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Performance aspects of an injury prevention program: a ten-week intervention in adolescent female football players

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The injury rate in football is high, and effective injury prevention methods are needed. An exercise program, the "11," has been designed to prevent the most common injury types in football. However, the effect of such a program on performance is not known. The aim of this randomized-controlled trial was to investigate the effect of the "11" on performance after a 10-week training period. Thirty-four adolescent female football players were randomly assigned to either an intervention ($n = 18$) or a control group ($n = 16$). The "11" is a 15-min program consisting of ten exercises for core stability, lower extremity strength, balance and agility. Performance tests included isokinetic and isometric strength protocols for the quadriceps and hamstrings, isometric hip adduction and abduction strength, vertical jump tests, sprint running and soccer skill tests. There was no difference between the intervention and control groups in the change in performance from the pre- to post-test for any of the tests used. In conclusion, no effect was observed on a series of performance tests in a group of adolescent female football players using the "11" as a structured warm-up program.

Background

Football is probably the most popular sport worldwide, with a growing interest and an increasing number of female players in particular (Norwegian Football Association, 2005). It is a contact sport and challenges physical fitness by requiring a variety of skills at different intensities. Running is the predominant activity, and explosive efforts during sprints, duels, jumps and kicks are important performance factors, requiring maximal strength and anaerobic power of the neuromuscular system (Wisløff et al., 1998; Cometti et al., 2001; Reilly & Gilbourne, 2003; Hoff & Helgerud, 2004).

Unfortunately, the game is associated with a high risk of injuries, which results in significant costs for the public health system (de Loes et al., 2000) and may even cause long-term disability for the injured player (Lohmander et al., 2004; von Porat et al., 2004; Myklebust & Bahr, 2005). Serious knee injuries, such as anterior cruciate ligament injuries, are of particular concern in female team sports (Powell & Barber-Foss, 2000; Myklebust et al., 2003; Agel et al., 2005; Olsen et al., 2005). Consequently, there is every reason to emphasize the prevention of injuries in football, and to develop and implement prevention programs for young players as early in their career as possible.

Several programs have successfully incorporated one or more exercise components, including plyometrics, strength, neuromuscular training, running and cutting movement patterns, to prevent injuries in female (Hewett et al., 1999; Heidt et al., 2000; Myklebust et al., 2003; Mandelbaum et al., 2005; Olsen et al., 2005) and male athletes (Askling et al., 2003). However, compliance is a concern (Myklebust et al., 2003), and it may be difficult to motivate coaches and players to follow such exercise programs merely to prevent injuries, unless there is a direct effect performance benefit as well.

Exercises used in prevention protocols have also been shown to have performance effects among male football players, such as increased strength (Askling et al., 2003; Mjølsnes et al., 2004). Core stability exercises may improve technical skills and total awareness of the game (Holm et al., 2004; Leetun et al., 2004; Paterno et al., 2004). Comprehensive neuromuscular training programs that combine plyometrics, core strengthening, balance, resistance or speed/agility training may improve several measures of performance concomitantly and at the same time improve biomechanical measures related to lower extremity injury risk (Hewett et al., 2004; Paterno et al., 2004; Myer et al., 2005; Myer et al., 2006b).

In football, the "11" has recently been developed by an expert group convened by FIFA (F-MARC, 2005) as a structured warm-up program targeting the most common injury types in football, i.e. ankle and knee sprains, groin and hamstring strains. To explore the potential for combining injury prevention training with performance, the aim of this randomized-controlled study was to assess whether the "11" can improve performance in a group of 16–18-year-old female football players.

Materials and methods

Study population

The study was conducted during the second half of the 2004 football season, and adolescent female football players from two elite sport high schools in Oslo, Norway, were invited. Before the start of the investigation, the 36 players available received written and oral information about the study, and it was emphasized that participation in the "11" program was voluntary. Written consent was obtained. The players were screened for injuries using a questionnaire at the start of the study, and they had to be uninjured to be included. Two players had to be excluded because of injury. This resulted in a total of 34 players, who, stratified by school, were randomized individually to an intervention group (IG, $n = 18$) and a control group (CG, $n = 16$). The participants were competitive players with 13.3 [standard deviation (SD) 2.1] hours of football activities per week and had been involved in organized football for 10 (1.5) years. The players were aged 16–18 years (17.1 $\pm$ 0.8). The study was approved by the Regional Committee for Research Ethics.

