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Effects of core stability on junior male soccer players' balance: randomized control trial

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Abstract

Despite the widespread popularity of the core stability trainings, research has not yet to establish specific guidelines that provide the most beneficial and deliberate protocols for young athletes. The aim of this study was to evaluate the effects of 8-week stable surface core stability training program on static and dynamic balance tasks with dominant and non-dominant foot stance among twelve-year-old soccer players. Fifteen of the soccer players were in the experimental group (Age=148.67±3.37 months, Height=154.19±9.43 cm, Weight=45.52±7.91 kg), 11 of them were (Age=145.73±3.84 months, Height=152.36±6.05 cm, Weight=45.19±7.85 kg) in the control group. Protocol was progressive as from static stable surface movements to dynamic stable surface exercises. Static and dynamic balance measured by Force Platform. Participants performed time-to-stabilization test for dynamic balance task. Averaged mean sway value in Anterio-Posterior and Medio-Lateral direction was used to evaluate unilateral static balance task. The effect of implemented program on dynamic and static balance performances were assessed by 2 x 2 univariate analysis of variance with repeated measures. Participating in soccer exercises improved dynamic balance for both dominant and non-dominant foot ($p<0.05$). Only significant interaction of implemented program and time was observed for dominant foot ($p<0.05$). However, no main effect of implemented program on dynamic balance performance for dominant and non-dominant foot and no implementation x time interaction for non-dominant foot were observed ($p>0.05$). Significant effect was observed for implementation in Medio-Lateral direction for dominant foot ($p<0.05$). We conclude that eight weeks stable surface core stability training might be added into exercise programs for improving stabilization after landing and static balance performance in specific directions among junior soccer players.

Keywords: Dynamic balance, static balance, core stability training, soccer, junior athletes

INTRODUCTION

The ability of stabilizing the core, which is defined as “to stabilize the body center against dynamic movements of the extremities and capability to absorb repetitive loading forces in the trunk” (Ezechieli et al., 2013), has critical function in any athletic performance. Initially, these type of exercises has been implemented only by physical therapists in the clinics to reduce back pain problems (Akuthota and Nadler, 2004; Alentorn-Geli et al., 2009; McGill, 2001; Van der Linden et al., 2013). However, core stability exercises have become very popular and these exercises are used by fitness instructors in fitness centers or strength and conditioning specialists in fitness clubs beside athletes in professional and amateur sport teams (Saeterbakken et al., 2011). Core Stability (CS) is essential for stabilizing the trunk in order to (a) provide support for movement patterns, (b) transfer forces and (c) reduce the energy leaking among limbs. This stabilization is defined as “neutral zone” which indicates minimal tension around the spinal segments (Panjabi, 1992a;1992b) and leads to better performance.

Kibler et al. (2006) indicated that “Core stability creates several advantages for integration of proximal and distal segments in generating and controlling forces to maximize athletic function.” The importance of these functions in athletic performance is being increasingly recognized. Bliss and Teeple (2005) identified CS as the center piece of training programs, because of its’ powerhouse and linking functions. Reed et al. (2012) highlighted that although core stability training (CST) implications resulted with improvements in aspects of general strength such as vertical jump and maximum squat load, generally out comes of various CST implications showed mixed results.

Soccer is one of the sports that CS plays crucial role as the environment during the game is ever-shifting and requires sudden postural responses and balance maintenance (Borghuis et al., 2011; Cholewicki et al., 2000). Reilly (2007) stated that agility and sprint are the most important criteria for developmental level soccer players. This has led to an emphasis of using core stabilization to improve control of core musculo-structure, which has role on rapid movement changes. Dawes and Roozen (2012), highlighted that level of control and strength of the core muscles will result with better movement patterns and performance, due to high neuromuscular control causing transfer of forces. Core stability is directly related to balance performance, as improving the control of core region of the body resulted with better dynamic balance in young athlete group (Sandrey and Mitzel, 2013). Considering this information, it is important to investigate how to develop specific performance components, such as CS, in soccer game in order to increase total performance among young soccer players. Exercise methods for improving athletic performance or developing children´s various abilities are highly controversial issues in the current literature. It is well known fact that junior athletes are not younger versions of adults. For example; in relation with stabilization of the trunk and adjusting the posture, psoas major muscle is more developed in professional adult athletes than young athletes even when the difference in the total muscle mass of the body is adjusted (Kubo et al., 2010). Hence, age should be considered when planning program for improving athletic performance and advancing skills. There are different methods for improving athletic methods for young athletes.

