

CHANGES IN THE FUNCTIONAL PARAMETERS OF BALANCE AND LOWER EXTREMITIES OF ADOLESCENT SHORT AND LONG DISTANCE RUNNERS AFTER EXERCISES ON UNSTABLE SURFACES

Miglė Bielskytė, Toma Petkutė, Renata Žumbakytė-Šermukšnienė
Lithuanian University of Health Sciences, Kaunas, Lithuania

ABSTRACT

Background. Results from the previous studies indicated benefits of training on unstable surfaces in various populations. Drawing upon them we hypothesized that training on unstable surfaces would help runners improve balance and lower extremity functional indicators.

Methods. The study included 20 adolescent athletes from Kaunas sports school “Startas”, aged 12–13 years, boys and girls running short and long distances. Their training consisted of 20 minute exercises on unstable surfaces performed two times a week. Participants were tested before and after applying the program. The tests applied were Y balance test, calf muscle strength testing with a Lafayette dynamometer, Single-legged Hop tests, *T*-test.

Results. Groups of short- and long- distance runners had better ($p < .05$) calf muscle strength of both legs after exercises on unstable surfaces program. Both groups also improved 6 m HOP test results of both lower extremities ($p < .05$). Some of the dynamic balance indicators statistically significantly improved after exercises on unstable surfaces in the groups of short- and long- distance adolescent runners. *T*-test results after exercises on unstable surface program improved ($p < .05$) in long- distance runner group (from 14.03 (12.44; 14.95; 13.85) s to 13.94 (12.36; 14.52; 13.65) s) and there were differences between short- and long- distance runner groups before and after exercises on unstable surfaces ($p < .05$).

Conclusion. This research showed that training on unstable surfaces helps runners to improve balance and lower extremity functional indicators and we recommend to include exercises on unstable surfaces to their training.

Keywords: track and field, dynamic balance, muscle strength, agility.

INTRODUCTION

Running is a cyclic event where the same movements of hands, feet and torso are repeated in all planes (Neumann, 2017). It is one of the main ways of human movement and one of the most popular types of physical activity for people of all ages. Running definitely has a lot of benefits but physically active and professional athletes, career-seeking adolescents or adults have greater risk of injury. This may be influenced by muscle imbalance, insufficient physical preparation or excessive load during training (Caine, Maffulli, & Caine, 2008; Sando & McCambridge, 2013). Injuries common in runners are non-contact

injuries of lower extremities below knees (Taunton, 2002). For injury prevention it is essential to have proper training and rest schedule, overall athletic preparation and attention to balance training. Runners who have good static and dynamic balance are better at fast and high quality specific movements, and their risk of injury decreases (Yaggie & Campbell, 2006).

Results from studies show some differences in physical and musculoskeletal systems between short and long distance runners. Short distance runners have better agility than long distance runners, and thus they can start and run faster

(Zech et al., 2010). Short distance runners are more muscular with fast fibres dominating in muscles, and long distance runners are less muscular, with slow fatigue resistant fibres dominating in muscles (O'Connor, Olds, & Maughan, 2007). Adolescents' musculoskeletal system is not completely developed, and thus the neuromuscular system is not enough adaptable during their rapid growth, therefore special attention should be paid to strength and stretching exercises (Huxley, O'Connor, & Healey, 2014), training specific movements and the quality of their performance.

Results from the previous studies evidenced benefits of training on unstable surfaces in various populations. Commonly such training is used in rehabilitation after injuries, some diseases or for elderly people (Huang, Chen, Lin, & Lee, 2014; Lesinski, Hortobágyi, Muehlbauer, Gollhofer, & Granacher, 2015). There are a lot of studies with basketball and football players, effects of their rehabilitation and injury prevention programs using unstable surfaces (Boccolini, Brazziti, Bonfanti, & Alberti, 2013; Gollhofer & Kriemler, 2010). Drawing upon previous studies, we hypothesized that training on unstable surfaces would help runners improve balance and lower extremity functional indicators (Alonso et al., 2012; Knight, Holmes, Chander, Kimble, & Stewart, 2016). The aim of this study was to evaluate changes in the functional parameters of balance and lower extremities of adolescent runners after training on unstable surfaces.

METHODS

Participants. The study included 20 adolescent athletes from Kaunas Sports School "Startas",

aged 12–13 years, boys and girls running short and long distances. They were divided into two groups according to their running distance – short and long distance runners groups, their characteristics are shown in Table 1.

