International Journal of
Sports Science
& Coaching

Original research article

International Journal of Sports Science & Coaching
1–13

DOI: 10.1177/17479541221097857
journals.sagepub.com/home/spo
SAGE

The effect of proprioceptive training on technical soccer skills in female soccer

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Abstract

Development of perceptual-cognitive motor skills is a crucial factor influencing soccer training and competition. The aim of the study was to examine the effects of neuromuscular coordination, proprioceptive and balance exercises on physiological attributes and technical skills in female soccer. Female soccer players competing in Greek A Division ($N = 48$) were assigned to intervention ($N_1 = 24$) and control groups ($N_2 = 24$). The Proprioceptive Training Intervention Program (PTIP) lasted approximately 20 min and was implemented five times per week for 16 weeks. It was hypothesized that the PTIP in addition to a regular training programme would significantly affect female soccer player perceptual-cognitive-motor capability as it was estimated with physiological attributes ($\dot{V}O_2max$ and agility) and motor performance soccer technical skills (juggling, heading, shooting, passing, and dribbling). All performance variables were measured prior and after the 16-weeks PTIP. Groups by Measures (2×2) ANOVAs with repeated measures on the second factor revealed that the intervention group decreased percent body fat and improved $\dot{V}O_2max$ and all technical skills in comparison to the control group after the PTIP ($p < 0.05$). The findings demonstrate the beneficial role of a proprioceptive training programme on both physiological attributes and technical skills in female soccer. Practical implications include the application of the intervention programme for monitoring and developing soccer players while also the use of the assessment tests to evaluate players.

Keywords

Proprioception, balance, intervention, technical skills, female soccer, aerobic capacity, agility, association football, neuromuscular control

Introduction

Soccer as an open-skill and competitive sport requires a multitude of perceptual-cognitive-motor skills to be performed under continuously and rapidly changing conditions.[1,2] Skill can be defined as an activity or a task that requires voluntary control, has a specific purpose or goal to achieve and has to be performed with high confidence and with the least amount of time and/or energy.[3] Perceptual-cognitive-motor skills in soccer are comprised of two components; one refers to technique (motor skill execution) and the other to decision-making (e.g. executive functions, anticipation, attention) (perceptual–cognitive skill).[4] As Mohr et al.[5] stated, soccer players may have good movement patterns (technique), maintain their technique under different fatigue states, and perform the appropriate action at the appropriate time (skill). Moreover, the skill element refers to the player's learned ability to perceive and execute the appropriate movement pattern based on the demands of the game. The core of this viewpoint is that the cognitive component of the player, in the form of decision making, is a critical performance component.[1]

An extensive number of research studies indicated that physical, physiological, mental, and technical skills are of paramount importance as they are crucial for successful soccer play (e.g..[6,7]) Soccer players are expected to be competent in aerobic and anaerobic capacity,[8] make correct

Reviewers: Sinikka Heisler (German Sport University Cologne, Germany)
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decisions under time constraints,[9] and perform technical soccer skills, such as dribbling, passing, shooting,[10] and heading[11] with speed and accuracy. Moreover, as it is stated by Ali[1] and Davids et al.,[12] many of the soccer skills required -such as passing, dribbling, shooting, and heading- are complex movement patterns and executed while standing on one leg, which underlines the importance of coordination abilities and perceptual cognitive processes in successful performance. Therefore, soccer training should focus on the development of proprioceptive-coordinative abilities as they can improve perceptual-cognitive components of players, such as anticipation, decision-making, and motor skill execution.

The cornerstone of the effective and successful execution of this combination of skills is proprioception and its importance has been recognized widely in the literature (i.e..[1)] Proprioception is a complex neuromuscular process and "refers to our sensation and perception of limb, trunk, and head position and movement" (,[3] pp. 115). It is reliant on sensory information transmitted to the central nervous system, involves afferent and efferent signalling, and plays a crucial role in stability and orientation while executing motor skills.[3] In addition, balance has been defined as the ability to maintain a (static) base of support and perform a task while maintaining a (dynamic) stable position.[13]

It is a well-documented fact that proprioceptive training programmes have been shown to reduce injury risks particularly lower extremity injuries.[14,15] In addition, proprioceptive training has been shown to improve balance,[16] agility performance,[17] ability to learn a new skill,[18] performance enhancement,[19] and even sport attainment.[20] More specifically, studies focusing on soccer have examined the effects of different warm-up methods and stretching techniques including proprioceptive training on agility, dribbling, shooting, anaerobic capacity, and performance. Amiri-Khorasani et al.[21] examined the effects of static, dynamic, and the combination of static and dynamic stretching within a pre-exercise warm-up on the Illinois Agility Test (IAT) in soccer players. The soccer players were tested for agility performance using the IAT after different warm-up protocols consisting of static, dynamic, combined stretching, and no stretching. The key finding of this research revealed that dynamic stretching was the most effective warm-up method for agility performance. Similarly, Gelen[22] compared the effects of different warm-up methods on a variety of soccer parameters such as sprinting, slalom dribbling, and penalty kicks. In line with previous findings, dynamic exercises were found to be the most facilitative for all the skills that were executed by the players. Another study examined the effects of warm-up protocols on anaerobic performance identifying that dynamic warm-up enhanced anaerobic performance in elite youth soccer players.[23] Recently, Boraczynski et al.[24] examined the effects of on-field proprioceptive exercises on motor performance among soccer players. The findings revealed that proprioceptive training, which included a variety of exercises such as single leg balancing games, standing on one foot while kicking the ball to a teammate, and using a balance trainer, can help prepubertal soccer players improve their motor coordination abilities and soccer skills. The authors highlighted the multidimensional benefits of proprioceptive training exercises in prepubertal soccer players.

However, there is scarcity of research examining the potential effects of proprioceptive training programmes on the development of technical skills. Despite its rapid growth, research on female soccer players is limited and inconsistent, particularly when compared to research on male players. Research has shown that female soccer matches have different requirements than male soccer matches such as fitness requirements and match performance characteristics (i.e.[25)] and female players are two times more likely to experience an anterior cruciate ligament injury.[26] Therefore, it is important to examine more in depth the female game to enhance our understanding which will enable practitioners to incorporate key exercise programmes (i.e. proprioceptive training) in their exercise routines to facilitate development.

Studies examining the effectiveness of proprioceptive training on female soccer players showed that the training programme led to reduction of the number of noncontact injuries (e.g. hamstring) while also reduced the rehabilitation time for noncontact injuries.[14] Similarly, adherence to the neuromuscular injury prevention programme (FIFA 11 +) which includes proprioceptive and balance exercises significantly reduced the injury risk and improved the balance of youth female soccer players.[27] Proprioceptive balance training can also improve performance related characteristics such as sprint ability[28] and jump performance (for a comprehensive review, see.[29,30)] Moreover, a limited number of studies have also identified the potential benefits of proprioceptive and balance training on technical skills in sports.[31,32]

A variety of tests have been used and evaluated in the literature enabling researchers to use them to assess training or intervention programmes in relation to performance in soccer (i.e..[1,10,33,34)] However, there is scarcity of research evaluating the potential effects of proprioceptive-coordinative exercises on specific technical skills in soccer, particularly in female soccer. As such, the aim of this study was to examine the effects of neuromuscular coordination, proprioceptive, and balance exercises on physiological attributes and technical skills in female soccer players. It was hypothesized that a specialized 16-week Proprioceptive Training Intervention Program (PTIP) in addition to a regular training programme would elicit significant improvements in female soccer players when compared to female soccer players that follow a regular training programme. Hence, for the purpose of the study, the proprioceptive training programme of the current study included variations of balancing on dynamic balance disks[35] as well as agility runs, juggling, kicking, passing, dribbling, shooting, and heading a ball toward a target.

