Body balance disturbation tolerance skills combat sports athletes and people with other motor experiences in dynamically changing circumstances in own research – a perspective for predicting personal safety during real-life performance in extreme situations

Authors' Contribution:
A Study Design
B Data Collection
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Abstract

Background and Study Aim: Body balance disturbation tolerance skills (BBDTS) is the ability to maintain the vertical posture in circumstances of the fall hazard. One of the extreme situations in which BBDTS is crucial is operating in the dark (e.g. night-time, unexpected breakdown or switching off of artificial lighting), when visual control of the surroundings becomes impossible. In some of the specific occupations (e.g. the profession of a tightrope walker) or other motor activities disturbed by stimuli of varying strength and duration, the upper limbs are helpful in maintaining (restoring) body balance. The aim of this study is knowledge about BBDTS in the dynamically changing circumstances of human activity under laboratory conditions.

Material and Methods: As in previous studies of our own (combat sports athletes, firefighters, horse riders, mountain bikers) the groups were not homogeneous in terms of combat sports practiced, seniority, or seniority and age, so the experiment in a laboratory setting was conducted with 27 third-year (male) physiotherapy students attending a safe falling class once a week. In the reference group (n = 25), the age range was from 20 to 23 years (M 21.16 ±0.6); body height from 170 to 198 cm (181.37 ±6.05); body weight from 65 to 87 kg (76.11 ±6.67. Characteristics of the other two students who performed the extended task (exercise) programme: Volunteer A, age 21 years, height 182 cm, weight 76 kg; Volunteer B, 21 years, 178 cm, 80 kg.

A rotational test ('RT') in quasi apparatus version was used to measure BBDTS. 'RT' consists of six tasks (consecutive jumps with body rotation of 360° alternately to the right and to the left). The overall result (motoric aspect) is the sum of the six tasks and includes 0 to 18 stipulated points. Criteria of an individual level of BBDTS are as follows: very high (0-1), high (2-3), average (4-9), low (10-12), very low (13-15), insufficient (16-18). The execution time (s) 'RT' was a qualitative supplementary criterion.

The high-dynamic-change experiment was based on performing 'RT' three times repeated at 1 minute intervals: trial I (under standard conditions), trial II (in darkened goggles); trial III (upper limbs restrained with an orthopaedic belt). The extended programme for volunteers included trial IV ('RT' in goggles and upper limbs restrained). Thus, the volunteers' specific effort exposure lasted 4 minutes.

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Results: Blindfolded eyes (trial II) is the strongest factor interfering with BBDTS: motor effect 8 ±2.61 points (min 3, max 12), a deterioration of the mean score relative to trial I by 2.68 points, p<0.001 (M 5.32 ±3.28 points; min 0, max 11); 'RT' execution time 19.99 ±5.26 seconds (min 12.94; max 33.72) – a deterioration of 5.84 seconds p<0.001 (trial I: 14,15 ±1.19 seconds; min 11.51; max 16.75). Results with restrained limbs are similar to trial I: 5.92 ±2.38 points (min 2; max 11), execution time 16.2 ±3.31 seconds (min 12.75; max 27.24) but statistically significant in relation points: trial II with trial III p<0.01; while in relations of execution time 'RT': trial I with trial II p<0.001, trial I with trial III p<0.01, trial II with trial III p<0.001. Volunteers took the longest to perform trial IV: A 38.16 seconds (previous respectively: 18.51-, 31.16-, 24.21 seconds; B 28.31 seconds (previous: 15.47-, 21.28-, 24.21 seconds)

Conclusions: The large inter-individual variation is evidence that there are individuals who are able to compensate for negative effects at a similar level, despite dynamically changing circumstances stressing components of the neurophysiological system responsible for BBDTS. Thus, the results of such and similar empirical arrangements can form the basis for the selection of persons for especially difficult rescue or intervention tasks. Thus, providing personal security for those who would not be able to cope with such tasks precisely because of low BBDTS. The results may also be useful in sports, prevention and therapy.

Keywords: firefighters • postural control • rotational test • stability

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PE – *abbreviation* physical education [52].

PT – physiotherapy student (in this paper).

Skill – *noun* an ability to do perform an action well, acquired by training [52].

Non-apparatus test – that motoric test (exercise endurance test) of the required reliability (accurate and reliable), which use does not require even the simplest instruments [41].

Quasi-apparatus test – can be conducted with simple instruments (a stopwatch, a ruler, a measuring tape, etc.) [41].

