Does core strength training influence kinetic efficiency, lower extremity stability, and 5000m performance in runners?

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Context: Core strength training (CST) has been popular in the fitness industry for a decade. Although strong core muscles are believed to enhance athletic performance, only few scientific studies have been conducted to identify the effectiveness of CST on improving athletic performance. **Objective:** Identify the effects of a 6-wk CST on running kinetics, lower extremity stability, and running performance in recreational and competitive runners. **Design and Setting:** A test-retest, randomized control design was used to assess the effect of CST and no CST on ground reaction force (GRF), lower extremity stability scores, and running performance. **Participants:** Twenty-eight healthy adults (age, 36.9±9.4yrs, height, 168.4±9.6cm, mass, 70.1±15.3kg) were recruited and randomly divided into two groups. **Main outcome Measures:** GRF was determined by calculating peak impact vertical GRF (vGRF), peak active vGRF, duration of the breaking or horizontal GRF (hGRF), and duration of the propulsive hGRF as measured while running across a force plate. Lower extremity stability in three directions (anterior, posterior, lateral) was assessed using the Star Excursion Balance Test (SEBT). Running performance was determined by 5000 meter run measured on selected outdoor tracks. Six 2 (time) X 2 (condition) mixed-design ANOVA were used to determine if CST influences on each dependent variable, $p < .05$. **Results:** No significant interactions were found for any kinetic variables and SEBT score, $p > .05$. But 5000m run time showed significant interaction, $p < .05$. SEBT scores improved in both groups, but more in the experimental group. **Conclusion:** CST did not significantly influence kinetic efficiency and lower extremity stability, but did influence running performance. **Key Words:** core exercise, stability, running performance

Core strength training (CST) is widely practiced by professionals with the goals of enhancing core stability and increasing core muscular strength, thereby improving athletic performance.[1-3] It is believed among the health and fitness professionals that in order to improve athletic performance and prevent risk of injury, CST is a vital component of strength and conditioning. Limited scientific studies have been conducted to determine the effect of CST on lower extremity stability and athletic performance.[1-3] Significant improvement in core strength have been documented as a result of CST.[1-3] However, these same studies failed to find significant changes in lower extremity stability, mechanics, or performance.[1-3] Results indicates that CST is a useful tool for strengthening core muscles, but the carryover to performance needs further investigation.

In a biomechanical analysis of running, abnormal range of vertical ground reaction forces (vGRFs) and horizontal GRFs (hGRFs) have been associated with overuse injuries.[4-6] Adequate stability in the lower extremity may have an important role in running efficiency, since poor stability may be linked to injuries in both athletics and daily living. Therefore, the purpose of this study was to determine the effects of 6-weeks of CST on GRFs, lower extremity stability, and overall running performance in runners. We hypothesized that CST would have the following positive influences: (a) decrease 5000meter run time, (b) increase star excursion balance test (SEBT) scores, (c) decrease peak impact vGRF, (d) increase peak active vGRF, (e) decrease the duration of breaking hGRF, and (f) increase the duration of propulsive hGRF.

Methods

Recreational and competitive runners were recruited via flyers from running clubs and running shoe stores in south Florida. An initial screening took place where potential participants were tested for core stability using the Sahrmann core stability test in accordance with Stanton et al.[3] Sahrmann scores are given in levels (1-5) with 5 being the highest level of core stability. Reliability for this test has been reported between .86 and .95.[3,9] Those with scores level 2 or lower were retained in the study since they would have the potential to benefit from the CST. Only one potential participant scored above level 2 and thus was omitted. Twenty-eight rear-foot striking runners (10 males, 18 females) volunteered for the study (age, 36.9±9.4yrs, height, 1.68±0.09m, mass, 70.1±15.3kg). To identify their running background, they answered specific questions about training strategies, pace, past injury history, and type of footwear used. Participants were then randomly divided into two groups; control and CST. Data were collected in a laboratory except the 5000m run which was completed at selected outdoor tracks.

To determine measures of GRF, participants were asked to run across an embedded AMTI force plate (Advanced Medical Technologies, Inc., Watertown, MA) that sampled at 600Hz. After warm-up, participants performed at least two trials making left foot contact on the plate at a comfortable running speed (2.65-3.35m/s = 8-10 minutes per mile pace). If they had abnormal steps prior to reaching the force plate, the trial was discarded, and they performed another. Peak Motus software (ver. 8.2, ViconPeak, Centennial, CO) was used to reduce the kinetic variables (peak impact vGRF, peak active vGRF, breaking hGRF, propulsive hGRF) with a Fast Fourier Analysis completing the smoothing. The peak impact vGRF and the peak active vGRF were obtained at initial contact and push-off, and were normalized to body weight (BW), and averaged for the groups (Figure 1). The duration of breaking hGRF and propulsive hGRF were standardized by percentage (e.g. total foot contact time @ 0.30 secs = 0.15 secs of breaking hGRF and 0.15 secs of propulsive hGRF; thus 50% & 50%).

