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ORIGINAL RESEARCH

EFFECTS OF TWO TYPES OF TRUNK EXERCISES ON BALANCE AND ATHLETIC PERFORMANCE IN YOUTH SOCCER PLAYERS

Atsushi Imai, PhD[1]
Koji Kaneoka, MD, PhD[2]
Yu Okubo, PT, PhD[3]
Hitoshi Shiraki[4]

ABSTRACT

Purpose/Background: Many athletes perform trunk stabilization exercises (SE) and conventional trunk exercises (CE) to enhance trunk stability and strength. However, evidence regarding the specific training effects of SE and CE is lacking and there have been no studies for youth athletes. Therefore, the purpose of this study was to investigate the training effects of SE and CE on balance and athletic performance in youth soccer players.

Methods: Twenty-seven male youth soccer players were assigned randomly to either an SE group (n = 13) or CE group (n = 14). Data from nineteen players who completed all training sessions were used for statistical analyses (SE, n = 10; CE, n = 9). Before and after the 12-week intervention program, pre- and post-testing comprised of a static balance test, Star Excursion Balance Test (SEBT), Cooper's test, sprint, the Step 50, vertical jump, and rebound jump were performed. After pre-testing, players performed the SE or CE program three times per week for 12 weeks. A two-way repeated-measures ANOVA was used to assess the changes over time, and differences between the groups. Within-group changes from pre-testing to post-testing were determined using paired *t*-tests. Statistical significance was inferred from $p < 0.05$.

Results: There were significant group-by-time interactions for posterolateral ($p = 0.022$) and posteromedial ($p < 0.001$) directions of the SEBT. Paired t-tests revealed significant improvements of the posterolateral and posteromedial directions in the SE group. Although other measurements did not find group-by-time interactions, within-group changes were detected indicating significant improvements in the static balance test, Cooper's test, and rebound jump in the only SE group ($p < 0.05$). Vertical jump and sprint were improved significantly in both groups ($p < 0.05$), but the Step 50 was not improved in either group ($p > 0.05$).

Conclusions: Results suggested that the SE has specific training effects that enhance static and dynamic balance, Cooper's test, and rebound jump.

Levels of Evidence: 3b

Keywords: core training, stabilization exercise, trunk muscle, trunk stability

[1] Mejiro University, Iwatsuki, Saitama, Japan.
[2] Waseda University, Tokorozawa, Saitama, Japan.
[3] Saitama Medical University, Iruma, Saitama, Japan.
[4] University of Tsukuba, Tsukuba, Ibaraki, Japan.

CORRESPONDING AUTHOR
Atsushi Imai
320 Ukiya, Iwatsuki, Saitama 339-8501, Japan
Email: atsu_shi_imai@yahoo.co.jp

INTRODUCTION

The trunk, which is defined for the purpose of this study as the region of the low back and pelvis, has important roles including the transfer of energy and the connection of movements between the lower and upper body.[1,2] Within the trunk, there are many muscles. These muscles are classified into local and global muscles depending on their anatomical orientation and function.[3] Local muscles, which have more direct or indirect attachments to the lumbar vertebrae, are associated with the segmental stability of the lumbar spine.[3] Global muscles, those that attach to the hips and pelvis, are related to torque production and to transfer of load between the thoracic cage and the pelvis.[3] The interdependency of the osseoligamentous structures, trunk muscles, and neural control of the muscles is needed for optimal trunk stability.[4] Particularly, coordination and co-contraction of these local and global muscles are important.[5] Thus, "trunk stability" is considered the ability to control the position and motion of trunk during dynamic loading and movement conditions.[6]

Various trunk exercises are often performed for improving strength and stability of the trunk. One type of trunk exercises, described as conventional trunk exercises (CE) include repeated flexion and extension of spine, such as sit-ups or back extensions, have been widely performed for improving trunk strength.[7] Another type of trunk exercises, described as trunk stabilization exercises (SE), which keep the lumbar spine in a neutral position and adjust functional postures with minimal accompanying trunk movements, such as the side bridge or back bridge, are commonly performed. The aim of SE is to restore and improve the coordination and control of the trunk muscles in order to enhance trunk stability.[8] Previous authors have demonstrated that SE is effective in not only rehabilitating and preventing the low back pain,[9,10,11] but also for improving balance[12] and athletic performance.[13] Moreover, it has been also reported that the warm-up program including SE reduced the incidence of anterior cruciate ligament injury.[14] Thus, the number of people who are interested in using SE as the training for improving athletic performance and for preventing injuries of low back and lower extremities is increasing.

