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IMPLEMENTATION OF AN UNSTABLE SURFACE EXERCISE PROGRAM IN PHYSICAL EDUCATION CURRICULUM: EFFECTS ON STRENGTH AND MORPHOLOGICAL FEATURES

IZVAJANJE PROGRAMA NESTABILNIH POVRŠIN PRI ŠPORTNI VZGOJI: UČINKI NA MOČ IN MORFOLOŠKE LASTNOSTI

ABSTRACT

Although unstable strength training has gained popularity among athletes and the recreational population, there is scarce data regarding the applicability of this type of exercise program in school settings. The aim of the study was to investigate whether the implementation of an unstable surface strength exercise program in physical education would contribute to the improvement of physical fitness in 14-years students. A sample of 220 adolescents (112 girls) was randomly assigned to either the EXP (calisthenics exercise under unstable conditions) or the CON group (prescribed physical education strength exercise program). Before and after the 12-week period, upper-body isometric and repetitive strength were accessed using 4 motor tests. In addition, skinfold thickness (ST) was determined in subscapular, pectoral, and abdominal areas. Both groups improved strength performance ($p < 0.01$), with greater increase in EXP compared to CON for all motor tests ($p < 0.01$, ES = 0.21 – 0.45). Both groups decreased total, subscapular and abdominal ST ($p < 0.05$), with no significant effect of group. Unstable surface strength exercises are effective in improving physical abilities and should be included in the regular physical education curriculum.

Keywords: adolescence, physical fitness, skinfold thickness, calisthenics

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IZVLEČEK

Čeprav je nestabilna vadba moči pridobila priljubljenost med športniki in rekreativno populacijo, je podatkov o uporabnosti tovrstnega vadbenega programa v šolskih okoljih malo. Namen raziskave je bil raziskati, ali bi izvajanje programa vadbe ne nestabilni površinski moči pri športni vzgoji pripomoglo k izboljšanju telesne pripravljenosti dijakov starih 14 let. Vzorec 220 mladostnikov (112 deklet) je smo naključno razporedili v EXP (kalistenično vadbo v nestabilnih razmerah) ali v CON skupino (predpisan program moči za športno vzgojo). Pred in po 12-tedenskem obdobju smo izmerili izometrično in ponavljajočo moč zgornjega dela telesa s štirimi motoričnimi testi. Izmerili smo tudi debelino kožne gube v subskapularnem, prsnem in abdominalnem predelu. Obe skupini sta izboljšali zmogljivost moči ($p < 0,01$), z večjim povečanjem EXP v primerjavi s CON za vse motorične teste ($p < 0,01$, ES = 0,21 – 0,45). Ugotovili smo značilno izboljšanje telesnih sposobnosti in jih je treba vključiti v redni učni načrt športne vzgoje.

Ključne besede: adolescenca, telesna pripravljenost, debelina kožne gube, kalistenika

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INTRODUCTION

Hypokinesia represents a global health problem in youth today. Despite the large number of sports and fitness clubs, about 80% of children meet with systematic physical activity only in the school settings (Organization, 2019). In this regard, physical education (PE) plays a pivotal role in promoting a healthy lifestyle and enhancing physical activity among youth (Kohl III & Cook, 2013). Unfortunately, there is a growing body of evidence suggesting that PE is not sufficiently focused on children's systematic and comprehensive physical development and lacks the application of innovative methods that should be implemented in the PE curriculum (Roetert, 2004; Stricker et al., 2020).

