ORIGINAL ARTICLE

The method to evaluate the susceptibility to injuries during the fall – validation procedure of the specific motor test

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- A Study Design
- B Data Collection
- C Statistical Analysis
- D Manuscript Preparation
- E Funds Collection

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Abstract

Background and Study Aim: In world literature an epidemiology of body injuries caused by the falls of people of different age and health condition is very well documented. However, there are not enough methods, which would make it possible to answer the question: which body parts of a given person are the most exposed to injuries during the fall and collision with a ground or other object. The aim of this paper is accuracy of *"the susceptibility test of the body injuries during the fall"* (**STBIDF**).

Material/Methods: The structure of STBIDF is: three motoric tasks performed on a tatami mats. A manner of the body parts protection (head, hands, hips, legs) was being assessed, the most exposed to damage during the fall. Any incorrect collision – simulated by the fastest possible change of the posture from vertical to horizontal (lying on the back), were documented by the errors of the first- ("1") or the second grade ("2"), and no errors "0". Total number of points is a general indicator of the susceptibility to body injuries during the fall (SBIDF): low (0), average (1–3), high (4–8), very high (9–14). Relatively for particular body parts (SBPIDF): low (0), average (1), high (2–6).

The young, healthy, physically active women (n=68), who were insignificantly diversified in terms of the age (20–25 years, average 21.26), however considerably in terms of the somatic development – the mean range of the body height 27 cm and body weight 34 kg, were examined.

Results: Most young women (57.35%) revealed a very high susceptibility to body injury caused by fall and collision with the ground or other obstacle and less than 6% showed the average susceptibility. The difference between the two proportions is statistically significant ($p<0.005$). Assuming a vertical posture as a reference system (also the initial posture of all tasks STBIDF), the more young women are susceptible to damage of a certain part of the body during the fall, the more distant from the ground. There is no statistically significant difference only between the proportion of young women's susceptibility to injury of hands and head during the fall. Both risks apply to more than 90% women. A very high convergence was found between results of individual tasks (made individually) and repeated simulation of falls of the same (Task 1) or very similar (Task 2 and 3) motor structure.

Conclusions: The test is simple and very safe tool and can be used for examining people of all ages who are able to independently change the posture from vertical to horizontal. The lack of ability to independently rise from the horizontal posture does not exclude the possibility of applying the test. Quite the opposite, the researcher (doctor, physiotherapist etc.) obtains additional information that such person, after the fall may be deprived of aid, therefore is susceptible to the effects associated with long-term staying on the ground. The test is accurate tool to verify prevention programs.

Key words: susceptibility test of the body injuries during the fall • collision avoidance • safe fall • exaggerated orthostatic response • epidemiology of injuries • ageing

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Background

The fall – depends on the context – is understood in two ways. From medical point of view, as a sudden, accidental change of the position as a result of the loss of balance (without the involvement of external forces) during walking or other activities, through which a person is on the ground or other low situated surface. We refer here to the definition, which Żak [1] based on the findings of Feder et al. [2] and Hauer et al. [3]. However we formulate one restriction: it is not true that the inevitable consequence of loss of balance and fall "is being injured".

Injured may be primarily a person unable to fall safely as well as well-prepared person, but in certain conditions having no control over the circumstances, which inevitably will cause certain damage to the body (i.e. during the fall in total darkness on the ground covered with sharp objects like glass, stones, etc.).

From theoretical point of view [4] and pragmatics of safe falling [5], the fall – accidental or intentional – is understood by us as a fully controlled operation. This means that in a situation of a sudden loss of balance (especially due to external forces – i.e. slippery ground, pushing) a trained person immediately controls the different parts of the body, according to the falling direction (forward, backward, sideways and intermediate directions) and other circumstances (force, identified vertical obstacles etc.) and because of these circumstances either remains in a horizontal posture, or after the collision with the ground or some obstacle will return to the vertical posture. Fall deliberately caused, we understand as a motor response to emergency situations, which a person properly identified and solved. Depending on the circumstances of action, after the safe fall the person either remains for some time in a horizontal posture or immediately returns to the vertical posture. The common assumption of motor action in both situations is the ability to control different parts of the body, so by the objective lack of external conditions of damage or structural failure, the collision with the ground or a specific vertical obstacle would be properly absorbed by the human movement system.

In scientific international literature the epidemiology of injuries caused by falling of people of different age and health condition is very well documented. According to World Health Organization [6] falls are the second biggest cause of unintentional death in the world and give way only to transport accidents. Every year about 424 000 deaths due to fall are reported, and the most susceptible age group are people over 65 years old.

Based on many studies and simulations it is expected that as a result of extending the life of people falls will affect an increasing number of older people. It is estimated that in England by 2025 the number of people over 65 years old will increase by three times, while over 80 years old will be doubled, and those exceeding 100 years old will be quadrupled [7, p. 5]. The authors of this report conclude that if no preventive action is taken, in 2025 the number of injuries of the oldest people as a result of falls and collisions will increase significantly. In the United States by 2040 the number of people over 65 will increase from 34 800 000 to 77 200 000, and in the group above 85 this ratio will be relatively higher [8].

The report of health and social consequences of falls is opened by fractures (64%), followed by fear of falling (44%), admission to hospital (32%), isolation (22%), loss of independence (14%), withdrawal from activity (12%), neurological damage (6%), social service home (2%) [9]. To fractures are exposed especially people with osteoporosis. The most fractures as a result of fall concern youths aged 15–18 and people over 60 [10]. However, fractures in children and youths do not often cause different complications, but the effects of falls of older people are a common cause of subsequent disability. Żak [1] summarizing the major results of epidemiological studies published in the years 1992–2005 states: in 1990 in the world came to about 1 600 000 fractures of the distal femoral epiphyses (forecast for 2050 is 6 260 000); fall is the cause of 25% of fractures of the spine; 90% fractures of the distal femoral epiphyses; 100% fractures of forearm; falls are the cause of more than 90% of non-vertebral fractures. Falls at home mostly occur in the bathroom, bedroom and kitchen. Persons hospitalized frequently fall near the bed, in the toilet, in the bathroom and in the hallway. The cause of 50% falls is a slip or stumble, 10% syncope, 10% dizziness, while 20–30% are other balance disorders (when a person is changing position from sitting to standing, performs turns, leans or reaches for an item, or during the walk).

