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Evidence of balance training-induced improvement in soccer-specific skills in U11 soccer players

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Abstract

The present study aim was to determine the role of balance training in improving technical soccer skills in young players. Two U11 soccer teams were randomly assigned one to either balance training (BT; n=22) or control group (Ctrl; n=21). At the end of their habitual soccer training (identical in BT and Ctrl), BT underwent additional balance training for 12 weeks (3sessions/week, 20 min *per* session), while Ctrl had a 20-min scrimmage. Before and after the intervention, BT and Ctrl underwent two soccer-specific tests (Loughborough Soccer Passing, LSPT, and Shooting, LSST, Tests), and bipedal and unipedal balance evaluations. After intervention, both groups decreased the trials time and improved passing accuracy, with larger improvements in BT than Ctrl [LSPT penalty time ($CI_{95\%}$): -2.20 s (-2.72/-1.68); ES ($CI_{95\%}$): -2.54 s (-3.34/-1.74)]. Both groups improved balance ability, with BT showing larger increments in bipedal tests than Ctrl [static balance: -29 mm (-42/-16); ES: -1.39 (-2.05/-0.72); limit of stability: 4% (3/5); ES 3.93 (2.90/4.95); unipedal *quasi*-dynamic balance: 0.07 a.u. (0.03/0.11); ES: 1.04 (0.40/1.67) and active-range of motion: -5% (-8/-2); ES -0.89 (-1.51/-0.26)]. Low-to-moderate correlations between the players' technical level and unipedal balance ability were retrieved, particularly in the non-dominant limb (*R* from 0.30 to 0.48). Balance training improved some technical soccer skills more than habitual soccer training alone, suggesting that young soccer players may benefit from additional balance training added to their traditional training.

Keywords: football; stability; unipedal stance test

Glossary

U11: under 11 category

BT: Balance training

Ctrl: Control group

%FM: Fat mass percentage

LSPT: Loughborough Soccer Passing Test

LSST: Loughborough Soccer Shooting Test

CoP: Centre of pressure

$STAT_{Bip}$ OE: Bipedal static balance with open eyes

$STAT_{Bip}$ CE: Bipedal static balance with closed eyes

$STAT_{Uni}$: Unipedal static balance

LoS: Limits of stability

$qDYN_{Bip}$: Bipedal *quasi*-dynamic balance

$qDYN_{Uni}$: Unipedal *quasi*-dynamic balance

ROM_{Act}: Active range of motion

TSI: Total stability index

ATE%: Percentage average total error.

Introduction

Balance is the process of maintaining the body centre of gravity vertically over the base of support and relies on rapid, continuous feedback and integration of afferent information coming from three sensory components, i.e., somatosensory, visual, and vestibular systems, resulting in smooth and coordinated neuromuscular actions.[1] Balance has been considered one of the most important fundamentals for non-contact injuries prevention [2,3,4] and rehabilitative training effects assessment [5] in sport. Despite the relationship between balance and sport injury risk has been established, [2,3,6,7] the relationship between balance and sport performance still remains unclear.[1]

In soccer, one of the most widespread and popular team sport in the world, balance seems to be related to the technical ability level.[5] Particularly, balance in soccer has been found to be also pivotal for fundamental motor skills, such as hopping, skipping, jumping, striking, and kicking.[8] Due to the high number of dynamic unilateral technical movements in soccer (e.g., kicking, passing), unilateral balance turns out to be critical to shoot or pass the ball accurately.[5,8,9]

In children and adolescents, the somatosensory, visual, and vestibular systems develop at different rates. The exact maturation-time of each factor is still under debate.[10] The complete somatosensory system maturation has been reported to occur in a very large time span, when kids are 3 to 12 years old.[11,12] The complete visual system development spans from 7–10 years [13,14] to 15 years.[11,12] Similarly, inconsistencies in the complete development of the vestibular system has been reported, ranging from the age of 7 [15] to 15–16 years.[12,16,17]

In addition to the maturation of the three sensory systems, balance development is also influenced by the level of activity and experience.[18] Professional soccer-players seem to have a more effective postural control and a lower dependence on visual feedback than amateur players,[5,19,20] allowing them to control the ball efficiently without any visual feedback.[19] Despite a relatively large number of studies focusing on balance training,[5,19–21] the relationship between balance ability and technical skills has not been extensively investigated so far. Such a population, characterized by a possible incomplete development of the three systems involved in balance ability, may benefit from specific balance training in addition to traditional soccer training to improve technical skills.

Rossler et al.[7] found slight performance enhancements in dynamic balance, agility, jumping performance and slalom dribbling in young soccer players (7-12 years) after a specific injury-prevention program (FIFA 11+ Kids). This program, which includes six exercises for lower limbs and trunk stability and strength, and one exercise on falling technique, was also more effective in injury prevention than a usual warm-up.[6] In a recent meta-analysis on the effectiveness of multimodal injury-prevention programs on neuromuscular adaptation in youth sports (10 to 19 years), Faude et al.[4] reported moderate to large effects on soccer-specific tasks (slalom dribbling and wall-volley tests). However, due to their "multimodal" nature, such programs included different types of intervention (e.g., plyometric and lower limb strength exercises) compared to balance exercises only.

Therefore, the aim of the present study was twofold: i) to assess whether balance training could play a role in improving the technical skills in U11 soccer players and ii) to investigate possible correlations between balance ability and technical skills. Our hypothesis was that a balance-training program could improve the technical skills more effectively than traditional soccer training alone in 10-year old soccer players.

Methods

Participants

Fifty-one 10-year old soccer players were initially recruited to participate in the present study. The candidates were players of two different soccer teams (Team A: N = 26; Team B: N = 25) from the U11 category, participating in the same championship. They were all involved in 90-min specific soccer training three times *per* week, plus the soccer match during the weekend. The inclusion criteria comprised: (i) no evident orthopaedic and/or neurological pathologies, (ii) no sight, hearing or vestibular disorders, (iii) no lower limbs injuries in the previous six months, (iv) familiarity with soccer activities for at least 1 year, and (v) no other concomitant practiced physical activities. Forty-three candidates, (22 from Team A and 21 from Team B) satisfied all the inclusion criteria (Fig 1). The two teams were randomly assigned to balance training [BT (Team A); N = 22; age: 10 ± 0.5 yrs; body mass: 33 ± 4 kg, stature 1.42 ± 0.06 m; leg dominance (right/left): 21/1], and a control group [Ctrl (Team B); N = 21; age 10 ± 0.7 yrs; body mass: 34 ± 4 kg; stature: 1.44 ± 0.07 m; leg dominance (right/left): 20/1].