Considering that strong musculature is a major component of overall fitness and motor competence, it is not surprising that strength development is one of the main goals of PE (Roetert, 2004). Analogously, resistance and bodyweight training have been commonly prescribed to enhance physical performance and reduce risk factors for obesity across a variety of age groups (Lesinski, Herz, Schmelcher, & Granacher, 2020). Over the past decade, unstable surface strength exercises (USSE) have gained popularity among athletes and recreational population. This type of training is closely related to proprioception, which refers to conscious awareness of the body and limbs (Aman, Elangovan, Yeh, & Konczak, 2015), and is performed by internal sensors (muscle spindle stretch receptor and Golgi tendon organ) and the vestibular system in the brain (Radák, 2018). Therefore, USSE is generally performed under unstable conditions, using various surfaces (balls and platforms) and body positions (Aman et al., 2015). Proponents of USSE suggest that the destabilizing training environments may stress the neuromuscular system to a greater extent compared to traditional strength training, providing a more varied and effective training stimulus (Behm, Muehlbauer, Kibele, & Granacher, 2015). Indeed, USSE has been shown to be a dominant training prescription for improving body stability and coordination, especially in rehabilitation (Behm & Colado, 2012). However, in terms of adaptations in strength and power, the results are less clear. In general, most studies have used resistance training regimen (with machines or free-weight) and found that USSE and traditional exercise prescription have almost similar effects on adaptations in strength and power of lower-body muscles (Cressey, West, Tiberio, Kraemer, & Maresh, 2007; Eckardt, 2016; Prieske et al., 2016). In fact, USSE may have some advantages in improving mobility (Pirauá et al., 2019) and trunk strength performance (Hoshikawa et al., 2013; Kibele & Behm, 2009; Granacher et al., 2014) in adolescents and seniors. In this regard, USSE has been particularly advocated for children and adolescents (Behm & Colado Sanchez, 2013; Behm et al., 2015), as strength gains in youth are almost exclusively due to neural adaptations (Lesinski et al., 2020), which could be particularly stimulated by unstable surface training (Radák, 2018).

In general, calisthenics exercises (using one's own body weight) have been propounded to improve physical abilities in the school settings (Šekeljić & Stamatović, 2018), and this sounds organizationally reasonable considering that calisthenics training is safe, cost-effective (Harrison, 2010), and can even outperform resistance training in improving some aspects of muscle strength and body morphology (Flanagan et al., 2002). Furthermore, training on machines or with free weights is difficult to implement in PE classes (Stricker et al., 2020). Therefore, it is rather surprising that there are few data on the effectiveness of calisthenic USSE in the school setting. Compared to the stable variants, USSE has been shown to potentiate higher electrical activity in stabilizing muscles during bodyweight (and elastic band) exercises (Behm, Anderson, & Curnew, 2002; Marshall & Murphy, 2006; Snarr & Esco, 2014; Lawrence & Carlson, 2015). For instance, Snarr & Esco (2014) found greater trunk muscle activity during unstable plank exercise, while Lawrence & Carlson (2015) reported greater core and soleus muscle involvement during unstable squats performed with elastic bands. Therefore, calisthenic USSE can be an extremely useful tool in PE to enhance physical abilities, especially in the adolescence (around 14 years of age), which is considered sensitive for strength development (Balyi, Way, & Higgs, 2013). Apart from the impact on physical performance, it would be interesting to investigate the effects of USSE on morphological features, especially those related to obesity risk factors. This could be important because the traditional method of preventing and treating obesity (i.e., aerobic exercise) is not very interesting to students (Haff, 2003; Roetert, 2004). Therefore, it is necessary to implement innovative content that will simultaneously increase children's motivation and also elicit the desired adaptive response.

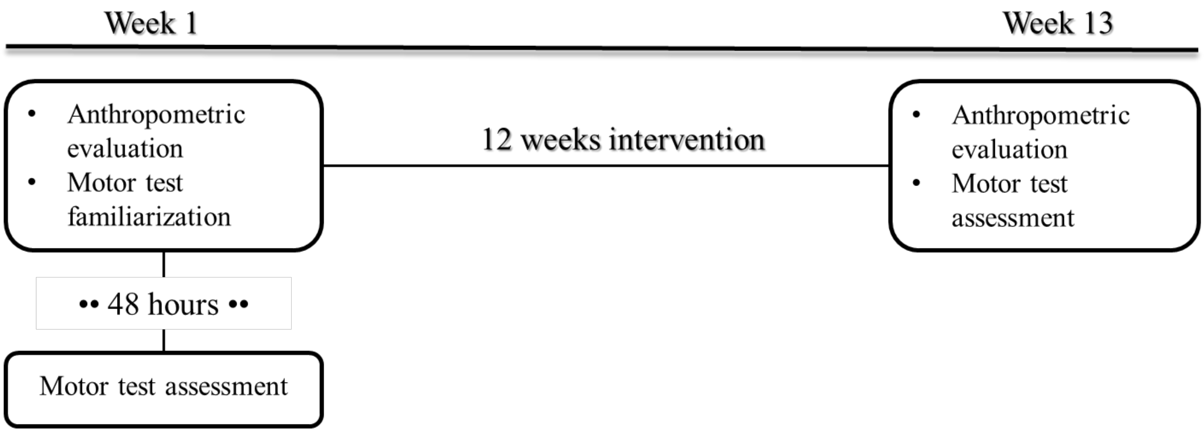
The aim of the current study was to compare the effects of 12 weeks of USSE and the prescribed PE program on changes in upper-body strength, trunk strength, and skinfold thickness among 14-year-old adolescents. Based on previous literature, we hypothesized that USSE will induce greater strength gains compared to the prescribed education program in adolescent boys and girls.