The study was carried out in Kaunas Sports School "Startas" in November – December, 2017. All the experimental procedures were approved by Kaunas Regional Biomedical Research Ethics Committee at the Lithuanian University of Health Sciences (No. BEC-KN-49) and conducted in accordance with the Declaration of Helsinki. Parents or foster parents of all subjects gave written informed consent.

The program applied was prescribed for all participants and consisted of 20 minute exercises on unstable surfaces performed 2 times a week for 5 weeks. The program consisted of exercises while standing on one or both feet on the unstable air-filled cushion. Exercises were applied during training after warm-up before the main part of the workout. Participants were tested before and after the application of the program.

Testing. Y balance test – or modified star excursion test is used to evaluate dynamic stability. This test is used to evaluate postural control and draw conclusions about athlete's reaching abilities while maintaining stable position (Shaffer et al., 2013). Participant moves one foot forward, backwards medial and lateral while standing on another foot.

Calf muscle strength measurement with Lafayette dynamometer is used for objective evaluation. Muscle strength is expressed in kilograms. We measured foot plantar flexion and dorsal flexion muscle strength. While measuring participant lies on the back on the couch so that the

Table 1. Baseline characteristics of research participants

Group	Age	Statistical difference between groups	Gender	Duration of sports participation (years)	Statistical difference between groups	Training per week (times)	Statistical difference between groups	Were previously injured (%)
Short distance runners	13 (12, 13, 12.6)	$p = .280$	7 females and 3 males	1.8 (1.0, 3.0, 1.8)	$p = .684$	3 (3, 5, 3.5)	$p = .739$	30
Long distance runners	12 (12, 13, 12.3)		5 females and 5 males	2.0 (1.0, 3.0, 1.9)		4 (2, 5, 3.6)		30

Note. Median (Minimum, Maximum, Mean).

foot is not laid on the base, and researcher stands in front of him (Mentiplay et al., 2015).

Single Leg Hop Test (HOP). These tests are performed to evaluate dynamic knee and ankle stability, lower extremities' neuromuscular coordination and muscle strength. There is a 6-meter line in the room, which is graded, then participant hops 6 meters as fast as possible (Johnsen, Eitzen, Moksnes, & Risberg, 2015). We evaluated the right and the left leg separately. There are no limitations for arms movements.

T-test is used to evaluate lower extremities' agility in four directions and body control, balance not losing the speed while changing directions of movement (Paoule, Madole, Garhammer, Lacourse, & Rozenek, 2000). Also the test evaluates speed, strength and agility of legs. Four markers are placed at certain distances. Participant needs to run in four directions with a sharp change of direction and a stop. The test is performed 2 times and the better result is recorded.

Mathematical statistical analysis was performed using IBM SPSS 22 software. Qualitative variables are given in percent. Quantitative data are presented as median (x_{me}), minimum value (x_{min}), maximum value (x_{max}) and arithmetic mean (\bar{x}) – x_{me} (x_{min} ; x_{max} ; \bar{x}). The Wilcoxon Criterion was used to compare two independent samples, Mann-Whitney Criteria – two dependent samples.

Differences are considered statistically significant when $p < .05$.

RESULTS

The study revealed that strength of foot plantar and dorsal flexion of muscles of both lower extremities in the groups of short and long distance runners statistically significantly increased after the program of exercises on unstable surfaces (see Table 2). There was statistically significant difference of left foot plantar flexion of muscle strength between the groups of short and long distance runners before exercises on unstable surfaces ($U = 19.0$; $p = .019$). Changes in the differences between runners' strength of calf muscle before and after exercises are given in Table 2.

After exercises on unstable surfaces, 6 m HOP test time statistically significantly decreased in both groups of short and long distance runners, except for the results of the left leg of short distance runners (Table 2).

