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ORIGINAL

EFFECT OF PROPRIOCEPTIVE TRAINING ON SPRINTERS

EFECTO DEL ENTRENAMIENTO PROPIOCEPTIVO EN ATLETAS VELOCISTAS

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ABSTRACT

Proprioceptive training is becoming increasingly integrated in sports performance, but its effects in the are under study in the present paper are still not well-known. The present study was aimed at determining the effect of six weeks of proprioceptive training on the balance, strength, and speed of sprinters. A total 33 medium-level sprinters were divided into two groups: a control group (17 subjects) and an experimental group (16 subjects). The training program in the latter group included 30 minutes a day of proprioceptive training using BOSU® and Swiss balls. Before and after the training program, stabilometry tests were completed for the horizontal (X) and vertical (Y) planes, as well as squat jumps, counter movement jumps, and a 30-meter sprint. An analysis of variance and covariance revealed a beneficial impact on postural balance in the experimental group, as well as moderate increases in jump power with no impact on the speed of sprinters.

KEY WORDS: Proprioception; speed; strength; postural stability; Swiss ball; performance.

RESUMEN

El trabajo propioceptivo está cada vez más integrado en el entrenamiento deportivo, sin embargo sus efectos en este ámbito son poco conocidos. El propósito de este estudio fue determinar el efecto de 6 semanas de entrenamiento propioceptivo sobre el equilibrio, fuerza y velocidad de atletas velocistas. Participaron 33 atletas velocistas de nivel medio que fueron clasificados en dos grupos: *control* (n=17) y *experimental* (n=16). El grupo experimental incluyó en su sesión de entrenamiento un programa propioceptivo de 30 minutos/día utilizando BOSU® y Swiss ball. Antes y después del programa se realizaron test de estabilometría en plano transversal (X) y sagital (Y), squat jump, counter-movement jump y carrera de velocidad de 30 m. El análisis de varianza y covarianza reveló efectos de mejora en el equilibrio postural de los atletas experimentales, así como incrementos moderados en la potencia de salto, que no se tradujeron en mejora de los resultados de velocidad de los atletas.

PALABRAS CLAVE: Propiocepción; velocidad; fuerza; estabilidad postural; swiss ball; rendimiento.

INTRODUCTION

Speed in athletics is particularly influenced by the amplitude and frequency of all body movements (Cometti, 2002). To improve both parameters, training must include muscle contractions at maximum intensity, correct biomechanical movements, and good stability in order to focus and maximize strength in movements (Cosio-Lima et al., 2003; Lin et al., 2007). In response to the stability factor, it has been shown that in unstable conditions force is considerably decreased (Marshall y Murphy, 2006), due to the fact that an accurate and precise contraction requires that the nervous system receives adequate information about the location and position from receptors in muscles, ligaments, joints, and skin (Behm et al., 2002 y 2003). This is called proprioception and helps perceiving conscious and unconscious sensations of muscle sense, postural balance and joint stability (Lephart & Fu, 2000).

It has been proven that athletes who cope with continued fatigue and disturbances that alter the proprioceptive system by sending distorted proprioceptive information suffer biomechanical alterations and lose movement efficiency (Yasuda et al., 1999). Authors agree that during racing, the neuromuscular spindle is the proprioceptive receptor which is responsible for movement execution, posture and maintenance of muscle tone. (Fitzpatrick et al., 1994; Ganong, 2004). It is therefore the only receptor that can be modified by the Central Nervous System through proprioceptive training (Ashton-Miller et al., 2001).

Based on this statement, and thanks to proprioceptive training and the consequent modification of neuromuscular spindles as the main proprioceptive receptors, improvements have been found in the strength of athletes at the start of an isometric action (Gruber & Gollhofer, 2004). In addition, biomechanical performance has been perfected in movements similar to the ones carried out in proprioceptive training (Ashton-Miller et al., 2001; González et al., 2011) and an increased muscle recruitment has been gained during contractile activity in exercises on an unstable platform (Behm et al., 2002, 2003; Marshall & Murphy, 2005; Anderson & Behm, 2005).

