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ORIGINAL

POSTURAL EVALUATION AND BALANCE ANALYSIS IN NORDIC SKIING BEGINNERS

EVALUACIÓN POSTURAL Y ANÁLISIS DEL EQUILIBRIO EN PRINCIPIANTES DE ESQUÍ NÓRDICO

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ABSTRACT

Cross-sectional study with evaluation of postural control before and after a course of initiation to Nordic skiing (5 days, 6 hours per day). The sample consisted of an experimental group of 25 subjects participated in the training and a control group of 8 subjects. It is intended to evaluate the effect of initial training of Nordic skiing on postural control in young athletes. The physical stability was evaluated by a stabilometric test, calculating the deviation of the area of the center of pressures by the use of a force platform with electronic sensors. No significant differences were observed in the degree of improvement of the balance between the experimental group and the control group. New studies with a greater emphasis on training in Nordic skiing and a greater number of subjects in the control group are required.

KEYWORDS: Postural control, balance, Nordic skiing, force platform, center of gravity.

RESUMEN

Se trata de un estudio de diseño transversal con evaluación del control postural antes-después de un curso de iniciación al esquí nórdico (5 jornadas, 6h/día), a un grupo experimental de 25 sujetos, participantes de la formación, y un grupo control de 8 sujetos. Se pretende evaluar el efecto de un entrenamiento inicial de esquí nórdico sobre el control postural en jóvenes deportistas. La estabilidad corporal se evaluó por medio de un test estabilométrico, calculando el área de desviación del centro de presiones por medio de una plataforma de fuerzas con sensores electrónicos. No se aprecian diferencias significativas en el grado de mejora del equilibrio entre el grupo experimental y el grupo control. Nuevos estudios con una mayor exigencia en la formación en esquí nórdico y un mayor número de sujetos en el grupo control son requeridos.

PALABRAS CLAVE: Control postural, Equilibrio, Esquí nórdico, Plataforma de fuerzas, Centro de gravedad.

INTRODUCTION

Background and state of the question

We humans are never in a state of perfect mechanical balance, due to the fact that we do not possess a static, rigid body; rather, it is in constant imbalance. We might define the concept of balance as the ability to maintain the body's mass centre position on the support base (Lephart, 2000). The perpetual quest for what we call stability or postural control (Ageberg, 2003) is a property of our bodies which consists of permanent pursuit of balance when such balance is disrupted, that is, a tendency to return to the initial position (Pierre-Marie & Weber, 2001).

Postural control during deambulation, bipedestation or sedestation represents the human being's ability to maintain the centre of pressure (COP), which coincides with the perpendicular projection of the centre of gravity (COG), within the stability limits (Fort, De Antolín, Costa, Massó, Rueda & Lloret, 2009). The stability limits are borderlines of an area in space in which the body may maintain its position without altering the support base; these limits are not fixed and change in accordance with the subject's activity conditions, the situation of the locomotive apparatus, emotional states and other environmentally related aspects (Romero-Franco, 2013). If at any time the COP is located outside the stability limits, the subject will inevitably fall unless a sudden correction manoeuvre is carried out. The system of balance prevents fall by means of constant posture adjustments in bipedestation and minimises destabilising influences such as gravity or other force vectors. In order to maintain postural control, the nervous system uses sensorial information provided by three sources (Hewett, Paterno & Myer, 2002): the peripheral mechanoreceptors, eyesight and the vestibular system. Furthermore, different strategies exist for maintaining balance, such as the ankle strategy and the hip strategy (Herdman, 1989; Bernal, Faus & Bernal, 2006; Herman, Barton, Malliaras & Morrissey, 2012), which vary depending on the intensity of the destabilising stimulus and prevent the COP from falling outside the stability limits. The ankle strategy rotates the body around the tibio-astragaline joint, thereby producing mainly anteroposterior stress. The hip strategy concentrates movements around this joint and is generated when the support base is small and when the COG moves rapidly towards the stability limits, producing mainly mediolateral stress.

