Short-term Effects of Proprioceptive Training With Unstable Platform on Athletes' Stabilometry

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Departments of [1]Health Sciences; [2]Didactics of Musical, Plastic and Corporal, University of Jaén, Jaén, Spain; and [3]Institute of Biopathology and Regenerative Medicine, Department of Anatomy and Embryology, Faculty of Medicine, University of Granada, Granada, Spain

Abstract

Romero-Franco, N, Martínez-López, EJ, Lomas-Vega, R, Hita-Contreras, F, Osuna-Pérez, MC, and Martínez-Amat, A. Short-term effects of proprioceptive training with unstable platform on athletes' stabilometry. *J Strength Cond Res* 27(8): 2189–2197, 2013—The purpose of this study was to determine the short-term stabilometric effects of proprioceptive training in athletes by using a BOSU ball and a Swiss ball as unstable platforms. Thirty-seven athletes from a variety of disciplines were divided into a control group ($n = 17$) and an experimental group ($n = 20$). Both performed a warm-up, and in addition, the experimental group carried out a proprioceptive exercise session after the warm-up. Proprioceptive exercise session consisted of six 25-minute exercise sessions with the BOSU ball and the Swiss ball as unstable platforms. Bipedal stabilometry was assessed before the training session (M_0), immediately after training (M_1), 30 minutes later (M_2), 1 hour after training (M_3), 6 hours after training (M_4), and 24 hours after training (M_5). Analysis of variance ($\alpha = 0.05$) revealed significant differences immediately after training (M_1) in speed ($p = 0.022$) and length covered by the center of pressure ($p = 0.021$) in the experimental group. These differences were even more acute 6 hours later (M_4; $p = 0.021$). In fact, the same group exhibited significant differences in mediolateral position after 30 minutes (M_2; $p = 0.001$) compared with the baseline measure and the control group. Apart from these, no other significant differences were found. A proprioceptive exercise session using a BOSU ball and a Swiss ball as unstable platforms induced short-term negative effects on the stabilometry of athletes. Likewise, an immediate trend to improvement was apparent in the stabilometry of the control group after the warm-up.

Key Words Swiss ball, BOSU, postural control, proprioception, immediate effects

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Introduction

Proprioception refers to the conscious and unconscious perception of postural balance, muscle sense, and joint stability (15). Proprioceptive training has the potential of improving sports improves technique because of the information it provides about the situation of the body as a whole (4,5,31). Previous studies showed medium- and long-term improvements through proprioceptive training with unstable platforms in static balance (11,25,26), gravity center control (25), effectiveness of joint movement (16), and strength parameters, such as an improvement in the onset of isometric action (13) in athletes.

Despite the benefits of proprioceptive training shown by previous research, there is no unanimous agreement in the literature regarding the association between proprioceptive training and sports performance in athletes. Lephart et al. (16) found improvements in stability and coordination of the knee after a proprioceptive exercise session, which implied greater effectiveness of the knee joint movement. This effectiveness was measured according to gait speed. Stanton et al. (27), however, found that although better stabilometry and body weight reduction were induced by a 6-week proprioceptive training program in athletes, their running technique was not improved. Likewise, Yaggie and Campbell (30) reported that proprioceptive training with unstable platforms improves proprioceptive inputs, which results in better specific strength and neuromuscular adaptation of postural control, but no significant differences were described in vertical jump. Finally, Gruber and Gollhofer (13) reported that the onset of isometric action was improved. Based on these results, their authors suggested that proprioceptive training might be beneficial for the explosive force of athletes. Despite this suggestion, Cressey et al. (8) did not observe significant differences in explosive force tasks (such as vertical jump). However, stabilometric findings were reported by Gioftsidou et al. (11), who found that a 12-week proprioceptive training program improved balance ability in sports people, and by Romero-Franco et al. (25), whose study showed improvement of postural stability and gravity center control after a 6-week proprioceptive training program.

Furthermore, few studies in the literature have assessed the short-term effects of proprioceptive exercise sessions, and they have been centered on analyzing the effects of proprioceptive training right after performance. Concerning this specific topic, during the last decade, several studies have reported that muscle activity was increased in electromyography (EMG) after proprioceptive exercise (2,4,5,17,19,21,22,28). Accordingly, muscle demand was immediately increased (18,19). Anderson and Behm (2) found that the activity of upper lumbar, lumbosacral erector spinae, abdominal muscles, and soleus muscles was increased while the athletes squatted in unstable conditions. Similar findings were reported by Vega-García et al. (28), Rodd et al. (24), and Behm et al. (4,5) who also reported that the maximum isometric force was reduced by 60% in exercises carried out on a Swiss ball as unstable platform. Likewise, Marshall and Murphy (19) reported an increase in the activity of abdominal muscle during exercises in which the instability was higher by putting some body parts out of the support base. Based on these results, it is suggested that right after proprioceptive training, muscle activity increases to compensate for the instability and to help keep the center of gravity over the base of support, thus preventing falls, which is a neuromuscular adaptation to gain a better postural control (7).