Y balance test results were diverse. Short distance runners had statistically significant better right leg dynamic balance in anterior direction, results changed from 65.5 (60.0, 80.0, 67.5) cm before to 71.5 (64.0, 79.0, 70.3) cm after exercises on unstable surfaces ($Z = -1.994$, $p = .046$). Long distance runners' group statistically significantly

Table 2. Short and long distance runners' test results before and after the program of exercises on unstable surfaces

Group	Foot	Plantar flexion strength before (kg)	Plantar flexion strength after (kg)	Statistical difference within group	Dorsal flexion strength before (kg)	Dorsal flexion strength after (kg)	Statistical difference within group	6 m HOP before (s)	6 m HOP after (s)	Statistical difference within group
Short distance runners	Right	8.1 (5.6, 10.7, 8.2)	10.6 (9.4, 13.5, 10.9)	$Z = -2.701$ $p = .007$	4.9 (2.9, 6.5, 4.9)	9.8 (6.2, 14.5, 10.3)	$Z = -2.803$ $p = .005$	2.05 (1.63, 2.26, 1.98)	1.91 (1.55, 2.13, 1.86)	$Z = -2.805$ $p = .005$
	Left	9.6 (6.4, 11.5, 9.6)	11.5 (7.2, 14.3, 11.0)	$Z = -2.143$ $p = .032$	5.8 (4.5, 7.5, 5.9)	11.7 (7.2, 14.6, 11.4)	$Z = -2.803$ $p = .005$	2.02 (1.63, 2.30, 1.98)	1.95 (1.55, 2.22, 1.92)	$p = .074$
Long distance runners	Right	8.8 (5.6, 10.8, 8.5)	10.9 (6.2, 12.5, 10.5)	$Z = -2.703$ $p = .007$	5.1 (3.1, 6.3, 4.9)	11.4 (7.6, 14.6, 11.1)	$Z = -2.805$ $p = .005$	2.06 (1.74, 2.41, 2.09)	1.98 (1.62, 2.32, 1.96)	$Z = -2.497$ $p = .013$
	Left	7.7 (5.6, 11.1, 7.8)	10.5 (8.4, 11.6, 10.3)	$Z = -2.701$ $p = .007$	5.4 (2.9, 8.3, 5.4)	11.6 (9.4, 14.9, 11.8)	$Z = -2.805$ $p = .005$	2.04 (1.60, 2.45, 2.01)	1.86 (1.63, 2.31, 1.87)	$Z = -2.296$ $p = .022$

Note. Median (Minimum, Maximum, Mean).

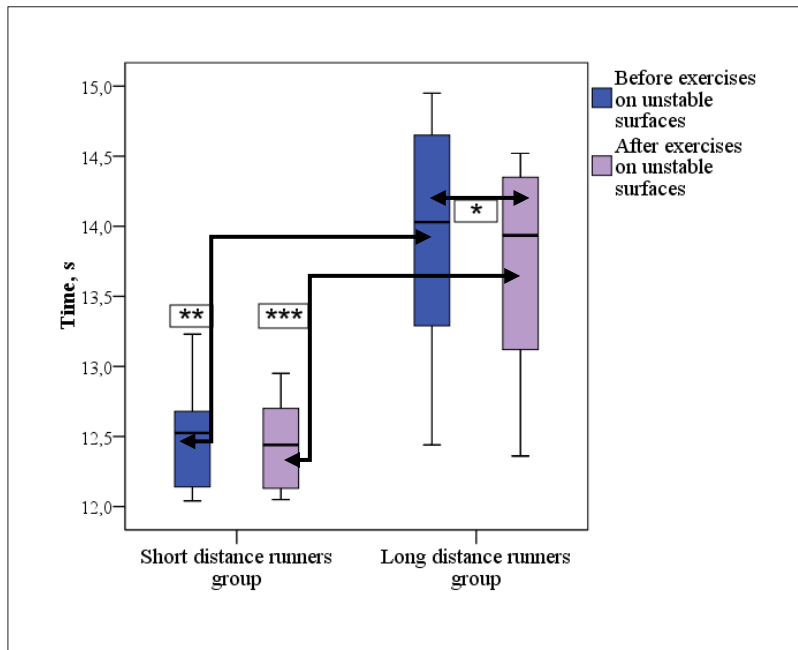


Figure. *T*-test results before and after the exercise on unstable surfaces program

Notes. Statistically significant changes * $p = .007$, ** $p = .004$, *** $p = .004$.

improved some of the right leg dynamic balance indicators: reach in forward direction changed from 64.0 (53.0, 76.5, 64.3) cm before to 68.5 (63.0, 78.0, 69.8) cm after exercises on unstable surfaces ($Z = -2.550$, $p = .011$); reach in posteromedial direction changed from 81.0 (70.0, 93.0, 81.9) cm before to 86.0 (71.5, 95.5, 84.7) cm after exercises on unstable surfaces ($Z = -1.989$, $p = .047$). Long distance runners' group statistically significantly improved posterolateral direction reach in the left leg from 86.5 (73.5, 103.0, 86.9) cm before to 97.0 (78.0, 104.0, 93.7) cm after exercises on unstable surfaces ($Z = -2.807$, $p = .005$).

