ORIGINAL ARTICLE

The diagnostic value of the 'Rotational Test' in preclinical studies – an example of combat and non-combat sports athletes research before and after an alpine skiing course

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- **A** Study Design
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Abstract

Background and Study Aim: Alpine skiing is a physical activity that stimulates (develops and maintains) primarily coordination motor abilities, mainly the balance of the body. Thus, for combat sports (martial arts) athletes, on the one hand it can be a means (a supportive sport) that enhances the body balance disturbances tolerance skill (BBDTS). On the other hand, the optimal BBDTS level increases the likelihood of learning to ski safely and is the basis for forecasting satisfactory motor effects during a few days of basic skiing course. The aim of this research was knowledge about the relationship between BBDTS and the motor effects of an intensive, multi-day basic alpine skiing course and with the body composition indices of combat- and non-combats sport athletes.

Material and Methods: Twenty-four physical education students were examined: 12 training combat sports (including 1 neo-gladiator); 12 (control group) practicing other sports or daily, varied physical activity. Age of the surveyed students (respectively); body height; body mass. The basic skiing course lasted 10 days: 6 teaching hours (45 minutes each) a day. Motor effects (skiing techniques) were assessed by 3 experts on a scale from 2 to 5 (with an accuracy of 0.5) and the criterion was the arithmetic mean of all scores. 'Rotational Test' (RT – quasi-apparatus version) measured the 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. Body composition was measured device Tanita 545N. Statistical analysis was based on a non-parametric Shapiro-Wilk Normality Test.

Results: Combat sports students athletes revealed a higher level of BBDTS (as documented by motor indexes and RT execution time) both before and after the basic alpine skiing course: before 0.42 ±0.49 RT points, 12.21±0.73 RT s; after 0.75 ±0.92 RT points, 12.41 ±0.83 RT s; other students (respectively): 5 ±1.47 points, 13.88 ±0.86 s; after 5.88 ±2.02 points, 14 ±0.93 s. The differences between the groups are statistically significant ($p<0.01$ or $p<0.05$). The motor learning outcomes of alpine skiing by students were similar.

Conclusions: This slight deterioration of both RT indices was found in both groups proves that intensive, long-lasting alpine skiing training is a significant neuro-physiological burden on the organism, regardless of previous motor specialization. Moreover, RT results prove that combat sports (martial arts) shapes BBDTS in an optimal way. Both RT evaluation criteria (points and test time) suggest that they are sensitive indicators and can be recommended as useful in preclinical studies of the nervous system (with certain limitations), that is the some aspects of the condition of organs and functions responsible for maintaining the balance of the body during human motor activity.

Keywords: body composition • motor safety • nervous system • preclinical test

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Body composition – the body composition of the body provides important information about nutritional status of the organism and assessed by the simplest method of electrical bio-impedance (BIA), using i.e. Tanita SECA devices, etc.

Motor safety – is consciousness of the person undertaking to solve a motor task or consciousness the subject who has the right to encourage and even enforce from this person that would perform the motor activity, who is able to do it without the risk of the loss of life, injuries or other adverse health effects [49].

Nervous system – the most complicated in structure and function system of the human body, its main tasks include managing many activities, often without our awareness, receiving information from the environment, managing the processes of thinking and making decisions.

Preclinical studies – in this work: the use of a motor test or a motor (psychomotor) simulation to diagnose a phenomenon related to a threat to health or even life.

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 [9].

Quasi-apparatus test – can be conducted with simple instruments (a stopwatch, a ruler, a measuring tape, etc.) [9].

Neo-gladiator – a person who trains mix martial arts (MMA) and similar forms of hand-to-hand fighting that do not meet the definition of sport according to the Olympic Charter [50].

INTRODUCTION

Research dedicated to the body balance disturbances tolerance skill (BBDTS [1]) is an alternative to the paradigm that reduces the measurement of the complex phenomenon of human body balance to static balance and dynamic balance. The technological leap of recent years has by no means revolutionised the issue, neither in terms of a radical change in theoretical foundations nor in methodological approaches. The external causes of loss of equilibrium by human beings operating under a wide range of circumstances on earth remain unchanged. However, the population of groups at increased risk of falling is increasing (expansion of neuro-degenerative diseases, ageing populations, are examples of leaders [2, 3]) and invariably for centuries loss of balance has been at the root of many unintentional falls [4-8].

Thus, the BBDTS phenomenon should be explored much more dynamically in terms of scientific and necessary preventive applications. On the other hand, the scientific argumentation concerning the knowledge of man covering also the area of the organic basis of success in his motor activity, but also concerning the factors responsible for neuro-degeneration, is increasing.

The authors of the RT validation procedure refer to the BBDTS characteristics of 18 groups of people who systematically undertake physical activity (occupational, sport or other), the success of which is determined to a greater or lesser extent by the BBDTS. The reference system is the results of RT performed with 100 female physiotherapy students aged 21 years. These data provide clear evidence that the more intensive and frequent the exposure of distractions, the more lasting the positive adaptive effects of the individuals so stimulated [1].

This important cognitive conclusion does not diminish the methodological demand that not only results should inspire confidence, but that they should also be achievable with simple tools (RT, whether non-apparatus or quasi-apparatus, fulfils this condition [see: 9-12, also 13]). The fulfilment of these purely scientific criteria, on the other hand, highlights the importance of the economic factor. If all these criteria are met together, there is the prospect of efficient implementations at low cost.

Thus, one of the most topical research questions should be whether people with years of experience stimulating the nervous and motor systems responsible for BBDTS quality will be more successful in learning new motor activities (techniques) requiring an optimal level of BBDTS.