INTRODUCTION

Physical fitness depends on body balance. Maintaining, achieving or restoring balance is an important part of evaluating athletes and patients. Research is carried out using a variety of methods and tests, still searching for the best way to evaluate. One test that breaks the paradigm that limits the measurement of the complex phenomenon of human body balance to static balance and dynamic balance is the developed 'Rotational Test' ('RT') [1]. It measures the phenomenon of body balance disturbation tolerance skills (BBDTS) which is the ability to maintain the vertical posture in circumstances of the fall hazard. The main criterion for evaluating this phenomenon is the cumulative points that inform about motor errors during testing. The results of past studies report on this coordination ability, either in terms of points (non-apparatus version) or combined points and time (quasi-apparatus version). Thus, the components of the results to date are both innate predisposition and long-standing environmental influences.

To date, BBDTS has been established for the Polish athlete population using 'RT' under standard conditions: aikido athletes, basketball players, boxers, free style wrestlers, Greco Romano wrestlers, handball players, judo athletes, kick-boxers, performers on horse-back, professional cyclists, shooting athletes Polish National Team, soccer players, sport dancers, sports gymnasts, swimmers, tennis players, [1], as well as paratroopers [2], physical education students but different sports specialization [3], physiotherapy students [1, 4], students of various faculties [5, 6], guard and students from Lithuania [7], early school-age children [8, 9].

Andrzej Tomczak initiated BBDTS research with dynamically changing circumstances as a function of time [10]. Four times he examined male soldiers (n = 8) from a special unit under restricted sleep conditions. He applied the test in a non-apparatus version. The number of mistakes in the 'RT' significantly increased in subsequent measurements from 4.4 points on day 1 to 9.4 points on day 4.

In a study by two co-authors of this publication [11] – BBDTS was assessed (twice) in 27 firefighters. The changing circumstances consisted of performing 'RT' (in the non-apparatus version) in sports tracksuit and in protective clothing. Different circumstances did not significantly influence the change of the 'RT' (sports tracksuit 3.96 points /protective clothing 5.07 points).

Artur Litwiniuk et al. [12] by quasi-apparatus version of 'RT' examined (two times: before and after the alpine skiing course) 24 physical education students. Participants were divided into two groups: physical education students practicing combat sport (n = 12), and physical education students practicing other physical activity (n = 12). The differences between the groups were statistically significant. The first group before course obtained 0.42 points and 12.21 s; after 0.75 points and 12.41 s. Second group before course obtained 5 points and 13.88 s; after 5.58 points and 14.0 s.

In addition, a study by Gąsienica Walczak et al. [13] analysed changes in BBDTS during increasing physical exercise: one professional hockey player, horse riders (n = 7), mountain bikers (n = 9). BBDTS was measured using 'RT' (quasi-apparatus version). Professional hockey player best tolerated body imbalance after short training session (RT score = 1 point – before 11 points). Mountain bikers also tolerated body imbalances better after training (M = 7.11 points – before 7.67). The average performance values of horse riders were higher after training (M = 10.43 points – before 9.14 points).

However, no attempt has been made to evaluate BBDTS in dynamically changing circumstances, such as reduced vision or upper limb motor capabilities. One of the extreme situations in which BBDTS is crucial is operating in the dark (e.g. night-time, unexpected breakdown or switching off of artificial lighting), when visual control of the surroundings becomes impossible. In some of the specific occupations (e.g. the profession of a tightrope walker) or other motor activities disturbed by stimuli of varying strength and duration, the upper limbs are helpful in maintaining (restoring) body balance. In some occupations during rescue or military operations, there may be a situation of inability to use the upper limbs to correct body imbalances, such as when moving a person.

The aim of this study is knowledge about BBDTS in the dynamically changing circumstances of human activity under laboratory conditions.

MATERIAL AND METHODS

Participants

As in previous studies of our own (PE students, firefighters, horse riders, mountain bikers, hockey player) the groups were not homogeneous in terms of combat sports practiced, seniority, or seniority and age, so the experiment in a laboratory setting was conducted with 27 third-year (male) physiotherapy (PT) students attending a safe falling class once a week. In the reference group (n = 25), the age range was from 20 to 23 years (M 21.16 ±0.6); body height from 170 to 198 cm (181.37 ±6.05); body weight from 65 to 87 kg (76.11 ±6.67. Characteristics of the other two students who performed the extended task (exercise) programme: Volunteer A, age 21 years, height 182 cm, weight 76 kg; Volunteer B, 21 years, 178 cm, 80 kg.

The reference group is physical education (PE) students (n = 6) training combat sports (boxing n = 3, karate kyokushin n = 2, wrestling n = 1). The body height range was from 173 to 182 cm (177.83 ±1.06), body weight from 57.9 to 76 kg (69.83 ±6.55).

