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Risk Factors of Lower Extremity Injuries and Sport Performance Following Functional Training in Young Soccer Players: Randomized Clinical Trial

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Original Article

Abstract

Introduction: As a result of insufficient neuromuscular adaptation, dynamic lower extremity alignment is exposed to biomechanical deficits in loading tasks. Therefore, in addition to neuromuscular retraining and decreasing risk of injuries, sport performance indices should be considered while designing injury prevention programs. This study aimed to investigate the effect of 10-week soccer-specific functional training (SSFT) on risk factors of lower extremity injuries and sport performance indices concurrently in young male soccer players.

Materials and Methods: In this randomized controlled trial, 27 young male soccer players were randomly allocated into a control group (n = 13) and experimental group (n = 14). The control group continued their regular soccer training. For experimental group, 3 sessions of SSFT were weekly introduced whitin their regular soccer training program for 10 weeks. SSFT included strength, balance, core, plyometrics, speed and agility exercises as well as the soccer-specific drills. Measurements consisted of the Landing Error Scoring System (LESS) and general and sport-specific performance tests including sprint, agility, power, balance, strength, and best and average time of Shuttle Sprint and Dribble Test (SDT) before and after SSFT in both groups. Analysis of covariance (ANCOVA) was used for statistical analysis ($P < 0.05$).

Results: From the pre-test to post-test, LESS score, time in 30-m test, arrowhead test, and average SDT in experimental group decreased significantly compared to control group ($P < 0.001$). Similarly, the improvement in experimental group was statistically significant for the countermovement-jump test, Y-Balance Test (YBT), and one-repetition maximum (1RM) tests ($P < 0.001$) compared to that in control group. The best SDT time was not significantly better in experimental group ($P > 0.05$).

Conclusion: SSFT designed based on functional capacity can be effective in reducing some risk factors of lower extremity injuries and improving sport performance in young male soccer players.

Keywords: Functional training; Injury risk factors; Dynamic lower extremity alignment; Sport performance

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Introduction

Soccer is the most popular sport in the world (1). Soccer players need high levels of power, speed, and agility to perform explosive movements such as heading, shooting, sprinting and dribbling (2). On the other hand, playing soccer may also induce an inherent risk of injuries which results in significant costs for the public health system and may even cause long-term disability for the injured player (3).

Poor dynamic limb alignment presents as the lack of control at the trunk, pelvis, hip, knee, or foot in the frontal or transverse plane. Poor shock absorption and greater ground reaction force have been linked with poor landing technique and subsequent greater risk of injury (4). Dynamic lower extremity valgus is the most prevalent biomechanical deficit (5) especially in young soccer players (3) which subjected the lower extremity and particularly the knees to greater ground reaction forces and high external knee abduction moments, especially in landing, pivoting, cutting and deceleration (6). Insufficient neuromuscular adaptation which cause deficits in proximal hip strength or neuromuscular control may lead to dynamic lower extremity valgus and promote the

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likelihood of anterior cruciate ligament (ACL) and patellofemoral joint (PFJ) injuries (5). One of the goals of injury prevention programs (IPPs) is improving the lower extremity valgus.

Fortunately, studies have shown that IPPs have successfully reduced the risk factors and rate of injuries in young soccer players (7). Despite the attractions of IPPs for coaches and players, the time requirements are the strongest negative aspect of the implementation of these programs (8, 9). Therefore, many researchers have focused on designing IPPs for improving sports performance indices in addition to neuromuscular retraining and reducing the rate of injuries (10, 11). Noyes, et al. (10) combined components from a published knee ligament intervention program for jump and strength training with other exercises and drills to improve speed, agility, overall strength and aerobic fitness whitin 6-week. They reported that this sports-specific ACL injury prevention training program could improve neuromuscular and performance indices in female high school soccer players. Zouita, et al. (11) reported that soccer training concomitant with 12-week of combined plyometric and resistance training leads to enhancement of explosive strength and related parameters and also improvement in endurance performance and reduces the occurrence of injuries in young elite male soccer players. However, compliance of the intervention programs is directly related to the cost-effectiveness level and feasiblity of program, utilizing sport-specific equipments, and on-the-field training (8).

Improving the functional applied strength (ability to produce force) of athletes in such a way that they can transfer their strength on an unstable surface, at different speeds, in multiple planes and many other abilities (functional range) represents an increase in their functional capacity within a particular movement pattern (12). The gap between functional capability and the filed demands places the athletes at the risk for injury or unfavorable performance. Indeed, improving athlete' functional capabilities is the key to increasing an athlete's durability (13). An intervention is more practical when included the exercises and movements that follow the similarity and context principles; ideal neuromuscular organization occurs when the movement pattern is similar to that of goal movement and practiced in the context of that particular movement (14). Hence, an intervention program relying on these concepts, will probably be successful in injury prevention and sport performance improvements at the same time. To our knowledge, until now there is no study available that investigated the effects of this type of interventions on risk factors of lower extremity injuries and sport performance indices in young soccer players.

Consequently, the goal of this study was to examine the effect of a 10-weeks integrative neuromuscular training, including strength and power exercises, balance exercises, core strength and endurance exercises, plyometric exercises, speed and agility exercises as well as the soccer-specific drills, on some risk factors of lower extremity injuries in young male soccer players. The study would determine whether such comprehensive soccer-specific functional training (SSFT) could enhance sport performance indicators in these subjects. The answer to this question provided the evidence for recommending this specifically designed program to players, coaches, trainers and sport rehabilitation spacialists for not only managing of neuromuscular deficiencies but also enhancing sport performance indices. We hypothesized that such kind of SSFT, when incorporated into a soccer training program, may reduce some risk factors of lower extremity injuries and improve general and specific sport performance indices.

Materials and Methods

Participants: The target population were twenty-seven young male soccer players ranging in age from 14 to 16 years who played in the young soccer league in Kerman. These players were members of the same young soccer club (under supervision of the sport center of Kerman University of Medical Science) and practice soccer 9–10 months a year. At the time of the investigation, they had at least 3 years of soccer experience and were participating in regular soccer training 5 sessions a week, for approximately 90 minutes a session with one competitive game per week, in addition to their school physical education.