Methods

Participants

Forty-eight female soccer players, competing in the Greek A Women Football (Soccer) Division ($M_{age} = 26.96 \pm 2.93$ years; $M_{height} = 168.69 \pm 3.14$ cm), participated in the study. Prior to their participation, it was confirmed that participants did not take any medication, had no pathological conditions or diseases, and had not participated in an organized proprioception and/or balance training intervention programme within the last six months prior to the start of the study. All female soccer players were outfield players and members of two professional football teams. Both teams were competing in the same division and were playing soccer for 14.79 ± 2.68 years.[1] Twenty-four players of one team were assigned to the Control Group ($M_{age} = 24.04 \pm 2.84$ years; years of playing soccer $M_{age} = 14.75 \pm 2.66$ years) and twenty-four of the other team to the Intervention Group ($M_{age} = 23.88 \pm 3.01$ years; years of playing soccer $M_{age} = 14.83 \pm 2.76$ years) and took part in a 16-week training intervention programme. Both teams were engaged in the usual training activities and followed similar training programmes with the supervision of their coaches, participated in 5 training sessions (duration ~ 90 min) and one competitive match per week, and had similar standings in their playing division. Thus, the difference between the two groups was that the Intervention Group also participated in the 16-week training intervention programme. In compliance with the ethical standards that govern human research (Declaration of Helsinki, 2008 version), all participants were required to read and sign a written informed consent.

Procedures

Physiological attributes. The measurements of the current study were based on the procedures of previous studies.[36,37] More specifically, standing height was recorded to the nearest 0.5 cm with a Seca Stadiometer (Birmingham, United Kingdom), while body weight was measured to the nearest 0.1 kg with a Seca Beam Balance 710 (Birmingham, United Kingdom). Body fat was calculated using the 7-skinfold method,[38] measured by an appropriate skinfold calipre (Harpenden Skinfold Caliper, Baty International, West Sussex, England). To estimate maximal oxygen uptake ($\dot{V}O_2$max) and maximal heart rate (HR max), each female soccer player performed an incremental treadmill (Technogym Runrace, Gambettola, Italy) running test to exhaustion. Oxygen uptake ($\dot{V}O_2$) was measured using a portable gas exchange analyzer (K4b2; Cosmed, Rome, Italy) that had been calibrated with known oxygen and carbon dioxide gas mixtures, while heart rate (HR) was measured telemetrically (Polar FT1 Model; Polar Electro Oy, Kempele, Finland). The $\dot{V}O_2$max protocol consisted of running at 7 km.h-1 for 1 min and 8 km.h-1 for 30 s Thereafter, the speed of the treadmill was increased by 0.5 km.h-1 every 30 s until exhaustion. The inclination of the treadmill during the $\dot{V}O_2$max test was 1%. The $\dot{V}O_2$max and HR max were determined as the highest values reached in a 15-s and 5-s period, respectively, during the last part of the incremental test The criteria for attainment of $\dot{V}O_2$max included 2 of the following: Respiratory Exchange Ratio (RER) > 1.1, HR max within 10 beats.min-1 of the estimated HR max based on age, a rating of perceived exertion equal to, or higher than 18, or a levelling off in $\dot{V}O_2$ (< 2 ml.kg-1.min-1) with a concomitant increase in treadmill speed. All measurements were collected before and after the PTIP.

Proprioceptive training intervention program. Participants in the intervention group underwent a 16-week PTIP with five sessions per week. Each session lasted for approximately 20 min. Prior to each session, participants had a 15 min warm-up. The PTIP consisted of agility ladder football drills, drills with hoops, and balance exercises on BOSU, TOGU, inflated balance disks, and mini trampoline. Practicing the following soccer drills and exercises, female players have the opportunity to cope with a constantly changing environment incorporating the combined perceptual-cognitive-motor components (i.e. decision making, motor skill execution) of the proprioceptive exercises. The main objective of practice with PTIP was to encourage a broad range of movement and different leg patterns to improve sharpness, quickness, proper foot positioning, coordination, and balance.

Agility Ladder Drills. The agility ladder used had dimensions of 5.55 m × 0.50 m and consisted of 12 unbreakable plastic "stairs", connected to each other by durable belts. Female soccer players were standing in an upright position and at a distance of 50 cm behind the ladder. After the signal of the teammate they had to perform a variety of technical running drills such as (a) forward sprint by placing one foot in each square, (b) forward sprint by placing two feet in each square, (c) forward straddle hops in-and-out, (d) standing to the side of the ladder and moving in a lateral fashion in-and-out all the way along the ladder, (e) single leg linear hops, (f) single leg lateral in-and-out hops, (g) slalom jumps with one leg in each square, and (h) diagonal quick slalom. All drills were performed in a quick manner and at the end of the ladder, at a distance of 1 m, a ball was placed. At a distance of 10 m from the ball, there were 3 small goals (1 m long and 60 cm high) that were placed, two diagonally in relation to the ball and one vertically.

The players, after passing the last square of the agility ladder, they had to choose and shoot the ball in one of the 3 goals, scoring a goal.

Drills with Hoops. Twenty-four hoops, 80 cm in diameter, were arranged to form two routes (12 hoops per route): a straight line with one-to-one setting and a straight line with two-one-two-one setting. Procedures and drills were similar to agility ladder drills, with the difference that when the players finished the route with the hoops, they dribbled with the ball fast for 10 m and then had to aim at one of the 3 small goals, scoring a goal with the foot of their choice.

BOSU Exercises. BOSU balance device (BOSU, Canton, OH) is designed to improve stability[39] and is used for balance training. Female soccer players had to keep their balance while standing on one leg (dominant and non-dominant) on the inflatable side (approximate height 25 cm) of the BOSU device. With the signal of the teammate, the player had to perform the following exercises. (1) The player was instructed to balance on the BOSU for 30 s, using interchangeably the dominant and the non-dominant leg with both arms at the waist (2) While balancing on the BOSU for 30 s, the teammate was throwing a ball from a distance of 5 metres and the player, in parallel with balance, had to return the ball using the inside (and/or the upper part) of the foot without, either the ball or the foot, touching the ground. (3) Same as the previous exercise, with the difference that player had to return the ball with a header. (4) Same as exercise 2, with the difference that the player had to juggle the ball as many times as possible for 30 s During juggling, the player could use various parts of the body without letting the ball touching the ground. (5) Same as exercise 2, with the difference that the player had to score a goal in one of the 3 small goals (1 m long and 60 cm high) which were placed, two diagonally in relation to the ball and one vertically, at a distance of 10 metres. All exercises lasted 30 s with a break of 30 s. Players were using the dominant and non-dominant leg, interchangeably, during PTIP. If they were falling or touching the ground, they had to return and stand on the BOSU until the completion of the 30 s period. Female soccer players had to perform the same exercises on (a) TOGU© Redondo ball with a base diameter of 40 cm and approximate height 20 cm, (b) inflatable balance discs (diameter of the base 33 cm and approximate height 20 cm), and (c) mini trampolines (30 cm height, 1.4 m diameter).

Six training stages were created across the soccer field to provide amble room for practicing. Each stage was consisted of two stations: two for agility ladder drills, 2 for hoop drills, 2 for BOSU, 2 for TOGU, 2 for inflated disks, and 2 for trampoline. To conserve more practice time, the players were divided into 12 pairs (one pair per station). Each pair had to practice at each stage for a 3-min time period. In stations where the players had to receive the ball from their teammates, they had to change roles every 30 s. All participants rotated at the same number of stations and the sequence of practicing the intervention exercises was presented in an unsystematic – random order for all pairs of participants.

Assessment of soccer technical skills. It is generally accepted that reliable discriminable measures are required in order to assess the effectiveness of training programmes on changes in soccer performance over time.[40–42] Results from a training intervention programme provide valuable information to the coach about players' performance enhancement.[43] For the purpose of the present study, pre- and post- programme assessment was specific to the aims of the PTIP and technical soccer skills were evaluated with juggling, heading, shooting, passing, dribbling, and agility tests.