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Study design

A rotational test ('RT') in quasi apparatus version [1] was used to measure BBDTS. 'RT' consists of six tasks (consecutive jumps with body rotation of 360° alternately to the right and to the left). The overall result (motoric aspect) is the sum of the six tasks and includes 0 to 18 stipulated points. Criteria of an individual level of BBDTS are as follows: very high (0-1), high (2-3), average (4-9), low (10-12), very low (13-15), insufficient (16-18). The execution time (s) 'RT' was a qualitative supplementary criterion.

The movie is available at the website of the journal Archives of Budo (www.archbudo.com) in the left menu (section: ArchBudo Academy) under link 'Rotational Test' (http:// www.archbudo.com/text.php?ids=351).

The high-dynamic-change experiment was based on performing 'RT' three times repeated at 1 minute intervals: trial I (under standard conditions), trial II (in darkened goggles); trial III (upper limbs restrained with an orthopaedic belt). The extended programme for volunteers included trial IV ('RT' in goggles and upper limbs restrained). Thus, the volunteers' specific effort exposure lasted 4 minutes.

PE students (reference group) performing 'RT' two times. Trial I before and trial II after alpine skiing course (10 days, 6 teaching hours (45 minutes each) a day).

Statistical analysis

The estimation of the results is based on the following indicators: frequency (N, n); mean (M); minimum (Min); Maximum (Max); standard deviation (SD or ±). We used the method of calculating the significance of the difference between two correlated sample averages proposed by Ferguson and Takane [15]. In the studies, the level of at least $p<0.05$ also for a directional test) and higher was shown as statistically significant differences.

RESULTS

Blindfolded eyes (trial II) is the strongest factor interfering with BBDTS: motor effect 8 ±2.61 points (min 3, max 12), a deterioration of the mean score relative to trial I by 2.68 points, $p<0.001$ (M 5.32 ±3.28 points; min 0, max 11); 'RT' execution time 19.99 ±5.26 seconds w (min 12.94; max 33.72) – a deterioration of 5.84 seconds $p<0.001$ (trial I: 14,15 ±1.19 seconds; min 11.51; max 16.75). Results with restrained limbs are similar to trial I: 5.92 ±2.38 points (min 2; max 11), execution time 16.19 ±3.31 seconds (min 12.75; max 27.24) but statistically significant in relation points: trial II with trial III $p<0.01$; while in relations of execution time 'RT': trial

Table 1. Body balance disturbation tolerance skills various three circumstances by physiotherapy students (n = 25).

Trial	Body rotation of 360° during jumps [points]						Indicator complex	
	1R	2L	3R	4L	5R	6L	points	time (s)
I	0.92 ±0.75 (0-2)	0.6 ±0.71 (0-2)	1.04 ±0.8 (0-2)	0.76 ±0.72 (0-2)	1.16 ±0.89 (0-3)	0.84 ±0.74 (0-2)	**5.32** ±3.28 (0-11)	**14.15** ±1.19 (11.51-16.75)
II	1.52 ±0.82 (0-3)	1.24 ±0.72 (0-3)	1.56 ±0.71 (0-3)	1.04 ±0.65 (0-2)	1.48 ±0.65 (0-3)	1.16 ±0.89 (0-2)	**8** ±2.62 (3-12)	**19.99** ±5.26 (12.94-33.72)
III	1.16 ±0.62 (0-2)	0.76 ±0.72 (0-2)	1 ±0.64 (0-2)	0.88 ±0.78 (0-2)	1.08 ±0.64 (0-2)	1.04 ±0.73 (0-2)	**5.92** ±2.38 (2-11)	**16.19** ±3.31 (12.75-27.24)
M	**1.2**	**0.87**	**1.2**	**0.89**	**1.24**	**1.01**	differences between: Trial I and Trial II	
SD	0.3	0.33	0.31	0.14	0.21	0.16	**2.68*****	**5.84*****
Min	0.92	0.6	1	0.76	1.08	0.84	differences between: Trial I and Trial III	
							0.6	**2.04****
Max	1.52	1.24	1.56	1.04	1.48	1.16	differences between: Trial II and Trial III	
							2.08***	**3.83*****

**p<0.01; ***p<0.001

Table 2. Body balance disturbation tolerance skills in different four circumstances by volunteer A.