Alpine skiing is a physical activity that stimulates (develops and maintains) primarily coordination motor abilities, mainly the balance of the body. Thus, for combat sports (martial arts) athletes, on the one hand it can be a means (a supportive sport) that enhances the body balance disturbances tolerance skill (BBDTS). On the other hand, the optimal BBDTS level increases the likelihood of learning to ski safely and is the basis for forecasting satisfactory motor effects during a few days of basic skiing course.

The aim of this research was knowledge about the relationship between BBDTS and the motor effects of an intensive, multi-day basic alpine skiing course and with the body composition indices of combat- and non-combats sport athletes.

MATERIAL AND METHODS

Persons

Twenty-four physical education students were examined: 12 training combat sports (including 1 neo-gladiator); 12 (control group) practicing other sports or daily, varied physical activity. Age of the surveyed students (respectively); body height; body mass they do not significantly differentiate the two groups of students.

The study was conducted under the research project no. 2 "Profession, competences and efficiency of work of a personal trainer, sport trainer and teacher of physical education in selected EU countries" of the Baltic Sport Sciences Society, Division of Latvian Academy of Sport Education, Riga, Latvia and Faculty of Physical Education and Health, Biala Podlaska, Jozef Pilsudski University of Physical Education, Warsaw, Poland

Study design

BBDTS

'Rotational Test' (RT – quasi-apparatus version) measured the BBDTS. The quality of documenting and analysis of the observation results (*video verification*) was ensured by the technique of filming the RT performed.

RT consists of six tasks (consecutive jumps with body rotation of 360° alternately to the right and to the left). *Evaluation method:* landing after the jump with body rotation on the designated line with both feet and maintaining balance means the lack of the error (the result is recorded as "0"), no contact of one foot with the line after landing is assessed as "1" (first degree error), "2" means the lack of contact with the line after landing or not maintaining this contact while correcting the posture (second degree error), "3" records leaning against the ground with a hand/hands or a fall (third degree error). Test execution time – the optimal result is obtained after ca. twelve seconds. It is a complementary information (documented with an accuracy up to 0.01 second) [1].

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 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) [1].

Ranking position (RP) it is the basic indicator of qualitative assessment. RP is based on the criterion of motor correctness (no error or points from 1 to 18) and the time of execution of RT (seconds). With the equality of points, the higher RP is taken by the person who will perform RT in a shorter time. If both indicators are equal, such persons are assigned the same RP. The in-depth qualitative analysis is based, on the one hand, on the indicators of the BBDTS typology, and, on the other hand, on their migration and RP migration (in each case the RT is repeated in different circumstances). In these studies, different circumstances are the results of observations before and after the basic alpine skiing course

We also use the methodological category "ranking position" in the qualitative analysis of other empirical variables.

Body composition

We based the characteristics of the body composition on the recommended indicators: body height (cm), Body weight (kg), BMI (body max index), body fat (%), body water (%), muscles (kg), bones, visceral fat (range) [14, 15]. Body composition was measured device Tanita 545N.

Motor effects of skiing techniques MEST

The basic skiing course lasted 10 days: 6 teaching hours (45 minutes each) a day. MEST were assessed by 3 experts on a scale from 2 to 5 (with an accuracy of 0.5) and the criterion was the arithmetic mean of all scores.

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 ±). In the studies, the level of at least $p<0.05$ (also for a directional test) and higher was shown as statistically significant differences. Statistical analysis was based on a non-parametric Shapiro-Wilk Normality Test. The interpretation of the correlation coefficient (r) is based on the J. Guilford's classification.

RESULTS

The statistically significant difference (1.64, $p<0.05$) is related only to BMI index and basically indicates the somatic similarity of the physical education students of both studied groups (Tables 1 and 2). A more detailed analysis (admittedly based on health interpretations of body composition indices and not in relation to athletes) shows that students practicing combat sports are characterised by higher body hydration: 75% of them exceed the upper limit of the normal norm

(Table 1), while 33.33% of students practicing other forms of physical activity (Table 2). A similar pattern of disproportion applies to underfat, respectively: 41.67% and 16.67% students.

The majority (seven) of the students practicing combat sport performed the 'Rotation Test' without errors before starting the alpine skiing course. The others made first degree errors. The mean score of 0.41 (range (0 to 1) indicates a very high BBDTS level. A more differentiating factor between the students tested is the time taken to perform the RT (from 10.7 to 13.6 seconds). One pair of students performed RT in an identical time of 12.2 seconds (code CS5 and CS8), the second in 12.3 seconds (code CS6 and CS9), the third in 12.8 seconds (code CS7 and NG11). In each pair, the first made no error, while the second made a first-degree error. Based on the first criterion of the qualitative analysis (considering the total scores, i.e. the rate of no or committed errors and the RT execution time), 12 ranking positions were identified. The qualitative analysis of the results based on the BBDTS typology qualifies most of the students to subtype A (non-errors) and the rest to B51 (five time lack of error and first degree error). All students performed the first and third jumps with body rotation without errors in terms of RT structure (Table 3).

MEST ten (83.33%) of the physical education students practicing combat sport were rated maximum (5 grade). The remainder scored slightly lower (4.83 grade). The 'Rotation Test' scores of these students deteriorated slightly both in terms of a higher number of errors (mean score of 0.75, 0.33 more in relation to the before skiing course test) and in terms of time taken to perform the RT (mean score of 12.41 seconds, 0.20 more). Both differences are not statistically significant. However, the increase in RT time concerns 10 (83.3%) students, while the leader of both studies, student CS1, performed RT shorter by 0.1 s, and student CS9 performed RT twice in the same time of 12.3 s (the reason for the negative migration of his ranking position from 9 to 11 were two first degree errors - in the first study he made one such error). The ranking positions of the first six students did not change. The reason for the switch in ranking positions by students CS7 and CS8 was primarily due to CS7 making a first-degree error in the second examination (student CS8 made a faster RT in both examinations). Student CS10 owes his advancement to the 9th ranking position

Table 1. Body composition indicators for physical education students practicing combat sports (n = 12) – ordinal variable: ranking position (RP) according to the results of the 'Rotation Test' before the alpine skiing course.