Stabilometry. Application to sport

Stabilometry consists of the evaluation of postural control on a force platform (Ageberg, 2003). Previous studies show that measurement by means of the force platform in the realm of sport cannot be entirely representative, given the fact that a dynamic component exists in the measurement of the subject and displacement of the centre of gravity may be altered by movements of the subject's foot or even by a change in the configuration of the parts of the body (Thomas & Whitney, 1959). In some platforms the static and dynamic components are therefore separated (Spaepen, Fortuin & Willems, 1979). In some other more recent studies postural control tests have been tried out using stabilometry in order to clinically measure the functional intensity of the lower extremities (Shiraishi, Mizuta, Kubota, Otsuka, Nagamoto & Takagi, 1996; Birmingham, 2000). Thus, after many reliable stabilometry test-retests have been conducted, a correlation ranging from moderate to excellent has been revealed when it comes to measuring body stability with a force platform (Ageberg, 2003; Birmingham, 2000) although, on the other hand, different measurement protocols have been developed, a fact which hinders subsequent data comparison (Friden, Zätterström, Lindstrand & Moritz, 1989; Shiraishi et al., 1996; Birmingham, 2000).

Stability analysis or postural control has been widely used in the clinical realm (Matsusaka et al., 2001). Its use in the sport sphere focuses principally on lesion evaluation for the sake of prevention or subsequent treatment (Freeman et al., 1965; Tropp, Ekstrand & Gillquist, 1984; Leanderson, Eriksson, Nilsson & Wykman, 1996; Romero-Franco, 2013).

The present paper sets out to apply stabilometry to the field of sports training, specifically to Nordic skiing, a sport in which balance is an essential performance component, above all at the beginner stage (Funollet, Inglés, Gomila & Funollet, 2013; Funollet & Inglés, 2014). To this end, we sought to verify whether or not a five-day initiation course into Nordic skiing might improve the postural control of the participating subjects through pre-analysis and post-analysis of the stabilometric parameters.

METHOD

Design

Intervention study of transversal design, with two analysis groups: an experimental group and a control group. The postural control of both groups was compared before and after a five-day Nordic skiing beginner's course lasting six hours per day, during which the subjects were taught a number of basic technical skills. Only the subjects in the experimental group took part in the course.

Sample (n)

A total of thirty-three subjects were selected and divided into the two groups mentioned above: the experimental group, composed of twenty-five subjects, eighteen men and seven women, and the control group of eight subjects, five men and three women (Table 1).

The chosen subjects were healthy, active (meaning that they engaged in some form of sport) people suffering from no kind of lesion.







	Weight (Kg)	Height (cm)	BMI	Age
Experimental Group	69.5±11.3	174.3±10.7	22.8±2.3)	25±5.3
Men	74.4±8.3	179.2±7.6	23.2±2.3	24.9±6.1
Women	56.9±7.5	161.9±6.3	21.7±2.1	25.1±3
Control Group	65.6±9.9	168.8±7.6	23±2.4	31.5±9.3
Men	68.5±8.5	171.5±8.3	23.2±0.7	34±11
Women	61±12.2	164.3±4	22.6±4.3	27.3±4.2

Table 1. Characteristics of the study subjects (± average standard deviation).

Stabilometry protocol

The stabilometry test was conducted using a force platform equipped with electronic sensors. Birmingham's 2008 stabilometric measurement protocol directives were followed throughout. This protocol guarantees reliable postural control measurement in bipedestation situations, rules out dynamic measurement through jumping and provides a set of correlation coefficients ranging between moderate and excellent.

The stabilometry test was carried out on two occasions, before and after the five-day initiation course into Nordic skiing. On each of the two occasions measurements were taken of the sway path of the centre of pressure both on the lateral axis and on the antero-superior axis. As Figs 1-6 show, the following positions were contemplated: 1) Bipodal balance with eyes open (BO); 2) Right unipodal balance with eyes open (RO); 3) Left unipodal balance with eyes open (LO); 4) Bipodal balance with eyes closed (BC); 5) Right unipodal balance with eyes closed (RC); and 6) Left unipodal balance with eyes closed (LC).