As it was emphasized before, the mechanism of CS is related to mechanism of balance and postural stability (Cosio-Lima et al., 2003). Preuss and Fung (2008) highlighted that CS is one part of balance and postural stability. For improving functional compounds of performance such as balance, researchers have started to conduct studies on different exercise methods such as CS and balance trainings (Bliss and Teeple, 2005; Boccolini et al., 2013; Hirsch et al., 2003). Therefore, it is important to understand the effect of CST in order to improve balance performance. Nevertheless, despite the widespread popularity of these exercises, research has not yet to establish a set of specific guidelines that provide the most beneficial and deliberate CS exercises for young athletes. As a result, the aim of this study was to evaluate the effects of an 8-week stable surface CST Program on static and dynamic balance tasks with support and kicking leg stance conditions among twelve-year-old soccer players. We hypothesized that an 8-week CST implementation would cause (1) decrease time in stabilization of intervention group in comparison of control for dominant and non-dominant foot, (2) decrease mean sway values of intervention group in comparison of control for dominant and non-dominant foot in anterio-posterior (AP) direction and lastly (3) decrease mean sway values of intervention group in comparison of control in dominant and non-dominant foot in medio-lateral (ML) direction.

METHODS

Design of the Study

The focus of this study was to examine the effects of strength and conditioning techniques on young athletes. In this study, static and dynamic balance performances were measured. In order to assess balance, force platform measurements were used. Participants were selected according to their age, similarities of soccer background and lack of injury. Pre-test Post-test Control Group Design was chosen to find more appropriate answers to the research questions of study, while eliminating the possibility of effectiveness of growth on athletic performance. The study was conducted after obtaining permissions of Ethical Board comity of the Middle East Technical University (28620816/83) and Gençlerbirligi Football Club. All participants, coaches and families of participants were informed about the procedure of the study. Only players who volunteered to participate and signed consent form included in the study. Parental consent forms were also obtained.

Research Group

At the beginning of the study intervention group consisted of 17 players and the control group was a total of 15 players. One player in the intervention group and one in the control group did not attend 80% of the exercises and was removed from the study. On the other hand, one player from intervention group and three players from control group were excluded from the study due to injury, which can affect the data collection procedure. As a result, the study completed with 12-year-old 26 soccer players. Fifteen of the soccer players were in the CST group (Age=148.67±3.37 months, Training Age=35.20±17.83 months, Height= 154.19±9.43 cm, Weight= 45.52±7.91 kg) and 11 of the soccer players (Age=145.73±3.84 months, Training Age=26.19±16.16 months, Height=152.36±6.05 cm, Weight=45.19±7.85 kg) were in the control group.

The soccer players were selected by purposive sampling method from the same soccer team in order to understand the effects of soccer training on balance. Participants were randomly assigned into two groups. Due to the, the school schedule one player, he was assigned to intervention group rather than the control. Both groups followed the same soccer-training program. The inclusion criteria of the study were: a) soccer background for at least 12 months, b) no previous injury prior to 6 months, c) no previous surgery on the lower extremity, d) lack of cardiovascular, vestibular, and neurological disorders, e) no previous background about instability problems. Club records were used to check these criteria, and interviews with coaches, parents and players were conducted.

Data Collection Instrument and Protocols

All participants attended two testing sessions (Pre-test and Post-test) in a research laboratory. The implementation of stable surface CST began within 1 week after the pre-test, and the post-test was conducted within 1 week CST program. Participants warmed up for 5 minutes before measurements. Warm up protocol consisted of 2 minutes jogging followed by static and dynamic stretching movements. Attendance to CST protocol and regular soccer practice was recorded.

The subjects were measured between the same time gaps (12.00-15.00) of the day, with the same protocol and all data were collected by the same researcher. The height, weight, arm span, leg length, feet size, and hip width of the participants were measured (MTX, Xsens, Netherland) two times, before pre-test and post-test. Comprehensively, participants' body sizes (height hip width, leg length and foot length) were taken and warm up protocols were conducted. All participants wore the same clothes provided by the club during sessions and measurements. The height and the foot size of the participants were measured without shoes by using digital scale. During the data collection, participants were not allowed to wear any footwear in order to induce effect of footwear on balance (Burke, 2012). Data were collected by using 1m x 1m force plate (Custom made, Bertec Corporation, OH, USA).

Dynamic Balance Test

Participants performed time-to-stabilization (TTS) test for dynamic balance task. This protocol was used previously to detect performance developments (DiStefano et al., 2010; Ross and Guskiewicz, 2004). Sampling rate was set as 100 Hz. Participants stood on a 30 cm high platform placed half of their body height away from a force plate with their hands on their hips. They were requested to jump forward and land with dominant foot and non-dominant foot for 3 times. Researchers instructed participants prior to test, asked them to stabilize as quickly as possible and explained the purpose of this protocol. Participants who felt uncomfortable, hooped on the platform after first contact and lost balance during stabilization, they were asked to repeat the protocol until the full protocol was completed. Ten seconds time window was chosen to detect stabilization time according to previous methodological findings (Fransz et al., 2015).