Despite previous findings in other athletes, there is little scientific evidence supporting the benefits of including proprioceptive training in the training routine of sprinters. In recent years, proprioceptive training initiatives have been undertaken using equipment such as BOSU® and Swiss balls (Stanton et al., 2004; Wahl & Behm, 2008).

The addition of proprioceptive work to athletic training has provided an important improvement in new ways of training, and in proprioceptive afferents reflected in performance such as reaction time and specific muscle strength, as well as in more stability and in the prevention of common injuries like ankle sprain (Gruber & Gollhofer, 2004; Yaggie & Campbell, 2006; Laudner & Koschnitzky, 2010). However, there are still many aspects of proprioceptive training which must be adjusted, like the type, volume and intensity of exercises.

Based on these arguments, the purpose of the present study was to analyze the effects of proprioceptive training in the balance, strength and speed of sprinters. Authors have hypothesized that proprioceptive training with BOSU® and Swiss balls as unstable platforms would increase postural balance of athletes, improving the effectiveness of lower-body muscle contraction and decreasing the time required to run the 30-meter distance.

METHODS

A quasi-experimental, pre-test-post-test control group design was used in this study. A six-week sprinter-specific proprioceptive exercise program was implemented. The study was carried out during September and October of 2010, at a time when all participant athletes were training in a pre-season period and their training consisted mainly of aerobic capacity and strength exercises.

Participants

Thirty-three medium-level male sprinters from the *Unicaja* athletic club of Jaén (age = 21.82 ± 4.84 years, height = 1.76±0.07 m, weight = 67.82±08.04 kg, body mass index = 21.89±2.37 kg_m^2), with a record that allows them to compete in regional-level events. All athletes belonged to sprint disciplines (100m, 200m, 400m, as well as 110m and 400m hurdles). All athletes with less than one year of experience and/or all those who had previously practiced proprioceptive training were excluded. Athletes were divided into two groups by means of simple random probability sampling. The control group comprised 17 subjects (age = 21.18 ±4.47 years, height = 1.75±0.02 m, weight = 65.3±9.79 kg, body mass index = 21.27±2.65 kg_m^2). This group simply continued with their daily workout routine. The experimental group, which comprised 16 subjects (age = 22.5 ± 5.12 years, height =1.77 ± 0.06 m, weight = 70.5±4.44 kg, body mass index =22.33±3.15 kg_m^2), added a sprinter-specific proprioceptive exercise protocol to their routine training.

Material

Six Swiss balls, 75 cm in diameter, six BOSU® Balance Trainers, six pairs of adjustable-weight dumbbells to fit the physique of the athlete and six pairs of three kg ankle weights were used for proprioceptive training purposes. A system of two OMRON® (Japan) photo-electrical cells and their receptors were place at the start line and the 30-meter line in order to measure running speed. In addition, an Ergo Tester Globus® (Italy) contact platform was used for jump measurements, as well as an EPS ® (Italy) baropodometric platform, which was used for the medial-lateral and anteroposterior stability tests.

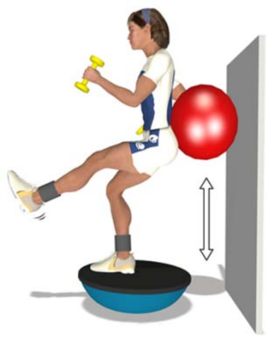
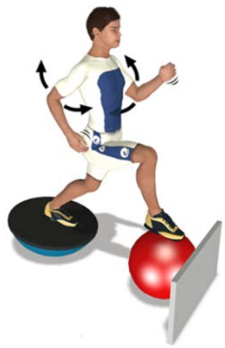
Procedure

This study was carried out during the months of September and October 2010, at a time when all athletes were training in a pre-season period with no competitions. Before taking part in the study, all subjects were briefed on how to correctly execute the tests and exercises, and were informed of the risks. Informed consent was obtained from all subjects. According to the standards of the World Medical Association Declaration of Helsinki of 1975 (2008 version), parents or legal guardians signed the informed consent form in the case of underage athletes.