<p>Fig. 1. <i>Bipodal balance with eyes open (BO)</i></p>	<p>Fig. 2. <i>Right unipodal balance with eyes open (RO)</i></p>	<p>Fig. 3. <i>Left unipodal balance with eyes open (LO)</i></p>
		
<p>Fig. 4. <i>Bipodal balance with eyes closed (BC)</i></p>	<p>Fig. 5. <i>Right unipodal balance with eyes closed (RC)</i></p>	<p>Fig. 6. <i>Left unipodal balance with eyes closed (LC)</i></p>
		

In each of these positions, centre of pressure data was collected during a period of ten seconds. Bipodal balance and unipodal balance on each leg, with eyes open and closed, were measured alternatively, and for analysis the subjects

were required to maintain each position for a total of five seconds. Each test therefore lasted a total of sixty seconds. In order for the subjects to become familiar with the test procedure, they adopted the positions once before the test was conducted.

To begin the test, each subject maintained a standing position with knees slightly flexed (approximately 15°); ten seconds later, each subject was required to raise the left foot, so that only the right foot remained in contact with the platform; after ten seconds had passed, the instructor asked the subjects to change foot. Ten seconds later, the same protocol was repeated with eyes closed and the foot change taking place every ten seconds. During the test, the subjects kept their eyes open, looking at a black DIN A4 sheet on the wall two metres from the platform. In the positions with eyes closed, the subjects did the same until they closed their eyes. During all the tests, the subjects were requested to remain as still as possible with their arms at their sides. If any of them failed to complete the test without losing their balance, they were asked to repeat.

Data collection and analysis

The software registered all the centre-of-gravity displacement data in each of the positions for ten seconds. For each of these positions a figure was obtained that generated two graphs (Fig. 7), in which we observe the sway path of the centre of gravity (first graph), both on the lateral axis (the red line on the second graph) and on the anteroposterior axis (the green line on the second graph).

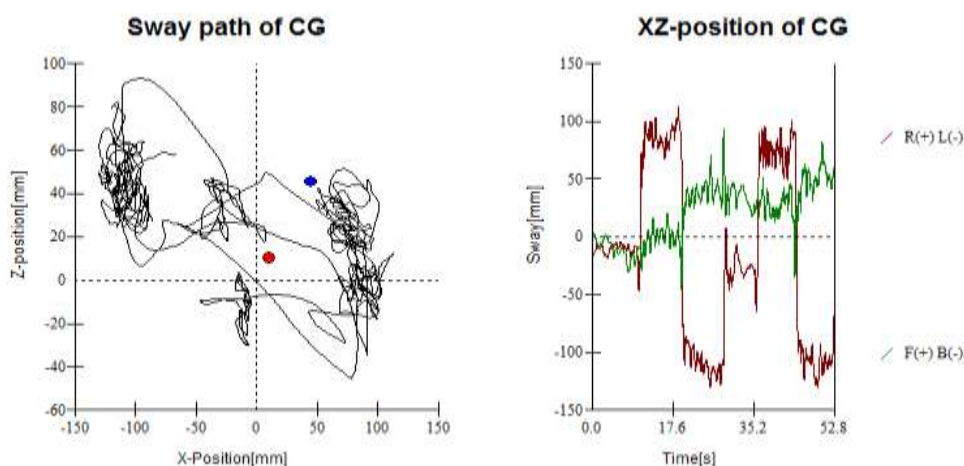


Fig. 7. (A) Sway path of the centre of gravity (A) and standard sway values of their deviations on the lateral axis and the anteroposterior axis.

The researcher took data from the five central seconds during which the subject was most stable. The standard sway path of the centre of gravity was noted for both axes. From the standard deviations on the lateral and anteroposterior axes the resultant was obtained, which provides us with a vector with which to quantify the value and the direction of the sway path of the centre of gravity

(Fig. 8). This same process was carried out for each subject and for the two tests conducted before and after the Nordic skiing initiation course.

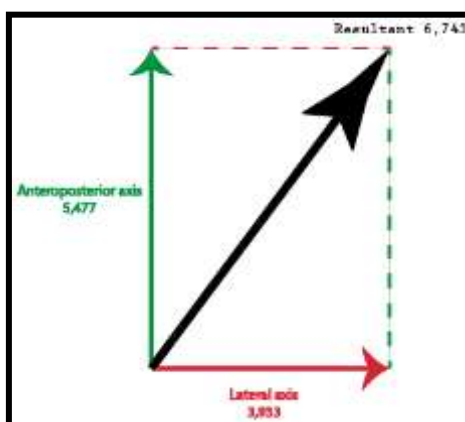


Fig. 8. Obtaining the resultant of the sway path of the centre of gravity.

