The method to evaluate the body balance disturbation tolerance skills – validation procedure of the 'Rotational Test'

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C Statistical Analysis
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Abstract

Background & Study Aim: Body balance disturbation tolerance skills (BBDTS) can be defined as the ability to maintain the vertical posture in the circumstances of the fall hazard. The aim of this study is appropriateness and reliability of 'Rotational Test' (RT) as BBDTS measurement tool.

Material & Methods: RT consists of six tasks (consecutive jumps with body rotation of 360° alternately to the right and to the left). The overall result is the sum of the six tasks and includes 0 to 18 stipulated points. *Criterion-oriented validity (concurrent validity and predictive validity); content validity*; *construct validity* have been assumed to be the main criteria of appropriateness. Reliability of the RT is based on the 'test-retest' formula. Following all phases of the validation process we have examined 1398 people aged from 6 to 60 years.

Results: RT individual results consisted of 0 to 18 points, however in homogeneous groups the average RT result varied from 0.33 to 11.06 points. RT satisfies methodological criteria of appropriateness and reliability of a tool which indirectly indicates the quality of the body mechanisms responsible for balance and postural control. Reliability of the RT has been determined as high ('test-retest' correlation varies from 0.828 to 0.848).

Conclusions: RT is sensitive to the factors modifying BBDTS – especially adaptive changes related to a long-term training as well as the influence of the current state of the body and/or a sudden change in the conditions of motor action. Thus, RT can be widely used in rehabilitation, health-related training, motor control (sport, physical education, etc.), the selection process in the army, police, emergency services, etc.

Key words: appropriateness • postural control • reliability • safe fall • stability

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Background

The problem of maintaining the posture (briefly: balance) has become an interest in numerous fields of science i.e. aviation medicine, biomechanics, kinesiology, neurology, sports medicine, sport science, etc.

Fall avoidance is discussed as one of the most important tasks of postural control [1,2]. Our interest in this issue is related to the research we have been conducting for many years that concerns the prevention of injuries due to falls or collisions with vertical obstacles or objects which are in motion [3–8]. These events are almost always resulting from errors in the stability and

Abilities (motor abilities) – stable, enduring traits that, for the most part, are genetically determined and that underlie a person's skill in a variety of tasks. People differ with respect to their patterns of strong and weak abilities, resulting in differences in their levels of skill [11].

Optical flow – the movement (or continuous flow) of patterns of light rays from the environment over a person's retina, allowing the person to detect motion, position, and timing [11].

Ambient vision – The visual system that allows people to detect the orientation of their body in the environment; it is non-conscious, takes in all of the visual field, and used for action and movement control [11].

Perceptual sentence – in the methodological meaning is constative utterance the result of some observation (result of the measurement).

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 [61].

Skill – The underlying potential for performance in a given task, which changes with practice experience, and a host of situational and environmental factors [11].

Sutemi (jap.) – the state of sacrificing one's all in a match, or executing a technique without thinking about the outcome [62].

Suples – specific throw in wrestling, when the attacker first down on his back.

postural orientation [2,8], including disorders of the optical flow and ambient vision [9–11].

In the field of human motor skills, balance is considered to be the ability of coordination [12]. There are numerous methodological concepts in balance studies. The division of the balance to static and dynamic is very common [11–14]. Despite the controversies over the legitimacy of this division, the fact is that the results of tests measuring both types of balance mutually are not highly correlated. In an important experiment conducted by Drowatzky and Zuccato [13], which was based on matching the results of six attempts to maintain the balance (three static: *stork stand*, *diver's stand*, *stick stand* and three dynamic: *sideward stand*, *bass stand*, *balance stand*), the highest correlation coefficient equalled 0.31 (coefficient of determination was only 9.61%). Schmith and Wrisberg in interpreting these results correctly concluded that: "(…) *the low correlations they fund suggested that there isn't even a general ability for balance. Rather, it appears that different balance tasks require different abilitiesfor controlling posture in different ways (…) the findings of this study (…) offer no support for the notion that people possess a solitary, general motor ability*" [11, p. 167].

Moreover, if the hypothesis is plausible, in spite of accuracy and similarities between typical human kind, the most elementary neuroanatomical and neurophysiological grounds of the body balance are individually determined [see i.e. 15]. However, an empirical argument quoted above is enough to doubt the possibility of creating the tool (test) measuring an individual potential in the universal meaning. This means that the result of such test would constitute a basis for predicting the opportunities to maintain the body balance in infinite number of even simple situations when the motor action is performed. Existence of such test and predictions would be an utopia on the current stage of science development. Body balance disturbation tolerance skills (BBDTS) is defined as the ability to maintain the vertical posture in circumstances of the fall hazard.

This definition is a direct consequence of the hypothesis that due to the nature of this neuroanatomical and neurophysiological grounds, abilities and prior motor experience some people are able to maintain vertical posture despite unfavourable circumstances, while others cannot in the same conditions. This hypothesis is a deeply ingrained elementary assumption stating that remaining factors of the internal and/or outside nature of people's actions are very similar and in some aspect identical or nearly identical (i.e. the degree of sobriety, clothes, used equipment, lighting, humidity, ambient temperature).

This assumption, however, has only a theoretical value. While it is relatively easy to determine the similarity between certain environmental factors of action (i.e. two people running on the ice), it is extremely difficult to accept as true only one of the two competitive explanations concerning the fall of one of them: (1) that it is the result of deficits on the level of neuroanatomical and neurophysiological bases for the body balance, including deficits of abilities and experience in motor skills, (2) that it is the factor or accumulation of factors that the observer would not be able to control either before the event, during the event or after the event. Since it is impossible to control these factors, according to the criteria of empirical correctness, probabilistic inference will remain grounded in the results of laboratory tests of BBDTS which in turn will create misunderstandings requiring some necessary simplifications. One of the main simplification is the assumption that regardless of the circumstances of the fall hazard, the general mechanism of BBDTS is determined according to the quality of neuroanatomical and neurophysiological mechanisms, abilities and prior motor experience of an individual.

The general distinction of fall hazard circumstances is based on three criteria. First (CFR 1) includes the imbalance caused by the external force acting on the man, who has no influence on it. The examples of such circumstances involve e.g. a person in a moving bus, tram or other vehicle that suddenly stops. In the second criterion (CFR 2) a force disrupting the balance of a man is a motor activity performed on a relatively stable surface. The complexity of the movement, motor experience, current physical predisposition, the degree of concentration on the task, anxiety and numerous other factors involving the internal nature of the person affect the fall hazard during this movement. The examples illustrating the criterion include a soloist dancer, acrobat, karate practitioner during formal training (*kata*), a person attempting to perform a new, unknown motor activity (i.e. dance step), etc. Third criterion (CFR 3) includes the cumulative effects of any external force(s) and internal factors concerning a person performing an action. This class of circumstances is the widest and at least two sub-groups can be identified therein in more detailed classification: (a) fall hazard when even a simple motor activity is hindered by external conditions (e.g. walking on slippery surfaces), (b) intentional action to cause a fall of another person or the need to maintain vertical posture for a specified time or in a fixed point of action (e.g. a sumo bout), or by preceding this situation by own fall (it is possible to end judo fight by throwing somebody from the group of *sutemi-waza* or *suples* in wrestling, self-defence as well as saving a person from a collision with some object in motion).

The aim of this article is the relevance and reliability of 'Rotational Test' as a tool for measuring body balance disturbation tolerance skills.

It is due to the objective of this paper why the 'Results' part has been written in a different manner than in a standard paper. In this paper, 'Results' comprises not only a set of perceptual sentence and corresponding tables and figures but also contains assumptions and detailed discussion (intermediate goals) and hypothesis adequate to the particular stages of validation procedure.

Material and Methods

'Rotational Test' (RT) as measurement tool of the body balance disturbation tolerance skills

Rotational Test procedure in quasi-apparatus version. (1) if this is the first performance of the test, carefully explain the rules and make a preliminary assessment: adopt a standing straddle position (legs to the width of hips) on safe but not excessively elastic ground (such criterion is fulfilled by the tatami mattresses) so that the middle part of the feet are on the designated line not wider than 1 cm (the most effective is the use of e.g. soft stretched rope enabling the examination of the blind; in case of examination of visually impaired person, the rope should be yellow); on the command 'ready' given by the principal investigator of the research, bend your knees and once you hear 'right' do the jump with a 360° rotation to the right and after landing once you hear 'correction', correct the posture so that the feet are on the designated line and according to the criteria described above; once you hear 'left' do the jump with a 360° rotation to the left; the command 'correction' given by the principal investigator is a call to correct the posture (if a person fails twice to maintain vertical posture, do not proceed to the main test – BBDTS would be assessed as insufficient); (2) the main test consists of 6 tasks, starting with the jump with a 360° rotation to the right. 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*). Each set of 'jump-landing-posture correction' should last about two seconds and the principal investigator of research starts a stopwatch while pronouncing "r" during the first command i.e. 'right' and stops it during the pronunciation of "t" in the last command i.e. "left".

Evaluation method: An assistant provides documentation for motor effects of the test: landing after the jump on the designated line with both feet and maintaining balance means the lack of the mistake (the result is recorded as **"0"**), no contact of one foot with the line after landing is assessed as **"1"** (first degree mistake), **"2"** means the lack of contact with the line after landing or not maintaining this contact while correcting the posture (second degree mistake), **"3"** records leaning against the ground with a hand/hands or a fall (third degree mistake).

Figure 1. *Rotational Test* observation post.

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). The examined person should not be pressed to perform the test as fast as possible. In fact, the attention should be paid to accurate performance of individual tasks, simultaneously respecting the commands, adaptation to the rhythm of jumps with rotations of a given person and necessary corrections.