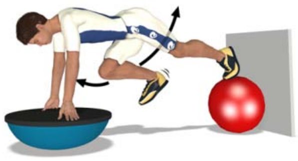
Intervention: proprioceptive training

The specific proprioceptive program was carried out three times per week during six weeks. Every proprioceptive training session took approximately thirty minutes, and included five proprioceptive exercises in each of the initial and final phases. The first phase of each exercise was carried out for the first three weeks. The second one (final phase) of each exercise was carried out for the last three weeks and consisted of the same exercises with the addition of weights to increase the intensity of exercises (figure 1). The correct execution of proprioceptive exercises and their intensity were supervised by a fitness specialist and a physical therapist with a specialization in sports injuries. To ensure the best supervision, subjects were divided into groups of ten to twelve athletes.

Athletes in the control group were asked not to include changes in their training routines and inform about any medication taken during the six weeks of the intervention period.

INITIAL PHASE – First three weeks	FINAL PHASE – Last three weeks
EXERCISE 1 *Initial phase*. From the position indicated, flex-extend shoulder. *30" for each limb.* 	**EXERCISE 1** *Final phase.* Same exercise but now each hand holds a 2 kg weight which increases by 1.5 kg every week. *30" for each limb.* 
EXERCISE 2 *Initial phase.* From the position indicated, flex-extend hip and shoulder simultaneously. *Repeat 10 times for each limb.* 	**EXERCISE 2** *Final phase*. Same exercise but now each hand holds a 2 kg weight which increases by 1.5 kg every week, and a 3 kg weight is attached to each ankle. *Repeat 10 times for each limb.* 
EXERCISE 3 *Initial phase.* From the position indicated, flex-extend shoulder . 30" for *each limb* 	**EXERCISE 3** *Final phase.* Hold the indicated position with a 10 kg bar which increases by 2 kg every week. The back leg is supported over the metatarsals. *30" for each limb.* 

EXERCISE 4
Initial phase.
The free leg does a whole circulation which ends with hip extended.

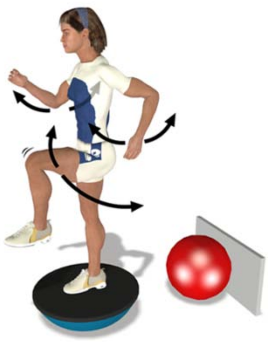


Repeat 10 times for each limb.

EXERCISE 4
Final phase.
Same exercise, but now with a 3 kg ankle weight in the free leg.

Repeat 10 times for each limb.

EXERCISE 5
Initial phase.
The free leg performs a hip, knee and ankle flexion synchronized with the high member which moves in flexion-extension.



Repeat 10 times for each limb.

EXERCISE 5
Final phase.
Same exercise but now each hand holds a 2 kg weight which increases by 1.5 kg every week and a 3kg weight is attached to each ankle.

Repeat 10 times for each limb.

Figure 1. Proprioceptive training program [created by the authors].

Measurement of results

All athletes undertook a plyometric test of squat jump (SJ) and counter movement jump (CMJ), a stabilometry and a 30-meter speed race with and without starting blocks before and after the intervention period. Before every test, all athletes performed a 30-minute warm-up, which included 10 minutes of light running and 20 minutes of stretching, progressive acceleration, unloaded full squats, and progressive height jumping.

Squat jump

This test was performed to measure the explosive strength of lower limbs in all subjects (Cressey et al., 2007). Athletes were instructed to perform a vertical jump from a position of knees bent at 90º, straight torso and hands on the waist, without countermovement and without help from the arms. Test was done three times on the contact platform with a two-minute rest between repetitions. The best try was registered.

Counter movement jump

This test was performed to measure the explosive strength of lower limbs in all subjects (González et al., 2006). Athletes performed the jump from an initial upright position with hand on the waist and a countermovement in which knees became bent at 90º. When jumping, knees had to be extended up to 180° without hyperextending the hips. Test was done three times on the contact platform with a two-minute rest between repetitions. The best try was registered.

