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ORIGINAL ARTICLE

Effects of a 6-week neuromuscular ankle training program on the Star Excursion Balance Test for basketball players☆

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Postural balance;
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Abstract
Background: The largest percentage of injuries in basketball affect the lower limbs, specially the ankle joint, and this is the major cause of missed days of training during a season. Moreover, ankle injuries can increase the risk factor of recurrent injuries.
Objectives: To determine whether a training program, based on specific ankle exercises for basketball, causes a change in the dynamic stability of a healthy group of basketball players, using the Star Excursion Balance Test (SEBT). Also, to determine the ideal number of repetitions to obtain a reliable measure of the test.
Materials and methods: Experimental study. Seventeen uninjured basketball players participated (8 experimental (EG), 9 control (CG)) (EG = 15.12 yrs ± 0.83 yrs//CG = 14.67 yrs ± 1.0 yrs). The EG performed the training program during the warm-up, and the CG completed the regular warm-up. The SEBT was performed before and after the 6-week training program. In statistical analysis MANOVA 2* 2 was used per group and time.
Results: Only the measurements for the Posterior–Lateral direction were significant, namely in 2 groups (CG: Mdif = 15.5, P = .002 (95% CI: 6.83–24.17 cm) EG: Mdif = 12.063, P = .014 (95% CI: 2.87–21.26 cm)). There were no differences in the SEBT between groups after the training protocol.

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Conclusions: One attempt seems to be sufficient for the completion of the test. The completion of a specific training program for healthy basketball players does not demonstrate improvements in the balance.

PALABRAS CLAVE
Equilibrio postural;
Propiocepción;
Entrenamiento;
Básquet;
Lesiones de tobillo

Efectividad de un programa de entrenamiento neuromuscular de 6 semanas de duración aplicado en el tobillo en la realización del star excursion balance test en jugadores de básquet

Resumen
Introducción: La mayoría de las lesiones que se registran en la práctica del baloncesto se localizan en la extremidad inferior, especialmente en el tobillo, y son la principal causa de ausencia en las sesiones de entrenamiento. Estas lesiones pueden repercutir en un aumento del riesgo de recidiva de la lesión.
Objetivos: Determinar si un programa de entrenamiento propioceptivo, confeccionado en base a ejercicios propios del baloncesto, podría provocar un cambio en la estabilidad dinámica de un grupo de jugadores de baloncesto, usando el Star Excursion Balance Test (SEBT) para su valoración. Determinar el número de repeticiones necesarias para la correcta interpretación del SEBT.
Material y métodos: Estudio experimental. Se seleccionaron 17 jugadores de baloncesto (8 grupo experimental [GE] y 9 grupo control [GC]); GE = 15,12 ± 0,83años; GC = 14,67 ± 1,0 años. El GE realizó un programa de entrenamiento específico durante el calentamiento, mientras que el GC completó su rutina habitual. El SEBT se realizó antes y después de 6 semanas de desarrollo del programa. Para el análisis estadístico se utilizó un MANOVA 2 * 2, por grupo y tiempo.
Resultados: Solo las mediciones para la dirección postero lateral fueron significativas en los 2 grupos (GC: MDIF = 15,5; p = 0,002; IC 95%: 6,83-24,17 cm; GE: MDIF = 12,063; p = 0,014; IC 95%: 2,87-21,26 cm). No existieron diferencias significativas entre los grupos para las demás direcciones.
Conclusiones: Una repetición del test fue suficiente. La realización de un programa específico de propiocepción para jugadores sanos de baloncesto no obtuvo mejoras en el equilibrio.

Introduction

Most of the injuries which take place in basketball occur in the lower limb.[1,2] The largest percentage of these affect the foot, the collateral ligament sprains being the most common injury.[3,4] This injury usually affects the anterior talofibular ligament (ATFL), and is the major cause of missed days of training during the season (from 1 to 3.5). In a study of 1094 players, Starkey[3] described ankle injuries as the leading cause of missed days of training (9.4%); Deitch et al.[5] found a similar relationship (18% of all injuries) when they followed professional players (NBA, WNBA) during six seasons and Borowski et al.,[1] recorded 1518 foot injuries (39.7%) in University basketball leagues.