The principal investigator of research should remain in a distance of ca. 2 meters in front of the examined person (if necessary the principal investigator can additionally indicate the direction of the jump with rotation). An assistant stands at the side of the principal investigator of research so that he is able to observe the feet of examined person (Figure 1). While gathering observations an assistant cannot look at the document (after completion of test, the results can be rewritten from the working paper to the research card). An examined person should be provided with comfort. The place where the test is performed should be free of any movement of other people or objects (i.e. fan, flash). Any noise or talks are unacceptable.

Non-apparatus version of the test can be conducted by one person, who is simultaneously giving commands and documenting the motor effects. Each subsequent RT implementation does not require the initial assessment (two initial jumps with rotation – first to the right, second to the left).

Evaluation criteria for both versions of the test (quasi-apparatus and non-apparatus). The overall result is the sum of the six tasks (consecutive jumps with body rotation) and includes 0 to 18 stipulated points. **"0"** indicates a very high ability to tolerate imbalances, while **"18"** means

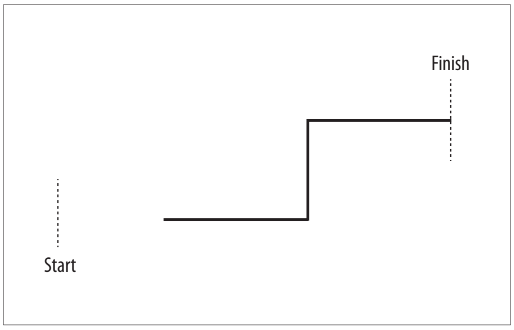

Figure 2. Scheme of the *'Three benches'* empirical system.

the exact opposite of that assessment. Corrected (in relation to the pilot version [16,17]) criteria of an individual level assessment determined by the 'Rotational Test' (RT) are as follows: very high (0–1), high (2–3), average (4–9), low (10–12), very low (13–15), insufficient (16–18).

Rotational test validation

The RT validation procedure is based on appropriateness/relevance and reliability/accuracy. As the main criteria of appropriateness we assumed: (1). *Criterion oriented validity – concurrent validity and predictive validity;* (2). *Content validity*; (3). *Construct validity.* Reliability test is based on the formula 'test-retest' (with 1 week interval).

In this procedure, the primary criteria of RT appropriateness are statements verging on *the oriented validity (concurrent validity and predictive validity)* and *content validity*. RT content (6 motor tasks) reflects circumstances of fall hazards defined above as CFR 2. If the hypothesis that people, who possess optimal quality of neuroanatomical and neurophysical mechanisms, the abilities and prior motor experience, are able to maintain the vertical posture despite unfavourable circumstances is true, the test result entitles the effectiveness of prediction also in reference to the CFR 1 and CFR 3. Although the most difficult situations can be assigned to CFR 3 circumstances, judokas and wrestlers know that many novices, even though they the lack special skills and experience, can even maintain a vertical posture for several seconds in spite of intensive master attacks. This most general argumentation appeals initially for fulfilled criterion of *content validity.*

If an examined person can be characterised with the correct body-building (in the sense of descriptive anatomy), lack of movement dysfunction (compliance with functional anatomy), as well as a similar age and previous motor experience, it is reasonable to assume that RT result reflects in the broadest sense the quality of neuroanatomical and neurophysiological mechanisms responsible for maintaining the body balance. If the nominal RT scale is nineteen point scale (from 0 to 18 pts.) and thus enables to create at least five class intervals of these so-called raw results, but in reliable sample of the population the distribution of processed results should be similar to the normal one (*concurrent validity* criterion would be fulfilled as the first).

However, if people meet the general conditions of above mentioned assumption but for a long time are stimulated by frequent disruption of the body balance which are adequate either to CFR 1 or CFR 2 or CFR 3 circumstances, or if it is a compilation of this circumstances (i.e. special force, stunts, training, etc.), the RT result contains the sum of information about the malleable neuroanatomical and neurophysiological mechanisms responsible for maintaining the body balance, as well as the abilities of a particular person. This general assumption is a preliminary explanation for empirical systems that have been developed in order to verify RT *criterion oriented validity*.

Construct validity is based on the fundamental assumption that a property which is revealed every time while using RT is the quality of the neuroanatomical and neurophysiological mechanisms responsible for maintaining the body balance. Therefore, regardless of whether the person is taking systematic physical activity with high intensification of the exercises, or sufficient number of incentives is missing, or even reduces the physical effort to essential motor self-service, it is hard to point any other body mechanism with so fundamental importance for BBDTS.

'Flamingo' Test

According to the Eurofit criteria [18].

'Three benches' empirical system

This test involves going through or running over three gymnastic benches arranged one after the other at the angle of 90°. The starting line is at the distance of 2 metres from the first bench (Figure 2).

'Military obstacle 1' empirical system

A person performing the test should move with help of a rope from a gymnastic ramp to a footbridge 5 metres long and 60 cm wide. The footbridge should be at the distance of 6.5 metres and hanging on four chains 55 cm over the ground (Figure 3). The time is measured from the moment of contact of one foot or feet with the footbridge to the moment of contact of at least one foot with the ground (after running the footbridge).

Figure 3. Footbridge on chains to be run through during *'Military obstacle 1'* empirical system.

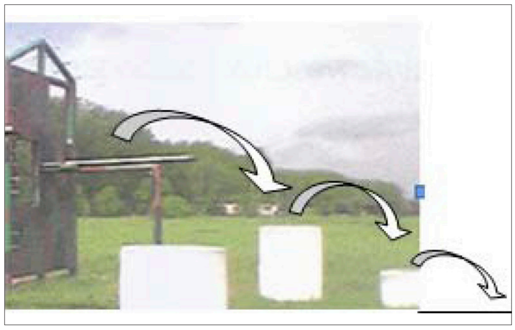

Figure 4. Scheme of the *'Military obstacle 2'* empirical system.

'Military obstacle 2' empirical system

The test involves running the footbridge 28 cm wide and 3.11 metres long placed 3 metres over the ground and jumping off first on the concrete ring 2 metres high, afterwards on the next being 1 metre high and finally on the ground (Figure 4). The time is measured from the 'start' command to the moment of contact of at least one foot with the ground (after running the footbridge and the rings).

The analysis of literature and scientific documentation

Apart from the publications concerning balance and related issues (balance loss, fall, etc.) the analysis comprises dissertations (B.A., M.A., PhD, habilitation thesis) in which the authors applied RT in non-apparatus version in various empirical systems subordinate to the objectives of validations stages. Hence, numerous independent reviewers and examination committees represented by sport science specialists have participated in all stages of validation process. One of the most important effects of the studies, observations and recommendations of the independent reviewers was the final development of RT in non-apparatus version.

Statistical analysis

The estimation of empirical variables (arithmetic mean, sample standard deviation, etc.), measure of skewness (g_1) and measure of kurtosis (g_2). Hypothesis testing (significance test – independent correlation coefficients). Correlation coefficient between pairs of specified variables.

Material

During the long-term validation procedure we examined above 4 000 persons. In this report we are taking into account the most important results of 1 398 persons (of women and men) aged from 6 up to 60 years: 268 pupils of primary schools, secondary schools, colleges; 443 students; 248 athletes; 90 paratroopers; 227 guards; 122 coincidental of different ages.

Results

The first stage of validation

Assuming that the circumstances of CFR 3 (especially the need for an active self-defence) are the most difficult situation for a person to overcome, the key issue is the duration and the method of stimulation of body imbalance. Several studies on the self-defence conducted during the last fifteen years are based on the highly conventional simulation of the attacks and counterattacks restricted by pre-arranged freedom [19–28]. Therefore, there are no methodological grounds to accept the result of one of the recommended self-defence test as an accurate frame of reference (external criterion) and to correlate with RT results (the prerequisite to apply *test by test* method in the process of *oriented validity* determination).

Judo fight (as a real, not simulated action) is the closest to the situation when an attacked person is losing a balance by an attacker who grabs his clothes or restricts his movement in a different manner (choking, twisting an arm, etc.). Maintaining balance during the self-defence and counterattacking in a relatively gentle manner (without hitting) also involves grabbing the opponent's clothes to transfer own strength in order to restore balance or thrown the opponent off the balance, including the performance of rotational movements with the body. Rotational defensive movements of the body are even more required in the situation when the opponent hits.

Close observation of judo fights performed by top class athletes (during the Olympic Games, world and continent championships) in the past thirty years provides significant empirical evidence in favour of the fact that particular sequences of alternating attacks and defence last from 15 to 30 seconds, while the breaks between the active phases of a fight last from 6 to 18 seconds [29].

Thus, recommended tests of so-called dynamic balance reflect neither the motor similarity of self-defence nor the duration of balance disturbances caused in a rational way by the attacked and attacker.

The constant duration of RT has not been assumed as the absolutely rigorous criterion. On the contrary, we have assumed the method of imbalance simulation i.e. jumps with a 360° rotation (alternatively to the right and to the left) to be optimal (in the sense of methodological correctness combined with application values), whereas the number of such motor tasks (six in total) has been hedged with several assumptions:

- the number of tasks should force the duration of RT similar to the lower limit of empirically determined sequence of judo fight (15 seconds);
- the subsequent tasks should not cause any negative feedback in people performing the RT;
- odd number of tasks (however, bigger than one) in relation to any direction of turns (right, left) eliminates the cases which may complicate and distort the interpretation of the results. The equivalence 'error ⇔ no error' is not possible, whereas it is easy to determine underlying tendency (e.g. a tendency to commit errors). In case of making comparison between tendencies in a symmetrical sense (the results of three rotations to the right and three rotations to the left alternatively), a broad comparative study of similarities, identity and diversity is possible. Errors possible during each task are evaluated in three-point scale from 1 to 3 (the extreme results of RT i.e. 0–18 points; in other words 0 to 9 points for each half of the test);
- the fulfilment of these objectives entities to the adoption of more general assumption that the result of entire test or its part provides the indirect information on the quality of the functioning of brain hemispheres and sub-systems responsible for balance during rotational movements and adoption on vertical posture ('correction' phase of RT) as a function of time. Thus, the test indirectly informs about the organism subsystems responsible for stability and postural control in a certain dynamics induced in laboratory conditions (i.e. in conditions which can be repeated in a controlled manner). This assumption is a very general extension of one of the factors, which had been adopted as BBDTS determinants, namely the quality of neuroanatomical and neurophysiological mechanisms. The variance of the RT result is burdened with the quality of abilities and prior motor experience of a given person what is a consequence of previously adopted reasoning.