Juggling tests. A series of juggling tests were performed to assess female soccer player coordination. The player had 3 trials to juggle the ball as many times as possible without the ball touching the ground. A maximum score of 100 touches was set for *free juggling (body)* and *alternating foot juggling tests.* Each trial was started with a ball drop to the foot by hand. The procedures were similar to Rösch et al.[33] with some differentiation in performance tests and evaluation as it is described below.

Free Juggling (body) test Participants had to perform 3 juggling trials and the ball could touch various parts of the body. The juggling sequence was at participant's free will and convenience. The measurement unit was set at 1 point per ball contact. The best measure of the three trials was kept for further analysis.

Alternating Foot Juggling test Participants had to juggle the ball with the sequence right-left- right or left-right-left foot without the ball touching the ground or other parts of the body. The measurement unit was 1 point per jug and the best measure of 3 trials was kept for further analysis.

Juggling (foot) test The player had 3 trials to jug the ball in the air with the right foot and 3 trials with the left foot. The measurement unit was 1 point per jug.[33] The best of the 3 measures on right and left foot were kept for further analysis.

Juggling (body) test This test was identical to Rösch et al. ([33] p. S-32, Figure 9). The player had 3 trials and the measurement unit was 1 point per successful sequence in each trial. The total points per sequence for the 3 trials were kept for further analysis.

Heading tests. Two tests were conducted for evaluating female soccer players' accuracy and coordination in heading a ball. The settings and procedures were in line with Rösch et al..[33] The first test was called *heading front* and the player, while standing at the penalty spot facing the goal, had to head the ball into the goal. The ball was lobbed to the player (two-handed overhead throw) by a teammate who was standing in a 3-meter distance just in front of the middle of the goalposts. The player had to aim at the segments with the highest score. The scoring points and the positions of player and teammate are presented in Figure 1. The player performed 3 trials and the total points were recorded for further analysis. The second test was called *heading side* and the player had to start each trial from a 3-meter distance behind the penalty spot. A teammate was standing at the side, at a 3-meter distance from the right goalpost towards the player and was lobbing the ball to the penalty spot with a two-handed overhead throw. The player was running to the penalty spot to head the ball into the goal, aiming at the segment with the highest score (top left segment - 6 points). The scoring points and the positions of player and teammate are presented in Figure 2. The player had to perform 3 trials and the total points were recorded for further analysis. In both heading tests the players were encouraged to aim at the segments with the higher scoring.

Shooting test This test was a modified version of Rösch et al.[33] shooting (dead ball) test and was used to evaluate shooting accuracy and coordination. The test required the player to shoot a ball into standard official goal that was divided into six segments. The ball was placed in a 16.5-meter distance from the middle of the goal. The scoring points are presented in Figure 3. The players had to perform 5 trials and were instructed to aim for the left and/or the right top segments with the highest points. The total points of the five trials were recorded for further analysis.

Passing tests. Two passing tests were used to evaluate passing accuracy and coordination over long and short distance. *Long passing* and *short passing* settings, procedures, and measurement units were in accordance with the guidelines provided by Rösch et al..[33] For *long passing* assessment (distance of 36 metres), the total measurement points (3 points if ball lands in the circle [radius of 2 metres] and 1 point in the 10 × 10 metres square) of 5 trials were recorded for further analysis. For *short passing* evaluation, a small goal was used (1 m long and 60 cm high) and the total measurement points (3 points if ball in the goal and 1 point if the ball hits the bars) of 5 trials were kept for further analysis.

Dribbling tests. A series of dribbling tests were used to evaluate coordinated manoeuvring a ball under time and speed demands.

Speed dribbling. Settings, procedures, and measures were in accordance with the guidelines provided by Rösch et al..[33] Photocell gates (Newtest, Powertimer, Finland) were set at the approximate hip height at first and last gates in order to measure players' time taken to cover the preset sequence while dribbling the ball (see 33, Figure 10). Each player performed two trials with 5 min of passive recovery. The best time (accuracy 0.01 s) achieved was selected for further analysis.

15-m ball dribbling (Ball-15m). This test required the player to dribble a ball while performing a 15-m agility run. The test was set and performed according to the guidelines provided by Mujika, Santisteban, Impellizzeri, and Castagna.[44] The same photocell gates were placed at the beginning (0 m) and end (15 m) of the planned route. Each player performed two trials with 3 min of passive recovery. The best time (accuracy 0.01 s) achieved was selected for further analysis.

Dribbling and passing. These tests were set up and evaluated according to the procedures outlined by Vänttinen et al. ([45] p. 549, Figure 3). At the 20 m *dribbling test*, photocell gates were placed at the start and finish lines. The *passing test* was started when the first pass and ended with the tenth pass hitting the wall. Digital electronic stopwatches (accuracy 0.01 s) were used for measuring time. All players had two practice trials for dribbling and passing tests. They had to perform 3 successful trials with 5 min of passive recovery. The best time achieved was used for further analysis for dribbling and passing tests.

Illinois Agility test *(with ball)*. The IAT was used to assess rapid and frequent changes of direction while the players were moving with the ball. The course layout was 10 metres in length and 5 metres in width. Start, finish, and turning points were marked with cones. Another four cones, spaced 3.3 metres apart, were placed lengthwise the centre of the testing area (see also.[21)] Photocell gates were placed at the start and finish lines (Figure 4). The players were standing with the ball in front of them (on the start line) and with the signal "Go", they started their trial. All players had a practice trial. The best performance of 3 successful trials was kept for further analysis.

All intervention exercises and evaluation tests were performed on natural grass and the players were wearing soccer shoes. Participants were also familiarised with the evaluation tests by performing one practice trial.

Statistical analyses

Physiological attributes (age, height, weight, body mass index [BMI], percent body fat, $\dot{V}O_2max$) were evaluated at the beginning and at the end of the study, and 2 by 2 (Groups × Measures) analysis of variance (ANOVA) with repeated measures on the second factor were calculated to locate significant differences between the Intervention and Control Groups at the pretest and posttest measures for weight, BMI, percent body fat, and $\dot{V}O_2max$. To evaluate group differences between the Intervention and Control Groups at the pretest and posttest measures of the technical soccer skills, 2 by 2 ANOVAs (Groups × Measures) with repeated measures on the last factor were used for analysing *juggling, heading*, *shooting*, *dribbling*, *passing*, and *Illinois agility test with ball*. Bonferroni *post hoc* analyses were applied for statistically significant interactions. All statistical analyses were computed with IBM SPSS for Windows (version 26.0) with the probability level set at $p < 0.05$.

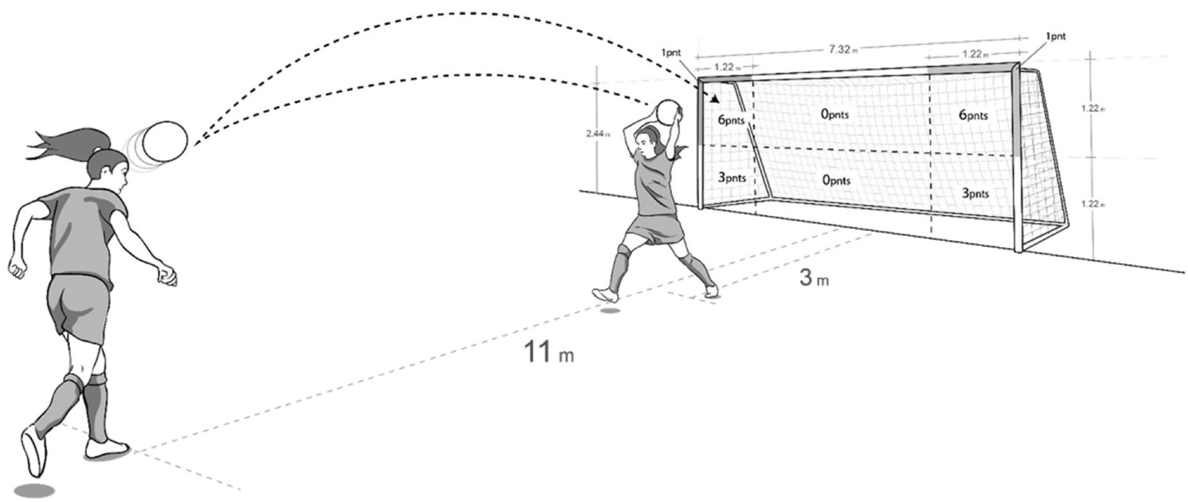

Figure 1. Scoring points, positions of player and teammate, and setting for *heading front test*.