METHODS

Study design

This controlled crossover study aimed to investigate the effects of USSE on upper-body strength and fitness among 14-years-old boys and girls. Participants were randomly assigned to either the experimental group (strength training under unstable condition [EXP]) or the control group (prescribed physical education strength program [CON]). Morphological (skinfold thickness) and motor (repetitive and isometric strength) variables were assessed before and after the 12-week period. The intervention was conducted during regular school hours to ensure compliance and to test the feasibility of integrating such a program into the physical education curriculum (Granacher, Muehlbauer, Maestrini, Zahner, & Gollhofer, 2011). The flowchart of the experimental design is shown in Figure 1.

Figure 1. Experimental design.



Participants

The sample consisted of 220 healthy students (108 boys, 112 girls, age: 14.2 ± 0.5 years, weight: 59.4 ± 12.1 kg, height: 1.7 ± 0.9 m, body mass index: 20.3 ± 2.8 kg/m^2) attending regular classes at four elementary schools in Belgrade (Serbia). All participants were free of musculoskeletal, neurological, and orthopedic disorders and none had an athletic background (less than 6 hours/week). In addition, subjects completed the Fels Physical Activity Questionnaire (FPAQ) for children to provide information about their physical activity level (Treuth, Hou, Young, & Maynard, 2005). Informed consent was obtained from the students and their parents or guardians prior to the experiment. Ethical approval was obtained from the Ethics Committee of the Faculty of Sport and Physical Education, University of Belgrade, and all experiments were conducted in accordance with the Declaration of Helsinki.

Morphological variables

Body height, body mass, and body mass index were taken as anthropometric measures. Body height was measured using Martin's portable anthropometer (Siber-Hegner, Switzerland) with an accuracy of 0.1 cm, whereas body mass was measured with an electronic scale (Tanita, Arlington Heights, IL, USA). Body mass index was calculated using the standardized formula proposed by the World Health Organization. Pectoral, subscapular, and abdomen skinfold thickness (ST) were determined using a Harpenden skinfold caliper (Harpenden, West Sussex, UK) according to procedures described by (Eston & Reilly, 2013). Briefly, subjects were in an upright position with their arm relaxed. For the pectoral ST, the marked point was located at the level of the nipple next to the sternum, while for the abdomen ST, the point was located 5 cm of the navel. For subscapular ST, the marked point was located below the left corner of the scapula. All ST acquisitions were performed on the left side of the body. Baseline and final measurements were performed by an experienced specialist in the morning hours (8-10 am) at constant room temperature (20-25°).

Strength variables

The test battery comprised a total of 5 items and was administered according to the standardized Eurofit and FitnessGram protocols (Meredith & Welk, 2010; Tomkinson et al., 2018). Specifically, for accessing repetitive strength of the chest and elbow extensor muscles – 30-second Chair Push-up test (freq); for accessing repetitive strength of the trunk muscles – 30-second Sit-up test (freq); for accessing repetitive strength of back muscles – Trunk extension test (freq); for accessing isometric strength of the back muscles – Trunk lift test (s). All testing sessions were supervised by two experienced PE teachers. Attention was paid to proper form throughout the testing.

