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Effects of a training program on stable vs unstable surfaces on postural stability

Efectos de un programa de entrenamiento en superficies estables frente a superficies inestables en la estabilidad postural

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Abstract

The training surface can modulate the body's response to training stimuli. The purpose of the article was to determine the influence of two types of training programs on stable/unstable surfaces on postural stability. 20 physically active participants with no history of lower limb injuries were randomly assigned to 3 groups (Control, Unstable Training, Stable Training), and performed supervised training in 16 sessions. Dynamic postural stability and static stability were assessed and tests were performed at baseline after completion of the training and 1, 2 and 4 weeks after the training process. The stable surface training group improved dynamic stability between the pre-test and the two first retention tests performed (p = .037, d = .780; p = .011, d = .989). The unstable training group significantly improved its dynamic stability level between the post-test and the retention test (2). The improvements found after the training session for the unstable training group do not mean an increase in stability higher than that obtained by the stable surface training group. The dynamic postural stability test seems more appropriate than the static tests for analyzing small changes related to the training of postural stability in healthy young people.

Key words: Balance; healthy subjects; biomechanics; stability training; surface.

Resumen

La superficie de entrenamiento podría modular la respuesta del cuerpo a los estímulos de entrenamiento. El propósito del artículo fue determinar la influencia de dos tipos de programa de entrenamiento sobre superficies diferentes, estables versus inestables sobre la estabilidad postural en personas jóvenes sanas. Participaron 20 sujetos físicamente activos sin antecedentes de lesiones de miembros inferiores, los cuales fueron asignados aleatoriamente a 3 grupos (control, entrenamiento inestable y entrenamiento estable). Realizaron un entrenamiento supervisado de 16 sesiones. Se evaluó la estabilidad postural dinámica y la estabilidad estática de los participantes a través de unas pruebas que se realizaron al inicio y después de la finalización del entrenamiento. Los mismos test de estabilidad se volvieron a pasar tras 1, 2 y 4 semanas después del proceso de entrenamiento. El grupo de entrenamiento en superficie estable mejoró la estabilidad dinámica entre la prueba previa y las dos primeras pruebas de retención realizadas (p = ,037, d = ,780; p = ,011, d = ,989). El grupo de entrenamiento en superficie inestable mejoró significativamente el nivel de estabilidad dinámica entre la prueba posterior y la prueba de retención (2). Las mejoras encontradas después de la sesión de entrenamiento para el grupo de entrenamiento en superficie inestable no significan un aumento de estabilidad mayor que el obtenido por el entrenamiento en superficie estable. La prueba dinámica de estabilidad postural parece más apropiada que las pruebas estáticas para analizar pequeños cambios relacionados con el entrenamiento de la estabilidad postural en jóvenes sanos.

Palabras clave: Equilibrio; sujetos sanos; biomecánica; entrenamiento de estabilidad; superficie.

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Introduction

It has been shown that both static and dynamic postural stability are an important factor in the sports practice, as deficits in this ability are related to the appearance of injuries (Hrysomallis, 2007; McGuine, Greene, Best, & Leverson, 2010; Ruhe, Fejer, & Walker, 2010; Wikstrom, Tillman, Smith, & Borsa, 2005). Static postural stability was defined as the ability to maintain the center of gravity (COG) within the base of support (BOS) in a static and straight position, either standing or sitting, while dynamic postural stability involves movement of both the BOS and the COM, and the COM is never kept within the BOS during single-limb support periods (Woollacott & Tang, 1997). This aspect has promoted the development of preventive training programs focused on the improvement of stability that have proved to be efficient (Kruger, Coetsee, & Davies, 2004; McKeon, & Hertel, 2008).

It is also been shown that some kinds of sports practice allow an improvement in postural stability (Aydin, Yildiz, Yildiz, Atesalp, & Kalyon, 2002; Bressel, Yonker, Kras, & Heath, 2007; Lephart, Giraldo, Borsa, & Fu, 1996; Wikstrom et al., 2005). Postural control can also be improved by means of different and specific balance training programs that focus on improving it (Ricotti, 2011).