Empirical system	Body rotation of 360° during jumps [points]						Indicator complex	
	1R	2L	3R	4L	5R	6L	points	time (s)
Trial I	2	1	2	2	2	1	**10** ±0.52 (1-2)	18.51
Trial II	3	2	2	3	2	2	**14** ±0.52 (2-3)	31.16
Trial III	2	2	2	2	2	2	**12** ±0 (2)	24.21
Trial IV	2	2	2	2	2	2	**12** ±0 (2)	38.16
M	2.25	1.75	2	2.25	2	1.75	differences between: Trial I and Trial IV	
SD	0.5	0.5	0	0.5	0	0.5		
Min	2	1	2	2	2	1	**2**	**19.65**
Max	3	2	2	3	2	2		

Table 3. Body balance disturbation tolerance skills in different four circumstances by volunteer B.

Empirical system	Body rotation of 360° during jumps [points]						Indicator complex	
	1R	2L	3R	4L	5R	6L	points	time (s)
Trial I	1	2	1	2	1	1	**8** ±0.52 (1-2)	15.47
Trial II	2	2	2	2	2	2	**12** ±0 (2)	21.28
Trial III	2	2	2	2	2	2	**12** ±0 (2)	24.21
Trial IV	2	2	2	2	2	2	**12** ±0 (2)	28.31
M	1.75	2	1.75	2	1.75	1.75	differences between: Trial I and Trial IV	
SD	0.5	0	0.5	0	0.5	0.5		
Min	1	2	1	2	1	1	**4**	**12.84**
Max	2	2	2	2	2	2		

Table 4. Body balance disturbation tolerance skills of combat sports athletes before and after alpine skiing course (n = 6).

Empirical system	Body rotation of 360° during jumps [points]						Indicator complex	
	1R	2L	3R	4L	5R	6L	Points	time (s)
Trial I	0	0	0	0	0	0	0	**11.68** ±0.62 (10.7-12.3)
Trial II	0	0	0	0	0	0	0	**11.85** ±0.76 (10.6-12.7)
							differences between: Trial I and Trial II	
							0	0.17

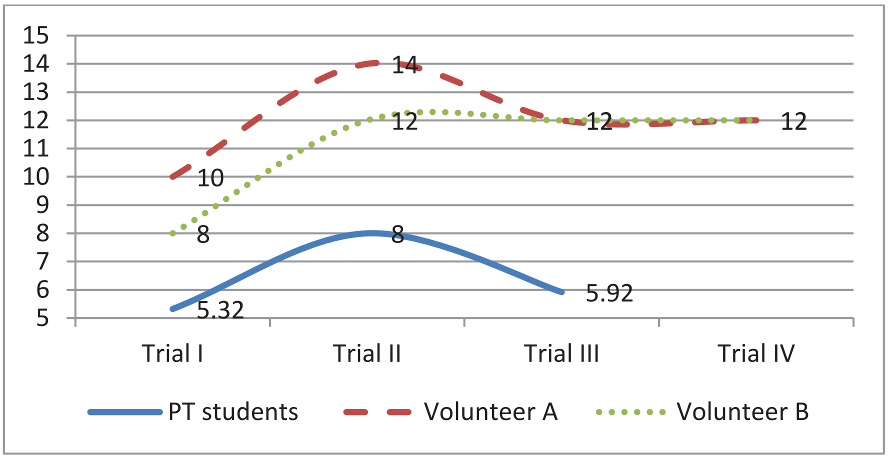

Figure 1. Synthetic visualization of the ability to tolerate body imbalances by a PT students and volunteers based on motor indicators ('RT' points reporting system).

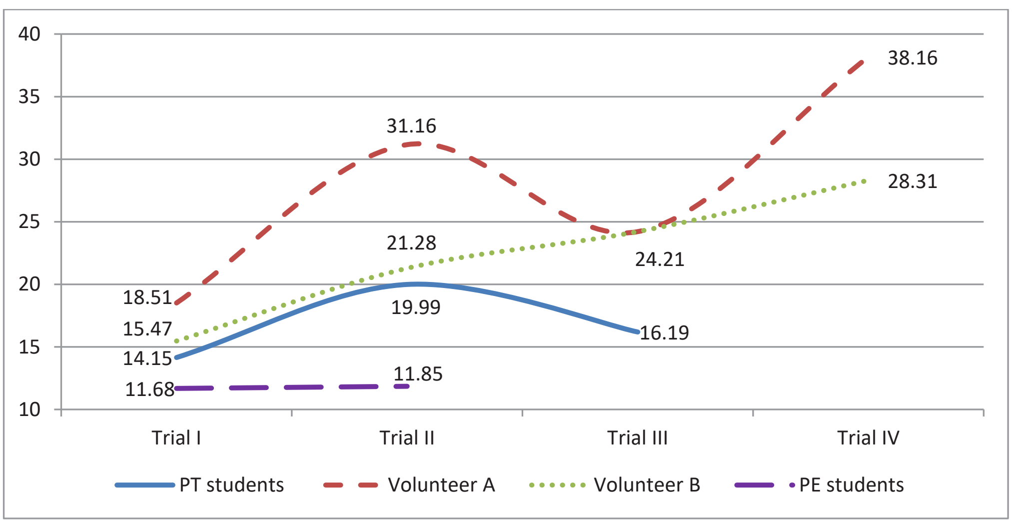

Figure 2. Synthetic visualization of the ability to tolerate body imbalances by a PT students, PE students and volunteers based on the timing of 'RT's (in seconds).