The push-up test measures the maximum number of upper-body lifts in 30 seconds with the arms resting on a chair (height 46 cm). Subjects begun the test with extended arms so that arms and legs are in the same plane. Then lowered the upper body until the chest touched the front edge of the chair and rised it again until the arms were fully extended.

The sit-ups test measures the maximum number of upper-body lifts from a lying position to a sitting position and vice-versa, all within 30 seconds. Subjects lied supine on a mat with knees bent at 90°. Arms were crossed at the nape, elbows extended to the side. Then the subjects flexed the trunk so that the lower back detached from the mat until the elbows touched the thigh.

The dynamic trunk extension test measures the maximum number of trunk extensions performed on the bench, with an accompanying sound repeated every 3 seconds. At the beginning of the test, participants are in the prone position with the lower body fixed and the upper body extended with the cranial edge of the iliac crest resting against the edge of the test bench. Then, subjects lowered (eccentric) and raised (concentric) the upper body according to an audible signal from the metronome (20 repetitions/minute). When lowering, subjects were asked to stop at the point where the upper body is at a 90° angle to the legs. The test ends when the subjects fail to complete more than 20 repetitions per minute or voluntarily withdraw.

The trunk lift test requires lifting the upper body off the floor and maintaining this position to perform the measurement. Subjects lied face down on the mat with their toes pointed back behind the body and hands placed under the thighs. A marker was placed on the floor at the level of the eyes to ensure that subjects maintained focus throughout the movement (to keep the head and spine aligned). Then the upper body is lifted off the floor in a controlled manner to a maximum height. The position must be held long enough to measure the distance from the floor to the chin. Two trials were allowed, with the best score recorded.

Experimental intervention

The exercise intervention was conducted with 3 sessions per week for a period of 12 weeks (first trimester). Participants from EXP participated in a program consisting of calisthenic exercises performed on unstable surfaces (soft mats, balance boards, air cushions) and on the floor (using various body positions and elastic bands, medicine balls, and Pilates balls). An example of a weekly exercise routine can be found in Table 1. The CON performed program according to the previous methods for the strength development established by the physical education curriculum (i.e., the same exercises as EXP under stable condition). Each session lasted 15-20 minutes and was conducted following the warm-up to ensure that participants were in a rested state to optimally benefit from the specific program according to the training principle of priority (Crum, 1993). For both groups, four exercises were performed in 3 sets with 30 seconds rest, organized according to the stationary method. The exercise program was taught by the two regular physical education teachers in order to keep the student-to-teacher ratio relatively small (2 teachers vs. 20-25 students).

Table 1. Example of a weekly plan for EXP group.

Day 1	Day 2	Day 3
Push-up on balance board (3x20 s, rest 30 s)	One arm push-up on balance board (3x15 s, rest 30 s)	Quadruped on soft mat (3x20 s, rest 30 s)
One-legged push of elastic band (3x15 s, rest 30 s)	Hands on medicine ball (3x20 s, rest 30 s)	Push-up with feet on Swiss ball (3x15 s, rest 30 s)
Plank with elbow lift (3x20 s, rest 30 s)	Hips lift with the foot on the ball (3x20 s, rest 30 s)	One-legged swing with elastic band (3x20 s, rest 30 s)
Quadruped (3x30 s, rest 30 s)	Prone on elbows (3x30 s, rest 30 s)	T - knee push-up with arm rise (3x30 s, rest 30 s)

Statistics

Statistical analysis was performed using the IBM SPSS Statistics software package (version 20, SPSS Inc, Chicago, IL, USA). Prior to the main analysis, normal distribution was checked by visual inspection and tested with the Shapiro Wilk test for each dependent variable. In addition, Levene's test for equality of variance was conducted. Between-group differences at baseline were tested using the independent t-test. Repeated measures ANOVA 2 (group: EXP, CON) x 2 (test: pre, post) was used to examine differences in changes of motor and ST variables between EXP and CON. Effect sizes (ES) were determined using G-power software (University of Kiel, Kiel, Germany, version 3.1) through partial eta squared obtained from the ANOVA output. ES were considered as: trivial: <0.50, small: 0.50-1.25, moderate: 1.25-1.90, and large: >2.0. All data are presented as means ± SD. p≤0.05 was considered a statistically significant determinant.