Recent studies have shown that traditional approaches regarding stability training programs in which several tasks are performed involving single-leg support on different support surfaces lead to improvements in balance ability, although this type of programs ends up being boring and not very stimulating for young people (Vernadakis, Gioftsidou, Antoniou, Ioannidis, & Giannousi, 2012). For this reason, a training program has recently been demonstrated involving the use of the Nintendo Wii virtual console, making it possible to improve postural stability (Vernadakis et al., 2012).

Furthermore, most of the static tests used in the assessment of stability are carried out bi-podally, as they have proven to be insufficiently sensitive to small changes in a healthy population. These tests have been criticized for their lack of sensitivity and reliability (Guskiewicz, & Perrin, 1996), which why static postural stability in a healthy athletic population is more commonly assessed by unipedal stance tests (Bressel et al., 2007; Ricotti, 2011; Vernadakis et al., 2012). However, it has been proven that, depending on the sport, it could create differences in stability between legs (Bressel et al., 2007; Perrin, Deviterne, Hugel, & Perrot, 2002). In contrast, other studies claim that the stimulus provided by the unipedal stance does not sufficiently alter this capacity in sportsmen (Emery, 2003), or the results are too simple and unspecific (Hrysomallis, 2011; Verhagen et al., 2005), it being necessary to resort to a dynamic postural stability test (Guillou, Dupui, & Golomer, 2007).

As Ricotti (2011) suggests, it is interesting to know to what extent training is able to modify balance ability, depending on the type of activity and/or training.

So far, it has been shown that there are differences between the static and dynamic manifestations of balance among the different sport modalities, and these have been associated with the characteristics of each one (Bressel et al., 2007). It has also been found that athletes practicing modalities where they constantly work under unstable situations show better performance in unstable testing. It has also been shown that static stability improves with the execution of varied training programs (Vernadakis et al., 2012).

It was thus hypothesized that people performing stable training programs will see an improvement later due to the low specificity of the stimulus, mainly on unipedal stance tests, with no differences observed on dynamic balance tests. However, greater changes are appreciated on dynamic stability tests by participants using training routines based on highly unstable stimuli, due to the similarity of the test with the training sessions.

The objective of this study was to determine which training method, on an unstable or stable surface, leads to better results for stability manifestations after evaluating the data obtained from static and dynamic assessment tests.

Methods

Participants

Twenty 'physically active' healthy participants, 16 males and 4 females, took part in the research (20.05 ± 0.8 years, 1.77 ± 0.09 m, 72.0 ± 8.7 kg). They were randomly assigned to one of three groups: control group (CG) (n=6), unstable training group (UTr) (n=7) and stable training group (STr) (n=7).

The level and characteristics of the physical activity outside the training sessions were monitored in a personal diary that each subject filled in during their participation in the study.

Both at the moment of the study and during the six months prior to taking part in the project, participants had not suffered any back or lower limb injuries. None of them deliberately trained balance ability outside the training sessions during the course of this study. All participants were informed about the characteristics of the study and provided informed consent according to the Declaration of Helsinki (1964-2000). An approval report was also provided by the University's Ethics Committee.

Measures

The independent variable in this study was the training group (CG, UTr and STr). The dependent variables were divided based on the tests used to measure balance ability in static balance variables and the characteristics of dynamic balance.

Many articles have calculated the length of the trajectory of the center of pressure (COP) as a valid outcome measure in different balance conditions (Jakobsen, Sundstrup, Krustrup, & Aagaard, 2011), so in this study the maximum displacement of the center of pressure (COP) was extracted in the anterior-posterior (ADx) and medial-lateral (ADy) axes. The area covered by the COP was obtained from the unipedal static tests. The lineal displacements were normalized following the process described by Baydal et al. (2004), at the height of the volunteers' legs in order to find the maximum angular displacements to later calculate the maximum angular displacements (α) for anterior-posterior and medial-lateral directional indices.