In addition, ankle injuries can have several consequences. From a functional point of view, the risk factor of recurrent injuries should be noted, as the risk of injury for individuals with previously injured ATFL increases by five.[6] From a morphological point of view, between 55% and 72% of cases lead to osteochondritis during the year after the injury,[7] and between 10% and 50% experience residual pain in the area, due to soft tissue entrapment of the ankle joint.[8]

Tearing the ATFL of the ankle joint is caused by a combined mechanism of plantar flexion and ankle supination, usually following a jump-landing cycle.[1,9] The sport with the highest risk of this happening is basketball[10] and among risk factors that can influence this injury it seems to include gender, height, weight, age and days of training.[8,9,11]

Given this problem, especially in previously injured individuals, one of the best solutions seems to be prevention. Several authors advise carrying out a preventive program to reduce the risk of ankle injury.[12–14] Freeman et al.[15] described improvements in stability in those patients who follow an exercise program rather than simply immobilizing the area. Eils and Rosenbaum[16] and McGuine and Keene[11] have found a decrease in injuries of between 35% and 38% in subjects who follow a program of proprioception and McKeon and Hertel[17] recorded improvements in rebalancing capabilities.

Although the reviewed studies refer mainly to individuals who have been injured previously, there is no common agreement regarding the effectiveness of these preventive exercises, and so, as discussed by Fort and Romero,[18] it is important to consider the neuromotor aspects of training. For this reason, we intended to focus on healthy individuals in order to determine the influence that this type of exercise can have on players with these characteristics.

Otherwise, Witchalls et al.,[19] detected that intrinsic functional deficits in stability were related to an increased risk of ankle injury. For these reasons, good levels of body balance should be considered as a protective mechanism against ankle sprains.

The aims of this study were: firstly, to analyze the effect of carrying out a preventive exercise program on the improvement of the balance ability among a group of healthy basketball players using the Star Excursion Balance Test (SEBT) and secondly to determine the number of repetitions which are necessary in order to obtain a reliable record.

Methods

Twenty male participants (10 experimental, 10 control) were recruited from 4 competitive youth teams of Basquet Manresa S.A.E. (Spanish basketball league) to participate in this study. According to Filipa et al.,[20] the sample size was calculated prior to the study,[21] and the result showed that it was necessary to recruit 6 subjects (3 for each group) so that the statistical power was 80% and the error α 0.05. In our study, we recruited 10 subjects for each group (study and control) so that the sample was adequately powered and the participant number was increased to avoid too small sample, in case any of the subjects abandoned the study.

They all had similar levels of physical activity, both in training and in their daily lives. All subjects signed an informed consent document and the rights of the subjects were protected. The study protocol was written with respect to the Declaration of Helsinki, and the Ethics Committee Sports Government of Catalonia accepted it.

The criteria to participate in this study were to have been free from any lower limb injury for at least 6 months, no history of lower limb surgery, to be free of vestibular disorders, to be right-footed, to attend the pre- and post-test sessions and to be able to include and carry out the training program in their daily routine. The final sample consisted of 17 subjects (8 subjects for the experimental group (EG) and 9 subjects in the control group (CG)) (EG mean age 15.12 yrs, s = 0.83 yrs/mean height 178.94 cm, s = 9.50 cm/mean weight 67.54 kg, s = 13.21 kg//CG mean age 14.67 yrs, s = 1.0 yrs/mean height 183.11 cm, s = 8.44 cm/mean weight 67.14 kg, s = 10.45 kg). There were no significant differences between both groups. Three subjects left the study before its completion as they were not able to attend on all the training days (the statistical power calculated retrospectively from α = 0.05 is shown in the statistical analysis). Their leg length was also measured as part of the study, from the anterior superior iliac spine (ASIS) to the lateral malleolus.[22] For the distribution of subjects into groups (experimental/control), participants were matched into pairs according to SEBT pre-test scores and anthropometric values (with the aim that each pair should be as similar as possible) and finally randomly placing each member of the pair either into the study or control group. When the two groups were constituted, no initial significant differences between the two (P > 05) were observed (Table 1).

Before starting the study, the participating candidates, together with their parents or legal guardians, were informed about the conditions of their participation. All participants and parents (in case of a minor) received and signed an informed consent form. None of the participants received any sort of monetary or in-kind reward for their participation in this study. The first day, and before the start of the first test, the participants' anthropometric measurements were recorded to confirm that they fulfilled all the necessary conditions to be included. Participants were placed into either the control group or the experimental group. Their height and weight were matched thus trying to avoid any alteration that their different measurements might have caused.