Static Balance Test

Participants stood steady with one leg stance with open eyes on the center of Force platform for thirty seconds. If participant was unable to maintain this single limb static position with their hands on their hips or if a hoop occurred during test, trial was conducted again. During open eyed unilateral balance test participants looked at the black point placed 3 meter away on the wall to maintain depth perception.

Data Reduction

Collected data from TTS and unilateral static balance test were transferred to MatLab (Version 2014a; MathWorks, Natick, MA, USA AP ground reaction force between the eighth and ninth seconds of single limb stance after landing were normalized to body weight (Ross et al., 2005) Yielded value used to determine a mean and standard deviation value for each component across trials. Unbounded third-order polynomial was rectified and placed on AP ground reaction force data. TTS for each component was identified as the point when polynomial fell below a specified threshold. All trials of each participant were averaged differently for each leg. AP calculation were taken into analysis as in both stable (DiStefano et al., 2010) and unstable (Cimadoro et al., 2013) dynamic stabilization tasks primarily involves muscles from the anteroposterior plane (Tia et al., 2011; Tia et al., 2012).

Static postural stability was examined with mean of absolute value of distance from AP and ML axis. The measurement used for assessing static balance had already been used in several studies (Golomer et al., 1999; Ross and Guskiewicz, 2004). Center of pressure (COP) mean sway in the AP and ML directions for bilateral stance was calculated. The AP and ML mean distance was defined as the average distance between the instantaneous AP or ML COP during 30 seconds.

Implementation of Core Stability Program

Exercise program lasted for 8-weeks, 2 days a week and 30 minutes a day. Totally 16 sessions were completed. Core stability training was held on Tuesdays and Thursdays every week at 15:45. Protocol was progressive as was suggested previously by Bliss and Teeple (2005) from static movements to dynamic movements and finally combination of these. CST was performed by intervention group as part of their regular soccer practice warm-up during implementation period. Core stability training protocol involved muscular activation of trunk muscles and consisted of Plank, Russian Twist, Shoulder Bridge, Side Plank, Leg Raise, Quadruped movements and performed in equal numbers or in seconds for both limb (Table 1). One of the researchers was responsible for supervising the CST implementation and providing feedback and corrections to junior soccer players. On the other hand, control group performed their regular warm-up protocol.

Table 1. Progression of exercise program

Weeks	Plank	Russian Twist	Shoulder Bridge	Side Plank	Leg raise	Quadruped
1.Week	3x10 sec static	3x10 reps	3x10 reps			
2.Week	3x15 sec static	3x10 reps	3x15 reps	3x10 sec static	3x10 reps	
3.Week	4x15 sec Static	4x15 reps	3x20 reps + 10 sec static	3x10 sec static	3x10 reps	3x20 sec static
4.Week	3x20 sec static	3x20 reps	3x20 reps + 10 sec static	3x15 sec static	4x10 reps	3x20 sec static
5.Week	4x20 sec static	4x20 reps	3x20 reps + 15 sec static	4x10 sec static	3x15 reps	4x20reps
6.Week		3x20 reps + 10 sec static	3x20 reps +15 sec static	3x15 reps +5 sec static	4x10 reps + 10 sec static	4x20 reps
7. Week		3x20 reps + 10 sec static	3x25 reps + 15 sec static	3x15 reps + 10 sec. static	4x15 reps + 10 sec static	4x25 reps + 10 sec static
8.Week		4x20 reps + 10 sec static	3x25 reps + 15 sec static	3x15 reps + 10 sec. static	4x10 reps + 15 sec static	4x20 reps + 20 sec static

Data Analyses

2 x 2 (Group x Time) univariate analysis of variance with repeated measures was used to test the effects of CST on dynamic balance performance. The impact of CST on static balance in AP and ML directions were tested with univariate analysis of variance (2 x 2) with training program as the “between-subject factor and” time as “the repeated measures factor”. The data were analyzed using SPSS Statistics 20.0 (SPSS Inc., Chicago, IL), and the significance level was set at $p < 0.05$.

RESULTS

Univariate Anova was performed to test the initial differences in TTS and results indicated non-significant differences in pre-test dynamic stabilization times for dominant ($F_{(1,24)}$=3.352, p=0.080) and non-dominant foot ($F_{(1,24)}$=3.897, p=0.060) between CST and control groups. The analysis revealed no significant univariate main effect of group for dominant in AP ($F_{(1, 24)}$=0.008, p=0.930) and ML ($F_{(1, 24)}$=2.819, p=0.106) directions. The analysis revealed non-significant univariate main effect of group for non-dominant in AP ($F_{(1, 24)}$= 0.431, p=0.518) and ML ($F_{(1, 24)}$=0.856, p= 0.774) directions.