The local University ethics committee approved the study that was performed in accordance to the principles of the 2013 Declaration of Helsinki. For all participants, the parents or the legal tutors gave their written consent after being fully explained of the purpose of the study and experimental design. The participants were free to withdraw from the study at any time.

Experimental design

The *a priori* sample size was calculated using statistical software (GPower, Dortmund, Germany). The sample size estimation was based on the traditional null-hypothesis testing. Since no study with a similar design was found, we assumed moderate training-induced effects, corresponding to f = 0.25. Considering a within-between subjects interaction, an α -error= 0.05, an estimated effect-size f = 0.25, two groups, two repeated-measures, a required power (1- β) = 0.8, the total sample size resulted in 34 participants. However, to prevent any possible bias due to dropouts, a total of 43 participants were included in the present investigation.

During the balance training period, the two groups underwent the same soccer training program. Two investigators (EC and EP) agreed with the coaches upon the soccer training activities to be performed during the intervention period with their team. The coaches also recorded the participants’ training compliance. All the participants had never been accustomed to balance training, as confirmed by the two coaches. Balance training was performed in-season, from March to June, while the players were regularly involved in the official championship.

The present randomised, controlled study had a whole duration of sixteen weeks: the first two and the last two weeks were dedicated to the pre- and post-training testing assessments, while the intervention was performed in the central twelve weeks. Pre- and post-training tests were maintained equidistant for all the players.

Within the first two weeks, the participants were involved in six different laboratory visits. The first and second days were devoted to familiarization purposes, during which the participants were accurately informed about the interventions setup and the static and *quasi*-dynamic balance tests (Day 1), and the technical-skills assessments (Day 2). During these visits, anthropometrics (body mass and stature) and percentage of fat mass (%FM) were also assessed. On Day 3, the participants performed the balance tests in a random order. On Day 4, these tests were repeated in a randomized counterbalanced manner. The same scheme was repeated for the technical skills tests on Day 5 and 6. Therefore, all tests were repeated twice and separated by at least 3 days. The static and *quasi*-dynamic balance tests were conducted in a laboratory at constant temperature (22 ± 1°C), and relative humidity (50 ± 5%), light intensity and diffusion. Each specific soccer skills test was performed in a soccer field adjacent to the laboratory, with synthetic grass and conducted at the same time of the day to minimize the circadian rhythm effects. The tests were assessed in both groups before (T_0) and after (T_1) 12-week intervention. The latter consisted in habitual soccer training for both groups, with the last 20 min dedicated to scrimmage for Ctrl and balance training for BT (see details below). Both groups trained three times *per* week. The participants were asked to abstain from caffeinated beverages or any meal for the three hours preceding each test, or from any form of vigorous exercise in the previous two days.

Experimental procedures

Body fat assessment

Skinfolds thickness was measured at triceps and subscapular sites to calculate the %FM. A skinfold calliper (mod measured. Holtain, Crosswell, Wales; measure range 0–48 mm, constant pressure: 10 g cm^{-2}, sensitivity: 0.1 mm) was used for this technique. A validated algorithm for this population was then applied to calculate %FM.[22]

Balance tests

Balance tests were conducted under static and *quasi*-dynamic conditions with the operators blinded about the participants' allocation. The total duration of balance tests was 10 min (≈ five min for static and five min for *quasi*-dynamic balance tests). To increase the level of concentration and motivation, the participants were tested alone, in a separate room. All balance tests were validated in healthy individuals ranging from 10 to 14 years.[23,24]

To determine the static balance ability (balance on stable surface), a computerized stabilometry (Stability, Tecnobody, Bergamo, Italia) was used. The platform consisted of three strain gauges set in a triangular position under a surface of 55 cm in diameter with a 20-Hz sampling rate and a sensitivity of 0.1.[25] The following tests were randomly performed.[25]

1. Bipedal static balance with open eyes ($STAT_{Bip}$ OE): the participants stood upright with a bipedal stance while visualizing a marker shown on a screen in front of them. Following the manufacturer's indications, the stance was standardized as follows: internal malleolus distance: 5 cm; axis of the foot: tilted 30° respect to the sagittal plane. The screen height was tailored to allow each participant to the view screen without any flexion or extension of the cervical spine. The lower limbs were kept parallel and the test lasted 30 s.
2. Bipedal static balance with closed eyes ($STAT_{Bip}$ CE): similarly to $STAT_{Bip}$ OE procedures, the participants stood upright with a bipedal stance (as described above) for 30 s with closed eyes.

3. Unipedal static balance ($STAT_{Uni}$): one foot was in the centre of the platform in parallel position to the sagittal plane. The participants, keeping their arms relaxed to their sides, had to remain for 30 s in the upright position with single leg stance. Test was repeated on both limbs in a randomized order. During the test, as in $STAT_{Bip}$ OE, participants had to focus on a marker shown on a screen in front of them. The area (mm^2) and the perimeter (mm) of the centre of pressure (CoP) were calculated during the $STAT_{Bip}$ OE, $STAT_{Bip}$ CE, and $STAT_{Uni}$. The ratio between the area and perimeter during $STAT_{Bip}$ OE and $STAT_{Bip}$ CE (OE/CE ratio) was also calculated.
4. Limits of stability (LoS): participants stood with the feet parallel to the sagittal plane and with a foot distance equal to the width of the hips. In addition, they were required to keep the head, trunk and legs vertically aligned. The participants had to incline their body towards the directions provided by the screen, until they were able to maintain the whole feet on the platform. The inclinations' orientations spanned along the 360° with 45°-intervals. Both the total time and the body inclination for each direction were recorded. The test had a maximum duration of 120 s. A performance index (i.e.: % of the target reached; % target) was calculated considering the total time needed to complete the test and the body inclination.

