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Effects of bodyweight neuromuscular training with and without instability on balance control in active universitarians

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ABSTRACT

The purpose of this study was to analyse the effects of a nine-week unstable vs stable bodyweight neuromuscular training programme on balance control. Seventy-seven physically active universitarians were randomly distributed into an unstable training group (UTG), a stable training group (STG), and a control group (CG). The intervention was conducted three times a week for nine weeks. Pre- and post-intervention assessments included static balance control under an unstable surface (eyes open (EOFS), eyes closed (ECFS), challenging visual-vestibular system (CVVS)), assessed as centre-of-pressure fluctuations with a force plate. A mixed ANOVA was performed to test the within- and between-subjects factors. After the intervention, no significant differences were found between groups. All groups presented significant improvements in balance measurements in EOFS (p = 0.01), ECFS (p = 0.01; p = 0.02), and CVVS (p = 0.01) conditions. The training groups tended to have significantly better balance control (antero-posterior) than the CG on EOFS. In the CVVS condition, the UTG tended to have better balance control than the CG. There was no overall significant training advantage gained by using unstable or stable surfaces in terms of the improvement in static balance control in active universitarians. Both training groups exhibited similar training adaptations.

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KEYWORDS
Static balance; force plate; training; unstable surface; young adults

Introduction

The central nervous system can maintain a safe upright stance and restore the body to its initial position after being imbalanced by sensory information (somatosensory, vestibular, and visual information), the peripheral nervous system, and the musculoskeletal system (Lucett Clark & Sutton, 2012). The integrative functions between the central nervous system and the multiple dynamic sensorimotor processes are crucial for postural control, postural orientation, and body balance (Duarte & Freitas, 2010; Lucett Clark & Sutton, 2012).

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Postural control and balance are the basis for the execution of complex technical movements and improvements in athletic performance, recreational sports, working skills, and everyday activities, thus providing an effective transfer of training adaptations (Clark & Sutton, 2012a). Most recreational and competitive movements, as well as regular daily tasks, require lateral, forward, and backward movements, during which the centre of pressure is often at the edge of the base of support (Boyle, 2016). Improved balance, both static and dynamic, is important for athletic performance (Kean et al., 2006; Kovacs et al., 2004; Leonard Behm et al., 2005; Sell et al., 2007). It is also needed for the prevention and rehabilitation of lower extremity injuries (Bellows & Wong, 2018; Hewitt et al., 2018; Runge et al., 2018; Strøm et al., 2016). This is because balance provides trunk and limb muscle activation and, consequently, greater stabilization functions to protect recovering muscles and articulations (D Behm & Colado, 2012; D. G Behm & Anderson, 2006).

Therefore, balance training programmes are frequently used in sports and fitness to continually increase the athlete's or client's awareness of their stability limits by creating controlled instability or perturbation of the musculoskeletal system that will facilitate neuromuscular capability, readiness, and reaction (Clark & Sutton, 2012a; D. G Behm & Anderson, 2006). Appropriated balance training can be prescribed, regressed, and progressed by changing the surface, visual conditions, body position, and movement that the exercise requires (Blahnik et al., 2008; Clark & Sutton, 2012a). Additionally, alternative challenges involving the use of unstable surfaces can be included in training to provide progressive overload and to stimulate strength and balance adaptations (Behm et al., 2015). In fact, many devices have been developed to provide an unstable surface and, therefore, alternative challenges. Such devices include wobble boards, Swiss balls, inflated discs, foam surfaces, hemispherical balls with an inflated dome side and a hard rubber flat side (e.g., bosu), foam rollers, suspended chains, ropes, or other devices (D Behm & Colado, 2012; Behm et al., 2015; Boyle, 2016; Kibele & Behm, 2009; Strøm et al., 2016).

Studies have reported the impact of unstable devices on the neuromuscular system, balance control, and functional performance in older adults (Choi & Kim, 2015; Emilio et al., 2014; Hafström et al., 2016; Zech et al., 2010), children and adolescents (Cerrah et al., 2016; Granacher et al., 2015, 2014), and healthy, active young adults (Estorninho et al., 2016; Kovacs et al., 2004; Lizardo et al., 2017; Namin et al., 2017; Perrin et al., 2002; Wahl Behm et al., 2005). Unstable training seems to influence proprioceptive input, reaction time, and muscular strength in postural control mechanisms via neuromuscular adaptations to activity (D. G Behm & Anderson, 2006; Yaggie & Campbell, 2006). It might also improve performance in specific functional tasks (i.e. time on ball, shuttle run), in dynamic skills, and in sway patterns in healthy, recreationally active young adults (Cuğ et al., 2016; Harput et al., 2015; Lizardo et al., 2017; Namin et al., 2017; Yaggie & Campbell, 2006).

On the other hand, there are limitations associated with instability training. For example, the unstable surface training may not influence activities that relate to power skills (Yaggie & Campbell, 2006). Additionally, the unstable surface training can lead to decreases in force output of the limb and increases in antagonist activity (D. G Behm & Anderson, 2006). It seems that the ability to exert force or power is questionable under instability training conditions (Anderson & Behm, 2004; D. G Behm & Anderson, 2006).