Many studies cited by Żak [1] show that 40% of older people who have fallen, although not injured, are not able to stand up alone. Long wait for help while lying on the ground or floor, causes a number of complications (hypothermia, pneumonia etc.). One of the main factors that increases mortality after the fall is being in a horizontal posture for at least 1 hour [11]. Furthermore, effects of a long-term lying after the fall can be accumulated in some people with effects of exaggerated orthostatic response. In such a situation an adoption of vertical posture can cause a sudden loss of consciousness.

Multifactorial prevention strategy covers four areas: strength and balance training, elimination of home risk factors; improving eye, cardiovascular, and mental

Table 1. Worksheet documenting the susceptibility to the body injuries during the fall.

Body part	Task 1	Task 2	Task 3	Total	SBPIDF
Legs	–	–	0 1 2		
Hips	0 1	0 1	0 1		
Hands	0 1 2	0 1 2	0 1 2		
Head	0 1	0 1	0 1		
Total				The overall indicator of SBIDF:	

function; verification of drugs taken [12]. It is estimated that it is possible to prevent 30–40% falls [13]. This means that in 60–70% circumstances, the fall is still inevitable. Thus the weakness of similarly constructed systems of injury prevention is focusing attention on reducing (decreasing) the number of falls in the course of daily or professional activities, however **it is almost impossible to avoid this kind of events (!)**. In our understanding, this type of prevention programs should primarily support the general education of people (especially children and youths) with a range of skills of safe falling and collision avoidance [4,5,14–17].

Apart from issue that there is no common implementation of so defined injuries prevention, we determine objectively that there is also no commonly used diagnostic methods that would enable us to answer the question: which parts of the body are the most exposed to injuries during the fall and collision with the ground or other object?

The aim of this paper is accuracy of "*the susceptibility test of the body injuries during the fall*" (STBIDF). Premises and assumptions of this test, by Roman M. Kalina, were published in Polish language edition of *Medical Tribune* in 2009 [16]. Thus adopted in Polish abbreviations for the name of this test and key indicators in glossary are compiled with English abbreviations.

For two reasons the test validation procedure is based primarily on the accuracy criterion. First of all, the aim which the test is supposed to serve and the need to ensure maximal motor safety of analysed persons (especially older people) determine the accuracy as the most important criterion (!). Second – editorial limitations are decisive factor.

Material and Methods

Assessment of the susceptibility to the body injuries during the fall

Subjects examined individually performed "*the susceptibility test of the body injuries during the fall*" (STBIDF). Before the test they have remained in the room from which it was impossible to observe examined subjects. After the test they filled in the questionnaire concerning sports activities and past injuries, and then watched another examined person, without the possibility to comment (in this way the verbal contact with examined person and the awaiting people was prevented).

The test consists of three motor tasks, which should be performed on a soft surface (such as tatami mat). The criterion for evaluation is the way of protection (or lack) of those parts of the body, which during the fall are the most exposed to injury (head, hands, hips, legs). Each incorrect collision of that body part with the ground – simulated by the fastest possible change of vertical posture (Figure 1A) to the horizontal (lie down on the back Figure 1B) – should be recorded in the worksheet STBIDF (Table 1) by circling number "0" (no error), "1' (first degree error) or "2" (second degree error).

Total number of points is a general indicator of susceptibility to injuries during the fall (SBIDF): low (0), average (1–3), high (4–8), very high (9–14). The measure of susceptibility of the predetermined parts of the body to injuries (SBPIDF) is the sum of the points from all tasks (summarized points from the rows of the worksheet) analyzed separately for the each parts of the body: low (0), average (1), high (2–6). The terms "susceptibility level" relative to the indicators SBIDF and SBPIDF are used in the analysis of empirical data.

Marginal values of SBPIDF (as a result of adding errors made during the tasks) for the different parts of the body include between: legs 0–2; hips 0–3; hands 0–6; head 0–3. However the marginal values of adding points estimated after completing the Task 1 and 2 are in the range of 0 and 4 points, and Task 3 in the range of 0 and 6 points. For this reason a comparative analysis (for the parts of the body and each tasks) takes into account the indicator of proportion of errors (expressed in percentage) applied to the possible maximal value of estimated points (SBPIDF%max). For example, for the hands this value is 6 points and 2 points for legs.

Figure 1A.

Figure 1B.

Figure 1C.

Figure 2.

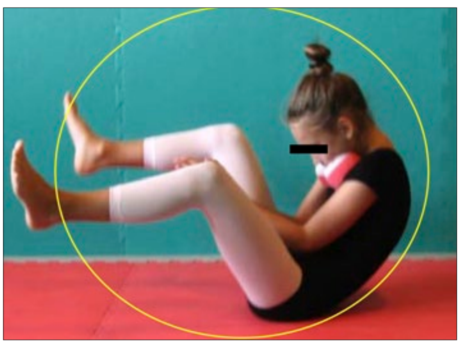

Figure 3.

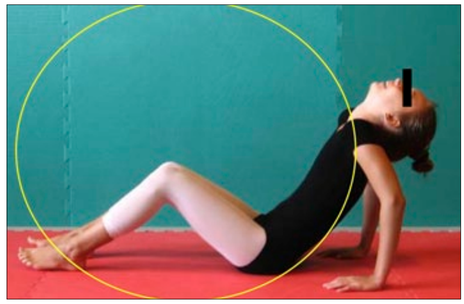

Figure 4.

Figure 5.

Figure 6.