Several researchers have examined the effects of trunk exercises on balance and athletic performance in healthy adults or collegiate athletes. They examined trunk exercise programs with combinations of SE and CE or only SE or only CE in order to investigate their effects.[12,15,16] Sato and Mokha[15] found that trunk strengthening exercises improved the 5,000 meter run time of healthy adults. Butcher et al[13] showed that SE improved the vertical jump in athletes. Additionally, Kahle et al[12] reported that SE improved dynamic balance in the healthy adults. Although several studies that investigated the training effects of trunk exercises have been reported, there have been few studies comparing the training effects of the SE and CE. Parkhouse and Ball[17] have reported that static balance of university students was improved by SE but not by CE. Childs et al[18,19] reported that effects on musculoskeletal injuries and abdominal strength were similar between SE and CE groups in the soldiers 18 to 35 years of age.

The effects of training on performance are variable, and are likely based upon the principle of the specific adaptation to imposed demands.[20] Thus, it would follow that training effects of SE would be different from those of CE. However, the beneficial aspects of each trunk exercise remain unclear due to lack of evidence. Moreover, the subjects of previous studies were university students, soldiers, or healthy adults, the study for the young sports players has not been reported.

Therefore, the purpose of this study was to investigate the training effects of SE and CE on athletic performance and balance in youth soccer players. The authors hypothesized that SE would improve balance and CE would improve athletic performance involving dynamic motions of the trunk.

METHODS

Participants

Twenty-seven youth male soccer players participated in this study. They were members of the same high school soccer club and were participating in soccer practice and games six times per week at the time of the investigation. Players were excluded from the study if they reported low back pain or had sustained a lower extremity injury that required treatment or which might have inhibited performance within the previous 12 months. Each player was randomly assigned to either the SE group (n = 13) or the CE group (n = 14). Nineteen of the original twenty-seven

Table 1. *Demographic data of participants*

	Training group	
	Trunk stabilization exercise ($n = 10$)	Conventional trunk exercises ($n = 9$)
Age (y)	16.5 ± 0.5	16.1 ± 0.6
Height (cm)	172.8 ± 5.7	171.7 ± 4.2
Body mass (kg)	60.2 ± 5.2	62.9 ± 4.6
Sports experience (yr)	8.6 ± 0.8	8.2 ± 1.9

players completed all tests and training program for the study. Six players (two from the SE group, and four from the CE group) dropped out because they experienced injuries unrelated to this study. Two other excluded players data were not included in analysis (one from the SE group, and one from the CE group) because they were not compliant with the training program and testing procedures. Data from nineteen players (ten from the SE group, nine from the CE group) were used for final statistical analysis. Demographic data are presented in Table 1. All players and their parents signed on informed consent and agreed with the study in advance. This study was approved by the Ethics Committee at the University of Tsukuba.

Procedures

This study was comprised of three steps: 1) pre-testing, 2) training interventions for 12 weeks, and 3) post-testing. The study was conducted during the preseason. Pre- and post-testing were both conducted on two separate days after a non-soccer-training day. On the first day, the sprint, vertical jump, rebound jump, and static balance tests were performed. On the second day, the measurements of dynamic balance, agility, and aerobic endurance were performed.

Prior to pre-testing, preparation session involving the demonstrations and practice of the testing was held once for all participants to achieve familiarization with the testing procedures. Players performed the SE or CE program three times per week for 12 weeks after pre-testing. Intervention programs were taught by the researcher's demonstrations. The coach monitored the attendance at the intervention program. All participants performed the same soccer practice and typical minimal physical training during the period of this study. During the period of performing trunk exercise programs, they were instructed not to do other additional physical training on an individual basis. Post-testing was conducted in the same way as the pre-testing after the 12-week intervention period.

Measurements and Procedures

Static balance test

To assess the static balance, the participants performed a single-leg stance with eyes closed for 20 seconds while on the platform of a foot pressure recorder (Gravicorder GS-7; Anima Corp., Tokyo). Data was measured by recording the total length of the center of pressure (LNG). Participants were instructed to perform single-leg stance using their dominant leg, placing both hands on their hips. The dominant leg was defined as the leg that was used to stand on the ground when kicking a ball. When a participant failed to maintain the single-leg stance or opened their eyes, the test was discarded and then repeated after a short rest. The measurement was performed twice and the better score of LNG was selected for analysis.