*Quas*i-dynamic balance tests were performed on a computerized platform (mod. Prokin, Tecnobody, Bergamo Italia), which was calibrated according to the manufacturer's guidelines and tailored to the participants' body mass to ensure an inclination of 5° on the three planes.[26] The following tests were randomly performed:[26]

1. Bipedal *quasi*-dynamic balance ($qDYN_{Bip}$): the participants stood upright with open eyes and received a visual feedback of the CoP trajectory on the screen. They were required to keep their CoP as close as possible to a permanent marker located in the centre of the screen. The test duration was 30 s.
2. Unipedal *quasi*-dynamic balance ($qDYN_{Uni}$): similarly to the $qDYN_{Bip}$, the participants were required to keep their CoP as close as possible to the permanent marker. The test duration was 30 s for each limb. The total stability index (TSI, a.u.) was calculated during $qDYN_{Bip}$ and $qDYN_{Uni}$

tests. TSI is influenced by the extension of the CoP perimeter while trying to maintain the CoP as closed as possible to the target.

3. Active range of motion (ROM_{Act}): the participants stood with one lower limb on the platform and the other one on the floor. They were required to press their CoP along the whole perimeter of their foot in three clockwise (with the right foot) and three counter-clockwise (with the left foot) movements. Their task was to keep the trajectory of the CoP within two concentric circles drawn within the screen. The maximum duration of the test was 120 s for each limb. For ROM_{Act} test, the percentage of the average total error (ATE%) was calculated. A decrease in ATE% reveals an increase in the accuracy in managing the CoP variations around the ankle joint.

Soccer skills tests

The Loughborough Soccer Passing Test (LSPT) and the Loughborough Soccer Shooting Test (LSST) were conducted in accordance to the protocol proposed by Ali et al.[27] The operators were blinded about the groups in which the participants were allocated.

For LSPT, one operator monitored the duration of the test, while a second operator was involved in calling out the order of passes, randomly determined by one out of four trial orders generated by the investigators. Each trial consisted of sixteen (eight long and eight short) passes. The time to complete all the passes and an extra penalty time, as reported in Ali et al.,[27] were calculated during the test. The extra-time for penalty was considered separately. A validation study on young soccer players (aged from 14 to 17 yrs) ranked as "non-elite players" who completed the LSPT test in about 67 s.[27,28] The same operators performed the tests.

To enhance the ecological validity of the LSST, a static life-size goalkeeper (1.9 m tall and 1.22 m large) was used. On the investigator's call, the participants sprinted to the appropriate field-zone, then played a *rebound* pass, turned 180° and, once in the shooting area, shot to the goal. Each trial consisted of 10 shots with 1-min rest periods between each shot. A total of six trial-orders were randomly assigned to each participant. The goalkeeper was placed to the opposite side to the *left/right* call. Furthermore, a coach encouraged the players to shoot across the goalkeeper towards the free space of the goal. The performance score was the mean of the total cumulative points accrued from all the shots on target. For more details about LSPT and LSST protocols, see Ali et al.[27] In LSST, both the time to complete the trial and the accuracy in shooting were considered separately. In a validity study,[27] the players who completed the test in about 8.0 s and scored 1.28 in the penalty task were ranked as “non-elite players”.

Balance training

To maintain the same training duration as in Ctrl group, the BT group dedicated the last part of the training session, typically devoted to scrimmage, to balance training. This part was performed on the grass pitch and lasted 20 min. Since the participants were not accustomed to balance exercises, to reduce the possible risks of injuries given by performing dynamic movements on unstable surfaces, the intervention was divided into three parts of four weeks each: static, *quasi*-dynamic, and dynamic. Each balance training session included five exercises of four minutes each.

For the development of static balance within the first four weeks, the exercises were progressively proposed as follows: (i) bipedal stance with uniaxial imbalance, (ii) bipedal stance with triaxial imbalance, (iii) unipedal stance with uniaxial imbalance, and (iv) unipedal stance with triaxial imbalance. Beyond this progression, exercise included also some variants, i.e. open or closed eyes and barefoot or with shoes.

During the second four weeks, the BT group worked on the development of *quasi*-dynamic balance following the exercise progression as in the first four weeks, with the introduction of a technical skill performed with the arms, head, trunk and lower limbs (e.g. throw-in movements, headers, passing movements or kick-ups).

During the last four weeks, different skills with the ball were performed on stable or unstable surfaces: walking on stable surfaces with a reduced size, walking on unstable surfaces, walking on unstable surfaces with changes of direction, running on unstable surfaces, jumping on unstable surfaces, unipedal ball conduction on stable or unstable surfaces.

Statistical analysis

Statistical analysis was performed using a statistical software package (IBM SPSS Statistics v. 19, Armonk, NY, USA). To check the normal distribution of the sampling, the Shapiro-Wilk's test was applied. To determine inter-day reliability between values, the intraclass correlation coefficient (ICC) and percentage change of the standard error of the measurement (SEM%) were calculated. The ICC was interpreted as follows: >0.90: *very high*; 0.89-0.70: *high*; 0.69-0.50: *moderate*.[29] The minimal detectable change at 95% confidence interval ($MDC_{95\%}$) was used to detect sensitivity of the effects on balance ability between T_0 and T_1.[30] The changes in the dependent parameters were calculated using the magnitude-based approach for analysis and reporting.[31] Pre-post change scores with confidence intervals for Ctrl and BT groups are reported. The smallest worthwhile change was calculated as the $MDC_{95\%}$. The likelihood that the observed effect size was larger than the smallest worthwhile change was calculated based on previous methods.[31,32] Quantitative chances of real differences in dependent parameters were assessed qualitatively as: <1%, *almost certainly not*; <5%, *very unlikely*; <25%, *unlikely*; 25–75%, *possible*; >75%, *likely*; >95%, *very likely*; >99% *almost certain*.[31] The ≥75%, likely, classification was used as the threshold for a meaningful difference.[32] The Cohen's *d* effect size was calculated for each parameter to quantify within- and between-groups magnitude changes[33] and interpreted as follows: 0.00-0.19: *trivial*; 0.20-0.59: *small;* 0.60-1.19: *moderate*; 1.20-1.99: *large* and > 2.00: *very large*.[32]

Pearson's moment product test was used to check possible correlations between balance and soccer skills variables in all the participants. The magnitude of the correlations was interpreted as follows: (R) < 0.1: *trivial*; 0.10-0.30: *low;* 0.31-0.50: *moderate*; 0.51-0.70: *high*, 0.71-0.90: *very high*; 0.91-0.99: *nearly perfect* and *perfect* for R = 1.[34]

Results

The adherence to BT was of 93% (738/792) and 91% in Ctrl (688 /756).

