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Original research papers

THE IMPACT OF ANKLE JOINT STIFFENING BY SKI EQUIPMENT ON MAINTENANCE OF BODY BALANCE

The impact of ski equipment on body balance

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Abstract

Introduction. In the initial phase of ski lessons, the skier encounters a completely new situation. The maintenance of body stability, which is influenced by various factors, attracts his entire attention. The aim of this study was to define the impact of ankle joint stiffening by ski equipment on the maintenance of body balance. ***Material and methods***. The research was conducted on 13-member group aged 20 to 24. All the subjects were male students at the Faculty of Physical Education and Sport in Biała Podlaska (graduates of the ski instructor course). Each participant carried out three postural exercises on the KISTLER dynamometric platform. Then the same exercises were performed with ski boots and skis. Two parameters were used for the analysis of body balance, namely the COP path length and the surface area of the stabilogram. ***Results***. It was stated in the study that ankle joint stiffening while standing on both skis did not have a negative impact on the postural stability. In majority of the tested subjects while standing on one ski, a considerable increase in the both analysed parameters occurred in relation to the same exercises performed without ski boots. That being so, it can be inferred that ski equipment causes deterioration of body stability. Moreover, it was noticed as a result of putting on ski boots and skis that body fluctuations increased slightly in relation to the growth of the base of support defined by the ski length and ski width setting. ***Conclusions***. On this basis, it was concluded that ski equipment does not have a negative influence on the maintaining body balance. The growth of body fluctuations during exercises is insignificant in relation to the increase of body base area. It is necessary to find new ways of compensating for body fluctuations in order to maintain body balance with ski equipment on.

Key words: body balance, skiing, postural stability

Introduction

Skiing requires one to maintain body balance in difficult conditions. For some people it is an easy task to master this art, whereas a more difficult one for others. However, initially all of them share the same goal, namely how to maintain body balance and avoid falling. In theory of sport, balance is understood as a motor coordination ability that enables one to maintain sustainable body posture (static balance) as well as its retention or recovery (dynamic balance) during motor activity or directly thereafter [1]. In biomechanics, balance is defined as an ability to maintain the projection of body's centre of mass (COM) within the supporting surface area [2, 3]. In the light of the above-mentioned definition, even considerable postural sways, but such during which the projection of the body centre of mass is within the area of the base, do not cause the loss of body balance. That is why Kuczyński uses a more precise term, such as stability of the balance system or body or postural stability [3]. According to the author, it is a more complex term connected with abilities, dynamic features and characterisation of all systems involved in maintaining body balance. Stability is a broader term than balance, which stands for the ability to recover the state of equilibrium, as Błaszczyk claims [4].

While standing still one imitates a single segment inverted pendulum [2, 3, 5, 6]. In order to justify the use of such simplification, the authors emphasise that while standing still on both feet, the body sways occur around one axis crossing the ankle joints. All body segments (excluding feet) are in fragile balance towards the ground and towards themselves. Separate body segments connected by joints, enabling only rotational motion, are balanced by the muscular system. Without stimuli disturbing still standing on both feet, the sways are so insignificant that one stabilises movements in all joints (excluding ankle joints) and imitates a stiff body. Such a body cannot stand vertically without a suitable stabiliser, and that is why the model should be expanded with a control variable e.g. the force changing the bottom end of pendulum relative to the supporting surface or a stabiliser in the form of a moment of force applied at the ankle joint. As a result of using the stabiliser, Morawski named this model as the controlled inverted pendulum [5]. The role of stabilisers in human body is fulfilled by the ankle joint flexor and extensor muscles. Undoubtedly, the model presented above is simplified and can be applied to standing still on both feet. During more complicated postural exercises it is necessary to involve more joints in order to compensate for the sways caused by any disturbances. Then the human body is no longer stiff and turns into several inverted pendulums, one on top of another. A specific situation appears when the ankle joint is blocked by stiff ski boots and makes it impossible for the ankle joint to compensate for the body sways. Such restriction implies the necessity of compensating for COM sways by other joints. The skier's centre of body mass is constantly exposed to different external forces such as gravity, centrifugal force and overexertion while turning on the slope. That being so, body balance must be constantly corrected [7]. It is possible to maintain body balance, when the resultant of gravity and centrifugal forces is turned towards the supporting surface set by the area between ski edges. On the one hand it is limited by the ski length, on the other by the ski width setting. In contrast to the ski length, the ski width setting can be corrected while skiing [8].

From the author's observations and reflections made during ski training courses, it appears that the first efforts to walk in ski boots often end in balance instability or even in a fall. Stability disorders increase to a greater extent after putting on skis, even during first basic exercises on the slope.

