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Predictive validity of STBIDF (the susceptibility test to the body injuries during the fall) – two methodological aspects

Authors' Contribution:
A Study Design
B Data Collection
C Statistical Analysis
D Manuscript Preparation
E Funds Collection

Bartłomiej Gąsienica-Walczak [1ABCDE], **Artur Kalina** [2ABCDE]

[1] University of Applied Sciences in Nowy Targ, Nowy Targ, Poland
[2] Plus-Rehabilitation Services Ltd., Cristal Lake, USA

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Abstract

Background & Study Aim: Fall-related injuries may be fatal or non-fatal. For each fall mortality event, there are 136 other fall injuries that require treatments in hospital emergency. One of the elements of the 'Polish School of Safe Falling' safe falling program is the aspect phenomena of the susceptibility of body injuries during the fall (SFI). Aim of this study was knowledge about predictive validity of SFI method based on the multi-aspect association of the results of motor simulations with two sets of adults – declaring body injuries as a result of an unintentional fall in the past and declaring the lack of such experience.

Material & Methods: The study was conducted on 213 people (123 women, 90 men), physiotherapy and physical education students. Age 21.29 ±0.85 years, body height 173.88 ±9.19 cm, body weight 67.99 ±13.19 kg, BMI 22.32 ±3.01 kg/m^2.

The SFI was tested using non-apparatus STBIDF (three motoric tasks performed on a soft surface). Any incorrect contact head, hands, hips, leg with surface were documenting by the error of the first degree (1 point) or the second degree (2 points), and no errors '0'. SFI evaluation in a general sense is based on four levels: 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 analysed separately for each part of the body: low (0), average (1), high (2–6). Indicators were correlated: SFI; N students; FISS (Fall Injury Severity Scale); CHEF (comprehensive health effects of fall).

Results: The average STBIDF (SFIindex) result of the surveyed students declaring trauma in the past (n = 160, which equals 75.12% of the total) was 8.22 ±2.67 points (borderline between medium and high levels). Among this group of people, the body part most exposed to damage (SBPIDF) was the head (average proportion 72.29%), and the least exposed to damage was the legs (22.81%). The result SBPIDF of students who did not declare any bodily injuries (n = 53) was as follows: hands 72.64%; legs 27.36%. In both fractions, fewer students made errors with using their heads than with their hands (by 4.4% and 9.4%).

Conclusions: The only factor that influences fall injury for people unprepared for this type of event is the extreme nature of the circumstances of the event. Very high correlation of quantitative and qualitative SFI indicators with the health effects of falls (CHEF) is the most important empirical argument that universal prevention of bodily injuries and death caused by falls should begin before the stage of school education. We associate the problem of actually reducing these extreme events throughout ontogeny with improving tools measuring SFI phenomena and creating new ones that can also be used in research on elderly and disabled people.

Keywords: cognitive-behavioural potential • innovative agonology • motor modifications • pre–test

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Author's address: Bartłomiej Gąsienica Walczak, Health Institute, Podhale State College of Applied Sciences in Nowy Targ, Kokoszków 71, 34-400 Nowy Targ, Poland; e-mail: bartlomiej.gasienica@ppuz.edu.pl

Fall – an event which results in a person coming to rest inadvertently on the ground or floor or other lower level [40].

Budo (Budō) – originally a term denoting the 'Way of the warrior', it is now used as a collective appellation for modern martial arts of ***kendō, jūdō, kyūdo*** and so on. The primary objective of these 'martial ways' is self-perfection (***ningen – kesei***) [24].

Innovative agonology – is an applied science dedicated to promotion, prevention and therapy related to all dimensions of health and regarding the optimization of activities that increase the ability to survive from micro to macro scales [31, p. 274].

INNOAGON – acronym 'innovative agonology' [32].

WoS – Web of Science.

The Delphi method (Delphi technique) – a method of group decision-making and forecasting that involves successively collating the judgments of experts [41].

The Lwów–Warsaw School – (Polish: *Lwowsko-Warszawska*) was an interdisciplinary school (mainly philosophy, logic and psychology) founded by Kazimierz Twardowski in 1895 in Lemberg, Austro-Hungary (Polish: *Lwów*; now: Lviv, Ukraine).

INTRODUCTION

Fall-related injuries may be fatal or non-fatal. Alamgir et al. [1] based on the data of the Centers for Disease Control and Prevention [2] claim that: 'for each fall mortality event, there are 136 other fall injuries that require treatments in hospital emergency'.

One of the elements of the safe falling program 'Polish School of Safe Falling' (symbolic name used by Iermakov et al. [3]) is the diagnosis of body parts most exposed to damage caused by a fall. This phenomenon, 'the susceptibility of the body injuries during a fall', begins with the publication of RM Kalina [4] in 2009, in which the author describes a simple tool for measuring it – 'the susceptibility test to the body injuries during the fall' (STBIDF). During three motor tasks involving a simulated fall backward in laboratory conditions, the legs, hips, arms, and head are observed at the moment of impact with the ground. However, the lower limbs are evaluated during the third task (initiated by jumping backwards from approximately 20 cm of elevation). This is an evaluation based on overly liberal criteria. During the second and third tasks, the examined person is obliged to perform additional motor activities (clapping hands and pressing the sponge with the chin to the body), which should eliminate the errors of collision with the ground of the hands and head. In 2011, the method was validated, but without the 'test-retest' procedure [5]. Two years later, RM Kalina [6] validated the non-apparatus safe falls preparations test (N-ASFPT). The most important effect of the first modification is to determine whether a person can freely perform a 'deep' squat, and this criterion became the pre-test. If he or she cannot, then the person performs tasks on an elevated platform (it may be a stack of mattresses, a rehabilitation bed, etc.). The motor simulation of the landing (element of the third task) is to stand on your toes before lying on your back on this elevation. In 2022, the reliability and objectivity of the STBIDF procedure based on the 'test-retest' procedure was published [7].

In 2021, a modified version of STBIDF was created with the symbol STBIDF-M [8]. The main premise of the modification was the clear conclusion from many conducted studies that a single evaluation of the lower limbs is insufficient to accurately assess the phenomenon of SFI in these body parts. It was the authors of this modification who first used the three-part neologism 'susceptibility fall injuries (SFI)' as a convenient name for the phenomenon of 'the susceptibility of the body injuries during a fall'.

However, an important inspiration for the research undertaken in this work were primarily the results (published in 2022) of observation based on the innovative method of diagnosing the SFI of children from 2 to 6 years [9]. The uniqueness of these studies is that, for obvious reasons, there was no point in asking about bodily injuries resulting from falls of the parents or guardians of these children (especially the children themselves). This remark does not deny the permanent phenomenon of bodily injury and even death resulting from unintentional falls in children of this age [10-12]. The analogies of the results drawn by the authors of these groundbreaking discoveries turned out to be inspiring. Kalina et al. [9, p. 222] emphasize two phenomena: 'One is the ability of a large proportion of two-year-olds, and only a few older children, to protect the distal parts of the four body segments (lower limbs, hips, upper limbs, head) during a collision with the ground due to an unintentional fall, which they have not yet realised (sensory memory). The second is to make errors during each fall and ground impact, which means extreme risk of loss of life or injury in non-laboratory circumstances'. Based on many studies using STBIDF, it was obvious that there are some adults who make the maximum or close to the maximum number of errors (in both quantitative and qualitative terms) during simulated falls in laboratory conditions.

Dariusz Boguszewski [13] was the first to correlate SFI with declarations of past bodily injury as a result of a fall. However, the author does not describe in detail the criteria for calculating correlations, nor does he provide precisely correlated indicators. Therefore, for the purposes of this work, we created a special scale to facilitate the evaluation of body damage (single and multi-organ) due to health effects. This methodological arrangement of the studied phenomena enables the analysis and synthesis of SFI at the interface of epidemiology and prevention, which must take into account motor and mental aspects (especially fear of falling and reducing traumatic effects) and cognitive aspects that are difficult to clearly evaluate.

Raczek et al. [14] report that one of the main criteria for the reliability of motor tests is accuracy. Among other things, they distinguish predictive validity, which: 'determines the accuracy with which sports results or progress in teaching motor activities can be predicted on the basis of test results'. Brzeziński [15] states that 'if we want to predict, based on the test results, the future occurrence of the behaviour described by the criterion, we talk about predictive validity'.

Raczek et al. [14, p. 147] in the mentioned work indicate that 'the validity of the test is most often determined by the correlation coefficient with the adopted so-called external criterion. It may be the result of another test previously found to be accurate'. Brzeziński [15, p. 902] believes that establishing validity using the *test by test* method may be insufficient and points out that: 'any new test should be introduced by demonstrating its convergent validity (convergent aspect of relevance) not only with other tests but – above all – with genuinely external (and therefore non-test) criteria by which the same variable can be assessed'. Ferguson and Takane [16] point out that: 'sometimes a descriptive statistic, analogous to the correlation coefficient, is needed to describe the degree of relationship. One of them is the «contingency coefficient»'.

Aim of this study was knowledge about predictive validity of SFI method based on the multi-aspect association of the results of motor simulations with two sets of adults – declaring body injuries as a result of an unintentional fall in the past and declaring the lack of such experience.

MATERIAL AND METHODS

Participants

The study was conducted on 213 people (123 women, 90 men), physiotherapy and physical education students. Age 21.29 ±0.85 years, body height 173.88 ±9.19 cm, body weight 67.99 ±13.19 kg, BMI 22.32 ±3.01 kg/m^2. The respondents were divided into two fractions: people who declared bodily injuries caused by falls in the past (n = 160), i.e. those with such traumatic experience, and people who did not declare such events (n = 53).

The criterion for including people (n = 34) in the fraction whose results constitute the main basis of the predictive validity of STBIDF study is related to people selected from among 160 people with traumatic experiences. Furthermore, we recruited only those who made a complete set of errors with the four observed body parts during the three test tasks during the STBIDF, as well as those who failed to make only one error (alternatively: hips, or hands, or head) during any of these tasks.

The respondents also completed author's survey that included information concerning, their physical activity, number of falls, and the number and kinds of injuries they had experienced due to falling [17].