As reported in Table 1, no differences in the anthropometric characteristics of the participants in both groups occurred from T_0 to T_1.

Reliability

Inter-day reliability and sensitivity of the measurements are reported in table 2. ICC, SEM% and $MDC_{95\%}$ values in static balance tests ranged from 0.890, 0.5%, and 1.4% to 0.941, 7.4%, and 20.5%, respectively. In *quasi*-dynamic balance tests, they spanned from 0.935, 1.8%, and 5.0% to 0.938, 2.0%, and 5.7%, respectively. Lastly, ICC, SEM% and $MDC_{95\%}$ values in soccer skills tests ranged from 0.936, 0.3%, and 1.0% to 0.951, 8.7%, and 24.0%, respectively.

Balance tests

Static balance tests

Results for static balance tests are reported in Table 3. Area in $STAT_{Bip}$ OE decreased at T_1 compared to T_0 in both BT (85% *likely*) and Ctrl (93% *likely*). Between T_0 and T_1, decrements in perimeter were found in the $STAT_{Bip}$ OE test only in BT (95% *likely*). Perimeter was also different between BT and Ctrl at T_1 (88% *likely*). In the BT group, the OE/CE ratio decreased at T_1 compared to T_0 (77% *likely*).

%Target in LoS test increased between T_0 and T_1 only in BT (100% *most likely*). %Target in LoS was also different between BT and Ctrl at T_1 (100% *most likely*). No changes occurred in all the other parameters considered in static balance tests.

Quasi-dynamic balance tests

Table 4 reports the results for *quasi*-dynamic balance tests. Between T_0 and T_1, TSI $q\text{DYN}_{\text{Bip}}$ improved in both BT (100% *most likely*) and Ctrl (100% *most likely*). On the contrary, TSI $q\text{DYN}_{\text{Uni}}$ improved only in BT (79% *likely*). A difference was also found between BT and Ctrl at T_1 (89% *likely*). Concerning ATE%, a difference was found in BT compared to Ctrl at T_1 (94% *likely*).

Soccer skill tests

The results for LSPT and LSST are presented in Table 5. Between T_0 and T_1, the time to complete LSPT decreased in both BT (100% *most likely*) and Ctrl (90% *likely*), whereas the extra-time for penalties was reduced only in BT (82% *likely*). A difference was found at T_1 between groups 93% *likely*). The time to complete LSST at T_1 diminished in both BT (94% *likely*) and Ctrl (100% *most likely*). On the contrary, between T_0 and T_1 accuracy increased only in BT (75% *possibly*).

Correlations between technical and balance parameters

At T_0, *low*-to-*moderate* correlations were found between (i) the time to complete LSPT and the area of the left and right legs in STAT_{Uni} (R = 0.30 and 0.31, respectively), (ii) the time to complete LSPT and the perimeter of the left leg in STAT_{Uni} (R = 0.31), (iii) the time to complete LSPT and DYN_{Uni} (R = 0.33 and 0.34), (iv) the extra time for penalty in LSPT and $q\text{DYN}_{\text{Bip}}$ (R = -0.44), and (v) the time to complete LSST and the area of the left and right legs in STAT_{Uni} (R = 0.37 and 0.34 respectively).

At T_1, *moderate* correlations persisted only between LSPT (time) and the perimeter of the left leg in $STAT_{Uni}$ (R = 0.48), and the time to complete LSST and the perimeter of the left leg in $STAT_{Uni}$ (R = 0.44). Moreover, a moderate correlation between LSPT (penalty) and LoS was retrieved (R = 0.40).

No correlations in the percentage differences between T_0 and T_1 in technical and balance parameters were found (R values ranging from 0.179 to -0.252).

Discussion

The present study aimed to investigate the role of balance training in improving technical skills in U11 soccer players. Possible correlations between balance ability and soccer skills variables were also explored. Although both BT and Ctrl showed overall *moderate*-to-*very large* improvements in the dependent parameters, BT was more effective in improving accuracy in LSPT and LSST. Additionally, *low*-to-*moderate* correlations between balance ability and the time to complete the LSPT and LSST tests emerged, particularly in the non-dominant limb. The present outcomes provide experimental evidence for supporting the inclusion of balance training to the traditional sessions in youth soccer players.

Preliminary considerations

In line with previous literature concerning LSPT and LSST,[27] all measurements presented from *high* to *very high* reliability values, highlighting that the tests used here were suitable for the current population. Furthermore, the pre-post changes in the dependent parameters were greater than the $MDC_{95\%}$, evidencing an adequate testing sensitivity

No meaningful changes in the anthropometric characteristics occurred after the intervention. Peterson et al.,[18] which included in their study 154 children aged 6–12 years, concluded that age alone accounted for only 16% of the balance ability variance, with stature, body mass, BMI and gender providing further 4% contribution. Thus, the differences in technical skills, as well as in static and *quasi*-dynamic balance tests in the present study could not be ascribed to variations in body mass, stature or FM%.

Effects of balance training on balance skills.

Despite both groups increased balance ability, the larger increments in bipedal parameters in BT than Ctrl highlighted that the addition of specific balance training to traditional soccer training was able to improve balance by a greater extent. Nevertheless, the present results confirm that traditional soccer training *per se* effectively improves balance ability.[1,5,35] Possible maturation- and/or further familiarization-induced effects could have occurred during the study period and may have improved the results in both BT and Ctrl.

Similarly to the current results, Biec and Kuczynski[35] reported that balance training effectively improved balance ability in pre-pubertal soccer players compared to sedentary, age-matched kids. Soccer is characterized by several short-lasting, multi-directional movements that continuously challenge balance in soccer players compared to sedentary people.[35] The same authors reported better scores in balance tests with closed eyes in soccer players than in sedentary people, arguing that the formers may have developed a lower reliance on visual feedbacks than inactive people.[35] Since in the present study no change in closed eyes tests was found, the present protocol might have been not specific enough to improve this skill.