Many physical activity and health professionals have used unstable platforms and functional exercises to promote physical abilities (e.g., balance), improve proprioception, and enhance athletic performance (Behm et al., 2015; Kibele & Behm, 2009; Yaggie & Campbell, 2006). Previous studies aimed to verify training effects by using two experimental groups (unstable vs stable) (Cuğ et al., 2016; Kibele & Behm, 2009) or one experimental group (unstable condition) vs a control group (Yaggie & Campbell, 2006). Little research has compared the training effects of unstable and stable training groups vs control group. Comparing the effects of unstable and stable surface training on balance control in active people would likely help to clarify the importance of such an intervention type.

To the best of our knowledge, little is known about bodyweight neuromuscular training on unstable and stable platforms and its effect on static balance control in physically active young adults. Therefore, this study aimed (i) to analyse the effects (within-group differences) of a nine-week unstable vs stable bodyweight neuromuscular training program on balance control in active university students and (ii) to analyse differences between training groups after the nine-week intervention.

Methods

Experimental approach

We carried out a randomized controlled trial to analyse the effects of bodyweight neuromuscular training with or without instability on balance control. A pre-post interventional study design was employed, and the assessed factors included anthropometry (height, seated height, mass, eight skinfolds) and static balance control. The sample consisted of physically active young adults who were university students of sports and leisure undergraduate courses. None of the participants had any formal bodyweight neuromuscular training prior to this study.

An initial information session was defined in which aspects of the study design were explained, including the study aims, the pre- and post-intervention assessment dates, the testing protocol, and the intervention plan. The tests were conducted in a laboratory before breakfast on a weekday (48 h after the last training/exercise session) between 8:30 a.m. and 10:00 a.m.

The experts (all sports science specialists) who measured the outcome measures were blinded for the study intervention and participant recruitment. The participants were instructed to avoid exercising for a minimum of 24 h and consuming alcoholic drinks for a minimum of 48 h before testing. The training program was conducted over nine weeks, with three sessions performed per week at approximately the same time of day.

Participants

Seventy-seven physically active university students voluntarily participated in this study (Table 1). The participants were randomly assigned (by computer) into either the control group (CG) or one of two training groups (UTG, unstable training group;

Table 1. Baseline anthropometric characteristics and physical activity level of the population studied, separated by group (mean ± SD).

	Age (yr)	Height (cm)	Body mass (kg)	Body Fat (%)	Moderate activity (days; min./week)	Vigorous activity (days; min./week)	Walk activity (days; mi./week)
UTG							
Total (N = 20; 6 males, 14 females)	19.3 ± 1.1	165.9 ± 9.5	61.3 ± 10.7	17.4 ± 5.7	2.8 ± 2.2; 127.0 ± 108.4	2.4 ± 2.0; 125.5 ± 124.3	5.1 ± 1.8; 221.0 ± 132.7
STG							
Total (N = 19; 9 males, 10 females)	18.8 ± 1.0	169.8 ± 8.1	63.5 ± 10.1	16.6 ± 4.9	1.8 ± 1.5; 77.4 ± 68.8	2.1 ± 1.4; 77.9 ± 48.1	5.6 ± 1.7; 225.0 ± 96.7
CG							
Total (N = 38, 33 males, 5 females)	19.1 ± 1.2	172.7 ± 8.9*	65.9 ± 10.9	13.1 ± 5.4	2.5 ± 1.9;121.6 ± 81.1	2.6 ± 1.9;139.7 ± 115.3	5.0 ± 2.4; 206.8 ± 132.3

UTG – unstable training group; STG – stable training group; CG – control group. * significant differences between sex ($p < 0,05$).

STG, stable training group). The participants completed a medical history questionnaire and the International Physical Activity Questionnaire (IPAQ, short form) to measure physical activity intensity. All of the participants performed sports activities (outdoor sports, football, basketball, and others) included in the curriculum of the leisure sports course program.

The inclusion criteria in the study were training at least three days per week and the absence of acute injuries. Exclusion criteria were: (1) previous experience in bodyweight neuromuscular training with unstable platforms or in sports that develop balance and proprioceptive skills (e.g., dance, ballet, skating, hockey); (2) neuromuscular diseases; (3) vestibular disorders; (4) visual impairment (corrected visual acuity worse than 20/100 or presence of a field detect) (Laughton et al., 2003); (5) cerebral concussions; and (6) chronic lower injury or any pathology or health problem that affects balance and postural control (Alcantara & Duarte, 2012; Anthony et al., 2016).