Stabilometry

This test was performed to analyze the postural stability of subjects in the anteroposterior (Y) and the medial-lateral plane (X) according to the path described by the center of pressure (Hoffman & Payne, 1995). These stabilometric parameters inform about the mean position of the center of pressure in the medial-lateral path, in the case of variable X, and in the anteroposterior path in the case of variable Y. All athletes were positioned on the baropodometric platform with a between-heels separation of five cm and the feet forming a 30º angle. In this position, athletes had to remain motionless for 52 seconds. This routine was carried out twice: the first one with open eyes and the second one with closed eyes. FootChecker 4.0 (Italy) was the software used to analyze results.

30-meter race

A speed race was performed to analyze the acceleration and maximum speed of all subjects (Ronnestad et al., 2008, Mehmet et al., 2009). The test required running 30 meters at maximum speed on the track. Two photoelectrical cells and their receptors were placed at the start and the 30-meter lines. All athletes had two tries. The first race was performed without starting blocks, from a semi-upright position with a more advanced standing foot and the contralateral hand resting on the ground. A countermovement from that position was not allowed. The second race was performed with starting blocks. A three-minute rest separated both races.

Statistical analysis

A Student's *t*-test for independent samples was used in the initial intra-group comparison. We performed a descriptive analysis of the data, an analysis of variance ANOVA 2 (group) x 2 (time), with a Bonferroni confidence interval adjustment and analysis of covariance (ANCOVA). A Kolmogorov-Smirnov test was used to adjust the normal distribution. Jump measurement, postural stability and the 30-meter speed race were used as dependent variables, and the type of training as independent variable. We used the Pearson correlation analysis to evaluate the relationship between dependent variables. Significance level was determined at $p<0.05$ for all the statistical tests. Data were analyzed using SPSS for Windows, version 19; SPSS, Inc., Chicago.

RESULTS

Table 1 shows the descriptive statistical analysis for the before-training results. All variables had a normal distribution. Statistically significant differences between groups were found in the 30-meters speed race and the stabilometric variable X (*p* = 0,014 y *p* = 0,038, respectively).

Table 1. Descriptive data (mean and standard deviation) of all variables before and after six weeks of proprioceptive training.

efore-training Measures			
Variables (before)	**Experimental (n=16)**	**Control (n=17)**	**P value**
X (mm)	1,83 ± 4,85	-1,88 ± 5,01	0,038*
Y (mm)	0,76 ± 5,51	3,31 ± 6,11	0,220
30 m ST (sec.)	4,31 ± 0,13	4,51 ± 0,28	0,014*
30 m CT (sec.)	4,44 ± 0,12	4,58 ± 0,29	0,091
CMJ (m)	0,45 ± 0,06	0,41 ± 0,07	0,087
SJ (m)	0,42 ± 0,05	0,39 ± 0,06	0,094
Measures after six weeks of a proprioceptive training program			
X (mm)	-0,78 ± 4,31	2,30 ± 2,74	0,010*
Y (mm)	-1,10 ± 6,83	2,89 ± 4,78	0,076
30 m ST (seg.)	4,33 ± 0,12	4,39 ± 0,21	0,118
30 m CT (seg.)	4,40 ± 4,51	4,57 ± 0,27	0,072
CMJ (m)	0,46 ± 0,06	0,40 ± 0,07	0,047*
SJ (m)	0,44 ± 0,02	0,38 ± 0,07	0,032*

X (mm) = Postural stability in the medial-lateral plane (X)
Y (mm) = Postural stability in the anteroposterior plane (Y)
30 m WoutSB (sec.) = 30 meters race without starting blocks
30 m WSB (sec.) = 30 meters race with starting blocks
CMJ (m) = Counter Movement Jump
SJ (m) = Squat Jump
*Statistically significant differences (*p* < 0.05)

Variance analysis in the mean height of SJ shows that the experimental group performed higher jumps in after-training measurements (mean = 0,44 ± 0,02 m) than the control group (mean = 0,38 ± 0,07 m), (p = 0,032) (figure 2). Similar results were shown by variance analysis in the after-training measurement of the mean height of CMJ, where the experimental group reached higher values (mean = 0,46 ± 0,06 m) than the control group (mean = 0,40 ± 0,07 m) (*p* = 0,047).