I with trial II $p<0.001$, trial I with trial III $p<0.01$, trial II with trial III $p<0.001$. Volunteers took the longest to perform trial IV: A 38.16 seconds (previous respectively: 18.51-, 31.16-, 24.21 seconds; B 28.31 seconds (previous: 15.47-, 21.28-, 24.21 seconds).

DISCUSSION

Innovative agonology [15-17] points to three aspects that are relevant from a personal security perspective: teaching of safe falls, avoiding collisions and reducing of aggressiveness [18, 19]. In addition, the BBDTS phenomenon is linked to both of these skills (safe falls [20] and avoiding collisions [21]). In particular, falling is most often caused by a loss of balance, while the need to immediately avoid a collision, especially with an object in motion, is a condition that causes a disturbance of balance regardless of whether a person is standing still or performing some locomotor activity. Also in both circumstances, falling (both when it is a previously unintentional activity, and then falling can be a means of, for example, avoiding collisions) and avoiding collisions with stationary and moving objects. A very important element is the use of the motor capabilities of the lower limbs. The legs are the body's most important shock absorber especially during a fall, and therefore the habit of compensating for loss of balance should be formed precisely by lowering the centre of gravity while maintaining the vertical position of the torso [22-25].

Helpful from the point of view of personal security are multidimensional tests which are a fundamental diagnostic tool in the prophylactic and therapeutic agonology [26, 27]. Innovative agonology recommends non-apparatus and quasi apparatus tests: body balance disturbation tolerance skills [1]; method of diagnosing body control errors during a simple motor activity [28]; multidimensional simulation research tools in the diagnosis of aggressiveness [29-31]; susceptibility test to the body injuries during the fall [32-36]; safe fall [37]; self-defence motor competence [38-40]; measurement of somatic health and survival abilities in the framework of the SPHSA questionnaire [18, 41-44].

The individual profiles of the volunteers we studied show the circumstances in which it is most difficult to control body imbalance. In the sense of the point score, such a circumstance is acting during vision limitation (trial II and IV). The laboratory trial of 'RT' in goggles and upper limbs restrained undertaken by only two volunteers is additional confirmation of the extremity of the situation. After all, firefighters often move in similar circumstances on slippery surfaces. In other laboratory conditions, just involving firefighters, one, with the highest body weight, refused to walk on a plank placed at a height of 2 meters in a combat suit [11]. This was a simulation of an emergency situation, and the methodology of innovative agonology emphasizes the importance of non-motor simulation methods at the stage of diagnosis and education of somatic health, mental health and especially various components of survival [26, 45].

Moreover, comprehensive periodic testing of special (with survivalist qualities) and general physical fitness, and associating these results with indicators of body composition, mental and social health indicators throughout ontogeny [46], is one of the most effective ways to permanently strengthen personal security.

Although Andrzej Tomczak, in a series of his multiple studies, used a non-apparatus version of 'RT' [47-50], he provided empirical, credible evidence that this unique tool for diagnosing the complex phenomenon of BBDTS in a simple way and for that, in difficult field conditions, can be successfully used in the promotion, prevention and therapy of people who are fit enough to perform 6 jumps with rotation, not necessarily 360 degrees. This is an important limitation of 'RT's applied uses (not age, but physical fitness, is the qualifying factor for testing). This limitation does not diminish the importance of Tomczak's conclusion in his monograph, in a sense the culmination of his many years of research, that 'RT' is the most sensitive of the other tests measuring motor coordination [51] when it comes to recording the effects of stress on the human neurophysiological system combined with physical exertion and sleep deprivation.

CONCLUSIONS

The large inter-individual variation is evidence that there are individuals who are able to compensate for negative effects at a similar level, despite dynamically changing circumstances stressing components of the neurophysiological system responsible for BBDTS. Thus, the results of such and similar empirical arrangements can form the basis for the selection of persons for especially difficult rescue or intervention tasks. Thus, providing personal security for those who would not be able to cope with such tasks precisely because of low BBDTS. The results may also be useful in sports, prevention and therapy.

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