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STATIC BALANCE OF VISUALLY IMPAIRED ATHLETES IN OPEN AND CLOSED SKILL SPORTS

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Abstract
Introduction. In elite sport, athletes are required to maintain appropriate body posture control despite a number of destabilising factors. The functions of body posture control are monitored by the central nervous system that constantly receives information from the vestibular and somatosensory systems as well as from the visual analyser. Visual impairment may contribute to a decrease in the level of motor abilities and skills; however, it does not prevent visually impaired individuals from taking up physical activity. Therefore, this study sought to assess the static balance of visually impaired goalball players and shooters. ***Material and methods***. The study included 37 goalball players and 20 shooters. A force platform was used to assess static balance. The study participants performed tests: standing on both feet with eyes open (BFEO) and closed (BFEC) (30 s), single left- and right-leg stance with eyes open (SLEO and SREO) as well as single left- and right-leg stance with eyes closed (SLEC and SREC). Statistical analyses were carried out using the following parameters: centre of pressure (CoP) path length [cm], CoP velocity [m/s], and the surface area of the stabilogram [cm^2]. ***Results***. No significant differences were found between goalball players and shooters in static balance levels. However, such differences were observed after taking into account the number of athletes who were capable of performing particular tests. ***Conclusions***. The findings indirectly confirm that there is a correlation between the type of physical activity and balance levels in visually impaired individuals. Further research ought to include tests performed on an unstable surface.

Key words: disability sport, visual impairment, static balance, goalball, pneumatic shooting

Introduction

Balance described as the state of body posture enables us to align forces and their moments that affect the body. It belongs to a group of coordination motor abilities that are needed to perform precise movements. Proper levels of static and dynamic balance are indispensable in doing a lot of everyday tasks and taking up physical activity [1]. In elite sport, athletes need to maintain appropriate body posture control despite a number of destabilising factors [2]. All sports induce specific equivalent adaptation mechanisms that result from the typical structure of movements [3], and long-term training may affect the acquisition of proper motor skills [4].

In each sport, different levels of particular motor abilities are required; however, a number of authors have highlighted the role of static and dynamic balance. Many studies sought to assess static and dynamic balance levels in sportspeople. Bressel et al. [5] assumed that competition conditions could affect the level of balance. They examined it in female football and basketball players (grass surface and wooden floor, respectively) and in female gymnasts (barefoot). Kachanathu et al. [6] examined football and basketball players to find out what influence a given sport had on balance levels. Kartal [7] performed similar analyses on tennis, volleyball, football, and basketball players. It is believed that in some sports, proper balance levels may contribute to achieving high outcomes. Judo is a good example, since several judo techniques require being able to maintain balance while trying to knock one's opponent off balance [8]. It was demonstrated that high levels of static balance in shooters influenced their scores [9]. In biathlon, postural stability while shooting is crucial to obtaining excellent results in this element [10]. A similar situation occurs in archery, where accuracy is linked to maintaining a still position just before shooting an arrow [11].

The functions of body posture control are monitored by the central nervous system that constantly receives information from the vestibular and somatosensory systems as well as from the visual analyser [12, 13, 14, 15]. Maintaining balance is a complex process which may be disturbed due to incorrect sensor-motor information or the lack of it [16]. It is believed that there are sports in which athletes trying to keep balance rely on other sources of information provided to the central nervous system. Judo competitors mainly use proprioceptive stimuli, while dancers rely on visual stimuli [6]. Thus, how is balance affected if it is hard or even impossible to receive any of these stimuli? Nearly 80% of the stimuli reach a recipient through the optic canal, which may indicate that an inability to receive these stimuli will affect static balance [14]. If the reception of visual stimuli is limited, static balance levels decrease [17]. Visual impairment may contribute to a decrease in the level of motor abilities and skills; however, it does not prevent visually impaired individuals from taking up physical activity. In fact, quite the opposite is the case. Physical activity produces a lot of positive physiological, psychological, and sociological effects [18]. Postural control of visually impaired individuals is possible owing to non-visual stimuli, that is proprioception, touch, hearing, and the vestibular system. The inability to receive visual stimuli exerts a negative influence on postural stability, and those affected by this dysfunction may have problems connected with it already at the level of mobility [19]. There is a scarcity of research on the fitness levels (including balance) of visually impaired sportspeople [20, 21, 22]. This issue seems to be interesting bearing in mind the role of vision in maintaining balance.