The aim of this study is to examine the impact of ankle joint stiffening by ski equipment on the maintenance of body balance. Attempts were made to find answers to the following questions: Are there any differences in parameters values describing body balance during postural exercises without ski boots in comparison to the same parameters registered during exercises with ski equipment?

Material and methods

The research was carried out on a 13-member group (participants of ski instructor course) aged 20-24. All the subjects were male students of the Faculty of Physical Education and Sport in Biała Podlaska. The research was conducted directly after their return from a ten-day ski training course. KISTLER dynamometric platform 9281C was used for measurement of stabilographic parameters. The research consisted of the following six exercises: 1. Standing on both legs without ski boots on, 2. Standing on one leg without ski boots, 3. Standing on one leg with the other one frontally crossed 4. Standing on both skis, 5. Standing on one ski, 6. Standing on one ski with the other one frontally crossed (Fig. 1).

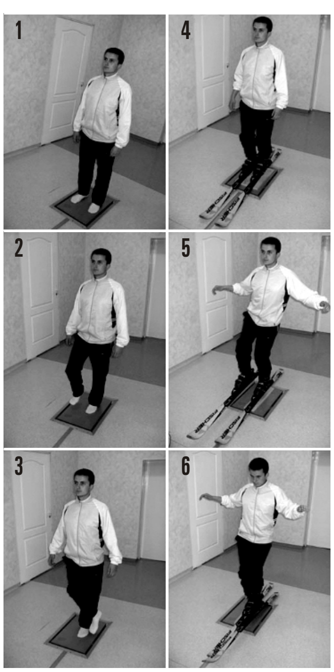

Figure 1. A subject during particular postural exercises

Each trial was recorded at the sampling frequency of 500 Hz and lasted 30 seconds. The main task of the subject was to maintain possibly maximum postural stability in the indicated positions. The platform surface was at the same level as the ground, and that is why a 25 mm wide board was used in order to increase its height.

Two parameters were used for the analysis of body balance, namely the surface area of the stabilogram and the path length of the projection of pressure centre on the supporting surface. The former is the area along which the projection of the point of application of the ground reaction force moves. The size of this area defines the extent of postural stability. The smaller the surface area of the stabilogram, the more precise it is to adjust the body balance. The latter describes the distance that the projection of the point of application of the ground reaction force covers within the supporting surface area during each trial [2, 3].

The analysis of the surface area of the stabilogram was conducted by means of Corel PHOTO-PAINT 12 on the basis of selected graphic files. The stabilogram charts were saved in different scales depending on the size of fluctuations. As a consequence, it was necessary to create a scheme in order to scale all charts homogenously. To select the surface area of the stabilogram Lasso instrument was used, which enabled its precise separation from the background. Then the Histogram option was used to define the number of pixels of the distinguished figure (Fig. 2). The value obtained was compared with the number of pixels per square cm on the chart. During the analysis of particular charts, some of their parts indicating the obvious randomness were omitted in order to optimize the value of the examined parameter.

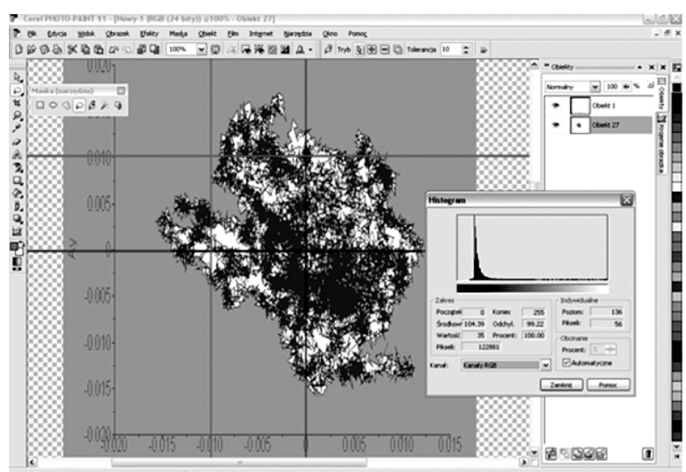

Figure 2. Corel PHOTO-PAINT 12 interface while measuring the surface area of the stabilogram

The path length of the COP projection was computed using every 25th sample, which made it possible to decrease the frequency from 500 Hz to 20 Hz recommended for this parameter. The total path length of the projection of COP was computed according to the following formula:

$$S = \sum_{n=1}^{3000} \sqrt{(X_{n+1} - X_n)^2 + (Y_{n+1} - Y_n)^2}$$

where:
s – total path length of the COP projection
(X_n, Y_n) – coordinates of the COP projection points
n – coordinates number of the COP projection (1-3000)

The differences between average results in particular postural exercises were statistically verified by means of the Shapiro-Wilk test for normality of data distribution and the t-Student test [9].

