2024
01

ORIGINAL ARTICLE

High-intensity interval training on unstable vs stable surfaces: effects on explosive strength, balance, agility, and Tsukahara vault performance in gymnastics

Khaled Abuwarda[1,2ABCDE], Mostafa Mansy[3BD], Mohamed Megahed[4ACD]

[1] *Department of Physical Education and Kinesiology, College of Education, Qassim University, Buraidah 51452, Saudi Arabia*

[2] *Department of theories and applications of exercises, gymnastics and sports performances, Faculty of Physical Education, Port Said University, Port Said 42526, Egypt*

[3]*Department of Physical Training and Sports Movement Sciences, Faculty of Physical Education, Arish University, Egypt*

[4]*Department of Track and Field Competitions, Faculty of Physical Education, Arish University, Egypt*

Authors' Contribution: A – Study design; B – Data collection; C – Statistical analysis; D – Manuscript Preparation; E – Funds Collection

Abstract

Background and Study Aim	This study compares the effects of high-intensity interval training (HIIT) on unstable and stable surfaces on explosive strength, balance, agility, and Tsukahara vault performance in gymnastics.
Material and Methods	A nonrandomized trial study was conducted on twenty-seven well-trained male vault players who were assigned into 3 equal groups, a HIIT unstable group (UG), a HIIT stable group (SG), and the control group (CG). The training period for the subjects lasted eight weeks, with 3 sessions each week. All of the aforementioned variables were assessed both before and after the training period.
Results	The main findings indicate that both UG and SG showed greater improvement than the CG on explosive strength, balance, agility, and Tsukahara vault performance in gymnastics (ES= 0.52 to 0.68, P<0.05). In addition, there were significant differences between the UG and SG in explosive strength, balance and Tsukahara vault performance (P<0.05) favoring UG, while no significant differences between UG and SG in agility. However, the UG as compared to the SG in agility had only limited additional effects. The UG and SG significantly increased all tests from pre- to post-test (ES= 1.10 to 4.78, 0.98 to 3.53), respectively (P<0.05). The CG significantly increased the explosive strength and Tsukahara vault performance tests from pre- to post-test ((ES= 0.77 to 0.78, P <0.05), while there were no significant differences in the balance and agility tests (P > 0.05).
Conclusions	HIIT with unstable surfaces can be used as an alternative method to improve explosive strength and balance. Also, it can be used alongside stable surface exercises when developing agility.

Keywords: HIIT, bosu ball, functional training, exercise, artistic gymnastics.

Introduction

Tsukahara vault, one of the vaulting skills in artistic gymnastics, is depended on a complicated movement structure and a high level of effort that can be performed in a short period [1, 2]. A Tsukahara vault consists of a faster run, a springboard take-off, a first-quarter turn in the pre-flight phase, a push-off from the vault table followed by a Corbett action, and a salto with longitudinal/transversal turn [1, 3]. Preparation for this vault includes, in addition to technical training, a substantial part of physical training [1]. To achieve an improvement in sports performance, It is critical to comprehend the relationships that are established between the various components of speed and strength during sprints or jumps [4]. The literature has indicated gymnasts must possess sufficient explosive strength to execute the various needed jumping skills while keeping body control [5, 6]. Others confirmed that the acrobatic elements depend on the development of explosive strength, which is why it is a crucial criterion in the selection model for these sports [7]. It refers to the jumps as an example of the lower limbs' explosive strength and the throw of the apparatus as the explosive strength of the upper limbs [8]. Hence, the dominant element in the Tsukahara vault performance is explosive strength, because, if its level is not sufficiently high, athletes are not able to correctly perform certain technical elements [1].

The Tsukahara vault movement relies not only on explosive strength but also on balance and agility [1, 2]. Balance entails the synchronization of many body muscles as well as the integration of sensory information [9]. Depending on the physical demands and circumstances of each sport, athletes must meet varying balancing criteria [10]. When athletes do a vault, they face situations where their balance changes with every move. In addition, agility is very important for completing the technical stages

doi:10.15561/26649837.2024.0105

that the player goes through while performing the Tsukahara vault quickly and with high efficiency. So, balance and agility are very critical for enhancing Tsukahara Vault performance, minimizing injury risk, and achieving higher sports scores.

A sort of physical activity known as high-intensity interval training (HIIT) alternates short bursts of intense exercise with active recovery or rest intervals. According to the literature, many sports employed it in their training regimens, including cyclists [11], swimmers [12], Middle-distance runners [13], badminton players [14], and taekwondo players [15]. All of them have proven efficient in improving physical abilities compared to traditional training.

Bosu, which stands for "both sides utilized," is a gym tool that enhances the strength and stability of muscles. It has an air-filled hemisphere and a level surface [16]. The two guiding principles of bosu ball training are time efficiency during the up/down movement and left and right-side balancing. Enhancing these two essential skills contributes to improving the efficiency of all movements [17]. Research has demonstrated that training on moving surfaces causes an increase in resistance because of higher neuromuscular load tension. This could lead to improvement in Muscle strength and neuromuscular coordination [18]. Recently, the bosu ball has grown in popularity among medical and fitness personnel. Injury rehabilitation [19], rehabilitation after surgery [20], core strength [21, 22, 19], trunk stability, burning cardio, physical and physiological parameters [23], balance [24], accuracy [25], growth hormone and building muscle and EMG activity [22, 26] are all aspects of bosu ball training study that have piqued the interest of many scholars.