Study design

The empirical layer of this work is based on elements of complementary research methodology [18]. The basis of the complementary approach is the assumption that since not every surveyed person has suffered bodily injury in the past as a result of an unintentional (or intentional) fall, the first methodological step is the need to determine whether there is a high correlation between the two fractions of surveyed students in the raw test results. This is the first methodological aspect announced in the title of the publication. First, it is obvious that an adult must have fallen several times in his life. Second, it would be absurd to expect an identical STBIDF raw score to be associated with the specific health outcomes of a past fall, since the causative factor is the extremity of the event, not the potential level of SFI. Third, only empirically established relationships between the indicators of both phenomena, SFI and CHEF (comprehensive health effects fall), will provide the basis for drawing conclusions about the predictive validity of STBIDF – and this is the second methodological aspect of the issue addressed in this work.

SFI measurement

The phenomena SFI was tested using non-apparatus STBIDF (three motoric tasks performed on soft surface) [4] preceded by a pre-test [6]. The validity of the test was verified with the participation of the author of this unique tool [5], and its reliability was verified using the test-retest method by an independent team of experts [7].

Any incorrect contact head, hands, hips, leg with surface were documenting by the errors of the first ('1') or the second grade ('2'), and no errors '0'. SFI evaluation in a general sense is based on four levels: 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 analysed separately for each part of the body: low (0), average (1), high (2–6). Indicators were correlated: SFI; N students; FISS (Fall Injury Severity Scale); CHEF (comprehensive health effects of fall).

Dilemmas related to the second methodological aspect

The authors compensate for the lack of consistency of these indicators by adopting the assumption of using three levels of SFI in relation to the overall STBIDF result (SFIindex) and SBPIDF (i.e. SFIindex appropriate for the observed body parts: SFIlegs, SFIhips, SFIhands, SFIhead). The central one is the one that accumulates points corresponding to the 'average' (A) level. The next two – 'below average' (BA) and 'above average' (AA).

The criteria for STBIDF, due to the four levels, are reduced to three and calculated for the group according to the following criteria: 'average', is based on the weighted average of the points 4, 5, 6, 7, 8 (according to STBIDF it is 'high level'); 'below average' is based on the weighted average of the points 0, 1, 2, 3 (i.e. accumulation of low and average levels); 'above average' is based on the weighted average of the points 9, 10, 11, 12, 13, 14.

This decomposition is convenient because if there are no '0' ('low') results in the studied population, there is no need to shift the results to the left from the originally determined 'average level' [4, 5]. In this situation, the central position will be taken by the results that actually qualify as 'high level' (weighted average of the points 4, 5, 6, 7, 8); 'below average' (weighted average of the points 1, 2, 3); 'above average' (weighted average of the points 'very high' 9, 10, 11, 12, 13, 14). When monitoring the raw results (SFIindex) of individual people in more detailed analyses, it has additional information value. The most important cognitive value are the results regarding the SFI phenomenon of individual body parts.

According to the SFIlegs evaluation criteria [4, 5], these three levels appear somewhat automatically, although the names are partly different: 'average' 1 point (name compatibility); below this level 0 point (according to SBPIDF criteria 'low'); 'above average' 2 points (according to SBPIDF 'high' criteria). When evaluating other body parts, the situation is similar – only 'average' is 1 point and the names match. In the case of 'hips' evaluation (torso, when the location of injuries is determined) and head, the 'above average' criterion, calculated for the group, is based on the weighted average of the points 2, 3. Because the upper limbs are evaluated most thoroughly during the three STBIDF tasks ('hands'), so the 'above average' criterion, calculated for the group, is based on the weighted average of the points 2, 3, 4, 5, 6. In the tables, we use convenient SFI names (with the name of the body part) informing about the results of the evaluation of the SBPIDF phenomenon.

Evaluation of the health consequences of unintentional falls

We base the initial assessment of health effects resulting from an unintentional fall on the Fall Injury Severity Scale (FISS), modelled on the work of Gennarelli and Wodzin [19] (Table 1). Based on these findings, we calculated the health effects by calculating the CHEF index – comprehensive health effects of fall (Table 2).

Table 1. Fall Injury Severity Scale.

Injury characteristics	Equivalent	
	points	verbal
abrasions, scratches	1	minor
hematomas, bruises	2	moderate
sprain and dislocation of joints, wounds, cuts	3	serious
shattered bone, rupture and tearing of ligaments	4	severe
broken bones, concussion	5	critical
brain oedema, serious fractures in the spine, chest and skull	6	maximal

Table 2. Criteria for evaluating comprehensive health effects of fall.

Number parts body	Health effects of fall injury (scale) on a five-point scale: A /only for one part of the body/:				
	1 small	**1.2 moderate**	**1.4 serious**	**1.6 very serious**	**1.8 critical, potentially fatal**
One	one small	twice or more moderate in one part of the body	one serious	twice or more very serious in one part of the body	one critical, potentially fatal
	B /for more than one body part/:				
Two	**2**	**2.2**	**2.4**	**2.6**	**2.8**
	two small	one moderate and one small or both moderate	two serious	at least one very serious and one small/moderate/serious or both very serious	both critical and potentially fatal
Three	**3**	**3.2**	**3.4**	**3.6**	**3.8**
	three small	two moderate and one small or three moderate	three serious	at least two very serious and one small/moderate/serious	at least two critical, potentially fatal
Four	**4**	**4.2**	**4.4**	**4.6**	**4.8**
	all small	three moderate and one small or all moderate	at least four serious	at least three very serious and one serious, or all very serious	at least three critical, potentially fatal

Assumptions, methods and detailed criteria for the analysis of quantitative and qualitative indicators measuring the phenomenon of repeatability of errors during three STBIDF tasks

Complementary approach (at the level of evaluation details suitable for association with knowledge about past body injuries as a result of falls) is enabled by SFI indicators that take into account the quantitative and qualitative assessment of observed body parts during simulated backward falls repeated three times in safe laboratory conditions. Each subsequent task takes into account motor modifications which, on the one hand, should facilitate the elimination of collision errors with hands and head, and on the other – by gradually increasing the coordination complexity – making the task more difficult.

However, the excessive liberalization of evaluation criteria mentioned in the introduction requires great care to correctly interpret the observation data. Since four parts of the body are observed three times, and the legs are evaluated only during the third task, and, in addition, first-degree (I°) and second-degree (II°) error ratings are applied to legs and hands, a score of 12 points (against an extreme score of 14 points) does not carry information about the subject's committing a set of first-degree errors. One of several possible compilations of 12 points may be the sum of II° three errors made with the hands (6 points), II° with the legs (2 points), three I° errors made with the hips (3 points), and I° error with the head (1 point). Depending on which test task the head-to-ground contact error was made, there are three possible interpretations related to the motor modifications used during the second and third STBIDF tasks. The compilation of errors with such a structure also means that the person did not make the mistake of colliding his head with the ground twice, so this is empirical quantitative evidence that they made 83.33% of errors, which is less than the criterion of recruitment to the subgroup of people with very high repeatability of errors (11 out of 12 possible, which is documented by the ratio of 91.67%, rounded 92%).

Only a score of 14 points informs about the complete repetition of errors in a quantitative and qualitative sense. Such a score further informs that the motor activity incorporated into the third task (a backward jump from an elevation preceding a simulated backward fall, in a sense a fourth 'quasi-task') increases the score by the II° leg error made during the ground collision. Thus, the 14 points score carries a higher weight for II° errors (57.14%) than for I° errors.

The SFIindex result of 13 points, associated with the repeatability of errors in all parts of the body, informs about two possible compilations of raw results. The repeatability of 100% errors in the quantitative sense is documented by the result of 92.86% (rounded 93%) errors in the qualitative sense in two circumstances. When the person made I° errors with their legs, but three times II° errors with their hands. The second variant – he made one I° error with his hands, but the other two and the only one that was evaluated with his feet were II° errors.

However, it is the result of 10 points, not 12, that sets the lower limit for the complete repeatability of errors in a quantitative sense. Hips, hands and head during each of the three test tasks (which means a sum of 9 I° errors), and the whole is completed by the error with I° legs during the 'quasi-task'. These evaluative subtleties result in a score of '0', which means no error, cannot affect the legs. Otherwise, it would mean an evaluation reduced to 75% of the body parts observed.

On an individual basis, it is possible to interpret that '0' refers to only one occurrence for any of the remaining body parts during any of the three test tasks. In this way, the criterion of inclusion in the group (fraction) of people with very high repeatability of errors, i.e. 92% (11 out of 12 possible), is met. The logical justification is the fact that any error in the collision of the hips with the ground is a consequence of the failure of the musculoskeletal system of the legs to fulfil the shock-absorbing functions [20], although the pre-test observations [6] confirmed the ability of the tested person to perform a deep squat.

The results of people meeting these evaluation criteria range from 9 to 13 points. The subtlety mentioned above can also be explained as follows: the virtual sum of 12 errors is a consequence of linking the I° hips errors with the first and second tasks. This means that the sum of 2 points is transformed virtually into 4 points, which is supposed to inform not about two, but actually about four errors concerning a total of two parts of the body. It was the legs that did not fulfil the expected function of cushioning the falling body, since the error was recorded in the 'hips' column in the test card.

Division and classification of repeatability of errors in a quantitative and qualitative sense

The main study of the predictive validity of STBIDF is related to the fraction of people who made a complete set of errors with the four observed body parts during three test tasks, as well as those who did not make only one error (alternatively: hips, or hands, or head) during any of these tasks.

Complete (during each test task) repeatability of errors E+E+E+E model*

In this model, 'E' means error, either I° or II°. Since an SFIindex result of 13 points does not necessarily mean that, in a quantitative sense, there was 100% repeatability of errors in each STBIDF task, the latter variant no longer fits into the E*+E+E+E model.

The mathematical decomposition of the E*+E+E+E model into numbers informs about the total result of I° (1 points) and II° (2 points) errors. The superscript next to the first number (E*) means that the result concerns the leg evaluation based on the subtask, which is only an element of the third task. Therefore, in numerical models it can be a result of either 2 points or 1 point and this is the first element of possible point compilations. The second concerns the hands and therefore in numerical models for complete error repeatability, possible compilations are shown in brackets after the third of the monitored numbers.