RESULTS

At baseline, there were no significant group differences for any of the variables tested (all p > 0.05).

Both groups significantly decreased total ST (EXP by 0.37 ± 1.15 mm, t = 3.561, p = 0.001, ES = 0.31; CON by 0.50 ± 1.45 mm, t = 3.461, p = 0.001, ES = 0.34), as well as subscapular (EXP by 0.12 ± 0.14 mm, t = 9.278, p < 0.001, ES = 0.85; CON by 0.11 ± 0.13 mm, t = 8.583, p < 0.001, ES = 0.84) and abdominal (EXP by 0.23 ± 1.12 mm, t = 2.253, p = 0.026, ES = 0.20; CON by 0.37 ± 1.43 mm, t = 2.614, p = 0.010, ES = 0.26). Only the changes in pectoral ST did not reach statistical significance (t = 1.770, p = 0.079 and t = 1.311, p = 0.193, respectively). The interaction group x time was not significant for any of the ST variables (Table 2; Figure 2).

In addition, both groups significantly improved scores for push-up (EXP by 1.89 ± 1.39 freq, t = 14.919, p < 0.001, ES = 1.35; CON by 0.89 ± 0.62 freq, t = 14.405, p < 0.001, ES = 1.43), sit-up (EXP by 2.15 ± 1.23 freq, t = 19.187, p < 0.001, ES = 1.74; CON by 1.31 ± 0.84 freq, t = 15.647, p < 0.001, ES = 1.57), dynamic trunk (EXP by 2.67 ± 2.11 freq, t = 13.887 p < 0.001, ES = 1.26; CON by 1.58 ± 1.05 freq, t = 14.965, p < 0.001, ES = 1.49) and trunk lift (EXP by 0.50 ± 0.42 cm, t = 12.977, p < 0.001, ES = 1.20; CON by 0.34 ± 0.29 cm, t = 11.814, p < 0.001, ES = 1.17) tests. The interaction group x time was always significant in favor of the EXP group (Table 2; Figure 2).

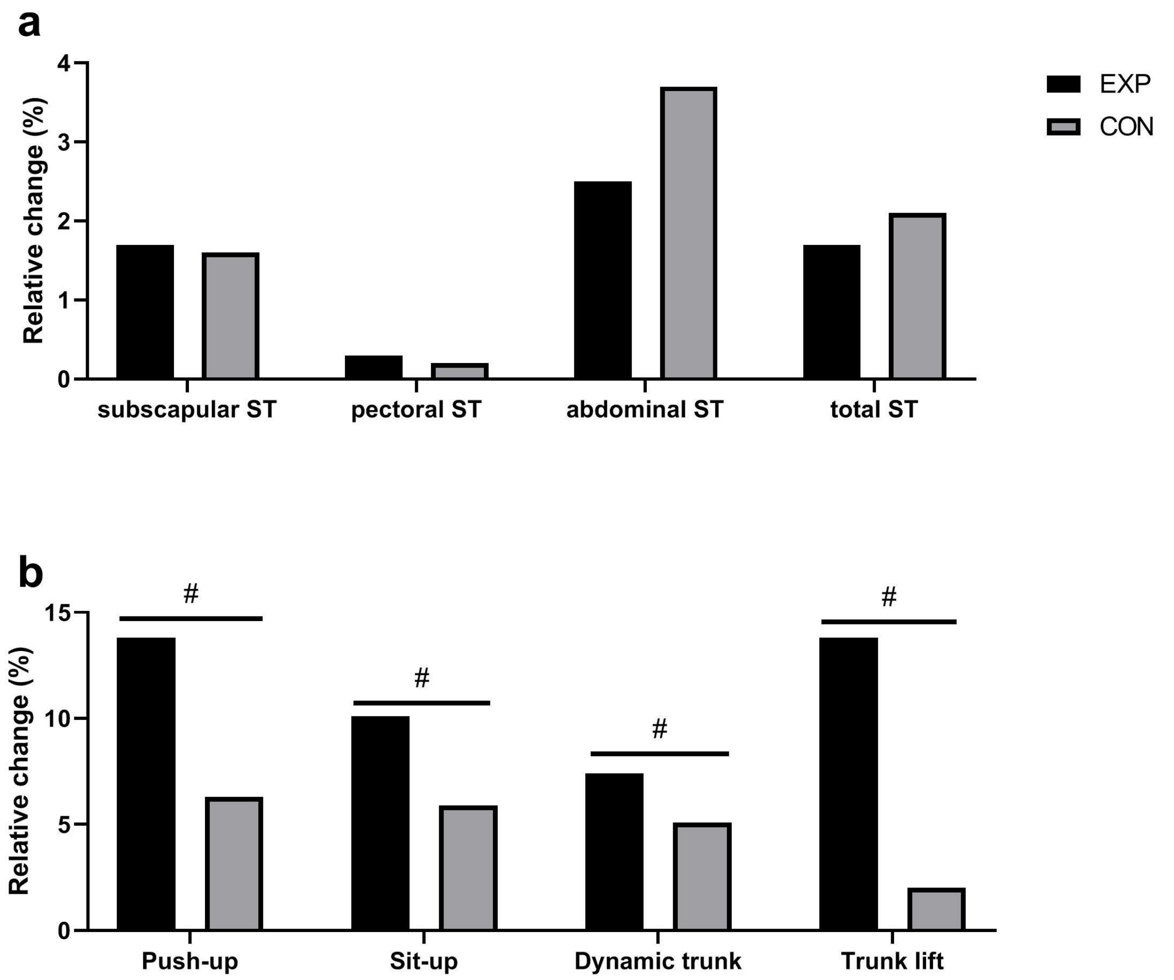
Table 2. ANOVA output for group differences in pre-to-post changes of tested variables.