On the other hand, numerous studies have compared the effect of the Bosu ball with other unstable surfaces on the balance and strength of the core muscles. for example, a wobble board [27], a swiss ball [28], and balance disc [29]. All showed the same improvement or increase in bosu ball training. Very few studies have focused on the effect of BOSU balls in sports that require excellent explosive strength, balance, and agility. For example, the training performed with a bosu exercise and wobble board had significant improvements in dynamic balance and core stability in recreational runners [27]. Another research found that the Bosu ball training after 6 weeks helped increase male football players' single-leg hop distance and vertical jump height [30]. An improvement in balance and accuracy was observed after 18 circuit training sessions with bosu ball in archery athletes aged between 14-17 years [25]. Simec et al. reported that 10-week balance training improved explosive strength in physically active men [31]. The bosu ball serves a vital role in increasing balance and functional fitness in the elderly population [32]. Another study discovered that training with a balancing disk and a bosu ball enhanced the strength of both the plantar flexor and ankle dorsiflexor muscles in sedentary children after 8 weeks [29].

To our knowledge, the literature has not determined whether HIIT on unstable or stable surfaces is more efficient for gymnasts, and which one is best suited to improve explosive strength, balance, agility, and Tsukahara vault performance. It is crucial to choose the training that is most beneficial for gymnasts. Thus, the goal of this study was to compare the effects of HIIT on stable and unstable surfaces on explosive strength, balance, agility, and Tsukahara vault performance in gymnastics.

Materials and Methods

Participants

The Participants consisted of Twenty-seven male vault players selected from Portsaid gymnastics region Clubs. Before beginning the study, they had received extensive training in the Tsukahara vault skill. Following that, they were divided into three equal groups: a control group (CG), a HIIT unstable group (UG), and a HIIT stable group (SG). Each participant had to meet the following three requirements: (i) be able to perform the Tsukahara vault with proficiency; (ii) be willing to engage in the training and continue it; and (iii) have no musculoskeletal problems or preexisting disease that would affect their ability on performance. The procedures and goals of the study were explained to the participants. Before the pre-test, each participant filled out a written consent form. The study was approved by Portsaid University (code: 202314013). The subjects' equivalence is described in Table 1.

Table 1. General characteristics of subjects (mean ± SD) and p-value between groups.

Variables \ Groups	unstable group (n=9)	Stable group (n=9)	control group (n= 9)	F	P value	Sig
	Mean ± SD	Mean ± SD	Mean ± SD			
Height (cm)	164.44± 5.96	164.67± 4.69	163.11± 7.25	0.174	0.842	NS
Body mass (kg)	54.67± 6.60	55.22± 5.80	56.11± 7.17	0.111	0.895	NS
Age (year)	16.11± 0.93	16.22± 0.97	16.00± 0.87	0.130	0.878	NS

n = sample size; NS= No statistically difference between groups

Research Design

Using pre-and post-tests, the authors performed a nonrandomized trial investigation on three groups: UG, CG, and SG. This investigation was split into 4 phases: (i) Phase 1 consisted of a one-week preliminary study meant to acquaint the candidates with the tasks and examinations. Furthermore, during this stage, the validity of the instruments and tests employed in the research was confirmed. Demographic data was collected at the familiarization meetings; (ii) a week of pre-testing was part of Phase 2; (iii) participants completed eight weeks of training in Phase 3; and (iv) a week of post-testing was part of Phase 4. The pre-test and post-test procedures were the same protocol.

Testing procedures

Pre- and post-tests were administered to all participants before and after eight weeks of intervention. The individuals were requested to abstain from caffeine-containing beverages and to refrain from exercising for 48 hours before the test. Moreover, abstain from heavy meals for a few hours before the tests. Three separate sessions for pre-testing were held at 48-hour intervals. Two tests were administered during the first session: the medicine ball throw test and the vertical jump test. The star excursion balancing test and the handstand test were the two assessments conducted in the second session. The gymnastics-specific shuttle run test and the Tsukahara vault performance test were the two assessments that were conducted during the third session. The tests were spaced 45 minutes apart. Low-intensity workouts, such as stretching and jogging, were done for ten minutes to warm up before the tests started. The following procedures were followed when conducting the tests:

The lower limbs' explosive strength was evaluated using the vertical jump test (VJT). The gymnast applies a thick layer of chalk on his fingertips before the jump test to take precise measurements. The gymnast performs a vertical jump with both legs while standing with his dominant side toward the wall, marking a chalk mark on the wall at the top of his jump. The jump needs to be executed by evenly pushing off from both lower limbs. After the jump, the gymnast stands flat-footed with the dominant side facing the wall, reaching directly overhead to touch the wall and make a chalk mark at the highest point. The examiner uses a tape measure to measure and record, to the closest centimeter, the distances between the tops of the two chalk markings in a line perpendicular to the floor. This test is credible and legitimate field-based [33, 34, 35].

The medical ball throw test (MBTT) was designed to measure the upper limbs' explosive strength. The participants' backs are pressed up against a wall as they sit on the floor with their legs completely stretched. Using both hands, the sitting participants propel the medicine ball explosively from their chest as far forward as they can at a 45-degree angle. The score was determined by measuring the distance between the front of the sitting line and the ball's landing place. To the closest centimeter, the measurement is recorded. A three-kg medicine ball is used to perform three measurements for these tests. The measurement with the best results out of the three will be considered. This field-based test is regarded as credible and genuine [36, 37].

The head-down inverted balance was evaluated using the handstand test (HST). On a low beam, the participants begin the handstand with their hands comfortably apart. When a gymnast reaches the handstand, timing starts, and timing ends when any other part of their body contacts the floor. If one of their hands deviates from their starting positions, timing also comes to an end. Time is expressed to the closest 0.01 second. This test consists of two trials for the participant, and the longest time will be used to determine the score. This test is credible and legitimate field-based [33, 34, 38].