A result of 1 point recorded three times regarding the evaluation of hands does not necessarily mean that the observed person supported himself with his hand three times before the torso came into contact with the ground. During the second and third tasks, such a record may mean stopping clapping hands while changing from vertical to horizontal posture, and this fact must be recorded in the test card. Hence, the 1+1+1 notation indicates that the person continues to support himself with his hand during the simulated fall, even though the hand clapping was intended to prevent this before he assumed a horizontal position. Information about the ability to slowly self-educate is included in alternative entries with a superscript: $1+1^{C}+1^{C}$ (the person stops clapping with his hands but does not support himself with his hand); $1+1^{S}+1^{S}$ (the person stops clapping with his hands and holds the sponge with one or both hands while changing from vertical to horizontal position). It is also possible to compile superscript entries for the second and third tasks.

For SFIindex 13 there are three possible compilations with an E* score of 2 points and are related to the evaluation of hands with a total score of 5 points (see Table 3). This result is proof that the person is resistant to motor modifications in the quantitative sense, since they made II° errors twice (supporting with two hands, changing the vertical to horizontal position) and I° error once. Although the phenomenon of 'resistance to motor modifications' is most strongly associated with the coordination layer of human motor skills, such a reduction in the interpretation of the result would be too far-reaching simplification. It is the compilations of points that show the possibilities of differentiating qualitative assessments. Disturbed cognitive functions in relation to the ability to control motor activity with hands are indicated by a system of detailed assessments 1+2+2 or 2+1+2. It is important to determine whether the 2+2+1 arrangement actually means supporting oneself with one hand during the third task, and whether 1^{C} or 1^{S} should apply. If so, there would be grounds for a qualitative interpretation of such a result as 'the ability to slow self-education', but only in relation to hands, not SFIindex. The hands are assessed most thoroughly (43% of the maximum SFIindex value) and therefore the adopted qualitative assessments are most closely related to the result of observing this part of the body.

The second and fourth numbers of the discussed model each time inform about three I° errors made with the hips and head, respectively. The limit score of 10 points is based on the only possible pattern of I° errors. Table 3 contains detailed criteria for quantitative and qualitative assessment of the individual STBIDF score of people with complete repeatability of errors in the quantitative sense.

Very high repeatability of errors (no single error with body parts highlighted in the brackets of the model) – model E+(E+E+E)*

The model of very high repeatability of errors alternatively allows for the observed person not to make an error in a quantitative sense either with the hips, hands, or head during any test task. The mathematical decomposition of this model into numbers takes into account the possibility of one '0' in any E in brackets. The highest SFIindex value of 13 points with one '0' is possible in two variants 2*+(2+6+3) or 2*+(3+6+2).

Criteria for an in-depth synthesis of detected hand errors in people with scores from 3 to 4 points and predictors of six phenomena

In the case of hand observations, a result of 3 or 4 points is evidence of one of four possible compilations, with one variant taking into account the error during each task (E+E+E), with 4 points being the sum of one II° and two I° errors. There are three possible compilations here: 2+1+1 (and this justifies the conclusion about the positive impact of clapping hands on reducing II° hand errors); 1+2+1; 1+1+2 (evidence of very low cognitive-behavioural potential).

Table 3. Qualification matrix of STBIDF results of people who each time made errors (but differing in terms of qualitative assessments) when the observed body parts collided with the ground during a simulated fall backward.

Mathematical model repeatability errors	Quantitative assessment			Qualitative assessment
	SFIindex		verbal	
	points	%		
2*+3+6+3	14	100	complete repeatability of errors	resistance to modifications motor and impaired functions cognitive
2*+3+5(2+2+1)+3	13	92.86	greater importance of first degree errors (61.54%)	
2*+3+5(2+1+2)+3	13			
2*+3+5(1+2+2)+3	13			
1*+3+6+3	13			
2*+3+4(2+1+1)+3	12	85.71	moderate dominance of first degree errors (80%)	very low potential cognitive-behavioural
2*+3+4(1+2+1)+3	12			
2*+3+4(1+1+2)+3	12			
1*+3+5(2+2+1)+3	12			
1*+3+5(2+1+2)+3	12			
1*+3+5(1+2+2)+3	12			
1*+3+4(2+1+1)+3	11	78.57	dominance of errors of the first degree (90%)	low potential cognitive-behavioural
1*+3+4(1+2+1)+3	11			
1*+3+4(1+1+2)+3	11			
2*+3+3(1+1+1)+3	11			
1*+3+3(1+1+1)+3	10	71.43	stable repeatability first degree errors (100%): possible compilations of superscripts 'C' and 'S'	resistance to motor modifications
1*+3+3(1+1^{C}+1^{C})+3	10			
1*+3+3(1+1^{S}+1^{S})+3	10			ability to slow self-education

Criteria for an in-depth synthesis of identified errors: 2 points or 1 point in relation to each part of the body separately

A score of 2 points allows for five compilations of a single or double '0' with either a pair of I° errors or a single II° error over the three tasks of the test. One II° error version: 2+0+0 (self-education); 0+0+2 (low cognitive-behavioural potential); the 0+2+0 system is an intermediate model but qualified for low cognitive-behavioural potential. Two I° errors version: 1+1+0 (slow self-education); 0+1+1 (low cognitive-behavioural potential); 1+0+1 intermediate model, qualified for low cognitive-behavioural potential.

A result of 1 point informs about one of three possible compilations of 'E I°' with '0' stated twice during three test tasks: 1+0+0 (ease of self-education); 0+0+1 (low cognitive-behavioural potential) and again the 0+1+0 variant. The specific nature of leg error evaluation obviously reduces interpretation to the third task – both in the sense of mathematical notation and verbal qualitative assessment. However, there is no point in monitoring the full set of possible compilations of detailed results when 1 point concerns two of the four body parts observed during the entire test, and the arrangement of the remaining ones is equal to or less than the sum of 9 points (e.g.

1 + 1 + 6 + 3 = 11 points). Also, in circumstances of the smallest possible result in the quantitative and qualitative sense, which may concern only one of the observed parts of the body.

Weighting matrices for a balanced synthesis of SFI and CHEF quantitative and qualitative assessments

We developed the matrices using the Delphi method using the consultation of an expert in complementary research methodology [21, 18]. The adopted weights are a simple tool for synthesizing both categories of assessments (quantitative and qualitative) in the mutual relations of SFI and CHEF phenomena. The description of this method requires repeating some of the information discussed earlier.

The basic reference system is the STBIDF raw results, so it is the most general quantitative and qualitative indicator of the SFI phenomenon. Conventionally, we assign the highest value of weight 1 to the result of 14 points, weight 2 to the result of 13 points, etc., and, consequently, weight 14 to the result of 1 point. However, the lowest weight value, i.e. 15, belongs to the flawless execution of STBIDF – a score of 0 points. Attributing weights to this phenomenon only make sense in two experimental circumstances or for the purposes of diagnostic practice. In both cases, a more or less extensive complementary approach applies. The first case concerns an individual, when indicators of phenomena that have no substantive or logical connections with SFI are associated. The second – research on the SFI phenomenon with the participation of a larger number of people with a clear dispersion of results and other empirical variables (daily physical activity or lack thereof, age, profession, health condition, etc.).

Further association of the quantitative component with other phenomena transforms such calculations into quantitative and qualitative assessments (indicators). In these studies, such a procedure takes place already at the moment of determining the number of people with complete repeatability and very high repeatability of errors with four parts of the body (legs, hips, hands, head) during a simulated fall in laboratory conditions (measured during STBIDF) with the criterion of having suffered in the past, as a result of a fall, damage to at least one part of the body to an extent qualifying the use of the 20-point CHEF scale.

The maximum number of errors made with each body part during the three STBIDF tasks is 12, but when taking into account qualitative assessments, an extreme score of 14 points is possible (the principle of the 14-point scale explained earlier). Making 11 errors meets the criteria for very high repeatability (92%), but due to the specificity of qualitative assessments, the lowest possible score is 9 points (and not, as logic suggests, 11). Therefore, due to the qualitative specificity of the STBIDF result, the five-element set of people with complete repeatability of errors (n = 14) ranges between 14 and 10 points. Also, the five-element set of people with very high repeatability of errors (n = 20) ranges from 13 to 9 points. Both sets combined into one 34-person fraction (i.e. as subsets) create a six-element set, the continuum of which is determined by points 14 and 9. This principle is the ordinal variable of the monitored results – from 14 to 9 raw STBIDF points.

Since 34 surveyed students met these criteria, assuming a proportional distribution of raw results into six subsets, each subset comes down to a statistical record of 5.67% of people. Therefore, the representation of 6 and more people (in this empirical system up to and including 34) meets the condition of exhausting the proportionality of the distribution of results (or its multiplication) due to the association of its specificity with detailed CHEF phenomena (the basic one is damage to at least one part of the body as a result of a fall in past). If a given phenomenon is assigned to 5 people from any of the distinguished subsets, then the quantitative proportion index will be 88%, and this is a consequence of dividing the number 5 by the proportion index 5.67 determined for 6 people. For one person, the value of this indicator is rounded to 18%. Weights from 1 to 6 are assigned according to the size together with the equivalent of the proportion indicator in % weight 1 (6 to 34 people) meets the conventional criterion of 100%, etc., to weight 6 (one person) 18%. A weight of 7 indicates that in a given subset there is no person with an established selection criterion, but his or her presence in the examined fraction authorizes damage to another part of the body as a result of a fall in the past (Table 4).

Table 4. Weight matrix for estimating the components of quantitative assessments of the SFI phenomenon in people who meet the criteria of complete and very high repeatability of errors during STBIDF – the reference system for balanced numbers of six sets is 6 people (each reduction changes the proportion of contribution to the total result of the fraction n = 34 and conversely).

