©Journal of Sports Science and Medicine (2013) **12,** 489-496
http://www.jssm.org

Research article

Effects of the 11+ and Harmoknee Warm-Up Programs on Physical Performance Measures in Professional Soccer Players

Abdolhamid Daneshjoo [1]✉, Abdul Halim Mokhtar [2], Nader Rahnama [3] and Ashril Yusof [1]
[1] Sports Centre, University of Malaya, Kuala Lumpur, Malaysia; [2] Faculty of Medicine, University of Malaya, Kuala Lumpur, Malaysia; [3] Faculty of Physical Education and Sport Science, University of Isfahan, Isfahan, Iran

Abstract
The purpose of this study was to examine the effects of the 11+ and HarmoKnee warm-up programs on performance measures in professional soccer players. Thirty-six male professional soccer players (age: 18.9 ± 1.4 years) were divided into 3 groups, the 11+, HarmoKnee and control group (n = 12 per group). The experimental groups performed the programs 3 times per week for 2 months (24 sessions), whereas the control group only performed their regular soccer training. The performance tests carried out were: 10m speed tests with and without a ball, 20m single sprint, vertical jump, Wall-Volley and Illinois agility tests. The 11+ group demonstrated significant increases from pre-to-post time points in the vertical jump (3.7%), Wall-Volley (5.4%) and Illinois agility tests (1.7%), while the HarmoKnee group showed a significant increase in Wall-Volley test, with a 5.2% increase. The repeated measures analysis revealed differences between the groups (large effect size) in the 11+ and HarmoKnee groups, compared to the control group, in 10m speed tests with and without a ball, 20m single sprint and Illinois agility tests ($p < 0.05$). Thus 8-weeks performing the 11+ warm-up program can enhance jump height, agility and soccer skill while the HarmoKnee program generally only improves soccer skill in young professional male soccer players.

Key words: Performance, vertical jump, Illinois agility test, sprint, Wall-Volley test.

Introduction

Soccer is unequivocally one of the most popular sports in the world (López-Segovia et al., 2011). A survey conducted in 2006 showed that there were a total of 265 million male and female soccer players and 5 million referees and officials or 4% of the world's population actively involved in the sport (FIFA, 2006). According to the International Federation of Association Football (FIFA), 90% of all registered players were male, with younger soccer players comprising the greatest proportion (54.7%) of all registered male players (FIFA, 2006).

Soccer players require a moderate to high levels of aerobic and anaerobic power, good agility, and a variety of technical and tactical skills to bolster the likelihood of their success in the sport (Carling et al., 2009; Reilly et al., 2000). In order to respond to the physical demands of play, training components such as anaerobic power, speed, and agility should be incorporated into training (Amiri-Khorasani et al., 2011; Steffen et al., 2008). Prior to participation, warm-ups are generally required to "ready" oneself for training or matches (Sander et al., 2013). Warm-up programs essentially constitute mild or moderate exercise types that are geared toward enhancing performance (Sander et al., 2013; Sotiropoulos et al., 2010; Subasi et al., 2008) by increasing blood flow and the elasticity and neuron activity of the muscles (Skof and Strojnik, 2007).

Several studies have considered the effects of warm-up programs on soccer performance; such effects include but are not limited to, improvements in the time to complete a 20m sprint (Kilding et al., 2008; Sander et al., 2013; Steffen et al., 2008), jump height (Kilding et al., 2008; Steffen et al., 2008) and time to complete the Illinois agility test (Amiri-Khorasani et al., 2010; Kilding et al., 2008). Two widely used soccer specific warm-up programs are the 11+ and HarmoKnee. Kiani et al. (2010) designed the HarmoKnee warm-up program for soccer players. It essentially consists of a warm-up and muscle activation, along with balance, strength and core stability exercises. The FIFA Medical and Research Centre (F-MARC) developed the 11+ warm-up program for soccer players. The 11+ program, an advanced version of the 11 program, includes running, strength, plyometric and balance components (Soligard et al., 2008). Only a small number of studies have focused on the 11+ and HarmoKnee. The main focus of these studies, was to test their effect on strength (Brito et al., 2010; Daneshjoo et al., 2012a) balance (Daneshjoo et al., 2012b), and prevalence of injuries (Soligard et al., 2008). However, there are earlier studies on the physical performance of soccer players using the 11 program (Kilding et al., 2008; Steffen et al., 2008). Kilding and coworkers (2008) observed an improvement in leg power (3-step jump and counter-movement jump) and 20m sprint, although they reported no changes in body mass, agility (Illinois test) and core stability of young soccer players. In contrast, Steffen et al. (2008) showed no significant differences between the 11 and control groups in terms of vertical jump, 40m sprint running, speed tests (10m with and without a ball) and soccer skill tests among adolescent female soccer players. Discovery of these discrepancies has led FIFA to develop the 11+ program that incorporates an increase in intensity and exercise components to potentially improve the physical performance of soccer players. Hence, further research into the effects of this advanced version of the 11+ program on the physical performances of soccer players is merited.