Task 1. Instructions for the test subject: "on the command GO lie down on your back as fast as possible". Performance: tested person should safely lie down on back as fast as possible – an attempt ends when heels, buttocks, back and head adhere to the ground (Figure 1A,B). When a person lies on the back and adhere chin to chest (Figure 1C – what is primarily the essence of the correctness of lying on the back at the end of Tasks 2 and 3), it means that she has perfect control of the head during the fall (!) and attempt is considered valid.

Assessment: "hips" – hitting buttocks on the ground or during a change of posture from vertical to horizontal; keeping right angle or obtuse angle between the thighs and shanks **1** point; "hands" – leaning both hands on the back or hips, or elbows hitting the ground **2** points, same with one hand **1** point (leaning forward with one or both hands on the ground when squating prior to rolling on the back is correct – Figure 2), "head" – holding the head leaning back during postural changes from vertical to horizontal or hitting head on the ground, instead of resting head down gently when already lying on the back **1** point.

Correct performance of the task relies on fast squat with simultaneous tilt of the head forward and putting hands forward – or leaning with both hands forward (Figure 2) – and gently rolling on the back and buttocks ("cradle"), keeping hands and head in front, adhering chin to chest (Figure 3). When lying on the back gently touch the ground with heels and occiput. Similarly lie down on the back doing the Tasks 2 and 3 (but the head should be placed on the mat after the command STOP), to recognize activity as correct. Figure 4 shows the accumulation of errors when changing posture from vertical to horizontal.

Task 2. Instructions for the test subject: "from the vertical posture, press the sponge with the chin to the chest, on the command READY start clapping hands, and on the command GO again lie on the back". Performance: tested person (this time pressing the washing sponge with the chin to the trunk) must lie on the back – clapping should stop at the command STOP. Assessment: identical to the task 1. Additional rigor – ceasing to clap, even though there was no leaning (hitting) hands on the ground **1** point (in the "hands"); falling out or holding the sponge with hands, or releasing the pressure of the chin when lying, despite the fact that the head did not hit the ground **1** point (in the "head") – in both cases, these events should be recorded in a worksheet, to facilitate detailed analysis of observational data.

Task 3 (tested person with sponge like in the Task 2, stands on a platform about 25 cm high, arranged from for example mattresses). Instructions for the test subject: "all activities remain the same, but after command GO first jump back". Performance: after the command READY tested person has to start clapping hands, after the command GO has to jump back and after the feet touch the ground should immediately lie on the back clapping hands – clapping should stop on the command STOP. Assessment: "legs" – landing with straight knees, or after a jump stopping for 1 second or longer **2** points, landing on one leg stepping down of the platform **1** point (Figure 5); "hips", "hands", "head" – the same criteria as in the Task 2.

Additional arrangements. The elderly or a person who for some reason may have problems with the jump or even a descent from the platform (reduced to 10 cm), replace this component of Task 3 with standing on toes (Figure 6). Assessment: "legs" – stopping after the next contact of entire feet with the ground for 1 second or longer **2** points; "hips", "hands", "head" – the same criteria as in the Task 2. If the tested person is unable to adopt vertical posture – regardless of the task and the specific characteristics of SBPIDF – stop the test, take the result of SBIDF 14 points as the binding and describe the event in the worksheet.

Assessment of appropriateness STBIDF

As the main criteria of accuracy we assumed: (1). *Criterion oriented validity – concurrent validity and predictive validity;* (2). *Content validity*; (3). *Construct validity.*

(1). *Criterion oriented validity.* In this procedure, the primary criterion of validity on the border of *concurrent validity and predictive validity* is the power of test of differentiation, however, taking into account its specificity. Already in the introduction we assumed that every person in certain circumstances of the loss of balance, fall and collision with the ground or other object may be injured or die. The result of SBIDF "0" points does not mean the lack of such susceptibility, but relatively low probability of such consequences of the fall (it is also a significant criterion of *content validity and construct validity*). The second assumption is that with sufficiently large random sample from the population, there is no guarantee that the observational data from this specific motor test will be subject to the rules of the normal distribution (according to the Gaussian curve). With the large sample the results should be differentiated by the tested persons at least due to three of the four fixed levels of SBIDF: average, high, very high. The third assumption says that number of people qualified to low level in population is very low. These three assumptions lead to the conclusion that the most reliable comparative criterion of future studies results using STBIDF (indicators of the test) are significances of the difference between two specific proportions. The consequence is the need to resolve two methodological issues. The first is to determine the conventional proportion pairs, which we call "relatively independent". The second – to determine simple, but adequate statistical tools.

By the "relatively independent" proportion we understand a set, which as a part of the same sample of the population is subjected to the procedure to determine significance of the difference with another set of measurements (also "relatively independent") from the same sample. This "relative independence" of both sets is determined by at least a third set of this sample ("the rest of the set / sets").

We calculate statistics based on modified formulas (12.1) and (12.2) of the Ferguson and Takane [18]. The standard error of the difference between the two proportions based on attempts to "relatively independent" we calculate:

$$s_{p1-p2} = \sqrt{pq\left(\frac{1}{N_f} + \frac{1}{N_R}\right)}$$

where: p – sum frequency of prevalence of the feature in both connected samples (f_1 i f_2) divided by sample count

$$p = \frac{f_1 + f_2}{N} = \frac{N_f}{N}$$

$$q = 1 - p; \quad N_R = N - Nf$$

The difference between two "relatively independent" proportions is calculated by dividing the difference between the proportions by the estimated standard error of the difference:

$$z = \frac{p1 - p2}{s_{p1-p2}}$$

(2). *Content validity*

Fourth assumption draws attention to the fact that the test has strong relations with the non-test criterion, adequacy of which should prove particular by the *content validity* procedures (in the empirical research methodology also called *logical* [19] or *internal* [20]). The most important, in our opinion, logical and common sense argumentation is that the most expressive elements of STBIDF are methods to control hands and head during the fastest possible change in the posture from vertical to horizontal (they are evaluated three times during test tasks – indicators *SBPIDF: hands, head*). These indicators are easily observed while the activity itself performed on a soft surface is safe and can be repeated many times in the non-test conditions.