A literature review indicates that study group inclusion criteria for balance examinations are for example the sports practised by the study participants as well as the settings in which they are performed. This makes it possible to assume that authors expect to observe differences in balance levels between athletes in open and closed skill sports. One of the classification criteria of motor skills is environmental stability and predictability while performing a given task. Tasks performed in changeable and unpredictable surroundings are defined as open skills, while activities performed in a stable and predictable environment are known as closed skills [23]. Open skill sports are the ones which require reacting to changing conditions; an example would be team sports. In closed skill sports (running, shooting, or archery), the conditions are stable and predictable [24].

One of the team sports that only visually impaired individuals practise is goalball. The purpose of the game is to try to throw a ball into the opponents' goal. There are two teams that consist of three players each, and the players are blindfolded. The position of the ball during the game can be determined owing to the bells imbedded in it. The specificity of the game requires adequate motor preparation as well as excellent spatial orientation and sound source location on the part of the players [25]. Shooting is an example of an individual sport practised by visually impaired athletes. They use standard equipment complete with an electronic audio system linked with elements of the gun sight. The closer a shooter aims to the centre of the target, the louder the sound they hear through the headphones. Owing to these adaptations, visually impaired shooters are capable of demonstrating precision similar to that of sighted athletes. All visually impaired shooters compete in one category [26].

The specificity and nature of both sports imply different levels of static balance in visually impaired sportspeople, particularly if we assume that athletes practising open skill sports rely on visual stimuli more than competitors in closed skill sports [24]. Therefore, this study sought to compare the static balance of visually impaired goalball players and shooters.

Material and methods

The study included 37 goalball players and 20 shooters (tab. 1). The participants were divided into three groups according to the classification of the International Blind Sports Federation: B1 – visual acuity poorer than LogMAR 2.60, B2 – visual acuity ranging from LogMAR 1.50 to 2.60 and visual field below 10 degrees, B3 – visual acuity ranging from LogMAR 1.40 to 1.0 and visual field below 40 degrees [27].

All participants gave their written informed consent after being provided with an explanation of the risks and benefits resulting from participating in this study, as outlined in the Declaration of Helsinki (2008). The athletes had the option to withdraw from the study at any time. The study was approved by the Senate Research Ethics Committee of the Józef Piłsudski University of Physical Education in Warsaw (SKN 01-33/2015).

The subjects' body height (cm) and body mass (kg) were measured. Static balance was assessed using an AMTI AccuSway force platform (ACS Model). The study participants performed the following tests: standing on both feet with eyes open (BFEO) and closed (BFEC) (30 s), single left- and right-leg stance with eyes open (SLEO and SREO), and single left- and right-leg stance with eyes closed (SLEC and SREC) (10 s). The participants performed two trials in each single-leg test. Statistical analyses were carried out using the following parameters: path length (cm), centre of pressure (CoP), CoP velocity (m/s), and the surface area of the stabilogram (cm^2). The data regarding age, disability experience, training experience, sport class, and training loads (hours per week) were obtained during the tests.

Table 1. Description of study participants

Gender	Males [n = 33]						Females [n = 24]					
Sport class [n]	B1		B2		B3		B1		B2		B3	
	G	S	G	S	G	S	G	S	G	S	G	S
	4	4	9	6	6	6	3	0	12	0	3	2

Sport	Males: Goalball players	Males: Shooters	Females: Goalball players	Females: Shooters
	$\bar{x}$ ± SD	$\bar{x}$ ± SD	$\bar{x}$ ± SD	$\bar{x}$ ± SD
Body mass [kg]	79.4 ± 13.9	89.3 ± 18.5	61.8 ± 11.96	69.0 ± 7.5
Body height [cm]	182.8 ± 8.3	175.9 ± 13.1	167.2 ± 6.8	166.5 ± 4.14
Age [years]	25.68 ± 7.23	49.21 ± 17.23	21.17 ± 7.82	41.0 ± 14.57
Disability experience FB/DL [n]	4/15	4/10	10/8	2/4
Training experience [years]	7.2 ± 4.2	2.5 ± 2	6.8 ± 4.3	2.5 ± 2.1
Training experience up to 10/above 10 years [n]	16/3	0/14	17/1	0/6
Training load [h/week]	6.3 ± 2.3	2.6 ± 1.6	6.7 ± 2.2	2.7 ± 1.6
Training load up to 10/above 10 [h/week] [n]	18/1	0/14	17/1	0/6

G = goalball players; S = shooters; FB = from birth; DL = during life.