Lower extremity stability was assessed using the SEBT according to procedures described by Gribble and Hertel[8] (Figure 2) that includes a measure of leg length. The SEBT was completed barefoot on both legs. Kinzey and Armstrong recommended that the instruction and demonstration improved the reliability of the test (from .67 to .86) with practice sessions; thus, adequate practice time was provided.[9] Only one trial of the 5000m run test was conducted pre- and post-6 weeks since maximal effort was expected. A 5000m run was completed at a 400m measured track. The run was done on a separate day than the laboratory test, but within seven days before and after. After warm-up, the 5000m run was timed with a stopwatch in mins and secs (e.g., 5000m = 19 min 43 sec). Temperature and humidity level were recorded for descriptive purposes.

Both groups performed pre- and post-training tests in the same order. The control group was instructed to maintain their training routine and report any alterations. The experimental group received the CST program that consists of five core-related exercises performed four times per week for six weeks. The CST protocol was created based upon previous published protocols, and experts advise from doctoral-level exercise physiologists and strength and conditioning specialists. The following exercises were visually demonstrated and verbally instructed by the investigator after the pre-training test: (a) abdominal crunch on a stability ball to target abdominal muscles, (b) back extension on stability ball to target back extensor muscles, (c) supine opposite 1-arm/1-leg raise to target back/hip extensors muscles, (d) hip raise on stability ball to target back/hip extensors muscles, and (e) Russian twist on a stability ball to target abdominal muscles. In addition, the CST group received a hard copy of exercise instructions including pictures and a training log. Stability balls were provided to the CST group as this training is considered to be a home training. They were instructed to fill out the training log after each session and were also contacted by the investigator at the end of each week to ensure adherence or answer any concerns. Each CST session took approximately 20 to 30 min. The group performed each exercise for two sets of ten repetitions during the first two weeks of the treatment period. Then, they performed each exercise for two sets of fifteen repetitions during the third and fourth week. Finally, they performed each exercise for three sets of twelve repetitions during the final two weeks of treatment period. Approximately 30 to 60 sec of rest periods were provided if desired. According to a past study[1], total session volume should increase to challenge strength improvement rather than performing the same volume throughout the treatment. Therefore, this study was designed to increase the volume of exercise sessions every two weeks.

All dependent variables were input into Statistical Package for Social Sciences (SPSS). Six 2 x 2 (group by time) mixed-design analysis of variance (ANOVA) with repeated measures were performed to determine any significant effect of CST on the dependent variables: (a) peak impact vGRF, (b) peak active vGRF, (c) duration of breaking hGRF, (d) duration of propulsive hGRF, (e) the scores of the SEBT, and (f) 5000m run time. Significance was defined as $p < 0.05$.

Results

Twenty participants (n_{con}=8, n_{exp}=12) completed the study (n_{con}: age 39.25 $\pm$ 10.81yrs, height 1.67 $\pm$ 0.84m, mass 63.03 $\pm$ 12.02kg; n_{exp}: age 37.75 $\pm$ 10.63yrs, height 1.67 $\pm$ 0.10m, mass 75.95 $\pm$ 16.89kg). Table 1 depicts the mean and standard deviations of the dependent variables of both groups pre- and post-training. There was a significant interaction in 5000m run time ($F_{(1,18)}$= 56.09, p<.05). CST had no significant influence on SEBT scores, or any aspects of the GRF variables. However, SEBT scores did show greater improvements in the CST group (n_{exp}: + 21.92cm, n_{con}: + 10.25cm).

Discussion and Conclusion

We sought to determine the influence of CST on running kinetics, lower extremity stability, and performance in runners. Results supported the hypothesis that CST would improve 5000m run time; however, there was no significant effect on the SEBT or kinetic variables.

Times significantly decreased in the 5000m run in the CST group. This is a positive outcome, and the first finding that shows CST affects performance. Weather conditions may have affected the times (pre=86^0 F, 64% humidity; post=73^0 F, 58% humidity). Conditions for maximal running effort were better at the post-test. SEBT scores improved in the both groups possibly from a test-retest effect. However, the CST group did show greater improvement (n_{exp}: +21.92cm; n_{con}: +10.25cm). Better SEBT scores indicate enhanced dynamic stability. Peak active vGRF changes were minimal in both groups (n_{con}: +0.03BW, n_{exp}: +0.01BW differences). Large active forces negatively affect runners, putting high pressure to the midfoot and forefoot. When a foot lands in front of the body while running (which often happens at downhill running and faster running velocity), it leads to longer duration of breaking hGRF because the body becomes more stiff to accept greater foot impact.[5] Reducing the duration of breaking hGRF and increasing the duration of propulsive hGRF would help carry forward momentum. Our results showed no significant effect, with both groups' increasing in duration of breaking forces (n_{con}: +1.37%, n_{exp}: +2.03%) and decreasing the duration of propulsive forces (n_{con}: -1.37%, n_{exp}: -3.45%).