Empirical verification. Directly after the STBIDF, tested people (in groups of 8–10) performed on a tatami mat after 6–8 repetitions of exercise with a very similar movement structure to the separate tasks (without sponge). An experienced observer, who knew and correctly identified all tested person, documented the cases of properly performed motor activities. *Exercise one*: walk in place, "on the command GO lie down on your back as fast as possible", the assessment criteria as in Task 1. *Exercise two*: walk in place, clapping hands "on the command GO lie down on your back as fast as possible" (the assessment criteria as in Task 2). *Exercise three*: walk in the place "on the command GO first jump high up and after landing on the mat lie down on your back" (the assessment criteria as in Task 3).

At least five times the correct control of hands (head) during these exercises is the fulfilment of the convergence criterion with proper control of these parts of the body during the appropriate tasks. Most of repetitions burdened by errors of the first or second degree, relative to lack of the correctness in tasks, fulfil convergence criteria of errors. The discrepancy is easy to determine.

(3). *Construct validity*

The basic criterion is the relation of STBIDF with the theoretical construct (theoretical variable). Jerzy Brzezinski [20], based on Cronbach's and Meehl's [21] findings, explains that *construct* is certain postulated competence of people, of which it is assumed that reveals itself in solution of the test. In case of the motor test, it is the ability (or lack thereof) to solve certain motor task (measured by either efficacy meaning compliance of the result with the aim, or the number and scale of errors). Means of solving a particular STBIDF tasks are measure of human capacity for optimal control of different parts of the body during sudden change of posture from vertical to horizontal (during simulated fall). Theoretical basis of this optimality explains the theory of safe (soft) falling [4]. In this validation procedure it should be proved that SBIDF and SBPIDF are sufficiently sensitive to environmental factors, modifying the way of human collision with the ground (degree of difficulty of the task, learning safe falls, etc.).

Statistical analysis

We calculated arithmetic means, standard deviations, range (minimum and maximum values) and range of the analysed empirical variables, skewness (g_1), standard skewness, kurtosis (g_2), standard kurtosis. We defined the significance of the difference between two proportions "relatively independent" and the proportions correlated of appropriate indicators of empirical variables. In the multi-feature analysis of basic indicators studied phenomena, we used a normalization of arithmetic means and standard deviation [22]. As a criterion for separation of compared groups of female students, in accordance with the aim of research, we adopted SBIDF indicator.

Persons

The surveys included 68 physiotherapy students (young, healthy, physically active women – out of 107 people, men and women participating in two courses of safe falling) of the fifth and sixth semesters of the first-degree studies (2009–20010) in the Podhale State Vocational School of Higher Education in Nowy Targ, Poland. Women were of insignificantly different age (20–25 years, mean 21.26). All participated in at least 90% of the lesson of the safe falling: the fifth semester of the first course "Theory and methodology of safe falling of the blind people" (10 hours of lectures, 10 lessons of exercises – 90 minutes, including 45 minutes learning of

Table 2. Estimation of the main empirical variables of 68 young women before starting the course of safe falling.

Empirical variable	Statistical indicators							
	$\overline{X}$	SD	Min	Max	Skewness		Kurtosis	
					g1	Stnd. skewness	g2	Stnd. kurtosis
Age [years]	**21.26**	0.70	20	25	**3.272**	11.000	**13.908**	23.400
Height [cm]	**168.1**	5.86	153	180	**–0.038**	–0.128	**–0.167**	–0.282
Weight [kg]	**58.35**	6.97	43	77	**0.135**	0.455	**–0.400**	–0.673
SBIDF [points]	**8.36**	2.31	3	12	**–0.644**	–2.170	**–0.147**	–0.247

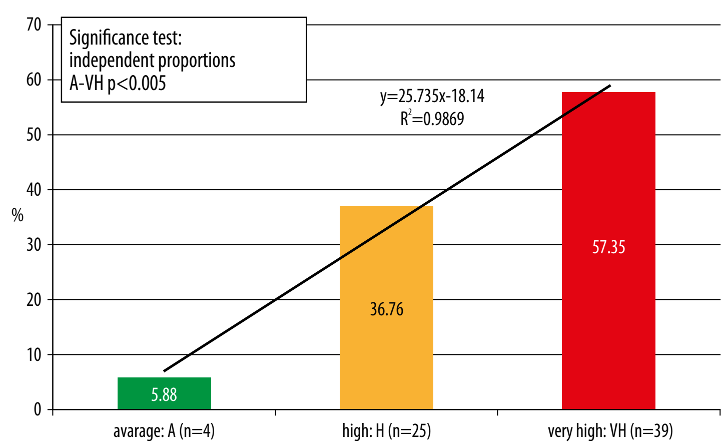

Figure 7. Structure of the susceptibility to body injuries during the fall of young women (n=68).

safe falling and 45 minutes observation of partner and documenting his/her physical effort; the sixth semester, second course, "Theory and methodology of safe falling of people after amputations" (the same structure of lectures and exercises).

Results

(1). *Criterion oriented validity*

Although tested women individually differed significantly in terms of somatic development – range of body height 27 cm and body weight 34 kg, the standard deviation of these two features indicates that only a little bit higher differentiation of inter-individual relates to body weight (Table 2). The factor of variation for age, height and body mass is: 3.31%, 3.49%, 12.0% respectively. Women were therefore – according to the assumption – a relatively homogeneous research material.

Most of the women (57.35%) revealed before starting safe falling course a very high susceptibility to injury due to falls and collisions with the ground or other obstacle (Figure 7). Less than 6% the average susceptibility. The difference between the two "relatively independent" proportions is statistically significant ($p < 0.005$).

Assuming a vertical posture as a reference frame (also initial posture of all tasks STBIDF), young women are especially susceptible to damage a part of the body during the fall, the more it is distant from the ground (Figure 8, Table 3). There is no statistically significant difference in the proportion only between susceptibility of female students to damage the hands and head during a fall. Both risks concern more than 90% of the women.