The coach and the team leader were contacted and an agreement was reached. Then, the players were screened for injuries using an injury report form at the start of the study and excluded from the study if they reported a history of orthopedic disorders, surgery, symptoms of pain and lower extremity injury that required treatment or which might have inhibited performance within the previous 12 months. None of the players had participated in a formal neuromuscular or resistance training program. Also, the players with Functional movement screening (FMS) score less than 14 were excluded from the study (15). According to different playing positions, each player was randomly allocated into the experimental group or the control group using the permuted block randomization method (table 2). The sample size in each group was estimated at least 13 subject to achieve a statistical power of 0.8 at a significant level of 0.05 with the large expected effect size (0.6) (16, 17).

All players and their parents were properly informed of the nature of the study (testing and training procedures) in an information meeting without being informed of its detailed aims and difference between study groups, and signed an informed consent form before the investigation. The study protocol was in accordance to the ethical standards and guidelines of the Ethics Committee of Research at the University of Tehran, Tehran, Iran, which approved the experimental protocol and the procedures involved (ethics code: IR.UT.SPORT.REC.1396.003).

Study Procedures: This study design registered by the Iranian Registry of Clinical Trials (reference code: IRCT20160623028597N2). Before beginning the protocol, all testing equipment and procedures were described for players in 2 preparation sessions. They were allowed to practice trials and provided visual and verbal feedback to achieve thorough familiarization about the basic elements of each test. Also, before starting the pre-testing, participants were analyzed by FMS.

The same soccer training sessions were designed for all players; each session generally consisted of a 15-minute warm-up, 20-minute technical training, 15-minute tactical training, 30-minute simulated competition, and a 10-minute cool-down. Instead of three soccer training sessions a week, experiment group participated in 3 SSFT sessions per week one in between for 10 weeks after pre-testing. The duration of SSFT sessions was 90 minutes.

Training-related changes were verified by analyzing of Landing Error Scoring System (LESS) (18) and general performance tests including sprint (30-m) (19), agility (arrowhead) (20), power (countermovement jump [CMJ]) (21), balance (Y Balance Test-Lower Quadrant [YBT-LQ]) (22) and strength (one repetition maximum [1RM] in back squats [BS] (23, 24), front squat [FS] (23, 24), deadlift [DL] (23, 24) and upright row [UR] (23, 24). Additionally, soccer-specific performance was assessed by the best and average time of Shuttle sprint and Dribble Test (SDT) (25, 26). Before testing, all players performed a warm-up of 15 minutes. Before 30-m, arrowhead and SDT tests, the warm-up consisted of submaximal running (5min), 2–3 submaximal short-distance sprints (e.g., 10–15m) and soccer-specific technical drills (e.g., short dribbling, pass game). Prior to LESS, CMJ, YBT-LQ and 1RM tests, low-intensity running followed by static and dynamic stretching, high knee lift and butt kicks, 3–5 CMJs and some of the submaximal free weight exercises (e.g., 6-8 repetitions in BS, FS, DL or UR according to the test day) were performed.

The tests were performed 3 days before the first training day and 3 to 5 days after the last training day. To keep the effects of fatigue minimal, pre-tests and post-tests were conducted on three non-soccer training days one in between in the weight room facilities and soccer fields. On the first day, the LESS, BS and UR tests were performed. On the second day, the measurements of CMJ, YBT-LQ, FS and DL were executed. Finally, on the third day, 30-m, arrowhead and SDT tests were completed. The sequence of tests in any testing day was the same as mentioned above. The rest interval after each test was at least 5-min. All participants were instructed to produce their maximal effort for each test. For all testing days, subjects were asked to refrain from any exhaustive physical activity other than their normal routine daily activities.

The testing process occurred under close supervision by the same inspector team, that consisted of two certified instructors and one soccer professional. Although each specific test was assessed by the same assessor for all participants, FMS, LESS, YBT-LQ tests were evaluated by an instructor and BS, FS, DL, UR tests were assessed by another instructor different from the first one. Likewise, the soccer professional assessed the 30-m, arrowhead, CMJ and SDT tests. The subjects and inspector team were blinded to the study design and groups to avoid any crossover or contamination. Also, the attendance of experimental group players in the intervention program was monitored. They participated in at least 24 of the 30 training sessions and didn't have any absence more than two consecutive sessions. During the intervention training period, all players were instructed not to do other additional physical training programs or conditioning programs on an individual basis.

Assessment of FMS: Stability and mobility, which can be checked by the FMS, are the basis of and are relevant to strength and flexibility (27). Strength and conditioning specialists can use the FMS as part of their monitoring battery on Fundamental movement patterns to identify functional limitations or asymmetries (27). According to Cook et al. (28), motion performance capability and techniques improves in an athlete only when he was armed with functional movements otherwise his efficiency exercise power reduces considerably.

The FMS involves seven tests that examine three different levels of movement difficulty (27). The overhead squat, in-line lunge and hurdle step tests are proposed to examine the three essential foot positions taken up in sport. The trunk stability and rotary stability tests are known as "transitionary patterns" and predominately assess transverse and sagittal core stability of the body. Finally, the "primitive, mobility patterns" of the body are assessed by the active straight leg raise and the shoulder mobility tests. In addition to the seven tests, there are three pain clearing tests which help out rule the possibility of back or shoulder pain. Overall FMS scores can range from 0 to 21 as the FMS tests have been fully described previously in several publications (15, 27). Chorba et al.(15) argued that a total score of <14 confers a greater risk of injury than a score ≥14.

According to Minick et al. (29), a high level of reliability can be secured if the FMS are scored by image analysis. Therefore, in this study, FMS tests were recorded using two Sony HDD Handycam (DCR-SR62 30GB hard disk drive, fps 30, Tokyo, Japan) (Figure 1) (29). Frontal and sagittal view recordings were obtained for all tests except the active straight leg raise and the shoulder mobility tests where only one view was necessary. Videos were analyzed using 2D video software (Kinovea 0.8.15). The certified instructor was allowed to view the videos as many times as possible to provide an accurate score by prior scoring criteria.