For TTS in dominant foot a 2 × 2 (CST × Time) Anova showed a significant main effect for time ($F_{(1,24)}$=13.318, p=0.001, eta^2=0.357, power=0.938) but not for CST ($F_{(1,24)}$=0.397, p=0.535). A significant CST by time interaction effect ($F_{(3,24)}$=8.461, *p*=0.008, eta^2=0.026, power=0.797) indicated that participants in the CST group decreased in TTS more than participants in the control group. Moreover, for TTS in non-dominant foot, a 2 × 2 (CST × Time) Anova showed a significant main effect for time ($F_{(1,24)}$=35.285; p=0.000, eta^2=0.600, power=1.000) but not for CST ($F_{(1,24)}$=2.332, p=0.140). Anova results showed a non-significant CST by time interaction effect ($F_{(3,24)}$=3.473, p= 0.126) for non-dominant foot. Participants in CST and control groups developments for dominant and non-dominant foot over 8-weeks demonstrated in Figure 1.

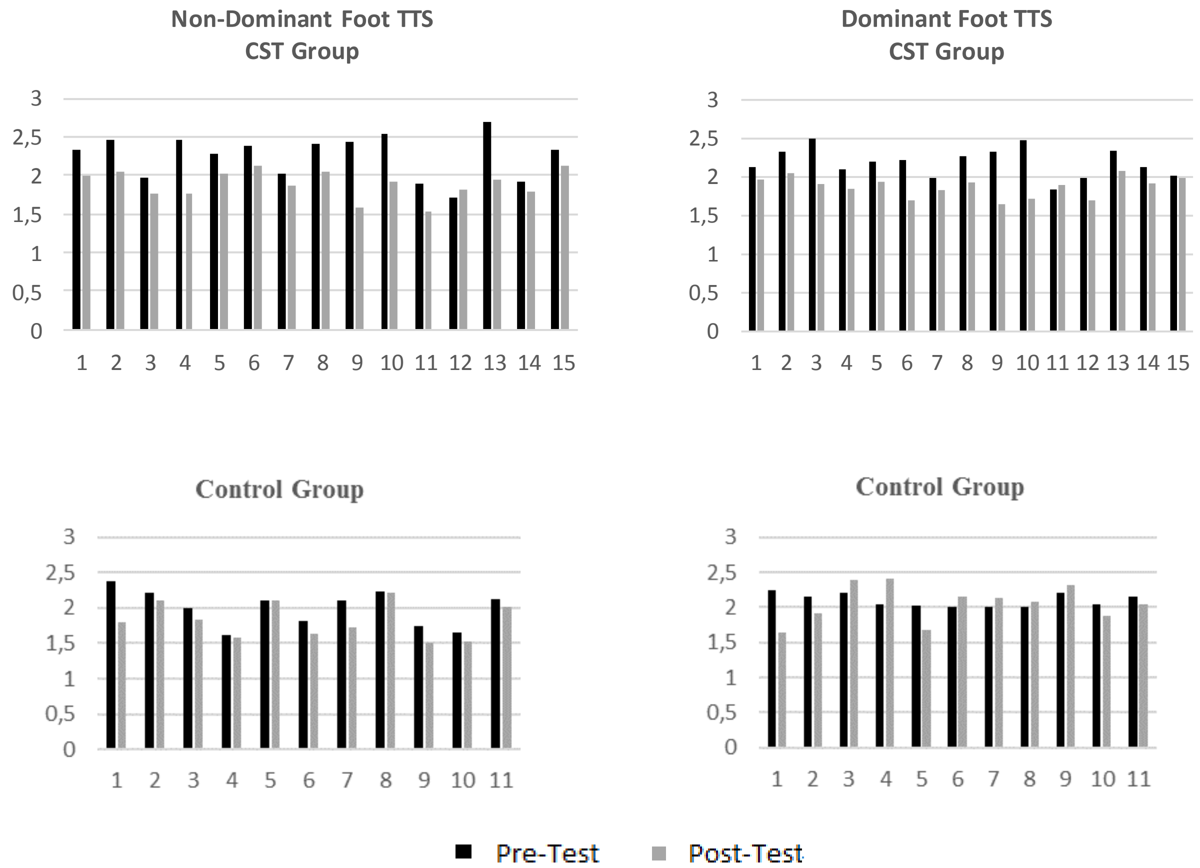

Figure 1. TTS dynamic balance test results of cst and control groups based on individuals

For static balance measurements with dominant foot, univariate Anova testing of COP in AP showed non-significant main effect for time ($F_{(1,24)}$=1.797, p= 0.193), CST ($F_{(1,24)}$=0.041, p=0.952) and interaction effect between time and CST ($F_{(1,24)}$=0.011, p=0.916). For ML direction CST main effect was observed ($F_{(1,24)}$=6.523, p=0.017, eta^2=0.214, power=0.689) which indicates that both group increased mean sway of their dominant foot in ML, however CST group increased less than control. However, there were no significant main effect of time ($F_{(1,24)}$=0.501, p=0.484) and interaction effect between time and CST ($F_{(1,24)}$=0.515, p=0.480) for dominant foot in ML direction.