The star excursion balance test (SEBT) was used to assess balance and muscular control. Testing should be conducted with subjects either barefoot or wearing gymnastics slippers. The dominant foot, or stance foot, should be positioned so that the great toe lines up with the grid's anteriorly projected line and the heel lines up with the grid's center. The participants are instructed to maintain a single-leg stance on the stance leg while extending as far as possible down the designated grid line with the opposite lower limp-to-toe touch. The participant then returns to the bilateral stance. The examiner marks the place where the participant touched it and measures it manually with a measuring tape. This procedure is repeated on all eight grid lines. Then, the distances of all eight reached were added. The total of the eight distances attained is divided by the length of the gymnast's leg to get the test score. This test is credible and legitimate field-based [34].

A gymnastics-specific shuttle run test (GSRT) as described by Sleeper et al. [33], was used to measure agility. Two cones were put diagonally at the corners of a gymnastics competition floor measuring 12m x 12m. Gymnasts ran five straight 17-meter shuttle sprints over the gymnastics floor's diagonal length. A digital stopwatch was used to time how long it took to complete the five sprints. Athletes participated in two trials, with the best time being used for further analysis. This test is credible and legitimate field-based [33, 34].

The Tsukahara vault performance test (TVP) was calculated according to International Gymnastics Federation Rules, code of points (2022-2024), and Men's Artistic Gymnastics [39].

The training program

Beginning on June 18, 2023, the training intervention ran for eight weeks. 24 sessions, i.e., three sessions each week, were completed by the unstable and stable groups. Every training session had a duration of around 75 to 80 minutes and was conducted at the same time every day of the week. Before every session, the participants warmed up for ten minutes by running and performing stretches [40]. Then, HIIT using on stable or unstable surfaces was carried out lasting from 15 to 25 min, and details of HIIT Program intervention are shown in Table 2. After that, participants practiced Tsukahara vault skills for 35 to 40 minutes. Cooling down took up the last 10 minutes of the session. Meanwhile, the control group went about their regular exercise routine.

HIIT on unstable and stable surfaces protocol. The experimental (Unstable and stable) groups performed three HIIT stations, where each one consisted of 8 movements that lasted 6 minutes. The eight-movement HIIT was implemented using the 30-second working and 15-second active recovery interval approach. The UG performed HIIT exercises using an unstable surface (bosu ball). The movements details in the three stations of the bosu ball are shown in Table 3. The stable group performed the same HIIT stations and exercises but using the stable surfaces, i.e.,step platforms or the floor.

Both groups performed HIIT movements for each session in the two sets during the first to third weeks at 85% HRmax, three sets during the fourth and fifth weeks at 90% HRmax, and four sets during the sexth to eighth weeks at 95% HRmax. There was a two-minute break in between each set.

Statistical Analysis

The Shapiro-Wilk and Levene tests were used on each variable to verify data normality and equal variance. Means and standard deviations (SD) are used to represent data. To identify differences between groups, tukey post hoc testing in conjunction with one-way ANOVA was used to investigate the baseline-post change. The use of paired sample t-tests allowed for the determination of significant group differences. Also, the change ratio (%) was utilized to determine percentage of improving between pre and post tests. The magnitude of effect size for (η2) is classified as

Table 2. Details of 8-Week HIIT Program intervention (HIIT using on stable or unstable surfaces).

8-Week HIIT Program intervention								
weeks	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**
Stations	1-2	1-3	2-3	1-2-3		1-2	1-3	2-3
station duration	6 minutes							
(Workload – Recovery) time	(30 sec - 15 sec)							
sets per station	1					2		
Sets duration	6 x 2 = 12 minutes			6 x 3 = 18 minutes		6 x 4 = 24 minutes		
Rest between sets	2 minutes							

Table 3. The movements details in the three HIIT stations of the bosu ball.

	Stations	**Station 1**	**Station 2**	**Station 3**
Movements	1	Squats over bosu ball	Back flips from bosu ball	Handstands over bosu ball
	2	One leg squats over bosu ball	Push-ups over bosu ball	Jump to back handspring from bosu ball to bosu ball and return to front handspring from the bosu ball to bosu ball
	3	Get down get up over the bosu ball	Front flips from bosu ball	Cartwheels over bosu balls
	4	One leg squats over bosu ball	Power line push-ups over bosu ball	Forward and backward leg swings over bosu ball
	5	drop and pop over bosu ball	Back flips from bosu ball	Handstand push-ups over bosu ball
	6	One leg squats over bosu ball	Plank up and down over bosu ball	Forward and backward leg swings over bosu ball
	7	Knee pulls over bosu ball	Front flips from bosu ball	Handstands over bosu ball
	8	One leg squats over bosu ball	Back flips from bosu ball	Jump to back handspring from bosu ball to bosu ball and then return to front handspring from the bosu ball to bosu ball

small ⩾ .01, moderate ⩾ .06, and large ⩾ .14, while Cohen's d was interpreted as small ⩾ 0.2, moderate ⩾ 0.5, and large ⩾ 0.8. The significance level of $p < 0.05$ was applied to all findings that were presented. IBM SPSS Statistics version 27.0 was employed for analysis.

Results

Baseline data

A one-way ANOVA showed that there were no significant differences between the groups at the pre-test for any of the variables [F= 0.121 to 0.947, p= 0.402 to 0.886 (P>0.05)]. Every participant followed the instructions and showed up for each of the 24 scheduled training sessions.