This stage of RT validation procedure provides sufficient arguments to consider it as an evidence of *content validity* and mainly of *construct validity*. Moreover, this line of reasoning justifies two hypotheses which verification is the basis for determining *oriented validity*.

The first hypothesis states that athletes training aikido, judo, ju-jitsu, wrestling, sumo, karate, kick-boxing, taekwondo, etc. (often performing offensive and defensive rotational movements) as well as dancers, gymnasts, etc. should tolerate balance disturbances during RT. Therefore, these groups of athletes constitute an adequate material in the process of determination of *oriented validity*.

The second hypothesis states that the compilation of RT results justifies the formation of two groups; the first consisting of those, who are able to maintain vertical posture during all physical activities immediately following each other and the second, who are not able to maintain vertical posture during identical physical activities performed in the same cycle. Among each group detailed typology enables to perform the differentiation arising from the use of four stage quality assessment of particular tasks ("0" standing for no error, "1" to "3" for first, second and third degree errors respectively). The unknown is, however, the proportion of established types in the population and the force modifying the typology due to the external factors (lighting, ground, medicines, substances, etc.) or the internal (neurological disorders, effort, amputations, anxiety, motivation, etc.), or cumulated effect of both factors. Empirical confirmation of the values of RT would constitute the evidence for fulfilling the criterion of *oriented validity* (in accordance to the objectives of a given empirical system or aspect of *concurrent validity* or *predictive validity*).

The second stage of validation

The empirical validation of tolerance for jumps with 360° rotation (henceforth: jumps) and the estimation of optimal RT tasks has been based on three empirical systems (each consisting of four series of jumps: 4, 6, 8, 10) during three days [30]. The interval between series of jumps has lasted for at least 5 minutes, but no longer than 10 minutes: day 1 – all jumps to the right; day 2 – all jumps to the left; day 3 – alternating jumps to the right and to the left. The subjects from the first class of the secondary school (35 volunteers among 220 students) could stop performing the exercise at any moment stating the explanation. Despite similar age and the same educational environment, students have varied in terms of somatic development what is a desired phenomenon in the study. The average height of girls amounted to 161.59 cm (152 to 170 cm; ±6.1); average weight was 49.23 kg (41 to 70 kg; ±9.86). The average height and weight of the boys amounted to 159.62 cm (147–173; ±8.36); 47.62 kg (34–65; ±9.01) respectively.

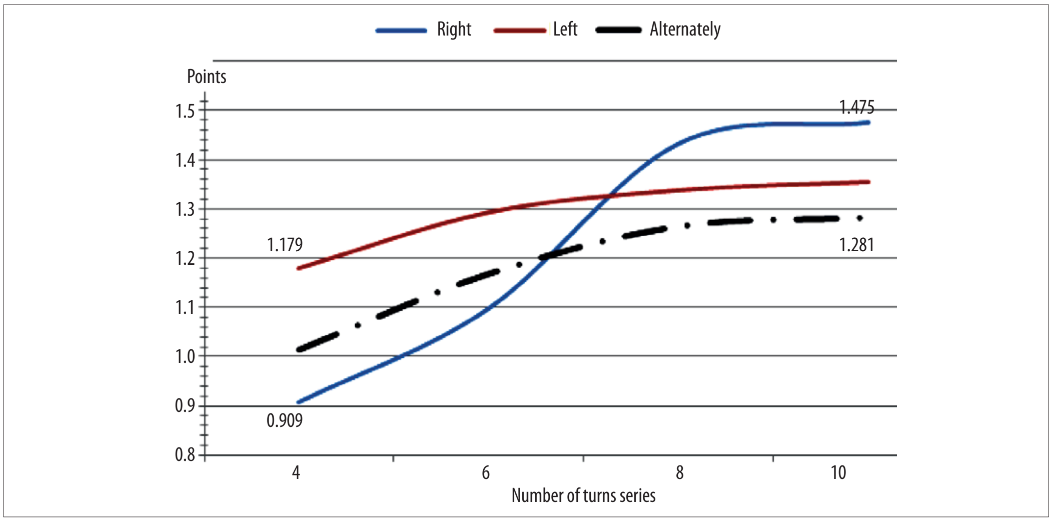

Figure 5. Profile of BBDTS girls (n=22) from the first class of the secondary schools, which were repeated for three days, each four series jumps with 360° rotation: day 1 – all jumps to the right; day 2 – all jumps to the left; day 3 – alternating jumps to the right and to the left.

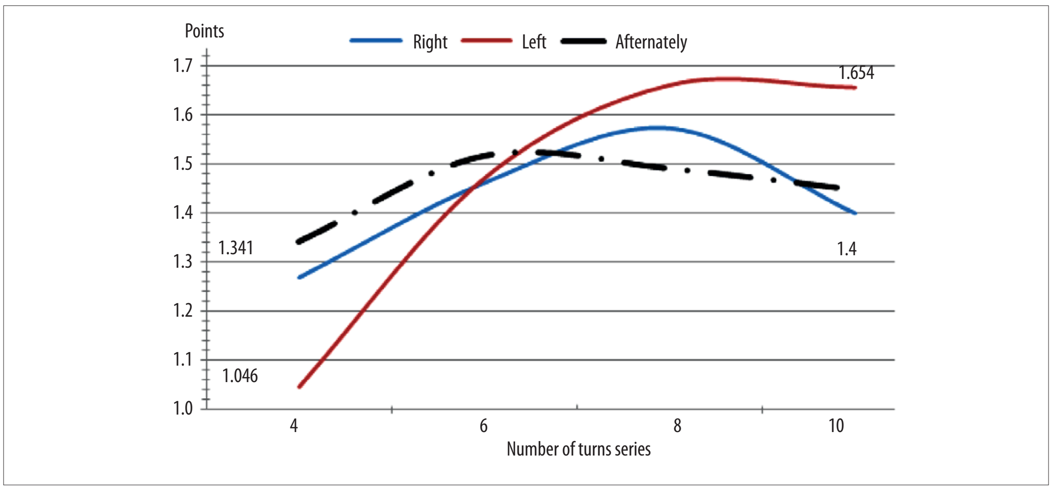

Figure 6. Profile of BBDTS boys (n=13) from the first class of the secondary school, which were repeated for three days, each four series jumps with 360° rotation: day 1 – all jumps to the right; day 2 – all jumps to the left; day 3 – alternating jumps to the right and to the left.

The full cycle of the study has been performed by 86% of girls and 85% of boys. It proves that sex does not differentiate secondary school pupils in relation to the ability to tolerate balance disturbances. First signs of discomfort (slight vertigo) have occurred in two girls during six jumps to the right, while in further three during eight jumps to the right (one has experienced nausea, the two vertigo). Worsening of the negative feelings has occurred during ten jumps to the right and three other girls have informed about the discomfort. One of them has resigned during this series (after four jumps) and have not participated in the following stages of the study. During the second day of the study (jumps to the left) nausea after six jumps was the reason to resign for one girl, while other pupil has informed about vertigo after eight jumps to the left (the day before she had experienced the discomfort twice after eight and ten jumps). In the third day of the study (alternating jumps to the right and to the left) the discomfort has been reported after six jumps by one of the participants, who has resigned from the participation in further studies.

In general, boys have tolerated the imbalance more effectively than girls. Only two of them have experienced nausea after eight jumps, whereas one of them had resigned from the study after performing two jumps. Both boys have resigned from further study.

The results of the observations indicate that six jumps with 360° rotation (due to the previous justification it is required to perform alternating jumps to the right and to the left) are the optimal number of RT tasks that should be tolerated by healthy people. Moreover, they should be able to repeat them for several times even after short intervals.

The significant part of this stage of validation is to decide whether a gradual increase in the number of balances disturbances would create favourable conditions to increase the number of errors in quantitative and qualitative sense or whether adaptative factors (stabilization or decrease in the number of errors) are being activated.

Three girls (14%) and only one boy (8%) have performed series of four jumps to the right without any error. During the remaining series of jumps, errors have been committed by all students. Boys have not committed third-degree errors (3 points) in almost the half of the tasks (49%), whereas girls in 30% of the tasks. The average error of girls has been almost 15% lower than boys' result.

The average error indicates that irrespectively of some differences in reaction of girls and boys for repeated balance disturbances (84 jumps with 360° rotation during three days) the tendencies are similar (Figures 5 and 6). Gradual increase in the number of tasks disturbing the body balance on the one hand favours errors both in quantitative and qualitative sense (the dynamics of errors in girls is to the right, whereas in boys to the left). On the other hand, adaptative mechanisms are emerging. The manifestation of adaptative factors is more distinctive, especially during the alternating jumps to the right and to the left (third day of the study). After an increase of 13% of the average error (in qualitative sense) during the series of six jumps in relation to four jumps, boys started gradually to reduce it. At first, almost by 2% (series of eight jumps) and afterwards by 4.5% (series of ten jumps) in relation to six jumps. Girls have revealed a distinct tendency to decrease the number of error performed during the series of eight and ten jumps despite the body load by further difficult tasks. During the series of six jumps they have increased the average error of 15% in relation to four jumps, while during the series of eight jumps in relation to six jumps the increase of 8% has been observed and afterwards respectively only by 1.4%.