Results

The results of the laboratory measurements were analysed, paying special attention to two parameters that describe the ability to maintain body balance, namely the path length of the COP projection on the supporting surface and the surface area of the stabilogram.

Table no. 1 presents average lengths of the COP projection and average surface areas of the stabilogram, along which the projection of the point of application of the ground reaction force moved during the six different postural exercises.

Table 1. Average lengths of the COP projection and average surface areas of the stabilogram defining body balance maintenance in particular exercises

	COP path length [m] and surface area of the stabilogram [cm^2]											
	Standing on both legs		Standing on both skis		Standing on one leg		Standing on one ski		Standing on one leg with the other one frontally crossed		Standing on one ski with the other one frontally crossed	
	Path	Area	Path	Area	Path	Area	Path	Area	Path	Area	Path	Area
Average	0,545	1,12	0,492	* 0,78	1,141	3,60	* 1,340	* 4,42	1,173	4,92	* 1,492	* 6,16
DS	0,152	0,42	0,086	0,32	0,163	0,83	0,288	0,98	0,191	1,20	0,426	1,90

*statistically, there is a difference between the average value of the parameter obtained in the exercises with ski equipment and that obtained without one (α=0,05)

The trial with the standing position on both skis is characterised by the lowest average length of the COP projection and the average surface area of the stabilogram. Among the four exercises that required maintaining body balance on one leg or ski, the lowest result of the average path length of the COP projection and the average surface area of the stabilogram was obtained in standing position on one leg without ski equipment.

The charts (Figure 3-8) present the lengths of the COP projection on the supporting surface and the surface areas of stabilogram obtained by individuals while performing postural exercises.

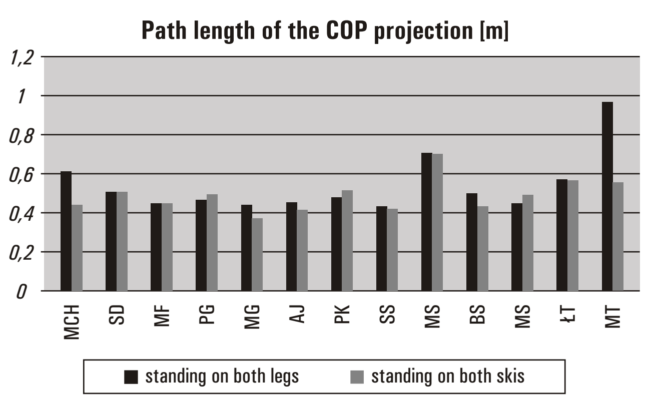

Figure 3. Path length of the COP projection while standing on both legs and while standing on both skis

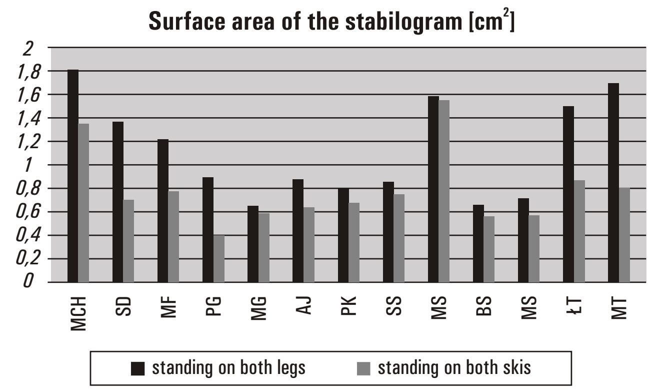

Figure 4. Surface area of the stabilogram while standing on both legs and while standing on both skis

Among the two parameters analysed, it is the surface area of the stabilogram rather than the path length of the COP projection which shows greater differences during exercises consisting in standing on both legs and on both skis (Fig. 3). All the subjects obtained lower surface areas of the stabilogram with ski equipment on. In case of the path lengths of the COP projection, three subjects obtained slightly lower parameter values in standing position without ski boots (Fig. 3). The remainder of them were characterised by more stable body posture after using ski equipment. However, the differences were less significant than in the standing position on one leg (Fig. 5, Fig. 7).