Both the 11+ and HarmoKnee are multifaceted

Received: 31 July 2012 / Accepted: 13 May 2013 / Available (online): 24 June 2013 / Published: 01 September 2013

soccer specific warm-up programs which aim to improve the general fitness of soccer players as well as considering intrinsic risk factors such as strength and balance. Generally, the exercises included in multifaceted warm-up programs have been shown to improve athletic performance among male soccer players (Fradkin et al., 2010). Specifically, improvements have been reported in counter movement jump height (Sotiropoulos et al., 2010), isokinetic strength (Brito et al., 2010; Daneshjoo et al., 2012a) and sprint ability (Fletcher and Jones, 2004). Core stability exercises are another important component included in multifaceted warm-up programs. These core exercises have been shown to improve technical skills and total awareness of the game (Holm et al., 2004; Leetun et al., 2004; Paterno et al., 2004). Thus, it would be expected that a multifaceted warm-up program should improve physical performance. Notably, a systematic review of warm-up, running speed, jumping and skill performances studies (1966-2008) reported that 79% (of 32 articles) showed improvements in jump height, time- to- complete sprint tests and technical skill performances while only 3% suggested no changes (Fradkin et al., 2010).

To date, no research has investigated the effects of the 11+ and HarmoKnee warm-up programs on the physical performance of young male professional soccer players. On the other hand, it is unknown whether the 11+ and HarmoKnee warm-up programs would enhance the physical capacity of professional soccer players. Therefore, we aimed to test the effects of the warm-up programs on the performance of young professional male soccer players.

Methods

Participants

Thirty-six healthy, young (n = 36) male professional soccer players (aged between 17 and 20) who regularly took part in soccer training sessions and whose medical histories were devoid of major lower limb injury or illness participated. Three top Iranian professional teams were selected. All participants were outfield players and members of one of the three professional teams. During the 2011 competitive season, all of these players participated in the Iranian premier official league championships (First Division). All subjects participated in common training consisting of technical and tactical drills such as passing, shooting, dribbling and heading drills. In addition, they played in small-sided games using 5×5 m and 10×10 m square grids. The players were discouraged from engaging in other physical activities. The participants were divided equally into 3 groups, namely the 11+, HarmoKnee and control group (n = 12 per group) (Table 1). Each group had an almost equal distribution of playing positions, including defenders, mid-fielders and strikers. Goalkeepers were excluded from this study due to the different physical and physiological demands placed upon them, and their training is very different to those of other players (Arnason et al., 2004; Gil et al., 2007; Ziv and Lidor, 2011). The study was approved by the Institute of Research Management and Monitoring, University of Malaya and the Sports Centre Research Committee.

Procedure

Towards the middle of the 2011 season, the coaches and team managers from the three professional teams were invited to a four-hour instruction course aimed at introducing the intervention programs. Three under-21 (U21) teams participated in this study, each one comprised approximately 30 professional players (matched at pre-test), from which 12 players were randomly picked to participate in the study. A one-way analysis of variance (ANOVA) did not show any significant differences between the groups during the pre-test for all variables measured ($p > 0.05$). Each subject performed only one of the selected warm-up programs.

Table 1. Descriptive characteristics of the subjects. Data are means (±SD).

Groups	FIFA 11+ n = 12	HarmoKnee n = 12	Control n = 12
Age (y)	19.2 (.9)	17.7 (.4)	19.7 (1.6)
Height (m)	1.80 (.05)	1.80 (.06)	1.80 (.05)
Mass (kg)	71.7 (4.6)	71.0 (7.6)	76.4 (5.8)

Prior to the commencement of the intervention programs, all players attended a workshop to learn the correct methods to perform the exercises. This workshop was conducted for each team separately. None of the teams knew about the exercises the other teams were performing. They received video instructions and illustrations on the intervention programs. The subjects were briefed on the procedures they would undergo before being asked to read and sign a consent form. All of the procedures were carried out in accordance with the Declaration of Helsinki with respect to human research. All the training sessions were supervised by one of the researchers to ensure they conformed to the standards of compliance and to make certain that correct technique was used. Verbal encouragements were given throughout the training period to help the subjects to concentrate on the quality of their movements. The exercise programs commenced on 15th April 2011 and were completed on 15th June 2011 (24 sessions).

The warm-up programs

The 11+ group

The 11+ consisted of three parts, the first of which involved running exercises (part 1). The second part covered six exercises, all of which comprised three levels of difficulty and were aimed at improving strength, balance, muscle control and core stability (part 2). The third and final part consisted of advanced running exercises (part 3). The varying levels of difficulty enhanced the program's efficiency and enabled coaches and players to individually adapt to the program. The 11+, which replaced the usual warm-up training, took approximately 20-25 minutes to complete. All of the exercises (27 exercises) focused on core stability, neuromuscular control, eccentric hamstring strength and agility (Table 2). This group performed the 11+ exercises three times per week.

HarmoKnee group

HarmoKneewarm-up program included five parts: warm up, muscle activation, balance, strength and core stability,

all of which can be combined and performed in a regular soccer training session (Table 3). Total program duration was 20 to 25 minutes (Kiani et al., 2010). Similar to the 11+, HarmoKnee was also performed three times per week.

Table 2. The ''11+'' warm-up training program. Exercises in the structured warm-up program (F-MARC).

Exercise	Duration
Part 1: Running Straight ahead, hip out, hip in, circling partner, shoulder contact, quick forward & backwards (6 running items, each item 2 sets)	8 minute
Part 2: strength, plyometric and balance **The bench** Static, alternate legs and one leg lift and hold (3 items, each item 3 sets)	10 minutes
Sideways bench Static, raise & lower hip, with leg lift (3 items, 3 sets on each sides)	
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, throwing ball with 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)	
Part3: Running exercise Across the pitch, bounding, plant & cut (3 items, each item 2 sets)	2 minutes

Control group

The control group was asked to continue with their regular training and warm-up sessions throughout the study period. In addition, prior to the commencement of the study, the control group was assured that they would receive the intervention program in the subsequent season.