	EXP		CON		F (time x group)	ES
	pre	post	pre	post		
Subscapular ST (mm)	7.55±2.68	7.43±2.67**	7.32±2.39	7.21±2.39**	0.314	0.03
Abdominal ST (mm)	6.02±2.44	5.79±2.23*	6.42±2.58	6.05±2.24**	0.694	0.05
Pectoral (mm)	6.02±2.57	6.00±2.70	6.28±2.54	6.27±2.56	0.080	0.01
Total ST (mm)	19.6±6.20	19.23±6.25**	20.02±6.15	19.52±5.84**	0.532	0.04
Push-up (freq)	13.66±5.41	15.55±5.48**	14.14±3.85	15.03±3.89**	44.620	0.45
Sit-up (freq)	23.16±3.93	25.51±3.71**	22.31±4.15	23.62±4.44**	33.738	0.39
Dynamic trunk (freq)	36.07±7.16	38.74±7.17**	35.89±5.52	37.47±5.83**	22.254	0.32
Trunk lift (cm)	18.05±4.02	15.55±3.99**	17.58±4.16	17.93±4.13**	10.023	0.21

* - significantly different than pretest (p < 0.05)

** - significantly different than pretest (p < 0.01)

Figure 2. Relative changes in skinfold thickness (panel a) and strength perfomance (panel b) between EXP and CON.



- indicates significant group differences ($p < 0.01$)

DISCUSSION

The aim of the present study was to investigate whether the introduction of USSE in PE classes would contribute to the improvement of physical fitness parameters in adolescent students. The main results revealed that the unstable surface program showed superiority in enhancing strength (isometric and repetitive) compared to the exercises performed on stable surfaces. On the other hand, subscapular and abdominal ST reduced equally following both exercise programs, while pectoral ST remained unaltered. These results suggest that unstable surface calisthenic exercises are effective in improving physical abilities (i.e., those related to strength gains) and should be included in the regular PE curriculum.