Normalizing the linear movement towards an angular displacement is assuming the model is a perfect inverted pendulum, in which the effect of intervention of knee or hip joints is not interpreted. Nevertheless, we think that this interpretation avoids problems related by the different heights of the volunteers.

The variables used for the dynamic balance study were extracted from the recording of ground reaction force (GRF) signals in the three spatial axes and were calculated from the dispersion measures. Additionally, a global dynamic postural stability index was extracted from all three axes. This variable represents the ability to maintain dynamic stability, where the lower the values, the better the dynamic stability, as there are fewer oscillations of the COG. These variables were the medial-lateral (MLSI), anterior-posterior (APSI), vertical (VSI) and dynamic postural (DPSI) stability indexes; they were calculated according to the formula used by Wikstrom et al. (2005) and adapted by Wikstrom et al. (2010). Wikstrom et al. (2010) modified the original formula to normalize the DPSI and the directional indices to the body weight of each participant, dividing each data point between the body weight to make the comparison between participants easier and to improve the precision of the measurements of DPSI. Therefore, the formulas for calculating these parameters were the following, where BW represents the body weight of the participants, GRF represents the force data and S the number of data points (Equation 1-4) (Wikstrom et al., 2010):

$$MLSI = \sqrt{\Sigma[(\{0 - GRFx\}/BW)^2]/S} \quad \text{(Equation 1)}$$

$$APSI = \sqrt{\Sigma[(\{0 - GRFy\}/BW)^2]/S} \quad \text{(Equation 2)}$$

$$VSI = \sqrt{\Sigma[(\{0 - GRFz\}/BW)^2]/S} \quad \text{(Equation 3)}$$

$$DPSI = \sqrt{[\Sigma(\{0 - GRFx\}/BW)^2 + \Sigma(\{0 - GRFy\}/BW)^2 + \Sigma(\{0 - GRFz\}/BW)^2]/S} \quad \text{(Equation 4)}$$

Body weight, height and sex of the participants were recorded as control variables before starting the study.

Testing procedures

All data corresponding to both static/dynamic balance variables were recorded by a Dinascan® force platform (Piezoresistive Platform Dinascan/IBV, model 600x350 mm, Valencia, Spain). The unipedal static tests were registered at a frequency of 60 Hz, with the dynamic ones at 180 Hz. The length of the tests was 20 seconds for each one.

Unipedal static tests consisted of maintaining the position of hip flexion and knee at 90º from the leg while the other leg is fully extended (Donath, Roth, Zahner, & Faude, 2012).

In order to assess dynamic postural stability, volunteers were asked to perform a destabilizing jump with single leg reception on a platform and to try and stabilize as quickly as they could. The test used was proposed by Wikstrom et al. (2005) and Ross, Guskiewicz, & Yu (2005). The dynamic balance assessment protocol was carried out previously by performing a jump in the anterior-posterior axis. The height at which participants should perform the jumps was previously calculated following the procedure described by Wikstrom et al. (2010). In order to keep the height of the jumps constant during the tests, an elastic band, placed at ground level, was used to adjust the maximum height reached by each subject in the jumps to 50%. To carry out the test, volunteers were asked to remain just behind a line located 70cm from the center of the force platform. From this position, participants had to perform a countermovement jump just above the elastic band to land on the platform on the dominant foot and trying to maintain a stable position for 20 seconds. COP displacement and ground reaction forces were only calculated once the volunteer landed on the force platform. The jump performed during the dynamic tests had a destabilizing purpose.

Each subject randomly performed a total of three valid repetitions for each test with each leg. Average values were calculated for all study variables, both static and dynamic.

Intervention

Intervention groups performed supervised balance training 4 d/wk for a total of 16 sessions of 30 minutes, focusing on the dominant leg.