RP	Student code	Sport discipline	Body height (cm)	Body weight (kg)	BMI	Body fat (%)	Body water (%)	Muscles (kg)	Bones	Visceral fat (range)
1	CS1	wrestling	173	57.9	19.3	6	68.3	52.4	2.8	1
2	CS2	boxing	177	74.1	23.7	7.7	67.7	67.8	3.5	1
3	CS3	boxing	182	76	22.9	6.1	69.1	70.7	3.7	1
4	CS4	karate kyokushin	180	68	21	17.3	57.9	57.2	3	2.5
5	CS5	karate kyokushin	178	73.4	23.2	6.7	67.5	63.5	3.3	1
6	CS6	boxing	177	69.6	22.2	5.4	68.7	61.2	3.2	1
7	CS7	taekwondo WTF	185	81.3	23.8	10.7	64.5	69.1	3.6	1
8	CS8	karate kyokushin	180	73.8	22.8	6.6	68	65.5	3.4	1
9	CS9	taekwondo WTF	186	84	24.3	10.3	65.6	73.2	3.8	1
10	CS10	boxing	185	79.9	23.3	11.9	62	58.2	3.1	1
11	NG11	MMA (NG)	175	73.1	23.9	9.2	66	64.2	3.4	1
12	CS12	karate kyokushin	172	66.7	22.5	15.2	59.7	53.5	2.8	2
Mean			**179**	**73.15**	**22.74**	**9.43**	**65.42**	**63.04**	**3.30**	**1.21**
Standard deviation			4.49	6.79	1.34	3.67	3.55	6.42	0.32	0.48
Minimum			172	57.9	19.3	5.4	57.9	52.4	2.8	1
Maximum			186	84	24.3	17.3	69.1	73.2	3.8	2.5

Table 2. Body composition indicators for physical education students practicing other forms of physical activity (n = 12) – ordinal variable: ranking position (RP) according to the results of the 'Rotation Test' before the alpine skiing course.

RP	Student Code	Body height (cm)	Body weight (kg)	BMI	Body fat (%)	Body water (%)	Muscles (kg)	Bones	Visceral fat (range)
1	OFPA1	168	78.9	28	11.8	65.7	66.1	3.4	2
2	OFPA2a	174	70.1	23.2	8.9	60.1	60.5	3.2	1
3	OFPA2b	175	73.1	23.9	5.2	69.8	60.8	3.3	1
4	OFPA3	172	73	24.7	13.8	64.8	56	3	1
5	OFPA4	183	85.4	25.5	13	62.9	68.5	3.6	1.5
6	OFPA5	190	85.4	23.7	15.7	61.7	68.4	3.6	1
7	OFPA6	177	82.3	26.3	17.6	60.2	69.2	3.6	4
8	OFPA7	181	72.9	22.3	14.3	61.6	64.8	3.4	2.5
9	0OFPA8	174	76.8	25.4	12.8	63.5	64.3	3.4	1.5
10	OFPA9	174	77.1	25.5	14.2	64.4	64.3	3.4	1.5
11	OFPA9	179	78.6	24.5	6.1	69.1	70.7	3.7	1
12	OFPA10	188	69.4	19.6	18.9	69.2	60	3.2	1
Mean		**177.92**	**76.92**	**24.38**	**12.69**	**64.42**	**64.47**	**3.40**	**1.58**
Standard deviation		6.28	5.23	2.04	4.01	3.30	4.25	0.20	0.86
Minimum		168	69.4	19.6	5.2	60.1	56	3	1
Maximum		190	85.4	28	18.9	69.8	70.7	3.7	4

Table 3. The results of the 'Rotation Test' (ordinal variable) of physical education students practicing combat sport (n = 12) before starting the alpine skiing course.

Student code	Sport discipline	Errors during jump with body rotation 360°							RT results		BBDTS	
		1R	2L	3R	4L	5R	6L	Points	time (s)	RP p+s	Typology	RP
CS1	wrestling	0	0	0	0	0	0	**0**	**10.7**	1	A	1
CS2	boxing	0	0	0	0	0	0	**0**	**11.2**	2	A	1
CS3	boxing	0	0	0	0	0	0	**0**	**11.8**	3	A	1
CS4	karate kyokushin	0	0	0	0	0	0	**0**	**11.9**	4	A	1
CS5	karate kyokushin	0	0	0	0	0	0	**0**	**12.2**	5	A	1
CS6	boxing	0	0	0	0	0	0	**0**	**12.3**	6	A	1
CS7	taekwondo WTF	0	0	0	0	0	0	**0**	**12.8**	7	A	1
CS8	karate kyokushin	0	0	0	1	0	0	**1**	**12.2**	8	$B5_1$	2
CS9	taekwondo WTF	0	1	0	0	0	0	**1**	**12.3**	9	$B5_1$	2
CS10	boxing	0	0	0	0	0	1	**1**	**12.7**	10	$B5_1$	2
NG11	MMA (NG)	0	0	0	0	1	0	**1**	**12.8**	11	$B5_1$	2
CS12	karate kyokushin	0	0	0	1	0	0	**1**	**13.6**	12	$B5_1$	2
Mean		**0**	**0.08**	**0**	**0.17**	**0.08**	**0.08**	**0.42**	**12.21**			
Standard deviation		0	0.28	0	0.37	0.28	0.28	0.49	0.73			
Minimum		0	0	0	0	0	0	0	10.7			
Maximum		0	1	0	1	1	1	1	13.6			

Note: **BBDTS** body balance disturbation tolerance skills; **RP** ranking position; **p+s** points + seconds; **A** no errors [6:0]; **$B5_1$** five time lack of error and first degree error [5:1] to the fact that he completed the test faster than student CS12 (both made one first degree error each). Student CS12 therefore moved up to 10th position in the ranking (although he also took the longest time to RT in the second test), as students CS9 and CS11 increased their number of errors. The qualitative analysis of the results is completed by a slight negative migration (25% of students) of the BBDTS typology indicators. All students performed only the first jumps with rotation without errors. The quantitative and qualitative analysis of these results is a testimony to the high stability of elements of the nervous system linked also to the motor system, which together determine BBDTS, in the majority (75%) of students practicing combat sport (Table 4).