Although ROM_{Act} performance improved in both groups, greater enhancements occurred in BT than in Ctrl. The ability to accurately rotate ankles in soccer players was thought to be related to balance ability (e.g.: stability of the supporting limb) and accuracy in ankle movements (e.g.: kicking or passing the ball), which are two pivotal characteristics of shooting or passing accuracy.[19] Therefore, the present data suggest that a specific balance training added to traditional soccer training in the selected group (U11) may improve the accuracy of ankle's control more than traditional soccer training alone.

Effects of balance training on soccer skills.

BT obtained greater improvements in passing and shooting accuracy, evaluated by the penalty time in LSPT and the points accumulated during shooting in LSST, respectively. Consistently, shooting accuracy and balance ability were reported to be reciprocally correlated in non-soccer player adults.[8] The same authors also reported that the perimeter covered by the CoP during the $STAT_{UNI}$ test was correlated to the time to complete both LSPT and LSST. Soccer players are required to simultaneously manage distinct lower limbs tasks, e.g., one limb provides body stability, whereas the other one dribbles, kicks or passes the ball.[36] Therefore, a better body stabilization could result in greater accuracy in technical skills, as previously reported.[8]

In a recent meta-analysis, Faude et al.[4] reported improvements in soccer-specific tests (slalom dribbling or the wall-volley test) after multimodal injury-prevention programs in youth soccer players. The authors speculated that an improved neuromuscular control during soccer-specific skills may enable athletes to better and faster manage the ball and, consequently, have more attentional capacity to control movements. Therefore, these improvements in sport-specific skills might contribute to decrease the injury risk.

Correlations between balance and soccer skills

The *low*-to-*moderate* correlations found in the present study at baseline suggest that the unilateral static and *quasi*-dynamic balance abilities are *moderately* associated with the passing accuracy and the LSPT/LSST performance. Interestingly, *moderate* correlations still persisted after balance training. Since soccer players frequently use the non-dominant limb to stabilize their body while kicking, passing the ball or dribbling,[8,36] players with a greater ability to control balance on the non-dominant limb are likely those who perform better the two tests. Moreover, $q\mathrm{DYN}_{Uni}$ *largely* improved only in BT, $STAT_{Uni}$ remained similar to pre-treatment values. These aspects suggest that a training period longer than 12 weeks and/or the inclusion of a higher number of specific single-limb exercises are required to improve the balance ability in unipedal condition.

Moreover, the present study showed *moderate* correlation between LoS and the penalty time in LSPT, suggesting that a better control of CoP might induce greater accuracy in passing the ball. However, notwithstanding the *moderate* correlations shown before and after the intervention, the lack of correlation between the changes in balance ability and the changes in soccer skill tests suggest that factors other than balance ability may play an important role in the passing and kicking accuracy. However, previous studies on this subject are lacking, thus an accurate comparison with the literature cannot be made.

Study limitations

The present study comes with some acknowledged limitations. Firstly, balance training was proposed increasing the exercises complexity every four weeks. As a result of this protocol, the exercises involving technical skills executed in unstable conditions were performed during the last 4 weeks of training. An earlier introduction of this kind of exercises could have strengthened the results obtained by BT. However, since the participants were novice regarding balance exercises, it was preferred to gradually increase the exercise difficulty to reduce the possible risk of injuries, as also suggested in a previous study [3]. Secondly, since a familiarization period was performed, the training-induced effects could have been enhanced. However, it must be acknowledged that the participants were unaccustomed to testing procedures and intervention. Lastly, it was not possible to provide the exact validity indices of the balance test used here in the present population.

Perspectives

It was shown here that balance training was able to improve balance ability and soccer-specific skills. Although the acknowledged complexity behind such a relationship, the current results highlighted the role of balance training in improving soccer-specific skills, such as passing and kicking accuracy. This suggests that U11 soccer players may benefit from additional balance training added to their traditional soccer sessions. Even if beyond the scope of the current study, an improvement in balance ability and in specific soccer skills (ball passing and kicking accuracy) might also play a role in risk injury prevention, as suggested in previous investigations.[4] Therefore, future studies are encouraged to provide such evidence. In addition, it was reported here that some *moderate* correlations between players' technical skills and their balance ability on a single limb exist, particularly on the non-dominant limb. This suggests that the non-dominant limb might play a major role in stabilizing the body during kicking or passing the ball and specific balance training may improve such skills. Lastly, as a future perspective, it would be interesting to investigate the effects of balance training on technical skills in other youth team sports.

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Figure captions

Figure 1. Flow chart of the participants enrolment and study design.

Table 1: Within-group (T_0-T_1) and between-groups changes (Δ) with 95% confidence interval (CI) in static balance tests. Effect size (ES) level of likelihood (P: positive; T: trivial; N: negative), and outcome interpretations are reported.

Acronyms: BT: balance training group; Ctrl: control group.

Participants characteristics											
Parameter		Within-group						Between groups			
		T_0 (m±SD)	T_1 (m±SD)	Δ ($CI_{95\%}$)	ES ($CI_{95\%}$)	P/T/N (%)	Outcome	Δ ($CI_{95\%}$)	ES ($CI_{95\%}$)	P/T/N (%)	Outcome
Age (yrs)											
	BT	10±0.5						0 (-0.37/0.37)	0.00 (-0.60/0.60)	0/100/0	*M Likely T*
	Ctrl	10±0.7									
Body mass (kg)											
	BT	33±4	32±4	1 (-1.43/3.43)	0.25 (-0.35/0.84)	50/41/9	*Possibly P*	-2 (-4/0)	-0.49 (-1.10/0.12)	4/96/0	*V Likely T*
	Ctrl	34±4	34±4	0 (-2.50/2.50)	0.00 (-0.60/0.60)	0/100/0	*M Likely T*				
Stature (m)											
	BT	1.42±0.06	1.43±0.06	-0.01 (-0.05/0.03)	-0.16 (-0.76/0.43)	0/100/0	*M Likely T*	-0.02 (-0.06/0.02)	-0.28 (-0.88/0.32)	0/100/0	*M Likely T*
	Ctrl	1.44±0.07	1.45±0.08	-0.01 (-0.06/0.04)	-0.13 (-0.74/0.47)	0/100/0	*M Likely T*				
Leg dominance (R/L)											
	BT	21/1									
	Ctrl	20/1									

Table 2: Interday reliability (ICC and SEM%) an sensitivity ($MDC_{95\%}$) in static, *quasi*-dynamic balance tests, and soccer skills tests. Comparisons between measurements obtained at T_0 during Day 3 and 4 for balance tests and Day 5 and 6 for soccer skills tests were performed.