The intervention program

The lower limb injury prevention program, the "11," was designed as a warm-up program. The exercises were chosen based on previous research on injury prevention and established principles for rehabilitation of groin, hamstrings, knee and ankle injuries (F-MARC, 2005). The 15-min program includes 10 exercises focusing on core stability, neuromuscular control, eccentric hamstrings strength and agility (Table 1). The 11th component, a focus on fair play, was not emphasized in the present study. The "11" was introduced to the players in the IG by a physical therapist, and they were provided with balance mats. The intervention program was to be carried out three times a week during football training at school. The players in the CG warmed up as usual, with jogging and ball-based exercises. More than 90% of the intervention sessions were supervised by the project coordinator. Player participation in all training sessions, as well as in the "11" for the IG in particular, was recorded throughout the study period.

Performance tests

Before the start of the intervention period and 1 week after the end of the intervention, the players took part in a testing procedure to assess the performance effects of the "11." The testing took place at the Norwegian School of Sport Sciences and the Norwegian Olympic Training Center. The test battery included five test stations and was completed within 3–4 h. The tests were conducted in the same order for each player for the pre- and the post-tests. One week before the pre-test, all players participated in a test run to familiarize themselves with the testing procedures. The test run and the pre- and post-tests were led by the same experienced lab personnel. The shoe type used by the players was recorded to ensure that the same equipment was used on both test days.

Lower extremity isokinetic and isometric torque

The strength testing protocol, also used by Raastad and Hallén (2000), consisted of tests for hamstring and quadriceps muscle function, including concentric, eccentric and isometric tests (REV9000, Technogym®, Gambettola, Italy). Only the dominant leg was tested. The players warmed up for 5 min on a bicycle with an intensity of 70–100 W. When the players underwent the test run, the dynamometer position, seat position and attachment arm length were recorded to ensure test replication. Straps were used to minimize movements of the torso and the thigh segment of the tested extremity. The arms were held across the chest. The hip angle was 90°. The axis of rotation of the dynamometer was aligned with the knee joint, and the angular movement of the knee joint was 90°.

Concentric isokinetic quadriceps and hamstring torques were measured at a test angular velocity of 60 and 240°/s, while eccentric isokinetic torque was tested at 60°/s only. After four warm-up repetitions, the players were instructed to perform three maximal concentric and four maximal eccentric

Table 1. The "11". Exercises and intensities of the structured warm-up program used (F-MARC, 2005)

Exercises	Intensities
Core stability	
The bench (1)	15 s × 4 repetitions
Sideways bench (2)	15 s × 2 repetitions on each side
Balance	
Cross-country skiing (3)	15 s × 2 repetitions on each leg
Chest pass in single-leg stance (4)	15 s × 3 repetitions on each leg
Forward bend in single-leg stance (5)	15 s × 3 repetitions on each leg
Figure of eights in single-leg stance (6)	15 s × 3 repetitions on each leg
Plyometrics	
Jumps over a line (sideways, forwards-backwards) (7)	15 jumps of each type
Zigzag shuffle (forwards and backwards) (8)	2 repetitions in each direction (20 m)
Bounding (9)	10–15 jumps × 3 repetitions (20 m)
Strength	
Nordic hamstrings (10)	5 repetitions

contractions for both hamstring and quadriceps at each angular velocity. There was a rest period of 1 min between the different angular velocities. The quadriceps:hamstring ratio (Q:H ratio) was calculated for all angular velocities for concentric torque, and for concentric quadriceps torque vs eccentric hamstring torque at 60°/s. The isometric quadriceps and hamstring torques were measured at 30°, 60° and 90° of knee flexion. The players performed a 5-s maximal contraction at each knee flexion angle. Between two contractions at the same angle, the players had a 10-s pause, while they were given a 20-s rest between contractions at different angles. Strength was reported as the peak torque recorded (N m), and the best of three concentric, four eccentric and two isometric repetitions were used in the data analysis.