Weight in relation to the raw STBIDF score		People's participation		Σ points of 6 persons (constant 5.67 × SFIpoints)
		N	%	
		evaluation component		
weight	SFIpoints	quantitative		quantitative-qualitative
1	14	6 to 34	100	**79.38**
2	13	5	88	**73.71**
3	12	4	71	**68.04**
4	11	3	53	**62.37**
5	10	2	35	**56.70**
6	9	1	18	**51.03**
7	between 14 and 9	0	injury to a body part other than the one being evaluated	

Assigning weights to CHEF metrics is a bit more complicated. Differentiation combines quantitative assessments (number of damaged body parts – from one to four) with qualitative assessments (degree of health risk). A weight of 1 is assigned only to injuries to four and three body parts (the most severe ones), while the extreme scores of injuries to two and one body parts are assigned a weight of 2. This score is relatively balanced especially with a weight of 2 assigned to four body injuries. There is a similarity to the proportion of the lowest result of the CHEF scale for damage to four parts of the body (4 / 4.8 = 0.8333 × 100%). The weight of 6 assigned to the score of 56% is a consequence of dividing the lowest score of the CHEF scale by the indicator 1.8). The quality standards assigned to the weights are based on the logical formula of multiplying the 5.67 index by the raw result of STBIDF point subsets from 14 to 9. That is,

Table 5. Matrix of weights for estimating quantitative and qualitative assessments of the CHEF phenomenon in a person who meets the criteria of complete and very high repeatability of errors during STBIDF – the reference system is the relation of similarity of the proportions of STBIDF points.

Weight	Individual error scale during STBIDF		Proportions (%) based on the CHEF scale			
			number of damaged body parts			
	points	%	four	three	two	one
1	14	100	92-100	95-100		
2	13	92.86	83-91	85-94	90-100	100
3	12	85.71		75-84	81-89	89-99
4	11	78.57			71-80	80-88
5	10	71.43				67-79
6	9	64.23				56-66
7	injury to a body part other than the one being evaluated					

6 people with a maximum score of 14 points contribute 79.38 estimated points to the total score of 34 people of this fraction (Table 5).

This matrix pattern can also be used when analysing and synthesizing the SFI body part (SBPIDF) results of people who reveal the ability to reduce errors as a result of motor modifications used during the second and third task of the test. The condition for establishing detailed criteria for quantitative scales is knowledge of the size of the set (fraction) of people who, under the influence of these motor modifications, will reduce SFI errors (determined by observations of the first task) already during the second and again the third STBIDF task.

Statistical analysis

The estimation of the results is based on the following indicators: frequency (N, n); arithmetic mean (M); weighted arithmetic mean ($\bar{x}$); minimum (Min); maximum (Max); standard deviation (SD or ±); skewness (g_1); kurtosis (g_2); significance level, probability (*p*). In the studies, the level of at least $p<0.05$ and lower was shown as statistically significant differences. The Pearson correlation coefficient between pairs of specified variables was calculated.

RESULTS

The first methodological aspect

The average STBIDF (SFIindex) result of the surveyed students declaring trauma in the past (n = 160, which equals 75.12% of the total) was 8.22 ±2.67 points (borderline between medium and high levels). Among this group of people, the body part most exposed to damage (SBPIDF or SFI body part) was the head (average proportion 72.29%), and the least exposed to damage were the legs (22.81%). The result of students declaring no bodily

Table 6. Estimation of raw results and proportions of the main SBPIDF and SFIindex indicators of the surveyed physiotherapy and physical education students (n = 213).

Statistical indicator	SBPIDF								SFIindex (points)	
	legs		hips		hands		head			
	points	%	points	%	points	%	points	%	points	%
students declaring injury (n = 160)										
M	**0.46**	**22.81**	**1.53**	**50.83**	**4.09**	**68.13**	**2.17**	**72.29**	**8.22**	**58.71**
SD	**0.64**	32.14	**1.27**	42.29	**1.76**	29.40	**1.02**	33.90	**2.67**	
Min	**0**	0	**0**	0	**0**	0	**0**	0	**1**	**7.14**
N [%]	***100** [62.50]*		***52** [32.50]*		***8** [5]*		***15** [9.37]*		***2** [1.25]*	
Max	**2**	100	**3**	100	**6**	100	**3**	100	**14**	**100**
N [%]	*13 [8.12]*		*56 [35]*		*52 [32.50]*		*83 [51.87]*		*3 [1.88]*	
g_1	1.10		−0.02		−0.62		−0.89		**−0.43**	
g_2	0.09		−1.67		−0.47		−0.49		**−0.05**	
students who do not declare injury (n = 53)										
M	**0.55**	**27.36**	**1.34**	**44.65**	**4.36**	**72.64**	**2.15**	**71.70**	**8.40**	**60**
SD	**0.64**	31.87	**1.24**	41.32	**1.69**	28.14	**1.06**	35.44	**2.59**	
Min	**0**	0	**0**	0	**0**	0	**0**	0	**0**	**0**
N [%]	***28** [52.83]*		***19** [35.84]*		***1** [1.89]*		***6** [11.32]*		***1** [1.89]*	
Max	**2**	100	**3**	100	**6**	100	**3**	100	**14**	**100**
N [%]	*4 [7.54]*		*15 [28.30]*		*21 [39.62]*		*28 [52.83]*		***2 [3.77]***	
g_1	0.74		0.26		−0.64		−0.91		**−0.48**	
g_2	−0.41		−1.57		−0.70		−0.53		**1.24**	

injury (n = 53) was: hands 72.64%; legs 27.36%. The slight negative skewness (g_1) of the SFIindex of both fractions, with similar values, confirms the similarity of the overall STBIDF result, regardless of the effects of unintentional falls in the past. However, the close to zero value of kurtosis (g_2 = −0.05) of students with a traumatic fall experience indicates that the distribution of raw scores is close to normal. The slightly platykurtic (g_2 = 1.24) distribution of SFI scores of students of the second fraction is caused not only by the similarity of the arithmetic mean of the scale of errors made with hands (72.64%) and with the head (71.70%). The second average is even slightly lower (Table 6).

Differences in proportions between fractions are not statistically significant and concern both individual body parts and the overall test result, i.e. the SFIindex (t-value −0.422, p-value 0.336) (Figure 1).

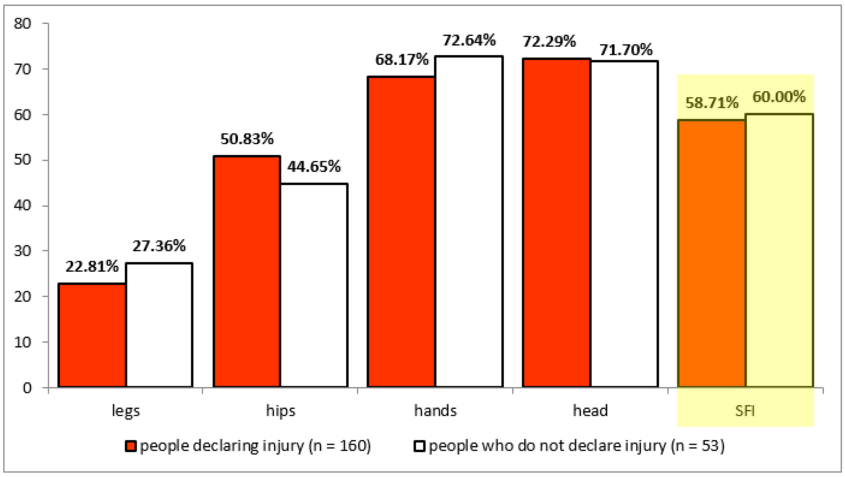

Figure 1. Proportions (%) of SBPIDF and SFIindex of students declaring (n = 160) and not declaring (n = 53) injuries due to falls in the past, calculated separately in relation to each fraction.

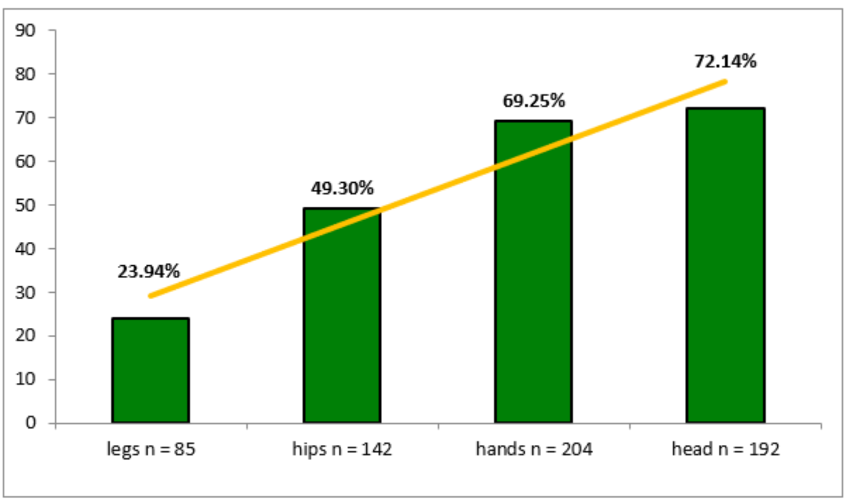

Figure 2. Temporary model of the error scale in the quantitative and qualitative sense (% calculated from the theoretically maximum raw score – from 2 to 6 points depending on the body part) population of Polish physiotherapy students (n = 213) making errors with the observed body parts during a collision with the ground during a three-time simulated backward fall in simplified laboratory conditions.

The model of the combined results of the examined students (n = 213) shows the regularity: the further the observed body part is from the ground, when the simulated series of backward falls during STBIDF is repeated three times from a vertical position, the greater the scale of errors made (measured by the proportion of raw results to theoretically maximum). The smallest difference (2.89%) concerns the comparison of hands and head (Figure 2). This model is more pronounced with respect to the fraction of students with traumatic experiences of unintentional falls. The difference between the scale of errors made with hands and with the head is 4.16% (Figure 1).

This regularity only partially refers to the proportion (number) of students from both fractions who made errors during the simulated backward fall. They made errors with their legs in identical proportions, and with their hips and hands in similar proportions. In both fractions, fewer students made quantitative errors with their heads than with their hands (by 4.4% and 9.4%). An extreme number of errors (making II° errors three times) when the most precisely diagnosed part of the body (hands) was made by nearly 40% of students from the fraction who had not experienced health effects of a fall in the past – while almost every third one had a traumatic experience (Table 7).

Table 7. Estimation of raw results and proportions of errors made by individual body parts (SBPIDF) when testing physiotherapy and physical education students of both fractions.