Power of diversifying indicators SBIDF SBPIDF is expressive. This phenomenon is even more clearly shown by the susceptibility analysis of injuries of various parts of the body during the fall in relation to the maximal possible amount of points (indicators SBPIDF%max). Range of results is 100 percent (Table 3). This range covers the entire scope of the scale STBIDF used for each diagnosed part of the body (from 0 to 6 for the hands, from 0 to 3 for the head and hips, and from 0 to 2 for the legs). The variability of the susceptibility estimated by standard deviation is various. The greatest dispersion of results concerns the hips, while similar is in the

Table 3. Ratio of the sum of all points of diagnosing the susceptibility to the body (SBIDF) and each body part (SBPIDF) to injuries during the fall to the maximal possible amount of points of a given indicator.

Empirical variable	Statistical indicator			
	$\bar{X}$	SD	Min	Max
SBIDF%max	**59.8**	16.50	21.42	85.71
SBPIDF%max: Legs	**22.1**	27.83	0.00	100.00
SBPIDF%max: Hips	**37.3**	38.85	0.00	100.00
SBPIDF%max: Hands	**71.1**	29.73	0.00	100.00
SBPIDF%max: Head	**84.8**	26.03	0.00	100.00

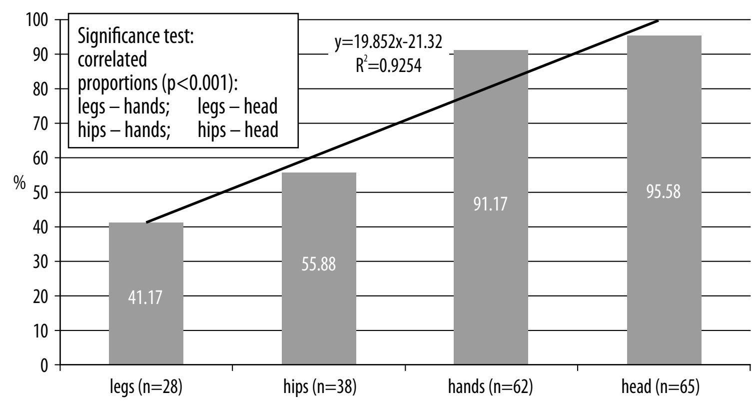

Figure 8. The proportions of young women (n=68) susceptible to injuries of particular parts of the body during the fall (SBPIDF).

case of other parts of the body. Significant differences in the number of women susceptible to injuries of various parts of the body (28 legs, 65 head) causes the average susceptibility of physiotherapy female students expressed as the relation of sum of all points diagnosing this phenomenon to the maximal possible sum of points (SBPIDF%max), to increase relatively proportionally (Table 3). The size of the indicator SBPIDF%max proves that the degree of threat the head during a fall and collision with the ground (84.8%)is the highest, and lowest for leg (22.1%).

(2). *Content validity*

People who correctly control hands and head while STBIDF simultaneously did not make errors during multiple repeating set of exercises in the session directly after the test. Similarly, those who could not properly control these body parts during STBIDF made errors in session after the test. This repeatability of errors (*hands* and *head*), and even their accumulation (*hands* at the level of statistically significant), is also particularly visible in comparing the results of Task 2 and Task 3 (Table 4). These observations are also important empirical evidence of *construct validity*.

(3). *Construct validity*

SBIDF indicator divided tested person into three separate groups due to the feature level: *average, high, very high* (Figure 7), which proves that this competence of people in comparable conditions (i.e. sudden change of posture from vertical to horizontal) reveal individually with different power. For most young women of similar age with insignificantly differentiated somatic growth, but with similar motor experiences, triple simulated collapse is a very difficult situation. Entitled is a conclusion that in real situation of loss of balance and fall over half of young women with similar characteristics cannot resolve this situation in an optimal manner. Few of them are able to overcome such a difficult situation with the optimal effect (avoid or minimize damage of the body). The lack of statistically significant differences between women, who revealed *average* and *high* levels, and *high* and *very high* respectively, is empirical evidence that the extremeness a real situation of loss of balance and fall in specific circumstances will reveal whether a person will be less or more efficiently in control of own body. Empirical data show that the probability of events concerns every third young woman with the specified morphological characteristics and similar weekly physical activity.

Table 4. Proportions [%] of young women (n=68) who before the course of safe falling made at least one error of control a particular part of the body during subsequent tasks STBIDF.

Body part/Task	Proportions of people making errors [%]			Significance test: correlated proportions [p<]		
	Task 1	Task 2	Task 3	Tasks 1–2	Tasks 1–3	Tasks 2–3
Legs*	–	–	42.6			
Hips	50.0	38.2	25.0	0.050	0.001	0.05
Hands	45.5	80.9	89.7	0.001	0.001	0.02
Head	72.0	88.2	92.6	0.010	0.001	–

* Assessment only in Task 3.

Table 5. Proportions [%] of young women (n = 68) who after the courses of safe falling made at least one error of control a particular part of the body during subsequent tasks STBIDF.

Body part/Task	Proportions of people making errors [%]			Significance test: correlated proportions [p<]		
	Task 1	Task 2	Task 3	Tasks 1–2	Tasks 1–3	Tasks 2–3
Legs*	–	–	3.0			
Hips	4.4	4.4	4.4	–	–	–
Hands	0.0	22.0	30.9	0.001	0.001	–
Head	17.6	4.4	14.7	0.050	–	–

* Assessment only in Task 3.