Despite the considerablenumber of studies that have assessed the short-term effects of proprioceptive training, it must be noted that all of them were focused on strength parameters (2,4,5,17,18,19,21,24,28). Thus, stabilometric data are left out even when these variables are directly related to medium- and long-term postural control because of proprioceptive training (11,13,16,25,26). Accordingly, the limitation of these studies on short-term effects was the lack of assessment of the stabilometric parameters: although they suggested that muscle activity was increased to gain postural balance, they did not analyze this potential improvement on stability (7).

To our knowledge, no study to date has evaluated the short-term effects of a proprioceptive exercise session on stabilometric measures. So far, studies have only looked into the assessment of medium- and long-term effects in stabilometric parameters (11,15,20,25–27), and the immediate effects of proprioceptive training are therefore not well known yet.

After revising previous studies, and considering the stabilometric improvements caused by proprioceptive training (11,15,20,25–27) and its immediately subsequent muscle activation (1,2,4,5,17,18,19,21,22,24,28), we hypothesized that proprio ceptive training will induce immediate improvements on the stabilometry of athletes and that such improvements will decrease until their normalization after 24 hours (something to take into account for the planning of further training). Based on the preceding arguments, the goal of our research was to determine the short-term effects that a proprioceptive exercise session with a BOSU and a Swiss ball as unstable platforms would have on the stabilometry of athletes. More precisely, our study evaluated the effects of a proprioceptive exercise session on the bipedal postural stability of athletes during the first 24 hours after a proprioceptive exercise session.

Methods

Experimental Approach to the Problem

The study had a quasi-experimental design with a control group, and it took 24 hours to complete. Six measurements were taken to analyze all stabilometric changes induced by a proprioceptive exercise session. The measurements were M_0 (before training), M_1 (immediately after training), M_2 (30 minutes after training), M_3 (1 hour after training), M_4 (6 hours after training), and M_5 (24 hours after training). Under randomized conditions, a group of athletes (experimental group) performed a 25-minute free warm-up followed by a 25-minute proprioceptive exercise session on an unstable platform (Swiss and BOSU ball). Meanwhile, the control group only performed the 25-minute free warm-up. Tests took place in February 2012, in the transitional period of the season for all athletes, where their training mostly consisted in aerobic work and strength exercises (12). The study was timed on different days because of schedule restrictions. Training started at 11 AM, and all athletes were instructed to sleep at least 8 hours the night before. Days and venues were different for the control and experimental groups to avoid them finding out which group they belonged to.

Subjects

Thirty-seven athletes from all athletic disciplines of the UNICAJA JAEN athletic club (Spain) voluntarily took part in the study. Athletes were between 17 and 33 years of age, and they were excluded if they had ever performed any proprioceptive training before or if they had any injuries at the time of data collection. Athletes were divided into 2 groups by simple random probability sampling: the "control group" composed of 17 athletes who performed a 25-minute free warm-up and the "experimental group" composed of 20 athletes who carried out a 25-minute proprioceptive exercise session in addition to the previous 25-minute free warm-up (Table 1). Research design was approved by the Ethics Committee of the University of Jaén, and written informed consent was obtained from each subject before participation according to the standards of the Declaration of Helsinki (rev. 2008). Parental consent was given for athletes under the age of 18.

Procedures

Baseline characteristics of the participants (Table 1) were initially collected by means of self-administered questionnaires in the presence of well-trained interviewers. A 100 g–130 kg precision digital weight scale (Tefal, Ecully Cedex, France)

Table 1. Sociodemographic and antropometric characteristics.*

Variable	All ($n = 37$) Mean	All SD	Control ($n = 17$) Mean	Control SD	Experimental ($n = 20$) Mean	Experimental SD	p
Age (y)	21.22	4.60	21.12	4.85	21.30	4.50	0.906
Height (m)	1.74	0.07	1.72	0.07	1.75	0.07	0.246
Weight (kg)	63.68	11.69	61.29	12.87	65.70	10.48	0.259
BMI (kg·m^{-2})	20.95	2.71	20.46	2.78	21.36	2.65	0.322
Years_training	7.08	4.47	6.29	4.16	7.75	4.71	0.330
Days_training	5.08	0.76	4.88	0.78	5.25	0.72	0.145
Gender							
Female	12	32.43%	7	41.18%	5	25.00%	0.925
Male	25	67.57%	10	58.82%	15	75.00%	
Mode							
Runner	17	45.95%	8	47.06%	9	45.00%	0.901
Jumper	17	45.95%	8	47.06%	9	45.00%	
Launcher	3	8.11%	1	5.88%	2	10.00%	
Student							
Yes	25	67.57%	14	82.35%	11	55.00%	0.077
No	12	32.43%	3	17.65%	9	45.00%	
Studies							
Primary	12	32.43%	5	29.41%	7	35.00%	0.904
Secondary	9	24.32%	4	23.53%	5	25.00%	
University	16	43.24%	8	47.06%	8	40.00%	

*Quantitative variables are shown in mean and *SD*. Categorical variables are shown in frequencies and percentages. The p values are from Student's t-test and chi-square tests, respectively. BMI = body mass index; Years_training = number of experience years in the sport; Days_training = periodicity of training sessions every weeks.