None of the students practising other physical activity than combat sport performed the 'Rotation Test' without errors before the start of the alpine skiing course. The leader of the rankings made three first-degree errors, six made four first-degree errors, while five made first- and second-degree errors. Although the average score of 5 points (range (3 to 8) indicates the dominance of the average BBDTS level, the actual proportion is as follows: high 8.3%; average 91.7% (n = 11). A more differentiating factor among the students tested is the time to perform RT (from 12.9 to 15.3 seconds). One pair of students performed the RT in an identical time of 12.9 seconds (code AFPA2a and AFPA2b) – the same time the leader of the ranking, but made

Table 4. The results of MEST and the 'Rotation Test' of physical education students practicing combat sport (n = 12) after the alpine skiing course – ordinal variable: RP the RT results after the skiing course.

Student Code	Sport discipline	MEST		Errors during jump with body rotation 360°						RT results after skiing course			Migration		BBDTS typology & migration M/p or n		
		grade (2 to 5)	RP	1R	2L	3R	4L	5R	6L	Points	time (s)	RP p&t	RP p&t before	Points &/orTime	after	before	I/D
CS1	wrestling	5	1	0	0	0	0	0	0	**0**	**10.6**	**1**	1	t –	A	A	
CS2	boxing	5	1	0	0	0	0	0	0	**0**	**11.4**	**2**	2	t+	A	A	
CS3	boxing	5	1	0	0	0	0	0	0	**0**	**11.9**	**3**	3	t+	A	A	
CS4	karate kyokushin	5	1	0	0	0	0	0	0	**0**	**12**	**4**	4	t+	A	A	
CS5	karate kyokushin	5	1	0	0	0	0	0	0	**0**	**12.5**	**5**	5	t+	A	A	
CS6	boxing	5	1	0	0	0	0	0	0	**0**	**12.7**	**6**	6	t+	A	A	
CS8	karate kyokushin	5	1	0	0	0	1	0	0	**1**	**12.4**	**7**	8	t+	$B5_1$	$B5_1$	
CS7	taekwondo WTF	5	1	0	1	0	0	0	0	**1**	**12.9**	**8**	7	p+&t+	$B5_1$	A	Mn
CS10	boxing	5	1	0	0	0	0	0	1	**1**	**13.1**	**9**	10	t+	$B5_1$	$B5_1$	
CS12	karate kyokushin	4.83	2	0	1	0	0	0	0	**1**	**13.8**	**10**	12	t+	$B5_1$	$B5_1$	
CS9	taekwondo WTF	5	1	0	1	0	1	0	0	**2**	**12.3**	**11**	9	p+	$B4_1$	$B5_1$	Mn
NG11	MMA (NG)	4.83	2	0	0	1	0	1	1	**3**	**13.3**	**12**	11	p+&t+	$C3_{i1}$	$B5_1$	Mn
Mean		**4.97**		**0**	**0.25**	**0.08**	**0.17**	**0.08**	**0.17**	**0.75**	**12.41**						
SD		0.07		0	0.43	0.28	0.37	0.28	0.37	0.92	0.83						
Minimum		4.83		0	0	0	0	0	0	0	10.6						
Maximum		5		0	1	1	1	1	1	3	13.8						

Note: **MEST** motor effects of skiing techniques; **BBDTS** body balance disturbation tolerance skills; **RP** ranking position; **p+s** points + seconds; **t–** reduction of RT execution time; **t+** extension of RT execution time; **p–** reducing the number/quality of errors during RT execution; **p+** increasing the number/quality of errors during RT execution; **A** no errors [6:0]; $\mathbf{B5_1}$ five time lack of error and first degree error [5:1]; $\mathbf{B4_1}$ four time lack of error and 2 errors of first degree [4:2]; $\mathbf{C3_{i1}}$ irregular distribution the lack of errors and errors of first degree [3:3]; **Mn** negative migration (deterioration of the result) fewer errors – the other pair in 13.7 seconds (code AFPA4a and AFPA4b). All students in these pairs made four first-degree errors each. Based on the first criterion of the qualitative analysis (total points and RT time), 10 ranking positions were extracted – according to the points criterion there are 5 ranking positions and according to the time criterion there are 9. The qualitative analysis of the results based on the BBDTS typology qualifies the majority of students (50%) to subtype $D2_1$ two time lack of errors and 4 errors of first degree [2:4], while the others to: $D1_i$ one-sided lack of errors and 5 errors of first and second [1:5] (25%); $C3_{i1}$ irregular distribution the lack of errors and errors of first degree [3:3] (8.3%); $D2_i$ two time lack of errors and 4 errors of first and second [2:4] (8.3%); E_i irregular errors of first and second degree [0:6] (8.3%). There was no case of faultless execution of even one jump with body rotation (in the sense of RT structure) by all students (Table 5).

The MEST results divide students practising other physical activity than combat sport into four ranking groups for this criterion. The most numerous (n = 7) are represented with a score of 4.83 grade; two each with 5 grade and 4.67 grade, only one with 4.5 grade. The results of the 'Rotation Test' deteriorated both in terms of a higher number of errors (mean score of 5.58, 0.58 more in

Table 5. The results of the 'Rotation Test' (ordinal variable) of physical education students practicing other physical activity (n = 12) before starting their alpine skiing course.