Isometric hip strength

Before the isometric strength tests for hip abductors and adductors, the players warmed up for about 5 min using a bicycle at an intensity of 70–100 W. The isometric strength of the adductor and abductor muscles was tested with a hand-held dynamometer (Hydraulic Push-Pull Dynamometer, Baseline® Evaluation Instruments, White Plains, New York, USA), similar to Krause et al. (2007). The tests were conducted with the players lying in a supine position on a bench. For the adductor muscles, tests were conducted with the knee in extended and flexed positions. When testing for adduction strength with the leg extended, the dynamometer was positioned 5 cm proximal to the medial ankle malleolus, while it was placed 5 cm proximal to the joint line of the knee on the medial side for testing in the flexed position. Isometric abduction was measured with the leg in the extended position only. The dynamometer was positioned 5 cm proximal to the lateral ankle malleolus. The arms were held across the chest during the test. Both legs were tested, with two maximal contractions for each test variable and a 10-s rest period between the two attempts. The highest value for each of the three tests was registered. The dominant leg for each player was recorded in order to analyze the values for the kicking and standing foot, respectively.

Jumping ability

Three different types of jump tests were performed on a force platform (AMTI, LG6-4-1, Watertown, Massachusetts, USA). As in a study of Wisløff et al. (2004), jumping height was determined as the center of mass displacement calculated from force development and player body mass, as measured on the force platform.

The starting position for the countermovement jump test was in the upright position, equal weight-bearing, feet at hip width and the players holding their hands on the iliac crest. The players bent their knees to 90° of flexion and in one continuous movement, without stopping at the lowest position, they immediately started their upward motion to jump as high as possible. The best of three attempts was used for the analysis. A vertical drop jump test followed immediately after. The players were standing on a box, 30 cm high, with their feet positioned at hip width. They were instructed to drop down from the box and immediately perform a maximum vertical jump while using their arms actively. The highest value of three attempts was recorded. Additionally, a 15 s continuous rebound jump test was performed on a Bosco jump mat (Ergojump, Globus Italia, Codogne, Italy). The players held their hands on the iliac crest, bending their knees to 90° of flexion, and jumped continuously on both legs for 15 s.

Video analysis

Based on the study by McLean et al. (2005), a digital video camera (30 Hz) secured to a tripod was placed 3 m on the opposing site of the force plate during the jumping tests. Two dimension frontal plane knee angles were calculated for each movement trial (countermovement jump and vertical drop jump), from which peak angles were obtained using a software program (NEAT, NEAT Visions Inc., Palm Beach Gardens, FL, USA). The mean angles of three attempts (right+left leg divided by two) were chosen for analysis.

Forty meter single sprint

The sprint test, a standard test for assessing football players maximum speed (Cometti et al., 2001), was performed on an indoor track. The test was recorded with infrared photocells connected to a digital timing devise system. The players warmed up for 10 min including sprints at submaximal intensity. The players performed two 40 m trials, separated by a 3 min recovery period. The best attempt was used for the analysis. The players started from a standing position, and the timing system was triggered as soon as they left the starting mat. Sprinting times were recorded to a resolution of 0.01 s.

Speed dribbling

An indoor hall with synthetic floor was used for the football tests. Five official balls (Roteiro Matchball Euro 2004, Adidas©, Herzogenaurach, Germany, size 5) were calibrated for air pressure (0.8 kg/cm^2) for every fifth subject. After warming up with ball-based exercises, the players performed a 20 m shuttle run both with and without a ball aimed to assess coordinated dribbling under time pressure and speed. The test was based on a straight dribbling test developed by Reilly and Holmes (1983), where five cones were placed in a straight line 2.80, 4.80, 6, 8 and 10 m 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. Starting from an upright position, the test was completed when the player, in control of the ball, passed through a gate with electronic timers. Two successfully completed trials with and two without a ball were recorded, and the best result for each test was chosen for analysis. The infrared photocells, connected to a stop watch, were triggered as soon as the players left the starting mat and stopped again when they passed the gate. All times were recorded to a resolution of 0.01 s.