Acronyms: $STAT_{Bip}$ OE: Bipedal standing with open eyes; Per: perimeter; $STAT_{Bip}$ CE: Bipedal standing with closed eyes; OE/CE Ratio: open/closed eyes ratio; R: right; L: left; $STAT_{Uni}$: Unipedal standing balance; LoS: Limit of stability; $qDYN_{Bip}$: balance in bipedal stance; TSI: total stability index; $qDYN_{Uni}$: balance in unipedal stance; ROM_{Act}: Active range of motion. ATE%: percentage Average Total Error; LSPT: Loughborough Soccer Passing test; LSST: Loughborough Shooting Passing test

		Parameter	Trial 1	Trial 2	ICC	SEM%	$MDC_{95\%}$
Static balance tests	STATBip OE	Area (mm^2)	329±28	309±27	0.930	2.3	6.3
		Per (mm)	376±21	341±21	0.926	1.6	4.4
	$STAT_{Bip}$ CE	Area (mm^2)	484±38	514±38	0.933	2.5	5.5
		Per (mm)	461±34	446±34	0.937	1.9	5.2
	OE/CE Ratio	Area	0.68±0.05	0.60±0.05	0.927	2.1	5.9
		Per	0.82±0.06	0.76±0.06	0.930	2.0	5.6
	$STAT_{Uni}$	Area R (mm^2)	1068±126	1151±162	0.920	3.7	10.2
		Area L (mm^2)	1564±328	1500±356	0.890	7.4	20.5
		Per R (mm)	1290±111	1376±113	0.930	2.2	6.2
		Per L (mm)	1273±75	1217±77	0.934	1.6	4.4
	LoS	Target (%)	92±2	96±2	0.941	0.5	1.4
Quasi-dynamic balance tests	qDYNBip	TSI (a.u.)	0.44±0.04	0.43±0.03	0.937	2.0	5.6
	$qDYN_{Uni}$	TSI (a.u.)	0.73±0.06	0.72±0.06	0.938	2.1	5.7

	ROM_{Act}	ATE% (%)	86±6	85±6	0.935	1.8	5.0
Soccer skill tests	LSPT	Time (s)	70.3±0.9	73.5±1.1	0.938	0.3	1.0
		Penalty (s)	12.1±0.8	12.8±0.9	0.951	1.5	4.9
	LSST	Time (s)	11.4±0.6	11±0.9	0.940	1.6	4.5
		Accuracy (a.u.)	1.7±0.6	1.8±0.6	0.936	8.7	24.0

Table 3: Within-group (T_0-T_1) and between-groups changes (Δ) with 95% confidence interval (CI) in static balance tests. Effect size (ES) level of likelihood (P: positive; T: trivial; N: negative), and outcome interpretations are reported. Shaded cells indicate a meaningful increase in performance.

Acronyms: BT: balance training group; Ctrl: control group; $STAT_{Bip}$ OE: Bipedal standing with open eyes; Per: perimeter; $STAT_{Bip}$ CE: Bipedal standing with closed eyes; OE/CE Ratio: open/closed eyes ratio; R: right; L: left; $STAT_{Uni}$: Unipedal standing balance; LoS: Limit of stability.

** a reduction in the value means an improvement in the performance; # an increase in the value means an improvement in the performance.*

Static balance tests											
Parameter		Within-group						Between groups			
		T_0 (m±SD)	T_1 (m±SD)	Δ ($CI_{95\%}$)	ES ($CI_{95\%}$)	P/T/N (%)	Outcome	Δ ($CI_{95\%}$)	ES ($CI_{95\%}$)	P/T/N (%)	Outcome
$STAT_{Bip}$ OE											
*Area (mm^2)	BT	304±37	239±29	65 (45/85)	1.92 (1.21/2.63)	85/12/3	*Likely P*	-7 (-24/10)	-0.25 (-0.85/0.36)	3/90/7	*Likely T*
	Ctrl	313±18	246±27	67 (53/81)	2.86 (2.00/3.73)	93/7/0	*Likely P*				
*Per. (mm)	BT	359±23	302±15	57 (45/69)	2.88 (2.04/3.73)	95/5/0	*Likely P*	-29 (-42/-16)	-1.39 (-2.05/-0.72)	88/12/0	*Likely P*
	Ctrl	361±24	331±25	30 (15/45)	1.20 (0.54/1.86)	65/23/12	*Possibly P*				
$STAT_{Bip}$ CE											
*Area (mm^2)	BT	490±44	451±43	39 (13/65)	0.88 (0.26/1.50)	59/30/11	*Possibly P*	-5 (-32/22)	-0.11 (-0.71/0.49)	4/83/13	*Likely T*
	Ctrl	501±50	456±44	45 (16/74)	0.94 (0.30/1.57)	66/29/5	*Possibly P*				
*Per. (mm)	BT	456±36	445±33	11 (-10/32)	0.31 (-0.28/0.91)	14/86/0	*Possibly T*	18 (-2/38)	0.54 (-0.07/1.14)	3/90/7	*Likely T*
	Ctrl	441±31	427±33	14 (-6/34)	0.43 (-0.18/1.04)	28/71/1	*Possibly T*				