Student code	Errors during jump with body rotation 360°						RT results			BBDTS	
	1R	2L	3R	4L	5R	6L	Points	time (s)	RP p+s	Typology	RP
OFPA1	1	0	1	0	0	1	**3**	**12.9**	**1**	$C3_{i1}$	1
OFPA2a	1	1	1	0	0	1	**4**	**12.9**	**2**	$D2_1$	2
OFPA2b	1	1	0	1	0	1	**4**	**12.9**	**2**	$D2_1$	2
OFPA3	1	1	0	0	1	1	**4**	**13.4**	**3**	$D2_1$	2
OFPA4a	1	1	0	1	1	0	**4**	**13.7**	**4**	$D2_1$	2
OFPA4b	0	1	1	0	1	1	**4**	**13.7**	**4**	$D2_1$	2
OFPA5	1	1	0	1	1	0	**4**	**13.8**	**5**	$D2_1$	2
OFPA6	1	1	1	1	0	2	**6**	**13.3**	**6**	$D1_i$	4
OFPA7	0	1	0	2	1	2	**6**	**14.6**	**7**	$D2_i$	3
OFPA8	1	1	2	1	1	0	**6**	**15.3**	**8**	$D1_i$	4
OFPA9	1	2	1	1	0	2	**7**	**14.9**	**9**	$D1_i$	4
OFPA10	2	1	2	1	1	1	**8**	**15.2**	**10**	E_i	5
Mean	**0.92**	**1**	**0.75**	**0.75**	**0.58**	**1**	**5**	**13.88**			
SD	0.49	0.41	0.72	0.60	0.49	0.71	1.47	0.86			
Min.	0	0	0	0	0	0	3	12.9			
Max.	2	2	2	2	1	2	8	15.3			

Note: **BBDTS** body balance disturbation tolerance skills; **RP** ranking position; **p+s** points + seconds; $\mathbf{C3_{i1}}$ irregular distribution the lack of errors and errors of first degree [3:3]; $\mathbf{D2_1}$ two time lack of errors and 4 errors of first degree [2:4]; $\mathbf{D_{2i}}$ two time lack of errors and 4 errors of first and second [2:4]; $\mathbf{D_{1i}}$ one-sided lack of errors and 5 errors of first and second [1:5]; $\mathbf{E_i}$ irregular errors of first and second degree [0:6] relation to the before skiing course) and in terms of the time taken to perform the RT (mean score of 14 s, 0.12 s more). Both differences are not statistically significant. The increase in RT performance time applies to 8 (66.7%) students, while among the remaining four, three (25%) performed the RT in a shorter time between 0.1 s and 0.4 s, and one student (8.3%) in an identical time to before skiing course (code OFPA4a). Three students reduced their errors and two of them (OFPA1 and OFPA2a) also reduced their RT time. Variations in both RT indicators (points and time) during the second examination resulted in 12 ranking positions due to this criterion. Three students remained in the same RT ranking positions: OFPA1 and OFPA2a reduced the number of errors and performed the RT faster, while student OFPA6 reproduced the error structure of the first examination but performed the RT longer by 0.3 s. The qualitative analysis of the results is completed by the differential migration of the BBDTS typology indicators. A positive one was found in three students (OFPA1, OFPA2a, OFPA2b) – also in three (OFPA6, OFPA9, OFPA10) this indicator proved stable - while in six (50%) the migration was negative. There was no case of flawless execution of even one jump with body rotation (in the sense of RT structure) by all students. The quantitative and qualitative analysis of these results does not authorize the conclusion about the stability of elements of the nervous system also related to the motor system of students practicing other physical activity than combat sport determining BBDTS (Table 6).

Between the tested groups of students the differences of both RT indices are statistically significant ($p<0.001$) each time in favour of practicing combat sport students. During the tests before starting the alpine skiing course the difference in points was 4.58 and in time 1.67 second. During

Table 6. The results of MEST and the 'Rotation Test' of physical education students practicing other physical activity (n = 12) after their alpine skiing course – ordinal variable: RP the RT results after skiing course.

Student Code	MEST		Errors during jump with body rotation 360°						RT results after skiing course			Migration		BBDTS typology & migration M/p or n		
	Grade (2 to 5)	RP	1R	2L	3R	4L	5R	6L	Points	time (s)	RP p&t	RP p&t before	Points &/or time	after	before	I/D
OFPA1	**5**	**1**	1	0	1	0	0	0	**2**	**12.7**	**1**	1	p−&t−	$B4_1$	$C3_{i1}$	Mp
OFPA2a	**4.67**	**3**	1	1	0	1	0	0	**3**	**12.8**	**2**	2	p−&t−	$C3_{i1}$	$D2_1$	Mp
OFPA2b	**4.83**	**2**	1	0	1	1	0	0	**3**	**13.1**	**3**	2	p−&t+	$C3_{i1}$	$D2_1$	Mp
OFPA3	**4.83**	**2**	1	1	0	0	1	2	**5**	**13.6**	**4**	3	p+&t+	$D2_i$	$D2_1$	Mn
OFPA54b	**5**	**1**	0	2	1	0	1	1	**5**	**13.8**	**5**	4	p+&t+	$D2_i$	$D2_1$	Mn
OFPA6	**4.83**	**2**	1	1	1	1	0	2	**6**	**13.6**	**6**	6	t+	$D1_i$	$D1_i$	
OFPA4a	**4.83**	**2**	1	1	0	2	1	1	**6**	**13.7**	**7**	4	p+	$D1_i$	$D2_1$	Mn
OFPA5	**4.83**	**2**	1	2	0	2	1	0	**6**	**13.9**	**8**	5	p+&t+	$D2_i$	$D2_1$	Mn
OFPA8	**4.5**	**4**	1	1	2	1	1	1	**7**	**14.9**	**9**	8	p+&t−	E_i	$D1_i$	Mn
OFPA9	**4.83**	**2**	1	2	1	2	0	1	**7**	**15.1**	**10**	9	t+	$D1_i$	$D1_i$	
OFPA7	**4.83**	**2**	0	2	1	2	1	2	**8**	**15.2**	**11**	7	p+&t+	$D1_i$	$D2_i$	Mn
OFPA10	**4.67**	**3**	2	1	2	1	1	2	**9**	**15.6**	**12**	10	p+&t+	E_i	E_i	
Mean	**4.80**		**0.92**	**1.17**	**0.83**	**1.08**	**0.58**	**1**	**5.58**	**14.0**						
SD	0.138		0.49	0.69	0.69	0.76	0.49	0.82	2.02	0.93						
Min.	4.5		0	0	0	0	0	0	2	12.7						
Max.	5		2	2	2	2	1	2	9	15.6						