Analysed factors provide a significant empirical evidence for the fact that an optimal method of balance disturbance simulation is to perform six jumps with 360° rotation (to the right and to the left alternatively). Similar in some way, but at the same different models of balance disturbances tolerance by girls and boys aged 13 constitute an indirect evidence of a significant flexibility of body's systems responsible for stability and postural control. Such statement is justified because pupils lack fully developed mechanisms responsible for counteracting balance disturbance as well as motor experience which seems helpful in such circumstances. The hypothesis suggested above predicts that such compensation mechanisms could be developed by aikido, judo, ju-jitsu, wrestling, karate, kick-boxing, taekwondo, dance, gymnastic training, etc. As the three-day study with the participation of secondary school pupils provides preliminary evidence for positive consequences of such training (intensive repetition of rotational movements), the results constitute a significant premise proving the hypothesis to be plausible. This fact, however, does not excuse from more detailed verification of this hypothesis.

Based on the empirical data and current reasoning, on this stage of validation procedure it is justified to conclude that *Rotational Test* informs accurately (although from the heart of the matter indirectly) about the quality of the functioning of brain hemispheres and sub-systems responsible for balance control during rotational movements and required adoption of vertical posture in a function of time. This conclusion refers to *construct validity*.

The third stage of validation

At this stage of validation (*oriented validity*) the hypothesis, that people training the above-mentioned sports and some forms of physical activity should tolerate balance disturbances during RT, is verified.

Behind this hypothesis lies the assumption that the optimal material for testing are academic athletes, conscripts, policemen, guards, etc., because methods of choosing to those forms of activity involve criteria of good health and optimal physical fitness (in Tables 1–4 the average result of RT proving nominally higher BBDTS is an ordinal variable). Possibly highest BBDTS does not constitute any significant selective criterion as in the case of some professional sports disciplines, circus arts, etc.

Hence, monthly and long-term influence of a training directed to stimulate body mechanisms responsible for stability and postural control should result in expected adaptative changes in healthy people. Correlation of training influence with individual abilities may result in a perfect adaptation even to all three circumstances of fall hazard (CFR), but may not translate directly into the greatest achievements during professional sports or professional activity.

There should be no surprise that sport champions or masters of a given occupation may perform RT with no error, but the same result may be achieved by people from the same group, but with no considerable successes. If people from specified groups, whose BBDTS level

Table 1. Groups of athletes, who are often subjected to fall hazard in a CFR 2 category.

Subject [references]	Gender & subgroup	Age [years]				BBDTS [points RT]			
		$\overline{X}$ (min – Xmax)	±	g_1	g_2	$\overline{X}$ (min – Xmax)	±	g_1	g_2
Sports gymnasts [31]	**Male** *training 3–13 years* (n=7)	**21.43** (20–23)	0.98	0.28	8.62	**0.43** (0–1)	0.53	0.37	–2.80
Sport dancers [32]	**Female** *training 5–8 years* (n=9)	**21.78** (16–26)	4.21	–0.20	–2.19	**0.44** (0–1)	0.53	0.27	–2.57
	Male *training 2–6 years* (n=6)	**20.83** (18–26)	3.13	0.88	0.04	**3** (2–4)	0.89	0.00	–1.88
Tennis players [31]	**Male** *training 1–15 years* (n=13)	**22.77** (21–24)	0.93	–0.21	–0.55	**3.6** (0–10)	2.60	1.14	1.74
Sport dancers [32]	**F & m** *training 2–4 years* (n=4)	**17.75** (15–21)	3.20	0.08	–5.52	**4** (0–1)	1.63	0.00	1.50
	F & m *training <1 years* (n=5)	**18** (16–22)	2.19	1.36	2.00	**5** (1–11)	3.35	1.15	2.00
Professional cyclists [32]	**Male** *training 9–15 years* (n=11)	**27.47** (21–33)	3.96	–0.02	–0.93	**5.18** (1–11)	3.28	0.34	–0.76

has not been studied before, will participate in the study, the interpretation of an errorless RT result should be as follows. The result proves that motor experience obtained in training remains in harmony with high quality of neuroanatomical and neurophysiological mechanisms as well as outstanding quality of motor abilities. At the same time it is hard to determine the contribution of the factors in RT result variance, but there is no way to exclude bilateral relations between those factors.

Thus, each RT result reflects those relations in some way. If people belonging to a certain group for a long time generate some category of errors, there are grounds, to put it simply, either to seek causes in unilaterality of training or shortages in neuroanatomical and neurophysiological mechanisms or motor abilities, or the combinations of several factors.

Comparative studies on RT results in non-apparatus version provide enough evidence to state that the strongest relation between factors discussed above involves people training gymnastics and dance (Table 1). These are the sports that can be qualified as CFR 2 circumstances i.e. when a force disrupting the balance of a man is a motor activity performed on a relatively stable surface. Similar adaptative effects are obtained by performers on horse-back having five-years' training experience (Table 2). This sport, however, can be qualified as one of the most sophisticated sub-group of CFR 3 circumstances, when the cumulative effects of external forces including the most important i.e. a horse in motion and internal factors i.e. generated by a person performing an action influence each other. High adaptative effects are also typical for people training combat sports and martial arts (especially judo, wrestling) as well as basketball and handball. During training sessions these athletes perform numerous rotational movements with high dynamics in a relatively limited space.

It seems that the hypothesis being verified is plausible. Thus, the conclusion is justified that RT is a tool fulfilling criteria of accurate assessment of a phenomenon being studied. In fact, the crucial part of the phenomenon in the part devoted to content validity and construct validity has been defined as the quality of neuroanatomical and neurophysiological mechanisms. The argumentation partially in favour for this conclusion are the results of shooting athletes specialized in shooting

Table 2. Groups of athletes, who are often subjected to fall hazard in a CFR 3 category or perform rotational movements of the body.

Subject [references]	Gender & subgroup	Age [years] $\bar{X}$ (min – Xmax)	Age ±	BBDTS results RT [points] $\bar{X}$	±	*X* min	*X* max
Performers on horse-back *Training 5 years [16]*	**Female &1 boy** (n=6)	**15.5** (13–16)	1.12	**0.33**	0.50	0	1
Basketball players *Training 3–15 years [31]*	**Male** (n=9)	**22.89** (22–24)	0.93	**1.11**	1.05	0	3
Judo athletes *Training 3–12 years [33]*	**Female** (n=9)	**19.44** (16–23)	2.35	**2**	2.36	0	7
Performers on horse-back *Training 4 years [16]*	**Female** (n=4)	**14.5** (10–16)	2.60	**2.3**	0.50	2	3
Kick-boxers *Training 1–20 years [34]*	**Male & 2 female** (n=30)	**23.60** (17–47)	6.16	**2.5**	2.42	0	11
Performers on horse-back *Training 1 year [16]*	**Female** (n=10)	**10**	–	**2.6**	1.80	0	5
Handball players *Training 4–15 years [31]*	**Male** (n=9)	**22.56** (21–24)	1.01	**2.67**	1.58	0	5
Judo athletes *Training 10–15 years [33]*	**Male** (n=16)	**21.5** (18–25)	2.42	**2.69**	2.36	0	7
Free style wrestlers *Training 3–17 years [35]*	**Male** (n=23)	**20.8** (16–24)	2.50	**2.9**	2.00	0	8
Boxers *Training 1–15 years [34]*	**Male & 3 female** (n=30)	**20.57** (16–33)	12.02	**3.23**	2.71	0	11
Greco romano wrestlers *Training 1–14 years [35]*	**Male** (n 24)	**21.5** (16–32)	3.60	**3.3**	3.00	0	11
Aikido athletes *Training 2–15 years [36]*	**Male** (n 22)	**27.9** (15–48)	9.08	**4.45**	2.32	0	8
Soccer players *Training 6–11 years [31]*	**Male** (n=9)	**22.22** (21–24)	0.97	**7.11**	2.66	4	11

Table 3. Groups of athletes participating in physical activities which do not threaten with falling (shooting) or perform activities in unnatural environment for a human (swimming).

Subject [references]	Gender	Age [years] $\bar{X}$ (min – Xmax)	Age ±	BBDTS [points RT] $\bar{X}$	±	*X* min	X max
Shooting athletes Polish National Team *training 3–14 years* [37]	**Male** (n=9)	**19.11** (16–23)	2.08	**2.8**	1.59	0	4
	Female (n=5)	**18.9** (17–20)	1.14	**4.8**	4.55	0	10
Swimmers *training 3–8 years* [31]	**Male** (n=8)	**22.25** (21–24)	0.97	**4.88**	2.60	0	8

in vertical posture, who participate in sports activity without fall hazard, but to be effective they need stable posture (Table 3).

The average RT result of people, who perform actions intensively from time to time in all specified circumstances of fall hazard (CFR 1, CFR 2, CFR 3), constitute another empirical evidence for oriented validity of the test. Paratroopers after ten-month of intensive military training possess higher BBDTS than guards, who are mostly recruited among former soldiers and policemen but are no longer regularly trained (Table 4). At the same time, it proves that maintaining high BBDTS requires continuous training.

Table 4. The relatively homogenous groups of people who are subjected with various frequency to fall hazard classified into CFR1, CFR 2, CFR 3 categories.

Subject [references]	Gender & subgroup	Age [years]		BBDTS [points RT]			
		$\bar{X}$	±	$\bar{X}$	±	X min	X max
Paratroopers *after 10 months military training* [17,38]	**Male** *reservists 2002* (n=30)	**21.5** (20–26)	1.43	**3.41**	2.99	0	10
	Male *reservists 2004* (n=30)	**21.2** (18–23)	1.27	**3.53**	2.49	0	9
Guard from Lithuania [24]	**Male** *private sector* (n=118)	**24.74** (19–43)	5.16	**6.13**	3.46	0	15
	Male *governments* (n=109)	**25.66** (20–37)	3.87	**6.29**	3.14	0	13

Table 5. The relatively homogenous groups of people who are subjected with various frequency to fall hazard classified into CFR1 categories.