The unstable training group sessions were balanced in a such way that each 4-session block was never repeated in the same order. The stable training group sessions were not balanced, so that each 4-session block was repeated in the same order until the 16 sessions were completed. All training sessions started with a general warmup that was both static and dynamic, followed by specific training of the lower part of the body to finish up with active and passive mobility exercises. The duration of the initial and final parts was 5 minutes. The sessions of the stable training group were based on the repetition of simple balance maintenance exercises with reduced and isolated mobility in each corporal axis. All exercises were performed on a stable surface. The unstable training sessions were based on balance tasks on a BOSU ball (unstable), with large motion ranges taking the participants to extreme situations of imbalance, implying the need to simultaneously use all parts of the body in the three spatial axes in order to overcome perturbations and restore balance. The specific training part of the sessions had a duration of 20 minutes.

The exercises proposed for the unstable training group set out to considerably change the external conditions of the task by changing the goal of every exercise and the sensory input, modifying the support base (e.g. movements over the BOSU ball with one foot, changes from one foot to the other, jumps and receptions over de BOSU ball with one or two feet, etc.). In the stable training program, the tasks were planned in order to keep the external conditions as stable as possible (e.g. monopodal support with leg flexed to the front, heels rise with flexed trunk, etc.).

Statistical analysis

To find out the training effects, the baseline for stability was the data recorded in the first test prior to the intervention (pre-test). Once the balance training was completed, the effects immediately after the intervention (post-test) were analyzed, as well as the possible retention effects after the post-test in the short (1 week), medium (2 weeks) and long term (4 weeks).

Firstly, the normality of the data was verified using the Shapiro-Wilk test, and homoscedasticity by the Levene test. A t-Student test was performed in order to determine whether there were differences between males and females. Confidence intervals of the differences (95% CI) and the size effect (Cohens'*d*) were calculated to identify meaningful changes. Cohens'*d* measurements of the size effect were determined by calculating the mean difference within groups and dividing it by the root mean square of both standard deviations. The extent of the size effect was determined as small (0.4), moderate (0.41–0.7), or large (0.71).

An ANOVA test for independent measures was then performed to analyze whether there were differences between the means of the analyzed variables, taking into account the types of training. Afterwards, a post-hoc Bonferroni analysis was performed to accurately determine the differences between phases (intra-group) and groups (inter-group). The level of significance was established at $p \leq .05$. Only those results referring to variables where significant differences derived from training were recorded. Statistical analysis was performed using SPSS (version 19.0; SPSS Inc, Chicago, IL).

Results

The results of the t-test showed no statistically significant differences ($p > .05$) regarding gender for any of the variables analyzed. Therefore, during this study all subsequent statistical analyses were conducted jointly, including men and women as a single sample for each of the groups.

*Intra-group analysis***.** The control group did not show significant differences in any of the variables analyzed, both for dynamic (Table 1) and static tests (Table 2).

Table 1. Descriptive results of the variables obtained in the dynamic postural stability tests

		MLSI		APSI		VSI		DPSI	
	Group	M	SD	M	SD	M	SD	M	SD
Pre-test									
	Control	0.125	.010	0.039	.011	0.327	.054	0.349	.057
	Unstable	0.118	.013	0.038	.009	0.365	.060	0.365	.035
	Stable	0.125	.009	0.036	.010	0.331**	.061	0.357**	.057
Post-test									
	Control	0.137	.019	0.045	.014	0.331	.075	0.362	.073
	Unstable	0.127	.024	0.046#	.014	0.339*	.066	0.366	.066
	Stable	0.132	.010	0.035#	.008	0.307	.042	0.337	.040
Re-test (1 week)									
	Control	0.139	.018	0.042	.010	0.322	.090	0.354	.086
	Unstable	0.138	.071	0.048#	.017	0.324	.100	0.430	.304
	Stable	0.127	.019	0.034#	.010	0.291**	.042	0.320	.044
Re-test (2 weeks)									
	Control	0.125	.012	0.036	.009	0.285	.045	0.314	.041
	Unstable	0.123	.025	0.046	.022	0.307*	.064	0.335	.067
	Stable	0.125	.013	0.036	.011	0.286**	.022	0.315**	.022
Re-test (4 weeks)									
	Control	0.127	.013	0.034	.006	0.276	.026	0.306	.025
	Unstable	0.121	.014	0.044	.019	0.313	.074	0.340	.072
	Stable	0.125	.013	0.034	.007	0.293	.021	0.321	.020