The effects of training intervention after 8-week

The effect on explosive strength

Between the groups, there was a significant difference for VJT (F= 13.492, P= < 0.001, η2= 0.677) and MBTT (F= 12.328, P= < 0.001, η2= 0.661). Post hoc analyses revealed that the differences were statistically significant in favor of both UG and SG compared to the CG in both tests. Additionally, we discovered significant differences between the UG and SG in VJT and MBTT in favor of the UG. The groups significantly increased VJT and MBTT from Pre[(UG 43.01±3.56 cm and 4.40±0.55 m; SG 42.63±4.04 cm and 4.28±0.43 m; CG 42.03±2.86 cm and 4.22±0.39 m), respectively] to Post [(UG 47.74±2.12 cm, Δ% = 11.38%, Cohen's d= 2.258, P= < 0.001<0.05 and 5.12±0.39 m, Δ% = 17.75%, Cohen's d= 3.325, P = < 0.001<0.05; SG 45.49±2.77 cm, Δ% = 7.30%; Cohen's d= 1.03, P= 0.015 <0.05 and 4.71±0.23 m, Δ% = 10.59%, Cohen's d= 1.89, P< 0.001<0.05; CG 43.13±2.74 cm; Δ% = 2.82%; Cohen's d= 0.772, P= 0.049 <0.05 and 4.33±0.32 m, Δ% = 2.79%, Cohen's d= 0.793, P= 0.045<0.05), respectively] (Fig.1).

The effect on balance

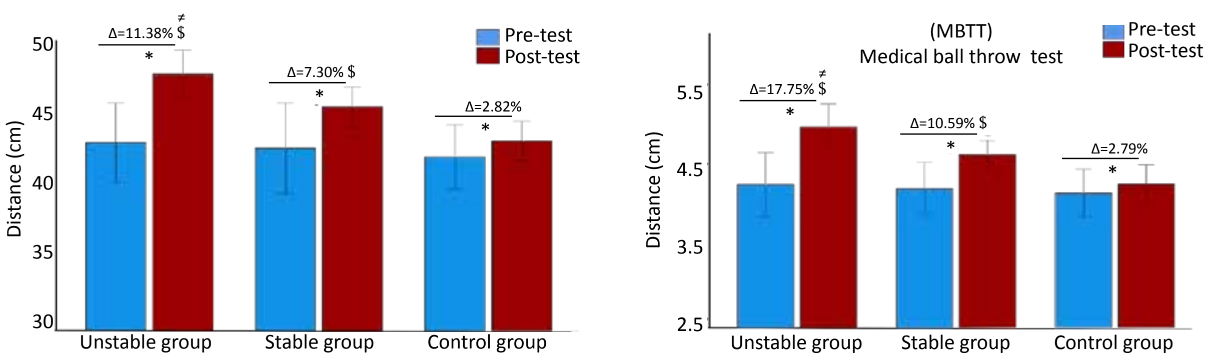
Between the groups, there was a significant difference for HST (F= 19.716, P= < 0.001, η2=0.622) and SEBT (F= 12.683, P= < 0.001, η2= 0.514). Post hoc analyses revealed that the differences were statistically significant in favor of both UG and SG compared to the CG in both tests. Additionally, we discovered significant differences between the UG and SG in HST and SEBT in favor of the UG. The UG and SG significantly increased HST and SEBT from Pre[(UG 44.09±6.19 sec and 727±48.48 cm; SG 42.53±6.70 sec and 714.22±50.56 cm), respectively] to Post [(UG 56.93±4.86 sec, Δ% = 30.22%, Cohen's d= 4.781, P = < 0.001<0.05 and 804.67±41.71 cm, Δ% = 10.80%, Cohen's d= 4.367, P= < 0.001<0.05; SG 50.59±3.67 sec, Δ% = 20.50%; Cohen's d= 2.450, P= < 0.001<0.05 and 762.33±34.93 cm, Δ% = 6.91%, Cohen's d= 2.588, P= < 0.001<0.05), respectively]. No significant differences were found in HST and SEBT from Pre (41.21±7.05 sec and 707.33±37.45 cm, respectively) to Post in CG (42.91±5.52 sec, 4.95%, P= 0.063 >0.05 and 720.11±29.08 cm, 1.89%, P= 0.076 >0.05 respectively) (Fig. 2).

The effect on agility.

Between the groups, there was a significant difference for GSRT (F= 12.857, P= < 0.001, η2= 0.517). Post hoc analyses revealed that the differences were statistically significant in favor of both UG and SG compared to the CG in both tests. The UG and SG significantly increased GSRT from Pre (UG 18.30±1.03 sec; SG 18.93±1.18 sec) to Post (UG 17.23±0.64 sec, Δ% = 5.61%, Cohen's d= 1.099, P = 0.019 <0.05; SG 17.92±0.39 sec, Δ% = 4.63%; Cohen's d= 0.981, P= 0.023 <0.05). No significant differences were found in GSRT from Pre (18.98±1.10 sec) to Post in CG (18.7±0.78 sec, 1.22%, P= 0.072 >0.05) (Fig. 3).

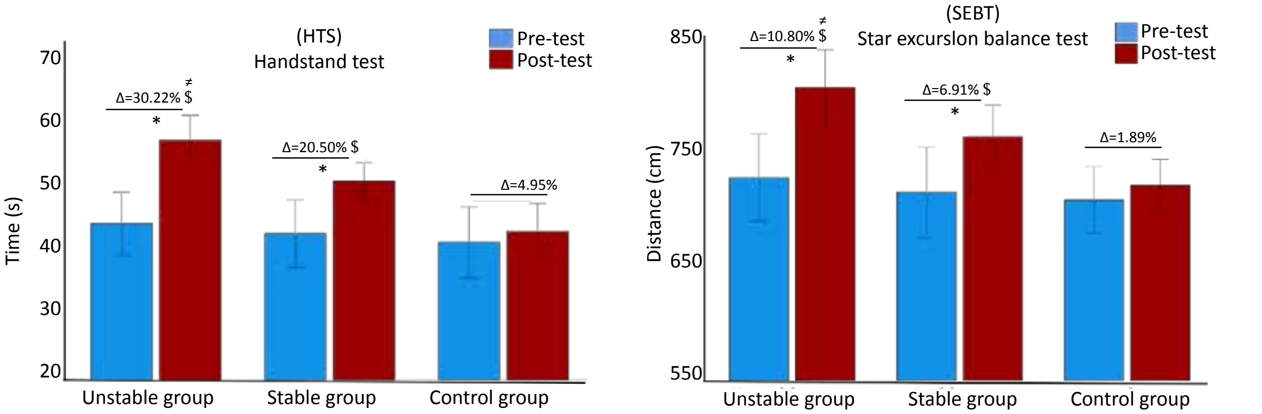
The effect on Tsukahara vault performance.