Subject [references]	Gender & subgroup	Age [years]				BBDTS results RT [points]			
		$\bar{X}$ (min – Xmax)	±	g_1	g_2	$\bar{X}$ (min – Xmax)	±	g_1	g_2
Warsaw residents /participants of scientific picnic 08 June 2002/ [33,34]	**Female** (n=40)	**18.58** (10–43)	8.75	1.15	0.42	**3.78** (0–10)	2.57	0.41	–0.53
	low PA (n=32)*	**17.5** (10–43)	8.91	1.53	1.60	**3.66** (0–10)	2.46	0.425	–0.20
	sporadic PA (n=6)	**25.67** (17–33)	6.74	–0.51	–1.88	**3.50** (0–9)	3.39	0.92	–0.17
	Male (n=82)	**20.27** (10–60)	12.12	1.43	1.23	**5.67** (0–12)	2.72	0.01	–0.56
	high PA (n=19)	**21.47** (10–54)	13.25	1.40	1.00	**5.68** (0–10)	2.85	–0.17	–0.67
	low PA (n=50)	**18.12** (10–60)	11.40	1.73	3.57	**5.76** (0–10)	2.65	1.24	–0.54
	sporadic PA (n=13)	**26.77** (11–48)	11.41	0,51	–0.83	**5.31** (1–12)	2.98	0.85	0.72
Students from Vilnius [24]	**Male** (n=117)	**19.25** (18–22)	0.83	–	–	**6.51** (0–12)	2.93	–	–

* PA – physical activity.

The most difficult is to separate people who are subjected to the external force causing fall hazard. The force would become a significant factor modifying BBDTS, under the condition that those people are not subjected to stronger stimuli at the same time (e.g. training). Accepting this far reaching simplification with reserve, the authors assume that citizens who travel long distances with a tram, bus, underground, etc. and are not physically active often experience balance disturbances transferred from the vehicles (braking, accelerating, change of direction, etc.). The above-described people are no match to most athletes (Table 5).

The fourth stage of validation

This stage is a continuation of *oriented validity* assessment, while a tool used is a typology of BDDTS (Tables 6 and 7). Accepted typology is referred to the RT result of 100 young females (physiotherapy students), aged 21, who have declared to be occasionally active and lack of previous motor experiences related to sport training. The average body height amounts to 167.76 cm (153 to 180 cm; ±5.92); g_1 0.07 indicates normal distribution of this characteristic, whereas the negative value of g_2 (–0.32) shows that the distribution is slightly negative (platykurtic). The

Table 6. The typology of ability to tolerate balance disturbances based on the result of Rotational Test (RT). Group I: has the ability to maintain vertical posture during all physical activities (0–12 pts.).

Subtype BBDTS [symbol]	Motor types and subtypes characteristics [proportion lack of errors *vs.* errors during 6 TO tasks]	RT pts. range [0–12]
	Type A ability to perform all motor tasks without an error (0 pts.)	
A	No errors [6: 0]	0
	Type B ability to perform the most of motor tasks without an error (0–4 pts.)	
$B5_1$	Five time lack of error and first degree error [5: 1]	1
$B5_2$	Five time lack of error and second degree error [5: 1]	2
$B4_1$	Four time lack of error and 2 errors of first degree [4: 2]	2
$B4_i$	Four time lack of error and 1 error of first degree and 1 error of second degree [4: 2]	3
$B4_2$	Four time lack of error and 2 errors of second degree [4: 2]	4
	Type C ability to perform half of motor tasks without an error (3–6 pts.)	
$C3_{ur1}$	One-sided lack of errors and errors of first degree [3: 3]	3
$C3_{i1}$	Irregular distribution the lack of errors and errors of first degree [3: 3]	3
$C3_i$	Irregular distribution the lack of errors and errors of first and second degree [3: 3]	4–5
$C3_{ur2}$	One-sided lack of errors and errors of second degree [3: 3]	6
$C3_{i2}$	Irregular distribution the lack of errors and errors of second degree [3: 3]	6
	Type D lack of ability to perform half of motor tasks without an error (4–12 pts.)	
$D2_1$	Two time lack of errors and 4 errors of first degree [2: 4]	4
$D2_i$	Two time lack of errors and 4 errors of first and second [2: 4]	5–7
$D2_2$	Two time lack of errors and 4 errors of second degree [2: 4]	8
$D1_1$	One-sided lack of errors and 5 errors of first degree [1: 5]	5
$D1_i$	One-sided lack of errors and 5 errors of first and second [1: 5]	6-9
$D1_1$	One-sided lack of errors and 5 errors of second degree [1: 5]	10
	Type E lack of ability to perform even one motor tasks without an error (6–12 pts.)	
E_{r1}	Regular errors of first degree [0: 6]	6
E_i	Irregular errors of first and second degree [0: 6]	7–11
E_{r2}	Regular errors of second degree [0: 6]	12

variability of body mass is higher. The average body mass amounts to 59.63 kg (43 to 100 kg; ±8.48). Positive skewness (g_1=1.27) indicates that most females weigh below 59.63 kg, while clear positive kurtosis (g_2=4.68) shows that the distribution is steeper than normal.

The average value of estimated motivation to perform RT equals five pre-arranged points (Table 8). Although negative skewness is low (g_1=–0.10), it indicates that larger numbers concentrate within the range of higher motivation. Hence, most students have been motivated to perform RT. This conclusion is justified by Yerkes-Dotson laws [39]. Only one student has declared minimal motivation (one point in motivation scale; RT result 10 points; RT duration 14.7 seconds). The highest motivation estimated by six students amounted to eight points. The value of negative kurtosis (g_2=–0.12) indicates that the distribution is slightly flattened (Table 8).

Central tendency, the variability of six tasks of RT results as well as skewness and kurtosis (Table 8) are similar. Slightly positive value of skewness (g_1 amounting from 0.11 to 0.52) indicates that larger numbers concentrate within the range of lower points estimating BDDTS in four-point scale (0 to 3). As a consequence negative kurtosis (g_2 from –0.18 to –0.72) shows flattened distribution

Table 7. The typology of ability to tolerate balance disturbances based on the result of *Rotational Test* (RT). Group II: has lack of ability to maintain vertical posture during all physical activities (3–18 pts.).

Subtype BBDTS [symbol]	Motor types and subtypes characteristics [proportion of third degree errors *vs.* lack of errors (and/or errors of lower degree) during 6 RT tasks]	RT pts. range [0–18]
	Type F lack of ability to maintain vertical posture at least during one ZR (3–13 pts.)	
$F1_0$	One error of third degree and no errors [1: 0(5)]	3
$F1_1$	One error of third degree and 1-5 errors of first degree [1: (1–5)]	4-8
$F1_2$	One error of third degree and 1-5 errors of second degree [1: (1–5)]	5-13
$F1_i$	One error of third degree and 2-5 errors of first and second degree [1: (2–5)]	6-12
	Type G ability to maintain vertical posture during the most of ZR (6–14 pts.)	
$G2_0$	Two errors of third degree and no errors [2: 0(4)]	6
$G2_1$	Two errors of third degree and 1–4 errors of first degree [2: (1–4)]	7-10
$G2_2$	Two errors of third degree and 1–4 errors of second degree [2: (1–4)]	8-14
$G2_i$	Two errors of third degree and 2–4 errors of first and second degree [2: (2–4)]	9-13
	Type H ability to maintain vertical posture during half of ZR (9–15 pts.)	
$H3_0$	Three errors of third degree and no errors (3: 0(3))	9
$H3_1$	Three errors of third degree and 1-3 errors of first degree [3: (1–3)]	10-12
$H3_2$	Three errors of third degree and 1-3 errors of second degree [3: (1–3)]	11-15
$H3_i$	Three errors of third degree and 2-3 errors of first and second degree [3: (1–3)]	12-14
	Type K lack of ability to maintain vertical posture during half of ZR (12–16 pts.)	
$K4_0$	Four errors of third degree and no errors (4: 0(2))	12
$K4_1$	Four errors of third degree and 1–2 errors of first degree [4: (1–2)]	13-14
$K4_2$	Four errors of third degree and 1–2 errors of second degree [4: 2)]	14-16
$K4_i$	Four errors of third degree and after 1 error first and second degree [4: (1–2)]	15
$K5_0$	Five errors third degree and no errors [5: 0(1)]	15
	Type L ability to maintain vertical posture during at least one ZR, but lack of ability to perform without an error (16–17 pts.)	
$L5_1$	Five errors third degree and first degree error [5: 1]	16
$L5_2$	Five errors third degree and second degree error [5: 1]	17
	Type Z lack of ability to maintain vertical posture (18 pts.)	
Zr3	Regular errors of third degree [6: 0]	18

of results. Both tendencies are reflected by RT result expressed in points. Positive skewness (g_1=1.41) of the duration of test performance proves that there is more people who had performed RT in a shorter time than an arithmetical mean. In fact, 59% of females performed RT in 14 seconds or faster. Positive kurtosis of the duration (g_2=2.67) reveals, on the other hand, the tendency opposite to RT results expressed in points i.e. the distribution is more steep than normal distribution.

Among the students clear dominance (76%) can be noticed of those able to maintain vertical posture during all physical activities following each other including type E (40%) i.e. females who lack the ability to perform even one task without an error (Figure 7). The distribution is clearly reflected by skewness (g_1=1.74) and kurtosis (g_2=2.99).

Predictive validity and an the usefulness of typology is demonstrated by the distribution of people who have obtained specified RT result, however, mostly (three to 12 points) they qualify to various types of BBDTS (Figure 8). Among six people, who have obtained the result of 3 points, two have committed only one error of the third

Table 8. The estimation results of the *Rotational Test* quasi-apparatus version 21-years old women (n=100) declaring occasionally active.