*Abbreviations: MLSI, medial-lateral stability index; APSI, anterior-posterior stability index; VSI, vertical stability index; DPSI, dynamic postural stability index. *Statistically significant differences between post-test and re-test, ** Statistically significant differences between pre-test and re-test, # Statistically significant differences between Unstable and Stable group.*

In the unstable training group (UTr) significant differences were observed in the static postural stability variables (Table 2). The Bonferroni test showed differences between the post-test and the retention test applied in the 2n week post intervention (re-test 2 wk) in variables ADx (95% CI = -1.26 / -0.06, F = 2.556, p = 0.026, d = 0.420) and area (95% CI = -197.7 / -8.78, F = 2.663, p = 0.037, d = 0.537) (figure 1).

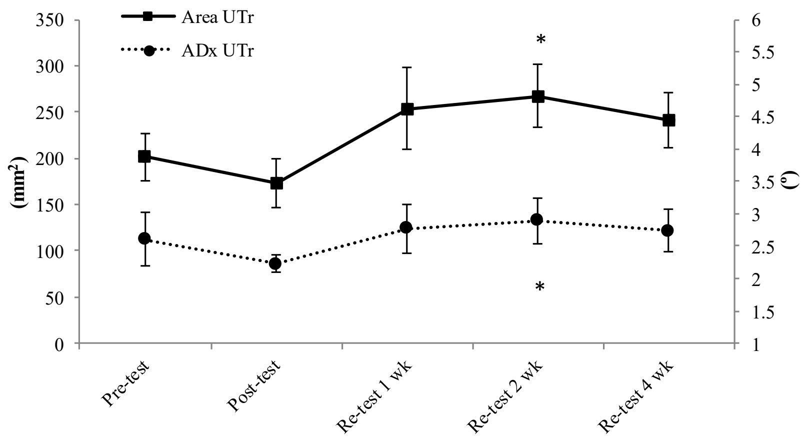

Figure 1. Significant changes in the static stability variables for the Unstable Training Group (UTr). * Significant differences between the post-test and the re-test 2.

Table 2. Results of angular displacements and area during Static Stability Tests

	Group	ADx (º)		ADy (º)		Area (mm2)	
		M	SD	M	SD	M	SD
Pre-test							
	Control	2.41	.53	2.01	.47	202.2	52.3
	Unstable	2.60	.82	1.89	.39	201.4	52.2
	Stable	2.24	.31	1.77	.24	166.0	34.2
Post-test							
	Control	2.51	.93	2.06###	.43	181.7	23.6
	Unstable	2.23	.48	1.78###	.33	172.4*	53.7
	Stable	2.23	.62	1.61###	.21	168.4	7.2
Re-test (1 week)							
	Control	2.41#	.46	1.87	.34	171.7	19.3
	Unstable	2.77#	.79	1.90	.48	253.9#	90.8
	Stable	2.04	.50	1.73	.33	158.9#	25.0
Re-test (2 weeks)							
	Control	2.71**	.51	2.17**	.20	227.2**	8.9
	Unstable	2.89**	.76	1.94**	.30	266.9*/**	68.3
	Stable	1.93**	.45	1.69**	.22	158.9**	43.3
Re-test (4 weeks)							
	Control	2.30	.46	1.98##	.25	179.0	21.1
	Unstable	2.74#	.65	1.93	.28	241.0#	60.5
	Stable	1.91#	.42	1.71##	.29	146.9#	50.7

*Abbreviations: ADx, maximum anterior-posterior angular displacement; ADy, maximum medial-lateral angular displacement measured in degrees (º). * Statistical differences between post-test and re-test, ** statistical differences between groups, # statistical differences between Unstable vs Stable group, ## statistically significant differences between Control vs Stable group, ### statistically significant differences between Control vs Stable y Unstable.*

In the dynamic postural stability tests, the Bonferroni test showed statistically significant differences in the vertical stability index (VSI) (95% CI = 0.01/ 0.08, F = 1.641, p = .045, d = .493) between the post-test and in the 2n week post intervention (re-test 2 wk).