Table 2. Test-retest reliability of data.*

Variable	Intraclass correlation	95% Confidence interval	p
Ymean	0.792	0.425 to 0.925	0.002‡
Xmean	0.593	−0.124 to 0.853	0.041†
DeltaX	0.772	0.371 to 0.918	0.003‡
DeltaY	0.770	0.366 to 0.917	0.003‡
Area	0.495	−0.396 to 0.817	0.092
Length	0.721	0.230 to 0.899	0.007‡
Speed	0.720	0.226 to 0.899	0.008‡
RMS	0.744	0.294 to 0.908	0.005‡
RMSX	0.832	0.537 to 0.939	<0.001§
RMSY	0.527	−0.305 to 0.829	0.072
RMSX2	0.723	0.235 to 0.900	0.007‡
RMSY2	0.337	−0.831 to 0.760	0.210

*Interclass correlation coefficients obtained by repeated-measures analysis of variance. Ymean = mean antero-posterior position; Xmean = mean mediolateral position; DeltaX = mediolateral rate covered by the center of pressure in mediolateral plane; DeltaY = mediolateral rate covered by the center of pressure in antero-posterior plane; Area = Area covered by center of pressure; Length = Length covered by center of pressure; Speed = Speed of center of pressure; RMSY and RMSY2 = Root mean squared amplitude of the CoP in antero-posterior direction; RMSX and RMSX2 = Root mean squared amplitude of the CoP in mediolateral direction.
†Differences between groups of the same mean $p < 0.05$.
‡Differences between groups of the same mean $p < 0.01$.
§Differences between groups of the same mean $p < 0.001$.

and a t201–t4 Asimed adult height scale (Asimed, Valencia, Spain) were used to obtain weight and height, respectively.

In addition, before commencement, all athletes were taught about the correct execution of tests and training. Then, all athletes were subject to a bipedal stabilometry test (M_0). After the test, all athletes performed a 25-minute free warm-up. In addition to this, the experimental group undertook a 25-minute proprioceptive exercise session with unstable platforms. At the end of the warm-up (control group) and at the end of the proprioceptive exercise training (experimental group), the second bipedal stabilometry (M_1) was carried out. The third stabilometry was carried out 30 minutes after training (M_2), the fourth 1 hour after training (M_3), the fifth 6 hours after training (M_4), and the sixth and last 24 hours after training (M_5). Participants were asked not to engage in any physical activity until the end of the study.

Bipedal Stabilometry. A Freemed baropodometric platform (Rome, Italy) and FreeStep v.1.0.3 software (Rome, Italy) were used to measure stabilometric parameters. The platform's surface is 555 × 420 mm, with an active surface of 400 × 400 mm and 8-mm thickness. All athletes were asked to stand on both feet over the baropodometric platform for 51.2 seconds. This test measures the center of pressure (CoP) position in the mediolateral plane (Xmean) and antero-posterior plane (Ymean). It also measures the area covered by the CoP, the speed of movement of the CoP, and the length covered by the CoP. Besides, the root mean squared amplitude of the CoP in mediolateral (RMSX) and antero-posterior (RMSY) directions (in millimeters) were reported. Other measures were the CoP rate in the antero-posterior direction (DeltaY) and in the mediolateral direction (DeltaX). The reliability of data is shown in Table 2.

Proprioceptive Exercise Session. The duration of the training session was 25 minutes. Six BOSU and Swiss balls and six 3-kg medicinal balls were used for the training. The proprioceptive exercise session used 6 Swiss and BOSU ball exercises (Figure 1). The correct performance of the exercises was carefully supervised by a fitness specialist and a sports physiotherapist, who worked with groups of 6 athletes.