For static balance measurements with non-dominant foot, univariate Anova testing of COP in AP direction, showed non-significant main effect for time ($F_{(1,24)}$=2.321, p=0.140), CST ($F_{(1,24)}$=1.353, p=0.256) and interaction effect between time and CST ($F_{(1,24)}$=0.474, p=0.498). Similarly, there were no any significant main effect of time ($F_{(1,24)}$=0.552, p=0.463), CST ($F_{(1,24)}$=0.644, p=0.432) and interaction effect of time x CST ($F_{(1,24)}$= .485, p=0.235) were observed in ML direction. Descriptive statistics of static measurements were shown in Table 2.

Table 2. Descriptive statistics of static measurements

Variable	Mean±SD			
	CST Group		Control Group	
	Pre-Test	Post-Test	Pre-Test	Post-Test
Dominant AP	16.81±15.74	13.80±12.44	16.32±11.29	13.75±7.77
Dominant ML	29.24±23.35	29.19±26.09	49.98±39.52	59.58±33.90
Non-Dominant AP	26.67±30.36	40.25±35.55	19.83±19.04	24.97±21.79
Non-Dominant ML	34.24±19.40	35.76±22.86	31.99±19.55	25.67±22.03

DISCUSSION

Core stability training is heterogeneous term; literature indicates studies represents a diverse range of movements, intervention styles and target population. Most of the CS studies conducted on athletic performance are focused on mature athletes. Although the importance of CS in athletic performance is being increasingly recognized, there are inconsistencies about optimal exercise protocols and methodologies through which CS have effective impact on junior athletes. Some of the studies demonstrated positive significant effects of CST on strength (Myer et al., 2008; Szymanki et al., 2010; Trzaskoma et al., 2010), vertical jump performance (Myer et al., 2006), static balance performance (Filipa et al., 2010; Aggarwal et al., 2010) among various populations. On the other hand, different studies indicated no effect of CST on various outcomes such as CS (Lust et al., 2009), flexor endurance test (Tse et al., 2005), dynamic balance measured by single leg hop (Aggarwal et al., 2010). Thus, the response to the applied combination of exercise type, intensity could be different, causing controversial issues related to applications. As previously emphasized by Cosio-Lima et al. (2003) the mechanism of CS is related to mechanism of balance and postural stability. The purpose of the study was to determine whether an 8-week CST training program in soccer would affect static and dynamic balance testing. In order to decrease the individual differences in the subjects, all subjects were grouped according to the morphological characteristics and pre-test performances. Prior to CST implementation, both the CST and control groups demonstrated similar performances in all measured variables.

The first hypothesis of this study was partially confirmed. The results for dynamic balance test showed that participation in soccer improves dynamic balance for both dominant and non-dominant foot which corroborates with previous research (Cug et al., 2015) implemented Star Excursion Balance Test (SEBT). They showed soccer players have significantly better dynamic balance performance in posterio-medial direction. However, sedentary control group indicated better balance performance in AP direction. Moreover, their findings support that athletic background has a direction-specific impact on dynamic stability but this might be test dependent. Bressel et al. (2007) also implemented SEBT and they highlighted that soccer players have similar balance performance with gymnasts. They suggested that unique sensorimotor challenges are imposed by soccer practice. Soccer players perform single-leg stance to reach ball for passing and shooting actions. These sensorimotor challenges have positive effect on balance performance. Participating in exercises that improves neuromuscular coordination (Paterno et al., 2004) and proprioception (Lephart et al., 1996) are also possible mechanisms that lead to decrease in stabilization time after landing in young soccer players.