Statistical indicator	SBPIDF							
	legs		hips		hands		head	
	points	%	points	%	points	%	points	%
	students declaring injury (n = 160)							
N [%]	***60*** *[37.50]*		***108*** *[67.50]*		***152*** *[95]*		***145*** *[90.60]*	
M	**1.22**	**61**	**2.26**	**75.33**	**4.3**	**71.67**	**2.39**	**79.67**
SD	**0.42**	21	**0.85**	28.33	**1.53**	25.50	**0.78**	26
Min	**1**	50	**1**	33.33	**1**	16.67	**1**	33.33
N [%]	*47 [29.37]*		*28 [17.50]*		*5 [3.13]*		*26 [16.25]*	
Max	**2**	100	**3**	100	**6**	100	**3**	100
N [%]	*13 [8.12]*		*56 [35]*		*52 [32.50]*		*83 [51.87]*	
g_1	1.41		–0.53		–0.41		–0.81	
g_2	–0.01		–1.41		–0.95		–0.86	
	students who do not declare injury (n = 53)							
N	***25*** *[47.17]*		***34*** *[64.20]*		***52*** *[98.10]*		***47*** *[88.70]*	
M	**1.16**	**58**	**2.09**	**69.67**	**4.44**	**74**	**2.43**	**81**
SD	**0.37**	18.50	**0.90**	30	**1.59**	26.50	**0.77**	25.67
Min	**1**	50	**1**	33.33	**1**	16.67	**1**	33.33
N [%]	*21 [39.62]*		*12 [22.64]*		*1 [1.90]*		*8 [15.10]*	
Max	**2**	100	**3**	100	**6**	100	**3**	100
N [%]	*4 [7.55]*		*15 [28.30]*		*21 [39.62]*		*28 [52.83]*	
g_1	1.98		–0.18		–0.53		–0.92	
g_2	2.06		–1.79		–1.10		–0.68	

The result of the fraction of students with traumatic experience

The declared location of injuries most often concerned the upper limbs of 88 people (41.31%), then the lower limbs of 74 people (34.74%), the torso of 38 people (17.84%) and the head of 31 people (14.55%). The most common types of injuries reported by the surveyed students are: bone fractures, most often in the upper limb (32.39%, n = 69); joint sprains, most often of the ankle (17.37%, n = 37); concussion (3.29%, n = 7).

Students who suffered bodily injury as a result of a fall in the past were the most numerous (n = 85) and represented those with a very high STBIDF result. The weighted arithmetic mean (x̃) of raw scores of 10.26 points indicates a tendency for the majority to group closer to the lower limit (9 points) for this norm. The almost full positive correlation (r = 0.972) of SFI indicators level (measured by the weighted arithmetic mean) and the number of students qualifying for a given SFI level was determined by the decreasing number of students at high (n = 65) and average (n = 10) levels, respectively. The numbers had a very high positive correlation (r = 0.894) with the CHEF index. The almost full negative correlation (r = −0.993) of N with FISS is caused by decreasing FISS values for individual SFI levels with increasing numbers of students. The almost complete negative correlation (r = −0.939) of the CHEF and FISS indices (although CHEF is an extension of the FISS scale) is caused by a slightly higher value (M = 2) for level high SFI (obviously identified with the FISS index) from 1.97 for the CHEF result, interpreted in an identical manner (Table 8).

The values of correlated indicators and correlation coefficients calculated for individual body parts differ significantly. Only the analysis of indicators regarding declared hand injuries caused by falls in the past, at the same time by the largest representation of students (n = 85), provides empirical evidence of two regularities. Firstly, the more extensive the body damage was (FISS and CHEF indices), the more errors the students made when performing STBIDF. Secondly, the more errors during the test and the more extensive body damage caused by at least one fall in the past, the larger the representation of the tested people. This regularity is disturbed only by the similar number of students classified at the SFI low (n = 3) and average (n = 2) levels, with an overwhelming number (n = 80) at the high level (Table 9).

Correlations of identical indicators are all positive, considered among people who have suffered multiple or simultaneous fall injuries in the past (n = 51). The regularity repeats again: the higher the accumulation of errors during STBIDF (SFI level index, measured by x̃), the larger the number of students. The correlations of the N variable with the SFI level and CHEF are the highest. The FISS index turned out to be the least susceptible to intercorrelations with other variables (Table 10).

The second methodological aspect Results of a quantitative-qualitative synthesis of empirical data on the fraction of students with a traumatic fall experience in the past

Among the students who made errors during each thrice-simulated backward fall, the dominant ones, in terms of qualitative assessment, were resistant to motor modifications and, according to the adopted classification, at the same time had impaired cognitive functions (9 out of 14 people, i.e. 64%). The rest are characterized by either very low or low cognitive-behavioural potential (Table 11).

Table 8. Average values of indicators of all people declaring bodily injuries in the past (n = 160) and their correlations of variables: E-points stands the weighted arithmetic mean (x̃) for empirical variables.

Level SFI		*N*	*FISS*	*CHEF*	*Correlation of variable indicator*			
name (points)	*E-points*		*E-points*			*Level SFI (E-points)*	*N*	*FISS*
average (1 to 3)	2.30	10	4	1.86	***N***	***0.972***		
high (4 to 8)	6.46	65	3.67	2	***FISS***	***−0.938***	***−0.993***	
very high (9 to 14)	10.26	85	3.61	1.97	***CHEF***	***0.763***	***0.894***	***−0.939***

Table 9. Average values of indicators of all people declaring bodily injuries in the past (n = 160) and their correlations of variables: E-points stands the weighted arithmetic mean (x̄) for empirical variables FISS and CHEF and partially Level SFI. The total number of injuries to individual body parts exceeds the number of students because some suffered multi-organ injuries.

Body part (n)								
legs (n = 77)								
Level SFI		***N***	***FISS***	***CHEF***	***Correlation of variable indicator***			
name (points)	***E-points***		***E-points***			***Level SFI (E-points)***	***N***	***FISS***
low (0)	0	46	3.39	1.47	***N***	***−0.999***		
average (1)	1	25	2.52	1.30	***FISS***	***−0.255***	***0.283***	
high (2)	2	6	3.16	1.43	***CHEF***	***−0.225***	***0.253***	***0.999***
hips (n = 41)								
level SFI		***N***	***FISS***	***CHEF***	***Correlation of variable indicator***			
name (points)	***E-points***		***E-points***			***Level SFI (E-points)***	***N***	***FISS***
low (0)	0	15	3	1.40	N	0.522		
average (1)	1	4	2.75	1.35	FISS	−0.037	0.833	
high (2 or 3)	x̄ 2.73	22	x̄ 2.95	x̄ 1.39	CHEF	−0.037	0.833	1
hands (n = 85)								
level SFI		***N***	***FISS***	***CHEF***	***Correlation of variable indicator***			
name (points)	***E-points***		***E-points***			***Level SFI (E-points)***	***N***	***FISS***
low (0)	0	3	3	1.40	***N***	***0.975***		
average (1)	1	2	3.50	1.50	***FISS***	***0.825***	***0.679***	
high (2 to 6)	x̄ 4.51	80	x̄ 3.66	x̄ 1.53	***CHEF***	***0.818***	***0.670***	***0.999***
head (n = 30)								
level SFI		***N***	***FISS***	***CHEF***	***Correlation of variable indicator***			
name (points)	***E-points***		***E-points***			***Level SFI (E-points)***	***N***	***FISS***
low (0)	0	3	3.67	1.53	***N***	***0.982***		
average (1)	1	6	5	1.80	***FISS***	***−0.176***	***−0.359***	
high (2 or 3)	x̄ 2.90	21	x̄ 3.67	x̄ 1.53	***CHEF***	***−0.176***	***−0.359***	***1***

Table 10. The weighted arithmetic means of indicators of students declaring multiple injuries to one or more body parts in the past (n = 51) and correlations of variables: E-points stands the weighted arithmetic mean (x̄) for empirical variables.

Level SFI		*N*	*FISS*	*CHEF*	*Correlation of variable indicator*			
name (points)	*E-points*		*E-points*			*Level SFI (E-points)*	*N*	*FISS*
average (1 to 3)	2	2	3	2.40	***N***	***0.963***		
high (4 to 8)	6.54	22	3.77	2.71	***FISS***	***0.192***	***0.449***	
very high (9 to 14)	10.22	27	3.11	2.85	***CHEF***	***0.988***	***0.992***	***0.340***

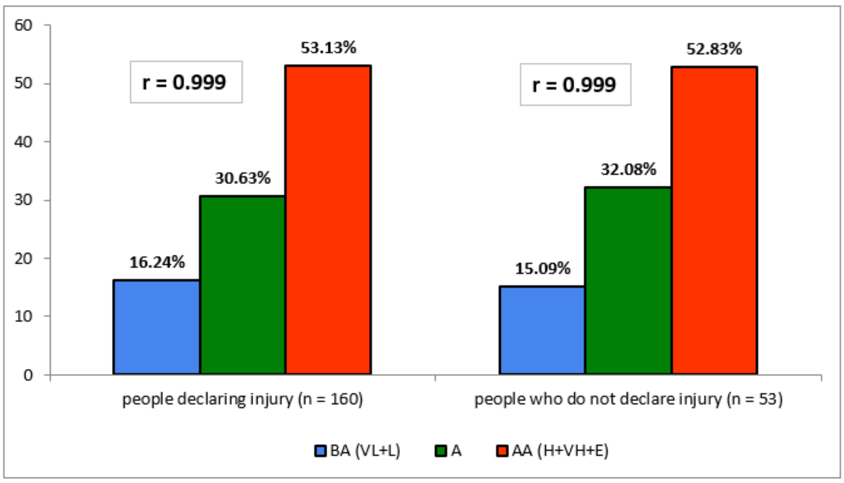

Figure 3. Proportions of students of both main fractions differing in the degree of risk of bodily injury during an unintentional fall (correlation of the number of students classified to the average level and the accumulated levels below and above this set): **A** average; **BA** below average; **AA** above average; **VL** very low; **L** low; **H** high; **VH** very high; **E** extreme.

Table 11. SFI profiles of students (n = 14) with complete error repeatability during a simulated backward fall in laboratory conditions.