Note: **MEST** motor effects of skiing techniques; **BBDTS** body balance disturbation tolerance skills; **RP** ranking position; **p+s** points + seconds; **t**– reduction of RT execution time; **t+** extension of RT execution time; **p–** reducing the number/quality of errors during RT execution; **p+** increasing the number/quality of errors during RT execution; **$B4_1$** four time lack of error and 2 errors of first degree; **$C3_{i1}$** irregular distribution the lack of errors and errors of first degree; **$D2_1$** two time lack of errors and 4 errors of first degree [2:4]; **$D2_i$** two time lack of errors and 4 errors of first and second [2:4]; **$D1_i$** one-sided lack of errors and 5 errors of first and second [1:5]; **E_1** irregular errors of first and second degree [0:6]; **Mp** positive migration (improved result); **Mn** negative migration (deterioration of the result) the research after the alpine skiing course respectively: 4.83 points and 1.59 second. The difference of 0.17 grade MEST is also in favour of practicing combat sport students (4.97) and is statistically significant (p<0.001).

In the group of students practicing combat sports half of the body composition indices are not significantly correlated with RT indices and variable MEST. The highest r coefficient concerns the MEST variable with body height and it is a high correlation (r = 0.565, p<0.05). Assuming the directional test is valid, BMI correlates positively with the three RT indices (from 0.539 to 0.512), while the RT before the alpine skiing course correlates positively (r =0.480^) with Body fat % and negatively (r =0.493^) with Body water % (Table 7). There is a logical justification for the fact that less fat students practicing combat sports make fewer mistakes and perform RT faster. The average, statistically insignificant correlation of RT before (points) with BMI is derived from the very even level of BBDTS students before starting their alpine skiing course (only two BBDTS ranking positions and 12 BMI).

In the group of students practicing other forms of physical activity than combat sports, seven out of eight body composition indicators are significantly correlated neither with RT indicators, nor with the MEST variable. The only and high, statistically significant negative correlation (r = −0.605, p<0.05) concerns BMI with RT scores before the alpine skiing course. In contrast to the results of students practicing combat sports, BMI weakly or moderately correlates negatively with the other RT indices (Table 8). However, there is no logical basis for referring to the directional test not only when associating BMI with RT indicators and the MEST variable, but also with the other body composition indicators.

In the group of students practicing combat sports, all intercorrelations of RT indicators are positive from almost full (r = 0.984, p<0.001) to high (r = 0.544^). All correlations of RT indicators

Table 7. Correlation of the 'Rotation Test' indices and variable the motor effects of skiing techniques (MEST) with body composition indices of students practicing combat sports (n = 12).

RT indicators and MEST (2 to 5 grade)	Body composition indicator							
	Body height (cm)	Body weight (kg)	BMI	Body fat (%)	Body water (%)	Muscles (kg)	Bones	Visceral fat (range)
RT before (points)	0.082	0.293	0.390	0.280	−0.276	−0.016	0.000	−0.015
RT after (points)	0.131	0.407	**0.539^**	0.191	−0.136	0.252	0.285	−0.165
RT time before (s)	0.111	0.373	**0.512^**	**0.480^**	**−0.493^**	−0.013	−0.014	0.221
RT after (s)	0.073	0.366	**0.539^**	0.413	−0.438	−0.020	−0.019	0.164
MEST (grade)	**0.565***	0.214	−0.153	−0.338	0.324	0.292	0.283	−0.274

***** p<0.05; **^** p<0.05 for a directional test

Table 8. Correlation of the 'Rotation Test' and motor effects of skiing techniques (MEST) indices with body composition indices of students practicing other forms of physical activity than combat sports (n = 12).

RT indicators and MEST (2 to 5 grade)	Body composition indicator							
	Body height (cm)	Body weight (kg)	BMI	Body fat (%)	Body water (%)	Muscles (kg)	Bones	Visceral fat (range)
RT before (points)	0.397	−0.377	**−0.620***	0.175	0.419	−0.011	0.029	−0.197
RT after (points)	0.484	−0.012	−0.409	0.485	0.140	0.129	0.169	0.020
RT time before (s)	0.317	0.022	−0.237	0.319	0.314	0.184	0.218	−0.128
RT after (s)	0.379	−0.046	−0.344	0.320	0.346	0.128	0.174	−0.135
MEST (grade)	0.068	0.483	0.336	−0.083	−0.060	0.349	0.315	0.136

*p<0.05

Table 9. Correlation of the 'Rotation Test' and motor effects of skiing techniques (MEST) indices of students practicing combat sports (n = 12).