Performance tests

Five standard soccer specific tests (in an indoor hall with synthetic flooring) were performed at the same time of the day under standardized environmental conditions (19-22°C). All tests were carried out between 8 am and 11 am. The time spent on each test was recorded (with a resolution of 0.01 s) using a handheld stopwatch (Sportline 240, Sportline,Inc, Hazleton, Pa) which was operated by one of the researchers. Performance tests were conducted by a different member of the research team. The tester was blinded to the type of intervention the players participated in. A standardized 15-min warm-up, including running, low-intensity cycling, calisthenics and dynamic stretching was performed before the tests.

The pre-testing was conducted one week prior to the first day of training, while the post-test was recorded three days after the final training session. All tests were conducted in the same order for each player during the pre- and post-tests.

10m speed test

After warming up with ball-based exercises, the players performed a 20m shuttle run both with and without a ball to assess their coordinated dribbling under time pressure and speed. The tests were based on a straight dribbling test developed by Reilly and Holmes (1983), (intraclass correlation coefficients (ICC) = 0.95) where five cones were placed in a straight line 2.8, 4.8, 6.0, 8.0 and 10.0m from the start line (perpendicular to the line). The players were instructed to dribble around alternate obstacles until the fifth cone was circled, and then return through the course in a similar fashion as fast as they could. The starting position was from an upright position. The test was completed when the player in control of the ball, crossed the finish line (Figure 1). Two successful complete trials, one with and one without the ball, were recorded, with the best results for each test being chosen for analysis (Steffen et al., 2008).

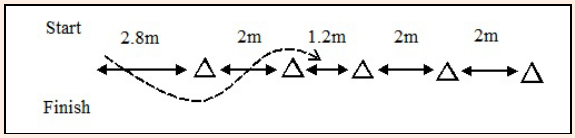

Figure 1. Speed dribbling, m= meter

Table 3. HarmoKnee warm-up training program. Exercises in the structured warm-up program.

Exercise	Duration
Warm-up Jogging (≥4-6 min), Backward jogging on the toes (Approximately 1min), High-knee skipping (Approximately 30 s), Defensive pressure technique (Approximately 30 s), One and one (≥ 2min)	≥ 10 min
Muscle activation Activation of calf muscles, quadriceps muscles, hamstring muscles, hip flexor muscles, groin muscles, hip and lower back muscles (6 items, each item 4s for each leg/side)	Approximately 2 min
Balance 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 30s)	Approximately 2 min
Strength Walking lunges in place, Hamstring curl (in pairs), Single-knee squat with toe raises (3 items each item Approximately 1 min)	Approximately 4 min
Core stability Sit-ups, Plank on elbows and toes, Bridging (3 items each item Approximately 1 min)	Approximately 3 min

20m single sprint

The 20m single sprint is a standard test for assessing soccer players' running speed (Rahnama et al., 2009). The participants performed two 20m trials, with a 3-min re-

covery period in between. The players started from a standing position, and the timing system was triggered as soon as they left the starting mat. The best attempt was used for the analysis.

Vertical jump

The vertical jump test has been shown to be a reliable test in measuring the jump performance of soccer players (ICC = 0.97), (Christou et al., 2006). Each subject performed two practice jumps prior to testing to ensure proper jumping techniques. They were instructed to jump vertically (initiated from a knee flexion of 90°), and execute a maximum vertical jump while swinging their arms actively. Jump height was determined using a measuring tape fastened to a dark paper on which each subject's pretest and post-test jump chalk prints would be clearly recorded. Each subject performed 2 practice jumps and the best score was used for analysis (Vanderford et al., 2004; Christou et al., 2006).

Wall-Volley test

This test is a standard test with high reliability (ICC=0.97) in terms of assessing soccer players' skill and accuracy in kicking a ball (Reilly and Holmes, 1983). Players were required to kick a ball from a wall and then trap or kick the ball on the rebound as many times as possible within a 30-sec period (Figure 2). The subjects were allowed to kick the ball from the air or ground while avoiding the use of their arms or hands. Each subject performed 3 sets of this test, with the best attempt used for the analysis (Vanderford et al., 2004; Reilly et al., 2007).

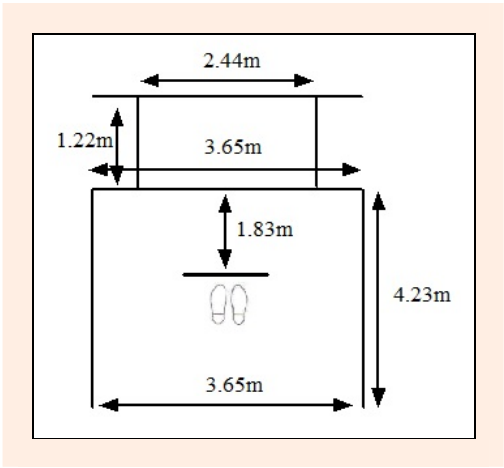

Figure 2. The soccer Wall-Volley test, m= meter

Illinois agility test

The Illinois agility test is commonly used in measuring agility in soccer (Kilding et al., 2008; Katis and Kellis 2009; Amiri-Khorasani et al., 2010). The reliability of this test has been reported to be high (ICC = 0.85) (Katis and Kellis 2009). The length of the zone is 10m, while the width (distance between the start and finish points) is 5m. Four cones were placed in the center of the testing area at a distance of 3.3m from one another. Four cones were used to mark the start, finish and two turning points. The subjects started the test lying face down, with their hands at shoulder level. The trial started on the "go" command, and the subjects began to run as fast as possible. The trial was completed when the players crossed the finish line without having knocked any cones over. Three trials were performed by every subject with the best score (time) used for analysis (Kilding et al., 2008; Amiri-Khorasani et al., 2010).