Next the delta values were calculated for each subject, values that correspond to the difference between the pre-course and post-course controls, and for one of the tested positions. Furthermore, we calculated the delta value for the difference between the right foot and left foot with eyes open and for the difference between the right foot and left foot with eyes closed. Lastly, using the delta values a T-test was conducted in order to discover the correlation between them and to determine whether or not significant differences existed between the pre-course and post-course controls in the different situations mentioned above.

Equipment

The stabilometry was conducted using an ML (Muscle Lab) force platform equipped with four force sensors, which offered a sample of 200Hz, as well as with a 16b Bit a/d converter. A laptop computer provided with Muscle Lab software was used. The platform measured 800 x 600 x 60 mm and was placed on the laboratory floor. Data was obtained at the Technological Innovation Laboratory on the premises of the Institut Nacional d'Educació Física de Catalunya (Barcelona).

RESULTS

All subjects of the experimental group successfully completed the Nordic skiing initiation course, having attended all the six-hour sessions spread over a total of five days. We compared bipodal balance with eyes open (BO), right unipodal balance with eyes open (RO), left unipodal balance with eyes open (LO), bipodal balance with eyes closed (BC), right unipodal balance with eyes closed (RC), left unipodal balance with eyes closed (LC), the difference between the right foot and the left foot with eyes open (DIO) and the difference between the right foot and the left foot with eyes closed (DIC) at the two moments when data

was collected, that is, before and after the Nordic skiing initiation course, and between the experimental group and the control group.

The graphs below compare the delta values of the resultant in each of the different positions with the respective averages of both groups, control and experimental. The graphs are grouped together in three figures: Fig. 9 shows the results of the three positions with eyes open; Fig. 10 groups together the three positions with eyes closed; and Fig. 11 shows the graphs that compare the left foot and right foot with eyes open and eyes closed. In all the graphs, the delta values are shown of the resultant of the subjects of the experimental group, represented by a circle on the left-hand side, while those of the control group are shown by a cross on the right-hand side of the graph. The average value of the experimental group is represented by a continuous line, while that of the control group, in each case, is represented by a dotted line. When the delta value lies below 0, this means that postural control has improved, whereas a positive value indicates that postural control has deteriorated between the initial and final tests.

Comparison between positions with eyes open (BO, RO, LO)