Participants in the study took the pre-test during the first week of the pre-season. From that moment, the experimental group underwent a 6-week proprioception training program at the rate of 3 weekly sessions. This program was carried out during the warm-up of the training session and was supervised by a previously instructed coach, while the control group simply carried out the usual warm-up session. All coaches were previously instructed by the main researcher about the training program, and follow-up sessions were held every two weeks by the main researcher. Participants continued with their daily routine without changing any of their usual habits and maintaining a similar level of physical activity and sport. After 6 weeks the post-test evaluation was performed.

The training program consisted of performing an exercise program of joint coordination, strength, balance and specific basketball skills (Table 2). During the course of the training program, the exercises became more difficult by increasing their duration by 15 s every two weeks. Thereby, the time increased from the initial 30 s at the beginning to 45 s after two weeks and finally a whole minute after four weeks. The number of series was equally increased by adding two additional series every two weeks. Similar protocols have been proposed by other authors.[13,14,23] The choice of exercises was conditioned by the fact that they should not involve any financial cost.

To evaluate the dynamic stability level, the SEBT was used. 4 strips of sticky tape were placed on the floor, 45 degrees apart, forming a star. The subjects remained in a standing position, placing their bare right foot (with the tip of the 2nd phalange) in the midpoint of the star, in a similar fashion as described in previous studies.[20,24–29] They were instructed to keep their arms to their body sides.

During the execution of the test, participants were asked to touch the farthest point possible with the tip of their left big toe in each of the 5 directions indicated (anterior (A), anterior lateral (AL), lateral (L), posterior lateral (PL), and posterior (P) (Fig. 1). These directions were chosen so as to unbalance the individual in a lateral direction, displacing the center of gravity (COG) laterally, thus forcing the mechanism of foot inversion. The invertor muscles, in a closed kinetic chain, play an important stabilizing role when the COG moves in a lateral direction with respect to the midline of the body.[30,31] Each of the participants made 3 practical

Table 1 Anthropometric measurements of the sample ($n = 17$).

Variable	Experimental group[a]	Control group[a]	*P* value
Age (years)	15.12 ± 0.8	14.67 ± 1.0	.17
Height (cm)	178.94 ± 9.5	183.11 ± 8.4	.95
Mass (kg)	67.54 ± 13.21	67.14 ± 10.4	.35

[a] Values are mean ± SD.

Table 2 Training programme performed during the warm-up, structured in five phases.

Walking exercises (15 meters line)	Standing exercises (maintaining)	Unipodal standing exercises (maintaining each limb)	Plyometrics (5 repetitions of each one)	Performing basketball movements (15 meters line)
Tip-toe	*On a pillow*	*Without any element*	*Jump-reception forward*	*Moving like defending action*
On the heels	*On a basket ball*	*With a tennis ball under the calcaneus*	*Jump-reception backward*	*Moving like defending action against another player*
On the lateral side of the foot	*On a BOSU*	*With a tennis ball under the metatarsus*	*Jump-reception band side*	*Running backwards*
Heel-toe			*Jump-reception standing on a pillow*	*Running backwards against another player*
Backwards	*In pairs: Improve level throwing a ball*	*In pairs: Improve level throwing a ball (with the tennis ball under the heel/metatarsus)*	*Jump-reception on a pillow unipodal standing*	*In pairs: running laterally/backwards throwing a ball.*
			Improve level throwing a ball when reception	

trials before the register trials, and finally made 6 attempts in all directions, following Hertel's instructions.[26] To ensure the proper execution of the test, participants received two direct orders: (1) not to raise their right heel at any time, and (2) not to put their weight on their left foot during the exercise. With the intention of avoiding any kind of knowledge about the test, no type of prior demonstration was carried out; subjects were only verbally encouraged to reach the maximum distance possible, in accordance with the recommendations made in previous studies.[13,32] The sample was not normalized regarding either height or weight given that significant differences were not found between the two groups ($P > 0.05$).

Statistical analysis

The normal distribution of the sample was shown with the Shapiro–Wilk test. The temporal stability (reliability) was analyzed in the pre-test, by comparing the different pairs of basketball players with the *Spearman Rank Correlation Coefficient (rho)* and the overall 6 repetitions with *Kendall's W*. Internal consistency was assessed using *Cochran's coefficient alpha*, from the maximum distance recorded in the pre-test in each of the directions. Measurements recorded in each direction were considered as dependent variables. The analysis of the sample size was made using the G Power 3 software, assuming the mean difference would be a 10% improvement and the standard deviation would be of 7.5%.