Statistical analysis

A two-way (3 × 2) ANOVA design with repeated measures was applied to examine the possible interaction between groups (the 11+ vs HarmoKnee vs control groups) and the time (pre- and post–tests) intervention phases. As for statistical significance, the post-hoc Bonferroni test was conducted to determine pair wise differences. The data met all the assumptions for linear statistics and the Levene's test was used to assess the homogeneity of variance between the groups. In order to determine the relationship between the 20m single sprint and agility, the Pearson correlation was used. The reliability of each test was assessed by the intraclass correlation coefficient (ICC). The effect sizes of each variable were tested using Cohen's d [$d = (M1 - M2 / \sqrt{((SD1^2 \times SD2^2) / 2)}$] within each group (0.1, 0.3, and 0.5 as small, medium, and large effects, respectively) and partial eta (η) squared between groups (0.01 = small effect, 0.06 = medium effect, and 0.14 = large effect), (Cohen, 1988; Pallant, 2007). Statistical significance was set at $p < 0.05$.

Results

10m speed test with a ball

The means of pre- and post-tests of the groups are presented in Table 4. High reliability was observed in the 10m speed test with a ball (ICC = 0.98). In the 10m speed test with the ball, the results did not show any significant differences between the pre-and post-tests ($F_{2,33} = 0.642$, $p = 0.429$). The results did, however, indicate significant differences between groups ($F_{2,33} = 4.9$, $p = 0.013$). The partial eta squared statistic indicated a large effect size (0.23) between the groups. The Bonferroni post-hoc test showed significant differences between the control and the 11+ ($p = 0.048$), as well as HarmoKnee ($p = 0.021$).

10m speed test without a ball

The reliability of the 10m speed test without a ball was high (ICC = 0.96). There was no significant main effect difference between the pre- and post-tests ($F_{2,33} = 0.700$, $p = 0.409$). However, significant differences between the groups ($F_{2,33} = 5.66$, $p = 0.008$) were observed. The partial eta squared statistic indicated a large effect size (0.26) between the groups. The results from the Bonferroni post hoc test indicated a significant difference between the control and the 11+ ($p = 0.031$), as well as HarmoKnee ($p = 0.012$).

20m single sprint

The 20m single sprint test demonstrated high reliability (ICC = 0.91). No significant main effect difference was found between the pre- and post-tests ($F_{2,33} = 4.06$, $p = 0.052$), but the results showed significant differences between the groups ($F_{2,33} = 7.89$, $p = 0.008$). The partial

Table 4. Tests at pre- and post-time points of the groups (values are mean ± *SD*), and percentage of change (Δ) [values are mean (95% CI)].

	Pre-test	Post-test	Δ% (95%CI)	Effect size
11+ group				
10m with ball (s)	8.7 (1.1)	8.1 (1.4)	-0.6 (0.01 to -1.2) [c]	0.236
10m without ball (s)	5.6 (0.4)	5.3 (0.4)	-0.3 (0.007 to -0.7) [c]	0.401
20m single sprint (s)	3.1 (0.4)	2.7 (0.3)	-0.3(0.003 to-0.64) [c]	0.392
Vertical jump (cm)	47 (6.3)	50.7(7.9)	3.7 (6.3 to 1.2) [b]	0.254
Wall volley test (points)	31.7 (1.3)	37.2(0.7)	5.4 (7.8 to 3.0) [a]	0.590
Illinois (s)	16.2 (0.3)	14.4(0.3)	-1.7 (-0.8 to -2.6) [b, c]	0.645
HarmoKnee group				
10m with ball (s)	8.5 (1.01)	8.1 (0.8)	-0.4 (0.9 to -0.1) [c]	0.239
10m without ball (s)	5.3 (0.5)	5.5 (0.6)	0.2 (0.6 to -0.1) [c]	0.194
20m single sprint (s)	2.93 (0.3)	2.88(0.3)	-0.05(-0.05 to 0.1) [c]	0.101
Vertical jump (cm)	50.2 (6.8)	51.9 (4.3)	1.6 (3.7 to -0.4)	0.143
Wall volley test (points)	30.7 (1.4)	35.8 (3.2)	5.2 (2.3 to 8.1) [b]	0.533
Illinois (s)	16 (0.1)	15.5 (0.2)	-0.4 (0.05 to -0.9) [c]	0.344
Control group				
10m with ball (s)	9.1 (1.4)	9.8 (1.6)	0.6 (-1.5 to 0.27)	0.239
10m without ball (s)	5.7 (0.6)	6.1 (0.5)	0.3 (-0.7 to 0.01)	0.295
20m single sprint (s)	3.1 (0.1)	3.2 (0.1)	-0.06(0.13 to -0.01)	0.217
Vertical jump (cm)	46.6(5.4)	48.9 (7.6)	2.3 (5.2 to -0.56)	0.211
Wall volley test (points)	32.3(3.5)	31.6 (3.8)	-0.7 (2.1 to -3.6)	0.102
Illinois (s)	16.5(1.2)	16.9 (1.2)	0.5 (-1.4 to 0.4)	0.205

Legend: s=second, m=meter; cm=centimetre, CI=confidence interval; a= significant difference between pre-to-post time points ($p < 0.001$); b= significant difference between pre-to-post time points ($p<0.01$); c= significant difference with control group ($p < 0.05$).

eta squared statistic indicated a large effect size (0.25) between the groups. The Bonferroni post-hoc test indicated significant differences between the control and the 11+ ($p = 0.023$), as well as HarmoKnee ($p = 0.019$).