Dynamic balance test

The Star Excursion Balance Test (SEBT) was used to assess dynamic balance because this test is simple and economical and demonstrated good reliability in previous studies.[21,22] While maintaining a single-leg stance with hands on the hips, participants were instructed to reach the end of the line along a grid in the anterior, posteromedial, and posterolateral directions with the opposite leg as far as they could. Six practices and three test trials were performed on a dominant leg in each direction.[23] The order of reaching directions was randomized. The test was discarded and then repeated in same way if a participant failed to maintain unilateral stance, lifted or moved the standing foot from the grid, or failed to return the reach foot to the starting position. The longest reach distance in each direction was recorded. For an accurate analysis, the data of reach distance was normalized by leg length to exclude the influence of the leg length. The leg length were measured from the most distal end of the anterior superior iliac spine to the most distal end of the lateral malleolus on each limb.[22]

Cooper's test

In general, the Cooper's test is used to determine aerobic endurance ability because VO2max and run-

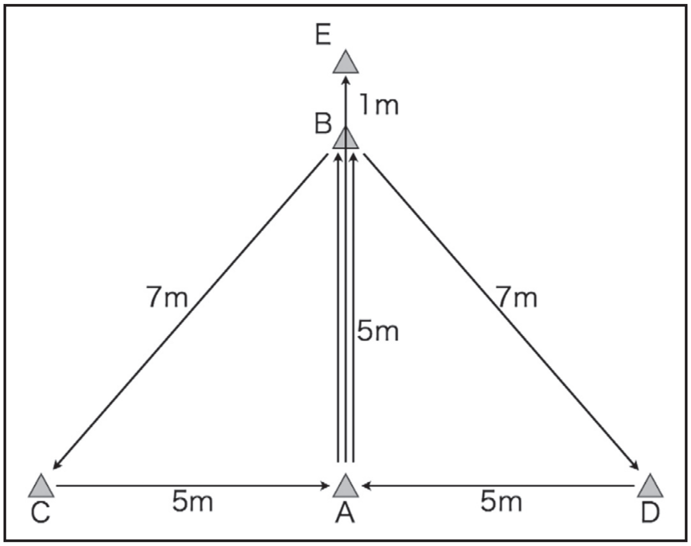

Figure 1. *The location and order of the Step 50: Participants start at A, and then sprint to B. They next go to A around C with a crossover step. Another sprint is towards B again, then go to A around D using a crossover step. From A, they sprint to B one more time, then back to A with a back pedaling. A final sprint to E ends one set.*

ning economy are related to this test.[24,25] Participants were instructed to run as many laps as possible on an outdoor track during 12 minutes. The examiner counted the laps completed during the 12-minute test period, while calling out the time elapsed at 3, 6, 9, and 12 minutes. A measuring wheel was used to determine the fraction of the last lap completed by each participant. This distance was added to the distance determined by the number of laps completed to give the total distance covered during the test.[26]

Agility test

The Step 50 was used as a measure of agility because this test is comprised of various movements required for playing soccer. This test is comprised of 50 meters of running including change of direction and various steps, such as the crossover step and back-pedaling. The location of the marker and order of movements are presented in Figure 1. The time of the step 50 was measured from the signal of the start to the passing of the goal gate using a photocell (Speedtrap; Fitness Apollo Japan, Co., Ltd., Tokyo) positioned on both sides of the goal line at a height of 1 m. Each participant performed the test twice, with a minimum 3-minute rest between trials to avoid fatigue. The faster time was selected for analysis.

Sprint

The 30-meter sprint test was used to determine quickness and speed. The sprint time for 30 m was measured using photocell (Speedtrap; Fitness Apollo Japan, Co., Ltd., Tokyo) positioned at the starting and finishing lines at a height of 1 m. Participants started from a standing position, placing their forward foot 0.5 m behind the sensor. The measurement of the time was performed twice. The faster time was selected for additional analysis.

Vertical jump

Explosive strength and power ability was assessed using a vertical countermovement jump test which is simple and popular. Participants performed a vertical countermovement jump with arm swing on a mat switch (Multi Jump Tester; DKH Inc., Tokyo). They were instructed to jump for maximum height in the vertical jump. The jump height was calculated using the following equation:

$$\text{Jump height} = (g \times \text{Flight time}^2)\ 8^{-1}$$

In this equation, g denotes the acceleration of gravity (9.81 m/s^2).[27]

The mat switch system measured the flight time as the time between the takeoff and subsequent ground contact. Therefore, participants were instructed not to bend the knee at ground contact. The measurement of the vertical jump was performed twice, of which the higher value of jump height was selected for analyses.

Rebound jump

The rebound jump (RJ) was used to assess ability of explosive power produced over repetitive jumps. This test is related to quick movements with a shorter ground contact time. Participants performed the rebound jump, which was to repeat the vertical jump six times, using a countermovement arm swing while on the mat switch (Multi Jump Tester; DKH Inc., Tokyo). Participants were instructed to shorten contact time to the greatest extent and jump as high as possible. The RJ-index was calculated on the basis of the jump height and the contact time (jumping height / contact time).[28] The measurement of rebound jump was performed twice. The higher RJ-index was selected for additional analyses.