Statistical variables	Motivation [points]	Body rotation of 360° during jumps [points]						Rotational Test	
		1R*	2L	3R	4L	5R	6L	Results [Σ points]	Time [S]
X	**5**	**1.08**	**1.04**	**1.29**	**1.10**	**1.33**	**1.28**	**7.12**	**14.24**
±	1.50	0.849	0.828	0.902	0.847	0.817	0.817	3.02	2.41
min	1	0	0	0	0	0	0	0	10.4
max	8	3	3	3	3	3	3	15	22.69
g_1	−0.10	0.45	0.25	0.15	0.52	0.11	0.12	0.14	1.41
g_2	−0.12	−0.35	−0.78	−0.77	−0.18	−0.48	−0.51	−0.33	2.67

* R – right; L – left.

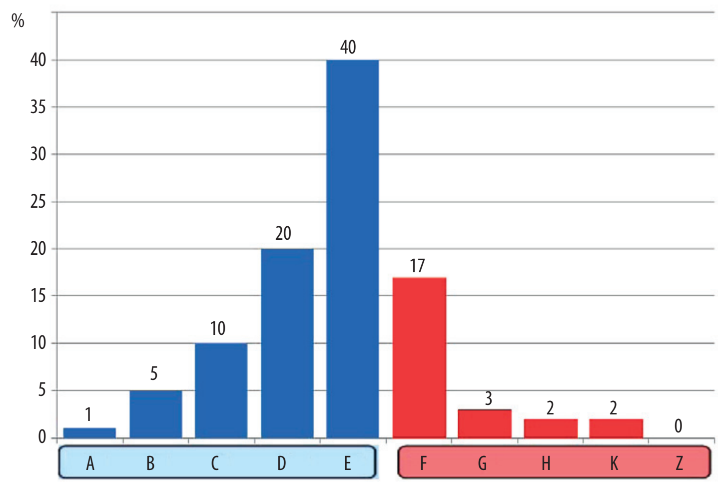

Figure 7. Distribution of BBDTS types of female students (n=100): blue – group I has the ability to maintain vertical posture during all physical activities; red – group II has lack of ability to maintain vertical posture during all physical activities.

degree type. Both females have been optimally motivated (five points) and performed RT slower than the average time (15.1 sec. and 17.2 sec.). Hence, there is a high probability that they have not been focused enough on each task. It is hard to reduce the value of such diagnosis for the use of rehabilitation of those who are to return to profession requiring constant concentration (e.g. work at heights, in fire service), in selection for those professions or for the use of almost every sport discipline.

The typology of BBDTS of athletes with long training experience and multiple participation in sport fight provides significant information on the forms of activity (exercises) which stimulate this skill to the highest degree (Table 9, Figure 9). The comparison of athletes, occasionally active females and those who lack sports motor experience reveals positive influence of sport on BBDTS (Figure 10).

The fifth stage of validation

Oriented validity established so far has been broadened by *test by test* method. This stage of validation does not aim at correlation of RT result with recommended balance tests, but its goal was to correlate it with external criterion (non-tested), since the previous application of *test by test* method (see the above-mentioned study conducted by Drowatzky and Zuccato [13]) provide evidence for low correlation of balance tests' results. In the studies on school-aged youths the empirical system 'three benches' [40–42] served as an external criterion, whereas when the test have been conducted on adults (soldiers) two elements of *military obstacle* have been considered as an external criteria [38]. Moreover, secondary school children have performed 'Flamingo' test [18] recommended by many scientists.

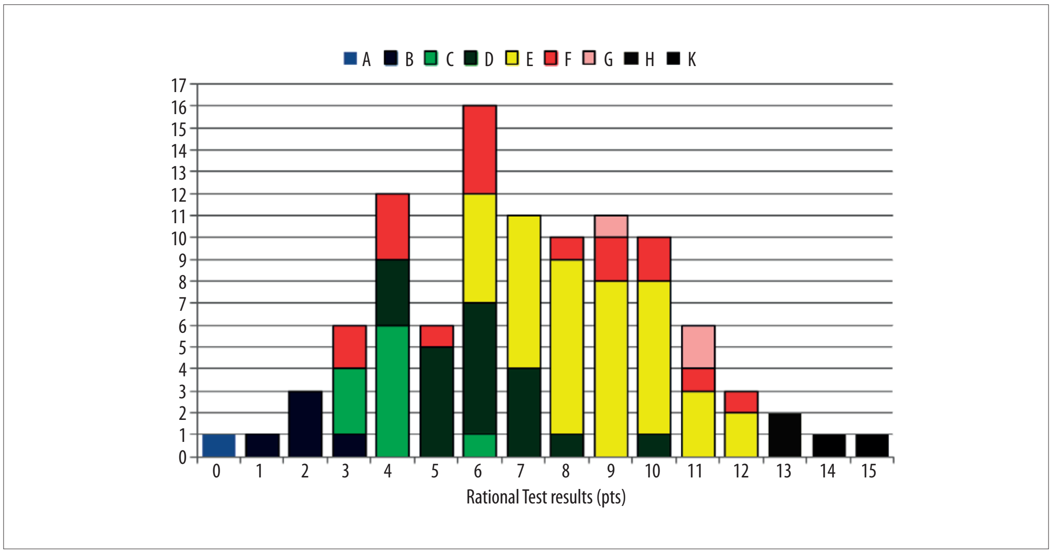

Figure 8. Frequency distribution of female students (n=100), which received a certain RT score but most of them qualify the various types of BBDTS.

Table 9. Proportions (%) athletes and 21-years old women qualified for the *Rotational Test* for specific types of BBDTS.

Sport	Group I: has the ability to maintain vertical posture during all physical activities					Group II: has lack of ability to maintain vertical posture during all physical activities			
	A	B	C	D	E	F	G	H	K
Performing on horse-back (n=6)	67	33							
Gymnastics (n=7)	57	43							
Sport dance (n=24)	56	44							
Basketball (n=9)	33	56	11						
Judo female (n=9)	45	22	11	22					
Judo male (n=16)	25	38	12	25					
Shooting male (n=9)	22	34	22	22					
Handball (n=9)	11	23	33	33					
Free style wrestling (n=23)	9	43	30	18					
Shooting female (n=5)	20	20	20		40				
Tennis (n=13)	8	31	31	15	15				
G-R wrestling (n=24)	21	25	21	25		4			
Aikido (n=22)	5	18	23	41	5	9			
Swimming (n=8)	13		25	25	25	13			
Soccer (n=9)				44	44	12			
Kick-boxing (n=28)	21	36	21	14	4		4		
Boxing (n=27)	4	44	30	7	11		4		
Cycling (n=11)		27	9	36	9	9	9		
Woman 21 years (n=100)	**1**	**5**	**10**	**20**	**40**	17	3	2	2

The result of RT performed by the youths with previous sports experience correlates more often with the external criterion (r=0.606 to 0.638; p<0.02). This regularity is not confirmed by tests on boys and girls

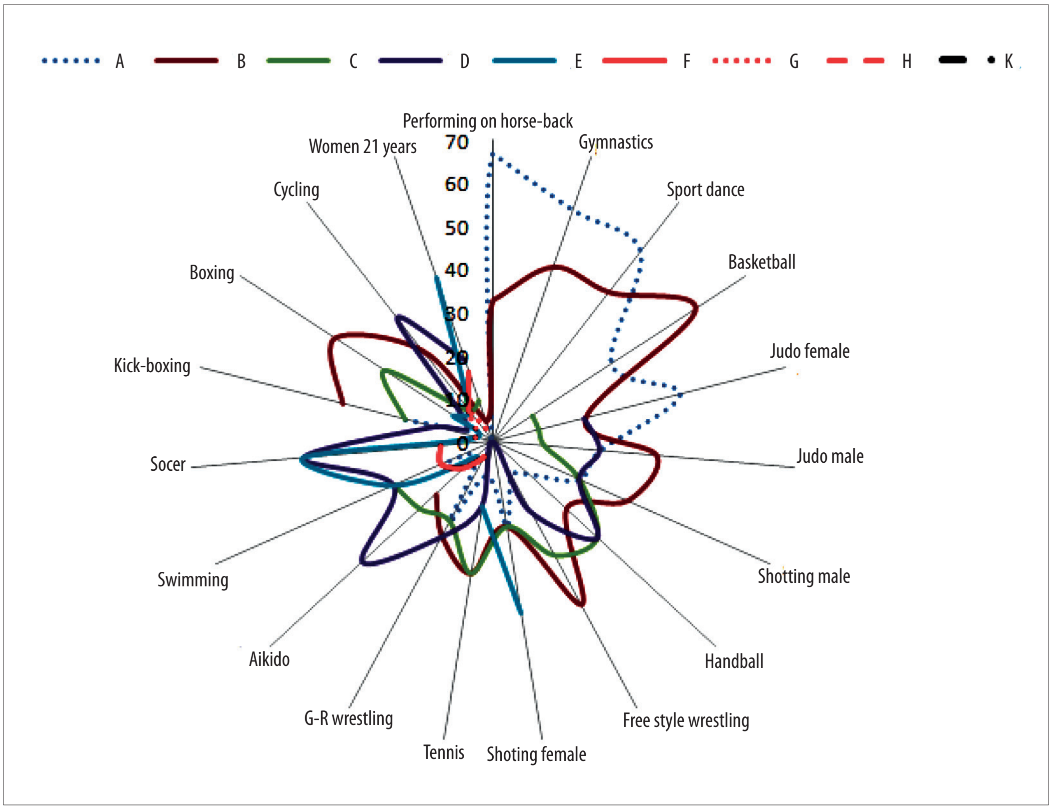

Figure 9. Visualization of the distribution BBDTS types of athletes representing 15 sport disciplines and female students who have declared to be occasionally active (according to the data presenting in Table 9).