Vertical jump

High reliability was found in the vertical jump test (ICC = 0.98). There was a significant main effect between the pre- and post-tests in the vertical jump ($F_{2,33} = 15.2$, $p = 0.000$). The partial eta squared statistic indicated a large effect size (0.31) between the groups. The results showed a significant increase only in the 11+ group from pre- to post-tests by 3.7% in jump height. The Cohen's d indicated a small effect (0.25) between times in the 11+. No significant differences were found between the groups ($p > 0.05$).

Wall-Volley test

The Wall-Volley test showed a high degree of reliability (ICC=0.97). There was a significant main effect between the pre- and post-tests ($F_{2,33} = 21.173$, $p = 0.000$). The partial eta squared statistic indicated a large effect size (0.39) between times. Both the 11+ ($p = 0.000$) and HarmoKnee ($p = 0.002$) showed significant increases in scores within the groups, with 5.4% and 5.2%, respectively. The Cohen's d indicated a large effect in the 11+ (0.59) and HarmoKnee groups (0.53). However, the results did not show any significant differences between the groups ($p > 0.05$).

Illinois agility test

The reliability of Illinois agility test was found to be high (ICC = 0.96). A significant main effect was observed between the pre- and post-tests ($F_{2,33} = 7.12$, $p = 0.012$). The partial eta squared statistic indicated a large effect size (0.18) between times. The results indicated a significant decrease in times within the 11+ ($p = 0.001$) by 1.7%. The Cohen's d indicated a large effect in the 11+ (0.64). Significant differences were found between the groups ($F_{2,33} = 11.94$, $p = 0.000$). The partial eta squared statistic indicated a large effect size (0.42) between the groups. The post-hoc Bonferroni test indicated significant differences between the 11+ ($p = 0.000$) and HarmoKnee ($p = 0.007$) compared to the control groups. Moreover, the finding showed a moderate correlation in the 11+ group between the results of Illinois test and the 20m single sprint ($r = 0.539$).

Discussion

The aim of this study was to investigate the effect of the 11+ and HarmoKnee warm-up programs on the physical performance of young professional male soccer players. Significant differences between the control group and the 11+ as well as HarmoKnee in the speed tests (10m with and without a ball and 20m sprint) were found. The 11+ and HarmoKnee both showed trends for improvement; however, the changes were not significantly different ($p > 0.05$) between pre-to-post time points in the 10m speed tests (with and without a ball) and 20m single sprint. From the present results it is difficult to conclude that these warm-up programs can improve speed performance. Of interest, however, is that Kilding et al. (2008), using the 11 program, reported changes among non-professional male soccer players (mean age 10.4 ± 1.4 y) in a 20m sprint following 30 sessions (6 weeks). This might have been due to the number of sessions (30) employed, mean age of the sample used and their level of skills. It can be argued that since professional soccer players already possess highly developed physical characteristics (Cometti et al., 2001), thus little improvement will be demonstrated. Moreover, speed performance is largely

dependent on genetic influences such as muscle fiber type, with only relatively small improvements observed with training programs (Ross et al., 2001; Tønnessen et al., 2011). The present findings suggest that both of the warm-up programs are in need of some modifications to enhance players' running speed. Sander et al. (2013) showed that five minutes of nonspecific running, coordination exercises, stretching and acceleration runs (within a warm-up) improved 10m and 30m sprint performance in young male soccer players. Repeated shuttle sprint training of 15-20m over a 7-week period improved the 30m speed test in adolescent professional male soccer players (Buchheit et al., 2010). Moreover, studies showed that plyometric training of forward and lateral hopping, shuffle, ladder drills, box and depth jumps (Michailidis, et al. 2013), 40-cm hurdle jumps and 40-cm drop jumps (Chelly et al., 2010) enhanced speed performance in soccer players. Hence, we suggest adding additional training elements such as plyometric training, ladder drills and repeated shuttle sprints in both programs to fully realize the enhancement of speed performance. Further studies examining the effects of these two modified warm-up programs on the sprint performance of professional soccer players are warranted.

The comparison in the vertical jump within the groups showed a significant increase in the post-test only in the 11+ group (3.7 %); however, the effect size was small. Kilding et al. (2008) examined the suitability of the 11 warm-up program for young soccer players and reported that leg power (3-step jump and countermovement jump) increased significantly (3.4%). Conflicting results were reported after a ten-week training program using the 11 warm-up program on female adolescent soccer players, where no difference in jump height was observed (Steffen et al., 2008). These differences could be attributed to such factors as the gender and age of the subjects. Although the findings of Kilding and his colleagues (2008) are quite similar to those of the present study, the skill levels of the subjects were different. They employed non-professional male soccer players, whereas professional players were employed in this study. In the present study, we used the 11+, which is an advanced version of the 11 (Soligard et al., 2008). Based on the magnitude of change in jump performance and comparing the level of the players from the two studies, the 11+ program would seem superior to the 11.