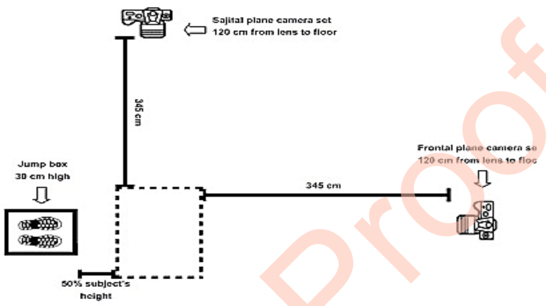

Figure 1. Camera placement during FMS and LESS tests and designed placement for LESS test.

Assessment of LESS: International Olympic Committee (IOC) recommended that the drop-jump screening tests be used to identify athletes at risk for a noncontact ACL injury (30). In this regard, the LESS test is one of the most notable screening tests that assess potentially high-risk movement patterns leading to lower limb injuries (18). The LESS involves undertaking a jump-landing task and aims to replicate the dynamic nature of activity and sport. The LESS involves whole-body movement which has become popular in both research and clinical practice. The scoring criteria for this screen are based on biomechanical faults that have been prospectively and retrospectively associated with injury as identified by the 'gold standard' 3D laboratory motion assessment. Research has suggested the LESS is a valid measure and has good interrater reliability (ICC=0.84) and excellent intrarater reliability (ICC=0.91) (18).

In the LESS, a lower score represents a better jump-landing technique resulting in lower injury risk. The LESS quartiles identify an excellent score (<4), a good score (≥4 but ≤5), a moderate score (>5 but ≤6), and a poor score (>6) (18).

For assessing the LESS test, subjects were asked to perform 3 trials of the jump-landing task. They were instructed to jump forward (not vertically) from a 30-cm high box, past a distance 50% of their height, marked by a line (figures 1). Immediately following that jump, subjects were instructed to jump vertically as high as they can. Subjects received no feedback on technique but were instructed to perform another trial if they did not jump with both feet from the box, did not jump past their indicated distance with both feet, or did not complete the task in a fluid motion. The jump-landing task was video recorded by two cameras. Video footage was analyzed by the certified instructor using the standardized LESS scoring sheet (18) through viewing the movement frame by frame or in slow motion. Dominant leg as "test leg" was designated as the leg most commonly used to kick the ball. All of the subjects' trials were averaged into a singular composite score.

The LESS scoring sheet scores an individual's landing technique based on a set of 17 criteria that are easily observable to the human eye (18). The 17 criteria examine lower extremity and trunk motion in the frontal and sagittal planes from initial ground contact until the subject jumps again vertically and can be subdivided into three main categories. The first category scores the jump-landing technique about the trunk and lower extremity position at the time of initial ground contact. The second category scores any faults associated with the feet between the point of contact with the ground and the time of maximum knee flexion. A third category scores trunk and lower extremity movements between the point of initial ground contact and the time of maximum knee flexion. The final two scoring criteria require the examiner to judge the amount of overall sagittal plane movement at the hips and knee from initial ground contact to maximum knee flexion angle and to provide an overall impression of jump technique (18).

Assessment of general performance

2.5.1 30-m test: The best way to test an athlete's speed is to assess their performance over sport-specific distances. For example, short sprints, lasting 10-40 m, are used to mimic the sprint distance typically observed during team sports (19). In this study, the 30-m sprint test was used. The sprint time for 30-m was measured using photoelectric timing gates (Speedtrap; Fitness Apollo Japan, Co., Ltd., Tokyo) positioned at the starting and finishing lines at a height of 1-m. Subjects started from a standing position, placing their forward foot 50-cm behind the sensor. They performed 3 repetitions with the best (fastest) times used for statistical analysis. A minimum of 2 minutes of recovery was provided between repetitions.

Arrowhead test: Agility is the result of a complex combination of speed, coordination, body control, turning ability, acceleration and deceleration, flexibility, power and functional lower body strength (19, 24). The arrowhead agility tests consisted of 4 sprints (two right, two left), with a 2-min rest between each sprint. Each subject started 50-cm behind the start line and sprinted 10-m forward to point A as on the diagram (figure 2) (20). From point A, the subjects turned to point B before turning to point C, and from point C, they turned again to accelerate in a straight line for 15-m over the initial start line to complete the run. The fastest times were recorded for data analysis. Photoelectric timing gates were used to accurately assess the time to completion. Also, if the subject step over the cone rather than turn it, the sprint was repeated. The reliability of the arrowhead agility test has reported excellent (ICC≥0.90) (20).

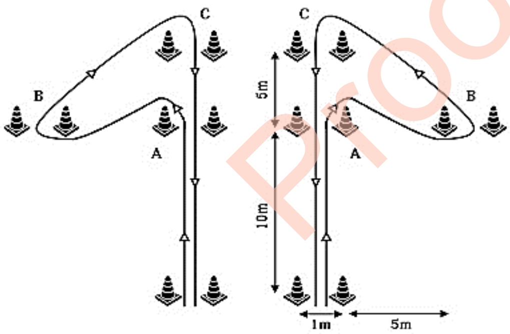

Figure 2. Arrowhead test.

CMJ test: Power is the product of two abilities, strength and speed, and is considered to be the ability to apply maximum force in the shortest time (24). Peak power can be predicted by height jumped with a very high level of reliability (21). The maximum vertical jump height was measured by the digital jumping tester (JS-D80, YAGAMI international training CO, Japan). Subjects performed a CMJ from a stationary position; they squatted down, swung their arms, and jumped upward as high as possible, touching the highest possible point on the digital jumping tester with their dominant hand. They performed 3 trials of the jump for maximal vertical height, with a 10-second rest period between trials. The average of the 3 maximal jumps was recorded as the subject's maximum vertical jump height.

YBT-LQ test: YBT-LQ protocol was designed to challenge the athlete's balance at her limit of stability. This dynamic balance motor skill has been suggested as a preparticipation as well as a return to sport test for athletes (13).