It is well documented that manipulation of strength training variables, such as type of exercise, volume, or contraction duration, elicit different morphological and functional responses in adults (Wilk, Zajac, & Tufano, 2021; Kojić et al., 2021). Unfortunately, there are few data regarding the effectiveness of different strength training programs in the PE literature (dos Santos Duarte Junior, López-Gil, Caporal, & Mello, 2021). In fact, most of the studies that were not conducted on adults consisted of young athletes or children with special needs, and their results should not be fully generalized to the school population (Smoll & Schutz, 1985). From the PE standpoint, it is proposed that children and adolescents perform strength exercises 2 or 3 times per week at submaximal intensity and full range of motion (Benedet et al., 2013). However, in addition to frequency, intensity, and range of motion, there are no general recommendations on the effects of other training variables on the components of physical fitness in adolescents. We believe that this is the first study to compare the effectiveness of exercise on stable and unstable surface conditions in school settings. In this regard, the present results showed that USSE provided additional benefits in the strength development of adolescent students, suggesting that stability conditions during strength exercise should be considered as an important variable when designing PE program. In fact, the EXP group displayed better results in all post-test strength measurements, with some (push-up, sit-up, and trunk lift tests) even showing double (or greater) differences in relative strength gains between groups (i.e., 10-14% vs. 2-7%). These results are in good agreement with a study from Hoshikawa et al. (2013) conducted on adolescent athletes in which addition of USSE to a soccer training routine improved hip extensor and flexor strength, as well jump height. Of note, Hoshikawa et al. (2013) observed no increase in trunk musculature (i.e., hypertrophy), suggesting that USSE promotes strength gains exclusively due to neural adaptations. Unlike adults, in whom hypertrophy plays an important role in motor performance (Kumagai et al., 2000; Erskine, Fletcher, & Folland, 2014), intra- and inter-muscular coordination have been identified as the key drivers of strength gains in children and adolescents (Legerlotz, Marzilger, Bohm, & Arampatzis, 2016), and these neural adaptations may be particularly stimulated by unstable surface training (Behm et al., 2015). In particular, USSE appears to affect inter-muscular coordination, due to greater involvement of the postural muscles in unstable surface training compared to the stable surface training variant when a similar external load is applied (Norwood, Anderson, Gaetz, & Twist, 2007; Anderson, Gaetz, Holzmann, & Twist, 2013; Snarr & Esco, 2014). In addition, unstable and proprioceptive training regimens have been shown to be highly effective in improving whole-body coordination (Yaggie & Campbell, 2006; Sánchez-Lastra, Varela, Cancela, & Ayán, 2019), which is considered an important determinant of overall physical fitness in adolescents (Vandorpe et al., 2012). Therefore, it is highly likely that USSE potentiates neural adaptations through pronounced coordination acquisition, which may lead to a superior strength gains in children and adolescents.

On the other hand, subscapular and abdominal ST were similarly reduced in both study groups. Although this may indicate the effectiveness of both exercise programs, it should be noted that adipose tissue decreases rapidly during puberty in both sexes, especially in boys between 13 to 15 years of age (Siegel, Hildebolt, Bae, Hong, & White, 2007). Therefore, the reduction in body fatness is likely the product of normal biological growth and maturation patterns (to some extent) and not solely the influence of exercise programs. Nevertheless, the present results have demonstrated that USSE is as effective as traditional PE prescription in reducing obesity risk factors. Still, considering the relatively low ES observed in both groups (≤ 1.25), aerobic exercise probably remains an essential tool for the prevention and treatment of obesity.

Finally, we are aware that our study has few limitations that we can report. First, our exercise program consisted mainly of isometric exercises for the strength development, so the present results must be interpreted with caution in regards to the effectiveness of dynamic USSE. This largely explains why we did not observe such dramatic strength gains in either study group, which is likely due to the factor of training specificity (Behm et al., 2015). Second, we did not examine the effects of the exercise programs on other components of physical fitness, such as coordination, balance, or strength-endurance abilities, which may be strongly affected by USSE. Finally, changes in muscle mass (hypertrophy) were neglected, which is a third limitation of the study.

CONCLUSION

In conclusion, the present results promote the use of unstable surface calisthenic exercises in trunk and upper-body movements to improve strength performance in adolescent boys and girls. From a morphological perspective, an unstable program does not appear to have additional effects in reducing risk factors for obesity (i.e., skinfold thickness). Considering that the application of this type of program is organizationally feasible and does not require extraordinary material, the authors suggest that the unstable surface strength routine should be introduced in PE classes to enhance the physical abilities of the adolescent population.

Declaration of Conflicting Interests

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

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