RT indicators and MEST (2 to 5 grade)	RT points before	RT points after	RT time before	RT time after
RT before (points)	-			
RT after (points)	**0.777****	-		
RT time before (s)	**0.590***	0.544^	-	
RT time after (s)	**0.582***	0.546^	**0.984*****	-
MEST (grade)	**−0.529^**	**−0.605***	**−0.605***	**−0.615***

***** p<0.05; **p<0.01; *** p<0.001; ^ p<0.05 for a directional test

Table 10. Correlation of the 'Rotation Test' and motor effects of skiing techniques (MEST) indices of students practicing other forms of physical activity than combat sports (n = 12).

RT indicators and MEST (2 to 5 grade)	RT points before	RT points after	RT time before	RT time after
RT before (points)	-			
RT after (points)	**0.841****	-		
RT time before (s)	**0.818****	**0.881****	-	
RT time after (s)	**0.875****	**0.943****	**0.962****	-
MEST (grade)	−0.497	−0.409	−0.528	−0.417

**p<0.01

with the MEST variable are negative and high (Table 9). This is empirical evidence that the skiing skills of students who made fewer mistakes and performed RT faster were rated higher. It is logical to refer to the directional test, an argumentation that coincides with the interpretation of the results summarised in Table 7. Furthermore, it is significant that the highest MEST score was given to 10 students (83.33%), and two were close to the highest, each at 4.83.

The almost complete correlation of RT time after alpine skiing course by students practicing other forms of physical activity than combat sports with the remaining RT indices, and very high correlation between the remaining ones, is a result of high differentiation of raw results (Table 10). On the other hand, these indicators are negatively correlated high and on average, but not statistically significantly, with the MEST variable. Despite the high variability of RT indices in this group of students and the more dispersed MEST scores (four ranking positions), a tendency was revealed that the skiing skills of students who made fewer mistakes and performed RT faster were rated higher. However, there is no logical basis for the reference to the directional test.

DISCUSSION

We used an quasi-apparatus version of 'Rotation Test' in this research in the video verification standard. In this way, we increased the reliability of the expert observations – for every doubt, it was possible to multiply the secondary observation until the experts' assessments agreed. The innovation of this research also lies in the fact that in the qualitative analysis of the results we refer, among other things, to the BBDTS typology. Precisely by increasing the reliability of the documented RT results, at the same time the confidence in the indicators of this typology has increased.

Therefore, since the BBDTS typology is based solely on the criterion of RT scores, the confidence of the observation results is such a very important element. When this methodological condition is met, the importance of qualitative analysis referring to the migration of indicators of the BBDTS typology increases. This makes the results of such analyses, in the case of repeated application of RT under changing circumstances, indirectly inform about the stability (or lack thereof) of those elements of the nervous system that are co-responsible for maintaining optimal motor performance of a working human being as a function of time. Although results of unique studies using RT precisely in changing circumstances (especially increasing exercise, sleep deprivation, or a combination of both criteria [16-22] – few previous studies have found an increase in imbalance in the morning, but this has been studied with other tools [23-25]) are available, there is no information on the migration of indicators of BBDTS typology.

On the other hand, there are available results of correlating in an original way two types of typology of BBDTS 27 firefighters in relation to other RT indicators and SRT indicators (simulation of rescue task: passage there and back on the balance beam fixed to a platforms located on two scaffoldings, 3 meters above the concrete ground). Typology of BBDTS in sports tracksuit (first kind) correlates very high (r = 0.884, p<0.01) with result RT points performed in sports tracksuit, also very high (r = 0.739, p<0.01) with level of BBDTS in sports tracksuit. Highly correlated (p<0.01) with the following indicators: result RT points performed in protective clothing weighing around 12 kg (r = 0.618); level of BBDTS in protective clothing (r = 0.529); typology of BBDTS in protective clothing (the second kind) r = 0.523; while on average with the ranking of firefighters (r = 0.396, p<0.05). Typology of BBDTS in protective clothing does not correlate statistically significantly (r = 0.285) with the basic ranking of firefighters. This kind of typology of BBDTS statistically significantly (p<0.01) correlates very highly with result RT points performed in protective clothing (r = 0.814) and with level of BBDTS performed in protective clothing (r = 0.789); highly correlates with level of BBDTS (r = 0.520, p<0.01) and on average with RT results in sports tracksuit (r = 0.478, p<0.05) [26].

The authors of the cited studies [26] limit the typology to general indicators of two categories: I (A, B, C, D, E); II of the second (F, G, H, K, Z [1]). An important finding is that firefighters who performed the SRT tasks faster made more mistakes (both in quantitative and qualitative terms) during RT. However, the authors found no statistically significant correlations between the RT results measured with points and the SRT results measured with the simulation time in seconds. In a study of firefighters, there was no significant correlation of RT indices with BMI [26].

A secondary analysis of the migration phenomenon mentioned above is possible, provided that either raw RT results are monitored in the available publications or the authors of the work have preserved them in archives. Conducting such a secondary analysis for the purpose of the discussion of this work in the first place is beyond the editorial scope of this publication. If there are even few publications monitoring raw RT results [27], we recommend to authors of papers already published, but also to researchers who have RT results repeated many times in a given empirical setting, not to give up the opportunity to perform a qualitative analysis along the lines of our work.

The advantage of any study using the 'Rotation Test' (those in the laboratory as well as in the field) is the possibility of obtaining important general information about the quality of functioning of the nervous system without the need for complex and expensive apparatus. This means that RT meets the criteria of a simple tool useful in screening, and in medical, sports (and a certain group of professions), diagnostics. With such an obvious conclusion, it is reasonable, among other things, to ask: why, in the structure of the International Physical Fitness Test (IPFT [28]), is there no sample measuring any manifestation of body balance?