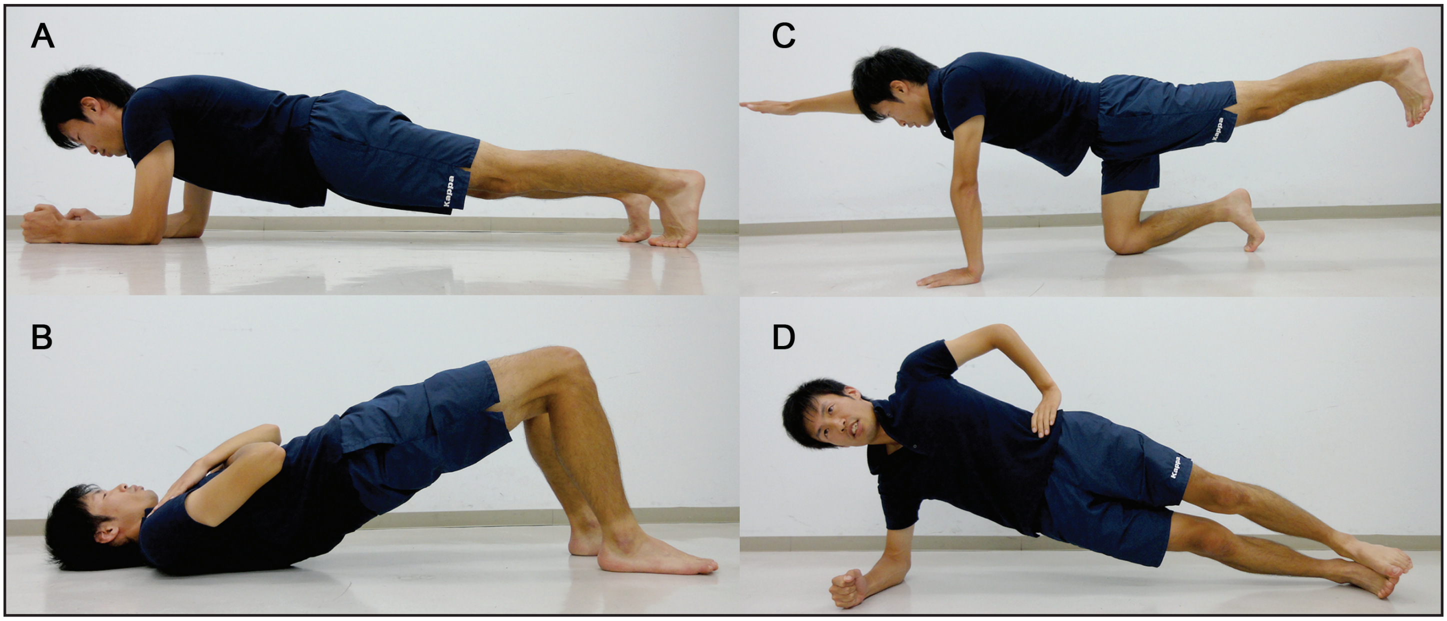

Figure 2. *Trunk stabilization exercises: (A) Front plank, (B) Back bridge, (C) Quadruped exercise, (D) Side bridge.*

Training program

Training programs were conducted three times per week for 12 weeks. The session of the SE and CE were performed at the final practice session of the day. All sessions were directed and supervised by the coach, who has qualifications as a certified strength & conditioning specialist (CSCS). The SE program was composed of four exercises that were the front plank, quadruped exercise, back bridge, and side bridge (Figure 2). Participants were instructed to maintain a neutral position of spine and to hold the posture of each exercise during set time (Table 2). The CE program was composed of four exercises that were the sit–up–1, sit–up–2, back extension–1, and back extension–2 (Figure 3). Participants were instructed to perform the maximum repetitions as many as they could during the set time for these exercises (Table 3). The intensity and volume of each trunk exercise were progressed gradually.

Trunk stabilization exercises

For the front plank, participants were instructed to maintain a prone position that supported the body by forearms and toes. In the next stage, they raised one arm, one leg, or one arm and opposite leg from a prone position and maintained the raising position. The quadruped exercise was performed in the quadruped position, progressing to raising the right arm and left leg or left arm and right leg. The side bridge was performed in a side lying position by supporting the body with the elbow and foot. For the back bridge, participants began by lying supine with their feet flat on the ground, knees bent at 90° and hands folded across the chest. They raised the pelvis to achieve and to maintain a neutral hip flexion angle. In the next stage, they raised one leg from the floor, extended the knee straight, and maintained this posture.