The interaction between time and CST was observed for only dominant foot. Firstly, this side to side (dominant and non-dominant) differences were explained by Heitkamp et al. (2001) in relation to the gains in strength and muscular imbalances caused by balance training. Although their study conducted on mature trained participants, results of this study indicates that the same mechanism could be effectual on junior soccer players. On the other hand, the results of this study indicated that there was no main CST effect on stabilization time for both dominant and non-dominant limbs. Contrary to results of this study, Filipa et al. (2010) used SEBT as outcome measure and found that 14-15 years old female soccer players improved their balance score after 8-week neuromuscular and CST. However, force platform measurements have been considered the ‘‘gold standard’’ for measuring static balance (Riemann et al., 1999). It was previously suggested that the performance improvements in SEBT is not caused by strength or CS improvements but, rather knee and hip flexion improvements. However, Myer et al. (2006), suggested that trainings methods for improving balance are important to improve force attenuation strategies when landing from a single leg hop. Finally, soccer training decreased landing force for both groups and this resulted in better stabilization time. Core stability training group decreased landing force more with combination of soccer drills, when compared with the control group for dominant foot but not for non-dominant foot.

Our findings did not support the second and third hypothesis that there would be a difference between the two groups in decreasing mean sway values in AP and ML directions. Both groups slightly decreased their mean sway values during unilateral balance test for dominant foot in AP direction. On the contrary, control group increased their mean sway, while CST groups mean sway value remained almost the same with pre-test values. On the other hand, there were increase in mean sway was observed in AP direction for both groups for non-dominant foot. Lastly, for non-dominant foot CST groups mean sway value remained almost the same in ML direction and control group slightly decreased mean sway values. A possible explanation of diverse progression patterns for dominant and non-dominant limbs could be attributed to Heitkamp et al. (2001) gains in strength and muscular imbalances caused by balance training. Another possible explanation may be the changes in postural control during adolescence. Adolescents develop at different rates in relation to biological age and development of the visual, vestibular, and somatosensory systems may account for age-related changes in balance control (Nolan et al., 2005). It has been previously reported that some aspects of postural control are still developing after 10 years of age (Nolan et al., 2005). Moreover, Viel et al. (2009) suggested that the mechanisms underlying postural control are still developing during adolescence, which is possibly caused by a transitory period of proprioceptive neglect in sensory integration of postural control.

The only significant main effect was observed for CST on static balance for dominant foot stance in ML direction. Descriptive statistics indicated that both group increased their mean sway values but mean value of CST group were significantly less compared to controls. Considering this change, Myer et al. (2008) employed 10-weeks training focused on neuromuscular development of the core region in high-school volleyball athletes and they suggested gaining strength in focused part of the body may improve the ability of female athletes to increase control of lower limb alignment and decrease motion and loads resulting from increased trunk displacement in athletic performance. Drinkwater et al. (2007) examined the effects of surface stability on muscle performance during a squat exercise with different loads. On the contrary, to this study, they used unstable platforms, which decreased measures of concentric force, velocity and power, in addition to squat depth and eccentric power. They concluded that training on an unstable surface promotes CS and balance. Lee and Han (2016) examined the effects of 10-week complex core balance training on isokinetic muscle functions of the knee and lumbus. The exercises they employed were very similar to exercises used in this study. The authors concluded that complex core balance training improved the isokinetic muscle function of the knee and lumbus in throwing performance.

CONCLUSIONS

This study has some methodological limitations. The primary limitations of the current study included a small sample size and limited generalizability of results. Secondly, despite the non-significant differences between some of the results, soccer players in the CST group showed beneficial improvements after the CST program. We conclude that implemented CST in addition to regular soccer practices and focused on core region strength and stability significantly improved dynamic balance for dominant and static balance in ML direction for non-dominant foot in junior male soccer players.

References

Aggarwal, A., Zutshi, K., Munjal, J., Kumar, S., Sharma, V. (2010). Comparing stabilization training with balance training in recreationally active individuals. *International Journal of Therapy and Rehabilitation*, 17(5), 244-253.

Akuthota, V., Nadler, S. F. (2004). Core strengthening. *Archives of Physical Medicine and Rehabilitation*, 85(3 Suppl 1), 86-92.

Alentorn-Geli, E., Myer, G. D., Silvers, H. J., Samitier, G., Romero, D., Lazaro-Haro, C., Cugat, R. (2009). Prevention of non-contact anterior cruciate ligament injuries in soccer players. Part 2: a review of prevention programs aimed to modify risk factors and to reduce injury rates. *Knee Surgery, Sports Traumatology, Arthroscopy*, 17(8), 859-879.

Bliss, L.S., Teeple, P. (2005). Core stability: the centerpiece of any training program. *Current Sports Medicine Reports, 4(3), 179-183.*

Boccolini, G., Brazzit, A., Bonfanti, L., Alberti, G. (2013). Using balance training to improve the performance of youth basketball players. *Sport Sciences for Health*, 9(2), 37-42.

Borghuis, A. J., Lemmink, K. A., Hof, A. L. (2011). Core muscle response times and postural reactions in soccer players and nonplayers. *Medicine & Science in Sports & Exercise*, 43(1), 108-114.