This situation partly justifies researchers using the IPFT in longitudinal studies of athletes of those sports in which success is related to the quality of the BBDTS. The result of Jagiello's research (individual and co-authored [29-32]) an others [33] is an example of such a gap. On the other hand, there is a group of researchers who compare the results of various balance tests, disregarding overall physical fitness [34]. Starosta and Baić [35], in their review of the tests used in the practice of training high-class wrestlers, emphasize the importance of compiling many conditioning and coordination abilities (including balance).

Cognitively valuable are publications whose authors associate the results of RT with different categories of empirical variables (even with those of logically dubious correlation). Joanna Syska [36], examining female students (n = 23) who realized a special course of modern forms of gymnastics and dance with elements of self-defence, did not find any significant association of RT results either with Eurofit indices (including the *flamingo balance test*) neither with indicators of somatic constitution, nor with physical fitness (measured by the Harvard test in Wolkow's version [37]), nor with results of psychological tests, nor with indicators of self-defence tests [38], nor with indicators of self-defence skills, nor with indicators of test fights [39]. However, statistically significant correlations were established in three subgroups separated by the criterion of the number (proportion) of test fights won. In the subgroup of female students who won all test bouts (n = 6), RT correlates negatively very highly with *plate tapping* score (r = −0.917, p<0.01). In the subgroup of female students who won at least one test fight but not all of them (n = 11) RT (for a directional test) correlates highly (p<0.05) negatively with the *bent arm hang* test score (r = −0.585) and with the performance index for defending against grappling, choking and punching (r = −0.557). In the subgroup of female students who lost all test bouts (n = 6) RT (for a directional test) correlates significantly (p<0.05) very highly positively with aggressiveness (r = 0.743) and Rohrer index (r = 0.732), while negatively with body height (r = −0.743); RT correlates on average (p<0.05) positively (r = 0.698) with body weight (r = 0.698), while it correlates negatively with indicators of defensive effectiveness by anticipatory strikes (r = −0.680) and with physical performance(r = −0.679) [36].

However, in other studies regardless of whether the researchers used a non-apparatus or a quasi-apparatus version of RT, statistically significant correlations of RT points have an important cognitive value: with the time (s) of the dynamic test 'Three benches' (r = 0.638, p<0.02) performed by 12-years old girls, who train volleyball (n = 15) and r = 0.606, p<0.02 performed by 12-years old boys, who train soccer (n = 15) [1]; with the time (s) more complex actions 'military obstacle 1 and 2' (r = 0.414 and r = 0.414, p<0.05) performed by 30 paratroopers [40]; with 'Flamingo' Test points (r = 0.400, p<0.05) performed by 12-years old boys, who are not engaged in sport (n = 30) [1]; with standing broad jump (r = 0.35, p<0.001) and with run 100 m (r = 0.31, p<0.01) performed by Lithuanian non-governmental guards (n = 118) [41].

The original correlations of RT results were made by Mroczkowski and Sikorski [42] in a study of 10-12 year old boys (n = 53) and girls (n = 35). There is high correlation (r = −0.612 boys, girls r = −0.578, both p<0.01) between the results of RT and global motor co-ordination test (Starosta's coordination meter: sum of maximum jumps with rotation to right and to the left [43, 44]). The less errors the examined children made during RT, the more favourable was the Starosta's test result. The authors also correlated the results of RT and global motor coordination test in the same direction. Tree jumps with 360° rotation (sum of points) in right and results global motor co-ordination test in right: boys r = −0.461, p<0.01; girls r = −0.508 p<0.01. Respectively for the left side, both tests: boys r = −0.602, p<0.01; girls r = −0.591 p<0.01. However, they did not present the correlation of RT results with the results *"The susceptibility test to the body injuries during the fall"* STBIDF [45].

The correlation of the non-apparatus RT results with the results of STBIDF was made by Robert Bąk [46] (51 students of the 4th year in the field of tourism and recreation: 27 women, 24 men, aged 22). In people with low and average SBIDF (the susceptibility to the body injuries during the fall) a statistically significant relationship with the high BBDTS capability was found (men r = 0.639, p<0.01). A statistically significant relationship SBIDF with the high BBDTS was found (men r = 0.639, p<0.01; women 0.583, p<0.01).

The results of our study are a good example – – as pointed out among others by Ferguson and Takane [47] – that limiting the range, in a statistical sense, sharply reduces the size of the correlation coefficient. Therefore, in analyses (especially review work), the range, should be considered as an important statistical indicator in the interpretation of RT results correlated with other empirical variables. This note is not an exhaustive recommendation. In subsequent studies with a higher degree of interdisciplinarity, it is possible to use the filming technique also for the In subsequent studies with a higher degree of interdisciplinarity, it is possible to use the filming technique also for the other cognitive purposes – for example, knowledge of the emotional state in different the circumstances of the experiment [48].

This discussion of results, although limited by editorial limitations, shows the methodological potential of the well validated 'Rotation Test' [1]. In further research, we recommend the use of the video verification standard, i.e. filming the test subjects, and documenting the results with full confidence that they are unencumbered by possible observer errors recording the result on the fly. Moreover, the researcher without an assistant is sufficient to apply the proposed apparatus version. Our second recommendation is to perform qualitative analyses of the BBDTS whenever RT is used in changing circumstances (cyclically or even just once).

CONCLUSIONS

This slight deterioration of both RT indices was found in both groups proves that intensive, long-lasting alpine skiing training is a significant neuro-physiological burden on the organism, regardless of previous motor specialization. Moreover, RT results prove that combat sports (martial arts) shapes BBDTS in an optimal way.

Both RT evaluation criteria (points and test time) suggest that they are sensitive indicators and can be recommended as useful in preclinical studies of the nervous system (with certain limitations), that is the some aspects of the condition of organs and functions responsible for maintaining the balance of the body during human motor activity.

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