Conventional trunk exercises

Sit–up–1 was performed the standard sit–up, knees bent at 90°, and hands folded across the chest. In the next stage, participants were supine position, the hips bent 60° off the floor; legs straight. They raised the upper body until hands touched toes. Sit–up–2 was performed the sit-up with trunk rotation. Participants were instructed to raise, bend, rotate the upper body to the left or right until the elbow touched the opposite thigh, and returned to the starting position. This was performed alternating on the right and left sides. In the next stage, participants were in the supine position with hands interlocked behind the head, the right knee bent at 90°, the right foot rested on the floor, and the left leg crossed over the right leg. They were instructed to raise and rotate the upper body until the right elbow touched the left knee from this starting position. They repeated on the one side during the set time. Opposite side

Table 2. *The program for trunk stabilization exercise group*

Exercise	Instruction and progress	Volume
Week 1, 2		
Quadruped	Raising the right arm and left leg (A), or left arm and right leg (B)	(A, B: hold for 10 s × 3 reps) × 1 set
Front Plank	Supporting with 4 points (A)	60 s × 2 sets
Back bridge	Supporting with both feet	60 s × 2 sets
Side bridge	On right side lying (A), or on left side lying (B)	(A, B: hold for 30 s)× 1 set
Week 3, 4		
Quadruped	Increase repetition	(A, B: hold for 10 s × 4 reps) × 1 set
Front Plank	Increase set	60 s × 3 sets
Back bridge	Increase set	60 s × 3 sets
Side bridge	Increase set	(A, B: hold for 30 s) × 2 sets
Week 5, 6		
Quadruped	Increase repetition	(A, B: hold for 10 s × 5 reps) × 1 set
Front Plank	Raising the right arm (B), left arm (C), left leg (D), or right leg (E)	(A, B, C, D, E: hold for 10 s) × 3 sets
Back bridge	Increase time	80 s × 3 sets
Side bridge	Increase time	(A, B: hold for 40 s) × 2 sets
Week 7, 8		
Quadruped	Increase repetition	(A, B: hold for 10 s × 6 reps) × 1 set
Front Plank	Raising the right arm and left leg (F), or left arm and right leg (G)	(A, F, G, F, G: hold for 10 s) × 3 sets
Back bridge	Raising the right leg (A), or the left leg (B)	(A, B: hold for 5 s × 5 reps) × 3 sets
Side bridge	Increase time	(A, B: hold for 50 s) × 2 sets
Week 9,10,11,12		
Quadruped	Increase repetition	(A, B: hold for 10 s × 7 reps) × 1 set
Front Plank	Increase repetition	(A, F, G, F, G, F, G: hold for 10 s) × 3 sets
Back bridge	Increase time	(A, B: hold for 10 s × 3 reps) × 3 sets
Side bridge	Increase time	(A, B: hold for 60 s) × 2 sets