Shooting distance

From the speed-dribbling test, the players went straight to the distance shooting test. No further warm-up than a few long kicks was therefore required. The shooting test allowed assessment of shooting power over a long distance from a dead ball (Rösch et al., 2000). After a free run-up, the players kicked the ball from its dead position with their dominant leg as far as possible. The shot was successful when the ball landed in a pre-defined 23°-angle sector. The best of three attempts was measured in 10 cm units.

Statistical methods

The primary hypothesis, that there would be a difference between groups in the change in performance from pre- to post-tests, was analyzed using unpaired *t*-tests. The results from pre- and post-tests are reported as means with SD, while the changes within the IGs and CGs from pre- to post-tests are given as means with a 95% confidence interval. An intention-to-treat analysis was performed including all players who completed the pre- and post-tests, as well as a per-protocol analysis restricted to players who participated in the pre- and post-tests and completed more than 20 training sessions with the "11." The best result obtained in each of the performance tests was used in the statistical analysis. The level of significance was chosen to be $\alpha = 0.05$, and all tests were two-tailed.

Results

Of the 34 players included in the study (IG, $n = 18$ and CG, $n = 16$), one player from the IG quit her football career midway through the study. Additionally, two players from the CG were excluded: one was injured and the other withdrew before the start of the training period for unknown reasons. Thus, the final sample consisted of 17 players in the IG and 14 in the CG. There were no significant differences between the two groups in any of the results on the pre-tests.

The IG completed a maximum of 30 training sessions of the "11" during the 10-week intervention period, with a mean completion of 22 ± 10 sessions (range 0–29). Twelve of the 17 players in the IG completed ≥ 20 training sessions with the "11." There was no difference in the total amount of football training between the intervention and CGs.

The results from the intention-to-treat analyses and per-protocol analyses were the same, and therefore, only the results of the intention-to-treat analysis are reported in detail (Table 2).

Lower extremity isokinetic and isometric torque

Maximal concentric, eccentric and isometric hamstring torques did not change from pre- to post-test within any of the groups, but within the CG there

Table 2. Results from the pre-test (mean ± SD) and change (Δ, mean ± 95% CI) from pre- to post-tests within the intervention and control groups, as well as between-group differences in the change from the pre- to the post-test (ΔG, mean ± 95% CI). Positive values denote an increase from pre- to post-tests (Δ) or a result in favor of the intervention group (ΔG).