The study was analyzed using a repeated measures analysis of variances (ANOVA 2 × 2: two groups (experimental–control) and two times (pre-training and post-training). The level of statistical significance was $P = 0.05$. Statistical analyses were performed using the programs PASW Statistics v18.0 © (IBM Corporation, NY) and Microsoft Excel 2007 © (2011 Microsoft Corporation).

Results

The statistical analysis of this study does not demonstrate any significant differences between the two groups (CG, EG) or between the two different times (pre or post) for the following directions: anterior (CG: Mdif = 1.82, $P = 0.508$; EG: Mdif = 0.063, $P = 0.983$); anterolateral (CG: $P = 0.697$, Mdif = 1.11; EG: Mdif = 0.312, $P = 0.918$); lateral (CG: Mdif = 1.33, $P = 0.591$; EG: Mdif = 0.563, $P = 0.830$) and posterior (CG: Mdif = 6.33, $P = 0.163$; EG: Mdif = 7.06, $p = 0.163$). Despite these results, there are significant differences between the times for the posterior lateral direction (CG: Mdif = 15.5, $P = 0.002$ (95% CI: 6.83–24.17 cm) EG: Mdif = 12, $P = 0.014$ (95% CI: 2.87–21.26 cm)), the control group being the one which shows a significant improvement in the post-test (Table 3).

Table 3 Mean and standard deviation of the reach distances in (cm), according to group (experimental or control), and time (pre or post). Significance (*P*) of the intervention per group and time.

Pre-test ($n = 17$)		Post-test ($n = 17$)		Significance effects			Evolution	
CG ($n = 9$)	EG ($n = 8$)	CG ($n = 9$)	EG ($n = 8$)	Main effects		Interaction	CG	EG
				Group *P* value	Time *P* value			
ANT[a]								
81.2 ± 9.55	83.19 ± 8.92	83.11 ± 7.21	83.13 ± 12.91	$F = 0.049$ $P = 0.828$ SP = 0.055	$F = 0.201$ $P = 0.660$ SP = 0.071	$F = 0.231$ $P = 0.638$ SP = 0.074	Mdiff = 1.82 $P = 0.508$ SP = 0.097	Mdiff = 0.063 $P = 0.983$ SP = 0.050
AL[a]								
73.67 ± 9.46	77.25 ± 10.92	74.78 ± 6.01	76.94 ± 12.80	$F = 0.427$ $P = 0.524$ SP = 0.094	$F = 0.038$ $P = 0.848$ SP = 0.054	$F = 0.122$ $P = 0.732$ SP = 0.062	Mdiff = 1.11 $P = 0.697$ SP = 0.051	Mdiff = 0.312 $P = 0.918$ SP = 0.066
L[a]								
64.94 ± 10.46	66.37 ± 7.34	66.28 ± 5.11	66.94 ± 7.96	$F = 0.092$ $P = 0.766$ SP = 0.059	$F = 0.287$ $P = 0.600$ SP = 0.079	$F = 0.047$ $P = 0.831$ SP = 0.055	Mdiff = 1.33 $P = 0.591$ SP = 0.048	Mdiff = 0.563 $P = 0.830$ SP = 0.055
PL[a]								
86.39 ± 9.64	86.94 ± 13.00	101.89 ± 11.14	99.00 ±12.65	$F = 0.06$ $P = 0.811$ SP = 0.056	$F = 21.606$ $P < 0.0005$[b] 95% CI: 7.46–20.1 SP = 0.991	$F = 0.336$ $P = 0.571$ SP = 0.084	Mdiff = 15.5 $P = 0.002$[b] 95% CI: 6.83–24.17 SP = 0.945	Mdiff = 12.063 $P = 0.014$[b] 95% CI: 2.87–21.26 SP = 0.743
POST[a]								
102.83 ± 17.36	99.06 ± 13.22	109.17 ± 8.82	106.13 ± 11.66	$F = 0.386$ $P = 0.544$ SP = 0.090	$F = 4.099$ $P = 0.061$ SP = 0.474	$F = 0.012$ $P = 0.914$ SP = 0.051	Mdiff = 6.33 $P = 0.163$ SP = 0.257	Mdiff = 7.06 $P = 0.163$ SP = 0.279

Abbreviations: CG, control group; EG, experimental group; ANT, anterior; AL, anterolateral; LAT, lateral; PL, posterolateral; POST, posterior; SP, statistical power.