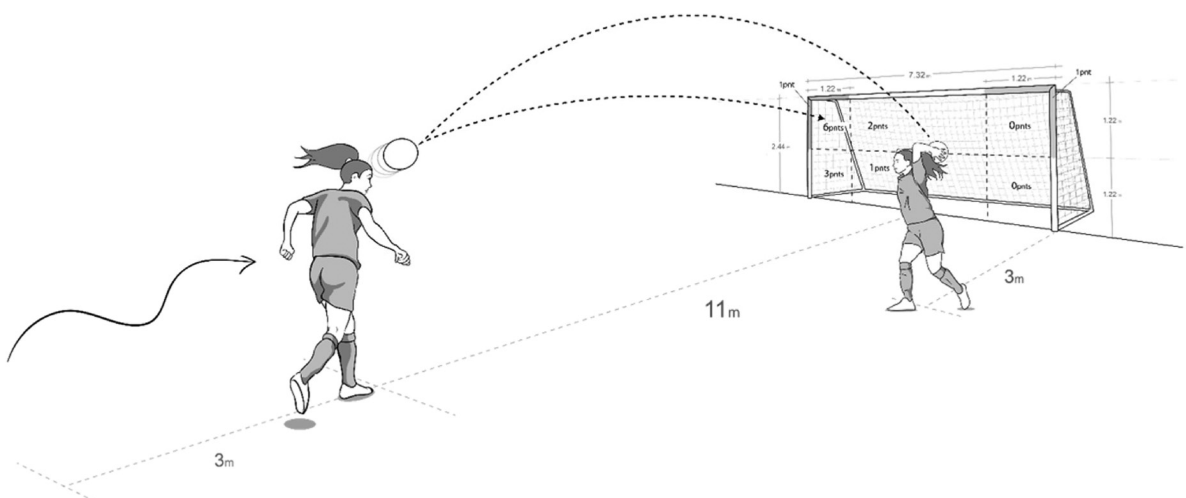

Figure 2. Scoring points, positions of player and teammate, and setting for *heading side test*.

Results

Physiological attributes

The results of the 2 by 2 ANOVAs (Groups × Measures) with repeated measures on the second factor for physiological data indicated statistical significances for: (1) $\dot{V}O_2max$ main effect for Measures ($F(1, 46) = 1020.92$, $p < .001$, *partial* $\eta^2 = .957$), and the interaction for Groups by Measures ($F(1, 46) = 11.32$, $p = .002$, *partial* $\eta^2 = .198$), (2) *percent body fat* main effects for Groups ($F(1, 46) = 9.51$, $p = .003$, *partial* $\eta^2 = .171$) and Measures ($F(1, 46) = 327.38$, $p < .001$, *partial* $\eta^2 = .877$), and the interaction for Groups by Measures ($F(1, 46) = 9.70$, $p = .003$, *partial* $\eta^2 = .174$), and (3) BMI main effects for Groups ($F(1, 46) = 4.38$, $p = .042$, *partial* $\eta^2 = .087$) and Measures ($F(1, 46) = 240.44$, $p < .001$, *partial* $\eta^2 = .839$). There were no statistically significant ($p < 0.05$) main effects and interaction for *weight*, and interaction for *BMI*.

Bonferroni *post hoc* analyses for interactions indicated that for: (1) $\dot{V}O_2max$, (i) Intervention Group posttest measure was significantly better than Intervention Group pretest and Control Group posttest ($p < 0.05$), and (ii) Control Group posttest was significantly better than Control Group pretest ($p < 0.05$), (2) *percent body fat,* (i) Intervention Group posttest measure was significantly less than Intervention Group pretest and Control Group posttest ($p < 0.05$), (ii) Control Group posttest was significantly less than Control Group pretest ($p < 0.05$), and (iii) Intervention Group pretest was significantly less than Control Group pretest ($p < 0.05$) (Table 1).

Soccer technical skills

Juggling tests. The Groups by Measures ANOVAs revealed statistical significances for: (1) *free juggling (body),* main