Table 2. Differences in static balance levels between goalball players and shooters (analysis of variance – ANOVA)

Variable	Goalball players		Shooters		Goalball players vs. shooters		ST	
	$\bar{x}$	SD	$\bar{x}$	SD	F	p	Goalball players	Shooters
BFEO Area Circ [cm²]	2.51	1.34	2.66	1.40	0.43	0.51	37	20
BFEO Path Length [cm]	38.80	1.29	37.56	9.80	0.26	0.60	37	20
BFEO V [m/s]	1.29	0.26	1.25	0.33	0.26	0.60	37	20
BFEC Area Circ [cm²]	2.69	1.86	2.65	3.20	0.00	0.98	36	20
BFEC Path Length [cm]	40.69	10.06	41.85	15.29	0.11	0.73	36	20
BFEC V [m/s]	1.36	0.33	1.39	0.51	0.11	0.73	36	20
SREO Area Circ [cm²]	18.82	13.85	14.19	9.24	1.57	0.21	37	17
SREO Path Length [cm]	78.03	33.25	37.79	7.34	0.20	0.65	37	17
SREO V [m/s]	7.80	3.23	7.34	3.80	0.20	0.65	37	17
SREC Area Circ [cm²]	22.89	17.16	21.57	8.42	0.04	0.83	30	8
SREC Path Length [cm]	83.79	23.78	105.1	36.09	3.95	0.05	30	8
SREC V [m/s]	9.03	4.62	9.34	4.43	0.70	0.40	30	8
SLEO Area Circ [cm²]	27.77	33.81	17.88	19.26	1.38	0.24	37	19
SLEO Path Length [cm]	117.2	46.9	64.1	27.6	0.82	0.36	37	19
SLEO V [m/s]	11.72	24.69	6.07	3.06	0.97	0.32	37	19
SLEC Area Circ [cm²]	27.25	19.45	36.32	33.34	1.48	0.22	36	15
SLEC Path Length [cm]	96.82	45.24	86.52	46.40	0.54	0.46	36	15
SLEC V [m/s]	9.68	4.52	8.65	4.64	0.54	0.46	36	15

$p < 0.05$; F = scores are shown in the table; BFEO = both feet eyes open; BFEC = both feet eyes closed; SREO = single right eyes open; SREC = single right eyes closed; SLEO = single left eyes open; SLEC = single left eyes closed; ST = successful trials.

Data analysis was performed using Statistica v. 10. Mean and standard deviations were calculated. The significance of differences between groups in gender, body mass, body height, disability experience, sport class, and training loads was assessed with the use of the analysis of variance (ANOVA) and Pearson's chi² test. Before the analysis, box-and-whisker calculations were made, and extreme results were removed. The level of significance was set at $p < 0.05$.

Results

The analysis did not reveal any differences in balance levels in terms of disability levels (sport class), disability experience, training experience, or training loads. The fact that there were no differences between goalball players and shooters (female and male) in body height ($F = 0.48$, $p = 0.49$) allowed comparisons between them.

No significant differences were found in balance levels between goalball players and shooters (tab. 2).

It was observed that not all study participants (shooters in particular) were able to complete the single-leg test with eyes closed. The analysis of successful trials with regard to the number of participants revealed significant differences between the groups. Goalball players demonstrated higher balance levels in the single-leg test with eyes closed (tab. 3).

Table 3. Differences in static balance levels between goalball players and shooters in the single-leg stance test with eyes closed taking into account the number of successful trials (Pearson's chi² test)

	SLEC ST/NS	SREC ST/NS
Goalball players	37/37	30/37
Shooters	15/20	8/20
Pearson's chi² test	10.13*	9.86*

*$p < 0.001$; SLEO = single left eyes closed; SREC = single right eyes closed; ST = successful trials; NS = number of subjects.

Discussion

The aim of the study was to compare static balance levels in visually impaired goalball players and shooters. It was assumed that the specificity of a given sport (open or closed skills) might differentiate competitors in terms of static balance levels. Goalball is a dynamic and unpredictable team sport with frequent pace and direction changes. In pneumatic shooting, the sequence of movements during a competition is predictable and well-known to each shooter. Static balance levels did not differentiate goalball players and shooters when it came to disability experience and disability levels (sport class), training experience, or training loads. This may stem from the fact that neither the goalball players nor the shooters relied on visual stimuli, and their balance levels were relatively high. Colak et al. [20] also noted that there were no differences in balance levels between goalball players of different sport classes. Klavina and Jekabsone [14] found that postural instability in visually impaired untrained individuals grew larger with an increase in disability levels. Similar observations were made by Tomomitsu et al. [17], who noted that balance levels in visually impaired individuals were lower in the case of people with greater impairments both in tests on a stable and unstable surface. Contrary to the research on able-bodied fencers, a significant correlation (r = 0.62) was found between training experience and postural stability levels [28].