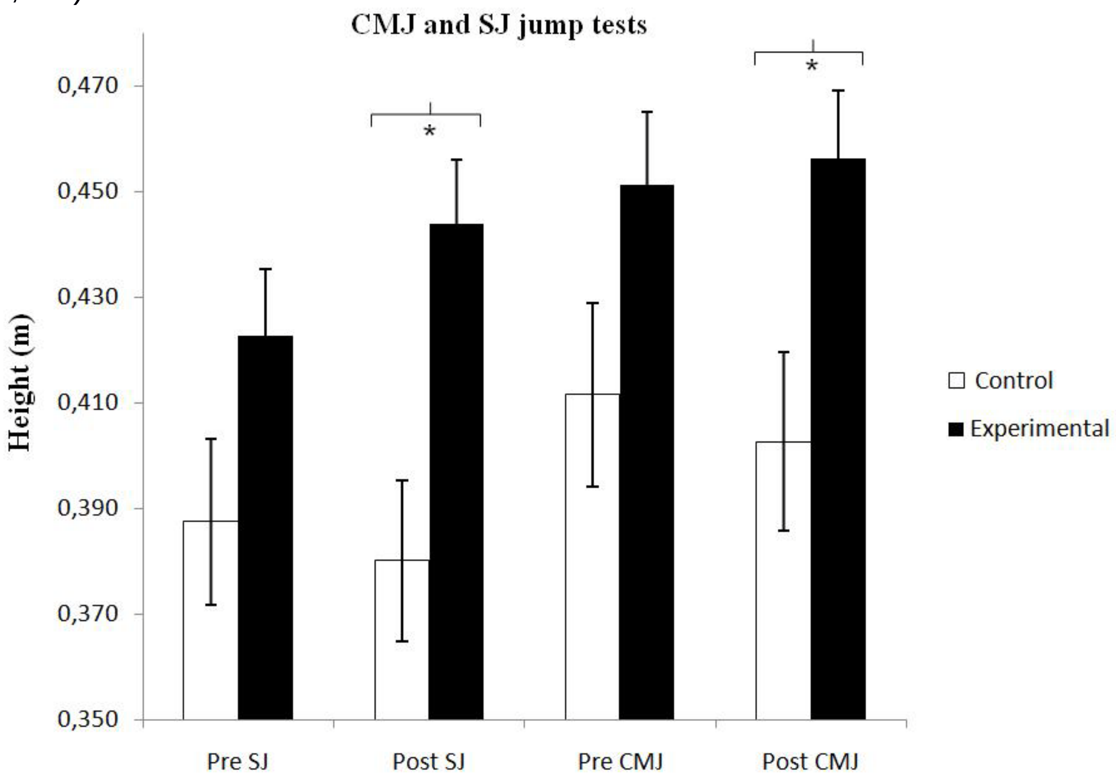


Figure 2. Graphic representation of the before- and after-training for the experimental and control groups for the squat jump (SJ) and counter movement jump (CMJ) tests.* *p* < 0,05.

On the other hand, two of the six study variables (variable X and the 30-meter speed race without starting blocks) showed statistically significant differences in the before-training measures between both groups. To equalize the initial differential effect, an covariance analysis (ANCOVA) was carried out, where before-training measures of both variables were included as covariate. This analysis showed significant differences for variable X (*p* = 0,010) favorable to the experimental group (mean = - 0,78 ± 4,31) with regard to the control (mean = 2,30 ± 2,74; figure 3). No significant differences were apparent in the analysis of the 30-meter race without starting blocks (*p* = 0,118). No main effect or interaction effect were found in the analysis of the 30-meter race with starting blocks.