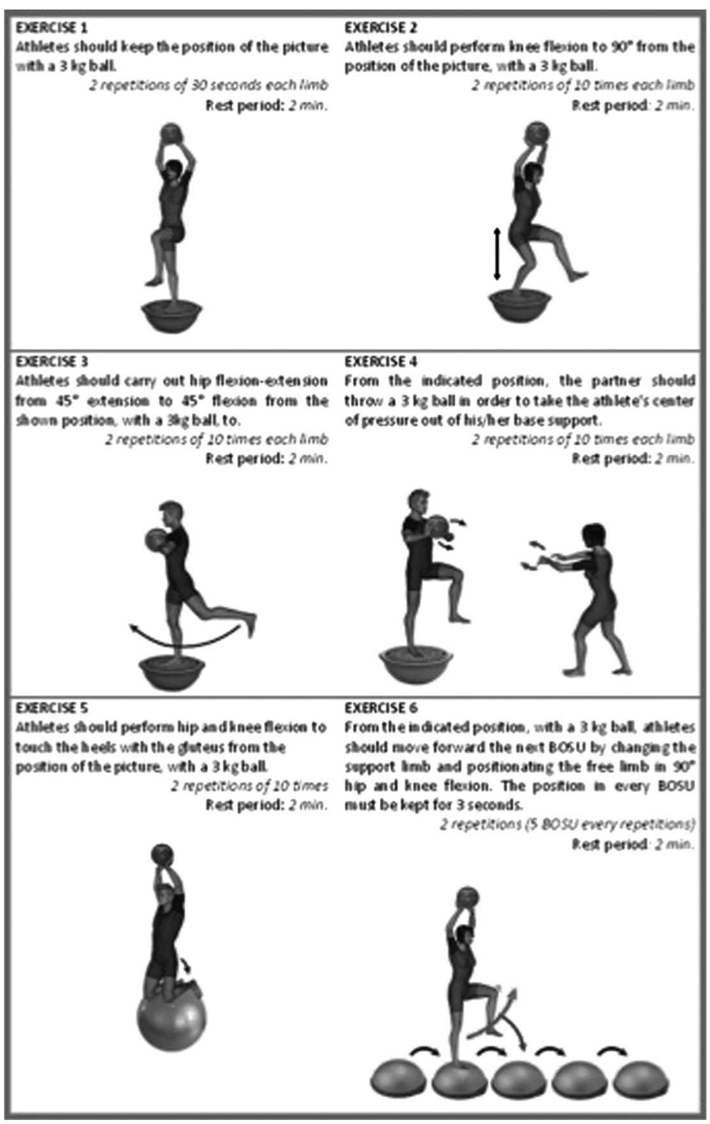

Figure 1. Proprioceptive training program performed by athletes.

Statistical Analyses

Mean and *SD* were included in the data description in continuous variables and frequencies. Nonetheless, percentages were included in categorical variables.

A Kolmogorov-Smirnov test was used to adjust the normal distribution of quantitative variables. For the demographic and morphological variables, a Student's *t*-test for independent samples was used in continuous variables and a chi-square test was used for categorical variables. The general linear model for repeated measures was used to assess the effect of the intervention groups, with time and intervention group as intra- and inter-subject variables, respectively (repeated-measures analysis of variance [ANOVA]). For the variables that showed significant baseline differences, the basal measures (pretreatment) were used as covariate. A Bonferroni test was used for paired comparisons, and significance was determined at $p < 0.05$. Data were analyzed using SPSS for Windows (version 17; SPSS, Inc., Chicago, IL, USA) and MedCalc 12.1 (Mariakerke, Belgium).

Results

Length, speed, area covered by CoP, and RMS are shown in Table 3. The covariance analysis (adjusted for pretreatment) for length and speed measures showed a group effect (p = 0.021 and 0.022, respectively). More specifically, the experimental group exhibited higher values of length and speed compared with the control group in M_1 ($p = 0.045$). These differences were higher in M_4 ($p = 0.009$). No significant differences were shown between groups in the rest of length and speed measures. No significant intra- and inter-group effects were found in area and RMS ($p > 0.05$).

In Table 4, mean results and *SD* of the area covered by the CoP in the XY plane are shown (RMSX, RMSX2, RMSY, and RMSY2). The repeated-measures ANOVA analysis showed no main group effects for any variables (p = 0.260 for the largest). Although a main time effect was found in RMSY2

TABLE 3. Mean values of length, speed, and area covered by the center of pressure and root mean squared.*

	Control ($n = 17$)		Experimental ($n = 20$)					Control ($n = 17$)		Experimental ($n = 20$)			
	Mean	*SD*	Mean	*SD*	*p*	Eta^2		Mean	*SD*	Mean	*SD*	*p*	Eta^2
Length (mm)†							Area (mm)						
Pre	383.33	60.70	326.79	57.76	Group 0.021	0.147	Pre	74.91	49.25	51.52	34.40	Group 0.159	0.056
$Post_{0Min}$‡	352.65	82.90	342.31	77.88			$Post_{0Min}$	59.09	47.41	69.56	85.21		
$Post_{30Min}$	431.72	182.54	360.11	84.41	Time 0.089	0.223	$Post_{30Min}$	169.35	286.43	61.14	53.71	Time 0.094	0.252
$Post_{1H}$	350.10	38.56	375.30	98.52			$Post_{1H}$	143.68	139.38	95.67	107.89		
$Post_{6H}$§	348.02	82.64	372.31	102.77	Group × time 0.669	0.071	$Post_{6H}$	102.78	75.28	87.93	70.77	Group × time 0.230	0.191
$Post_{24H}$	348.12	88.03	360.51	98.61			$Post_{24H}$	74.11	67.84	101.99	112.11		
Speed (mm)†							RMS (mm)†						
Pre	89.47	14.20	76.25	12.98	Group 0.022	0.144	Pre	0.40	0.06	0.35	0.06	Group 0.216	0.045
$Post_{0Min}$‡	82.44	19.23	80.54	18.17			$Post_{0Min}$	0.38	0.09	0.38	0.07		
$Post_{30Min}$	100.46	39.79	85.40	20.84	Ttime 0.106	0.212	$Post_{30Min}$	0.57	0.49	0.38	0.08	Time 0.475	0.104
$Post_{1H}$	81.54	7.90	87.78	21.93			$Post_{1H}$	0.38	0.05	0.41	0.12		
$Post_{6H}$‡	78.06	19.48	83.93	23.03	Group × time 0.669	0.066	$Post_{6H}$	0.37	0.08	0.71	1.36	Group × time 0.500	0.100
$Post_{24H}$	80.96	21.42	83.15	22.41			$Post_{24H}$	0.39	0.08	0.39	0.09		