Mathematical profile model	**N**	**SFI**		**CHEF%**	**Verbal assessment**	
		points	**%**	**%**	**quantitative**	**qualitative**
2*+3+6+3	3	14	100	85.19	complete repeatability of errors	resistance to modification motor and impaired cognitive functions
1*+3+6+3	6	13	92.86	83.53	higher weight of first degree errors (61.54%)	
1*+3+5(2+2+1)+3	1	12	85.71	100	moderate dominance of first degree errors (80%)	very low potential cognitive-behavioural
2*+3+4(2+1+1)+3	1	12	85.71	78.97		
1*+3+4(2+1+1)+3	3	11	78.57	74.08	dominance of errors of the first degree (90%)	low potential cognitive-behavioural

Table 12. Estimation of empirical variables and correlation of individual SFI% and CHEF% indicators between sets of students who made errors during each three-time simulated fall (n=14).

SFI sets			CHEF%	Correlations
points	N	SFI%		
14	3	100	85.19 (77.78÷100)	individual results
13	6	92.86	83.53 (77.78÷88.89)	
12	2	85.71	89.48 (78.95÷100)	**r = 0.289**
11	3	78.57	74.08 (55.56÷88.89)	between sets of SFI% and CHEF%
	weighted averages			
12.64	**-**	**90.31**	**82.71**	**r = 0.544**

A subset of people with complete repeatability of errors in a quantitative sense

The correlation between the results of individual variables SFI% and CHEF% is weak (r = 0.289). The correlation of these variables is high (r = 0.544) when the indicators are averaged within sets of people with STBIDF raw scores from 14 points to 11 points (Table 12).

When the priority for creating a homogeneous set is based on people with the maximum SFI% (n = 3), the average score of this indicator of the remaining students (n = 11) is also higher than the CHEF% variable. However, this similarity is not reflected in the differences in the proportions of the indicator pairs. Those with SFI max points exceed their CHEF% by 15%, while others by 5%. The differences between SFI% are greater (12%) than CHEF% (3%). The correlation of these pairs of indicators is full and positive. Changing the priority of creating a homogeneous set (100% CHEF%, n = 2) also causes a full and positive correlation of indicators. Although the difference relations are similar – they are higher on the 'priority' side – the nominal values are different. For example, in the 'rest of students' set the difference in indicators is only 1.26% (Table 13). It would not be justified to attach much importance to the prognostic value of the sets created in this way.

Among the students who made 92% of errors during each three-time simulated backward fall, there is a slight predominance, in terms of qualitative assessment, of low cognitive-behavioural

Table 13. Correlation of SFI% and CHEF% variables grouped according to the priority criterion for people with the maximum score of one of these empirical variables.

Correlated sets		M indicators		Correlated sets		M indicators	
SFI priority	N	SFI%	CHEF%	CHEF priority	N	SFI%	CHEF%
SFI max points	3	100	85.19	CHEF max points	2	92.86	100
rest of students	11	87.66	82.04	rest of students	12	78.57	79.83
		r = 1				**r = 1**	

potential (n = 9), ahead of 8 students with very low potential and 3 with slow self-education. Moreover, under the influence of motor modifications used in the test, three students showed a tendency to reduce errors with their hands, and two with their hips (in fact, to correctly use the shock-absorbing capabilities of the muscles and joints of the lower limbs) (Table 14).

There is little correlation between the results of the individual variables SFI% and CHEF% (r = 0.031). The correlation of these variables is average (r = 0.386) when the indicators are averaged within sets of people with STBIDF raw scores from 12 points to 9 points (Table 15).

When the priority for creating a homogeneous set is based on people with the maximum CHEF% (n = 8), the average score of this indicator of the remaining students (n = 12) is also higher than the SFI% variable. The correlation of these pairs of indicators is full and positive. (Table 16).

Synthesis based on repeated error verification during three STBIDF tasks

The results of combining subsets into one fraction of 34 people who revealed either complete (100%) or very high in quantitative terms (92%) repeatability of ground impact errors in laboratory conditions, partially modify the previously disclosed dependencies. However, they provide

Table 14. SFI profiles of students (n = 20) with very high repeatability of errors (92%) in a quantitative sense during a simulated backward fall in laboratory conditions.

Mathematical profile model	N	SFI		CHEF%	Verbal assessment	
		points	%	%	quantitative	qualitative
1*+3+6+2(1+0+1)	3	12	85.71	96.29	92% errors, balance of the sums of I° and II° errors	very low potential cognitive-behavioural
1*+2(0+1+1)+6+3	2	12	85.71	74.61		
1*+2(1+0+1)+6+3	1	12	85.71	78.95		
1*+2(1+1+0)+6+3	2	12	85.71	89.47		very low potential cognitive--behavioural (slow hip self-education)
1*+2(1+0+1)+5(2+2+1)+3	2	11	78.57	94.45	92% of errors, predominance of I° errors	low potential cognitive-behavioural
2*+3+3(2+0+1)+3	1	11	78.57	100		
1*+2(1+1+0)+5(2+2+1)+3	1	11	78.57	66.67		slow self-education
1*+3+4(2+1+1)+2(1+0+1)	2	10	71.43	100		low potential cognitive-behavioural (slow hands self-education)
1*+2(1+0+1)+4(2+1+1)+3	1	10	71.43	100		
1*+2(1+1+0)+4(2+1+1)+3	1	10	71.43	78.95		slow self-education
1*+3+4(2+1+1)+2(1+1+0)	1	10	71.43	77.78		
1*+3+2(0+1+1)+3	2	9	64.29	81.57	92% errors, only I°	low potential cognitive-behavioural
1*+3+3(1+1+1)+2(1+0+1)	1	9	64.29	88.89		

Table 15. Estimation of empirical variables and correlation of individual SFI% and CHEF% indicators and between sets of students with very high repeatability of errors (92%) in a quantitative sense.

SFI sets			CHEF%	Correlations
points	N	SFI%		
12	8	85.71	87.94 (77.78÷100)	individua results
11	4	78.57	88.89 (66.67÷100)	
10	5	71.43	91.35 (77.78÷100)	**r = 0.031**
9	3	64.29	84.13 (77.78÷88.89)	between sets of SFI% and CHEF%
weighted averages				
10.85	**–**	**77.50**	**88.41**	**r = 0.386**

Table 16. Correlation of SFI% and CHEF% variables grouped according to the priority criterion of students with the maximum CHEF% fraction result with very high repeatability of errors in a quantitative sense (n = 20).

Correlated sets		M indicators	
CHEF priority	N	SFI%	CHEF%
CHEF max points	8	78.57	100
rest of students	12	76.79	80.68
		r = 1	

new information important from the perspective of the main goal of the work – the predictive validity of STBIDF. The number of declared bodily injuries exceeds the number of people forming this fraction (obviously). Most often, as a result of a fall, the upper and lower limbs were injured. It was slightly more often an isolated event (17 incidents in total), but also as one of injuries to three parts of the body (n = 13). The variation in the CHEF index in relation to individual body parts is insignificant (range of extreme results 6.27%) and concerns hands and head. The differentiation of the SFI variable is more pronounced. Between head and hips/torso 13.72%, but the difference in the averaged CHEF and SFI indicators is small (1.74%). One discrepancy, that the SFI% value is higher than CHEF% and not the other way around, is the reason for the high negative correlation (r = −0.631) of both indicators in relation to the observed body parts (Table 17).

A more detailed comparison of the above empirical data with quantitative CHEF and SFI indicators shows the methodological advantages of using quantitative and qualitative indicators (Table 18, and Figure 4). Although the correlation of the quantitative indicators of SFI with CHEF is slightly higher (r = 0.701) and positive than the correlation of the quantitative and qualitative indicators of these empirical variables (r = −0.613), the different directions of the relationship provide different information about both studied phenomena. In Table 18, the results of the second column belong to the category of quantitative indicators, but in the third, fourth and fifth table columns they become a component of quantitative and qualitative assessments of the SFI phenomenon in relation to individual body parts and, on average, what is the SFI indicator for the fraction of people with complete and very high resistance to motor modifications aimed at reducing ground impact errors during a simulated backward fall during the second and third test tasks.

Table 17. Weighted averages of quantitative and qualitative indicators CHEF and SFI, in mutual dependency relationships, for the observed body parts of 34 people.

Distribution of events for 34 people		Distribution of injuries to body parts according to CHEF classification			Weighted average	
body part	**n**	**three**	**two**	**one**	**CHEF%**	**SFI%**
legs	17	6	2	9	84.84	82.36
hips/torso	11	7	1	3	85.49	77.71
hands	18	7	3	8	88.49	82.57
head	5	1	-	4	82.22	91.43
			Total		r = **–0.631**	
					for 34 people	
	51	21	6	24	**85.26**	**83.52**

At the highest level of generality of the interpreted results, the above conclusion is validated by the correlations of the weights of the quantitative and qualitative indicators SFI with CHEF. The most frequently studied fraction is represented by students whose raw STBIDF results are 12, 11 and 13 points (weight 1). The distribution of the number of people according to this criterion between 14 and 9 points is close to normal (Table 19, fifth column).

The distribution of quantitative components and weight in relation to the raw STBIDF score (quantitative-qualitative) provides important empirical evidence of varying predictive validity of STBIDF (Table 20 and 21).

The almost full positive correlation (r = 0.917) of the number of SFI and CHEF variable weights (always lower among CHEF indicators) emphasizes the very high prognostic value of STBIDF in relation to the body parts observed during this test (Table 22).

The most representative results for the entire predictive validity of STBIDF procedure were provided by people whose raw test score was 12 points (n = 10) and 13 points (n = 6). The smallest number of weights for the SFI variable in the largest subset of students (n = 10) and the almost identical number of CHEF weights among the remaining subsets are also quantitative evidence of a very high prognostic value of STBIDF (Table 23). This subset constitutes over 29% of the people included in this validation and accumulates the highest weights of both empirical variables.

Individual profiles

Individual profiles of nine students with a hand error score of 4 points (2+1+1) provide empirical evidence that even among people with very high error repeatability during simulated backward falls, hand clapping has some effect on reducing II° hand errors. Three out of 34 students did not make any errors with their hands during the second test task (one result was 2+0+1, two were 1+0+1), but in their case it would be inappropriate to conclude that clapping had a modifying effect on reducing hand errors.