Threat scale of the injuries of different parts of the body caused by the fall show indicators SBPIDF (Figure 8, Tables 3 and 4). These are important empirical evidence that the test is sufficiently sensitive to environmental factors, which – according to the experience of many people, but also from elementary logic – determine how to resolve this difficult situation by a particular person. The possibility to observe three times ways in which the tested person controls the hips, hands and head in the simulated fall, is a chance for correct diagnosis in relation to those parts of the body. Diagnosis method for controlling legs is limited to the Task 3 only seemingly. Reduced proportion of people who make errors during subsequent hips control tasks (all differences statistically significant – Table 4), proves more accurate use of the absorbing function of leg muscles during rapid changes of posture from vertical to horizontal. Although this phenomenon is partly explained by the effect of warm-up (three fast squats with short intervals), probably the dominant factor is the higher level of adaptability to the new situation of motor action.

In this case STBIDF reveals these capabilities. The need for proper control of the body in such situations precisely explains the theory of safe falls. The authors of the "soft fall" theory [4] argue that during a fall the muscles tend to play the amortising role best if the joint system over which they run is set at the most convenient angle. For example a jump down from a certain height onto the feet is best amortised by extensors of lower limbs, provided that the person implementing this movement task keeps the correct angle of bending in knee and hip joints.

The empirical data presented in Tables 5 and 6 and Figure 9 clearly demonstrate the very high sensitivity of indicators SBPIDF as tools documenting the effects of the influence of environmental factors. After two courses of safe falling, the young women differ on the level statistically significant in quality of the control twice with hands, and once with head during the following tasks (Table 5). Before the course there were eight differences and they concerned hips (Table 4). Despite teaching students the proper hands control during loss of balance and collision with the ground, when the task difficulty increases (first Task 2, than Task 3), the number of people making errors increases as well. Different are motor responses for head control. When sponge is not used during Task 1, nearly one-fifth of young women make error – despite endured training. The use of sponge (Task 2) significantly reduces errors. Despite sponge usage women again generate errors when the level of difficulty of the task is increased (Task 3). But these are not statistically significant differences. However the high sensitivity of indicator on revealing the adaptability of specific persons is confirmed.

Table 6. Proportions [%] of young women (n = 68) who made an errors of control of hips, hands and head during subsequent tasks STBIDF – test before and after two courses of safe falling.

Study period	Body part and result of observation								
	Hips			Hands			Head		
	Task 1	Task 2	Task 3	Task 1	Task 2	Task 3	Task 1	Task 2	Task 3
Before course	50.0	38.2	25.0	45.5	80.9	89.7	72.0	88.2	92.6
After courses	4.4	4.4	4.4	0.0	22.0	30.9	17.6	4.4	14.7
Difference	**45.6**	**33.8**	**20.6**	**45.6**	**58.9**	**58.8**	**54.4**	**83.8**	**77.9**
Significance test: correlated proportions [p<]	0.001	0.001	0.01	0.001	0.001	0.001	0.001	0.001	0.001

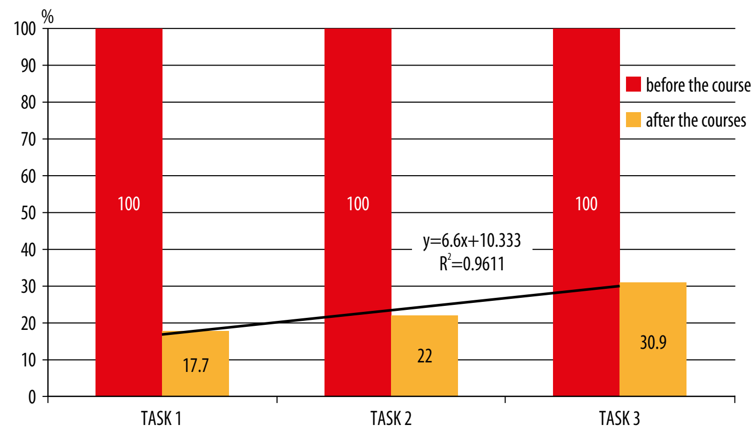

Figure 9. Proportions [%] of young women (n=68), who made at least one error of control a parts of the body during the subsequent tasks STBIDF – test before and after two courses of safe falling (significance test: correlated proportions p<0.001).

Comparison of the results of STBIDF before and after completed courses (Table 6) shows that the test is accurate diagnostic tool for human susceptibility to injuries during the fall. The results provide evidence that intra-individual characteristics (more than twenty years of motor experience, before a man begin education of safe falling) strongly determine the ways in which particular person collides with the ground during a sudden loss of balance. The evidence of the accuracy of construction and content of individual tasks is the comparative proportion of young women before and after the courses safe falling who have committed at least one error in controlling a particular part of the body (Figure 9). Before the course none of those women was able to faultlessly control the body even during a single task. After a two-step training that ability was shown by over 82% of them during the Task 1. The increasing level of difficulty of subsequent tasks proved to be accurate tool for selection of this ability – Task 2 (78%), Task 3 (69%).

The distance existing between young women, who revealed the average level of susceptibility to injuries during the fall, from those who revealed a very high level is primarily determined by the fact that those who are less susceptible are making fewer errors in controlling hands and hips (trunk). They are also taller and a little bit heavier (Figure 10).

Discussion

In our opinion presented theoretical and empirical argumentation entitles us to draw a conclusion that the test meets the scientific criteria for diagnosing human susceptibility to body injuries during fall – both in a broad sense (SBIDF index) and in detailed sense (SPBIDF index). The results of this part of validation procedure (concerning test accuracy) cannot be grounds for drawing conclusions on the whole population. On contrary, the test is a specific tool. It assesses human features which appear only in specified situations and apply to everybody – when the fall and collision with the ground or other barrier is inevitable.