Between the groups, there was a significant difference for TVP (F= 23.885, P= <0.001, η2= 0.666). Post hoc analyses revealed that the differences were statistically significant in favor of both UG and SG compared to the CG in both tests. Additionally, we discovered significant differences between the UG and SG in TVP in favor



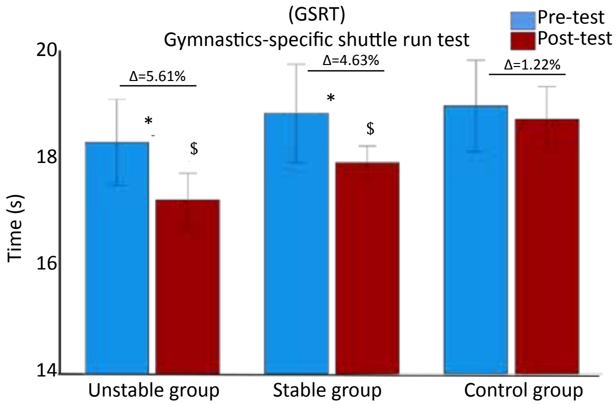
Note. * Significant difference from the pre-test. $ Significant difference from the control group. ≠ significant difference from the stable group. Δ Change ratio % from pre-test.

Figure 1. The effect of training intervention on VJT and MBTT.



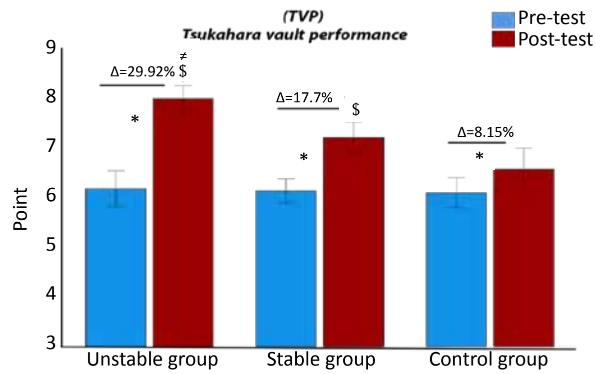
Note: * Significant difference from the pre-test. $ Significant difference from the control group. ≠ significant difference from the stable group. Δ Change ratio % from pre-test.

Figure 2. The effect of training intervention on HST and SEBT.



Note: * Significant difference from the pre-test. $ Significant difference from the control group. Δ Change ratio % from pre-test.

Figure 3. The effect of training intervention on GSRT.



Note: * Significant difference from the pre-test. $ Significant difference from the control group. ≠ significant difference from the stable group. Δ Change ratio % from pre-test.

Figure 4. The effect of training intervention on TVP.

of the UG. The groups significantly increased TVP from Pre (UG 6.21±0.47 point; SG 6.17±0.32 point; CG 6.13±0.39 point) to Post (UG 8.05±0.34 point, Δ% = 29.92%, Cohen's d= 4.632, P = < 0.001<0.05; SG 7.25±0.41 point, Δ% = 17.7%; Cohen's d= 3.533, P= < 0.001<0.05; CG 6..61±0.55 point, Δ% = 8.15%; Cohen's d= 0.792, P= 0.045 <0.05). (see Fig.4)

Discussion

The findings of this study indicate that after eight weeks, both HIIT on unstable and stable groups showed greater improvement than the control group for explosive strength, balance, agility, and Tsukahara vault performance in gymnastics. HIIT seems to be necessary to provoke additional improved explosive strength, balance, and agility because of the high-intensity exercises that were performed with a 30-second working and 15-second rest interval. In addition, HIIT on unstable surfaces improves explosive strength and balance better than HIIT on stable surfaces, while HIIT on unstable surfaces improves agility almost similarly to HIIT on stable surfaces.

Regarding explosive strength, our study showed that HIIT on unstable surfaces has better training effects on explosive strength compared with HIIT on stable surfaces. Where the HIIT on unstable surfaces had a large effect on explosive strength [Cohen's d= VJT (2.258) and MBTT (3.325)] by increasing the VJT (11.38%) and MBTT (17.75%), which outweighed the HIIT on stable surfaces improved by 7.30% and 10.59% and control groups by 2.82% and 2.79%, respectively, creating a large effect size between 3 groups [η2= VJT (0.677) and MBTT (0.661)]. When it is focused on an unstable surface literature review, we came upon a paper that was carried out by Romero-Franco et al., which found significant improvement in jump strength in sprinters after 6 weeks of proprioceptive training with unstable tools, i.e., bosu ball and Swiss ball [41]. Caglayan et al. observed increased vertical jump in wrestler athletes after plyometric training on an unstable surface, i.e., bosu ball and trampoline

[42]. In a study conducted on athletic children, it was found that strength training with bosu balls improved vertical jump and standing long jump [43]. Another study on adolescent children found that core strength training on unstable and stable surfaces for 6 weeks caused a significant increase in explosive strength test data and unstable surface training showed an improvement compared to stable surfaces [44]. These outcomes are consistent with the measurements we collected after eight weeks, which may support increased explosive strength in the unstable group better than the stable group. Thus, exercises executed using unstable surfaces could improve explosive strength in Tsukahara vault players better than stable surfaces.