Our results indicated an improvement in Wall-Volley skill test within the groups. Both the 11+ and HarmoKnee showed significant increases in scores (5.4% and 5.2% respectively). The effect size analysis also indicated large effects in both groups. Therefore, it can be concluded that there is a difference between the two warm-up programs compared to the control group. Previous studies have reported positive effects of different training programs on soccer skill tests (Christou et al., 2006; Billot et al., 2010). Billot et al. (2010) found that the kicking skill of 20 male amateur soccer player*s* improved after a 3-week electro stimulation training program on the quadriceps muscle. The results of this study suggested that the warm-up training programs positively influenced the players' performance in the Wall-Volley skill test. Many factors influence performance on sport-specific skill tests, including physiological factors (sprint, strength, power), neural control of movement and perceptual-cognitive skills such as anticipation and visual search strategies (McMillan et al., 2005; Russell et al., 2011). It is likely that the multifaceted warm-up programs have the potential to increase the stimulus of these factors.

The results indicated a decrease in time taken for Illinois test in the 11+ by 1.7%, whereas no difference was observed in HarmoKnee group. The Cohen's d indicated a large effect size in the 11+ program. These results seem to suggest that the 11+ may be more beneficial in improving agility in young male soccer players than the HarmoKnee program. The above findings are in agreement with those of an earlier study that investigated the effect of 10-week intervention training in young male soccer players (Simek Salaj et al., 2007). The experimental group reported significant changes in the Y20 agility test. Agility is a complex ability which depends on coordination, the mobility of the joint system, dynamic balance, and strength, as well as stabilizing and suppressing strength and speed (Simek Salaj et al., 2007). One potential explanation for the present results could be the fact that our intervention programs included the essential components to improve agility. The Illinois test reflects the performance of combined speed and agility (Katis and Kellis, 2009; Vescovi and VanHeest, 2010). Motor skills common to soccer such as sprinting and jumping actions, have similarities in muscular, biomechanical and kinematic characteristics (Vescovi and Mcguigan, 2008; Zajac, 2002) and are closely associated (Vescovi and McGuigan, 2008). During the acceleration period, instantaneous leg power is required to propel the whole body mass to maximum speed in the shortest possible time (Farlinger et al., 2007). Pauole et al. (2000) reported a moderate correlation (r = 0.53) between the agility and sprint time (36.58 m; 40 yd) in 105 college-aged male athletes. In this study, a moderate correlation (r = 0.54) was also reported in the 11+ group between Illinois and 20m single sprints.

There are a few limitations to the present study that should be addressed. This study was performed at mid-season (competition season), which means that some players might have played more games than others and potentially had a higher baseline fitness level, which could have affected any potential changes in performance. In order to account for this limitation, we chose soccer players that had played in more competitions, as evidenced by their playing history and recommendations by the coaches. Another limitation was the time measuring device used in the present study. To account for this, time was measured by an experienced researcher, which generated the high reliability of all tests in the present study.

Conclusion

It can be concluded that neither the 11+ nor HarmoKnee improved players' performance in the speed test (10m with and without a ball) and 20m single sprint between pre-to-post time points. The 11+ did improve vertical jump, Wall-Volley and Illinois agility test performance,

while the HarmoKnee group showed a significant increase in performance on Wall-Volley test.

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

References

Amiri-Khorasani, M., Abu Osman, N. A. and Yusof, A. (2011) Acute effect of static and dynamic stretching on hip dynamic range of motion during instep kicking in professional soccer players. *The Journal of Strength and Conditioning Research* **25(6),** 1647-1652.

Amiri-Khorasani, M., Sahebozamani, M., Tabrizi, K. G. and Yusof, A. B. (2010) Acute effect of different stretching methods on Illinois agility test in soccer players. *The Journal of Strength and Conditioning Research* **24(10),** 2698-2704.

Arnason, A., Sigurdsson, S.B., Gudmundsson, A., Holme, I., Engebretsen, L. and Bahr, R. (2004) Physical fitness, injuries, and team performance in soccer. *Medicine and Science in Sports and Exercise* **36(2),** 278-285.

Billot, M., Martin, A., Paizis, C., Cometti, C. and Babault, N. (2010) Effects of an electrostimulation training program on strength, jumping, and kicking capacities in soccer players. *The Journal of Strength and Conditioning Research* **24(5),** 1407-1413.

Brito, J., Figueiredo, P., Fernandes, L., Seabra, A., Soares, J.M., Krustrup, P. and Rebelo, A. (2010) Isokinetic strength effects of FIFA's "The 11+ injury prevention training programme. *Isokinetic Exercise Sciences* **18,** 211-215.

Buchheit, M., Mendez-Villanueva, A., Delhomel, G., Brughelli, M. and Ahmaidi, S. (2010) Improving repeated sprint ability in young elite soccer players: Repeated shuttle sprints vs. explosive strength training. *The Journal of Strength and Conditioning Research* **24(10),** 2715-2722.

Carling, C., Le Gall, F., Reilly, T. and Williams, A.M. (2009) Do anthropometric and fitness characteristics vary according to birth date distribution in elite youth academy soccer players? *Scandinavian Journal of Medicine and Science in Sports* **19(1),** 3-9.

Chelly, M.S., Ghenem, M.A., Abid, K., Hermassi, S., Tabka, Z. and Shephard, R.J. (2010) Effects of in-season short-term plyometric training program on leg power, jump-and sprint performance of soccer players. *The Journal of Strength and Conditioning Research* **24(10),** 2670-2676.

Christou, M., Smilios, I., Sotiropoulos, K., Volaklis, K., Pilianidis, T. and Tokmakidis, S.P. (2006) Effects of resistance training on the physical capacities of adolescent soccer players. *The Journal of Strength and Conditioning Research* **20(4),** 783-791.

Cohen, J. (1988) *Statistical power analysis for the behavioral sciences.* Hillsdale, NJ: Erlbaum.