*Length = Length covered by center of pressure; Area = Area covered by center of pressure; Speed = Speed of center of pressure; RMS = Root mean squared; Eta^2 = Eta square, a measure of the magnitude of the treatment effect; Pre = measures before the training session; $Post_{0Min}$ = measures just after the training session; $Post_{30Min}$ = measures 30 minutes after the training session; $Post_{1H}$ = measures after 1 hour after the training session; $Post_{6H}$ = measures 6 hours after the training session; $Post_{24H}$ = measures 24 hours after the training session.

†Repeated-measured analysis of variance test adjusted for baseline measurement (pretreatment).

‡Differences between groups of the same mean $p < 0.05$.

§Differences between groups of the same mean $p < 0.001$.

TABLE 4. Root mean squared in antero-posterior and mediolateral planes.*

	Control ($n = 17$)		Experimental ($n = 20$)					Control ($n = 17$)		Experimental ($n = 20$)			
	Mean	*SD*	Mean	*SD*	*p*	Eta^2		Mean	*SD*	Mean	*SD*	*p*	Eta^2
RMSX (mm)							RMSX2 (mm)						
Pre	0.30	0.06	0.37	0.46	Group 0.942	0.000	Pre	1.66	0.80	1.60	0.54	Group 0.589	0.080
$Post_{0Min}$	0.29	0.07	0.30	0.06			$Post_{0Min}$	1.62	1.05	1.61	0.79		
$Post_{30Min}$	0.45	0.46	0.32	0.14	Time 0.658	0.096	$Post_{30Min}$	2.81	3.54	1.53	0.63	Time 0.558	0.114
$Post_{1H}$	0.28	0.04	0.32	0.12			$Post_{1H}$	1.39	0.83	1.89	1.07		
$Post_{6H}$	0.29	0.06	0.30	0.07	Group × time 0.546	0.117	$Post_{6H}$	1.84	0.84	1.74	0.78	Group × time 0.151	0.221
$Post_{24H}$	0.28	0.05	0.30	0.08			$Post_{24H}$	1.36	0.70	1.73	0.87		
RMSY (mm)†							RMSY2 (mm)						
Pre	0.27	0.04	0.22	0.04	Group 0.368	0.024	Pre	2.01	0.85	1.64	0.81	Group 0.260	0.036
$Post_{0Min}$‡	0.24	0.05	0.24	0.04			$Post_{0Min}$§	1.79	0.85	1.95	1.11		
$Post_{30Min}$	0.34	0.19	0.25	0.04	Time 0.082	0.228	$Post_{30Min}$	2.59	1.23	1.80	1.12	Time 0.047	0.293
$Post_{1H}$	0.26	0.03	0.26	0.06			$Post_{1H}$	3.01	1.44	2.36	1.95		
$Post_{6H}$‡	0.27	0.04	0.27	0.07	Group × time 0.529	0.094	$Post_{6H}$§	2.59	0.76	2.29	1.11	Group × time 0.126	0.233
$Post_{24H}$	0.26	0.07	0.25	0.06			$Post_{24H}$	2.23	1.14	2.41	1.57		

*RMSY and RMSY2 = Root mean squared amplitude of the CoP in antero-posterior direction; RMSX and RMSX2 = Root mean squared amplitude of the CoP in mediolateral direction; Eta^2 = Eta square, a measure of the magnitude of the treatment effect; Pre = measures before the training session; $Post_{0Min}$ = measures just after the training session; $Post_{30Min}$ = measures 30 minutes after the training session; $Post_{1H}$ = measures after 1 hour after the training session; $Post_{6H}$ = measures 6 hours after the training session; $Post_{24H}$ = measures 24 hours after the training session; CoP = center of pressure.

†Repeated-measured analysis of variance test adjusted for baseline measurement (pretreatment).

‡Differences between groups of the same mean $p < 0.05$.

§Differences between groups of the same mean $p < 0.001$.