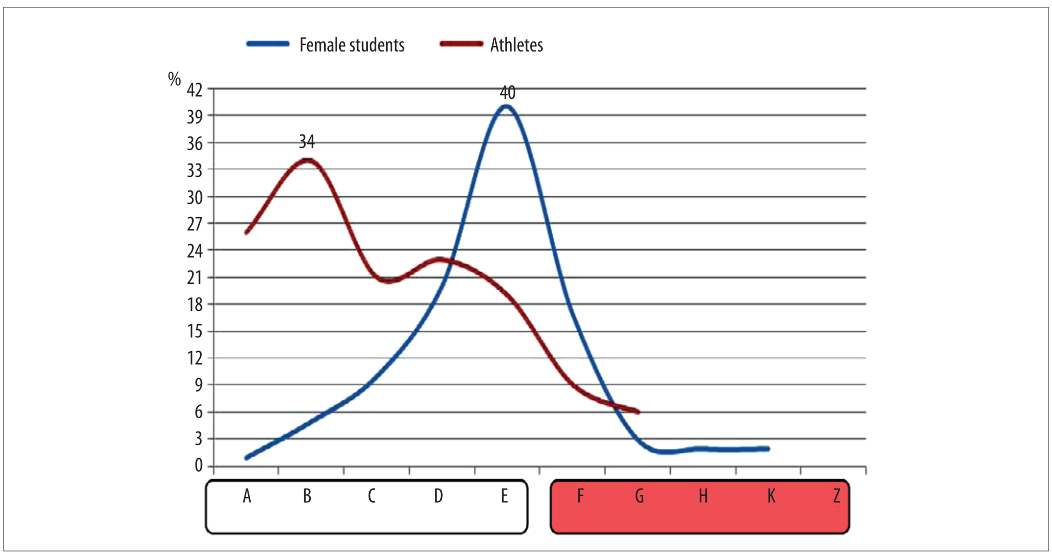

Figure 10. Distribution of BBDTS types among female students (n=100) and athletes (n=218) of different sport disciplines (according to the data presenting in Table 9).

not participating in sport. The average correlation of RT with 'Flamingo' test confirmed only with studies of one group may be accidental (Tables 10–15).

The studies on adult men (30 paratroopers) have confirmed a statistically significant correlation (p<0.05) of RT result with two empirical systems i.e. *'military obstacle 1'* (r=0.482) and *'military obstacle 2'* (r=0.414). The correlations of RT results with simple simulations of motor actions in case of real loss of balance (running over the benches) have been confirmed during the correlation of RT results with more complex actions (*military obstacle 1* and *2*). Therefore, it is justified to assume that people who will perform RT with no errors have greater

Table 10. The interdependence of the results of *Rotational Test* in quasi-apparatus version with other balance tests performed by 12-years old boys, who are not engaged in sport (n=30).

Test/empirical system	Coefficient r		Estimation of variables					
	1	2	Results	±	x_{min}	x_{max}	g_1	g_2
1. *Rotational Test* [pts]	–	–	**7.07**	2.57	5	12	0.09	–0.55
2. *'Flamingo' Test* [pts]	**0.400***	–	**12.63**	3.71	7	19	0.33	–0.94
3. *'Three benches' empirical system* [s]	0.094	0.262	**4.10**	0.41	3.31	4.91	0.30	–0.33

*p<0.05

Table 11. The interdependence of the results of *Rotational Test* in quasi-apparatus version with other balance tests performed by 12-years old boys, who train soccer (n=15).

Test/empirical system	Coefficient r		Estimation of variables					
	1	2	Results	±	x_{min}	x_{max}	g_1	g_2
1. *Rotational Test* [pts]	–	–	**4.27**	1.16	3	7	0.97	0.80
2. *'Flamingo' Test* [pts]	0.018	–	**11.73**	3.59	6	19	0.93	0.81
3. *'Three benches' empirical system* [s]	**0.606****	0.176	**4.13**	0.47	3.5	4.8	–0.01	–1.68

** p<0.02.

Table 12. The interdependence of the results of *Rotational Test* in quasi-apparatus version with other balance tests performed by 12-years old girls, who are not engaged in sport (n=30).

Test/ empirical system	Coefficient r		Estimation of variables					
	1	2	Results	±	x_{min}	x_{max}	g_1	g_2
1. *Rotational Test* [pts]	–	–	**8.93**	3.54	3	15	–0.17	–1.40
2. *'Flamingo' Test* [pts]	0.235	–	**5.37**	4.01	0	15	0.74	–0.06
3. *'Three benches' empirical system* [s]	0.170	0.297	**6.46**	1.50	4.02	9.59	0.49	–0.39

Table 13. The interdependence of the results of *Rotational Test* in quasi-apparatus version with other balance tests performed by 12-years old girls, who train volleyball (n=15).

Test/empirical system	Coefficient r		Estimation of variables					
	1	2	Results	±	x_{min}	x_{max}	g_1	g_2
1. *Rotational Test* [pts]	–	–	**1.60**	1.55	0	5	0.78	0.12
2. *'Flamingo' Test* [pts]	0.420	–	**4.13**	2.50	0	8	–0.08	–1.34
3. *'Three benches' empirical system* [s]	**0.638****	0.112	**5.09**	0.75	4.02	6.25	0.12	–1.23

** p<0.02.

Table 14. The interdependence of the results of *Rotational Test* in quasi-apparatus version with other balance tests performed by 14-years old boys, who are not engaged in sport (n=18).

Test/empirical system	Coefficient r		Estimation of variables					
	1	2	Results	±	x_{min}	x_{max}	g_1	g_2
1. *Rotational Test* [pts]	–	–	**9.83**	4.37	1	18	–0.19	–0.14
2. *'Flamingo' Test* [pts]	0.159	–	**11.78**	4.52	1	15	–0.18	0.29
3. *'Three benches' empirical system* [s]	–0.085	0.360	**4.78**	0.63	3.98	6.10	0.72	–0.43

chance to achieve the goal of a real action, despite the time pressure, small or unstable surface, urgent need to change the direction and/or the altitude and other factors causing imbalance.

Table 15. The interdependence of the results of *Rotational Test* in quasi-apparatus version with other balance tests performed by 14-years old boys, who train handball (n=17).

Test/empirical system	Coefficient r		Estimation of variables					
	1	2	Results	±	x_{min}	x_{max}	g_1	g_2
1. *Rotational Test* [pts]	–		**7.71**	4.28	1	14	–0.08	–1.01
2. *'Flamingo' Test* [pts]	0.362	–	**7.41**	5.77	1	15	0.36	–1.61
3. *'Three benches' empirical system* [s]	–0.105	0.230	**4.46**	0.47	3.89	5.40	0.92	0.10

Table 16. Results of *Rotational Test* during test-retest procedure.

Statistical variables	Group "A" (n=35)				Group "B" (n=15)	
	Motivation [points]		Results RT [Σ points]		Results RT [Σ points]	
X	**6.80**	**6.89**	**6.40**	**6.86**	**4.80**	**4.80**
±	1.68	1.68	3.21	3.15	2.57	3.10
min	3	2	0	2	1	0
max	10	10	13	15	10	12
g_1	–0.30	–1.20	0.43	0.14	0.66	0.71
g_2	–0.35	2.66	0.00	–0.33	–0.23	0.83
Test-retest [r]	**0.818**		**0.848**		**0.802**	
R^2	67		72		64	

This means that the same phenomena that influence out effectiveness (or its lack) during motor activity with high risk of losing the balance form a basis for RT results. It seem reasonable to conclude that RT result is correlated with those neuroanatomical and neurophysiological mechanisms which are activated when we are exposed to forces hindering maintenance of vertical posture and increasing the risk of falling. Therefore, RT provides an indirect and general information about the quality of neuroanatomical and neurophysiological mechanisms responsible for balance maintenance in the most difficult conditions of alternating dynamic and static motor activity.

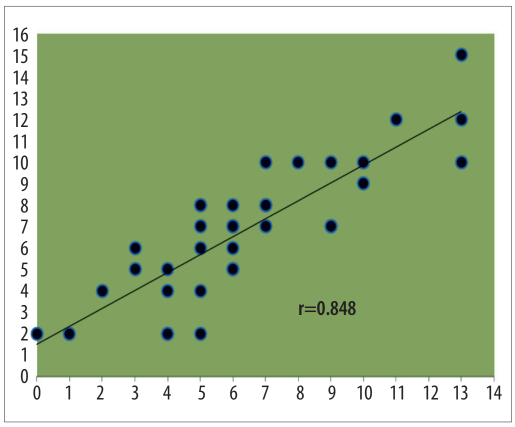

Figure 11. Results of test-retest procedure (r=0.848) *Rotational Test* repeated by recreation and physiotherapy students (n=35) in the interval of the week.

The sixth stage of validation

High reliability has been confirmed by studies conducted with the use of test-retest method repeated in the same time on two independent groups. Each study was conducted one week apart (Table 16). Group 'A' consisting of 35 randomly selected students of recreation and physiotherapy (22 males, 13 females) aged 20–22 with various motor experiences and different weekly physical activity. Group 'B' consisting of 15 male students of physical education, aged 19 (first year of studies), who voluntarily participated in judo specialization, but have never practiced any combat sports. Group 'A', beside similar age, has been largely varied (sex, motor experience, interests, etc.), but they have participated in RT obligatorily in class. Selection process to group 'B' was based on possibly high amount of similarities, while the test has been performed by students voluntarily.

The studies on group 'A' have been based on the possibility of action formula [43,44]. Directly before RT each person from group 'A' has informed about motivation expressed in ten-point scale. The participants have no possibility to access the declaration of the others.

The correlation of RT repetitiveness is high. It is higher (r=0.848) in group 'A' (Figure 11). The certainty that the

Table 17. The level of disturbation the body balance tolerance skills based on the result of *Rotational Test* (RT) and accepted typology BBDTS.