[a] Average of 6 attempts expressed in cm (±SD).

[b] Significant at $P < .05$.

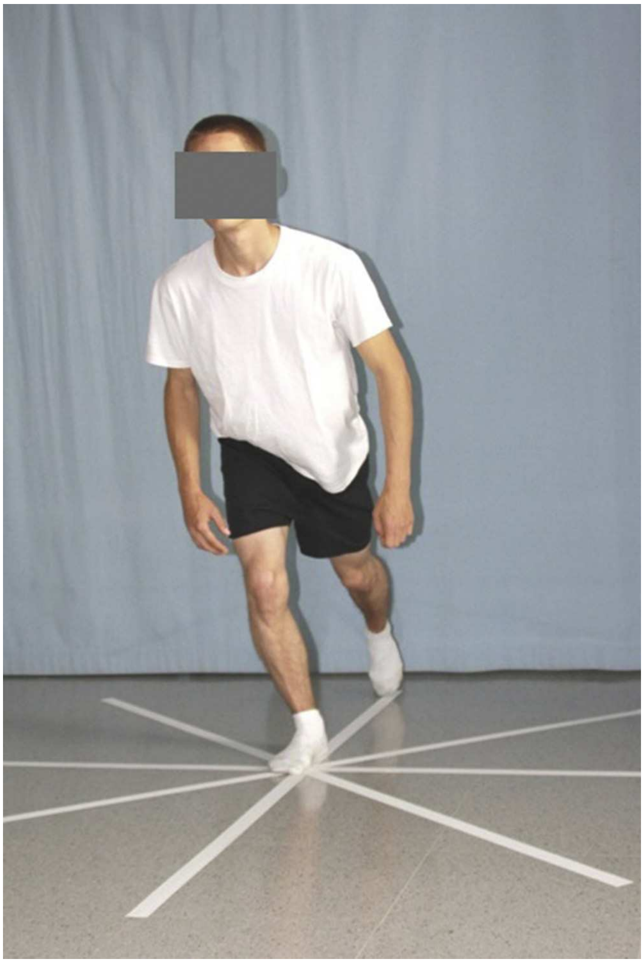

Figure 1 Participant performing the Star Excursion Balance Test.

Also, the measurements showed similar results in all instances, except for the attempts 1–6 in the AL measurement (*Spearman rho* = 0.287) and attempt 3–6 in the PL measurement (*Spearman rho* = 0.464).

Regarding the assessment of internal consistency, a statistically significant association between the items was found, without any redundancy between them (*Cronbach* alpha = 0.803).

Discussion

The *Star Excursion Balance Test (SEBT*) has been widely used as a means for assessing the degree of dynamic stability due to the simplicity of its technical and instrumental applications. Confidence intervals 0.84–0.92,[27] from 0.82 to 0.87,[29] and 0.80 to 0.93[13] have been reported in this test. Regarding the reliability of the test, its temporal stability in the sample studied was analyzed giving the result of a Cronbach alpha of 0.803. Several authors have used this method as a predictive test for the appearance of injuries[28] and also for the analysis of lower limb dynamic stability.[24,32,33] According to Munn et al.[30] people with a previous ankle injury have an eccentric deficit of the ankle musculature during inversion movements, which leads to greater instability. In the same way, Wilkerson and Nitz[31] suggested that in this position, when the COG is displaced laterally, this type of muscle contraction acts as a stabilizer of the foot in closed kinetic chain movements, avoiding the sharp fall of the foot in inversion which generally leads to injuries. During the performance of the selected directions, the foot always tries to stay flat, and in contact with the ground. When the COG moves laterally, the invertor muscles start to work eccentrically in order to maintain the medial arch of the foot and the rearfoot in contact with the ground. This contraction slows down the lateral displacement of the body's COG, compensating the moment of force generated (torque) and avoiding the inversion position. In this study, 5 of the possible directions were evaluated, waiting that in these directions; the foot invertor muscles should be working eccentrically. Unfortunately, no significant improvements were found.