TABLE 5. Mean values of mean mediolateral position and antero-posterior position and mean values of mediolateral rate covered by the center of pressure in mediolateral and antero-posterior plane.*

	Control ($n = 17$)		Experimental ($n = 20$)					Control ($n = 17$)		Experimental ($n = 20$)			
	Mean	*SD*	Mean	*SD*	*p*	Eta^2		Mean	*SD*	Mean	*SD*	*p*	Eta^2
Xmean (mm)							DeltaX (mm)						
Pre	2.77	2.75	4.84	3.70	Group 0.001	0.273	Pre	8.12	3.67	8.10	2.35	Group 0.438	0.017
Post$_{0Min}$	4.06†	3.16	3.87	2.84			Post$_{0Min}$	9.87	5.88	9.47	4.17		
Post$_{30Min}$‡	2.46	1.89	5.95§	3.10	Time 0.181	0.258	Post$_{30Min}$	17.87	23.16	7.61	2.85	Time 0.089	0.255
Post$_{1H}$∥	4.13§	1.99	6.03§	2.20			Post$_{1H}$	7.29	4.07	10.70	8.20		
Post$_{6H}$	3.18	2.31	4.14	3.52	Group × time 0.016	0.350	Post$_{6H}$	8.64	3.03	9.08	4.17	Group × time 0.085	0.258
Post$_{24H}$	3.78	2.09	4.97	3.54			Post$_{24H}$	7.47	4.14	9.13	3.17		
Ymean (mm)							DeltaY (mm)						
Pre	27.34	12.32	31.80	10.28	Group 0.509	0.013	Pre	9.61	3.66	8.60	4.50	Group 0.307	0.030
Post$_{0Min}$	29.07	10.26	32.97	11.05			Post$_{0Min}$	8.26	3.85	9.07	4.33		
Post$_{30Min}$	30.18	10.19	32.53	10.85	Time 0.010	0.374	Post$_{30Min}$	14.97†	10.79	8.58	5.34	Time 0.006	0.293
Post$_{1H}$	25.96	3.67	29.73	11.67			Post$_{1H}$	12.37	6.19	10.66	6.76		
Post$_{6H}$	27.47	11.08	23.85	10.01	Group × time 0.156	0.218	Post$_{6H}$	11.43	3.56	10.97	4.72	Group × time 0.039	0.303
Post$_{24H}$	28.41	8.65	28.34	12.41			Post$_{24H}$	9.32	3.81	10.79	5.24		

*Xmean = mean mediolateral position; Ymean = mean antero-posterior position; DeltaX = mediolateral rate covered by the center of pressure in mediolateral plane; DeltaY = mediolateral rate covered by the center of pressure in antero-posterior plane; Eta^2 = Eta square, a measure of the magnitude of the treatment effect; Pre = measures before the training session; Post$_{0Min}$ = measures just after the training session; Post$_{30Min}$ = measures 30 minutes after the training session; Post$_{1H}$ = measures after 1 hour after the training session; Post$_{6H}$ = measures 6 hours after the training session; Post$_{24H}$ = measures 24 hours after the training session.

†Differences respect to pretreatment measure in the same group $p < 0.05$.

‡Differences between groups of the same mean $p < 0.001$.

§Differences respect to pretreatment measure in the same group $p < 0.01$.

∥Differences between groups of the same mean $p < 0.05$.

($p = 0.047$), the effect of interest to our investigation (group $\times$ time interaction) was not found in the variables related to the area covered by the CoP (RMSX, RMSX2, RMSY, and RMSY2, with $P = 0.151$ for the largest).

Finally, Table 5 shows the mean values of the CoP mean position in the mediolateral (Xmean) and the antero-posterior plane (Ymean), and the mean values of CoP rate in the mediolateral plane (DeltaX) and the antero-posterior plane (DeltaY). The repeated-measures ANOVA test (2 groups $\times$ 6 times) showed a main group effect and a group $\times$ time interaction in Xmean ($p = 0.001$ and 0.016, respectively). More specifically, the experimental group obtained significantly higher values than the control group in M_2 and M_3 ($p < 0.001$ and 0.010, respectively). The Xmean results were significantly higher in M_2 and M_3 ($p < 0.001$) compared with M_0 in the experimental group. Similar results were observed in the control group. The DeltaY variable showed a main time effect ($p = 0.006$) and a group $\times$ time interaction ($p = 0.039$). In the measurement taken 30 minutes after training (M_2), the experimental group remained at the mean value but the control group showed a significant increase ($p = 0.025$). No main effect and interaction were found in Ymean and DeltaX.

Discussion

The present study was designed to evaluate the effects of a 25-minute proprioceptive exercise session on the stabilometry of athletes. The results observed pointed out the presence of negative short-term effects on the stabilometry of athletes, which could be because of the potential acute fatigue caused by the demands of the proprioceptive exercise session. It must be taken into account that it lasted 25 minutes and that it implied a more demanding training session for the experimental group, and possibly with longer-lasting effects. Whereas some previous studies found, right after proprioceptive exercise session, an increase in the activity of agonist-antagonist muscles in EMG (1,2,17,18,19), which is prone to result in more stability as proved by Marshall and Murphy (18), in the present survey, the acute fatigue could have masked any positive stabilometric results.

According to our results, length and speed were significantly increased immediately after the proprioceptive program (M_1). This data could be translated as a less stable CoP. The immediate increase shown in length and speed was accentuated 6 hours later (M_4). Our data support Drinkwater et al. (9) who, apart from identifying the increase in the activity of antagonist muscles, reported short-term deterioration in sports conditioning parameters as a consequence of proprioceptive training.