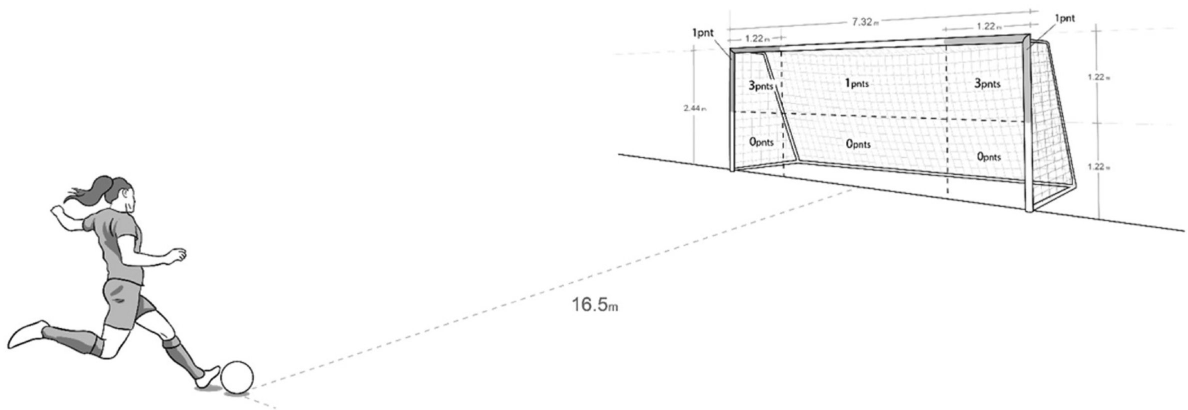

Figure 3. Scoring points and setting for *shooting test.*

effects for Groups ($F(1, 46) = 14.65$, $p < .001$, *partial* $\eta^2 = .242$) and Measures ($F(1, 46) = 241.50$, $p < .001$, *partial* $\eta^2 = .840$), and the interaction for Groups by Measures ($F(1, 46) = 173.96$, $p < .001$, *partial* $\eta^2 = .791$), (2) *alternating foot juggling,* main effects for Groups ($F(1, 46) = 14.65$, $p < .001$, *partial* $\eta^2 = .242$) and Measures ($F(1, 46) = 134.21$, $p < .001$, *partial* $\eta^2 = .797$), and the interaction for Groups by Measures ($F(1, 46) = 9.70$, $p = .003$, *partial* $\eta^2 = .745$), (3) *juggling with right foot test,* main effects for Groups ($F(1, 46) = 60.81$, $p < .001$, *partial* $\eta^2 = .569$) and Measures ($F(1, 46) = 174.90$, $p < .001$, *partial* $\eta^2 = .792$), and the interaction for Groups by Measures ($F(1, 46) = 144.42$, $p < .003$, *partial* $\eta^2 = .758$), (4) *juggling with left foot test,* main effects for Groups ($F(1, 46) = 27.93$, $p < .001$, *partial* $\eta^2 = .378$) and Measures ($F(1, 46) = 201.02$, $p < .001$, *partial* $\eta^2 = .814$), and the interaction for Groups by Measures ($F(1, 46) = 171.28$, $p < .001$, *partial* $\eta^2 = .788$), (5) *jugging body test* (i) *chest-foot-head,* main effects for Groups ($F(1, 46) = 14.74$, $p < .001$, *partial* $\eta^2 = .243$) and Measures ($F(1, 46) = 53.82$, $p < .001$, *partial* $\eta^2 = .539$), and the interaction for Groups by Measures ($F(1, 46) = 47.68$, $p < .001$, *partial* $\eta^2 = .509$), (ii) *head-left foot-right foot,* main effects for Groups ($F(1, 46) = 18.04$, $p < .001$, *partial* $\eta^2 = .282$) and Measures ($F(1, 46) = 57.82$, $p < .001$, *partial* $\eta^2 = .557$), and the interaction for Groups by Measures ($F(1, 46) = 50.37$, $p < .001$, *partial* $\eta^2 = .523$), and (iii) *foot-chest head,* main effects for Groups ($F(1, 46) = 17.38$, $p < .001$, *partial* $\eta^2 = .274$) and Measures ($F(1, 46) = 54.62$, $p < .001$, *partial* $\eta^2 = .543$), and the interaction for Groups by Measures ($F(1, 46) = 46.82$, $p < .001$, *partial* $\eta^2 = .504$). Bonferroni *post hoc* analyses for interactions indicated that for (1) *free juggling (body) test,* (2) *alternating foot juggling,* (3) *juggling with right foot,* (4) *juggling with left foot,* and (5) *jugging body test* for *chest-foot-head*, *head-left foot-right foot*, and *foot-chest head,* Intervention Group posttests were significantly better ($p < 0.05$) than Intervention Group pretests and Control Group posttests (Table 2).

Heading tests. The results of the Groups by Measures ANOVAs indicated statistical significances for: (1) *heading front,* main effects for Groups ($F(1, 46) = 4.74$, $p = .035$, *partial* $\eta^2 = .093$) and Measures ($F(1, 46) = 30.03$, $p < .001$, *partial* $\eta^2 = .395$), and the interaction for Groups by Measures ($F(1, 46) = 21.84$, $p < .001$, *partial* $\eta^2 = .322$) and (2) *heading side,* main effects for Groups ($F(1, 46) = 6.09$, $p = .017$, *partial* $\eta^2 = .117$) and Measures ($F(1, 46) = 53.22$, $p < .001$, *partial* $\eta^2 = .536$), and the interaction for Groups by Measures ($F(1, 46) = 32.93$, $p < .001$, *partial* $\eta^2 = .417$). Bonferroni *post hoc* analyses for interactions indicated that for *heading front* and *heading side,* Intervention Group posttests were significantly better ($p < 0.05$) than Intervention Group pretests and Control Group posttests (Table 3).

Shooting test Statistical significances were found for *shooting test* between Groups ($F(1, 46) = 38.37$, $p < .001$, *partial* $\eta^2 = .455$) and Measures main effects ($F(1, 46) = 68.98$, $p < .001$, *partial* $\eta^2 = .570$), and Groups by Measures interaction ($F(1, 46) = 52.17$, $p < .001$, *partial* $\eta^2 = .531$). Bonferroni *post hoc* analyses for the significant interaction indicated that Intervention Group posttest measure was significantly better ($p < 0.05$) than Intervention Group pretest and Control Group posttest (Table 3).

Passing tests. Similar statistically significant findings were revealed for: (1) *short passing,* main effects for Groups ($F(1, 46) = 19.52$, $p < .001$, *partial* $\eta^2 = .298$) and Measures ($F(1, 46) = 42.18$, $p < .001$, *partial* $\eta^2 = .478$), and the interaction for Groups by Measures ($F(1, 46) = 38.02$, $p < .001$, *partial* $\eta^2 = .452$) and (2) *long passing,* main effects for Groups ($F(1, 46) = 11.28$, $p = .002$, *partial* $\eta^2 = .197$) and Measures ($F(1, 46) = 60.17$, $p < .001$, *partial* $\eta^2 = .567$), and the interaction for Groups by Measures ($F(1, 46) = 48.36$, $p < .001$, *partial* $\eta^2 = .513$). Bonferroni *post hoc* analyses for interactions indicated that for *short passing* and *long passing* Intervention Group posttests were significantly better ($p < 0.05$) than Intervention Group pretests and Control Group posttests (Table 3).

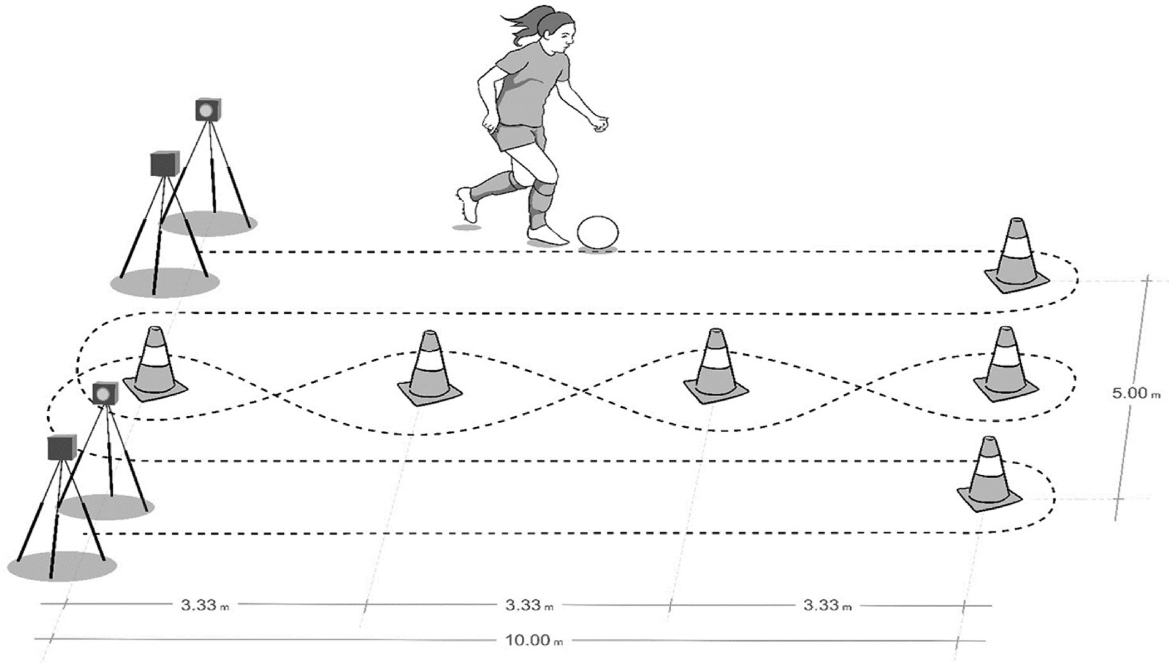

Figure 4. Illinois agility test with ball.

Table 1. Means, standard deviations (±), and statistical significances (p < 0.05) for physiological attributes for intervention (N = 24) and control (N = 24) female soccer players.

Variable	Groups	Pretest	Posttest
Weight (Kg)	Intervention	57.68 ± 1.97	56.21 ± 1.95
	Control	57.81 ± 1.60	56.66 ± 1.62
$\dot{V}O_2$max (ml.Kg-1.min-1)	Intervention	54.74 ± 1.70	57.02 ± 1.59[a,b]
	Control	54.26 ± 1.50	56.08 ± 1.57[a]
% Body Fat	Intervention	16.73 ± .91[c]	14.95 ± 1.04[a,b]
	Control	17.20 ± .73	15.95 ± .81[a]
BMI	Intervention	20.15 ± .61	19.64 ± .64
	Control	20.45 ± .53	20.04 ± .56

Note: [a] significantly different from same group pretest [b] significantly different from control group posttest [c] significantly different from control group pretest.