One limitation that may have affected the results was the group differences (body mass and typical running pace) due to the randomized selection. In average, the control group weighted more and typical running pace was slower. Another limitation was the change in running velocity at GRF tests. During the GRF test, running velocity was not controlled (it was a self-selected pace). Although the participants were instructed not to change running speed while crossing the force plate, the running speed was varied between the pre- and post-training GRF tests (n_{con}: pre-test 2.99m/s, post-test, 3.08m/s; n_{exp}: pre-test 2.64m/s, post-test 2.81m/s). Thus, it is questionable to compare changes in kinetic variables to past studies.[4-6]

Further control in consistent running velocity may be required by using a treadmill. We chose not to use a treadmill since treadmill running mechanics have been found to differ from actual ground running. It is also possible that the training frequency and duration were not enough to elicit the hypothesized effects. CST is considered a vital component of the strength and conditioning as well as rehabilitation, but only limited studies were conducted to reveal the true effects of the CST.[1-3] The core strength related studies can be approached not only in the athletic population, but also in the general population who suffer pain and injuries which relate to postural alignment.

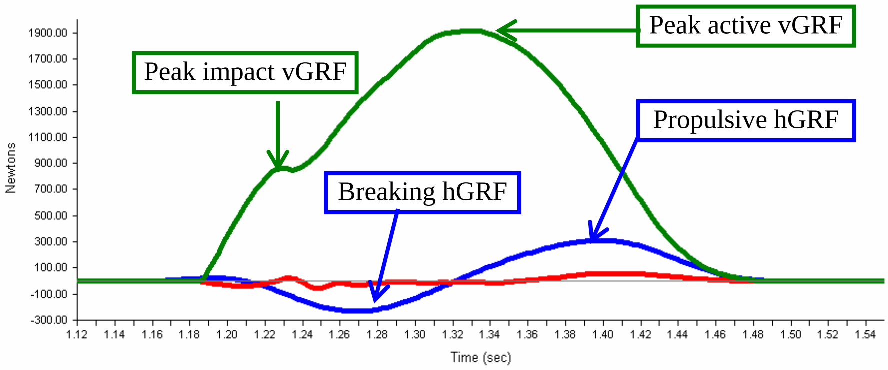

Figure 1: Kinetic variables of ground reaction forces

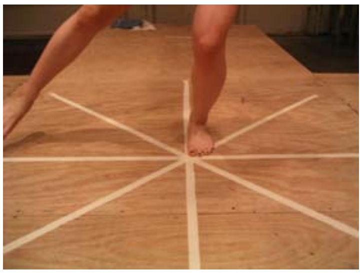

Figure 2: Star Excursion Balance Test

Table 1. Summary of the descriptive results with significance.

	$n_{exp} = 12$			$n_{con} = 8$		
	Pre	post	dif	pre	post	dif
Impact vGRF: BW	1.65 ± 0.38	1.74 ± 0.46	+0.09	1.99 ± 0.38	1.89 ± 0.24	-0.10
Active vGRF: BW	2.30 ± 0.36	2.31 ± 0.42	+0.01	2.49 ± 0.26	2.52 ± 0.24	+0.03
Breaking hGRF: % ***	47.30 ± 5.91	49.33 ± 6.81	+2.03	53.11 ± 4.77	54.48 ± 4.76	+1.37
Propulsive hGRF: % ***	52.70 ± 5.92	49.25 ± 6.70	-3.45	46.89 ± 4.77	45.52 ± 4.57	-1.37
SEBT:cm **	198.75±26.70	220.67±26.90	+21.9	199.13±26.34	209.38±26.89	+10.25
5000m run: min:sec *	29:29 ± 2:38	28:42 ± 2:23	-0:47	26:30 ± 1:59	26:13 ± 1:54	-0:17

Note. ***** denote significant interaction, $p < .05$, ****** denote significant main effect: training, $p > .05$, ******* denote significant main effect: group, $p > .05$.

References

1. Cosio-Lima LM, Reynolds KL, Winter C, Paolone V, Jones MT. Effects of physioball and conventional floor exercises on early phase adaptations in back and abdominal core stability and balance in women. *J Strength Cond Res.* 2003;17(4):721–5.
2. Scibek JS, Guskiewicz KM, Prentice WE, Mays S, Davis JM. The effects of core stabilization training on functional performance in swimming. Unpublished master’s thesis, University of North Carolina, Chapel Hill, North Carolina, USA. 2001.
3. Stanton R, Reaburn PR, Humphries B. The effects of short-term swiss ball training on core stability and running economy. *J Strength Cond Res.* 2004;18(3):522–8.
4. Bus SA. Ground reaction forces and kinematics in distance running in older-aged men. *Med Sci Sport Exer.* 2003;35:1167–75.
5. Gottschall JS, Kram R. Ground reaction forces during downhill and uphill running. *J Biomech.* 2005;38:445–52.
6. Hreljac A. Impact and overuse injuries in runners. *Med Sci Sport Exer.* 2004;36(5):845–9.
7. Olmsted LC, Carcia CR, Hertel J, Shultz SJ. Efficacy of the star excursion balance tests in detecting reach deficits in subjects with chronic ankle instability. *J Athl Train.* 2002;37:501–6.
8. Gribble PH, Hertel J. Considerations for normalizing measures of the star excursion balance test. *Meas Phys Educ Exer Sci.* 2003;7(2):89–100.