The YBT-LQ was performed by use of a YBT Kit. Subjects performed the YBT-LQ for both lower limbs. It required each subject to maintain single-limb stance control while reaching with the free lower limb in the anterior, posteromedial, or posterolateral directions, followed by returning to the start position. The testing order was three trials standing on the right foot reaching in the anterior direction followed by three trials standing on the left foot reaching in the anterior direction. This procedure was repeated for the posteromedial and the posterolateral reach directions. The reach distance attained was measured by reading the tape measure in centimeters at the near edge of the reach indicator, closest to the center of the instrument, at the point where the most distal part of the foot reached (22).

To compare results among athletes, reach distance was normalized to lower limb length; on a mat table with the subject supine measured from the most inferior aspect of the anterior superior iliac spine to the most distal portion of the medial malleolus with a cloth tape measure. To express reach distance as a percentage of lower limb length, the normalized value was calculated as reach distance divided by limb length then multiplied by 100. The greatest reach distance for each direction was used for analysis. A performance score on the YBT-LQ directions was calculated by averaging the greatest normalized reach distance (right and left) in each direction. A trial was considered invalid if the subject failed to maintain a single-limb stance, touched down on the reaching limb, failed to return to the starting position, or pushed or kicked the reach indicator to increase distance. The YBT-LQ protocol has been shown to possess good inter- and intrarater reliability (22).

1RM test: Maximum strength refers to the highest force that can be performed by the neuromuscular system during a maximum contraction. It is reflected by the heaviest load an athlete can lift in one attempt and is expressed as 100 percent of maximum or 1RM. It is crucial for training purposes to know one's maximum strength for each exercise since it is the basis for calculating loads for every strength phase. The intensity in strength training is often based on a percentage of 1RM. Strength has a high correlation to other facets of fitness (24).

1RM can be calculated directly using the maximal test and indirectly using the submaximal test. In this research, 1RM was calculated indirectly using the formula: 1RM=weight/(1.0278-[0.0278 x repetition]), with a maximum 10 repetition performance of players put into the 1RM formula to find 1RM (23). Relative strength values were used for analyses. These values were calculated by dividing the 1RM measured in kilograms by subjects' body mass measured in kilograms.

Assessment of soccer-specific performance (SDT): SDT was designed as a reliable measure for field hockey performance. The task required an individual to dribble a ball on a grass surface to multiple touchlines and back to the starting position for time. This task not only measures agility and speed but also added a component of ball handling. Ball handling is required any time a player receives the ball making is infinitely repeatable (25). This sport-specific task was also adapted for soccer players to measure soccer ball handling performance during a shuttle run task. This task would mimic changes in speed, direction, and ball handling performance mimicking on-field play (26).

The SDT consisted of 3 trials of maximal sprints covering 30 meters while performing a sport-specific task. Timed rests of approximately 2 minutes were given between each trial. Each trial of the SDT required 3 changes of direction, subjects were required to cross the line with the ball to be valid (figure 3) (25, 26).

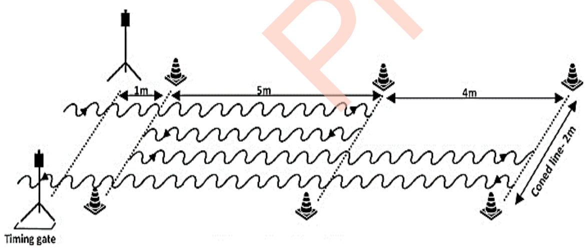

Figure 3. SDT field layout

They were given no feedback during the trial on technique. The only verbal instruction was to keep the ball within the coned area. Time was measured using photoelectric timing gates placed at approximately hip height above the ground. The timing gates were not placed at the start and finish of the task but at the 1-m mark to eliminate reaction timing, starting speed, and make the distance the required 30-m. The SDT measured peak soccer-specific performance (best SDT), indicated by the fastest trial time, and an average soccer-specific performance outcome (average SDT), indicated by the average time of all 3 trials (25, 26).

SSFT program: Two certified instructors and one soccer professional apart from the investigative team supervised all training sessions for EG. Instructors monitored and ensured that the load was appropriate for every subject to prevent skeletal and muscular injuries. Each training session involved a series of warm-up and cooldown exercises. Specifically, the subjects jugging for 5 minutes followed by static stretching of the calves, groin, hip flexor, low back, and chest muscle groups. If it was required, Self-Myofascial Release (SMFR) related to tibialis anterior, calf and thoracic erector spine muscles were done by foam rolling in subjects with mobility limitations after warm-up. The static stretches were repeated as part of the cooldown after completing each session.

The SSFT program involved exercises and drills aimed at improving speed, agility, power, balance, strength as well as soccer-specific drill. These exercises and drills were progressed to more demanding exercises in a four-phase mode over the 10-week training period. The training load increased by adding more resistance, repetitions, sets and exercise modifications. Details of SSFT programs are presented in Table 1. According to this table, some 1RMs values required in free weight training were recalculated and refreshed at the end of week 4 and week 7.

Statistical analyses: All statistical analyses were performed using the SPSS software, version 24.0 (IBM Corporation, Chicago, IL). Data were screened for normal distribution using the Shapiro-Wilk test. An independent samples t-test was used to find significant differences in the characteristics of study participants between groups. Subsequently, an analysis of covariance (ANCOVA) was used to determine the significant training effects of the SSFT program on experimental group. The level of significance was set at $P<0.05$, and where appropriate, partial eta-squared (partial η^2) was reported as a measure of the effect size. A partial eta-squared of 0.02, 0.13, and 0.26 represented small, medium, and large effect sizes, respectively (31). Also, in this study a paired-samples t-test was used to detect within-group changes for either group.

Results

Since in this article the number of players in both groups was the same from the beginning to the end of the study process and did not have a drop in subjects and there were pre-test and post-test data for all of the subjects, no consort flow diagram was presented.