Table 18. Proportions of students (%) out of 34 who revealed either complete (100%) or very high in quantitative terms (92%) repeatability of ground impact errors from 102 possible separately observed body parts during the three STBIDF tasks, and also quantitative and qualitative SFI and CHEF indicators in relation to four body parts (additionally an atypical indicator).

Indicator type	Body part			
	legs	hips/torso	hands	head
quantitative	sum of all or individually 92% errors			
	100 (n = 102)	90.20 (n = 92)	97.06 (n = 99)	93.14 (n = 95)
	students' injuries			
	50 (n = 17)	32.35 (n = 11)	52.94 (n = 18)	14.71 (n = 5)
quantitative and qualitative	**SFI body part index (%)**			
	82.36	77.71	82.57	91.49
	CHEF body part (%)			
	84.84	85.49	88.49	82.22
atypical SFI	above or below 102 nominal errors in relation to the maximum quality rating based on II° errors (^ total only I° errors)			
	57.35	−9.80 (90.20^)	82.35	−6.86 (93.14^)

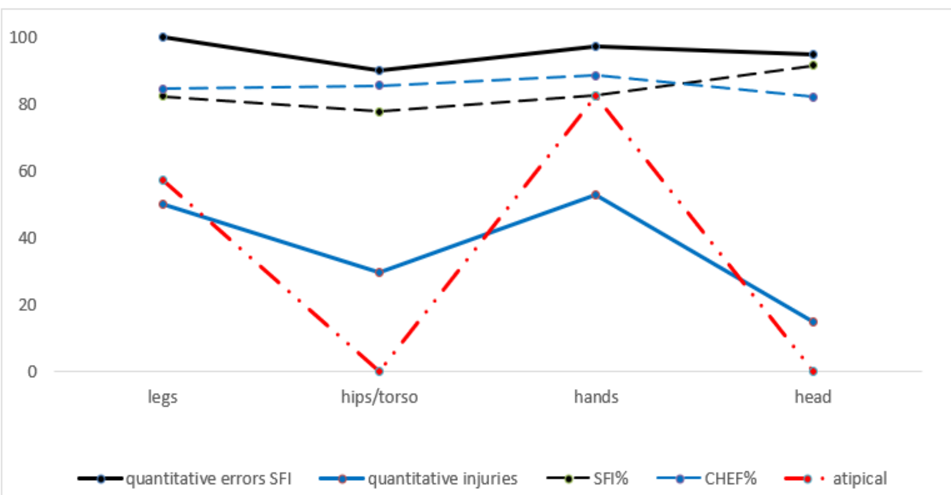

Figure 4. Visualization of quantitative and qualitative SFI and CHEF indicators, as well as atypical SFI.

Table 19. Based on raw scores and proportions, weights assigned to quantitative-qualitative indicators the SFI phenomenon.

Individual evaluation component			Evaluation component of the 34-people fraction			
SFI quantitative-qualitative			SFI quantitative			SFI quantitative-qualitative
STBIDF raw score		WEIGHT	criteria in relation to STBIDF raw score	PEOPLE (proportion with respect to the constant 5.67)		
SFIindex						
points	%		%	N	%	WEIGHT
14	100	1	100-100>	3	50	4
13	92.86	2	83-99	6	100	1
12	85.71	3	50-82	10	100>	1
11	78.57	4	33-49	7	100>	1
10	71.43	5	18-39	5	88	2
9	64.29	6	1-17	3	50	4
0	**see Table 4**	**7**	**∑**	**34**	**∑**	**13**

Table 20. Basic estimation and WEIGHT correlations of SFI and CHEF for legs and hips/torso (PEOPLE – proportion with respect to the constant 5.67).

STBIDF raw score		Legs					Hips/Torso				
		SFI quantitative		SFI quantitative-qualitative	CHEF quantitative-qualitative		SFI quantitative		SFI quantitative-qualitative	CHEF quantitative-qualitative	
SFIindex		PEOPLE					PEOPLE				
points	%	N	%	WEIGHT	%	WEIGHT	N	%	WEIGHT	%	WEIGHT
14	100	0	0	7	0	7	0	0	7	0	7
13	92.86	3	53	4	85.58	3*	1	18	6	78.95	3*
12	85.71	6	100	1	84.72	2*	6	100	1	85.95	2*
11	78.57	6	100	1	79,63	4	0	0	7	0	7
10	71.43	1	18	6	78.95	3*	2	35	5	89.48	2*
9	64.29	1	18	6	85.71	3*	2	35	5	83.34	4
∑ PEOPLE		**17**					**11**				
∑ WEIGHT				**25**		**22***			**31**		**25***
correlation of WEIGHT indicators of SFI variables with CHEF				**r = 0.347**					**r = 0.713**		

*participation of people with injuries to two and/or three body parts as a result of a fall

Table 21. Basic estimation and WEIGHT correlations of SFI and CHEF for hands and head (PEOPLE – proportion with respect to the constant 5.67).

STBIDF raw score		Hands					Head				
		SFI quantitative		SFI quantitative--qualitative	CHEF quantitative--qualitative		SFI quantitative		SFI quantitative--qualitative	CHEF quantitative--qualitative	
SFIindex		PEOPLE					PEOPLE				
points	%	N	%	WEIGHT	%	WEIGHT	N	%	WEIGHT	%	WEIGHT
14	100	2	35	5	88.89	3	1	18	6	77.78	5
13	92.86	2	35	5	83.92	2*	2	35	5	77.78	5
12	85.71	7	100	1	84.96	2*	2	35	5	88.89	3*
11	78.57	1	18	6	100	2	0	0	7	0	7
10	71.43	5	88	2	91.35	3	0	0	7	0	7
9	64.29	1	18	6	85.71	2*	0	0	7	0	7
∑ PEOPLE		18					5				
∑ WEIGHT				25		14*			37		34*
correlation of WEIGHT indicators of SFI variables with CHEF				r = 0.677					r = 0.644		

*participation of people with injuries to two and/or three body parts as a result of a fall

Table 22. Correlated weight numbers of SFI and CHEF in relation to the observed body parts during STBIDF.

Injuries	WEIGHT (N)		
body parts	N	SFI	CHEF
legs	17	25	22*
hips/torso	11	31	25*
hands	18	25	14*
head	5	37	34*
∑	**51**	**118**	**95**
correlations of the cardinality of SFI and CHEF weights			
r = 0.917			

*participation of people with injuries to two and/or three body parts as a result of a fall

Table 23. Raw results of the STBIDF test in relation to the SFI and CHEF weights.

STBIDF raw score	Subset	Injuries	WEIGHT (N)	
SFIindex (points)	N	Total	SFI	CHEF
14	3	3	25	22
13	**6**	**8**	**20**	**13***
12	**10**	**21**	**8**	**9***
11	7	7	21	20
10	5	8	20	15*
9	3	4	24	16
∑	**34**	**51**	**118**	**95**
correlations of the cardinality of SFI and CHEF weights				
r = 0.821				

*participation of people with injuries to two and/or three body parts as a result of a fall

DISCUSSION

There are four possible consequences of unintentional and intentional falls: death, lifelong disability, injuries that heal surgically or on an outpatient basis over time, no negative health effects. IHME (Institute For Health Metrics and Evaluation) statistics in cyclical reports (Global Burden of Disease [10, 22]) provide information on the scale of the first two phenomena in the global, continental, regional and individual countries sense. The latest report from 2018, analysed in detail, provides information that falls were the third most common cause of death globally (9.73 per 100,000 people). Fall was classified as the leading cause of YLD (years lived with disability) with a rate of 276.36 per 100,000 [23].

These statistics do not distinguish between unintentional and intentional falls. It is obvious that it is impossible to obtain such information in death cases. Also, in the case of people who will spend the rest of their lives with disabilities and have also lost the ability to communicate with people. Since it is not common practice to teach safe falls in lower-level schools (an exception is the budo curriculum within physical education in Japan [24]), it is not surprising that the distinction between the effects of falls into unintentional and intentional is not included in the reports on patients of two sets: about the status of disabled and cured people. This question is not asked of these patients during the medical interview.

Isolated cases of effective protection of the body as a result of a forced fall by external forces are reported either in scientific publications or media reports. Kalina et al. [5] describe two incidents of students in this period of their lives when they participated in a safe fall course. Both of them successfully performed a rear fall with turn – one by falling from a height of about 1.5 meters while renovating the building's facade, the other by being hit by a car.

These synthetic premises emphasize the importance of research on the SFI phenomenon by specialists of the 'Polish School of Safe Falling', which is also synthetically reported by Iermakov et al. [3] and Gąsienica-Walczak and Klimczak [25]. So far, the only report available, taking into account the results of SFI diagnosis of various social groups, includes references to 9 publications [26]. Also the only monograph, a significant part of which is dedicated to the phenomenon of SFI, by Dariusz Boguszewski [13] takes into account specific social groups – combat sports athletes (n = 90; no bodily injuries were declared by 37; the remaining 53 had at least one injury) and a reference group of men in a similar age of physically active (n = 49) and inactive (n = 52). Boguszewski, among others, correlated the STBIDF results with the number of injuries to the observed body parts and, as you can guess, with the overall STBIDF result, i.e. SFIindex. The author found positive correlations with Spearman's Rho between BMI and SBPIDFhips ($r = 0.272$, $p<0.01$) and with the SFIindex ($r = 0.227$, $p<0.05$) in the group of combat sports athletes. Only injuries in the lower limbs correlated positively with the SBPIDFlegs indicator ($r = 0.212$, $p<0.05$). However, the almost identical relationship between these damages and SBPIDFhead ($r = 0.211$) should be treated as accidental. The author found more significant correlations in control groups. BMI of physically active men positively correlated with SBPIDFhead ($r = 0.444$, $p<0.01$) and SFIindex ($r = 0.393$, $p<0.01$), while the number of head and spine injuries correlated with the SBPIDFhead indicator ($r = 0.519$, $p<0.001$). Only in the group of physically inactive men, the sum of body damage correlated positively with SFIindex ($r = 0.306$, $p<0.05$). This is important empirical evidence that physical activity, especially when associated with frequent falls (as occurs in hand-to-hand combat forms such as judo, hapkido, wrestling, sumo, etc.) meets preventive expectations related to body injuries due to an unintentional fall.