Cometti, G., Maffiuletti, N.A, Pousson, M., Chatard, J.C. and Maffulli, N. (2001) Isokinetic strength and anaerobic power of elite, subelite and amateur French soccer players. *International Journal of Sports Medicine* **22(1),** 45-51.

Daneshjoo, A., Mokhtar, A.H., Rahnama, N. andYusof, A. (2012a) The effects of injury preventive warm-up programs on knee strength ratio in young male professional soccer players *PLoS ONE* **7(12),** e50979.

Daneshjoo, A., Mokhtar, A.H., Rahnama, N. and Yusof, A. (2012b) The effects of comprehensive warm-up programs on proprioception, static and dynamic balance on male soccer players. *PloS One,* **7(12),** e51568.

Farlinger, C.M., Kruisselbrink, L.D. and Fowles, J.R. (2007) Relationships to skating performance in competitive hockey players. *The Journal of Strength and Conditioning Research* **21(3),** 915-922.

FIFA (2006) *FIFA big count 2006: 270 million people active in football.* Available from URL: www.fifa.com/aboutfifa/media/newsid=529882.html.

Fletcher, I.M. and Jones, B. (2004) The effect of different warm-up stretch protocols on 20 meter sprint performance in trained rugby union players. *The Journal of Strength and Conditioning Research* **18,** 885-888.

Fradkin, A.J., Zazryn, T.R. and Smoliga, J.M. (2010) Effects of warming-up on physical performance: a systematic review with meta-analysis. *The Journal of Strength and Conditioning Research* **24(1),** 140-148.

Gil, S.M., Gil, J., Ruiz, F., Irazusta, A. and Irazusta, J. (2007) Physiological and anthropometric characteristics of young soccer players according to their playing position: Relevance for the selection process. *The Journal of Strength and Conditioning Research* **21(2),** 438-445.

Holm, I., Fosdahl, M.A., Friis, A., Risberg, M.A., Myklebust, G. and Steen, H. (2004) Effect of neuromuscular training on proprioception, balance, muscle strength, and lower limb function in female team handball players. *Clinical Journal of Sport Medicine* **14,** 88-94.

Katis, A. and Kellis, E. (2009) Effects of small-sided games on physical conditioning and performance in young soccer players. *Journal of Sports Science and Medicine* **8,** 374-380.

Kiani, A., Hellquist, E., Ahlqvist, K., Gedeborg, R., Michaëlsson, K. and Byberg, L. (2010) Prevention of soccer-related knee injuries in teenaged girls. *Archives of Internal Medicine* **170(1),** 43-49.

Kilding, A. E., Tunstall, H. and Kuzmic, D. (2008) Suitability of FIFA's "The 11" training programme for young football players-impact on physical performance. *Journal of Sports Science and Medicine* **7,** 320-326.

Leetun, D.T., Ireland, M.L., Willson, J.D., Ballantyne, B.T. and Davis, I.M. (2004) Core stability measures as risk factors for lower extremity injury in athletes. *Medicine and Science in Sports and Exercise* **36,** 926-934.

López-Segovia, M., Marques, M.C., van den Tillaar, R. and González-Badillo, J.J. (2011) Relationships between vertical jump and full squat power outputs with sprint times in U21 soccer players. *Journal of Human Kinetics* **30,** 135-144.

McMillan, K., Helgerud, J., Macdonald, R. and Hoff, J. (2005) Physiological adaptations to soccer specific endurance training in professional youth soccer players. *British Journal of Sports Medicine* **39(5),** 273-277.

Michailidis, Y., Fatouros, I.G., Primpa, E., Michailidis, C., Avloniti, A., Chatzinikolaou, A. and Draganidis, D. (2013) Plyometrics' trainability in pre-adolescent soccer athletes. *The Journal of Strength and Conditioning Research* **27(1),** 38-49

Pallant, J. (2007) *SPSS survival manual: a step by step guide to data analysis using SPSS.* 3rd edition. Crows Nest, N.S.W.: Allen & Unwin.

Paterno, M.V., Myer, G.D., Ford, K.R. and Hewett, T.E. (2004) Neuromuscular training improves single-limb stability in young female athletes. *The Journal of Orthopaedic and Sports Physical Therapy* **34(6),** 305-316.

Pauole, K., Madole, K., Garhammer, J., Lacourse, M. and Rozenek, R. (2000) Reliability and validity of the T-test as a measure of agility, leg power, and leg speed in college-aged men and women. *The Journal of Strength and Conditioning Research* **14(4),** 443-450.

Rahnama, N., Bambaeichi, E. and Daneshjoo, A.H. (2009) The epidemiology of knee injuries in Iranian male professional soccer players. *Sport Sciences for Health* **5(1),** 9-14.

Randers, M.B., Nielsen, J.J., Krustrup, B.R., Sundstrup, E., Jakobsen, M.D., Nybo, L., Dvorak, J., Bangsbo, J. and Krustrup, P. (2010) Positive performance and health effects of a football training program over 12 weeks can be maintained over a 1 year period with reduced training frequency. *Scandinavian Journal of Medicine and Science in Sports* **20,** 80-89.

Reilly, T., Atkinson, G., Edwards, B., Waterhouse, J., Farrelly, K. and Fairhurst, E. (2007) Diurnal variation in temperature, mental and physical performance, and tasks specifically related to football (soccer). *Chronobiology international* **24(3),** 507-519.

Reilly, T., Bangsbo, J. and Franks, A. (2000) Anthropometric and physiological predispositions for elite soccer. *Journal of Sports Sciences* **18(9),** 669-683.