Table 1. 10-week SSFT program (Phase 1: Preparatory/ Weeks: 1, 2/ Training sessions: 1-6)

Common free weight exercises and other exercises and drills separated by a week		Intensity	Repetitions	Sets	Rest (s)
1. Barbell back/ front squat heels raised		60-69 %1RM	15-20	3-4	90-120
2. Two hand romanian deadlift		60-69 %1RM	15-20	3-4	90-120
3. Seated leg extension (machine)*		60-69 %1RM	15-20	3-4	90-120
4. Leg curl (machine)*		60-69 %1RM	15-20	3-4	90-120
5. Barbell bench press		60-69 %1RM	15-20	3-4	90-120
6. Dumbbell two arm upright row		60-69 %1RM	15-20	3-4	90-120
7. Dumbbell standing shrugs		60-69 %1RM	15-20	3-4	90-120
	8.1. Step down on the unsteady surface (mat) (sessions 1, 2)	body weight	each leg 5 repetition	3	30
	8.2. Two-leg balance on wobble board (session 3)	body weight	30s	3	30
Week 1	9. One-leg balance on mat, tossing the ball	body weight	on each leg 5-8 tossing the ball	3	30
	10. Prone bridge	body weight, static	15-20s	3	15-20
	11. Supine bridge	body weight, static	15-20s	3	15-20
	8.1. Prone bridge (one leg) (sessions 4, 5)	body weight, static	each leg 10s	3	20
	8.2. Prone bridge (one leg) (session 6)	body weight, dynamic	each leg 10 reps	3	20
Week 2	9.1. Supine bridge (one leg) (sessions 4, 5)	body weight, static	each leg 10s	3	20
	9.2. Supine bridge (one leg) (session 6)	body weight, dynamic	each leg 10 reps	3	20
	10.1. Side bridge (elbow and knee) (sessions 4, 5)	body weight, static	each side 10s	3	20
	10.2. Side bridge (elbow and feet) (session 6)	body weight, static	each side 10s	3	20

Table 1. 10-week SSFT program (Phase 2: Hypertrophy/ Weeks: 3, 4/ Training sessions: 7-12) (continue)

Common free weight exercises and other exercises and drills separated by a week		Intensity	Repetitions	Sets	Rest (s)
1. ABC exercises#		body weight	20m in each exercise	2	10
2. Barbell back/ front squat heels raised		70-84 %1RM	10-12	3-4	90-150
3. Two hand romanian deadlift		70-84 %1RM	10-12	3-4	90-150
4. Seated leg extension (machine)*		70-84 %1RM	10-12	3-4	90-150
5. Leg curl (machine)*		70-84 %1RM	10-12	3-4	90-150
6. Barbell bench press		70-84 %1RM	10-12	3-4	90-150
7. Dumbbell two arm upright row		70-84 %1RM	10-12	3-4	90-150
8. Dumbbell standing shrugs		70-84 %1RM	10-12	3-4	90-150
	body weight	each leg 15s	3	30	
	body weight	each leg 15s	3	30	
	body weight, static	15-20s	3	15-20	
Week 3	body weight, dynamic	10 reps	3	20	
	body weight, static	15-20s	3	15-20	
	body weight, dynamic	10 reps	3	20	
	body weight, static	each side 10s	3	20	
	body weight, static	each side 10s	3	20	
Week 4	body weight, static	each side 10s	3	20	
	body weight, dynamic	each side 10 reps	2-3	30	

The attrition rate was 0 and no results can be expressed in ITT. On the base of independent samples t-test results, no significant baseline differences were found between groups in the characteristics of study participants (P > 0.05) (table 2).

The ANCOVA showed significant training effects of the SSFT program on experimental group (table 3). There were significant decreases in LESS score (F = 18.531, P ≤ 0.001) and time in 30-m test (F = 144.455, P ≤ 0.001), right and left arrowhead tests (F = 110.375, P ≤ 0.001; F = 62.756, P ≤ 0.001 respectively) and average SDT (F = 77.109, P ≤ 0.001) after 10-week SSFT program.

Significant increases were observed in vertical jump test (F = 54.897, P ≤ 0.001), average of maximal normalized reach distance YBT-LQ in three directions (anterior: F=157.528, P ≤ 0.001; posterio lateral: F = 23.119, P ≤ 0.001; posterio medial: F = 42.283, P ≤ 0.001) and all of the 1RM tests (BS: F = 87.534, P ≤ 0.001; FS: F = 115.534, P ≤ 0.001; DL: F = 74.536, P ≤ 0.001; UR: F = 32.779, P ≤ 0.001) as a result of 10-week SSFT program. This program didn't affect the best SDT time significantly (F = 2.321, P = 0.141).

Table 1. 10-week SSFT program (Phase 3: Strengthening/ Weeks: 5-7/ Training sessions: 13-21) (continue)

Common free weight exercises and other exercises and drills separated by a week		Intensity	Repetitions	Sets	Rest (s)
	2. Barbell back/ front squat	≥85 %1RM	6-8	4-5	120-180
	3. Two hand romanian deadlift	≥85 %1RM	6-8	4-5	120-180
	4. Dumbbell two arm upright row	≥85 %1RM	6-8	4-5	120-180
Week 5	1. Speed and agility drills (active and reactive)[§]	maximal effort	7-10 reps (each rep less than 10-12s)	1	20s between each rep
	5. Four-way single-leg squat matrix (Standard, forward, lateral, rotational)	body weight (open arms to closed arms behind the head)	2-4 reps in each direction	2-3	60
	6. Pistol squat with the suspension system	body weight	each leg 10 reps	2-3	60
	7. Barbell lateral step-up	10-15% body weight	each leg 10 reps	3	60
	8. Kneeling hip extension	body weight	10 reps	3	60
Week 6	1. Resistance speed and agility drills (active and reactive)[§]	maximal effort	7-10 reps (each rep less than 10-12s)	1	20s between each rep
	5. Dumbbell forward lunge	10-15% body weight	each leg 5 reps	2	60
	6. Weight plate lateral lunge	10-15% body weight	each leg 5 reps	2	60
	7. Dumbbell reverse crossover lunge	10-15% body weight	each leg 5 rep	2	60
	8. Kneeling Russian curl	body weight	10 reps	3	60
Week 7	1. Speed and agility drills (active and reactive)[§] in combination with mind engagement	maximal effort	7-10 reps (each rep less than 10-12s)	1	20s between each rep
	5. Tuck jumps	body weight	10 reps	3	60
	6. Jackknife with rotation	body weight	10 reps	3	60
	7. Superman with swissball	body weight, static and dynamic	20s	3	60