Nevertheless, the lack of complete recovery might explain the negative results reported in the present study and in the sports parameters indicated by Drinkwater et al. (9). The fatigue induced by proprioceptive exercises could amount to an overload of proprioceptive inputs for the central nervous system of the athlete, thus preventing any positive benefit. Accordingly, in medium- and long-term conditions, where acute fatigue is not present, previous studies found an improvement in stabilometry and in sports parameters as a consequence of proprioceptive training (26,27). Stanton et al. (27) found that proprioceptive training improved core stability in sportsmen. Besides, Mattacola et al. (20), Stanton et al. (27), and Romero-Franco et al. (25) also found improvements on stabilometric parameters after 6 weeks of proprioceptive training.

The acute fatigue and the lack of recovery could also explain the deterioration in the mediolateral CoP position shown by our study. This parameter increased 30 minutes (M_2) and an hour (M_3) after the proprioceptive exercise session compared with the control group and with the baseline measurement. This increase could be interpreted as a more unstable medial-lateral position, which is deviated from the center in the medial-lateral plane. For this same variable, Romero-Franco et al. (25) and Bieć and Kuczyński (6) found a medium-term improvement after 6 weeks of proprioceptive training, with recovery having been completed at the moment of data collection.

Also, although any improvement of the CoP position might be because of the short-term design of the present study, the data suggest differences between the mediolateral and the antero-posterior plane, as seen in Romero-Franco et al. (25) and Bieć and Kuczyñski (6). They found medium-term improvements only in the mediolateral plane after 6 weeks of proprioceptive training, suggesting a priority in the improvement of this plane. These findings could be explained by the deterioration that the mediolateral plane suffers according to our results and a possible evolution of these parameters through time. Likewise, we did not observe any short-term effects in the antero-posterior plane as described by Romero-Franco et al. (25) and Bieć and Kuczyñski (6), who did not observe any improvement in this plane after 6 weeks of proprioceptive training. Contrary to our results, Hoffman and Payne (14) found improvements on postural sway in both the mediolateral and the anterior-posterior directions after 10 weeks of proprioceptive training. This could mean that an overall improvement takes longer to occur.

On the other hand, the control group exhibited a trend toward improvement in several stabilometric parameters at M_1. These data confirm the findings reported by Xu et al. (29), Bartlett and Warren (3), or Friemert et al. (10), who suggested that a warm-up before sports practice significantly improves proprioception and proprioceptive system performance in a general way. Besides, this improving trend was not found in later measures, supporting evidences from Miller (cited by Rabadán (23)) who no noted that the delay between warm-up and competition should be no longer than 5 minutes because of the considerable decrease of the warm-up effects in sports performance after this time.

In conclusion, contrary to our initial hypothesis, the findings of the present study suggest that a 25-minute proprioceptive exercise session can deteriorate static posturography in athletes. These findings were observed immediately after training and later became more acute in most of the affected variables. In fact, the mean position in the medial-lateral plane also suffered negative changes and resulted in a more deviated mediolateral position. These negative effects could be explained as a consequence of the acute fatigue induced by the potentially demanding proprioceptive exercise session. On the other hand, the control group showed a general trend to improve the static posturography as a consequence of the warm-up they performed.

Practical Applications

This study shows that a 25-minute proprioceptive exercise session has negative short-term effects on the bipedal postural stability of athletes. Our results also indicate the presence of a general improvement trend in the control group after a warm-up. According to our results, coaches, personal trainers, and physical therapists should take into account that, immediately after proprioceptive exercises, acute fatigue makes the athlete less stable, which is an important piece of information to plan subsequent training sessions. They should also give extra importance to the initial warm-up. Despite the negative short-term effects of a proprioceptive exercise session, this training is still recommended to be included in the training routine because of the positive medium- and long-term effects reported in previous studies conditions of no fatigue. Proprioceptive training may allow the athletes to gain better static and dynamic postural control. A better stabilometry can have important applications, not only to prevent injuries such as ankle sprains or knee injuries but also to improve sports conditioning parameters.