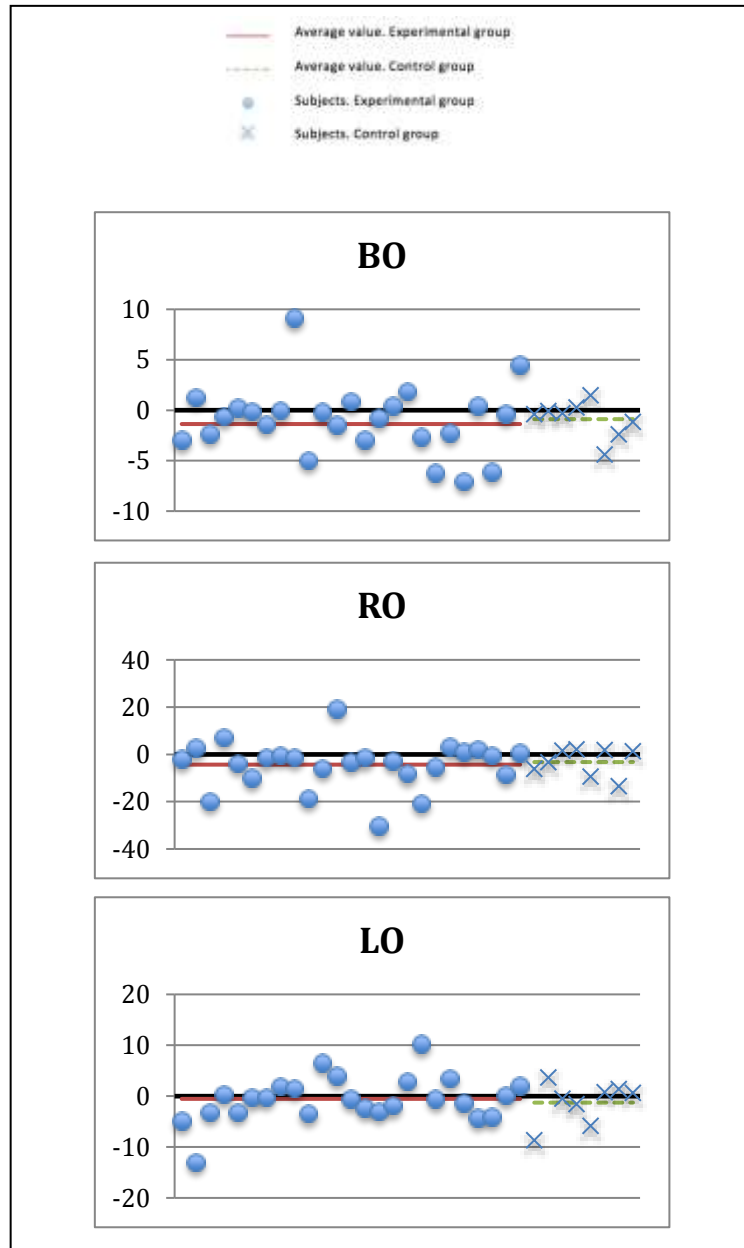


Fig. 9. Comparison between the delta values of the resultants in the three positions with eyes open. BO: bipodal balance with eyes open; RO: right unipodal balance with eyes open; LO: left unipodal balance with eyes open.

The three graphs in Fig. 9 reveal that great dispersion exists of the delta values of the resultants of all the subjects analysed and in the three tested positions, and that there are no significant differences between members of the experimental group and the control group, since both groups reveal cases of improvement to and deterioration in postural control. If we observe the average value, we see that in all three positions and in both groups balance has improved, although the difference between the control group and the experimental group may not be regarded as significant in terms of the p-values

resulting from the T-test for the three positions with eyes open ($p=0.947$ in BO; $p= 0.711$ in RO; $p=0.667$ en LO).

Comparison between positions with eyes closed (BC, RC, LC)