Table 1. 10-week SSFT program (Phase 4: Transferring/ Weeks: 8-10/ Training sessions: 22-30~) (continue)

Common free weight exercises and other exercises and drills separated by a week		Intensity	Repetitions	Sets	Rest (s)
	1. Barbell back/ front squat	>95 %1RM	2-3	5-6	180-300
	2. Two hand romanian deadlift	>95 %1RM	2-3	5-6	180-300
	3. Power clean with barbell	10-15% body weight	2-3	5-6	180-300
Week 8	4. Speed and agility drills (active and reactive)[§] with ball	maximal effort	7-10 reps (each rep less than 10-12s)	1	20s between each rep
	5. Squat jumps	body weight	10 reps	2-3	60
	6. Lateral box drive	body weight	each leg 10 reps	2-3	60
	7. Jump onto step	body weight	10 reps	2-3	60
	8. X-hops (right leg)	body weight	a quadrant pattern with 2-3 reps	2	120
	9. X-hops (left leg)	body weight	a quadrant pattern with 2-3 reps	2	120
	10. Sled drag	10-15% body weight	10-15s	2-3	60
Week 9	4. Resistance speed and agility drills (active and reactive)[§] with ball	maximal effort	7-10 reps (each rep less than 10-12s)	1	20s between each rep
	5. Single leg hop and hold	body weight	each leg 4-5 reps	2	60
	6. Jump and go	body weight	10 reps (each rep 5s)	1	15s between each rep
	7. Scissor jumps	body weight	7-10 reps	2	60
	8. Multiple double-leg jumps over the barriers	body weight	7-10 reps	2	60
	9. Multiple single-leg jumps over the barriers (Right)	body weight	7-10 reps	2	60
	10. Multiple single-leg jumps over the barriers (left)	body weight	7-10 reps	2	60
	11. Multiple lateral double-leg jumps over the barriers	body weight	7-10 reps	2	60
Week 10	4. Speed and agility drills (active and reactive)[§] in combination with mind engagement and ball	maximal effort	7-10 reps (each rep less than 10-12s)	1	20s between each rep
	5. Squat depth jump	body weight	10 reps	2	120s (and 5s between each rep)
	6.1. Depth jump to second box (sessions 28, 29)	body weight	10 reps	2	120s (and 5s between each rep)
	6.2. Repeated depth jump (session 30)	body weight	5 reps	3	60
	7. Depth jump with lateral movement	body weight	5 reps	2	120s (and 10s between each rep)

*: It was only used in subjects who had weaker results in the 1RMs (specially pre-tests related to squat or deadlift exercises) compared to other subjects.
#: Some ABC exercises consisted of skippings, butt kickers, high knee skips, high knee running, high knee bounce skips were instructed and trained.
§: In combination with ABC exercises with and without using a ladder.
~: Training sessions in the transferring phase were performed in the soccer field.

Table 2. Characteristics of study participants (mean±standard deviation of the mean)

Characteristic	Experimental Group (n=14) (5 Def, 6 Mid, 3 Att)#	Control Group (n=13) (4 Def, 5 Mid, 4 Att)#	Between-group Pvalue
Age (y)	14.62±0.51	14.83±0.42	0.261
Body mass (kg)	52.08±7.53	52.91±6.47	0.762
Body height (m)	1.62±0.09	1.64±0.10	0.656
Body Mass Index (BMI) (kg/m^2)	19.61±1.09	19.55±1.10	0.892
FMS Score§	16.14±1.40	16.00±1.22	0.781

#: Def: defenders, Mid: midfielders, Att: attackers.
§: Only players with FMS Score ≥14 participated in this study.

Discussion

Present study investigated the effect of a comprehensive SSFT on sport performance indicators in young athletes. The findings of the present study indicated significant improvements in some risk factors of lower extremity injuries (LESS score) along with sport performance indices after 10-week of concuminant SSFT and soccer training in young male soccer players.

The effects of combined intervention programs on risk factors of injuries and their concurrent effects on sports performances have been reported previously (10, 32-34). Dynamic jump-landing tests, such as the LESS, are performed at a much greater speed and as such involve much greater dynamic control to be performed correctly (4). The LESS test involves a rapid deceleration when landing from a 30cm box before accelerating back into a jumping action (18). In this regard, Noyes et al. (10) reported significant improvement of lower extremity alighment following a sport-specific training program in highschool' female soccer players for preventing knee ligament injuries; While before training, 62% of the players had dynamic valgus during landing of a jumping task, only 4% of them showed the same alignment intervention.

Table 3. Changes in some risk factors of lower extremity injuries and general and specific sport performance indices following a 10-week SSFT program in young male soccer players (mean ± standard deviation of the mean)

Variables	Groups	Pre-tests	Post-tests	Within-group P value	Between-group P value	η²
LESS Score	Experimental	6.71±1.38	5.07±0.91	<0.001	<0/001	0.436
	Control	7.07±1.18	6.53±1.26	0.089		
30-m test (s)	Experimental	4.68±0.27	4.41±0.25	<0.001	<0.001	0.858
	Control	4.64±0.23	4.61±0.22	<0.001		
Right Arrowhead Test (s)	Experimental	8.69±0.32	8.45±0.27	<0.001	<0.001	0.821
	Control	8.65±0.25	8.67±0.23	0.109		
Left Arrowhead Test (s)	Experimental	8.68±0.30	8.43±0.25	<0.001	<0.001	0.723
	Control	8.66±0.26	8.64±0.24	0.102		
Vertical Jump Test (cm)	Experimental	34.28±5.48	43.14±6.74	<0.001	<0.001	0.696
	Control	36.61±6.78	37.38±7.08	0.106		
YBT-LQ/anterior (%)	Experimental	71.38±7.81	78.28±9.17	<0.001	<0.001	0.868
	Control	73.06±3.83	72.9±4.47	0.743		
YBT-LQ/Posterio Lateral (%)	Experimental	92.90±5.88	98.89±8.67	<0.001	<0.001	0.491
	Control	91.56±8.84	92.95±10.02	0.634		
YBT-LQ/Posterio Medial (%)	Experimental	96.88±5.51	105.83±5.59	<0.001	<0.001	0.638
	Control	98.29±6.73	101.50±8.41	0.076		
1RM test/BS (kg/body mass)	Experimental	0.89±0.22	1.24±0.27	<0.001	<0.001	0.785
	Control	0.85±0.19	0.87±0.19	<0.001		
1RM test/FS (kg/body mass)	Experimental	0.63±0.18	0.94±0.20	<0.001	<0.001	0.828
	Control	0.58±0.13	0.62±0.14	<0.001		
1RM test/DL (kg/body mass)	Experimental	0.77±0.15	1.01±0.19	<0.001	<0.001	0.756
	Control	0.74±0.12	0.75±0.12	0.373		
1RM test/UR (kg/body mass)	Experimental	0.36±0.06	0.46±0.07	<0.001	<0.001	0.577
	Control	0.36±0.04	0.37±0.05	<0.001		
Best SDT (s)	Experimental	11.13±1.78	11.07±1.72	0.053	0.141	-
	Control	11.20±1.83	11.18±1.81	0.540		
Average SDT (s)	Experimental	12.02±2.18	11.15±1.71	<0.001	<0.001	0.763
	Control	11.92±1.91	11.85±1.79	0.092		