The sample size estimation was calculated in Gpower software (v3.1.9.7, University of Duesseldorf, Duesseldorf, Germany) for an alpha of 0.5 and a beta of 0.8. Results suggested an N of 36 participants. However, we recruited 77 participants in the present study. Flowchart of participants based on a consort statement is present in Figure 1. Participants were screened by the main researcher. All participants gave written informed consent to participate in this research. The study followed the ethical standards for research conducted in humans as established by the Declaration of Helsinki and was approved by the local ethical committee of the Polytechnic Institute of Viana do Castelo, School of Sport and Leisure with the code number IPVC-ESDL180801.

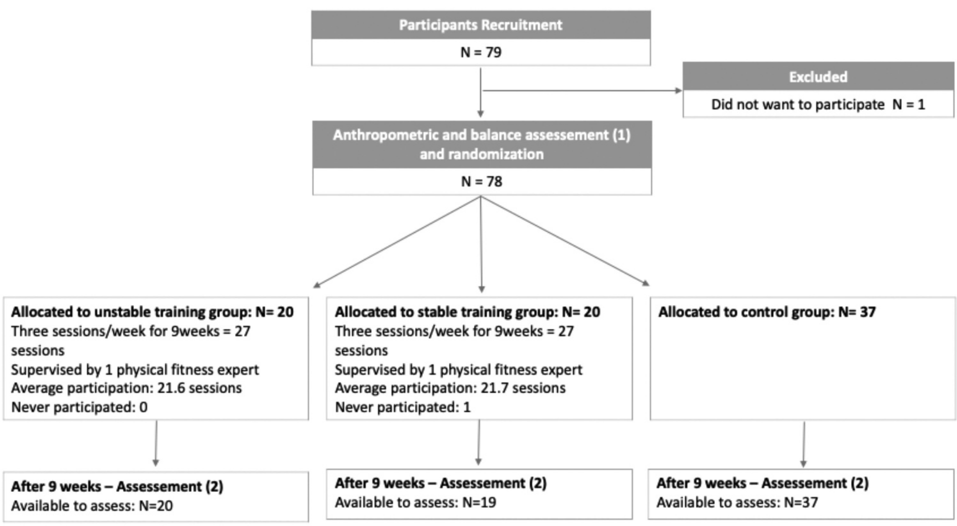

Figure 1. Flowchart of participants based on a consort statement: two training groups (UTG, unstable training group; STG, stable training group) and control group (CG).

Table 2. Description of the training program applied to both training groups (UTG and STG).

Name	Sets	Repetitions (reps)	Rest (seconds)
Warm-Up			
Alternating press push	2	15	45–60
Basic walk on top	2	15	45–60
Squat with overhead press	1	15	45–60
Side squat with trunk rotation	1	10	45–60
Lunge/plank progression (F/L)	1	6	45–60
Training Program			
Stationary lunge[1]	3	15	45–60
Hip abdution2	2	15	45–60
Quick side-push away around dome[3]	1	6 in each direction	45–60
Skiing moguls[4]	2	10	45–60
Dome squat[5]	2–3	15	45–60
Single leg balance[6]	2	30–45 sec.	45–60
Hot lava[7]	2	2 min.	45–60
Lateral front run[8]	2	2 min.	45–60

Exercise setup/execution – unstable training group (stable training group performed the same exercises without bosu)

[1]One foot on the top of bosu dome and other foot on the floor (lunge position). Flexing both knees to a maximum depth of 90 degrees flexion. Then extend the knees and hips and return to the starting position.

2 Stand on top of the bosu dome, with one foot in the middle and with lightly touch the other foot on the side of the dome for support. Raise de unweighted leg to the side (hip abduction) and lower the leg back down to the starting position.

[3]Stand on the floor to one side of the dome. Bend both knees and load the outside leg, lifting the heel of the inside foot, preparation for the side-push on bosu dome. Place the foot of the inside leg on top of the dome. Push off the outside leg and quickly transfer the weight from the outside leg to inside leg, then back to the outside leg, around bosu dome.

[4] Stand in a centred position on top of the bosu dome with feet about hip width apart. Flex the knees, hips and ankles in preparation to jump. Performing alternating jumps that turn 45° degrees.

[5] Stand in a centred position on top of the bosu dome with feet about hip width apart. Flex the knees, hips and ankles and perform a squat movement. Extend the hips, and knees and return to the starting position.

[6] Stand on top of the bosu dome, with one foot in the middle and with lightly touch the other foot on the side of the dome for support. Slowly raise the unweighted leg, flex the knees and hips in support leg and find balance.

[7] Place several unstable platforms (bosu´s) in a line (zig-zag/staggered pattern). Stand in a centred position on top of the first dome, facing the line of platforms. Jump or leap diagonally to the next dome and stick the landing for a brief moment.

[8] Place several unstable platforms (bosu´s) in a line. Stand on the floor behind the first dome, facing front. Step up onto the dome, then back down to the floor (similar to a basic step). Step up the next dome to the side and repeat the basic step up and down.