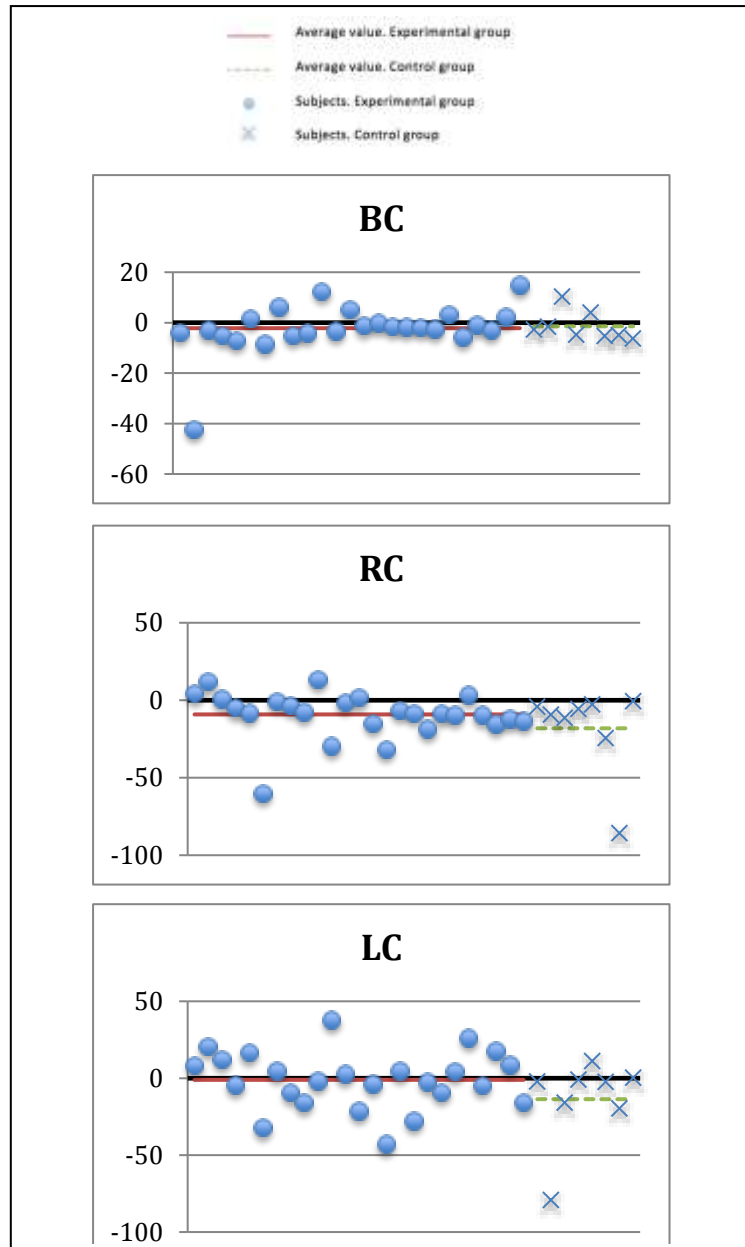


Fig. 10. Comparison between the delta values of the resultants in the three positions with eyes closed. BC: bipodal balance with eyes closed; RC: right unipodal balance with eyes closed; LC: left unipodal balance with eyes closed.

Fig. 10 shows the graphs resulting from analysis of the same positions with eyes closed. Although we observe that the dispersion of the delta values of the resultants of all the subjects analysed in this case is lower, and that in all three positions an improvement took place in the average control values both in the experimental group and in the control group, nonetheless no significant

differences exist between the members of the two groups, since improvement and deterioration took place in both. Thus, as occurred with the positions with eyes open, the difference between balance improvement between the experimental group and the control group may not be regarded as significant in terms of the p-values resulting from the T-test for the three positions with eyes closed ($p=0.799$ in BC; $p=0.416$ in RC; $p=0.268$ in LC).

Comparison between the right foot and left foot with eyes open (DIO) and closed (DIC)

Lastly, a comparison was made between the resultants of the delta values between the right foot and the left foot in the unipodal balance positions analysed, with eyes open and eyes closed respectively. Fig. 11 contains two graphs that compare the right foot and the left foot, one for balance with eyes open and the other for balance with eyes closed.

We observe that dispersion in the increase or decrease of the difference between both feet is greater in the positions with eyes open than with eyes closed.

Even so, no significant differences are observed between the control group and the experimental group in terms of the p-values resulting from the T-test for the positions with eyes open ($p=0.565$ in DIO) or for the positions with eyes closed ($p=0.707$ in DIC).

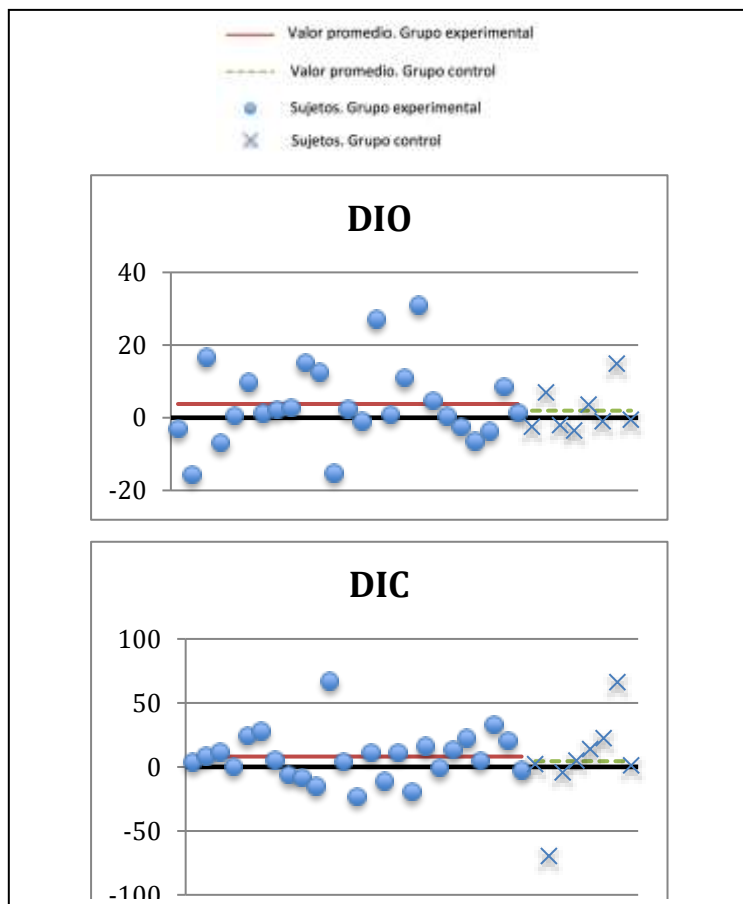


Fig. 11. Comparison between the delta values of the resultants for the right foot and left foot, with eyes open (DIO) and eyes closed (DIC).