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References

1. Anderson, KG and Behm, DG. Maintenance of EMG activity and loss of force output with instability. *J Strength Cond Res* 18: 637–640, 2004.
2. Anderson, K and Behm, DG. Trunk muscle activity increases with unstable squat movements. *Can J Appl Physiol* 30: 33–45, 2005.
3. Bartlett, MJ and Warren, PJ. Effect of warming up on knee proprioception before sporting activity. *Br J Sports Med* 36: 132–134, 2002.
4. Behm, DG, Anderson, K, and Curnew, RS. Muscle force and activation under stable and unstable conditions. *J Strength Cond Res* 16: 416–422, 2002.
5. Behm, DG, Leonard, A, Young, W, Bonsey, A, and Mackinnon, S. Trunk muscle EMG activity with unstable and unilateral exercises. *J Strength Cond Res* 28: 30, 2003.
6. Bieć, E and Kuczyński, M. Postural control in 13-year-old soccer players. *Eur J Appl Physiol* 110: 703–708, 2010.
7. Colado, J, Chulví, I, and Heredia, JR. *Physical exercise in conditioning rooms. Scientific and medical basis for safe and healthy practice* Madrid, Spain: Médica Panamericana, 2008.
8. Cressey, EM, West, CA, Tiberio, DP, Kraemer, WJ, and Maresh, CM. The effects of ten weeks of lower-body unstable surface training on markers of athletic performance. *J Strength Cond Res* 21: 561–567, 2007.
9. Drinkwater, EJ, Pritchett, EJ, and Behm, DG. Effect of instability and resistance on unintentional squat-lifting kinetics. *Int J Sports Physiol Perform* 2: 400–413, 2007.
10. Friemert, B, Bach, C, Schwarz, W, Gerngross, H, and Schmidt, R. Benefits of active motion for joint position sense. *Knee Surg Sports Traumatol Arthrosc* 14: 564–570, 2006.
11. Gioftsidou, A, Malliou, P, Pafis, G, Beneka, A, Godolias, G, and Maganaris, CN. The effects of soccer training and timing of balance training on balance ability. *Eur J Appl Physiol* 96: 659–664, 2006.
12. Granell, JC and Cervera, VR. *Theory and planning of sports training.* Barcelona, Spain: Paidotribo, 2003.
13. Gruber, M and Gollhofer, A. Impact of sensorimotor training on the rate of force development and neural activation. *Eur J Appl Physiol* 92: 98–105, 2004.
14. Hoffman, M and Payne, VG. The effects of proprioceptive ankle disk training on healthy subjects. *J Orthop Sports Phys Ther* 21: 90–93, 1995.
15. Lephart, SM and Fu, FH. *Proprioception and Neuromuscular Control in Joint Stability.* Champaign, IL: Human Kinetics, 2000.
16. Lephart, SM, Pincivero, DM, and Rozzi, SL. Proprioception of the ankle and knee. *Sports Med* 25: 149–153, 1998.
17. Marshall, P and Murphy, BA. Core Stability exercises on and off a Swiss Ball. *Arch Physi Med Rehab* 86: 242–249, 2005.
18. Marshall, P and Murphy, B. Changes in muscle activity and perceived exertion during exercises performed on a Swiss ball. *Appl Physiol Nutr Metab* 31: 376–383, 2006.
19. Marshall, P and Murphy, B. Increases deltoid and abdominal muscle activity during Swiss ball bench press. *J Strength Cond Res* 20: 4, 2006.
20. Mattacola, CG and Lloyd, JW. Effects of a 6-week strength and proprioception training program on measures of dynamic balance: A single case design. *J Athl Train* 32: 127–135, 1997.
21. Michael, JW and Behm, DG. Not all instability training devices enhance muscle activation in highly resistance-trained individuals. *J Strength Cond Res* 22: 1360–1370, 2008.
22. Norwood, TJ, Anderson, SG, Gaetz, MB, and Twist, PW. Electromyographic activity of the trunk stabilizers during stable and unstable bench press. *J Strength Cond Res* 21: 343–347, 2007.
23. Rabadán, IC, Morente, AM, Benítez, JDS, and Guillén, MC. Theoretical and practical guidance for the application of warm-up competition in team sport. *Revista Digital–Buenos Aires* 106, 2007. Available at: http://www.efdeportes.com/efd106/calentamiento-de-competicion-en-deportes-de-equipo.htm.
24. Rodd, DW, Enzler, D, and Henning, N. Electromyografic analysis of the rectus abdominus. *Med Sci Sports Exerc* 34: 292, 2002.
25. Romero-Franco, N, Martínez-López, E, Lomas-Vega, R, Hita-Contreras, F, and Martínez-Amat, A. Effects of proprioceptive training program on core stability and center of gravity control in sprinters. *J Strength Cond Res* 26: 2071–2077, 2012.
26. Schibek, JS, Guskiewicz, KM, Prentice, WE, Mays, S, and Davis, JM. The effect of core stabilization training on functional performance in swimming. Master's Thesis, University of North Carolina, Chapel Hill, 2001.
27. Stanton, R, Reaburn, PR, and Humphries, B. The effect of short-term Swiss ball training on core stability and running economy. *J Strength Cond Res* 18: 522–528, 2004.
28. Vega-García, F, Grenier, S, and McGill, S. Abdominal muscle response during curl-ups on both stable and labile surfaces. *Phys Ther* 80: 564–569, 2000.
29. Xu, D, Hong, Y, Li, J, and Chan, K. Effect of tai chi exercise on proprioception of ankle and knee joints in old people. *Br J Sports Med* 38: 50–54, 2004.
30. Yaggie, JA and Campbell, BM. Effects of balance training on selection skills. *J Strength Cond Res* 20: 422–428, 2006.
31. Yasuda, T, Nakagawa, T, Inoue, H, Iwamoto, M, and Inokuchi, A. The role of the labyrinth, proprioception and plantar mechanosensors in the maintenance of an upright posture. *Eur Arch Otorhinolaryngol* 256: 27–32, 1999.