Speed dribbling. The Groups by Measures ANOVAs for *speed dribbling test* indicated statistically significant main effects for Groups ($F(1, 46) = 6.75$, $p = .013$, *partial* $\eta^2 = .128$) and Measures ($F(1, 46) = 77.96$, $p < .001$, *partial* $\eta^2 = .629$), and the interaction for Groups by Measures ($F(1, 46) = 71.30$, $p < .001$, *partial* $\eta^2 = .608$). Bonferroni *post hoc* analyses for the significant interaction indicated that Intervention Group posttest measure was significantly faster ($p < 0.05$) than Intervention Group pretest and Control Group posttest (Table 4).

Ball-15m. Statistical significant differences were found for *ball-15m test* for Groups ($F(1, 46) = 318.86$, $p < .001$, *partial* $\eta^2 = .874$) and Measures main effects ($F(1, 46) = 139.73$, $p < .001$, *partial* $\eta^2 = .752$), and Groups by Measures interaction ($F(1, 46) = 107.41$, $p < .001$, *partial* $\eta^2 = .700$). Bonferroni *post hoc* analyses for the significant interaction indicated that: (i) Intervention Group posttest measure was significantly faster ($p < 0.05$) than Intervention Group pretest and Control Group posttest and (ii) Intervention Group pretest significantly faster ($p < 0.05$) than Control Group pretest (Table 4).

Dribbling and passing tests. ANOVAs for *dribbling and passing tests* indicated statistical significances for: (1) *dribbling,* main effects for Groups ($F(1, 46) = 28.01$, $p < .001$, *partial* $\eta^2 = .378$) and Measures ($F(1, 46) = 444.12$, $p < .001$, *partial* $\eta^2 = .906$), and the interaction for Groups by Measures ($F(1, 46) = 400.10$, $p < .001$, *partial* $\eta^2 = .897$) and (2) *passing,* main effects for Groups ($F(1, 46) = 793.91$, $p < .001$, *partial* $\eta^2 = .945$) and Measures ($F(1, 46) = 144.19$, $p < .001$, *partial* $\eta^2 = .758$), and the

Table 2. Means, standard deviations (±), and statistical significances ($p < 0.05$) for juggling tests for intervention ($N = 24$) and control ($N = 24$) female soccer players.

Variable	Groups	Pretest	Posttest
Free juggling (points)	Intervention	46.04 ± 10.46	71.50 ± 11.39[a,b]
	Control	45.50 ± 12.56	47.58 ± 11.44
Alternating foot juggling (points)	Intervention	28.79 ± 7.46	47.87 ± 8.22[a,b]
	Control	30.04 ± 6.40	31.46 ± 7.22
Juggling with right foot (points)	Intervention	19.54 ± 2.21	28.25 ± .94[a,b]
	Control	19.63 ± 2.50	20.04 ± 2.60
Juggling with left foot (points)	Intervention	17.13 ± 1.83	24.42 ± 2.36[a,b]
	Control	17.21 ± 2.60	17.50 ± 2.80
Jugging body test			
(chest-foot-head) (points)	Intervention	2.38 ± .65	3.75 ± .74[a,b]
	Control	2.38 ± .71	2.42 ± .65
(head-left foot-right foot) (points)	Intervention	1.92 ± .58	3.13 ± .45[a,b]
	Control	1.96 ± .46	2.00 ± .59
(foot-chest head) (points)	Intervention	1.42 ± .50	2.50 ± .51[a,b]
	Control	1.42 ± .50	1.46 ± .51

Note: [a] significantly different from same group pretest [b] significantly different from control group posttest.

Table 3. Means, standard deviations (±), and statistical significances ($p < 0.05$) for heading, shooting and passing tests for intervention ($N = 24$) and control ($N = 24$) female soccer players.

Variable	Groups	Pretest	Posttest
Heading front (points)	Intervention	7.92 ± 2.13	10.54 ± 2.43[a,b]
	Control	7. 92 ± 1.87	8.13 ± 2.01
Heading side (points)	Intervention	8.04 ± 1.63	10.83 ± 1.95[a,b]
	Control	8.17 ± 1.71	8.50 ± 1.56
Shooting (points)	Intervention	6.83 ± 1.40	10.04 ± 1.46[a,b]
	Control	6.63 ± 1.01	6.75 ± .94
Short passing (points)	Intervention	7.83 ± 1.17	11.04 ± 2.27[a,b]
	Control	7.75 ± .99	7.83 ± 1.45
Long passing (points)	Intervention	5.21 ± .98	7.50 ± 1.10[a,b]
	Control	5.42 ± 1.10	5.54 ± 1.02

Note: [a] significantly different from same group pretest [b] significantly different from control group posttest.

Table 4. Means, standard deviations (±), and statistical significances ($p < 0.05$) for time dependent variables for intervention ($N = 24$) and control ($N = 24$) female soccer players.

Variable	Groups	Pretest	Posttest
Speed dribbling (secs)	Intervention	22.05 ± .75	20.80 ± .91[a,b]
	Control	22.06 ± .91	22.04 ± .90
Ball-15m (secs)	Intervention	3.88 ± .18[c]	3.43 ± .09[a,b]
	Control	4.57 ± .28	4.54 ± .21
Dribbling (secs)	Intervention	25.67 ± .52	23.71 ± .55[a,b]
	Control	25.59 ± .67	25.54 ± .64
Passing (secs)	Intervention	34.47 ± 1.5[oc]	31.30 ± 1.42[a,b]
	Control	46.07 ± 2.12	45.75 ± 1.59
Illinois Agility (secs)	Intervention	18.79 ± 1.07	17.21 ± .67[a,b]
	Control	18.75 ± .78	18.64 ± .67

Note: [a] significantly different from same group pretest [b] significantly different from control group posttest [c] significantly different from control group pretest.

interaction for Groups by Measures ($F(1, 46) = 95.39$, $p < .001$, *partial* $\eta^2 = .675$). Bonferroni *post hoc* analyses for significant interactions indicated that for: (1) *dribbling,* Intervention Group posttest measure was significantly faster ($p < 0.05$) than Intervention Group pretest and Control Group posttest, and (2) *passing,* (i) Intervention Group posttest measure was significantly faster ($p < 0.05$) than Intervention Group pretest and Control Group posttest and (ii) Intervention Group pretest measure was significantly faster ($p < 0.05$) than Control Group pretest (Table 4).

Illinois Agility test with ball. The ANOVA results for *Illinois Agility test with ball* indicated statistically significant main effects for Groups ($F(1, 46) = 9.73$, $p = .003$, *partial* $\eta^2 = .175$) and Measures ($F(1, 46) = 126.02$, $p < .001$, *partial* $\eta^2 = .733$), and the interaction for Groups by Measures ($F(1, 46) = 93.90$, $p < .001$, *partial* $\eta^2 = .671$). Bonferroni *post hoc* analyses for the significant interaction indicated that Intervention Group posttest measure was significantly faster ($p < 0.05$) than Intervention Group pretest and Control Group posttest (Table 4).

Discussion

The aim of this study was to determine whether a 16-week PTIP performed prior the usual soccer-specific training programme could significantly affect female soccer player perceptual-cognitive motor capability as it was estimated with physiological attributes (V ˙O2max and agility) and motor performance soccer technical skills (juggling, heading, shooting, passing, and dribbling). The findings of the study, and specifically the posttest as compared with the pretest measurements, demonstrated that female soccer players following the PTIP had an improvement in decision-making (perceptual–cognitive skill) and motor skill execution.