There were statistically significant differences between the *T*-test time 14.03 (12.44, 14.95, 13.85) s before and 13.94 (12.36, 14.52, 13.65) s after exercises on unstable surfaces program in long distance runners' group ($Z = -2.701$, $p = .007$); difference in *T*-test time ($U = 12.0$, $p = .004$) between short and long distance runners' groups before exercises on unstable surfaces training the was statistically significant, also there was a statistically significant *T*-test time difference between short and long distance runners' groups after exercises on unstable surfaces training ($U = 12.0$, $p = .004$) (Figure 1).

DISCUSSION

In this study, we assessed the effect of balance exercises on lower extremity functional parameters, agility and balance in adolescent short and long

distance runners. After a 5-week balance training program we noted an improvement in most of the balance, agility and lower extremity functional parameters, and these indicators differed between short and long distance runners.

Agility, balance and muscle strength is crucial for runners. All of these features are related and complementary because without the appropriate muscle strength it is not possible to run fast or run long distances, agility can affect the running start, in case of poor balance it is more difficult to run, keep body weight on one leg and shift weight to the other one (Knight et al., 2016; Yaggie & Campbell, 2006; Zech et al., 2010).

In our study, these Y balance test parameters significantly improved after the application of the exercise program: reaching in anterior direction by testing the right leg improved in both groups, reaching in posterolateral direction with the left leg and reaching in posteromedial direction with the right leg improved in the long- distance group only. Research shows that improvement of Y balance test scores was noted in female basketball players after an 8-week neuromuscular training program (Benis, Bonato, & Torre, 2016). Furthermore, it has been shown that a 4-week balance training program improves the static and dynamic balance, lower extremity muscle strength and the vertical jump height in young healthy people (Gollhofer & Kriemler, 2010). Improved balance leads to faster specific sport-driven movements and better athlete agility – sudden start, backward and sideways

running, sudden starting and stopping (Yaggie & Campbell, 2006). Long-term balance exercises reduce the risk of injury (Nam, Cha, & Kim, 2016), and incorporated into the training program reduces the occurrence of sports-related injuries in various sports (Gollhofer & Kriemler, 2010; McGuine & Keene, 2006; Zech et al., 2010).

After the exercise program applied on unstable surfaces, we obtained significantly greater strength of calf muscles in both legs for short and long distance runners. In the study of Cuğ and colleagues, 4-week balance-training program also improved ankle force production and dynamic postural control in healthy young adults (Cuğ, Duncan, & Wikstrom, 2016).

In our study, the results of HOP tests after the exercise program were ambiguous (results of the right and left leg differed). After exercises on unstable surfaces, there was a statistically significant improvement in 6-meter jumping test result in the groups of short and long distance runners. Munro and colleagues assessed the impact of retesting on HOP test results, and the study showed that learning the test also affects its performance (Munro & Herrington, 2011).

There was a statistically significant difference in *T*-test performance between short and long distance running groups both before and after balance exercises. The *T*-test results were better in short distance runners. This may be due to different running distances and different training patterns. There was also a statistically significant improvement in *T*-test scores for long distance runners after the exercise program. Pauole and colleagues found significant differences in *T*-test results between athletes and non-athletes: the results of *T*-test in athletes and physically active

people were better than those in non-athletic and sedentary subjects, as well as male test results were better than female results (Pauole et al., 2000).

Running requires optimal neuromuscular coordination. Not only sufficient strength, endurance and coordination, but also dynamic balance is important for it (Anderson & Behm, 2005). Balance training on unstable surfaces has a positive effect not only on static and dynamic balance, but also it improves the agility and coordination necessary for the movements used in the sport and reduces the risk of sports-related lower extremity injuries (Anderson & Behm, 2005; Gollhofer & Kriemler, 2010; Nam et al., 2016; Yaggie & Campbell, 2006; Zech et al., 2010).

CONCLUSIONS

After exercises on unstable surfaces adolescents running short and long distances improved some of their functional indicators of balance and lower extremities – calf muscle strength, agility, and dynamic knee and ankle stability. Also the group of short distance runners had better agility than the group of long distance runners before and after the program of training on unstable surfaces. Based on the data received we recommend to include exercises on unstable surfaces into their training.

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