As to balance, we found a large effect [Cohen's d= HST (4.781) and SEBT (4.367)] upon the unstable group by the improved HST (30.22%) and SEBT (10.80%). This data was greater than the stable group improved by 20.50% and 6.91% and the control group by 4.95% and 1.89%, respectively, creating a large effect size between groups [$\eta 2$= HST (0.622) and SEBT (0.514)]. Upon reviewing the research pertaining to unstable exercises and their effects on balance, our result was aligned with Prasetyo et al., who reported significantly improved balance after 18 sessions of circuit training with a bosu ball in young archery athletes [25]. It also agreed with Nugraha et al.'s study, which reported significant differences in balance for basketball players after being given bosu ball exercise treatment compared to the TheraBand exercise [45]. Similarly, A, Elfateh's study found a significant increase in balance after 10 weeks of bosu ball exercises applied to university students [46]. Most likely, throughout the eight weeks of training, neurological adaptations occurred, which led to an increase in balance in our research. Our findings are consistent with literature demonstrating the benefits of proprioceptive and vestibular stimulation from rebounding exercises utilizing Bosu balls for postural control and balance [47]. Thus, we believe that HIIT on unstable surfaces has a positive effect on balance because it increases the number of motor units that function to maintain equilibrium and activates the synergist muscle groups more efficiently.

In terms of agility, our study found no significant differences between unstable and stable groups. However, the unstable group as compared to the stable group had only limited additional effects. The unstable group increased the GSRT by (5.61%), while the stable group increased by 4.63%, with a large effect size (Cohen's d= 1.099 and 0.981), respectively. Compared to the control group, this improvement was significantly higher with 1.22%, creating a large effect size between 3 groups ($\eta 2$= 0.517). Upon reviewing the literature on unstable exercises, we found only studies that focused on unstable exercises and their effect on agility, which corroborated our findings. Where Cressey et al., observed no significant improvement in the agility of collegiate males' soccer players after 10-week lower-body exercises performed between unstable surfaces group and the control group, but significant improvements were observed within groups [48]. It is believed that the changes in explosive strength, balance, and agility following high-intensity interval training applied to unstable and stable groups, which were shown to be superior to the control group in the current study, are brought on by the heavy usage of high-intensity, repetitive movements.

The present study showed that HIIT on unstable surfaces had a large effect size on Tsukahara vault performance (Cohen's d= 4.632) by the increased TVP points (29.92%). This was greater than the stable group improved by 17.7% and the control group by 8.15%, creating a large effect size between 3 groups ($\eta 2$= 0.666). In our opinion, the improvement of explosive power, balance, and agility is the reason for the increase in Tsukahara vault performance.

Conclusions

The goal of this study was to assess how HIIT affected gymnasts' explosive strength, balance, agility, and Tsukahara vault performance on unstable vs stable surfaces. According to our research, HIIT on unstable surfaces maximized explosive strength and balance more effectively than HIIT on stable surfaces. While HIIT on unstable surfaces enhances agility almost as much as it does on stable surfaces. As a result, if the goal of training is to enhance agility, then HIIT on unstable surfaces has limited advantages over HIIT on stable surfaces. In all variables, the HIIT unstable and stable groups fared better than the control group. Because HIIT can enhance players' explosive strength, balance, and agility and free up more practice time for other areas, we advise gymnastics coaches to give it some thought. Additionally, an alternate technique to enhance explosive strength and balance is to utilize HIIT on unstable surfaces. Additionally, it may be utilized alongside exercises on stable surfaces when enhancing agility.

Acknowledgement

The authors express their gratitude to Qassim University's Deanship of Scientific Research for providing funds for the publishing of this study.

Conflict of interest

There was no declared conflict of interest by the authors.