Both goalball players and shooters manifested similar balance levels in tests performed on both feet with their eyes open and closed. However, it was observed that compared to goalball players, fewer shooters were able to perform the 10-s single left- and right-leg stance tests with eyes closed. This fact indicated significant differences between the athletes practising the two sports in the above-mentioned tests. Goalball players manifested higher balance levels in single-leg tests with eyes closed (shorter path and smaller surface area of CoP) (tab. 2). This may point to the role of vision in maintaining static balance and to the specificity of the sport discipline. During shooting, there is no single-leg support phase, which may account for lower balance levels in single-leg tests. Hawkins and Sefton [29] proved that in shooting, the highest level of stabilisation was obtained when standing on both feet 30 cm apart. Elite shooters exhibit high levels of static balance when standing on both feet and shooting. There is evidence that there exists a correlation between shooting accuracy and fitness (with balance and postural stability as the main components). Mononen et al. [9] focused on assessing correlations between shooting accuracy and stability levels. For instance, velocity of CoP displacement in shooting tests was analysed. Significant correlations (r = 0.3-0.8) were found between balance parameters and results in shooting. Correlations between stability levels and the results in biathlon shooting were noted by Sattlecker et al. [10]. A similar structure of movement can be seen in archery. A common feature of both sports is that athletes aim at a target with one eye closed, which may affect stability. It was revealed that stability played a significant role in each of the three archery events. However, in each of them, competitors used different strategies to maintain it [11].

In the case of individuals with disabilities, there are usually differences in the level of balance maintained without visual control. This was observed, for example, in tennis players [30], basketball and football players, windsurfers [3], and untrained individuals [2, 3, 15]. All this shows the role of vision in maintaining balance.

The character and structure of movement in a given sport may exert an influence on static balance levels. This was confirmed by the findings of research that assessed the differences between balance levels in young female figure skaters and their counterparts who only attended PE classes [1] as well as by the results of studies that compared handball players [31], football players [4], basketball players, and swimmers [32] against untrained individuals. In all these cases, sportspeople exhibited significantly higher balance levels. However, no significant differences were found in balance levels between football players aged 16-19 years and their untrained peers in tests performed while standing on both feet [2]. Furthermore, visually impaired athletes demonstrate higher balance levels than untrained people, as revealed in studies involving goalball players [20] and tandem cyclists [33].

One of the aims of current studies in this field is to compare static balance levels between athletes practising different sports. Researchers have been trying to determine the influence of these sports on balance levels. Compared to swimmers, basketball players demonstrated higher levels of static balance [32]. As far as individuals practising team sports are concerned (basketball and football), no differences were found [6]. In the case of single-leg tests, Kartal [7] revealed similar levels of static balance in volleyball, basketball, and football players, while tennis players manifested significantly higher levels of this ability. Female basketball players displayed high levels of static balance, while female gymnasts and football players exhibited lower yet comparable levels [5]. In most cases, athletes practising open skill sports were found to show higher levels of static balance than those who represented closed skill sports. The findings of the present study confirm this model.

Conclusions

The study focused on athletes practising two sports that differed in terms of movement structure. The fact that the study participants were visually impaired could be significant in the context of the research problem (static balance levels). Moreover, this work is one of the few studies concerning balance levels in visually impaired sportspeople. A few conclusions can be drawn, taking into account the intricacy of the issue under discussion. Static balance levels did not differentiate visually impaired athletes with respect to disability levels and experience. This may point to a possibility of obtaining high levels of static balance even by congenitally blind individuals. However, this is conditioned by a properly selected intervention programme that involves for example practising sports. The findings may constitute indirect evidence that there is a correlation between physical activity and static balance levels in visually impaired people. The fact that shooters demonstrated lower balance levels than goalball players may stem from the specificity of this particular sport. The study results may also point to the need of developing training programmes in both sports. It seems justified that balance exercises should be implemented in training in both open and closed skill sports bearing in mind the specificity of a given sport. Further research ought to include dynamic balance tests performed on an unstable surface.

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