Testing protocol

Anthropometric measures

All participants wore light clothing and stood barefoot. Each participant's height was measured to the nearest 0.1 cm with a portable stadiometer (Seca 217, Hamburg, Germany). Bodyweight was measured to the nearest 0.1 kg with a mechanical floor scale (Seca 760, Germany). Eight skinfolds (triceps, subscapular, biceps, suprailiac, abdominal, supraspinal, thigh, and calf) were assessed with a Harpenden calliper (British Indicators, Ltd., London, UK). Body fat percentage was estimated using the equation proposed by Withers et al. (987). All anthropometric variables (height, weight, skinfolds) were measured by a single certified expert (ISAK Level 2) according to the protocol of the International Society for the Advancement of Kinanthropometry (ISAK).

Static postural control

Static postural control under unstable conditions was assessed by measuring COP fluctuations at 1000 Hz with a force plate (Kistler, model 9260AA6, Winterthur, Switzerland). The results of the static balance tests were performed by an expert.

Participants stood barefoot on a foam surface (density: 50 kg/m^3; dimensions: 49 × 39 × 5.5 cm) placed on top of a force plate. The unstable surface seems to make the balance test more dynamic and closer to a sports context (Alcantara & Duarte, 2012; Brachman et al., 2017). Participants completed three 30-second trials under three different conditions: (a) quiet standing, eyes open (EOFS); (b) quiet standing, eyes closed (ECFS); and (c) quiet standing, eyes open, challenging the visual-vestibular system (CVVS) (looking at light signals that change 10 to 10 seconds: 1º eye level, 1.80 metres off the floor; 2º looking up, 3.60 metres off the floor; 3º looking to the floor; 4º eye level). Participants were given one minute of rest between trials (Pirôpo et al., 2016) and one minute of rest between conditions (Alcantara & Duarte, 2012). The trial order (i.e. EOFS, ECFS, CVVS) was randomized across participants to reduce order effects (Patel et al., 2008; Pirôpo et al., 2016).

Each participant could select their preferred stance width (Duarte & Freitas, 2010) and was instructed to stand quietly with their arms hanging at their sides while they placed their head in a normal forward-looking position and focused on a target located at eye level, approximately three metres away (Alcantara & Duarte, 2012; Cruz et al., 2010; Jang et al., 2008). Before testing began, each participant performed one practise trial for each condition, and the data for the three experimental trials were then collected for each condition. The average of the three trials was used for further analysis.

The force and torque signals were amplified (type 5695B, Winterthur, Switzerland) and recorded with commercial software (Bioware, 2812 A), which computed the COP time series in the antero-posterior and medio-lateral directions. After filtering (fourth-order zero-lag 20 Hz low-pass Butterworth filter), classical sway measures were computed to assess the direction, distance, and velocity of the COP trajectory, with greater values indicating poorer balance. These measures included total COP displacement, which represents the overall antero-posterior and medio-lateral movements over 30 seconds (cm), and total mean velocity, which signifies the total COP distance travelled in one trial divided by the duration of the trial. Displacement and mean velocity in the antero-posterior and medio-lateral directions were also computed. All sway measures were computed through scripts written in Matlab code (R2013a, Mathworks Inc., Natick, MA, USA).

Training program

The training programs began within two days following the pre-test. The training protocol consisted of neuromuscular exercises with bodyweight used as resistance (see Table 2).

The unstable training group (UTG) performed the training program on an unstable platform with an inflated dome side and a hard rubber flat side (i.e., a bosu) that was 25 inches in diameter. The dome was inflated to a firm density and height of around 8–10 inches from the floor. The stable training group (STG) performed similar neuromuscular training on the floor. The CG was asked to maintain their daily routines. We collected the information if they changed their training routines by a questionnaire, in the second moment of the evaluation.

The intervention plan was designed by a physical fitness expert based on previous literature (Blahnik et al., 2008; Cuğ et al., 2016; Harput et al., 2015; Yaggie & Campbell,

Table 3. Outcome measures before and after a 9-week functional training program.