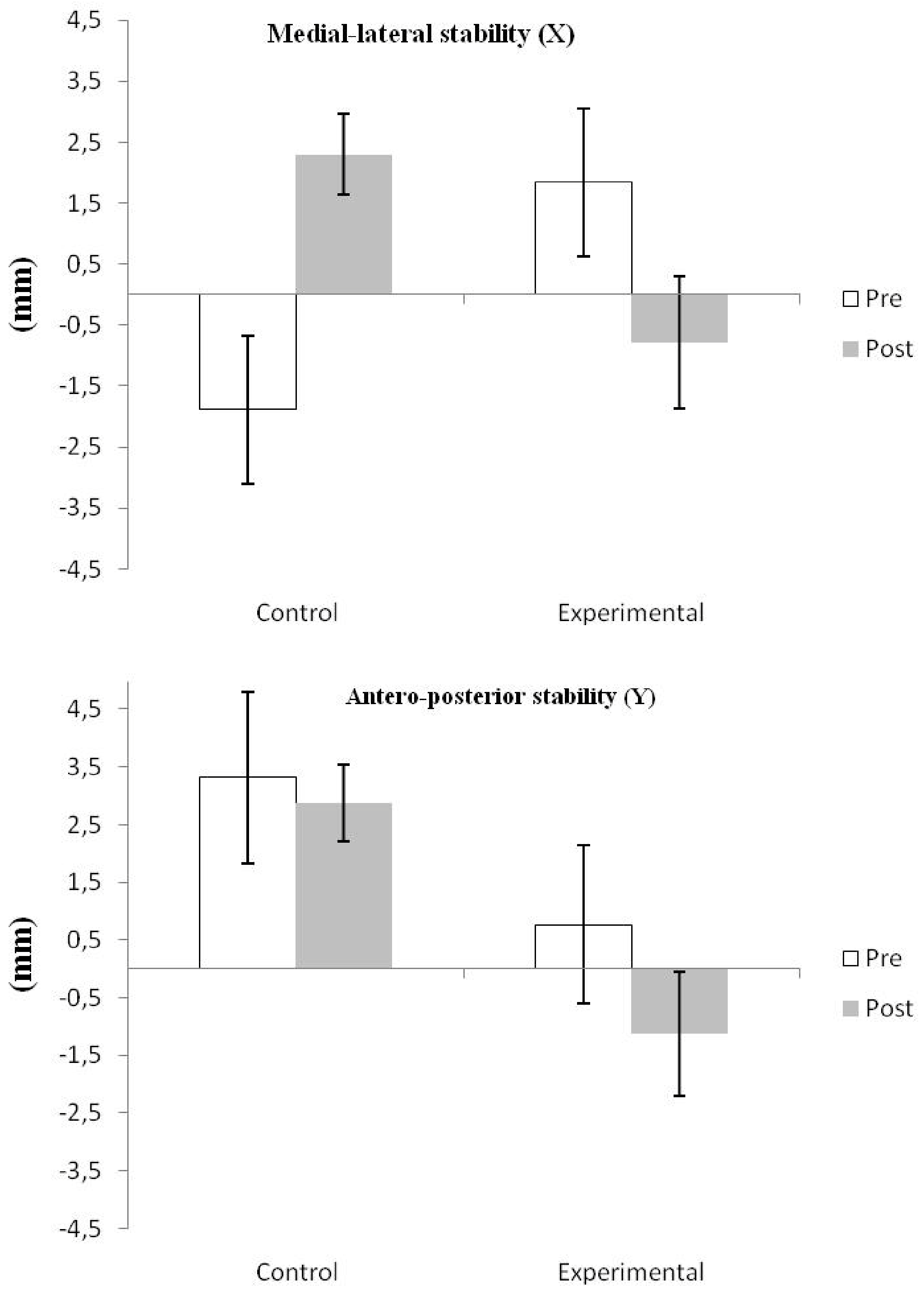


Figure 3. Graphic representation of the before- and after-training results in postural stability according to the path described by the center of pressure.

High statistically significant associations between before-training measurements of the 30-meter race with starting blocks and without starting blocks became apparent in the correlation analysis (*r* = 0,62, *p* < 0,05), and particularly so in after-training measures (*r* = 0,86, *p* < 0,01). Besides, correlations between SJ and CMJ jumps were really high in before-training measurements (r = 0,88, p < 0,001) and after-training measurements (r = 0,89, p < 0,001).