Physiological attributes

Participants of the PTIP had significantly higher $\dot{V}O_2max$ and agility when comparing their levels before and after the intervention programme and against the control group. In addition, body fat was significantly lower for the players who took part in the programme. Existing literature has examined the potential benefits of various types of intervention programmes on soccer players in relation to physiological attributes. For instance, a study which adopted a program that included plyometric exercises such as cyclic and acyclic horizontal and vertical jumps, with left, right, and both legs demonstrated improvements in endurance performance regardless of gender of soccer players.[46] Research has also examined the effects of high intensity interval training sessions identifying significant improvements on the $\dot{V}O_2max$ of female soccer players.[47] Recent research has identified that $\dot{V}O_2max$ significantly reduced while body fat and body weight increased after a 4-week off-season period (transition period) amongst elite female soccer players. This study highlighted that physiological changes may occur following a transition period after an off-season and the need for the development of controlled training and injury prevention programmes.[48]

Most of the interventions focused on agility have been using agility and speed related exercises and were proven to be effective for improving sprint and agility performance amongst soccer players.[49] Even though the intervention programme of the study did not adopt sprint/agility exercises per se; it demonstrated significant improvements in the agility performance of female soccer players. This could be attributed to either the drills with agility ladders and hoops that were included in the programme or possibly it could be partially attributed to the overall benefits of the intervention followed by the female soccer players of the current study. The frequency and length of the intervention programme which lasted for 16-weeks and was used five times per week for approximately 20 min could also be a determining factor of those physiological benefits.

Technical skills

Furthermore, a variety of technical skills either generic such as juggling or more specific such as heading, shooting, passing, and dribbling were significantly improved following the 16-week PTIP. The differences were observed when comparing between pre- and post-intervention while also between the different groups. In line with the current findings, previous studies adopting plyometric, strength exercises and sprint training have clearly demonstrated improvements on jumping, sprinting ball-shooting performance, and agility.[6,50,51] More specifically, a 9-week plyometric and sprint training significantly improved explosive actions such as sprinting, change of direction, jumping and ball-shooting speed for adolescent soccer players.[51] An intervention that consisted of a combination of heavy-light resistance and soccer specific drills demonstrated an enhancement in spring ability among youth elite male soccer players.[6] Additionally, a plyometric intervention programme improved the explosive strength in female soccer players enabling them to improve shooting performance.[50]

Thus, considering the findings from previous literature it can be concluded that interventions programmes can be beneficial for numerous performance related characteristics, however the ideal nature of such interventions is yet to be confirmed. Interestingly for instance, an intervention programme which included 10 exercises focused on core stability, neuromuscular control, strength, and ability lasting 15 min and was carried out three times a week for 10 weeks showed no significant effects on performance variables amongst adolescent female soccer players.[52] There are numerous reasons that could explain the ineffectiveness of this intervention such as the nature of the exercises included or the length and frequency of the intervention itself. More specifically, when comparing the intervention used by Steffen et al.[52] to the intervention of the current study major differences can be observed in the frequency (two times vs. five times per week), length (10 weeks vs. 16 weeks) and the type of exercises. The training programme of the current study was to our knowledge the first attempt to combine those specific exercises which highlights the significance and novelty of our findings. It is therefore important to recognize the benefits of structured training programmes akin to the one adopted in the current study as they can be used as part of or in addition to the warm-up exercises to probe perceptual-cognitive-motor skill components and enhance performance amongst soccer players.

To summarize, the results found in the present study support the idea that the 16-week PTIP is effective for improving agility, speed, and accuracy in female soccer players and, consequently, technical skills such as juggling, shooting, heading, passing, and dribbling, indicating an overall improvement in neuromuscular coordination, proprioception, and balance capabilities. Moreover, the insignificant decrease of body weight and BMI, and the significant improvement in $\dot{V}O_2max$ and reduction in body fat showed adaptations that could be attributed to neurophysiological changes that possibly mediated for the upgrade of the perceptual-cognitive-motor skills used in the study. Finally, considering the improved performance of female soccer players before and after the PTIP in the tests used to assess the technical skills, we recommend that setting and scoring procedures of these tests can be utilized for evaluating acquisition and learning of soccer related perceptual-cognitive-motor skills.

Future research and practical applications

The findings of the current study identified the multiple potential benefits of a proprioceptive intervention programme on female soccer players. Considering the scarcity of research in female sports and particularly soccer it is of paramount importance to further investigate the effects of different types of training sessions to identify the most effective ways of preparing athletes. The current study provided some insight into the benefits of proprioceptive training, however future studies need to examine a variety of training methods to evaluate their effectiveness for soccer players of different ages and skills while also adopt longitudinal designs to investigate the long-term effects of those methods.

The practical applications of those findings relate to the structure of training sessions in soccer specifically in relation to warm-up. It appears that coaches and sport practitioners could incorporate the exercises described in the current study in the warm-up routines or use them in addition to their existing warm-up routines. The multidimensional benefits of this approach suggest that this type of activities could have a higher impact on the development and performance of players when compared to traditional warm-up drills used in the first part of the training sessions. Apart from the well documented evidence related to the benefits of proprioceptive training on injury prevention, the benefits of such a training programme can enhance neuromuscular coordination leading to the improvement of physiological attributes and technical skills. As such, the exercises and tests used in the current study can be easily utilized by coaches in training and evaluating programmes to both monitor and develop male and female soccer players.

Acknowledgements

We thank the participants of the study for their commitment and efforts.

Declaration of conflicting interests

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Funding

The author(s) received no financial support for the research, authorship, and/or publication of this article.

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Data availability

Data are available from the authors upon reasonable request

Note

1. The pre-test measurements of physiological attributes (weight, VO_2max, and BMI) and soccer technical skills (motor performance) revealed non-significant differences between the players of the two groups.

References

1. Ali A. Measuring soccer skill performance: a review. *Scand J Med Sci Spor* 2011; 21: 170–183.
2. Tessitore A, Perroni F, Cortis C, et al. Coordination of soccer players during preseason training. *Strength Cond Res* 2011; 25: 3059–3069.
3. Magill RA and Anderson D. *Motor learning and control*. McGraw-Hill Publishing, New York, 2017.
4. Starkes J, Cullen J and MacMahon C. A life-span model of the acquisition and retention of expert perceptual-motor performance. In: W A and H N (eds) *Skill acquisition in sport: research, theory and practice*. London: Routledge, 2004, pp.259–281.