References

1. Moroșan C, Hantău C, Athanassios Y. Methodological Aspects Regarding The Improvement Of Tsukahara Vault (Tempo). *Discobolul – Phys Educ Sport Kinetotherapy J*. 2023;62(1):1–13. http://doi.org/10.35189/dpeskj.2023.62.1.1
2. Kochanowicz A, Kochanowicz K, Niespodziúski B, Mieszkowski J, Aschenbrenner P, Bielec G, et al. Maximal Power of the Lower Limbs of Youth Gymnasts and Biomechanical Indicators of the Forward Handspring Vault Versus the Sports Result. *J Hum Kinet*. 2016;53(1):33–40. http://doi.org/10.1515/hukin-2016-0008
3. Marian C, Ion M, Vladimir P. Study of Biomechanics Characteristics of Tsukahara Vault in Women's Artistic Gymnastics. *Procedia - Soc Behav Sci*. 2012;46:3742–6. http://doi.org/10.1016/j.sbspro.2012.06.139
4. Ranisavljev I, Matić M, Janković N. The relationship between maximal strength, vertical jump, acceleration and change of direction performance. *Facta Univ Ser Phys Educ Sport*. 2020;591. http://doi.org/10.22190/FUPES191103053R
5. Marina M, Jemni M. Plyometric training performance in elite-oriented prepubertal female gymnasts. *J strength Cond Res*. 2014;28(4):1015–25. http://doi.org/10.1519/JSC.0000000000000247
6. Jemni M, Sands WA, Friemel F, Stone MH, Cooke CB. Any effect of gymnastics training on upper-body and lower-body aerobic and power components in national and international male gymnasts? *J strength Cond Res*. 2006;20(4):899–907. http://doi.org/10.1519/R-18525.1
7. Verkhoshansky Y, Siff MC. Strength and the muscular system. Supertraining Rome, Italy Ultim Athl Concepts; 2009.
8. Laffranchi B. *Sports training applied to rhythmic gymnastics*. Unopar; 2001. (In Portuguese).
9. Çelenk Ç, Arslan H, Aktuğ ZB, Şimşek E. The comparison between static and dynamic balance performances of team and individual athletes. *Eur J Phys Educ Sport Sci*. 2018; http://doi.org/10.5281/zenodo.1134618
10. Megahed M, Tarek Z. Suspension training versus free weight training: effects on explosive power, dynamic balance, and discus throwers performance. *Pedagog Phys Cult Sport*. 2023;27(2):102–11. http://doi.org/10.15561/26649837.2023.0202
11. Paton CD, Hopkins WG. Combining explosive and high-resistance training improves performance in competitive cyclists. *J strength Cond Res*. 2005;19(4):826–30. http://doi.org/10.1519/R-16334.1
12. Gussakov I, Nurmukhanbetova D, Kulbayev A, Yermakhanova A, Lesbekova R, Potop V. The impact of the high level of intensity training process on the performance and recovery of young swimmers at the national level. *J Phys Educ Sport*. 2021;21(1):440–3. http://doi.org/10.7752/jpes.2021.01044
13. Megahed M, Al-Torbany M, Al-Ghool M, Tarek Z. Effects of high-intensity interval training using "Tabata protocol" on respiratory parameters, special endurance, and 800-m runners' performance. *J Hum Sport Exerc*. 2023;18(4):842–857. http://doi.org/https://doi.org/10.14198/jhse.2023.184.09
14. Nugroho S, Nasrulloh A, Karyono TH, Dwihandaka R, Pratama KW. Effect of intensity and interval levels of trapping circuit training on the physical condition of badminton players. *J Phys Educ Sport.* 2021;21:1981–7. http://doi.org/10.7752/jpes.2021.s3252
15. Mischenko N, Kolokoltsev M, Gryaznykh Ä, Vorozheikin A, Romanova E, Suslina I. Endurance development in Taekwondo according to the Tabata protocol. *J Phys Educ Sport*. 2021;21:3162–7. http://doi.org/10.7752/jpes.2021.s6421
16. Colleen C, Taylor M, Aronovitch J. *Get On It!: BOSU® Balance Trainer Workouts for Core Strength and a Super Toned Body*. Simon and Schuster; 2008.
17. Wing CH. The BOSU Ball. *ACSMs Health Fit J.* 2014;18(4):5–7. http://doi.org/10.1249/FIT.0000000000000048
18. Behm DG, Anderson K, Curnew RS. Muscle force and activation under stable and unstable conditions. *J Strength Cond Res*. 2002;16(3):416–22.
19. Komal C Jadhav DANS. Effectiveness of Bosu ball exercises on pain and disability in subjects with chronic low-back pain at the end of four weeks. *Int J Appl Res*. 2020;6(10):300–5.
20. 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. http://doi.org/10.1519/1533-4287(2003)017<0721:eopacf>2.0.co;2
21. Willardson JM, Fontana FE, Bressel E. Effect of surface stability on core muscle activity for dynamic resistance exercises. *Int J Sports Physiol Perform*. 2009;4(1):97–109. http://doi.org/10.1123/ijspp.4.1.97
22. Vera-Garcia FJ, Grenier SG, McGill SM. Abdominal muscle response during curl-ups on both stable and labile surfaces. *Phys Ther*. 2000;80(6):564–9.
23. Turgut M, Akbulut T, İmamoğlu O, Çınar V. The effect of 3 month cardio bosu exercises