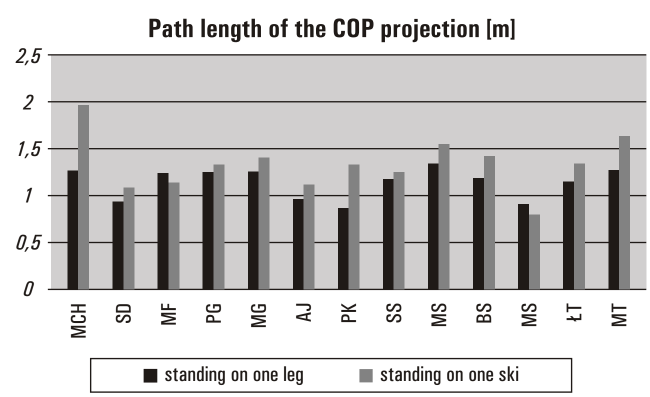

Figure 5. Path length of the COP projection while standing on one leg and while standing on one ski

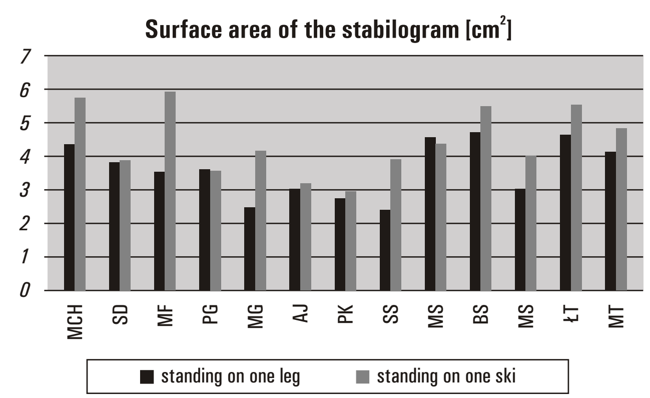

Figure 6. Surface area of stabilogram while standing on one leg and while standing on one ski

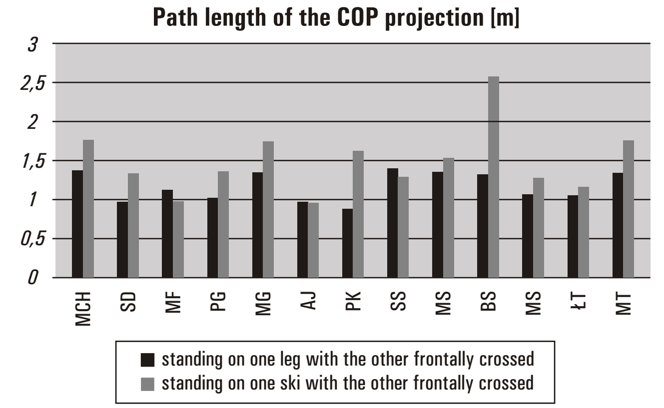

Figure 7. Path length of the COP projection while standing on one leg with the other one frontally crossed and while standing on one ski with the other one frontally crossed

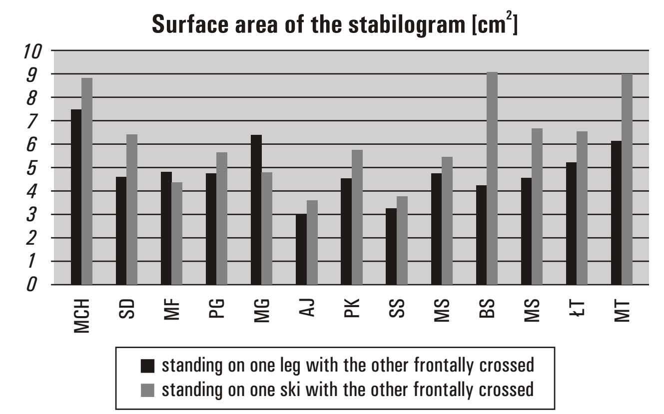

Figure 8. Surface area of stabilogram while standing on one leg with the other one frontally crossed and while standing on one ski with the other one frontally crossed