Although in our own research we did not separate sets of people based on their physical activity, the methodology used, different from the one cited above, provides important empirical evidence about the predictive validity of STBIDF. Apart from individual body parts, this is evidenced not only by the results of correlation analyses of the adopted indicators in the fraction of students (n = 160) who declared having suffered at least one body injury in the past caused by at least one fall with such consequences. An important criterion confirming this accuracy is also the result of comparing the distribution of students' proportions in both fractions, taking into account the errors made when individual parts of the body hit the ground while performing STBIDF (Figure 1). The differences in proportions are not statistically significant. Therefore, it makes sense to interpret this result that the extreme circumstances in which students from the declaring fraction fell did not compare to those in which students from the other fraction (n = 53) suffered numerous bodily injuries.

On the one hand, it would be too precipitative to conclude that in similar circumstances of a fall, the probability of bodily injury would be high or very high. For example, several students reported suffering serious bodily injuries as a result of falling from a horse. Based on empirical data obtained in accordance with the STBIDF evaluation criteria (written declaration of the examined person), it is impossible to determine whether there were more such circumstances, and the participants of the event did not suffer an injury qualifying for distinction, even on the FISS scale. Therefore, in future modifications of the already modified version of STBIDF-M [8], the written declaration should be replaced with an interview with the examined person. An important criterion will also be to determine the circumstances of the most extreme fall that did not result in a body injury that would require the use of the FISS scale. On the other hand, comparing the proportion of students from both fractions who documented the risk of damage to a given body part with the maximum number of evaluation points provides evidence of close similarity. Moreover, when diagnosing hands, errors were made more often by students from the fraction without traumatic experiences related to falls (the difference is 4.5% – Figure 1).

However, the most important methodological argument confirming the prognostic accuracy of STBIDF are statistical calculations based on the levels of generality of indicators (raw STBIDF results) adopted in this work, integrated into three sets – 'average', 'below average' and 'above average', as well as the results of the applied methods of correlating the weights assigned to the SFI and CHEF indicators. Although the population sample was large (n = 213), only one of the subjects performed the STBIDF correctly and had not suffered any injury as a result of an unintentional fall in the past. The methodological implications of this likely result are explained in the 'Material and Methods' section, and the empirical effects are provided in the 'Results' section. This dilemma did not apply to the SBPIDF indices of the three times evaluated body parts (hips, hands and head), but it clearly differentiated the qualitative side of the assessments when the calculations take into account the SFI phenomenon of the legs. Despite this complication, during the synthesis of the obtained results, it turned out that the most valuable, general indicator for the evaluation of the SFI phenomenon is the proportion of ground collision errors made during a three-time simulated backward fall. Although the legs were also observed three times, the indicator differentiating errors into the first degree (1 point) and the second degree (2 points) comes only from the third task, when the simulated fall should be preceded by jumping backwards from a platform. 'Should' because a significant part of the surveyed students, instead of jumping down, started the descent with one leg and joined the other (1 point).

It will be interesting to verify the evaluation value of the error repeatability index in studies of the SFI phenomenon based on the results of observations derived from the use of STBIDF-M [8]. The simulated backward fall after jumping off is repeated three times during six tasks. The increased number of tasks has an additional evaluation advantage, as it will more confidently enable the classification of examined people in terms of their cognitive-behavioural potential. At the extremes of the continuum are people who are resistant to motor modifications and those who, under their influence and without the need for verbal explanations, reduce the impact of the distal parts of the body with the ground during a fall in laboratory conditions.

These two empirically discovered, opposing phenomena are the most clear evidence of the prognostic value of STBIDF [4]. One of these phenomena is the resistance of some adults educated at a higher level to motor modifications that should, without the need for verbal explanations, reduce the errors of collision with the ground of distal body parts, which in extreme circumstances of an unintentional fall are subject to various damages. The results of these studies focus on a group of people with complete and very high resistance to these modifications (21.25% of the fraction of students who in the past suffered bodily injury as a result of an unintentional fall). This work, however, does not determine what part of the students of this fraction reduces errors indicating SFI during the second and third STBIDF tasks, how extensive bodily injuries these people have suffered in the past, or whether there is a relationship between the quality of reduced errors in the overall or selective sense (one of the observed body parts) with body damage resulting from a fall in the past. We intend to investigate these phenomena after previously correcting the criteria for assessing hips and legs in relation to each other during the first and second STBIDF tasks.

At the highest level of generality of the synthesis of results measuring SFI and CHEF phenomena, the prognosis regarding people resistant to motor modifications is confirmed by the correlation of weights assigned to the main indicators of both these phenomena. A similar predictive value of STBIDF is demonstrated by an almost linear relationship (r = 0.999) in the student sets of both fractions based on the methodology of merging STBIDF raw scores into three sets. This is basically the only possible and sensible correlation for students who did not suffer injuries as a result of a fall and is related to the method adopted. The evidence for the predictive validity of the STBIDF or its contradiction (i.e. lack of validity) changes when observations are separated into individual body parts. Since the proportions of results calculated in this way in both groups of students are very similar (Figure 1) and since the correlations are identical (Figure 3), it means that probable trauma resulting from an unintentional fall in the past is not a factor significantly modifying the STBIDF results.

The assumption of probable post-accident trauma, articulated above, is justified by the first author's many years of teaching practice. When he used tests diagnosing the SFI phenomenon in various circumstances (blindfolded, hands tied, etc.) and also using a modified version of STBIDF (STBIDF-M [8]), several students communicated some fear of taking the test, justifying their fears with past bodily injuries, as a result of an unintentional fall. In our opinion, this remark is important also because a person being tested for the first time does not have the opportunity to observe people tested before him. Therefore, these concerns were expressed only after communicating what to do after the HOP ('lie down on your back as fast as possible') command. The results of correlational studies therefore provide evidence that these are indeed isolated cases.

An in-depth synthesis of empirical data showed not only the scale of risk for some adults of even inevitable bodily injury resulting from a fall in a certain class of extreme circumstances, but even more serious consequences. Despite the introduction of motor modifications in the second and third tasks, which should eliminate some of the errors, it turned out that 2.35% (taking into account the results of both fractions, i.e. n = 5 out of 213 students) were extremely resistant to these modifications – STBIDF result (SFIindex) 14 points. These proportions are consistent with the finding that among four-, five – and six-year-old children (a total of 125 observed in safe laboratory conditions [9]), 3.2% (n = 4) ended each fall also by making the mistake of colliding with the ground with their hands, and a few also head. Taking into account the 191 observed children aged 2 to 6 years, this proportion is 2.09%.

Andrzej Mroczkowski et al. [27], although they limited the description of the phenomenon to the head, they conclude the result of their own observations as follows: 'High persistence of committing the error of controlling head during test indicates its diagnostic value in detecting susceptibility to head injuries during a fall' [27, p. 60]. The 'Results' section listed the hand error result of the student (2+0+1), whose profiles from before and after the mid-semester safe fall course are available in a scientific publication [28]. This example shows the sense of interpreting the results individually and in a complementary approach. A student with progressive morbid obesity, after specialized training, completely reduced the errors of the legs and hips from the repeatability level of 100% documented by STBIDF, and the errors of the hands from 50% to 16.6%, and the head from 100% to 66.67%. He has mastered the technique of safe falling, making his competencies equal to the most able students. He increased his muscle strength by over 20%, maintained his body balance disturbance tolerance skills at 61% of the ideal result and worsened his suppleness by 6%, which is related to his health condition.

Both the broader association of the results of our research presented in this work with the findings regarding the phenomenon of SFI in children aged 2 to 6 years [9] and the observations of Mroczkowski et al. [27], Mroczkowski [28, 29] and the adaptive effects of a student with morbid obesity [30] go beyond the general editorial framework of this discussion. However, a characteristic feature of all these cited studies and the results of our observations is that they come from the use of unique innovative agonology tools [31] (INNOAGON [32]). This shows the cognitive potential of complementary research methodology [20, 18], that is, the basic method of this new applied science. This is noticed by researchers of seemingly distant phenomena such as struggle against cancer, combat with aggression, fight for survival, etc. [33-36]. What is surprising, however, is the fact that before agonology (1938 [37]) and much later INNOAGON [32] broke into the awareness of some scientists from outside the methodological school of Lviv and Warsaw, from 1902 to March 2023, the authors of 1,568 publications qualified by WoS for various categories of disciplines used the term 'self-defence' in the titles of these works [38]. 'Self-defence' is, after all, a specific case of defensive struggle. And the phenomenon of defensive struggle is explored either by science about struggle, abbreviated as 'agonology' [39] and this is a narrow understanding of this phenomenon, or in a broad understanding, i.e. consistent with the definition of INNOAGON (see glossary). This state of affairs can therefore be considered an important premise of social expectations for science to indicate universal ways to overcome phenomena that pose the highest level of threat to health and life, from the micro to macro scale. This class includes the consequences of unintentional falls. In countries with aging populations, a fall is one of the events with the highest risk to health and life.

CONCLUSIONS

No significant differences were found between SFI in the groups of people declaring and not declaring bodily injury in the past as a result of an unintentional fall. Therefore, the only factor that influences fall injury for people unprepared for this type of event is the extremeness of the circumstances.

Since the phenomenon of supporting oneself with one's hands during each unintentional fall begins in the fourth year of life and affects over 3% of the population of children between four and six years of age, and every fifth person aged about 23 is resistant to motor modifications aimed at reducing collision errors with four body parts during a simulated backward fall, the intensification of SFI during ontogeny is currently one of the most serious public health problems. Moreover, the very high correlation of quantitative and qualitative SFI indicators with the health effects of falls (CHEF) is the most important empirical argument that universal prevention of bodily injuries and death caused by falls should begin before the stage of school education. We associate the problem of actually reducing these extreme events throughout ontogeny with improving tools measuring SFI phenomena and creating new ones that can also be used in research on elderly and disabled people.

LIMITATIONS

The study has several limitations. Therefore, the authors suggests that future studies should be conducted on larger samples, with a new version of STBIDF-M. Instead of a survey, a thorough interview should be conducted regarding damage suffered as a result of a fall in the past.

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