Improved levels of stability seem to appear between 4 and 8 weeks of specific training depending on the number of weekly hours applied in the program, the most common being between 3 and 5 days a week.[10,14,17] Hubscher et al.[23] on the other hand suggested that it is necessary to spend a minimum of 10 min per session, more than once a week, and for a minimum of 3 months for improvements to be visible. Matsusaka et al.[34] found that the maximum improvement occurs during the 6th week of the program when 5 sessions are carried out per week. In our study, the duration of the program was 6 weeks and was made to coincide with the duration of the pre-season and the application of 3 times a week coincided with the number of weekly training sessions of the different teams on which the participants of the study played. Although in his latest review Gribble et al.[35] confirmed the positive effect of a training program in implementing the SEBT, even in healthy individuals, it has to be taken into consideration that the subjects in those studies were not active athletes, which could explain the non-occurrence of those changes in our study. Failure to find significant differences between the two groups may be due to several reasons: As Steffen et al.[36] attested, the intensity of the exercises may not be a sufficient stimulus to generate changes in balance in our sample. This fact suggests that it is essential to bear in mind both the type of people who participate in the test as well as their fitness level when creating specific programs to improve balance. As Fort and Romero[18] point out in their review, the specific training chosen according to the study sample and the subjects' sporting abilities is a very important factor to consider when designing protocols for prevention and rehabilitation. Yaggie and Campbell[14] suggested that the lack of chronic ankle instability (CAI) can be the cause of not finding any changes. Similar conclusions were drawn by Demura and Yamada[24] and Munro and Herrington,[27] which did not find any significant differences when comparing the records obtained in healthy participants. It could also be conducted including core in the training programs to provide better results.[35]

Furthermore, levels of dynamic balance measured in the participants of this study during the completion of the pretest were similar, which confirms the homogeneity of the sample. Some variations can just be observed by analyzing the results of the post-test for the PL direction, both in the study group and the control group. The sample was exclusively male, since there seems no evidence that the gender of the sample used has any impact on test results.[8,27]

On the other hand, the results of our study seem to indicate the existence of a good internal consistency in the various records obtained, with a great balance between the 5 directions measured, giving weight to the sample used for the study and confirming the chosen test as a reliable tool. The results obtained in this study concur with the studies of Olmsted et al.[28] and Mckeon et al.,[17] which stated that the posterior lateral and posteromedial directions were the ideal ones to demonstrate the evolution in balance, probably because they involve the twisting of the torso. Similar results were also obtained by Filipa et al.,[20] McKeon et al.[17] and Yaggie and Campbell,[14] who found significant improvements in the posterior lateral and posteromedial directions in their respective studies, but not for the other directions tested. In contrast, Sefton et al. [32] did not find significant differences in the test conducted on injury free individuals and individuals with ankle instability, since strategy, strength and muscle control are important for its correct execution.

Regarding our results, we can suggest that the training sessions were enough stimuli to increase the rebalancing capability of these healthy players. Even if they do not have to use a specific time to develop this capability, they could train other aspects concerning the technique of the sport. In this regard, however, it is important to note that it is possible that training can reduce injury risk factors[18] and so this is why the specific tasks of the sample must be focused on. By the results obtained in our study, we can say that one attempt was enough to get a reliable record, as conducting more repetitions could lead to the onset of fatigue, especially when this occurs in the hip muscles.[33,37] On checking temporal stability, it can be shown that all attempts are very reliable in each of the directions (A: *Kendall's* $W = 0.941$; AL: *Kendall's* $W = 0.685$; L: *Kendall's* $W = 0.825$; PL: *Kendall's* $W = 0.806$; P: *Kendall's* $W = 0.907$). These results agree with those obtained by Hertel et al.[26] and Demura and Yamada,[24] but contradict the findings reported by Munro and Herrington,[27] who considered that measurements were not stabilized until the 4th attempt, and recommend 18 sessions of 6 attempts each to achieve a reliable result. Fatigue[33] may explain some of our results (attempt 1–6 AL *Spearman's rho* = 0.287; attempt 3–6 PL *Spearman's rho* = 0.464).

This study had the limitation that electromyography techniques were not used. Although small improvements were found in SEBT in our study, other changes in the pattern of muscle recruitment could turn up. Future studies using electromyography should be performed.

Conclusions

The results obtained in our study do not show a significant difference between the experimental and control groups in the SEBT for the A, AL, L, and P directions. However, they are significant for the PL direction in the post-test of both groups. One attempt seems to be sufficient for the completion of the test. The PL direction seems to be the most important for showing the possible evolution of the different test records obtained in the pre-test and post-test.

The protocol of this study was approved by the Clinical Research Ethics Committee of the Sports Government of Catalonia.

Conflict of interest

The authors declare that there is no conflict of interest.

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