LESS: Landing Error Scoring System; YBT-LQ: Y Balance Test-Lower Quadrant; 1RM: one repetition maximum; BS: back squats; FS: front squat; DL: deadlift; UR: upright row; SDT: Shuttle sprint and Dribble Test.

They also reported significant improvements in the performance indices. DiStefano et al. (33) compared the effects of an isolated resistance training program and an integrated training program on movement quality of a jump-landing task and performance measures in members of an introductory weight training course with mean 19 years old. Of the most important findings was that the integrated training group performed better on the LESS test after 8-week. In another study, youth soccer players with the highest baseline LESS score sustained the greatest improvement after an anterior cruciate ligament IPP (34).

The results of the LESS in the pre-test of this study revealed that there were potential risk factors for lower extremity injuries, which implied poor movement control and low quality functions in the participants. In multi-joint tasks, such as jump-landing, each joint must be in complete coordination with others so that the various components of the task be integrated together well as an overall strategy. On the other hand, for motor skills involving multiple joints as a normal kinetic chain, the maximum ability to exceute the skill depends on the weakest link of the chain; this way, when there is a deficit in a joint, transition and absorption of forces throughout the kinetic chain will be restricted and the quality of the skill performance will be decreased (35).

Eccentric strength may be one of the most important factors controlling dynamic lower extremity valgus during jumping or cutting (5). Gluteal musculature deficits, that lead to valgus stress on the knee, may be managed by strengthening components in this intervention program such as double and single-leg squats, step-up, types of lunge, deadlift, power clean, types of bridge, kneeling hip extension and russian curl exercises. Lunge exercises variants require greater dynamic flexion of hip and increases the demand on the gluteal musculature particularly gluteus maximus. Facilitation and strengthening of the Gluteal musculature reduces the femoral internal rotation and adduction, through which the knee valgus and tibial rotation will decrease, and lower extremity alignment will be saved (5).

Increasing activation of the hamstring musculature decrements the anterior shearing force on the tibia, knee valgus, and tibial rotation. Strengthening components of the proposed program may address hamstring deficits, increasing the likelihood of co-contraction during jump landing and cutting (36). Routine exercises with eccentric loads such as kneeling hip extension and russian curl are effective in strengthening the hamstring; therefore they were included in the intervention program alongside the leg curl and deadlift exercises.

Single-leg movements reduces strength discrepancies, or leg dominance (36). In present intervention program, squat jumps, lateral box drive, X-hops, single-leg hop and hold, and scissor jumps exercises were used progressively to establish the dynamic balance on the opposite side. Hopping exercises improve muscle strength, coordination, joint stability, and balance and lead to better control of synergists via changing the neuromuscular system (36). In addition to the dynamic balance exercises cited above, the proposed exercises was designed to enhance position sense awareness by means of step down on unsteady surface, one leg balance on mat and tossing ball, two/one-leg balance on wobble board and one-leg balance with resistive tubing.

During landing, the trunk receives a large impact after ground contact because of the large ground reaction forces (37, 38). It is commonly agreed that trunk stability is important to perform a jump following landing and there is a strong association between the lumbopelvic complex stability (proximal dysfunction) and increased risk of lower limb injuries (37). Peak knee abduction moment is correlated to torso lean as more torso lean higher ACL load and risk of injury (38).

Some exercises in present program were designed to counteract agaist trunk dominance; the different types of prone and supine and side bridges, side bridges, kneeling russian curl, jackknife with rotation and superman with swissball are some of these excersises. Classical strength-training exercises like aforementioned protocol simulate favourable adaptation in trunk musculature (39).

Not one singular component of the IPP may be known as the most effective part in injury prevention, but the plyometric training subset is often the the one of largest impact because of resembling the sports activities (36). Examples of plyometric training exercises used in this study were tuck jumps, multiple double/single-leg jump over the barrier, multiple lateral double-leg jump over the barrier, squat depth jump, depth jump to the second box, and repeated depth jump.

The functional training interventional program ended up with plyometric drills with rapid change of directionjump and go and depth jump with lateral movement after instructor command to name a few. These drills require higher muscle activity than controlled landing exercises (36) and are more similar to sport-related activities; thus, they may probably have had an important role in knee stability training.

In summary, functional training intervention program presumably has led to a higher level of skilled performance for jump-landing task (LESS test) when eliminating potential kinetic chain deficits and knee instability inducing factors were emphasized through multi-muscle and multi-joint activities with a combination of upper and lower body exercises, utilizing the whole body in most exercises, and refining the technique by instructions on the proper landing strategies.

According to the results of this study, all of the 1RM tests showed improvement after strength training with free weights. To justify these results in coordination with Specific Adaptation to Imposed Demands principle, high-threshold strength training (intensity in range from 85-100% 1RM and low repetitions) may increase force generation and improve sport performances through both hypertrophy and neural adaptations of the muscles (40).