OE/CE Ratio											
Area	BT	0.62±0.08	0.51±0.07	0.11 (0.06/0.16)	1.44 (0.77/2.10)	77/16/7	*Likely P*	-0.03 (0.07/0.01)	-0.42 (-1.03/0.18)	31/65/4	*Possibly T*
	Ctrl	0.63±0.08	0.54±0.07	0.09 (0.04/0.14)	1.18 (0.52/1.83)	74/20/6	*Possibly P*				
Per.	BT	0.79±0.09	0.68±0.08	0.11 (0.06/0.11)	1.27 (0.62/1.92)	74/19/7	*Possibly P*	-0.09 (-0.14/-0.04)	-1.04 (-1.68/-0.40)	69/30/1	*Possibly P*
	Ctrl	0.82±0.09	0.77±0.09	0.05 (-0.01/0.11)	0.55 (-0.07/1.16)	58/42/0	*Possibly P*				
$STAT_{Uni}$											
*AreaR (mm^2)	BT	1111±133	1011±116	100 (24/176)	0.79 (0.17/1.40)	44/55/1	*Possibly T*	83 (14/152)	0.72 (0.11/1.34)	5/95/0	*Likely T*
	Ctrl	998±110	928±109	70 (2/138)	0.63 (0.01/1.25)	33/63/4	*Possibly T*				
*AreaL (mm^2)	BT	1501±330	1336±274	165 (-20/350)	0.53 (-0.07/1.14)	12/88/0	*Likely T*	-19 (-155/117)	-0.08 (-0.68/0.51)	1/99/0	*M Likely T*
	Ctrl	1489±313	1355±146	134 (-18/286)	0.54 (-0.08/1.15)	0/100/0	*M Likely T*				
*Per R (mm)	BT	1301±130	1171±129	130 (51/209)	0.99 (0.36/1.61)	60/27/13	*Possibly P*	-125 (-210/-40)	-0.89 (-1.52/-0.26)	64/36/0	*Possibly P*
	Ctrl	1322±159	1296±146	26 (-69/121)	0.17 (-0.44/0.77)	3/97/0	*M Likely T*				
*Per L (mm)	BT	1254±100	1241±106	13 (-50/76)	0.12 (-0.47/0.72)	1/99/0	*M Likely T*	35 (-30/100)	0.33 (-0.28/0.93)	1/52/47	*Possibly T*
	Ctrl	1269±114	1206±105	63 (-5/131)	0.56 (-0.05/1.18)	55/40/5	*Possibly P*				
LoS											
#Target (%)	BT	91±2	97±1	-6 (-7/-5)	-3.73 (-4.70/-2.75)	0/0/100	*M Likely N*	4 (3/5)	3.93 (2.90/4.95)	0/0/100	*M Likely N*
	Ctrl	91±1	93±1	-2 (-3/-1)	-1.96 (-2.70/-1.23)	13/28/59	*Possibly N*				

Table 4: Within-group (T_0-T_1) and between-groups changes (Δ) with 95% confidence interval (CI) in *quasi*-dynamic balance tests. Effect size (ES) level of likelihood (P: positive; T: trivial; N: negative), and outcome interpretations are reported. Shaded cells indicate a meaningful increase in performance.

Acronyms: BT: balance training group; Ctrl: control group; $q\mathrm{DYN}_{Bip}$: balance in bipedal stance; TSI: total stability index; $q\mathrm{DYN}_{Uni}$: balance in unipedal stance; ROM_{Act}: Active range of motion. ATE%: percentage Average Total Error.

** a reduction in the value means an improvement in the performance; # an increase in the value means an improvement in the performance.*

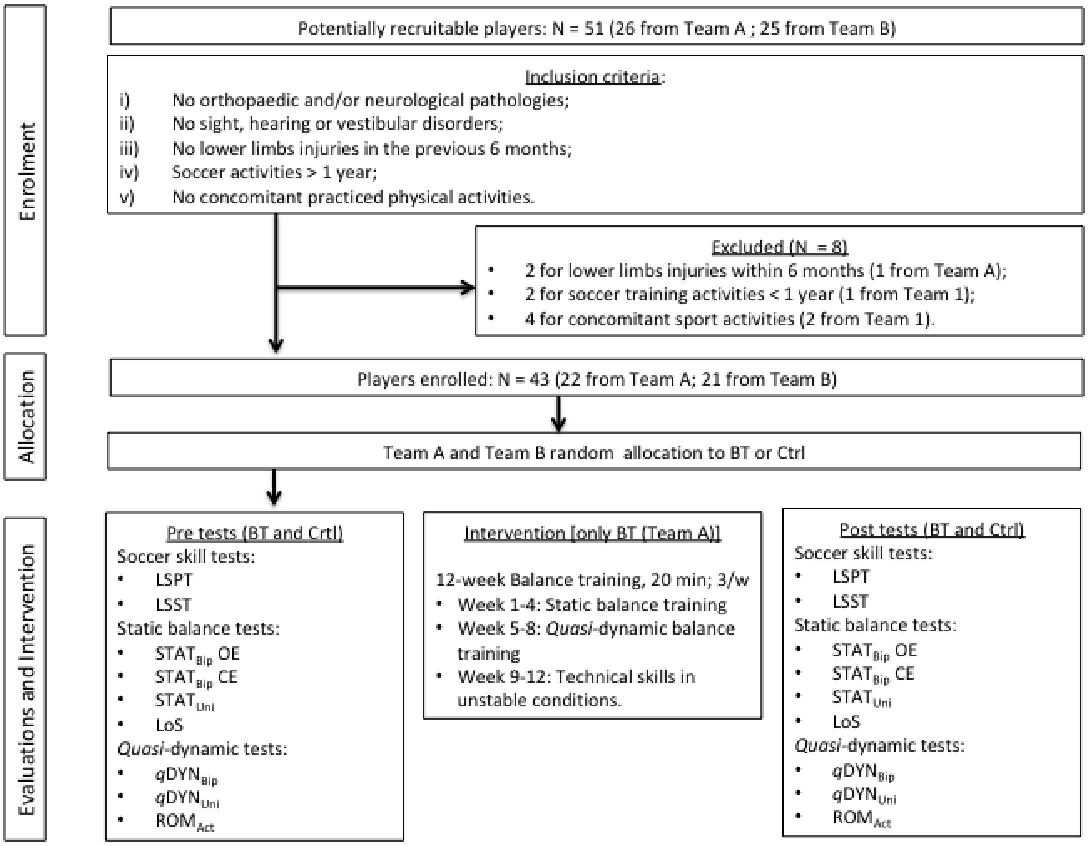
Quasi-dynamic balance tests											
Parameter		Within-group						Between groups			
		T_0 (m±SD)	T_1 (m±SD)	Δ ($CI_{95\%}$)	ES ($CI_{95\%}$)	P/T/N (%)	Outcome	Δ ($CI_{95\%}$)	ES ($CI_{95\%}$)	P/T/N (%)	Outcome
$q\mathrm{DYN}_{Bip}$											
#TSI (a.u.)	BT	0.43±0.03	0.56±0.07	-0.13 (-0.16/-0.10)	-2.37 (-3.14/-1.60)	0/0/100	*M Likely N*	0.02 (-0.02/0.06)	0.28 (-0.32/0.88)	2/57/41	*Possibly T*
	Ctrl	0.43±0.03	0.54±0.07	-0.11 (-0.14/-0.08)	-2.00 (-2.75/-1.26)	0/0/100	*M Likely N*				
$q\mathrm{DYN}_{Uni}$											
#TSI (a.u.)	BT	0.74±0.06	0.85±0.05	-0.11 (-0.14/-0.08)	-1.95 (-2.69/-1.22)	4/17/79	*Likely N*	0.07 (0.03/0.11)	1.04 (0.40/1.67)	1/10/89	*Likely N*
	Ctrl	0.73±0.07	0.78±0.08	-0.05 (-0.10/0.00)	-0.65 (-1.26/-0.05)	3/40/57	*Possibly N*				
ROM_{Act}											
*ATE% (%)	BT	89±6	72±6	17 (13/21)	2.78 (1.93/3.63)	69/11/20	*Possibly P*	-5 (-8/-2)	-0.89 (-1.51/-0.26)	94/6/0	*Likely P*
	Ctrl	86±5	77±5	9 (6/12)	1.77 (1.07/2.46)	64/20/16	*Possibly P*				