In the stable training group (STr), no statistically significant differences were observed in any of the variables obtained from the static tests.

Statistically significant differences were recorded in the dynamic stability indices VSI and DPSI. More specifically, a certain improvement in stability in VSI was observed between the pre-test and the two first retention tests (95% CI = 0.001/ 0.079, F = 3.720, p = .037, d = .780; 95% CI = 0.006/ 0.083, p = .011, d = .989), and also in the DPSI variable between the pre-test and the 2n week post intervention test (ret-2) (95% CI = 0.004/ 0.079, F = 3.462, p = .018, d = .806) (Table 1).

Inter-group analysis. No statistically significant differences were recorded between groups in none of the static/ dynamic variables analyzed by the initial test.

Statistically significant differences were observed in the post-test for the static variable ADy between the control group and the two training groups (UTr and STr) (F = 8.276; 95% CI = 0.02/ 0.55, p = .031, d = .161; 95% CI = 0.17/ 0.72, p = .001, d = .254), as balance levels were better in the training groups. Likewise, statistically significant differences were highlighted for the dynamic stability index APSI between the unstable training group and the stable one (95% CI = 0.001 / 0.02, F = 4.569, p = .019, d = .180), the stable training group showing higher levels of stability. This behavior was repeated throughout the first retention test for variables ADx, Area and APSI (95% CI = 0.21/ 1.23, F = 6.838; p = .004, d = .205; 95% CI = 20.13/ 169.97, F = 5.930, p = .005, d = .153; 95% CI = 0.002/ 0.024, F = 4.954, p = .015, d = .174), the scores obtained by the stable training group being considerably lower.

During the 2n week post intervention (re-test 2 wk), significant differences were observed in the variables obtained by the static stability tests ADx, ADy and Area. Specifically, in the ADx variable statistically significant differences were found between the stable training group (STr) and both groups (Control and Unstable UTr) (F = 13.250; 95% CI = -1.29/ -0.26, p = .000, d = .413; 95% CI = -1.44/ -0.47, p = .001, d = .493). The same behavior was observed in the variable ADy between the stable training group (STr) and both groups (Control and Unstable UTr) (F = 11.764; 95% CI = -0.70/ -0.27, p = .001, d = .532; 95% CI = -0.46/ -0.03, p = .022, d = .267). A similar behavior was observed in the Area variable between the STr group and the Control group and UTr (F = 5.381; 95% CI = -132.58/ -4.01, p = .036, d = .236; 95% CI = -197.08/ -18.97, p = .015, d = .358).

Finally, in the last long term retention test (re-test 4 wk), statistically significant differences were observed between STr and UTr in variables ADx (95% CI = 0.38/ 1.28, F = 10.563, p = .001, d = .283) and Area (95% CI = 26.50/ 161.63, F = 6.110, p = .004, d = 1.685) as well as between the stable training group (STr) and the control group in ADy (95% CI = -0.52/ -0.01, F = 4.270, p = .037, d = .209).

Discussion

Stability training is nowadays regarded as one of the most important bases for a good physical condition improvement plan, regardless of whether we are seeking to increase an already high level of performance or just an improvement in the quality of life of elderly people, since stability has often been linked to the occurrence of injuries and the risk of falls in this population group (Verhagen et al., 2005). The present study has analyzed the effects of training methods on static and dynamic postural stability. One of them has been developed on stable and solid surfaces, employing stimuli to destabilize, while the other training program focused on destabilizing exercises on unstable surfaces. All 3 groups (stable, unstable and control) were evaluated using the single jump protocol test and single limb static tests.