on some motoric, physical and physiological parameters in sedentary women. *Sp Soc Int J Ph Ed Sp*. 2018;18(2):48–52.
24. Cuğ M, Duncan A, Wikstrom E. Comparative Effects of Different Balance-Training-Progression Styles on Postural Control and Ankle Force Production: A Randomized Controlled Trial. *J Athl Train*. 2016;51(2):101–10. http://doi.org/10.4085/1062-6050-51.2.08
25. Prasetyo H, Siswantoyo, Prasetyo Y, Hartanto A. Circuit training bosu ball: Effect on balance and accuracy of archery athletes. *Pedagog Phys Cult Sport*. 2023;27(3):229–34. http://doi.org/10.15561/26649837.2023.0307
26. Saeterbakken AH, Andersen V, Jansson J, Kvellestad AC, Fimland MS. Effects of BOSU ball(s) during sit-ups with body weight and added resistance on core muscle activation. *J Strength Cond Res*. 2014;28(12):3515–22. http://doi.org/10.1519/JSC.0000000000000565
27. Roshni, Kalra S, Pal S, Pawaria S, Yadav J. Comparative Study of Wobble Board and Bosu Ball along with Strength Training on Lower Limb Strength, Dynamic Balance, Agility and Functional Performance of Runners with Lateral Ankle Instability. *J Clin Diagnostic Res*. 2021;15(5). http://doi.org/10.7860/JCDR/2021/46588.14820
28. Sawant YV, Chavan S. Effectiveness of Bosu Ball Versus Swiss Ball Exercises on Bowling Speed Among Male Sub-Elite Cricket Fast Bowlers in Sangli City- A Comparative Study. *Int J Heal Sci Res*. 2022;12(6):285–98. http://doi.org/10.52403/ijhsr.20220637
29. Demir A. Comparison Of Effect Of Balance Disc And Bosu Ball On Ankle Dorsiflexor And Plantarflexor Muscle Strength. *Eur J Phys Educ Sport Sci*. 2019;1:25–30.
30. Salot C, Sathya P, Paul J. Effects Of Bosu Ball Exercise On Jump Performance In Football Players. *Int J Physiother*. 2020;7(4):136–9. http://doi.org/10.15621/ijphy/2020/v7i4/740
31. Šalaj SŠ, Milanović D, Jukić I. The effects of proprioceptive training on jumping and agility performance. *Kinesiology*. 2007;39(2):131–41.
32. V P, Sandhiya D R, P V, Parveen M M. Efficacy of otago exercise versus bosu ball exercise in balance-impaired elderly people. *Innovare Journal of Medical Sciences*, 2020; 25–28. http://doi.org/10.22159/ijms.2020.v8i6.38989
33. Sleeper MD, Kenyon LK, Casey E. Measuring fitness in female gymnasts: the gymnastics functional measurement tool. *Int J Sports Phys Ther*. 2012;7(2):124–38.
34. Sleeper MD, Kenyon LK, Elliott JM, Cheng MS. Measuring Sport-Specific Physical Abilities In Male Gymnasts: The Men's Gymnastics Functional Measurement Tool. *Int J Sports Phys Ther.* 2016;11(7):1082–100.
35. Mkaouer B, Hammoudi-Nassib S, Amara S, Chaabène H. Evaluating the physical and basic gymnastics skills assessment for talent identification in men's artistic gymnastics proposed by the International Gymnastics Federation. *Biol Sport*. 2018;35(4):383–92. http://doi.org/10.5114/biolsport.2018.78059
36. Hammami M, Hermassi S, Gaamouri N, Aloui G, Comfort P, Shephard RJ, et al. Field Tests of Performance and Their Relationship to Age and Anthropometric Parameters in Adolescent Handball Players. *Front Physiol*. 2019;10:1124. http://doi.org/10.3389/fphys.2019.01124
37. Takanashi Y, Kohmura Y, Aoki K. Evaluation of explosive strength ability of the upper body for athletic throwers. *J Hum Sport Exerc*. 2020;17(1). http://doi.org/10.14198/jhse.2022.171.19
38. Kaldas J, Bisson C, Hogue AC, Apinis C, Berbiche D, Gaudreault N. Construct validity and inter-rater reliability of the Gymnastic Functional Measurement Tool in the classification of female competitive gymnasts in Canada. *Phys Ther Sport*. 2017;28:9–14. http://doi.org/10.1016/j.ptsp.2017.07.006
39. De Gymnastique FI. *Code of points Men's Artistic Gymnastics (2022-2024)*. International Gymnastics Federation; 2022.
40. Megahed M, Tarek Z. Improving spatio-temporal stride parameters, lower limb muscles activity and race walkers' records after 12-weeks special exercises using rhythmic auditory. *Sport TK-Revista Euroam Ciencias del Deport*. 2023;12:7. http://doi.org/10.6018/sportk.506961
41. Romero-Franco N, Martínez-López E, Lomas-Vega R, Hita-Contreras F, Martínez-Amat A. Effects of proprioceptive training program on core stability and center of gravity control in sprinters. *J Strength Cond Res*. 2012;26(8):2071–7. http://doi.org/10.1519/JSC.0b013e31823b06e6
42. Caglayan A, Kayhan RF, Kurt A, Yuce M. The effect of pliometric studies on unstable soils on bilateral leg balance and strength of wrestlers. *J Int Soc Res*. 2018;11:59.
43. Aysan HA. Investigation of the effect of bosuball strength training on some parameters in 14 year old football playing children. *Cross Sect Acad J*. 2019;5(18):174–82.
44. Granacher U, Schellbach J, Klein K, Prieske O, Baeyens JP, Muehlbauer T. Effects of core strength training using stable versus unstable surfaces on physical fitness in adolescents: a randomized controlled trial. *BMC Sport Sci Med Rehabil*. 2014;6(1):40. http://doi.org/10.1186/2052-1847-6-40
45. Nugraha PD, Soegiyanto S, Kristiyanto A, Azam M. The effect of ankle strengthening exercise on balance in youth basketball players. *Pedagog*

Phys Cult Sport. 2022;26(1):57–67. http://doi.org/10.15561/26649837.2022.01.07
46. Elfateh A. Effects Of Ten Weeks Of Instability Resistance Training (Bosu Ball) On Muscular Balance And The Learning Level Of Fencing Basics. *Ovidius Univ Ann Ser Phys Educ Sport Mov Heal*. 2016;16:34-40.
47. Abd-Elmonem AM, Elhady HSA. Effect of rebound exercises on balance in children with spastic diplegia. *Int J Ther Rehabil*. 2018;25(9):467–74. http://doi.org/10.12968/ijtr.2018.25.9.467
48. Cressey EM, West CA, Tiberio DP, Kraemer WJ, Maresh CM. The effects of ten weeks of lower-body unstable surface training on markers of athletic performance. *J Strength Cond Res*. 2007;21(2):561–7. http://doi.org/10.1519/R-19845.1

Information about the authors:

Khaled Abuwarda; (Corresponding Author); khttps://orcid.org/0000-0003-0411-3291; K.libda@qu.edu.sa; Department of Theories and Applications of Exercises, Gymnastics and Sports Performances; College of Education, Qassim University (Buraidah, Saudi Arabia); Faculty of Physical Education, Port Said University (Port Said, Egypt).

Mostafa Mansy; https://orcid.org/0009-0006-0620-5455; mostafa.mansy@phy.aru.edu.eg; Department of Physical Training and Sports Movement Sciences, Faculty of Physical Education, Arish University; Arish, Egypt.

Mohamed Megahed; https://orcid.org/0000-0003-4355-7653; mohamed.mgahed@phy.aru.edu.eg; Department of Track and Field Competitions and Sports Training, Faculty of Physical Education, Arish University; Arish, Egypt..

Cite this article as:

Abuwarda K, Mansy M, Megahed M. High-intensity interval training on unstable vs stable surfaces: effects on explosive strength, balance, agility, and Tsukahara vault performance in gymnastics. *Pedagogy of Physical Culture and Sports,* 2024;28(1):43–52.
https://doi.org/10.15561/26649837.2024.0105

Received: 04.11.2023
Accepted: 25.12.2023; Published: 28.02.2024