	UTG (N = 20)		STG (N = 19)		CG (N = 38)		Within group		Interaction	
	Pre	Post	Pre	Post	Pre	Post	p	Partial	p	Partial
EOFS DAP (cm)	23.64 ± 6.62	21.59 ± 6.27	22.55 ± 2.60	23.24 ± 5.14	27.59 ± 6.54	26.22 ± 4.36	0.22	0.02	0.35	0.03
EOFS DML (cm)	36.70 ± 8.25	33.66 ± 8.39	42.03 ± 7.96	35.67 ± 7.49	42.35 ± 10.11	35.78 ± 6.39	0.01	0.34	0.21	0.05
EOFS TD (cm)	49.47 ± 11.77	43.95 ± 11.04	49.68 ± 5.85	46.74 ± 9.47	53.80 ± 9.98	49.02 ± 7.74	0.01	0.19	0.67	0.01
EOFS VAP (cm/s)	0.76 ± 0.23	0.72 ± 0.21	0.75 ± 0.09	0.77 ± 0.17	0.92 ± 0.22	0.87 ± 0.15	0.46	0.01	0.53	0.02
EOFS VML (cm/s)	1.22 ± 0.28	1.12 ± 0.28	1.40 ± 0.27	1.19 ± 0.25	1.41 ± 0.34	1.19 ± 0.21	0.01	0.34	0.21	0.05
EOFS TV (cm/s)	1.54 ± 0.24	1.47 ± 0.37	1.65 ± 0.19	1.56 ± 0.31	1.79 ± 0.33	1.63 ± 0.26	0.01	0.13	0.54	0.02
ECFS DAP (cm)	28.18 ± 8.54	25.61 ± 8.27	32.00 ± 12.64	30.01 ± 9.76	32.11 ± 9.01	30.54 ± 7.77	0.07	0.05	0.92	0.01
ECFS DML (cm)	51.21 ± 13.55	44.53 ± 11.39	57.36 ± 19.21	49.89 ± 13.28	60.56 ± 16.71	50.73 ± 14.07	0.01	0.41	0.49	0.02
ECFS TD (cm)	63.66 ± 16.91	56.08 ± 15.11	72.68 ± 25.52	63.77 ± 17.39	75.10 ± 19.64	64.77 ± 16.95	0.01	0.34	0.76	0.01
ECFS VAP (cm/s)	0.94 ± 0.28	0.85 ± 0.28	1.07 ± 0.42	1.00 ± 0.32	1.11 ± 0.34	1.02 ± 0.26	0.02	0.08	0.97	0.01
ECFS VML (cm/s)	1.71 ± 0.45	1.48 ± 0.38	1.91 ± 0.64	1.66 ± 0.44	2.02 ± 0.56	1.69 ± 0.47	0.01	0.41	0.51	0.02
ECFS TV (cm/s)	2.12 ± 0.56	1.87 ± 0.50	2.42 ± 0.85	2.13 ± 0.58	2.50 ± 0.65	2.16 ± 0.56	0.01	0.34	0.76	0.01
CVVS DAP (cm)	21.98 ± 5.02	19.73 ± 4.25	23.70 ± 6.04	24.33 ± 6.46	26.77 ± 6.58	24.93 ± 4.33	0.11	0.04	0.25	0.04
CVVS DML (cm)	37.55 ± 8.46	32.96 ± 5.51	40.47 ± 9.07	36.92 ± 7.25	43.44 ± 10.21	37.78 ± 7.69	0.01	0.25	0.64	0.01
CVVS TD (cm)	47.67 ± 10.10	42.04 ± 7.23	50.23 ± 9.88	48.68 ± 10.20	55.47 ± 12.25	49.80 ± 9.24	0.01	0.14	0.35	0.03
CVVS VAP (cm/s)	0.72 ± 0.18	0.67 ± 0.15	0.79 ± 0.21	0.80 ± 0.22	0.90 ± 0.23	0.82 ± 0.14	0.09	0.05	0.27	0.04
CVVS VML (cm/s)	1.25 ± 0.28	1.10 ± 0.18	1.35 ± 0.30	1.23 ± 0.24	1.45 ± 0.34	1.26 ± 0.26	0.01	0.24	0.65	0.01
CVVS TV (cm/s)	1.59 ± 0.34	1.40 ± 0.24	1.73 ± 0.41	1.62 ± 0.34	1.85 ± 0.41	1.66 ± 0.31	0.01	0.18	0.65	0.01

Within-group (time); interaction (time X group); FS-foam surface; EO-eyes open; EC-eyes closed and foam surface; CVVS-challenging visual-vestibular system; DAP-displacement of COP antero-posterior; DML-displacement of COP medio-lateral; TD- total displacement of COP; VAP-mean velocity antero-posterior; VML-mean velocity medio-lateral; TV-total mean velocity. UTG – unstable training group; STG – stable training group; CG – control group. significant different $p < 0.05$.

2006). The training period consisted of three supervised training sessions per week, each lasting around 45 min, for nine weeks. All of the training sessions were led by a single physical fitness expert with more than 10 years of experience. The sessions involved bodyweight neuromuscular exercises (particularly exercises targeting lower extremity strength) (e.g., lunge, squat, single-leg stance, hip abduction) and progressed from the simplest to the most complex (challenging somatosensory, vestibular and visual system) (see Table 2 for details). Each week, the participants were presented with exercise progressions, more challenging exercises, or simply different exercises without impairing their technique or safety (Blahnik et al., 2008; Clark & Sutton, 2012b; Yaggie & Campbell, 2006). The progressions were designed to challenge one or more of the sensory systems in maintaining balance. Additions and modifications to the intervention plan included rotating the head laterally, tilting the head upward or downward, keeping the eyes open

Table 4. Changes in outcome measures after the intervention.