Bressel, E., Yonker, J.C., Kras, J., Heath, E.M. (2007). Comparison of static and dynamic balance in female collegiate soccer, basketball, and gymnastics athletes. *Journal of Athletic Training*, 42(1), 42-46.

Burke, J.R. (2012). Effects of footwear comfort perception on the neuromuscular control of balance. *International Journal of Neuroscience*, 122(4), 209-220.

Cholewicki, J., Simons, A. P., Radebold, A. (2000). Effects of external trunk loads on lumbar spine stability. *Journal of Biomechanics*, 33(11), 1377-1385.

Cimadoro, G., Paizis, C., Alberti, G., , Babault, N. (2013). Effects of different unstable supports on EMG activity and balance. *Neuroscience Letters*, 548, 228-232.

Cosio-Lima, L.M., Reynolds, K.L., Winter, C., Paolone, V., Jones, M.T. (2003). Effects of physioball and conventional floor exercises on early phase adaptations in back and abdominal core stability and balance in women. *The Journal of Strength & Conditioning Research*, 17(4), 721-725.

Cug, M., Wikstrom, E.A., Golshaei, B., Kirazci, S. (2015). The Effects of Sex, Limb Dominance and Soccer Participation on Knee Proprioception and Dynamic Postural Control. *Journal of Sport Rehabilitation, 25(1), 31-39.*

Dawes, J, Roozen, M. (2012). Developing Agility and Quickness (NSCA Ed.). Champaign, IL: Human Kinetics.

DiStefano, L.J., Padua, D.A., Blackburn, J.T., Garrett, W.E., Guskiewicz, K.M., Marshall, S.W. (2010). Integrated injury prevention program improves balance and vertical jump height in children. *The Journal of Strength & Conditioning Research*, 24(2), 332-342.

Drinkwater, E. J., Pritchett, E. J., Behm, D. G. (2007). Effect of instability and resistance on unintentional squat-lifting kinetics. *International Journal of Sports Physiology and Performance*, 2(4), 400-413.

Ezechieli, M., Siebert, C. H., Ettinger, M., Kieffer, O., Weisskopf, M., Miltner, O. (2013). Muscle strength of the lumbar spine in different sports. *Technology and Health Care*, 21(4), 379-386.

Filipa, A., Byrnes, R., Paterno, M.V., Myer, G.D., Hewett, T.E. (2010). Neuromuscular training improves performance on the star excursion balance test in young female athletes. *Journal of Orthopaedic, Sports Physical Therapy*,40(9), 551-558.

Fransz, D.P., Huurnink, A., de Boode, V.A., Kingma, I., , van Dieën, J.H. (2015). Time to stabilization in single leg drop jump landings: An examination of calculation methods and assessment of differences in sample rate, filter settings and trial length on outcome values. *Gait & Posture*, 41(1), 63-69.

Golomer, E., Dupui, P., Sereni, P., Monod, H. (1999). The contribution of vision in dynamic spontaneous sways of male classical dancers according to student or professional level. *Journal of Physiology*, 93(3), 233-237.

Heitkamp, H.C., Horstmann, T., Mayer, F., Weller, J., Dickhuth, H.H. (2001). Gain in strength and muscular balance after balance training. *International Journal of Sports Medicine*, 22(4), 285-290.

Hirsch, M.A., Toole, T., Maitland, C.G., Rider, R.A. (2003). The effects of balance training and high-intensity resistance training on persons with idiopathic Parkinson's disease. *Archives of Physical Medicine and Rehabilitation*, 84(8), 1109-1117.

Kibler, W.B., Press, J., Sciascia, A. (2006). The role of core stability in athletic function. *Sports Medicine*, 36(3), 189-198.

Kubo, T., Muramatsu, M., Hoshikawa, Y., Kanehisa, H. (2010). Profiles of trunk and thigh muscularity in youth and professional soccer players. *The Journal of Strength & Conditioning Research*, 24(6), 1472-1479.

Lee, M., Han, G. (2016). The effect of peculiar complex core balance training on isokinetic muscle functions of the knee and lumbus. *Journal of Physical Therapy Science*, 28(4), 1294-1297.

Lephart S.M., Giraldo J.L., Borsa P.A., Fu F.H (1996). Knee joint proprioception: a comparison between female intercollegiate gymnasts and controls. *Knee Surgery,Sports Traumatology,Arthroscopy*, 4(2), 121–124.

Lust, K.R., Sandrey, M.A., Bulger, S.M., Wilder, N. (2009). The effects of 6-week training programs on throwing accuracy, proprioception, and core endurance in baseball. *Journal of Sport Rehabilitation*, 18(3), 407-426.

McGill, S. M. (2001). Low back stability: from formal description to issues for performance and rehabilitation. *Exercise and Sport Sciences Reviews*, 29(1), 26-31.