It is worth noting that there were no differences between pre-test and post-test in any of the groups and tests. This could be explained by the fact that we proposed the training sessions as massed tasks, and previous studies had demonstrated that massed tasks produced worse results than distributed practice groups during both the acquisition (post-test) and retention phases (Dail & Christina, 2004; Lee & Genevesse, 1989). All the statistically significant results were achieved after a period without practicing, showing decreased performance after the end of the training program.

Intra-group analysis discussion

The intra-group results show how the unstable training group lost stability between the post-test and the results obtained in the static variables Area and ADx two weeks after the completion of the training sessions. It is true, however, that a trend towards improvement is appreciated after the training process, this being an aspect that we consider conditioned the occurrence of the differences found between the post-test and the re-test results after these two weeks. We understand that there were really no differences, as the records observed in the pre-test, post-test, ret-test 1 and ret-test 4 do not differ significantly. These results are consistent with studies that could not find significant changes to static postural stability following a training process (Holme et al., 1999; Powers et al., 2004; Verhagen et al., 2005), as the differences were found between the post-test and the re-test after two weeks and showed values very similar to the initial ones.

In this sense, Riemann (2002) concluded that the number of studies showing a positive effect in the implementation of stability training programs in patients with chronic ankle instability is about the same as those that fail to show any benefits, this being the case of our study on the unstable training group and the static variables.

One of the possible explanations as to why no stability improvements have been found by the static balance tests can be associated with the answer described by Kiers et al. (2012) who, retrieving the conclusions of Brumagne et al. (2005), explain that the stimulus produced by unstable surfaces on the muscle spindles of the sural triceps has a lesser effect on the displacements of the center of pressure (COP) when compared with rigid surfaces, so that any possible changes would not be a consequence of an improvement in the proprioception. However, it has been proven that there are other morphological and neurophysiological factors (proprioception, postural control, strength and neuromuscular response to disturbances) regulating stability with an effect on 'functional insufficiency' related to stability, as explained by Hertel (2002), that can lead to improvement.

It is also true that those who trained on an unstable surface significantly improved their dynamic stability skill ability between the pre-test and the test performed two weeks after finishing the training program in the vertical stability index variable (VSI). In this case, a trend towards maintaining the improvement over time in the dynamic tests was observed, while differences associated to training, detected by the static tests, were lost over the 2n week post intervention, returning to the initial levels after two weeks of training. We could say that there is a relation between the effect of the training method associated to the type of stimuli presented during the training routines and the kind of test used to measure stability. These results would be in line with previous studies where dynamic stability improvements are found in sportsmen who add highly unstable training situations to their exercise routine (Bressel et al., 2007; Ross et al., 2007).

Furthermore, the volunteers who undertook stable training showed no significant differences in any of the measuring tests. This lack of significance could be due to the small size of the sample, an aspect to be considered in future studies, where the number of volunteers should be increased (Hupperets, Verhagen, & van Mechelen, 2009), or simply due to the fact that no considerable changes were confirmed by the static stability tests, as shown by previous studies (Holme et al., 1999; Powers et al., 2004; Verhagen et al., 2005).

However, it is in the dynamic variables VSI and DPSI that a meaningful stability improvement of the stable training group participants was observed. This behavior is similar to the one described by the unstable training volunteers, indicating that both groups improved their dynamic postural stability regardless of the training method followed. While it is true that the training effects may be compared via dynamic tests against static ones, no significant differences were observed within each group. These results could be conditioned by the tests' own characteristics, an aspect worthy of review in future research.

The results do not show significant advantages for the unstable training group in the post-test phase nor in the retention phase, compared to the static group (Schollhörn et al, 2012), although these scores should be treated with caution due to the size of the sample in our study. Furthermore, the absence of previous research assessing the effects of these training methods limited the possibilities of comparing the results obtained in this study.