	Intervention group ($n = 17$)		Control group ($n = 14$)		Between-group ΔG (95% CI)
	Pre-test	Δ	Pre-test	Δ	
Lower extremity isokinetic torque					
Q_{con} 60° s^{-1} (N m)	141.0 (17.3)	3.1 (– 3.0 to 9.2)	142.3 (16.9)	1.6 (– 4.3 to 7.5)	1.5 (– 6.7 to 9.8)
Q_{ecc} 60° s^{-1} (N m)	186.8 (19.9)	4.1 (– 6.3 to 14.4)	174.3 (37.9)	14.1 (– 1.1 to 29.3)	– 10.0 (– 27.0 to 7.0)
Q_{con} 240° s^{-1} (N m)	99.4 (9.6)	– 0.2 (– 5.8 to 5.3)	97.5 (8.9)	0.9 (– 5.2 to 7.1)	– 1.2 (– 9.15 to 6.7)
H_{con} 60° s^{-1} (N m)	85.8 (13.7)	– 0.9 (– 5.3 to 3.5)	91.5 (9.8)	– 2.1 (– 5.2 to 1.1)	1.2 (– 4.2 to 6.6)
H_{ecc} 60° s^{-1} (N m)	104.5 (15.0)	– 1.4 (– 5.8 to 3.0)	106.5 (11.7)	– 4.1 (– 11.0 to 2.9)	2.7 (– 4.9 to 10.2)
H_{con} 240° s^{-1} (N m)	75.7 (9.8)	1.1 (– 2.5 to 4.6)	76.9 (9.1)	– 1.0 (– 6.2 to 4.2)	2.1 (– 3.8 to 7.9)
Lower extremity isometric torque					
Q_{iso} 30° (N m)	99.6 (14.8)	1.9 (– 3.5 to 7.3)	100.0 (11.8)	0.2 (– 4.2 to 4.7)	1.6 (– 5.3 to 8.6)
Q_{iso} 60° (N m)	165.5 (26.9)	4.1 (– 4.2 to 12.4)	163.9 (19.2)	8.3 (– 1.4 to 18.0)	– 4.2 (– 16.3 to 8.0)
Q_{iso} 90° (N m)	153.2 (22.3)	4.1 (– 4.4 to 12.7)	150.1 (21.6)	16.4 (5.7 to 27.2)	– 12.3 (– 25.3 to 0.7)
H_{iso} 30° (N m)	88.1 (16.4)	3.8 (– 4.0 to 11.6)	97.0 (14.3)	– 1.5 (– 9.0 to 5.9)	5.3 (– 5.2 to 15.8)
H_{iso} 60° (N m)	80.4 (14.2)	4.7 (– 1.3 to 10.8)	83.8 (15.2)	4.9 (– 2.3 to 12 2)	– 0.2 (– 9.2 to 8.8)
H_{iso} 90° (N m)	69.6 (10.9)	– 0.5 (– 6.6 to 5.5)	67.4 (16.2)	0.6 (– 5.2 to 6.5)	– 1.1 (– 9.3 to 7.0)
Ratio (Q:H)					
Q:H_{con} 60° s^{-1} (%)	61.0 (7.9)	– 2.0 (– 5.5 to 1.2)	64.8 (7.2)	– 2.2 (– 5.0 to 0.7)	0.2 (– 4.3 to 4.7)
Q:H_{ecc} 60° s^{-1} (%)	56.3 (8.3)	– 1.5 (– 5.5 to 2.5)	62.9 (10.4)	– 7.6 (– 12.9 to – 2.2)	6.1 (– 0.2 to 12.4)
Q:H_{con} 240° s^{-1} (%)	76.5 (9.2)	1.1 (– 3.1 to 5.4)	78.9 (5.5)	– 0.8 (– 6.5 to 4.8)	2.0 (– 4.7 to 8.6)
Q_{con} 60° s^{-1}:H_{ecc} 60° s^{-1}(%)	1.4 (0.2)	0.1 (– 0.1 to 0)	1.3 (0.2)	0.1 (– 0.2 to 0.1)	0 (– 0.2 to 0.1)
Isometric hip strength					
Kicking foot extended (kg)	15.5 (2.1)	0.6 (– 0.2 to 1.5)	16.4 (2.2)	0.9 (– 0.4 to 2.1)	– 0.2 (– 1.6 to 1.2)
Kicking foot flexed (kg)	16.8 (3.1)	0.4 (– 1.2 to 2.0)	15.4 (2.1)	2.1 (0.5 to 3.8)	– 1.7 (– 4.0 to 0.5)
Standing foot (kg)	12.8 (1.6)	– 1.8 (– 3.0 to – 0.6)	13.9 (1.6)	– 2.0 (– 3.1 to – 0.9)	0.2 (– 1.4 to 1.8)
Jumping ability					
Countermovement jump (cm)	27.9 (3.2)	– 0.7 (– 1.5 to 0)	27.9 (2.4)	– 1.4 (– 2.2 to – 0.7)	0.6 (– 0.4 to 1.6)
Vertical drop jump (cm)	31.7 (4.0)	– 0.3 (– 1.2 to 0.6)	32.4 (3.4)	– 1.6 (– 3.0 to – 0.1)	1.3 (– 0.2 to 2.9)
Rebound jump (cm)	23.3 (3.6)	– 0.8 (– 1.9 to 0.2)	22.9 (3.4)	– 0.5 (– 2.2 to 1.3)	– 0.4 (– 2.2 to 1.5)
Video analysis					
Countermovement jump (°)	175.9 (7.2)	– 1.0 (– 4.6 to 2.6)	176.8 (5.4)	– 0.3 (– 3.3 to 2.6)	0.6 (– 3.9 to 5.2)
Vertical drop jump (°)	167.0 (7.3)	0.2 (– 2.2 to 2.5)	167.6 (5.1)	0 (– 4.2 to 4.3)	– 0.1 (– 4.5 to 4.2)
Single sprint					
40 m (s)	5.97 (0.25)	– 0.04 (– 0.2 to 0.11)	5.93 (0.26)	0.01 (– 0.05 to 0.07)	0.03 (– 0.06 to 0.11)
Football tests					
Dribbling without a ball (s)	5.65 (0.37)	– 0.10 (– 0.19 to – 0.16)	5.52 (0.22)	– 0.08 (– 0.21 to 0.05)	– 0.02 (– 0.17 to 0.12)
Dribbling with a ball (s)	9.79 (0.85)	– 0.68 (– 1.10 to – 0.26)	9.98 (0.82)	– 0.71 (– 1.11 to – 0.32)	0.03 (– 0.53 to 0.59)
Long distance kick (m)	35.1 (4.8)	– 1.1 (– 2.8 to 0.7)	36.2 (5.6)	– 0.9 (– 2.2 to 0.43)	– 0.2 (– 2.4 to 2.0)