Above mentioned specificity is very complex and multithreaded. From the methodological and application point

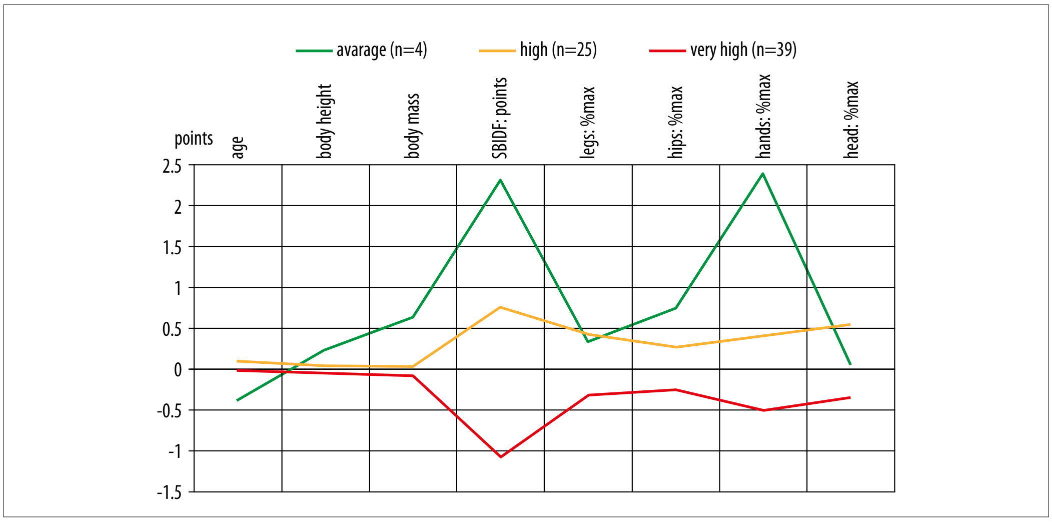

Figure 10. Normalized to the arithmetic means and standard deviations (n=68) indicators of the basic empirical variables of physiotherapy female students, who differ in the level of susceptibility to body injuries during the fall (SBIDF).

it is important to clearly emphasize that developing any norms for the whole population based on the SBIDF indicator would be clearly an absurd. Determining norms of body injuries for the specific age groups would mean resignation in many areas of health prevention, not only in body injuries prevention. Monitoring human susceptibility to body injuries caused by fall or collision in different age groups is a different issue. STBIDF is a tool which, when used widely, can make the said monitoring very reliable. Based on knowledge acquired in such way the rational preventive actions should (!) be taken.

We put an exclamation mark after the world "should" in previous sentence as it is striking why regardless of strong empirical evidence of effectiveness of educational programs of safe falling for people in different age groups [5,14,15,17] there are still no implementations especially in physical education classes compulsory for the youth. There are some exceptions. In Japan judo classes have been compulsory in schools for many years [23]. It is known that the basis of judo is teaching of safe falling (*ukemi-waza*). Thus Japan is one country where currently the youngest part of population is covered with body injuries prevention based on safe falling education. From the perspective of tendency towards prolonging the population age Japan has the best developed prevention system. In the future – when the current youth is of retirement age – the number of deaths and body injuries caused by fall and collision with the ground or other obstacle among elderly will be considerably reduced. However it is necessary to practice the safe falling skills as a part of constant health training [24,25].

Artur Kalina [15] based on declarations of 38 judo experts mainly from Poland, but also from Austria, Germany and former Yugoslavia, proved that safe falling education of children, elderly, and people who suffered from body injuries in the past is not harmful to their health. Out of thousands of people who were taught safe falling techniques only few suffered from body injuries during training. In four cases the experts pointed own error as a cause of injuries and more than once the cause was displacement of mattresses (the accidents happened at the beginning of experts' professional carriers). From medical, psychological and methodological point of view it is important that 55.5% of experts declared certainty (and 26.3% did not exclude such possibility) that they were successfully teaching safe falling techniques to people who suffered from body injuries in the past or had movement impediment due to other reasons.

Basing the body injuries prevention on the sports aspect of judo should be regarded with caution. One of the advantages of judo is also the fact that learners of this martial art not only acquire safe falling skills (*ukemi-waza*), but are also taught how to secure their partners during formal throw training (*nage-waza*), and competitors during fight (*randori*). Epidemiology of judoists body injuries shows that paradoxically both those elements fail during sport fights. The main cause for that is the fact that throwing a competitor out of balance and leading him to fall on his back is the end of the fight (scoring 10 points – so called "big point" *ippon*) while fall to the side or with an insufficient dynamic gives 5 or 7 points (*yuko, waza-ari*), which might be enough to victory. Thus a contestant thrown out of balance avoids falling on his back. On the other hand a contestant performing a throw is not focused on securing his competitor but tries to score *ippon*. This is how a proportion of judo contestants body injuries caused by falling can be explained.

Motor safety – it 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 [24].

Susceptibility test of the body injuries during the fall STBIDF (TPUCPU)

Susceptibility to body injuries during the fall SBIDF (PUCPU)

Susceptibility to particular body parts injuries during the fall SBPIDF (PUCCPU)

According to German studies [26] among judoists who suffered from body injuries 72% were being attacked during fight, the number was 60.5% in Polish researches [27]. More detailed analysis show that among main direct causes of contestants' body injuries during attack is leaning on a hand while falling and collision with the mat. These injuries are intensified by a contestant who attacks and make errors (especially when falls on the body of a competitor). Today's statistics confirm these trends. However, there is empirical basis which indicates the phenomenon of injuries in judo (as a sport discipline) should be linked especially to the quality of teaching methodology, and therefore to the competence of teachers. In Japan during a year there are 36 to 54 accidents for 1000 athletes [28], and therefore injury rate is around 5%. In France, the accident happened to 21% of the students of judo [29]. In Italy the rate was 58.1% [30], but among students practicing judo in a year, there were less accidents: 259 out of 1000 athletes [31]. In Polish judo clubs that rate in the comparable period was from 5.5% to 47% [27].

However we recommend as a "sport of the life" both, *randori* training and other forms of judo, in which the vertical posture is the initial moment of motor actions. The controlled fall and the need to protect the falling body of the partner (competitor in *randori*) are in fact the basic elements of these forms. Recent publications [32–37] re-discover the great possibilities of judo, not only in terms of injury prevention, but also as means of increasing the personal safety (self-defense) [38], a comprehensive human development and sustain psychophysical availability at the optimal level by the entire life.