Discussion

In this study we compared the laboratory results of postural stability parameters obtained in particular postural exercises with and without ski equipment. The surface area of the stabilogram and the total path length of the COP projection were the examined parameters. The lower values of the aforementioned parameters provide evidence of smaller fluctuations and greater precision in the maintenance of body balance [3]. The average values of both, the surface area of the stabilogram and the path length of the COP projection for exercises on both legs were lower in the case of standing on the platform with ski equipment on. The situation looks opposite when we compared the values of parameters for exercises performed on one leg. In such cases, the subjects achieved higher values with ski equipment than without it. Moreover, it was observed that the path length of the COP projection showed smaller differences between the exercises with and without skis compared to the surface area of stabilogram. It can be explained with different ways of compensation for fluctuations in the case of particular exercises. According to the assumptions of the inverted pendulum model described in the study, the compensation for fluctuations appears mainly at the level of the ankle joint while standing on one leg without ski boots. With ski boots, the ankle joint is stiffened to a large extent, so that any movements are limited, especially in the frontal plane. That is why it is necessary to find other methods of compensating for body fluctuations. During the test it was observed that movements restoring postural stability while standing on one leg were performed in the frontal plane in the hip joint, whereas in the sagittal plane, these movements were primarily performed in the hip and in the knee joints. Furthermore, the motions were larger but slower than in the exercises without ski equipment. The path length of the COP projection depends on such factors as the velocity and the frequency of fluctuations. However, it does not have any impact on the surface area of the stabilogram, subject mainly to their scope. That is why the surface area of the stabilogram seems to be a more suitable parameter that can be used to compare particular exercises.

To maintain body balance while standing on both legs it is necessary to compensate for fluctuations mainly in the sagittal plane, because in the frontal one the body is supported in two points. Compensating motions are insignificant enough to be restricted by joint-stiffening ski boots enabling certain motions in the sagittal plane. According to the above-mentioned assumptions, lower values of area while standing on both legs in comparison to standing on both legs but without ski boots could be explained by the fact that a stiff ski boot constitutes a point of reference for a part of the shank located in its interior. Thus, it enabled to receive information on the direction of fluctuations coming from sensory receptors located in the region of the shank. Such an increased amount of information can influence early application of appropriate compensating motions, which are minimal in case of standing on both legs.

A totally different situation occurs during exercises performed on one leg. In this case, higher postural instability is characteristic for exercises with ski equipment, due to the ankle joint stiffening by ski boots. In a standing position on one leg without ski boots, compensating motions occur mainly in the ankle joint as a result of body stiffening and also its similarity to the inverted pendulum. They are substantially more significant than during standing on both legs. Because of that ankle joint stiffening requires new ways of compensating for fluctuations. As it was mentioned before, compensating motions occur in this case mainly in the hip ankle, whereas in the sagittal plane also in the knee joint. Probably, it is the necessity of applying a new compensating method against the one used in everyday life which causes difficulties for beginners. Another reason for stability deterioration during exercises performed on one leg can be both an increase of mass and a moment of inertia of the raised limb with a ski boot and a ski in relation to the corresponding trial but without ski equipment. Even minimal motions of a ski weighting few kilograms can influence the growth of the parameters registered by the platform.

The lower values of the surface area in exercises that involved standing on both legs with ski equipment can prove its positive impact on the maintenance of body balance. However, one can assume that fluctuations while skiing at higher speeds and on irregular slopes, constantly changing body position during turning rather are bigger than during relatively motionless standing. Because of that minimal compensating motions in the hip ankle are insufficient, as it is in this case. The exercises performed on one leg seem to be more representative ones in this case, because body fluctuations are big enough to apply other ways of their compensation. During standing on one leg with the other raised freely the value of the surface area of the stabilogram increases on average by 23%, whereas by 25% in a standing position on one leg with the other crossed in relation to the average values describing the same standing positions but without ski equipment. At the first moment, a conclusion arises that ski equipment makes it difficult to maintain body balance, because trials with it are characterized by substantially higher values of stabilographic parameters. Despite the increase of the surface area of the stabilogram with ski equipment, the COP projection remains within the figure formed by feet outline during standing on both legs and foot outline during standing on one leg. Human being with ski boots and skis increases also several times the body base set by ski length on the one hand and ski width setting on the other hand. According to the abovementioned remarks, it can be stated that ski equipment has a positive impact on maintenance of body balance.

Moreover, similarly to other authors' research [2, 3, 10, 11] substantially higher values of the balance parameters were observed while standing on one leg in comparison with standing on both legs with and without ski boots.

Conclusions

- Ski equipment does not have a negative impact on the maintenance of body balance. The growth of body fluctuations during exercises is insignificant in relation to the increase of body base field.
- It is necessary to find new ways of compensating for body fluctuations in order to maintain body balance with ski equipment on. In such cases, compensating movements appear mainly in the hip and knee joints and not in the ankle joints, just as it is the case of standing still.
- Exercises familiarizing a skier with ski equipment are recommended during first ski lessons. When practising such exercises a future skier learns new ways of compensating for balance fluctuations. Different kinds of games and activities, which include elements of keeping appropriate positions, or walking with ski boots on one ski and with the whole ski equipment, seems to be especially helpful.

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