Con, concentric; ecc, eccentric; iso, isometric; Q, quadriceps; H, hamstrings.

was a significant increase in isometric quadriceps torque at 90° ($P = 0.01$). However, no significant differences were observed between groups in the change from pre- to post-test for any of the hamstring or quadriceps strength tests. Consequently, there were no significant between-group differences in the quadriceps:hamstring ratio change. P-values for these 16 lower extremity strength variables ranged from 0.06 to 0.96.

Isometric hip strength

No between-group differences in the change from the pre- to the post-test were detected for any of the three tests ($P = 0.77$ for kicking foot extended, $P = 0.12$ for kicking foot flexed, $P = 0.82$ for standing foot).

Jumping ability

In the pre- and post-tests, the analysis showed comparable mean jumping performance values in the two groups for all three of the maximal jump tests. Consequently, there were no significant between-group differences in the change from the pre- to the post-tests observed ($P = 0.21$ for countermovement jump, $P = 0.08$ for vertical drop jump, $P = 0.68$ for rebound jump).

Video analysis

After the end of the intervention period, similar changes in stance phase valgus angles for countermovement jump and vertical drop jump were found in the intervention and the CGs. No between-group differences in the change were detected ($P = 0.77$ for countermovement jump, $P = 0.95$ for vertical drop jump).

Forty meter single sprint

The sprint times recorded did not differ from pre- to post-test within the IG (0.04 ± 0.03 s) or the CG (0.01 ± 0.03 s). There was no significant difference between the two groups in the change from the pre- to the post-test in the 40 m single sprint performance ($P = 0.53$).

Speed dribbling

In the straight dribble test (with the ball), both groups performed significantly better in the post-test than in the pre-test ($P = 0.003$ for the IG and $P = 0.002$ for the CG), but there were no significant differences between the two groups in the change ($P = 0.91$ with the ball, $P = 0.75$ without the ball).

Long-distance kick

In the pre- and post-test, the players in the intervention and CGs had comparable results in shooting distance, and there was no between-group difference in the change from the pre- to the post-test ($P = 0.88$).

Discussion

The main finding of this investigation was that no significant performance differences were observed in any of the variables tested between an IG using the injury prevention program and a CG warming up as usual. The most likely explanation is that the training volume and intensity for each of the exercises were too low to result in performance improvements. In addition, the test battery available may not have detected all potential improvements in performance.

If training protocols were designed to not just prevent injuries but also increase performance, combined performance and prevention training could be instituted with a higher potential for athlete compliance. However, in the present case, no increased performance was detected.