Table 5: Within-group (T_0-T_1) and between-groups changes (Δ) with 95% confidence interval (CI) in soccer skill tests. Effect size (ES) level of likelihood (P: positive; T: trivial; N: negative), and outcome interpretations are reported. Shaded cells indicate a meaningful increase in performance.

Acronyms: BT: balance training group; Ctrl: control group; LSPT: Loughborough Soccer Passing test; LSST: Loughborough Shooting Passing test

** a reduction in the value means an improvement in the performance; # an increase in the value means an improvement in the performance.*

Soccer skill tests											
Parameter		Within-group						Between groups			
		T_0 (m±SD)	T_1 (m±SD)	Δ ($CI_{95\%}$)	ES ($CI_{95\%}$)	P/T/N (%)	Outcome	Δ ($CI_{95\%}$)	ES ($CI_{95\%}$)	P/T/N (%)	Outcome
LSPT											
*Time (s)	BT	71.9±1.9	66.1±0.9	5.8 (4.9/6.7)	3.83 (2.81/4.83)	100/0/0	*M Likely P*	-0.80 (-1.71/0.11)	-0.53 (-1.14/0.08)	12/68/20	*Possibly T*
	Ctrl	72.8±1.5	66.9±1.9	5.9 (4.8/7.0)	3.38 (2.46/4.32)	90/5/5	*Likely P*				
*Penalty (s)	BT	11.1±0.9	6.9±0.8	4.2 (3.7/4.7)	4.84 (3.67/6.02)	82/6/12	*Likely P*	-2.20 (-2.72/-1.68)	-2.54 (-3.34/-1.74)	97/3/0	*V Likely P*
	Ctrl	11.8±0.9	9.1±0.9	2.7 (2.2/3.2)	2.94 (2.07/3.82)	71/8/21	*Possibly P*				
LSST											
*Time (s)	BT	12.2±0.7	9.7±0.5	2.5 (2.1/2.9)	4.04 (3.01/5.07)	94/5/1	*Likely P*	-0.30 (-0.58/-0.02)	-0.65 (-1.26/-0.04)	62/38/0	*Possibly P*
	Ctrl	11.9±1.0	10.0±0.4	1.9 (1.4/2.4)	2.45 (1.67/3.25)	100/0/0	*M Likely P*				
#Accuracy (a.u.)	BT	1.6±0.6	2.2±0.4	-0.6 (-0.9/0.3)	-1.16 (-1.79/-0.52)	0/25/75	*Possibly N*	0.20 (-0.08/0.48)	0.43 (-0.17/1.04)	23/32/45	*Possibly N*
	Ctrl	1.7±0.5	2.0±0.5	-0.3 (-0.6/0.01)	-0.59 (-1.21/0.03)	5/55/39	*Possibly T*				


Enrolment
Potentially recruitable players: N = 51 (26 from Team A ; 25 from Team B)
Inclusion criteria:
i) No orthopaedic and/or neurological pathologies;
ii) No sight, hearing or vestibular disorders;
iii) No lower limbs injuries in the previous 6 months;
iv) Soccer activities > 1 year;
v) No concomitant practiced physical activities.
Excluded (N = 8)
• 2 for lower limbs injuries within 6 months (1 from Team A);
• 2 for soccer training activities < 1 year (1 from Team 1);
• 4 for concomitant sport activities (2 from Team 1).
Allocation
Players enrolled: N = 43 (22 from Team A; 21 from Team B)
Team A and Team B random allocation to BT or Ctrl
Evaluations and Intervention
Pre tests (BT and Crtl)
Soccer skill tests:
• LSPT
• LSST
Static balance tests:
• $STAT_{Bip}$ OE
• $STAT_{Bip}$ CE
• $STAT_{Uni}$
• LoS
Quasi-dynamic tests:
• $qDYN_{Bip}$
• $qDYN_{Uni}$
• ROM_{Act}
Intervention [only BT (Team A)]
12-week Balance training, 20 min; 3/w
• Week 1-4: Static balance training
• Week 5-8: *Quasi*-dynamic balance training
• Week 9-12: Technical skills in unstable conditions.
Post tests (BT and Ctrl)
Soccer skill tests:
• LSPT
• LSST
Static balance tests:
• $STAT_{Bip}$ OE
• $STAT_{Bip}$ CE
• $STAT_{Uni}$
• LoS
Quasi-dynamic tests:
• $qDYN_{Bip}$
• $qDYN_{Uni}$
• ROM_{Act}