Reilly, T. and Holmes, M. (1983) A preliminary analysis of selected soccer skills. *Physical Education Review* 61, 64–71.

Ross, A., Leveritt, M. and Riek, S. (2001) Neural influences on sprint running: Training adaptations and acute responses. *Sports Medicine* **31(6),** 409-425.

Russell, M., Benton, D. and Kingsley, M. (2011) The effects of fatigue on soccer skills performed during a soccer match simulation. *International Journal of Sports Physiology and Performance* **6(2),** 221-231.

Sander, A., Keiner, M., Schlumberger, A., Wirth, K. and Schmidtbleicher, D. (2013) Effects of functional exercises in the warm-up on sprint performances. *The Journal of Strength and Conditioning Research* **27(4),** 995-1001.

Simek Salaj, S., Milanovic, D. and Jukic, I. (2007) The effects of proprioceptive training on jumping and agility performance. *Kinesiology* **39(2),** 131-141.

Skof, B. and Strojnik, V. (2007) The effect of two warm-up protocols on some biomechanical parameters of the neuromuscular system of middle distance runners. *The Journal of Strength and Conditioning Research* **21(2),** 394-399.

Soligard, T., Myklebust, G., Steffen, K., Holme, I., Silvers, H., Bizzini, M., Junge, A., Dvorak, J., Bahr, R. and Andersen, T.E. (2008) Comprehensive warm-up programme to prevent injuries in young female footballers: cluster randomised controlled trial. *BMJ: British Medical Journal* **337.**

Sotiropoulos, K., Smilios, I., Christou, M., Barzouka, K., Spaias, A., Douda, H. and Tokmakidis, S. P. (2010) Effects of warm-up on vertical jump performance and muscle electrical activity using half-squats at low and moderate intensity. *Journal of Sports Science and Medicine* **9,** 326-331.

Steffen, K., Bakka, H., Myklebust, G. and Bahr, R. (2008) Performance aspects of an injury prevention program: a ten-week intervation in adolescent female football players. *Scandinavian Journal of Medicine and Science in Sports* **18(5),** 596-604.

Stone, K.J. and Oliver, J.L. (2009) The effect of 45 minutes of soccer-specific exercise on the performance of soccer skills. *International Journal of Sports Physiology and Performance* **4(2),** 163-175.

Subasi, S.S., Gelecek, N. and Aksakoglu, G. (2008) Effects of different warm-up periods on knee proprioception and balance in healthy young individuals. *Journal of Sport Rehabilitation* **17(2),** 186-205.

Tønnessen, E., Shalfawi, S.A., Haugen, T. and Enoksen, E. (2011) The Effect of 40-m repeated sprint training on maximum sprinting speed, repeated sprint speed endurance, vertical jump, and aerobic capacity in young elite male soccer players. *Journal of Strength and Conditioning Research* **25(9),** 2364-2370.

Vanderford, M.L., Meyers, M.C., Skelly, W.A., Stewart, C.C. and Hamilton, K.L. (2004) Physiological and sport-specific skill response of Olympic youth soccer athletes. *Journal of Strength and Conditioning Research* **18(2),** 334-342.

Vescovi, J. and VanHeest, J. (2010) Effects of an anterior cruciate ligament injury prevention program on performance in adolescent female soccer players. *Scandinavian Journal of Medicine and Science in Sports* **20(3),** 394-402.

Vescovi, J.D. and McGuigan, M.R. (2008) Relationships between sprinting, agility, and jump ability in female athletes. *Journal of Sports Science* **26(1),** 97-107.

Zajac, F.E. (2002) Understanding muscle coordination of the human leg with dynamical simulations. *Journal of Biomechanics* **35(8),** 1011-1018.

Ziv, G. and Lidor, R. (2011) Physical characteristics, physiological attributes, and on-field performances of soccer goalkeepers. *International Journal of Sports Physiology and Performance* **6(4),** 509-524.

Key points

- The 11+ improves performance by means of Illinois agility, vertical jump and Wall-Volley tests whereas HarmoKnee improves Wall-Volley test. Incorporating 11+ as a part of the warm-up program by the young teams would be beneficial in agility, leg power and soccer skill respectively.
- Further modification of both programs may be required to fully realize the players' speed performance potential.
- Data from this research can be helpful for soccer trainers in choosing programs to enhance performances in young male professional soccer players.

AUTHORS BIOGRAPHY

Abdolhamid DANESHJOO
Employment
PhD student of the Sports Centre, University of Malaya, Kuala Lumpur, Malaysia
Degree
MSc, PhD student
Research interests
Sports injuries, injury prevention.
E-mail: daneshjoo.hamid@gmail.com

Abdul Halim MOKHTAR
Employment
Faculty of Medicine, University of Malaya, Kuala Lumpur, Malaysia
Degree
MD
Research interests
Sports medicine
E-mail: drhalim@um.edu.my

Nader RAHNAMA
Employment
Faculty of Physical Education and Sport Science, University of Isfahan, Isfahan, Iran
Degree
PhD
Research interests
Sports injuries, fatigue, ergonomic, musculoskeletal function assessment.
E-mail: nrahnama@fsu.edu

Ashril YUSOF
Employment
Sports Centre, University of Malaya, Kuala Lumpur, Malaysia
Degree
PhD
Research interests
Sports physiology.
E-mail: ashril@um.edu.my

✉ **Abdolhamid Daneshjoo**
Sports Centre, University of Malaya, Kuala Lumpur, Malaysia