DISCUSSION AND CONCLUSIONS

The purpose of the present study was to analyze the effect of six weeks of proprioceptive training with Swiss balls and BOSU® balls in the sports performance of sprinters. Stabilometric, SJ and CMJ plyometric tests, as well as a 30-meters speed race with and without starting blocks were carried out. The reliability of the 30 meters speed race and plyometric tests as physical condition and performance was reported by Martín et al. (2001). The intervention program was tolerated by all athletes and no sign of health deterioration or injury was detected by the end of the study.

Stabilometric results showed significant differences in the medial-lateral plane (X) with an improvement from the experimental group, although no differences were found in anteroposterior plane (Y). These results agree with those of Schibek et al. (2001), Stanton et al. (2004), Gioftsidou et al. (2006), Yaggie & Campbell (2006), Huang & Lin, (2010) and Romero-Franco et al. (2012), whose surveys showed significant improvements in the postural balance of athletes after performing a training program which included proprioceptive work as the main exercise. Similar results were reported by Bieé & Kuczinsky, (2010) in soccer players, who showed medial-lateral stabilometric improvements, but not anteroposterior ones. The explanation of these results might lie in the length of the program, as Hoffman & Payne, (1995) reported anteroposterior stabilometric measurements in addition to the medial-lateral ones after ten weeks of proprioceptive training.

Plyometric tests analysis found improvements in SJ and CMJ jumps for the experimental group. Similar results were shown by Cressey et al. (2007), who found improvements in the jump of those athletes who had included proprioceptive work on unstable platforms in their training routines, although these results were also present in the group including proprioceptive work on stable platforms. In addition, the present study found a decrease in the statistical limit of the height of jumps for the control group but not for the experimental group. To explain these findings, it should be taken into account that proprioceptive training might have a mitigating effect in the decline of the explosive force of athletes. This could be a long-term benefit, given the fact that the training in the pre-season period, when the present study was carried out, mainly comprised aerobic capacity and strength work, which have been considered counterproductive for jump power and race speed (Baechle & Earle, 2007).

On the other hand, a 30-meter speed race was chosen as a standard to test the maximum speed of athletes (García-López et al., 2001; Cometti, 2002; Fernández et al., 2007). No significant differences were found in speed results after proprioceptive training. Similar results were reported by Cressey et al. In 2007, after ten weeks of proprioceptive training, where both groups, who carried out proprioceptive work on unstable platform and who carried out the same work on stable platform improved from their before-training measurements, although the stable training group had a higher percentage of improvement in a 40- yard test (3,9% from a 1,8% for the unstable platform group). In contrast with our results, Yaggie & Campbell showed in 2007 that a proprioceptive training program improved the reaction capacity of athletes, which is considered a fundamental parameter for the 30-meters speed race. An improvement in this parameter should have been reflected in the results of the present study. The difference between results could be explained by the presence of aerobic resistance, which decreases the maximum racing speed (Baechle & Earle, 2007). This could therefore mask certain improvements in these parameters.

Despite these findings, the present study had important limitations. The authors consider that sample size was enough to obtain optimal results, due to the fact that some parameters such as the Y stabilometric variable and the 30-meter speed race with starting blocks were at the statistical limit. There would have probably been statistically significant differences with a larger size sample. The duration of the intervention time was another great limitation, as it might not have allowed full adaptation of the athletes to the proprioceptive training. A complete adaptation might have been reflected in more notable improvements in the speed and jump variables.

Based on the previous information, it can be concluded that six weeks of proprioceptive training program (three days/week) comprising specific exercises for sprinters improves the medial-lateral postural balance of athletes. The proprioceptive training through Swiss balls and BOSU balls moderately increases jump power, although these improvements are not transferred to a faster racing speed. For further studies, we recommend extending the intervention period to at least twelve weeks, as well as including athletes from different competition levels and age ranges. A wider range of exercises for sprinters might also be beneficial in future research.

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