149.5±20.5	-10.1(-23.9 to 3.8)
Q $120°\cdot s^{-1}$	152.4±20.2	159.6±7.3	7.2(-8.0 to 22.3)	146.1±17.7	159.3±12.1	13.1(2.3 to 24.0)
HarmoKnee						
H $120°\cdot s^{-1}$	149.8±14.6	154.9±10.7	5.1(-3.7 to 13.9)	142.8±22.0	149.9±16.7	7.1(-1.9 to 16.1)
Q $120°\cdot s^{-1}$	159.8±8.4	159.7±8.5	-0.1(-5.40 to 5.42)	156.5±10.9	157.2±12.8	0.7(-7.6 to 9.0)
Control						
H $120°\cdot s^{-1}$	161.1±4.2	159.9±5.5	-1.1(-5.6 to 3.3)	156.7±7.1	149.8±18.1	-6.9(-18.7 to 4.9)
Q $120°\cdot s^{-1}$	161.9±12.0	166.7±17.0	4.8(-9.7 to 19.4)	162.1±6.9	154.4±29.1	-7.8(-26.4 to 11.1)

Note: Q=quadriceps muscles; H=hamstring muscles; Nm= Newton meter; °.s-1=degree per second; pre= pre-test; post= post-test, CI= confidence interval concentric muscle action [12]. Therefore, training elements of HarmoKnee intervention programmes such as single leg stance, plyometric and balance exercises will produce stronger quadriceps musculature. The HarmoKnee programme could be adopted for greater concentric quadriceps strength improvement compared to the 11+ programme. Further emphasis on certain exercises to improve the quadriceps strength or new additions of exercises may help to enrich the 11+ programme. The muscle strength improvement might reduce the susceptibility of a player to injury, particularly towards the end of soccer matches [4, 23].

The 11+ and HarmoKnee programmes showed significant increases in the concentric strength of the hamstring muscles in within-group analysis. Both the 11+ and HarmoKnee programmes include special strength training for hamstring muscles such as Nordic hamstring and hamstring curl respectively. Hence, these are the most likely cause of the observed improvement in the hamstring strength. The hamstring muscles are important for the stabilization of the knee joint. They function as a joint compressor which controls the anterior movement of the tibia [16]. Clark et al. [5] in their study examined the effect of Nordic hamstring training on strength, and found that Nordic hamstring had a positive effect on increasing joint stability during the final take-off phase of the jumping activity, allowing for more efficient transfer of force through the joint, which provided useful strength and adaptation to prevent soft-tissue injuries and enhancing strength of the quadriceps and hamstrings [5]. They concluded that Nordic hamstring exercise produced favourable neuromuscular adaptation for the possible prevention of hamstring muscle injury in soccer players [5].

The results did not show significant differences between groups in concentric quadriceps muscle strength. Professional soccer players have higher quadriceps strength than non-professional players [11], which is mainly attributed to soccer training through which most players develop quadriceps muscles. A higher training intensity may be required for the programmes to increase the quadriceps strength in professional male soccer players.

The results showed significant differences in the concentric hamstring strength of the 11+ and control groups in the dominant and non-dominant legs. In contrast, no significant difference was observed between the HarmoKnee and control groups. Therefore, it can be suggested that the 11+ programme is more beneficial than the HarmoKnee programme in increasing hamstring strength in young professional male soccer players. The training components of the 11+ and HarmoKnee programmes have many similarities such as running, the plank, jumping training, walking lunges, and balance, among others, but there are also some different exercises in the two programmes [19, 34]. The major differences of the 11+ compared to HarmoKnee are 3 items of Nordic hamstring and 3 items of sideways bench. Furthermore, the HarmoKnee programme has bridging, sit-ups and 6 additional muscle activation items as compared with the 11+ programme. These differences in the training components may be a possible cause of the different results observed in the hamstring muscle strength. The FIFA 11+ programme has more plyometric training than the HarmoKnee programme. In a meta-analysis, Hewett et al. [15] found that plyometric training was a common component that effectively reduces knee injury rates. Plyometric training induces more muscle-dominant neuromuscular adaptations to correct neuromuscular imbalances in athletes [22]. Attention to the importance of hamstring strengthening on restoring normal strength profiles can decrease the risk of knee injury [4].

When comparing the concentric strength of quadriceps and hamstring muscle between the velocities, significant differences in quadriceps and hamstring muscles were found. The results showed higher strength in $60°\cdot s^{-1}$. The angular velocity is inversely proportional to the peak torque, where at lowest speed ($60°\cdot s^{-1}$) highest peak torque was produced. More motor units can be recruited at the slower speeds than higher speed, allowing more torque production [22]. The present findings support this proposal that slow speed ($60°\cdot s^{-1}$) is the optimum speed for measuring isokinetic knee strength in young male professional soccer players [13].

The present results showed that the 11+ and HarmoKnee programmes do not have the potential to improve eccentric strength of hamstring and quadriceps muscles. Hamstring muscle strains have been found to commonly occur during the eccentric phase of muscular contraction [2, 29]. During the late swing phase of running gait [2] and late stance phase of over ground sprinting [27] the hamstrings eccentrically contract to decrease the forward momentum from the leg and foot, to prevent over extension and potential injury [2]. The presence of a high force eccentric contraction likely contributes to the high rates of hamstring injury during maximal speed running [27]. From the present results it is difficult to conclude that these warm-up programmes can decrease hamstring injuries. Thorborg [39] reported that eccentric exercise named hamstring lower is more beneficial than Nordic hamstring to improve hamstring strength [39]. Adding this hamstring lower and increasing the intensity of Nordic hamstring exercise may improve the eccentric hamstring strength gains in professional soccer players.

CONCLUSIONS

The results of this study showed that the HarmoKnee programme increased concentric quadriceps strength only within groups (comparing pre- and post-tests). No significant difference was observed between groups. Overload is required for measurable concentric and eccentric quadriceps muscular adaptation in young male professional soccer players. The results also revealed that the 11+ and HarmoKnee programmes increased concentric and eccentric hamstring strength in young male professional soccer players, within groups. The results showed that the 11+ programme significantly increases concentric hamstring strength, within and between groups. The 11+ programme has more impact than the HarmoKnee programme on increasing concentric hamstring strength in young male professional soccer players. Further research that investigates which components (i.e., balance, core stability, neuromuscular control and agility) in the 11+ programme contributed to its significance is underway. We also suggest adding more training elements in both programmes that aim to increase concentric and eccentric strength of the quadriceps and eccentric strength of the hamstring.

Acknowledgment
This research was supported by a University of Malaya Research Grant (PV076/ 2011A).

Conflict of interest: There is no conflict of interest to declare by any of the authors.

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