Low volume and intensity

Other studies show that successful injury prevention programs include exercise stimuli with a potential for improving sports performance (Hewett et al., 1999; Heidt et al., 2000; Askling et al., 2003; Paterno et al., 2004; Myer et al., 2005; Myer et al., 2006a). When comparing the "11" with these programs, there are essential differences in the content and structure, mainly the duration, the possibilities for variation of the involved exercises and the progression of intensity.

Myer et al. (2005) found that there were significant performance effects of a comprehensive neuromuscular training program for all training components, i.e. plyometrics, strength, core stability and speed training. Some of the exercises used in their program were similar to those composing the "11." However, each training session was performed intensively for 90 min three times a week compared with the 15-min bouts of the "11". Progression guidelines were also used for each of the exercise groups (Myer et al., 2005).

Other training programs, successfully combining performance aspects and injury prevention, were also designed to be carried out intensively over a short pre-season period, but with 60–90-min sessions three times weekly (Hewett et al., 1996, 1999; Heidt et al., 2000). Two randomized studies on strength training showed that a 10-week training program based on eccentric hamstring training effectively developed maximal eccentric hamstrings strength in well-trained football players (Askling et al., 2003; Mjølsnes et al., 2004). We found no strength increase in the IG, even if the same exercise was used.

In the current study, the exercises were used as a warm-up program, and we therefore limited the duration of the whole program to 15 min. This restricted the ability to increase the number of repetitions substantially and the progression of the training stimulus was clearly lower than e.g. Askling et al. (2003) or Mjølsnes et al. (2004). Low training intensity is also the most likely reason for the lack of change in varus–valgus angles in landing activities after the training period, a result that contrasts with that of other studies (Hewett et al., 1996; Myer et al., 2005; Myer et al., 2006b). Training volume, intensity and progression are key determinants for the outcome, and it appears that the current exercise prescription was insufficient.

Test battery

Even if the players appeared to increase their exercise capacity during the intervention period, e.g. they were clearly able to do more repetitions with a better quality of the hamstring, core stability and jumping exercises, the tests revealed no significant improvements. Although the test battery used was thought to be the best suited for assessing the effect of the program, the specificity of the tests available is not 100%.

There is a high degree of mode specificity for strength training, meaning that one will need a test that is very similar to the exercise being trained to fully detect a potential improvement (Svensson & Drust, 2005). Isokinetic strength tests do not reflect the movements of the limbs involved during sprinting, kicking a ball or jumping (Cometti et al., 2001). Wisløff et al. (1998) therefore suggested that tests using free weights will reflect the functional strength of the football player more accurately. Nevertheless, isokinetic testing is a safer and more reliable measure of strength in persons not familiar with free weight training (Svensson & Drust, 2005), and the only method available to test eccentric muscle performance. Also, a significant increase in eccentric hamstring torque has been detected using the same isokinetic test as the present (Mjølsnes et al., 2004). The measurements of 60 and 240°/s for the isokinetic tests were selected because these angular velocities cause little fatigue and have shown high test–retest reproducibility (Raastad & Hallén, 2000). We used the "functional" hamstring/quadriceps ratio, defined as the ratio of maximal eccentric hamstring torque relative to concentric quadriceps torque (H_{ecc}/Q_{con}), which was introduced by Aagaard et al. (1995). This ratio is thought to be relevant when focusing on the prevention of knee ligament as well as hamstring injuries. During knee joint movements, specifically during high levels of muscle force in knee extension, quadriceps contraction forces may result in anterior-directed shear of the tibia relative to the femur. The H_{ecc}/Q_{con} is thought to indicate the extent to which the hamstring muscles are capable of counteracting the anterior shear forces and, consequently, prevent the knee from ligament injury. In a similar way, it is assumed that it is the forces generated by concentric quadriceps muscle activity during maximal running that need to be counteracted by eccentric hamstring muscle action, at least when braking the forward swing of the lower leg during the final part of the swing phase and when hamstring strains are thought to occur (Bahr & Holme, 2003). Nevertheless, as no significant differences were observed for any of the isokinetic test variables, the results would be the same regardless of which ratio is used.