	UTG (N = 20)			STG (N = 19)			CG (N = 38)			
	Δ	p[a]	d	Δ	p[a]	d	Δ	p[a]	d	Significant comparisons
EOFS DAP (cm)	−2.05	0.09	0.32 *Small*	0.69	0.55	−0,17 *Trivial*	−1.37	0.23	0.25 *Small*	UTG- CG: p = 0.01 STG- CG: p = 0.02
EOFS DML (cm)	−3.04	0.11	0.37 *Small*	−6.36	0.01	0.82 *Moderate*	−6.57	0.01	0.78 *Moderate*	ns
EOFS TD (cm)	−5.52	0.02	0.48 *Small*	−2.94	0.17	0.37 *Small*	−4.78	0.01	0.54 *Small*	ns
EOFS VAP (cm/s)	−0.04	0.46	0.18 *Trivial*	0.02	0.54	−0.15 *Trivial*	−0.05	0.24	0.27 *Small*	UTG- CG: p = 0.01 STG- CG: p = 0.02
EOFS VML (cm/s)	−0.10	0.10	0.36 *Small*	−0.21	0.01	0.81 *Moderate*	−0.22	0.01	0.78 *Moderate*	ns
EOFS TV (cm/s)	−0.07	0.21	0,22 *Small*	−0.09	0.22	0.35 *Small*	−0.16	0.01	0.54 *Small*	UTG- CG: p = 0.02
ECFS DAP (cm)	−2.57	0.03	0.31 *Small*	−1.99	0.38	0.18 *Trivial*	−1.57	0.39	0.19 *Trivial*	ns
ECFS DML (cm)	−6.68	0.01	0.53 *Small*	−7.47	0.03	0.45 *Small*	−9.83	0.01	0.64 *Moderate*	ns
ECFS TD (cm)	−7.58	0.01	0.47 *Small*	−8.91	0.04	0.41 *Small*	−10.33	0.01	0.56 *Small*	ns
ECFS VAP (cm/s)	−0.09	0.03	0.32 *Small*	−0.07	0.37	0.19 *Trivial*	−0.09	0.13	0.30 *Small*	ns
ECFS VML (cm/s)	−0.23	0.01	0.55 *Small*	−0.25	0.03	0.46 *Small*	−0.33	0.01	0.64 *Moderate*	ns
ECFS TV (cm/s)	−0.25	0.01	0.47 *Small*	−0.29	0.04	0.40 *Small*	−0.34	0.01	0.56 *Small*	ns
CVVS DAP (cm)	−2.25	0.01	0.48 *Small*	0.63	0.60	−0.10 *Trivial*	−1.84	0.12	0.33 *Small*	UTG- CG: p = 0.01
CVVS DML (cm)	−4.59	0.01	0.64 *Moderate*	−3.55	0.01	0.43 *Small*	−5.66	0.01	0.63 *Moderate*	UTG- CG: p = 0.05
CVVS TD (cm)	−5.63	0.01	0.64 *Moderate*	−1.55	0.37	0.15 *Trivial*	−5.67	0.01	0.52 *Small*	UTG- CG: p = 0.01
CVVS VAP (cm/s)	−0.05	0.04	0.30 *Small*	0.01	0.84	−0.05 *Trivial*	−0.08	0.04	0.42 *Small*	UTG- CG: p = 0.01
CVVS VML (cm/s)	−0.15	0.01	0.64 *Moderate*	−0.12	0.01	0.44 *Small*	−0.19	0.01	0.63 *Moderate*	UTG- CG: p = 0.05
CVVS TV (cm/s)	−0.19	0.01	0.65 *Moderate*	−0.11	0.03	0.29 *Small*	−0.19	0.01	0.52 *Small*	UTG- CG: p = 0.02

Δ: change from baseline to post-intervention; significant different $p < 0.05$; 0.0–0.2, trivial; 0.2–0.6, small; 0.6–1.2, moderate; 1.2–2.0, large; > 2.0 very large; UTG – unstable training group; STG – stable training group; CG – control group; ns – no significant.

or closed, reducing the contact points, adding other movements to the base movement, or adding an external stimulus (Blahnik et al., 2008; Cuğ et al., 2016; Yaggie & Campbell, 2006). If the participants attended over than 80% of all sessions, they were included in the study.

Statistical analyses

Descriptive statistics included mean, standard deviation, and 95% confidence interval (95% CI) values. The normality of the sample was evaluated using the Shapiro-Wilk test, and the equality of error variances was determined using Levene's test ($p > 0.05$). The examined dependent variables were: (1) displacement of COP antero-posterior (DAP) and medio-lateral (DML); (2) total displacement of the centre of pressure (TD); (3) mean velocity antero-posterior (VAP) and medio-lateral (VML); and (4) total mean velocity (TV).

After the confirmation of the assumption of normality, two-way ANOVA was executed to test the differences between the sexes in the static balance test for each condition (EOFS, ECFS, and CVVS). No differences were found in the group and sex interaction. Therefore, we decided not to separate the sample by sex. A mixed ANOVA was performed to test the within-subjects factor (time: pre- and post-intervention) and between-subjects factor (groups: UTG, STG, and CG). Mauchly's test was used to test the severity of departures from sphericity. Violations of sphericity were corrected using the Huynh-Feldt correction for each condition (pre-test and post-test) (greenhouse-Geisser > 0.75) (Field, 2012). If significant interactions were detected in the mixed ANOVA, a Bonferroni post hoc test was used. Cohen's standardized effect size was calculated for pairwise comparisons. The magnitude of differences was defined based on the following thresholds (Cohen, 2013): 0–0.2, trivial; 0.2–0.6, small; 0.6–1.2, moderate; 1.2–2.0, large; >2.0, very large. The statistical procedures were executed in SPSS (version 27, IBM, USA) ($p < 0.05$).