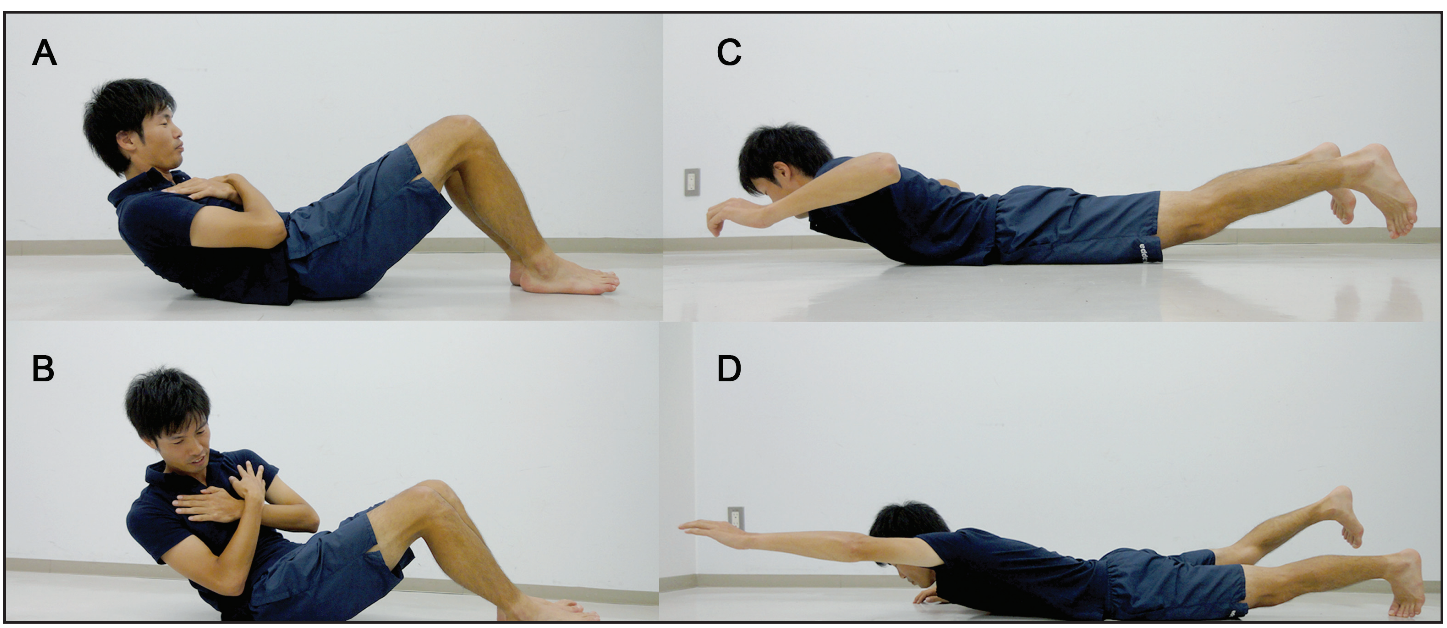

Figure 3. *Conventional trunk exercises: (A) Sit-up-1, (B) Sit-up-2, (C) Back extension-1, (D) Back extension-2.*

Table 3. *The program for conventional trunk exercise group*

Exercise	Instruction and progress	Volume
Week 1,2		
Sit–up–1	Standard sit-up	40 s × 3 sets
Sit–up–2	Sit-up with trunk rotation	40 s × 3 sets
Back extension–1	Raising the upper body and legs	40 s × 3 sets
Week 3,4		
Sit–up–1	Increase time	50 s × 3 sets
Sit–up–2	Increase time	50 s × 3 sets
Back extension–1	Increase set	40 s × 4 sets
Back extension–2	Raising the arm and contralateral leg	50 s × 2 sets
Week 5,6		
Sit–up–1	Increase time	60 s × 3 sets
Sit–up–2	Raising the single side (A) Right side (B) Left side	A, B: 25 s × 3 sets
Back extension–1	No change	40 s × 4 sets
Back extension–2	No change	50 s × 2 sets
Week 7,8		
Sit–up–1	Hip bend 60° off the floor and leg was straight	50 s × 3 sets
Sit–up–2	Increase time	A, B: 30 s × 3 sets
Back extension–1	Increase time	45 s × 4 sets
Back extension–2	Increase time	55 s × 2 sets
Week 9,10,11,12		
Sit–up–1	Increase time	60 s × 3 sets
Sit–up–2	Increase set	A, B: 30 s × 4 sets
Back extension–1	Increase time	50 s × 3 sets
Back extension–2	Increase time	60 s × 3 sets

was performed in the same way after finishing the side. For the Back extension–1, participants raised the upper body and lower extremities off the floor simultaneously from a prone position, and downed to the prone position. For the Back extension–2, participants raised one arm and opposite leg simultaneously from the prone position, and returned to the starting position. This movement was alternately repeated during the set time.

Statistical analysis

Statistical analyses were performed using software (SPSS for Mac ver. 19; SPSS Inc. Chicago, IL, USA). All data were presented as mean γ̄ standard deviation. Normality and equal variance assumptions were checked using the Kolmogorov-Smirnov test and Levene test, respectively. Statistical significance was inferred from $p < 0.05$. Baseline data of characteristics, balance, and athletic performance between groups were compared using an independent *t*-test. A two-way (group × time) repeated-measures ANOVA with a mixed-model design was used to assess the over time changes and between-group difference. Paired *t*-tests were used to determine within-group changes from pre-test to post-test. Effect sizes (ESs) were calculated using Cohen's *d* for comparing pre-test and post-test results. Effect sizes were interpreted as small (0.21–0.50), medium (0.51–0.80), or large (>0.81).

RESULTS

Baseline

Results of balance and athletic performance tests are presented in Table 4. There were no significant differences between SE and CE groups at the baseline for demographic characteristics, balance, and athletic performance (all $p > 0.05$), except for the Step 50 ($p = 0.029$).