5. Mohr M, Krustrup P and Bangsbo J. Match performance of high-standard soccer players with special reference to development of fatigue. *J Sports Sci* 2003; 21: 519–528.
6. Mujika I, Santisteban J and Castagna C. In-season effect of short-term sprint and power training programs on elite junior soccer players. *J Strength Cond Res* 2009; 23: 2581–2587.
7. Sarmento H, Clemente FM, Harper LD, et al. Small sided games in soccer–a systematic review. *Int J Perform Anal Sport* 2018; 18: 693–749.
8. Dolci F, Hart NH, Kilding AE, et al. Physical and energetic demand of soccer: a brief review. *J Strength Cond Res* 2020; 42: 70–77.
9. Roca A, Ford PR and Memmert D. Creative decision making and visual search behavior in skilled soccer players. *PloS one* 2018; 13: e0199381.
10. Russell M, Benton D and Kingsley M. Reliability and construct validity of soccer skills tests that measure passing, shooting, and dribbling. *J Sports Sci* 2010; 28: 1399–1408.
11. Wahlquist VE and Kaminski TW. Purposeful heading in youth soccer: a review. *Sports Med* 2020; 3: 1–4.
12. Davids K, Araújo D, Correia V, et al. How small-sided and conditioned games enhance acquisition of movement and decision-making skills. *Exerc Sport Sci Rev* 2013; 41: 154–161.
13. Kleppang TT and Jørgensen L. Dynamic balance and gait speed improve in persons with Parkinsoń s disease after Lee Silverman Voice Treatment (LSVT)-BIG training: a single subject experimental design study. *Eur J Physiother* 2020; 22: 86–96.
14. Joyner DC. *The effectiveness of an 8-week sport-specific intervention program on improving proprioception, balance, and function in adolescent female soccer players*. Doctoral dissertation, California State University, Fresno, 2017.
15. Riva D, Bianchi R, Rocca F, et al. Proprioceptive training and injury prevention in a professional men's basketball team: a six-year prospective study. *J Strength Cond Res* 2016; 3: 461–475.
16. Romero-Franco N, Martínez-López E, Lomas-Vega R, et al. Effects of proprioceptive training program on core stability and center of gravity control in sprinters. *J Strength Cond Res* 2012; 26: 2071–2077.
17. Šimek S, Milanović D and Jukić I. The effects of proprioceptive training on jumping and agility performance. *Kinesiology* 2007; 39: 131–141.
18. Malliou P, Amoutzas K, Theodosiou A, et al. Proprioceptive training for learning downhill skiing. *Percept Mot Skills* 2004; 99: 149–154.
19. Soomro N, Sanders R, Hackett D, et al. The efficacy of injury prevention programs in adolescent team sports: a meta-analysis. *Am J Sports Med* 2016; 44: 2415–2424.
20. Han J, Anson J, Waddington G, et al. Sport attainment and proprioception. *Int J Sports Sci Coach* 2014; 9: 159–170.
21. Amiri-Khorasani M, Sahebozamani M, Tabrizi KG, et al. Acute effect of different stretching methods on Illinois agility test in soccer players. *J Strength Cond Res* 2010; 24: 2698–2704.
22. Gelen E. Acute effects of different warm-up methods on sprint, slalom dribbling, and penalty kick performance in soccer players. *J Strength Cond Res* 2010; 24: 950–956.
23. Needham RA, Morse CI and Degens H. The acute effect of different warm-up protocols on anaerobic performance in elite youth soccer players. *J Strength Cond Res* 2009; 23: 2614–2620.
24. Boraczynski MT, Sozanski HA and Boraczynski TW. Effects of a 12-month complex proprioceptive-coordinative training program on soccer performance in prepubertal boys aged 10–11 years. *J Strength Cond Res* 2019; 33: 1380–1393.
25. Mohr M, Krustrup P, Andersson H, et al. Match activities of elite women soccer players at different performance levels. *J Strength Cond Res* 2008; 22: 341–349.
26. Prodromos CC, Han Y, Rogowski J, et al. A meta-analysis of the incidence of anterior cruciate ligament tears as a function of gender, sport, and a knee injury–reduction regimen. *Arthroscopy* 2007; 23: 1320–1325.
27. Steffen K, Emery CA, Romiti M, et al. High adherence to a neuromuscular injury prevention programme (FIFA 11+) improves functional balance and reduces injury risk in Canadian youth female football players: a cluster randomised trial. *Br J Sports Med* 2013; 47: 794–802.
28. Fletcher IM and Jones B. The effect of different warm-up stretch protocols on 20 meter sprint performance in trained rugby union players. *J Strength Cond Res* 2004; 18: 885–888.
29. Gebel A, Prieske O, Behm DG, et al. Effects of balance training on physical fitness in youth and young athletes: a narrative review. *J Strength Cond Res* 2020; 42: 35–44.
30. Kiss R, Schedler S and Muehlbauer T. Associations between types of balance performance in healthy individuals across the lifespan: a systematic review and meta-analysis. *Front Physiol* 2018; 9: 1366.
31. Jadczak L, Grygorowicz M, Dzudzinski W, et al. Comparison of static and dynamic balance at different levels of sport competition in professional and junior elite soccer players. *J Strength Cond Res* 2019; 33: 3384–3391.
32. Ogard WK. Proprioception in sports medicine and athletic conditioning. *J Strength Cond Res* 2011; 33: 111–118.
33. Rösch D, Hodgson R, Peterson L, et al. Assessment and evaluation of football performance. *Am J Sports Med* 2000; 28: 29–39.
34. Rostgaard T, Iaia FM, Simonsen DS, et al. A test to evaluate the physical impact on technical performance in soccer. *J Strength Cond Res* 2008; 22: 283–292.
35. Prentice EW. *Rehabilitation techniques for sports medicine and athletic training*. 7th Revised ed. Thorofare, NJ: SLACK Incorporated, 2020.
36. Souglis A, Bogdanis GC, Chryssanthopoulos C, et al. Time course of oxidative stress, inflammation, and muscle damage markers for 5 days after a soccer match: effects of sex and playing position. *J Strength Cond Res* 2018; 32: 2045–2054.
37. Souglis AG, Papapanagiotou A, Bogdanis GC, et al. Comparison of inflammatory responses to a soccer match between elite male and female players. *J Strength Cond Res* 2015; 29: 1227–1233.
38. Jackson AS and Pollock ML. Practical assessment of body composition. *Phys Sportsmed* 1985; 13: 76–90.
39. Yaggie JA and Campbell BM. Effects of balance training on selected skills. *J Strength Cond Res* 2006; 20: 422–428.
40. Huijgen BC, Elferink-Gemser MT, Ali A, et al. Soccer skill development in talented players. *Int J Sports Med* 2013; 34: 720–726.
41. Rebelo-Gonçalves R, Figueiredo AJ, Coelho-e-Silva MJ, et al. Assessment of technical skills in young soccer goalkeepers: reliability and validity of two goalkeeper-specific tests. *J Sports Sci Med* 2016; 15:516.

42. Russell M and Kingsley M. Influence of exercise on skill proficiency in soccer. *Sports Med* 2011; 41: 523–539.
43. Svensson M and Drust B. Testing soccer players. *J Sports Sci* 2005; 23: 601–618.
44. Mujika I, Santisteban J, Impellizzeri FM, et al. Fitness determinants of success in men's and women's football. *J Sports Sci* 2009; 27: 107–114.
45. Vänttinen T, Blomqvist M and Häkkinen K. Development of body composition, hormone profile, physical fitness, general perceptual motor skills, soccer skills and on-the-ball performance in soccer-specific laboratory test among adolescent soccer players. *J Sports Sci Med* 2010; 9: 547.
46. Ramírez-Campillo R, Vergara-Pedreros M, Henríquez-Olguín C, et al. Effects of plyometric training on maximal-intensity exercise and endurance in male and female soccer players. *J Sports Sci* 2016; 34: 687–693.
47. Rowan AE, Kueffner TE and Stavrianeas S. Short duration high-intensity interval training improves aerobic conditioning of female college soccer players. *Int J Exerc Sci* 2012; 5: 6.
48. Parpa K and Michaelides MA. The effect of transition period on performance parameters in elite female soccer players. *Int J Sports Med* 2020; 41: 528–532.
49. Shalfawi SA, Haugen T, Jakobsen TA, et al. The effect of combined resisted agility and repeated sprint training vs. Strength training on female elite soccer players. *J Strength Cond Res* 2013; 27: 2966–2972.
50. Campo SS, Vaeyens R, Philippaerts RM, et al. Effects of lower-limb plyometric training on body composition, explosive strength, and kicking speed in female soccer players. *J Strength Cond Res* 2009; 23: 1714–1722.
51. de Villarreal ES, Suarez-Arrones L, Requena B, et al. Effects of plyometric and sprint training on physical and technical skill performance in adolescent soccer players. *J Strength Cond Res* 2015; 29: 1894–1903.
52. Steffen K, Myklebust G, Andersen TE, et al. Self-reported injury history and lower limb function as risk factors for injuries in female youth soccer. *Am J Sports Med* 2008; 36: 700–708.