Results

Baseline anthropometric characteristics and physical activity level are presented in Table 1.

Significant differences were found between groups for height. Specifically, the CG participants were taller than those in the UTG ($p = 0.02$). No age, body mass, body mass index, or physical activity level differences were found between groups ($p > 0.05$).

The main results, before and after the nine-week intervention, are presented in Table 3.

No significant effects were observed for training groups (interaction time X group). Furthermore, no overall significant training advantage presented itself in any condition (EOFS, ECFS, CVVS) for unstable vs stable bodyweight neuromuscular training methods.

Within-group comparations revealed significant improvements in all groups (UTG, STG, CG) in most of the measurements in all conditions after training. Objectively, for the EOFS condition, there were statistically significant decreases in DML, TD, VML, and TV ($p < 0.05$). However, no statistically significant differences were found between groups before and after the intervention. In the ECFS condition, statistically significant decreases were found in all groups in terms of DML, TD, VAP, VML, and TV ($p < 0.05$). No statistically significant between-group differences were detected before and after the intervention. Regarding the CVVS condition, statistically significant decreases were found in DML, TD, VML, and TV

($p < 0.05$). Again, no statistically significant differences were found between groups before and after the intervention. Specific information can be observed in Table 3.

The changes in outcome measures after the intervention are presented in Table 4.

When adjusted for baseline values, the UTG showed statistically significant decreases in TD in the EOFS condition. Meanwhile, the STG showed statistically significant decreases in DML and VML, and the CG showed statistically significant decreases in DML, TD, VML, and TV ($p < 0.05$). After the intervention, the UTG and STG were statistically significantly different than the CG regarding DAP and VAP measures ($p < 0.05$). The UTG was statistically significantly different from the CG for the TV measure ($p = 0.02$). When adjusted for baseline values, in the ECFS condition, the UTG showed statistically significant decreases in all variables ($p \leq 0.03$), while the STG and CG showed statistically significant decreases in DML, TD, VML, and TV ($p < 0.05$). In the CVVS condition, the UTG and CG showed statistically significant decreases in DML, TD, VAP, VML, and TV ($p < 0.05$). The STG showed statistically significant decreases in DML, VML, and TV ($p < 0.05$). After the intervention, the UTG presented statistically significant differences from the CG in terms of their DAP, DML, TD, VAP, VML, and TV values ($p < 0.05$). Specific information can be observed in Table 4.

Discussion

The purposes of this study were to analyse the effects (within-group differences) of a nine-week unstable versus stable bodyweight neuromuscular training intervention on balance control in active universitarians and to analyse the between-group differences after the nine-week period. The main findings revealed that there were no statistically significant differences between groups for the static balance measures after nine weeks of training.

Some researchers have studied the effects of instability resistance training programs on strength, balance, and functional performance (D. G Behm & Anderson, 2006; Kibele & Behm, 2009; Yaggie & Campbell, 2006). Previous studies showed that the greater instability promoted by exercising on an unstable surface stresses most the neuromuscular system to a greater extent than when exercising on a stable surface (D. G Behm & Anderson, 2006). Accordingly, studies have reported that balance training improves performance in specific functional tasks (i.e. time on ball, shuttle run), especially in postural control and ankle force production in healthy, recreationally active young adults (Cuğ et al., 2016; Harput et al., 2015; Lizardo et al., 2017; Namin et al., 2017; Yaggie & Campbell, 2006). However, others have reported no main effects for training groups in terms of strength, balance, or functional performance (Behm et al., 2015; Kibele & Behm, 2009; Tran et al., 2015).

In the present study, no statistically significant differences were found between groups. Overall, our data showed no significant differences or main effects for training groups. This finding is consistent with the results presented in previous works that observed the effects of instability resistance training (Behm et al., 2015; Kibele & Behm, 2009). Additionally, Tran et al. (2015) investigated two different resistance training interventions (unstable and stable) on strength, power, and sensorimotor abilities in adolescent surfers. The authors concluded that unstable training did not have any significant advantages when compared to traditional stable resistance training in terms of strength, power, or sensorimotor ability.

Our findings also demonstrated that over time, all of the groups (both training groups and the control group) exhibited significant decreases in balance measures – specifically DML, TD, VML, and TV – for all conditions (EOFS, ECFS, CVVS). This finding suggests that during a nine-week period, all of the groups (UTG, STG, CG) presented better static balance control in all conditions.