Table 4. *Summary results of all tests performed.*

	Exercise	Pre	Post	*P*-value	% Change	ES
Height (m)	SE	172.8 ± 5.7	173.2 ± 6.0	0.083	0.2	0.07
	CE	171.7 ± 4.2	172.0 ± 4.1	0.400	0.2	0.08
Weight (kg)	SE	60.2 ± 5.2	59.7 ± 6.0	0.274	-0.9	0.08
	CE	62.9 ± 4.6	63.3 ± 5.2	0.538	0.6	0.08
LNG (cm)	SE	153.15 ± 28.95	126.79 ± 17.57 *	0.022	-15.0	1.10
	CE	139.00 ± 23.16	130.28 ± 22.47	0.130	-5.8	0.38
SEBT Anterior (%)	SE	77.21 ± 9.11	76.73 ± 4.80	0.821	-0.2	0.07
	CE	76.36 ± 4.90	74.38 ± 4.65	0.066	-2.5	0.42
SEBT Posterolateral (%) ‡	SE	96.24 ± 12.89	104.72 ± 8.13 *	0.021	10.0	0.79
	CE	98.42 ± 11.33	97.44 ± 7.15	0.761	-0.2	0.11
SEBT Posteromedial (%) ‡	SE	101.49 ± 7.18	110.03 ± 9.27 *	0.013	8.7	1.03
	CE	105.60 ± 5.75	104.73 ± 6.11	0.594	-0.8	0.15
Cooper's test (m)	SE	3303.0 ± 63.8	3355.0 ± 82.9 *	0.002	1.6	0.70
	CE	3210.0 ± 116.7	3225.6 ± 113.1	0.367	0.5	0.14
Step 50 (s)	SE	15.77 ± 0.5 †	15.57 ± 0.21	0.212	-1.3	0.55
	CE	16.23 ± 0.28	16.08 ± 0.48	0.309	-0.9	0.38
30 m sprint (s)	SE	4.73 ± 0.18	4.49 ± 0.14 *	0.000	-5.2	1.53
	CE	4.89 ± 0.15	4.63 ± 0.21 *	0.003	-5.2	1.43
Vertical jump (cm)	SE	36.39 ± 3.60	40.96 ± 2.62 *	0.000	13.2	1.45
	CE	33.36 ± 3.62	36.92 ± 3.16 *	0.009	11.4	1.05
RJ Index	SE	1.813 ± 0.426	1.950 ± 0.449 *	0.009	7.8	0.31
	CE	1.762 ± 0.394	1.824 ± 0.423	0.399	4.3	0.15

* Significant difference between the pre-test and post-test ($p < 0.05$)

† Significant differences between SE and CE at the pre-test ($p < 0.05$)

‡ Significant group-by-time interaction ($p < 0.05$)

SE, Trunk stabilization exercise group; CE, Conventional trunk exercise group; LNG, Total length of the center of pressure; SEBT, Star Excursion Balance test; RJ Index, Rebound jump index; ES, Effect size.

Static and dynamic balance

ANOVA showed significant group-by-time interactions for the posterolateral (F = 6.350, p = 0.022) and posteromedial (F = 18.612, p < 0.001) directions of the SEBT. Paired *t*-tests revealed significant improvement of the posterolateral (p = 0.011; ES = 0.65) and posteromedial (p = 0.001; ES = 0.77) directions in the SE group but no improvement in the CE group (p > 0.05). For the anterior direction of the SEBT, no significant group-by-time interaction and the improvement between pre- and post-tests were observed. Although the LNG data did not show the significant group-by-time interaction (F = 1.712, p = 0.208), paired *t*-tests revealed significant improvement between pre-test and post-test in the only SE group (p = 0.015; ES = 1.07).

Athletic performance

There were no significant group-by-time interactions of all athletic performance data. For within-group change from pre-test to post-test, significant improvements were revealed in the Cooper's test (p = 0.002; ES = 0.70) and rebound jump (p = 0.009; ES = 0.31) in the SE group, but were not observed in the CE group (all p > 0.05). Also, vertical jump and sprint improved significantly in both the SE and CE groups (all $p < 0.01$), but significant improvement of the Step 50 was not observed in either group (all $p > 0.05$).

DISCUSSION

The purpose of this study was to investigate the influence of SE and CE on balance and athletic performance in youth soccer players. Results showed improvements in static and dynamic balance, Cooper's test, and rebound jump in the only SE group, and in vertical jump and sprint in both groups. These results suggested that training effects on balance and athletic performance differ between SE and CE.

Static and dynamic balance

The results of the present study demonstrated that static balance was improved by the SE program but not by the CE program. This result was consistent with the study conducted by Parkhouse and Ball.[17] In addition, it has been reported that SE improved the static balance immediately.[29] Thus, it is possible that SE are useful for improving static balance. Moreover the SE group showed a significant improvement in the posteromedial and posterolateral directions but not in the anterior reach direction of the SEBT. This result concurred with the study of Filipa et al[2] that investigated the effect of neuromuscular training with a focus on trunk stability. Hoch et al[30] indicated that the range of motion of the dorsiflexion of the foot has a large effect on the anterior direction of the SEBT. Thus, it was suggested that the anterior direction may be less affected by trunk exercises. On the other hand, previous studies have shown that SE improved the posteromedial and posterolateral directions of the SEBT.[12,22] These directions of the SEBT require control of the position of the trunk because participants must lean their trunk forward in order to maintain and adjust balance.[31] The current findings indicated that the SE is effective in improving the posterolateral and posteromedial directions of the SEBT.