DISCUSSION

The results obtained from the stabilometry test are not the ones we expected. The initial hypothesis was refuted, since no significant differences were observed between the experimental group and the control group as regards improvements in postural control.

Consequently, we observed that the differences between the improvement values were not significant enough to allow us to state that a thirty-hour initiation course into Nordic skiing will improve balance measured using Birmingham's (2008) stabilometric measurement protocol. As we mentioned in the introduction, the hypothesis had been put forward on the basis of the fact that Nordic skiing is a sport in which balance is an essential component, above all at beginner's level. The results obtained in this study contrast with students' perceptions recorded in previous courses (Funollet, Inglés, Gomila & Funollet, 2013; Funollet & Inglés, 2014). A fundamental need therefore exists to discuss them and subsequently redesign the study for future occasions.

In a considerable number of previous studies significant differences were found between the groups analysed. Furthermore, in all these studies a protocol was

applied based on static positions in the stabilometry tests to evaluate changes in balance. It is for this reason that we opted for static bipodal or unipodal positions in our analysis. While it is true that in Nordic skiing positions are never static, our objective was to evaluate the effect of dynamic sliding work on improvement to static postural balance.

The results of Ageberg's study (2003) show balance differences between injured (in this specific case with anterior cruciate ligament injury) and uninjured subjects, which denotes the importance of this joint in postural control. Similarly, several other studies reveal significant differences in postural control between genders, the sway path of the centre of pressure being greater in men than in women (Hewett, Paterno & Myer, 2002; Fort et al., 2009), or depending on age (Ageberg, 2003; Vaquero, González, Cárceles & Simón, 2013). Even so, there are also studies that show that certain gaps continue to exist in the significance of these differences (Wilmore & Costill, 2007). In our case, although this is not shown in the graphs, we have not found significant gender differences as regards improvement to balance.

The small total sample used for this study (N=33), as well as the small number of members of the control group (n=8), might explain why significant results were not obtained. Furthermore, we should stress that the subjects were sportspersons and that, therefore, the training effect generated by repetition of the test over a short period of time, both in the experimental group and the control group, might have led to improvement in both. Consequently, we cannot discern improvement generated as a result of the Nordic skiing initiation course. Moreover, we believe that the fact that we conducted an excessively basic training programme, consisting of familiarisation with and initiation into Nordic skiing, may not have provided sufficient stimulus when it comes to improving balance. This was the case in the study by Kavanaugh, McNabb & Revett (1996), in which the subjects engaged in two hours of skiing practice per day over a period of six days, after which their postural stability had improved. However, subsequent studies cast doubts on these results, due precisely to the low level of work load involved (Nasuti & Temple, 2010). Our study followed the guidelines contained in the Nordic skiing training manual by Funollet & Inglés (2014), based on the ten concepts featured in the manual. Although over the five-day period all these concepts were covered, they may not have been gone into deeply enough.

GUIDELINES FOR THE FUTURE

For future studies a greater study sample in the experimental group and, above all, in the control group, will therefore be essential. At the same time, we must increase the degree of exigency and, by extension, the duration of the initiation course into Nordic skiing, with a view to ensuring the significance of the training acquired. By increasing the sample and the exigency of the course we may ascertain the real difference in balance improvement between the experimental group and the control group. Furthermore, with the intention of

generalising the effect of training on the level of balance in sliding sports, we believe that the next step should be to design a comparative study between different forms of these sports, such as Alpine skiing, snowboard and Telemark.

Moreover, we believe that in the stabilometry test it would be advisable to establish a measurement variance for each subject. Submitting each subject to a number of initial tests chosen at random would allow us to obtain the variance in their stabilometric measurements, thereby avoiding improvement produced by the training effect through repetition of the same test.

We should also take the possibility into account of conducting a dynamic analysis of balance, with a view to applying this study to other forms of sport, as mentioned above.

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