Emphasizing the prognostic value of STBIDF we draw attention to two verified empirical arguments however, beyond the official validation procedure. The first concerns the observation that we made during the first course – safe falling for the blind. During the fifth lesson the task of 10 randomly selected students (women and men who had covered eyes with a band) was running at a distance of 6 meter alternately forward and back Each person held in hand a baby doll made of soft material. Students were informed that the purpose of this exercise is to improve the simple rescue activity in conditions of the lack of the visibility. During the exercise the other students expressed applause loud ovation and verbal doping. When an exercising athlete already ran very smoothly, assistants of the experimenter (at the time when athlete run backward), put five mattresses (each 4 cm thick, size 100×100 cm). None of the participants of the experiment fell back in a professional manner, even though during the previous four lessons preceding the experiment, each had perforemd approximately 150 repetitions of exercises with similar content (instead of dolls, we used rolled foam mattress). With the exception of one person, others either leaned with one hand or both hands losing control of the doll. A student, who was holding a doll with both hands at the moment of impact with the ground, could not protect it. Doll's head hit the mat with the high dynamics when student after the loss of balance was rolling – in a correct manner – from buttocks to the back.

The second argument refers to the three events for which there is no doubt that they are reliable. In the moment of these events, two people were already graduates of both courses of safe falling in the Podhale State Vocational School of Higher Education, Nowy Targ, Poland, one (Bartholomew) participated in 15 lessons:

Michael (23 years old) doing repair work standing on a ladder, the feet of about 1.5 m above the ground. As a result of his own error he was falling to the back with a ladder. He threw the heavy crowbar away to a safe distance and after his feet touched the concrete ground he immediately made a *rear fall with turn*. The ladder after a moment fell down in place, where he collided with the ground. Because he professionally steered his body, he avoided injury both in the moment of collision with the hard ground, as well as possible strikes by the ladder (by immediate rotation of the body).

Bartholomew (21 years old) after the jogging (the body was sufficiently prepared for physical effort) was walking across pedestrian crossing (previously making sure the street is empty) when suddenly, car run on the crossing. Hit with a huge force he made consecutively two *rear fall with turn* on asphalt. When he immediately took a vertical posture he noticed that the car was moving away. Doctors were surprised that on the Bartholomew's body they found no injuries and no evidence of a collision with the car.

Agnes (24 years old) was travelling by bus when the driver stopped suddenly. An old man (about 190 cm, more than 100 kg) standing next to her fell forward with huge force. Agnes grabbed his arm and gently slid him to the floor of the bus unharmed.

Above examples entitle us to draw a conclusion that among the students participating in the experiment dominated motor reactions, which they have gained during more than twenty years of living, before they started learning to control own body during a fall. Thus, people corresponding to the characteristics require lots of care. Teaching of safe falls should be intense (at least 3 trainings per week). Is also entitled to conclude that people who have high level of ability to learn new motor function are able, even for a short period of education (even if only 15 lessons) to reach optimum abilities of the protection of own body or other people exposed to the inevitable collision with the ground or vertical obstacles.

Proceeding in this paper accuracy of STBIDF is reinforced by the arguments belonging to the non-tests. The importance of this type of argument emphasizes Jerzy Brzezinski [20], who refers to many methodologists of science even from the middle of previous century.

An important methodological matter is that people using STBIDF were able to correctly identify specific phenomenon of the studied features (human susceptibility to injuries during the fall). It is easiest to determine whether the person with the horizontal posture, leaning on one or both hands or not; at the time of adhesion back to the ground protects head (pulling chin to the body) or connecting the head is simultaneous with the back or slightly delayed; when should clapping hands (Tasks 2 and 3) during change of posture from vertical to horizontal interrupts this process; when to control the sponge, pressing chin to the body (Tasks 2 and 3), sponge falls. The problem for many inexperienced observers is to see whether the body in the moment of collision with the ground, the angle between the thighs and shins is obtuse or right (first-degree error), or whether these two parts of the body are at an acute angle. It is very easy to find the difference. When there is obtuse- or right angle is it clearly to hear the moment of body collision with the ground. The more acute angle, the lower are sound effects, and the body freely moves to the rolling phase. The significance of this phenomenon precisely explains the theory of safe falling [4]. Lesser problem is to see whether the tested person after the jump from the platform (Task 3) stop for a second or longer, or that after landing do not bend the knees (error grade 2). Person using the test must be aware of the need to identify these facts. This phenomenon also explains in detail by the authors of the theory of safe falling [4]. It is not a problem to say that the tested person leaves the platform with one leg (not jumps), or lands after jump down on one leg (error of 1 degree).

Research projects in the near future, in our opinion, should first of all verify the accuracy of this test. The condition is certainty that perception of people using STBIDF and awareness of the observed phenomena do not raise objections. We recommend each investigator that carefully studied the instructions of STBIDF and content of the above paragraph.

Referring in conclusion to ascertainment that we put in the introduction that the weakness of the systems of injuries prevention is to focusing attention on reducing the number of falls in the course of daily or professional activities, while avoiding this kind of events is impossible, we would like to emphasize that we are not concerned about decreasing the role of this kind of research and recommendations. On contrary, the importance of such researches in cognitive and applied meaning, the best proved by the multiplicity and high level of scientific papers presented during the 10{th International Conference on Fall Prevention and Protection [39]. Permanent, multi-faceted researches on the causes of falls and building prevention systems, we concentrate on the same level of validity as the teaching of safe falling. It does not change the fact that this knowledge should support common education of people from the scope of the skills of safe falling and avoiding collisions, but not inversely.

Conclusions

The test is simple and very safe tool and can be used for examining people of all ages who are able to independently change the posture from the vertical to horizontal. The lack of ability to independently rise from the horizontal posture does not exclude the possibility of applying the test. Quite the opposite, the researcher (doctor, physiotherapist etc.) obtains additional information that such person, after the fall may be deprived of aid, therefore is susceptible to the effects associated with long-term staying on the ground. The test is accurate tool to verify prevention programs.

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