We tested isometric hip strength even if the "11" did not include any exercise specific for the adductor muscles. However, both core stabilization exercises and dynamic balance exercises could, to a certain extent, influence the adduction muscles (Akuthota & Nadler, 2004; Leetun et al., 2004). Isometric strength testing of hip adduction and abduction does not reflect the muscle recruitment pattern during football movement patterns. One might argue that the ability to demonstrate core stability should be tested in more physiologic positions. Dynamic testing of lower extremity alignment during a close kinetic chain activity e.g. single leg step-down may have been an appropriate supplement to the present performance test battery (Zeller et al, 2003).

Countermovement jumps and vertical drop jumps are standard tests to assess jumping ability in football players (Cometti et al., 2001). During the intervention period, the players appeared to perform the plyometric exercises with a higher intensity as they became familiar with them. Still, no significant improvement was seen in any of the tests for jumping ability compared with the CG. In part, this may reflect poor jumping technique during the testing, because many of the players struggled when tested. If the average values of the three best attempts for each player were used to minimize outliners, between-group results then became significantly different in favor of the IG for countermovement jump and vertical drop jump (data not shown).

The "11" did not contain any specific sprint exercises. However, because the thigh musculature, especially hamstrings strength, is of importance in sprint (Reynolds et al., 2001; Askling et al., 2003; Kraemer et al., 2003), increased strength could result in improved sprint times. This was not the case, but perhaps not surprising, considering that no effect on isokinetic or isometric hamstring torque was seen either.

One argument against focusing on injury prevention exercises in warm-up programs is that they may conflict with the development of technical skills. The purpose of including football tests in the test battery (speed dribbling and long-distance kick) was to assess this. In spite of spending less time with the ball, the players in the IG performed just as well on the test as the players in the CG.

Methodological issues

Calculations before the study using a power of 80% showed that a group difference of changes of at least 12 N m (eccentric hamstring torque) and 2.7 cm (jumping ability) was needed to detect a significant effect of the intervention program with 17 players in each group. However, the present results indicate that more than 310 players would have had to be included in each group to detect the observed differences in eccentric hamstrings strength with the observed standard deviation with 80% power at the 5% significance level.

The tests and intervention period were planned for the second half of the season, after the 7-week summer break, to achieve the greatest training intensity at school and to minimize out-of-school activities for the players. The post-tests were performed up to 4 weeks after the end of the competitive football season, and this may have negatively influenced the physical condition of the players on the test day. However, this applies to both groups and should not result in any bias between groups.

Conclusions

No significant effects were observed on different performance variables among adolescent female football players participating in a 10-week injury prevention program, the "11," compared with players who trained as usual.

Perspectives

Pre-season training contributes to the fitness level of players, and physically fitter players can compete at a higher level (Árnason et al., 2004; Hägglund et al., 2005). Higher levels of both strength and neuromuscular control may reduce injury risk and would be favorable in football by allowing more powerful sprints, jumps and duels (Wisløff et al., 1998; Leetun et al., 2004). The benefits of eccentric hamstrings training on injury risk (Askling et al., 2003; Árnason et al., 2007) and increasing strength (Askling et al., 2003; Mjølsnes et al., 2004) have been reported in three recent trials. Therefore, the potential role of systematic fitness and strength training as part of warm-up and football training should be evaluated. For future investigations, large-scale projects should be implemented in order to clarify the potential of injury-preventive exercises in performance and injury risk. However, it appears that the current exercise prescription was insufficient and that a more intense training stimulus is needed to increase fitness substantially. Even so, there is a limit to how much time teams and coaches are willing to spend on exercise programs to prevent injury. For youth and adolescent teams, who typically practice two to four times a week, asking them to spend a similar amount of time on injury prevention exercises is not realistic, even if the injury prevention program also were shown to improve football performance. In our opinion, to successfully implement injury prevention exercises in the regular training program of youth and adolescent football teams on a consistent basis, the duration of the program should not exceed 20 min per session, and preferably be designed to replace the ordinary warm-up exercises used by the team.

Key words: injury prevention, conditioning, strength, neuromuscular, plyometrics, warm-up, pre-season training.

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