Myer, G.D., Brent, J.L., Ford, K.R., Hewett, T.E. (2008). A pilot study to determine the effect of trunk and hip focused neuromuscular training on hip and knee isokinetic strength. *British Journal of Sports Medicine*, 42(7), 614-619.

Myer, G.D., Ford, K.R., Brent, J.L., Hewett, T.E. (2006). The effects of plyometric vs. dynamic stabilization and balance training on power, balance, and landing force in female athletes. *The Journal of Strength & Conditioning Research*, 20(2), 345-353.

Nolan, L., Grigorenko, A., Thorstensson, A. (2005). Balance control: sex and age differences in 9-to 16-year-olds. *Developmental Medicine & Child Neurology*, 47(07), 449-454.

Panjabi, M.M. (1992a). The stabilizing system of the spine. Part I. Function, dysfunction, adaptation, and enhancement. *Journal of Spinal Disorders*, 5(4), 383-389..

Panjabi, M.M. (1992b). The stabilizing system of the spine. Part II. Neutral zone and instability hypothesis. *Journal of Spinal Disorders*, 5(4), 390-396.

Paterno M.V, Myer G.D., Ford K.R., Hewett T.E .(2004). Neuromuscular training improves single-limb stability in young female athletes. *Journal of Orthopaedic & Sports Physical Therapy*,34(6), 305–316.

Preuss, R., Fung, J. (2008). Musculature and biomechanics of the trunk in the maintenance of upright posture. *Journal of Electromyography and Kinesiology*, 18(5), 815-828.

Reed, C.A., Ford, K.R., Myer, G.D., Hewett, T.E. (2012). The effects of isolated and integrated 'core stability'training on athletic performance measures. *Sports Medicine*, 42(8), 697-706.

Reilly, T. (2007). *The Science of Training - Soccer: A Scientific Approach to Developing Strength, Speed and Endurance.* NewYork: Routledge.

Riemann, B.L., Guskiewicz, K.M., Shields, E.W. (1999). Relationship between clinical and forceplate measures of postural stability. *Journal of Sport Rehabilitation,* 8(2), 71-82.

Ross, S.E., Guskiewicz, K.M. (2004). Examination of static and dynamic postural stability in individuals with functionally stable and unstable ankles. Clinical Journal of Sport Medicine, 14(6), 332-338.

Ross, S.E., Guskiewicz, K.M., Yu,B. (2005). Single-leg jump-landing stabilization times in subjects with functionally unstable ankles. *Journal of Athletic Training*, 40(4), 298-304.

Saeterbakken, A.H., van den Tillaar, R., Seiler, S. (2011). Effect of core stability training on throwing velocity in female handball players. *The Journal of Strength & Conditioning Research*, 25(3), 712-718.

Sandrey, M.A., Mitzel, J.G. (2013). Improvement in dynamic balance and core endurance after a 6-week core-stability-training program in high school track and field athletes. *Journal of Sport Rehabilitation*, 22(4), 264-271.

Szymanski, D.J., Szymanski, J.M., Schade, R.L., Bradford, T.J., McIntyre, J.S., DeRenne, C., Madsen, N.H. (2010). The relation between anthropometric and physiological variables and bat velocity of high-school baseball players before and after 12 weeks of training. *The Journal of Strength & Conditioning Research*, 24(11), 2933-2943.

Tia, B., Paizis, C., Mourey, F., Pozzo, T. (2012). Do equilibrium constraints modulate postural reaction when viewing imbalance? *Brain and Cognition*,79(2), 89-95.

Tia, B., Saimpont, A., Paizis, C., Mourey, F., Fadiga, L., Pozzo, T. (2011). Does observation of postural imbalance induce a postural reaction? *PloS one*,6(3), e17799.

Trzaskoma L., Tihanyi J., Trzaskoma, Z. (2010) The effect of a shortterm combined conditioning training for the development of leg strength and power. *The Journal of Strength & Conditioning Research*, 24 (9): 2498-2505.

Tse M.A., McManus A.M., Masters R.S. (2005) Development and validation of a core endurance intervention program: implications for performance in college-age rowers. *The Journal of Strength & Conditioning Research*, 19 (3): 547-52.

van der Linden, M.L., Bulley, C., Geneen, L.J., Hooper, J.E., Cowan, P., Mercer, T.H. (2013). Pilates for people with multiple sclerosis who use a wheelchair: feasibility, efficacy and participant experiences. *Disability and Rehabilitation*, 36(11), 932-939.

Viel, S., Vaugoyeau, M., Assaiante, C. (2009). Adolescence: a transient period of proprioceptive neglect in sensory integration of postural control. *Motor Control*, 13(1), 25-42.