Bodyweight neuromuscular programs under unstable conditions promote important neuromuscular adaptations, not as a result of increased recruitment or activation of motor units, but as a result of improved coordination of agonists, antagonists, synergists, and stabilizers. Additionally, it seems that unstable conditions promote greater antagonist activity, comparatively with stable conditions. The Behm et al. (2002) study showed that the unstable plantar flexor and leg extensor conditions experienced 30.7% and 40.2% greater antagonist activity than the stable conditions. This might be why subjects controlled the position of the limb when producing force (Behm et al., 2002). The increased stress and the muscle activation of limbs in the unstable training conditions have been postulated to promote greater neuromuscular adaptations and can be attributed to the increased stabilization functions (D. G Behm & Anderson, 2006).

Similar improvements in static balance by the STG may be attributed to the instability involved in controlling the unilateral exercises of the training program. The majority of exercises performed were unilateral lower limb exercises. When performing such exercises, one must produce strong contractions while standing on a single leg. Unilateral lower body training is useful for improving muscle balance since it requires more proprioception, stability, and kinaesthetic awareness than bilateral activities (Hwang et al., 2006). This is especially true for inexperienced participants.

Furthermore, trunk strengthening can occur when performing exercises for the limbs when the exercises are performed unilaterally (Leonard Behm et al., 2005). Unilateral resistance exercises may also offer the bonus of stimulating trunk stabilizers to a great extent, and the literature shows the positive influence of trunk strength and core stability on balance control (D. G Behm & Anderson, 2006; Szafraniec et al., 2018). Unilateral resistance actions would provide a disruptive moment arm to the body, providing another type of unstable condition (D. G Behm & Anderson, 2006).

Surprisingly, the CG showed improvements in static balance control without performing the experimental training program. A possible explanation for this is that all members of the CG experienced new practical activities as part of their daily routines in the leisure sports course program (outdoor sports, football, basketball, and others). Most sports involve a combination of stability and force-producing functions (e.g., the running forehand in tennis and the quick lateral, forward, and backward movements in basketball, football, and many other sports) and might have promoted significant neuromuscular adaptations in the CG that contributed to improvements in balance control. These variables were not controlled in the present study; however, they may have influenced the results.

In future studies, these variables have to be considered. Alternately assessment of postural balance through static balance tests may not be the most appropriate for the participants. Perhaps the application of dynamic balance tests would be better (Curtolo et al., 2017; Karimi & Solomonidis, 2011; Sell, 2012), such as the balance error scoring system (Bressel et al., 2007; McLeod et al., 2009), the jump test (Zech et al., 2014), the star excursion balance test (Curtolo et al., 2017; Eisen et al., 2010; McLeod et al., 2009;

Mohammadi et al., 2012), or the Y balance test (Benis et al., 2016; Coughlan, Fullam, Delahunt, Gissane, & CaulField, 2012; Cuğ et al., 2016; Elena et al., 2015; Namin et al., 2017).

However, our data also showed that after nine weeks of bodyweight neuromuscular training, the unstable training group (UTG) and stable training group (STG) tended to have significantly better balance control than the control group (CG) in the antero-posterior displacement of COP for the EOFS condition (DAP: $p = 0.01$; $p = 0.02$; VAP: $p = 0.01$; $p = 0.02$). The UTG was statistically significantly different from the CG for the TV measure ($p = 0.02$) and demonstrated better balance control (antero-posterior and medio-lateral) when compared to the CG in the CVVS condition. The lack of previous evidence based on similar objectives and measures makes it difficult to discuss the results in depth.

Conclusion

All groups in the present study achieved improvements in terms of static balance control under all conditions. Overall, no single condition (EOFS, ECFS, CVVS) appeared to provide a training advantage over the others in terms of the use of unstable or stable bodyweight neuromuscular training methods.

Study limitations and recommendations for future studies

In the present study, the sample included active young adults with different levels of sports experience, which may have influenced the training intervention. Therefore, prior to the static balance assessment, the type, frequency, and intensity of exercises regularly performed by participants should be characterized. Participants could then be separated by sports activities.

Static balance in bipedal support was assessed, and most of the exercises were performed with unipedal support; perhaps assessing static balance measures using unipedal support would be better. We verified the impact of bodyweight neuromuscular training with and without instability on balance, but our study involved only lower body exercises. It would be worthwhile for future studies to include in training program upper body and core exercises.

Also, it would be interesting to investigate the effects of the same training program and methodology in athletes returning from an injury in order to regain proprioception and improve sensory signals. Finally, the relatively small sample size of the present study is another limitation that reduces the generalizability of the data that we presented.

Practical applications and study relevance

Overall, both methods of bodyweight neuromuscular training provide similar benefits for static balance measures in young adults. Bodyweight neuromuscular training with or without an unstable platform could be an appropriate strategy for beginners in the practice of physical activity and athletes. Instability bodyweight exercises should be incorporated in conjunction with stable exercises to provide a variety of training experiences. However, the findings of this study may be misleading, as the improvements reported in all groups might have been due to the natural ability of individuals or some confounding factors.

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