BBDTS Level	RT points range	BBDTS Typology		
		Subtype	**Type**	**Group**
Very high	0-1	A $B5_1$	A	I
High	2-3	$B5_2$ $B4_1$ $B4_i$ $C3_{ur1}$ $C3_{i1}$ $F1_0$	B, C, F	
Average	4-8	$B4_2$ $C3_i$ $C3_{ur2}$ $C3_{i2}$ $D2_1$ $D2_i$ $D2_2$ $D1_1$ $D1_i$ Er_1 El $F1_1$ $F1_2$ $F1_i$ $G2_0$ $G2_1$ $G2_2$	B, C, D, E, F, G	I II
Low	9-13	$D1_i$ $D1_1$ E_i Er_2 $F1_2$ $F1_i$ $G2_1$ $G2_2$ $G2_i$ $H3_0$ $H3_1$ $H3_2$ $H3_i$ $K4_0$ $K4_1$	D, E, F, G, H, K	
Very low	14-15	$G2_2$ $H3_2$ $H3_i$ $K4_1$ $K4_2$ $K4_i$	G, H, K	II
Unsatisfactory	16-18	$K4_2$ $L5_1$ $L5_2$ Zr_3	K, L, Z	

participants during both sessions have shown motivation on the same level is high as well (r=0.818) despite the fact that the choice was not voluntary. Hence, RT fulfils the criteria of a tool which can be used in various systems of selection to particular professions and hard tasks.

The final recommendation

The entire argumentation provided so far, the synthesis of empirical data collected, the use of method in successive approximations and expert opinion have formed the basis for the development of BBDTS standards (Table 17). Together with the typology presented above (Tables 6 and 7) they constitute the complete documentation on which the in-depth analysis of BBDTS can be based. The only criterion limiting the use of *Rotational Test* are the conditions which would involve the violation of ethical standards obligatory in research. However, this restriction does not result from the structure of the test or its methodology.

Discussion

The authors have tried to avoid *face validity* on each stage of validation process. This methodological trap has been revealed by Guilford [45]. Contemporary methodologist and psychometrics expert, Jerzy Brzezinski [46], while referring to Mosier's [47] and Bechtoldt's [48] papers highlights that some accepts tests based on *faith validity*, while others on *validity by assumption.* This issue is, however, not sufficiently publicized or is even concealed in papers concerning validation of motor tests [14,49–52].

The circumstances of *Rotational Test* development are also significant. The first author of this paper and the author of the test has been led to the solution by the results of two observation. In the seventies of last century during judo trainings he associated the interdependence of two phenomena. During a warm-up, judokas performed numerous exercises consisting of 360° or even 720° rotations and maximal rotations in both directions. Those, who did not fall during the exercises or did fell occasionally, made their opponents lose balance during randori (training fight) and maintained vertical posture more effectively. The experience and performance level of judokas was similar (3–5 years of experience, 2–1 kyu, first dan). It was not a definition of BBDTS an inspiration to develop a tool to measure this phenomenon, but the reflection on phenomenon (phenomena) which determine the effectiveness (or its lack) during both types of motor activity. Further way to solve a problem has been described as detailed as possible in this paper (bearing in mind all editorial limitations).

The definition of BBDTS and argumentation explaining this phenomenon are therefore based on in-depth studies combining various sciences, consultations, results of many observations and experiments as well as own motor experience (especially judo, skiing, tennis, military training).

RT critic may make an allegation that there are people unable to perform the test and that the multitask test exceed motor abilities especially of the elderly. Counterargumentation to that is simple and hard to refute. The impossibility to perform RT justifies the result of 18 points, insufficient assessment of BBDTS and classifying this person as type 'Z'. Keeping the definition of BBDTS and justification based on validation procedure in mind, the following directive should be formulated: if a person is not able to perform at least one task during RT (jump with 360° rotation, but just incomplete jump e.g. with 270° rotation), it means that limitation of this motor abilities lies in neuroanatomical or neurophysiological mechanisms or is a compilation of both factors, or results from the nature of anatomical deficiencies (in the structure of muscle or muscles, joint and/or bone structures, etc.); a variance of impossibility to perform RT may be caused by low level of motor abilities and/or lack of relevant motor experience. The main reason of difficulties in counteracting the conditions when a person is subjected to forces hindering vertical posture i.e. an actual reason of insufficient BBDTS remains to be determined. In the next stage it is necessary to decide about creating relevant compensation mechanisms. A simple syllogism of Aristotle leads to a conclusion that people with insufficient BBDTS i.e. diagnosed as type 'Z' should be taught the mechanism of safe falling [3–6]. It is the most reliable mechanism to compensate for the inability of maintaining vertical posture.

Following this line of reasoning, we would reach another significant conclusion. RT is a very useful tool for screening assays. Is there a need to conduct expensive and longer-lasting apparatus tests (e.g. with the use of tensometric platform [53,54]) during e.g. preliminary qualification of candidates for a particular profession (construction, emergency services, police, army, etc.) if the results of vast majority of this tests possess limited power informing about the essence of balance maintenance similarly to non-apparatus and quasi-apparatus tests (tests assessing either static or dynamic balance are recommended).

Such reasoning for the use of sport is not ethical. Low level of BBDTS may not constitute an excuse for disqualification of anyone to train their dream sport (with the exception of health risk that could be caused by repeating exercises specific for some sport or other contraindications). On the contrary, during validation process we have determined a group of sports that may be used even in rehabilitation of people with very low BBDTS. An open issue is to individually adjust exercise methodology for a particular person.

Observations of 37 boys and 21 girls (58 in total) aged 6–12, who have participated in three-month preliminary judo training in a big Polish city have revealed some disturbing information [55]. Sixteen boys (the average RT result amounted to 11.06 with individual variance from 2 to 18 points) and six girls (RT=9.25; variance 6 to 14 points) have resigned already in first weeks of the training. The average result of boys who have finished the training amounted to 7.3 prior to the course and variance has fluctuated between 0 to 16 points, whereas after the training boys obtained 5.48 and 0 to 11 points respectively. Girls results at first amounted to 5.8 and 0 to 10 points, while after the training 4 and 0 to 10 points respectively. Judo teacher(s) should be blamed for this didactic mistake i.e. inability to arouse interest at the training. Mental effects of failing to practice judo may have much deeper implications than missed opportunity (documented by quoted RT results) of obtaining motor effects significant for safety.

This result is complemented by the statement that the influence of judo training on balance has been noticed for a long time, even though the scientists have used tools which have not reflected the essence of body movements similar to those used in judo. However Witkowski and Cieśliński [56] have induced dynamic rotational movement in 120 judokas using Barany chair. First attempt – the marching test without destabilizing was carried out on wooden balance bars consisting of five bars 3 m long having different width (9, 7, 5, 3, 1 cm and 10 cm height). The test was repeated after destabilisation on Barany chair (10 turns by 18 seconds). In both attempts better balance was revealed by most experienced judokas (8 years and more).

Extending the duration of training experience in some sports (including judo) especially by adults is essential for their motor safety. In the elderly, due to the involutional changes, the ability to correct balance starts to deteriorate. After the experiment conducted by Allum et al. [57], who had investigated the effects of ageing on balance corrections induced by sudden stance perturbation in different directions, it has been revealed that mechanisms compensating for fall hazard change together with age. In this experiment, simulations of balance disturbances did not involve rotational movements and the characteristics of CFR 3 category when the fall hazard is the highest.

Since the usefulness of RT in BBDTS diagnosis has been confirmed in the course of observations and periodic intensification of exercises stimulates BBDTS of people who already possess high adaptation, than both RT and specific sports are worth recommending in rehabilitation of people classified as II BBDTS group (Table 7). BBDTS of wrestlers during the preparation training was estimated at 5.1 with variance from 0 to 12 points, whereas three months after, it amounted to 3 with variance from 0 to 9 points [58]. Positive effects on BBDTS have been documented caused by long lasting use of modern gymnastic and dance forms with the use of self-defence by young females [26]. Prior to the experiment the RT result equalled 7 and variance was from 0 to 14 points (the RT result of peers in the control group was 7.68 with variance 1 to 15 points). After the experiment it amounted to 5.43 with variance from 0 to 13 points (females from the control group 7.37 and 1 to 14 points respectively).

Change in BBDTS caused by environmental factors can be studied with the use of RT in various empirical, didactic and diagnostic systems for the use of selection or rehabilitation (neurological, patients with ocular disorders, after limb amputations, diabetics, etc.). Some publications (based on a pilot version of RT) informing about the influence of sleep deprivation on BBDTS have already been published [59].

The simulation research are promising [60]. The conclusions of these studies (developed methodological procedures) may have profound significance in rehabilitation of the blind and even after serious limp amputation. Physiotherapy students (n=16), who had participated in basic safe falling training, have performed RT in quasi-apparatus version in 15-minute intervals in three different conditions: A) with no limitations; B) with eyes covered (lack of vision should not always be equated with simulated blindness because each person can be subjected to fall in the darkness); C) with arms tied with an orthopaedic belt (simulated arm amputation). An important condition for an experiment was the ability of safe falling possessed by all students. It turned out that the most difficult conditions were posed by lack of vision (B). The average RT result amounted to 8.69 with variance from 1 to 10 points and average duration of the test was 18.42 sec. (12.94 to 27.87 sec.). The differences between both indicators (points and time) are statistically significant ($p<0.05$) compared to other conditions. The average result of RT in A and C condition remains identical i.e. 6.94 points, the duration was similar; A 14.30 sec., C 14.51 sec.

Wide application of RT in rehabilitation of the most difficult neurological cases, ocular disorders and amputation patients makes sense and fulfils ethical criteria under the condition that patients will be taught of safe falling methods. *Rotational Test* is complemented by non-apparatus and quasi-apparatus tests which are used in promotion of safe falling as the primary method for preventing injuries in people regardless of their age, health condition and degree of disability [3–6]. There are no limitations of RT use in case of healthy people. The RT result associated with the test measuring susceptibility of injuries during the fall [7] will reveal how necessary it is to educate people in safe falling.

Conclusions

RT is sensitive to the factors modifying BBDTS – especially adaptive changes related to a long-term training as well as the influence of the current state of the body and/or a sudden change in the conditions of motor action. Thus, RT can be widely used in rehabilitation, health-related training, motor control (sport, physical education, etc.), the selection process in the army, police, emergency services, etc.

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