For athletes, multi-joint exercises have greater specificity transfer than single-joint exercises (35). Hence, the squat is a big and compound exercise that utilizes a large muscle mass and loads the axial spine (12). Greater squat strength is associated with faster 5-m, 20-m, 30-m and 60-m sprint times (41). Also higher full squat strength is more significantly correlated with higher vertical jump and Penta jumps records (41). According to Sander et al. (42), complex weightlifting exercises like back and front squats result in improvements in 1RM tests of these exercises and 30-m sprint time. As a compound exercise, Deadlift also contains movements spanning three joints with concentric extension and stabilization of the hip, knee and ankle joints and therefore, strengthening through this exercise will improve performance (12). Moreover, it is the precursor to power exercises such as the power clean, that are essential aspects of an athlete’s programmed power phase (12).

Combining strength training and power training improves explosive performance and power-related skills to a greater extent than any of them alone (43). This may explain improved speed, agility and power tests in present study. It is known that high pull, power clean, and weighted squat jump have the greatest effect in sprint and jump performances because they consisted of simultaneous triple-extension of the ankle, knee, and hip joints (44). Power clean exercise besides other explosive exercises like sled drag was administered for the sake of higher explosive performance.

Plyometric training consists of high velocity movements that challenge the proprioceptive system data required for both eccentric and concentric contractions (45). In agreement with the specificity principle of training, Johnson et al. (46) indicated that plyometric programs considerably increased children ability to jump and run with a smaller strengthening results. The results of the present study concerning better records in agility test were comparable to those of a previously published study (47). In Meylan and Malatesta's research (47), the significant change in agility time performance demonstrated that a plyometric program can have a positive influence on a field agility test similar to soccer game-play and therefore may have an impact on true soccer performance. Improved agility performance may be resulted from power maturation or enhanced eccentric strength of the lower limbs, which can impact direction performance during the deceleration phase. Moreover, better agility performance can be attributed to neural adaptations and in particular intermuscular coordination (48).

In this study, YBT-LQ improved in all three directions. Possible reasons for improving balance encompass increased strength, improvement of co-contraction and neuromuscular control of lower extremity muscles after participating in the hopping exercises as previous studies confirmed that participating in similar exercise programs may improve these parameters significantly in young soccer players of the same background (32, 44, 47, 49). In these exercises when single-leg hop and then suddenly hold is done, concentric and eccentric contractions, in jumping and landing respectively, are practiced progressively in the anterior-posterior, medial-lateral, and rotary directions (49).

Ball-shooting speed in Wong et al. (44) research increased significantly after combined strength and power training. The short-term effects of a complex 6-weeks training program on agility with the ball (dribbling the cones) and shooting speed was investigated by Cavaco et al. (50) and was proved that combination of strength and plyometric exercises is an effective method in promoting abilities and motor skills associated with soccer among young players.

Sport-specific performance tests discussed in the aforementioned studies can not be considered as soccer-specific tasks performed by most players and can not be infinitely repeatable during play or competition on the soccer field. From this perspective, the present study used an SDT that contained such features.

In the present study, the improvement was observed only in average SDT. It seems that the improvements in general sport performances, including strength and power, speed and agility and balance have been probably transmitted to improve the acceleration, speed and agility needed simultaneously with ball handling in the SDT. Subjects dribbled the ball in the least possible time between the starting position and the finishing lines. Furthermore, alongside the other exercises in this study, speed and agility drills, resistance speed and agility drills and speed and agility drills in combination with mind engagement, in the form of active and reactive, were used in the fifth, sixth and seventh weeks, respectively. For the more attention to similarity and context principle in SSFT, these drills in the eighth to tenth weeks were practiced in the soccer field by ball. These drills may be effective in improving the average SDT.

In contrast, the functional training intervention program did not have any significant effect on the best SDT due to the ball handling, and more clearly changing the direction of the ball at finishing lines. Soccer players may put various soccer techniques into service while this fact was unfortunately neglected when designing the intervention program; Practicing returning drills from the finishing lines may potentially change the results.

In sum up, the exercises and drills designed in the form of SSFT can be considered as a way to enhance general and specific sport performances in young male soccer players. The proprioception changes and neuromuscular adaptations across motor units, synergistic control such as co-contraction pattern, and the activity and recruitment of antagonist muscles and intermuscular coordination during similar programs worth further research.

The evaluation of clinical jump-landing task and sport performance measurements used in this study are applicable to the athletic population and feasible for use by clinicians. Furthermore, the combination of IPP with intervention program was able to be simultaneously improve some of the lower extremity injury risk factors and performance indicators i.e. this approach successfully enhances sport performances utilizing the concept of functional capabilities. The heed of the training principle of specificity or being task-specific for exercise to achieve maximum transferability was a notable point in this intervention program.

Limitations

The results of the present work may not be generalized to the elite levels, other age groups and girls.

Recommendations

According to this article, SSFT is suggested to coaches, players, and the health care team for reducing some risk factors of lower extremity injuries and improving the sport performance indicators.

Conclusion

This study showed that SSFT designed based on functional capabilities in combination with regular soccer training reduced some risk factors of lower extremity injuries and induced sport performance improvements in young non-elite male soccer players.

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Authors' Contribution

Nadjmeh Afhami: study design and ideation, attracting financial resources for the study, study support, executive, and scientific services, providing study equipment and samples, data collection, manuscript preparation, specialized evaluation of the manuscript in terms of scientific concepts, approval of the final manuscript to be submitted to the journal office, responsibility to maintain the integrity of the study process from the beginning to the publication, and responding to the referees' comments; Reza Siamaki: study design and ideation, study support, executive, and scientific services, providing study equipment and samples, data collection, manuscript preparation, specialized evaluation of the manuscript in terms of scientific concepts, approval of the final manuscript to be submitted to the journal office, responsibility to maintain the integrity of the study process from the beginning to the publication, and responding to the referees' comments.

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Conflict of Interest

The authors declare no conflict of interest. The corresponding author attracted the basic study related to this article from Sirjan University of Technology and has been working as an assistant professor of physical education and sports sciences at Sirjan University of Technology since 2017. Reza Siamaki has been an assistant professor of sports pathology and corrective movements at the Asrar Institute of Higher Education since 2019.

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