Athletic performance

The SE group showed significant improvement in the rebound jump. During landing, the trunk receives a large impact after ground contact because of the occurrence of large ground reaction forces.[32,33] Thus, abdominal muscles must activate in order to stabilize the trunk and to control the trunk position before ground contact in preparation for landing.[34,35] After ground contact, low back muscles work to control the position of the trunk and to shift the direction from the descending to the ascending motion.[35] These previous studies suggested that trunk stability and appropriate coordination of trunk muscles are important to perform a jump following landing. In the present study, therefore, the enhancement of the rebound jump could be due to the improvement in the control of the position and motion of the trunk against landing impact.

The Cooper's test significantly improved in the only SE group. Maximal oxygen consumption and running economy are important factors for this test.[24,25] Stanton et al.[36] reported that the maximal oxygen consumption and running economy were not improved by trunk exercises using a Swiss ball. However, they did not measure the time of the running trial. Sato and Mokha[15] reported that combined trunk exercises of SE and CE was improved the time of 5,000 m running trial. Although there is lack of scientific evidence suggesting why SE leads to improvements in the Cooper's test, it was suggested that SE might be effective in enhancing performance in long distance running.

Sprint and vertical jump improved in both groups. Butcher et al[13] reported that vertical jump was improved by short term SE due not to an increase of strength, but rather to improvement of neuromuscular control and coordination. Thus, although vertical jump was improved in both groups, its mechanisms for improving could differ between SE and CE. On the other hand, it has also been reported that trunk exercises did not improve the sprint and vertical jump.[17] Therefore, improvements in vertical jump and sprint might be due to other factors, such as the increase in the strength of lower extremities, the influences of soccer practice, and growth and development.

In the present study, neither group improved in the agility test. This result supported the findings of previous studies.[2,6] Jamison et al[2] found that SE did not improve any of their included agility tests, such as the three-cone test and 20-yd short shuttle test. In addition, Mills et al[6] reported that the SE statistically improved the T-test, but this improvement is misleading because there was no association between trunk stability tests and the measure of agility. Therefore, it was suggested that trunk exercises could not be very effective for developing agility.

Practical application

The results of the current study demonstrated that the SE program is effective in improving static and dynamic balance, aerobic performance, and explosive power. These results would be useful information in order to plan trunk exercise programs using the SE. In this study, the SE program comprised of the front plank, quadruped exercises, back bridge, and side bridge was performed three times per week for 12 weeks. Previous studies have showed that a 6-week SE program improved balance, but did not improve athletic performance.[17] On the other hand; this results of this study demonstrated not only the improvements in balance but also the improvements in athletic performance, such as the Cooper's test and rebound jump. Therefore, the period of 12 weeks might be necessary for improving both balance and athletic performance. Moreover, although previous studies used the combination of the SE and CE, results of this study suggested that the SE produce superior benefits to CE, including improving balance and athletic performance in youth athletes.

Limitations

Some limitations exist in this study. Firstly, this study had no control group, who did not participate in trunk exercises. Therefore, we were unable to ascertain whether trunk exercises increased sprint and vertical jump capability. Secondly, this study was performed with a small sample size and the target was limited to male youth soccer players, thus limiting the generalizability of the results. In addition, this study showed a disproportionate number of dropouts, particularly from the CE group. These factors would diminish the impact of the statistically significant differences found between the SE and CE groups. Thirdly, the improvement mechanisms of improvements in athletic performance and balance have not been ascertained yet because the authors assessed the effect of trunk exercises using only field tests. Further confirmation is necessary in larger and more diverse populations including women and aging people in order to generalize the results of this study. Moreover, studies that investigate the biomechanics and physiology of the outcome measures are needed in the future, in order to clarify the improvement mechanisms of the outcomes relating to athletic performance.

CONCLUSION

In conclusion, the results of the present study investigating the training effects of the 12 weeks of SE or CE, revealed that SE are effective in improving static and dynamic balance, Cooper's test, and the rebound jump. Athletes who performed both types of exercises improved performance in the sprint and vertical jump tests. These results suggest that enhancements of balance, Cooper's test, and rebound jump occur after participation in the SE program.

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