Inter-group analysis discussion

When we analyze the inter-group effects, it can be concluded that training through the application of tasks that alter athletes' postural stability produces a trend towards balance from the beginning of the training until later periods without practice in the angular displacements in the medial-lateral axis (ADy), regardless of whether the training applied is unstable or stable. These scores could be interpreted as a result of a learning process, as described by Hupperets et al. (2009), as none of the groups showed differences in this variable between pre-test and post-test, and because the effect size is considered small ($d \leq .20$) (Cohen, 1988).

The small effect size found in the inter-group analysis highlights the fact that the changes appreciated are more related to the effect of learning described by Hupperets et al. (2009) than to real improvements in stability.

However, it is true that stable training significantly reduces anterior-posterior angular displacements (ADx) when the effect size is small ($d = .493$), increasing postural stability significantly in this axis over the medium and long term. Something similar happens with medial-lateral angular displacements (ADy) and between the stable and control groups ($d = .532$). These results are in line with the trends in variable ADx found intra-group in the participants who undertook stable training.

Regarding the variability caused by each training method, we propose unstable training as the higher variability group according to their inherent neural noise. It is supposed that unstable training effects would appear after periods without training the skill, due to the occurrence of hysteresis when control parameters are not applied during the training sessions (Frank, Michelbrink, Beckmann, & Schöllhorn, 2008), resulting in a lower loss of performance compared to static training. It was supposed that, when we applied this to balance training, the static training group would obtain better results in the short term, while in the medium and long term the unstable, and more variable, training group would be the best option once all control parameters have completely disappeared, but these results are far from those expected. In this study, we observed that a static training group based on the repetition of tasks improved their balance performance over the short and medium terms, reducing the anterior-posterior and medial-lateral displacements.

Limitations

Interpreting the inter-group results, it is difficult to conclude which of the proposed training methods has a greater effect on the improvement of postural stability. Differences were found between groups according to the training method which, due to the small effect size, cannot be interpreted as an improvement associated with the type of training but with the characteristics of the participant (Cohen, 1988). Likewise, the length of the training program could be interpreted as a limitation, but previous studies have been of similar length (Behm, & Colado, 2012; Bruhn, Kullmann, & Gollhofer, 2006; Granacher, Gollhofer, & Kriemler, 2010; Granacher, et al., 2011), but these limitations should be considered in future studies.

Although the intra-group analysis shows results of greater statistical power in the above interpretation, the unstable training group being the one tending to improve vertical dynamic stability (VSI) with training. However, the results obtained by the stable training group are better, both for this parameter and for the general stability index (DPSI). The implementation of tasks that continuously push the participants to extreme situations of imbalance, the performance of exercises on unstable surfaces and the systematic variation of three spatial axes' motion ranges did not lead to an increase in stability any higher than that obtained by stable training. These results could be in line with the approaches of authors such as Davids, Glazier, Araujo, & Bartlet (2003) on the advisability (or not) of applying an excess of variability –understood as level of noise– to motor learning processes with the aim that the introduced variation does not push the athlete away from its execution under common conditions.

In the same way, the dynamic postural stability indices proposed by Wikstrom et al. (2010) seem more suitable for analyzing small changes related to the training of postural stability in young, healthy people. In contrast, changes recorded by static variables did not provide enough information to confirm the positive effect of a training method on postural stability.

Finally, we would point out that the results of this study should be compared through prospective studies to determine the effects of the diverse training methods and their relation with the assessment tests in order to design more specific protocols for the analyzed variables.

Conclusion

This paper aims to provide more information on the biomechanical response after two different balance training programs on different surfaces. While it is true that several studies have described the effects of stability training, there is no study that has analyzed the effect of different programs on different surfaces with healthy participants. We have also used different tests to see which are more sensitive to slight changes.

This paper describes the effects of two balance training programs and the retention over time of the main changes achieved after the programs.

The results mainly have a practical and clinical application, as we can then recommend a dynamic stability test that is more sensitive to slight changes in healthy people. We can also conclude that there is no clear consensus on which type of balance training is better -stable or unstable-, with stable training causing major changes in our study.

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