ARCHIVES OF BUDO
Journal of Innovative Agonology

e-ISSN: 1643-8698

Section: ***PREVENTIVE MEDICINE FROM INNOAGON PERSPECTIVE*** *Original Paper*

Motor modifications versus movement habits in measuring the SFI phenomenon

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Authors' Contribution:

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

Received: date: 18.11.2024
Accepted: date 20.12.2024
Published: date 20.12.2024

Dictionary:

Fall – is unintentional, a sudden change from vertical to horizontal posture. Falling often leads to injury; that is why it is qualified in the International Classification of Disease (ICD). Codes include falls on the same or upper level, as well as others, unspecified falls. Falls results with a collision with walls, furniture, ground or other objects or obstacles [24].

Abstract:

Background and Study Aim: SFI is an abbreviation informing about the phenomenon of susceptibility to bodily injuries during a fall (unintentional or intentional). The assumption of motor modifications of subsequent tasks of the tests used is to create circumstances with two opposite properties: those that facilitate subconscious reduction of collision errors of some body parts with the ground during a simulated backward fall; those that make the simulated fall more difficult. The aim of the study is the cognitive value of motor modifications used in the basic test measuring the SFI phenomenon in relation to the movement habits of young adults.

Material and Methods: Secondary analysis was performed on observations of 35 physiotherapy students participating in the 'test-retest' procedure (7 days apart) of 'susceptibility test body injuries during a fall' (STBIDF). The analysis was based on modified (more precise) criteria for observing the SFI phenomenon, taking into account recommendations from previous studies. The consequence is an increase from 14 to 15 points of the extremely negative STBIDF result (SFI Index) – the sum of errors of each of the five observed body parts (legs, hips, each hand separately, head) during three simulated backward falls.

Results: Students made 59.43% of possible errors during the 'test' procedure, and 60.95% during the 'retest'. The smallest fraction (25.71%) turned out to be students who reduced errors of body impact with the ground during the simulated backward fall. Completely resistant to motor modifications during the test (100% errors) were 5.71% during 'test' and 'retest', of which one person (2.86%) during both stages of evaluation. Effectiveness of 'sponge and clapping' in reducing errors with both hands and head simultaneously: Task 1 test vs. Task 2 (20%); Task 1 vs. Task 3 (12%); retest, 14%; 8%, respectively.

Conclusions: The motor habits established during adolescence, associated with multiple changes of vertical to horizontal posture during the day (tilting the head), and even more often sitting on platforms (chairs, etc.) or the ground, supporting oneself with hands (also when getting up), suppress the positive adaptive potential of the applied motor modifications in STBIDF. These observations, associated with the previous recommendations of the experts of the 'Polish School of Safe Falling', extend the evidence of ignoring necessary interventions starting from preschool education.

Keywords: fall at the same level, fall from a height with the feet down, Polish School of Safe Falling

1. Introduction

SFI is an abbreviation informing about the phenomenon of susceptibility to bodily injuries during a fall (unintentional or intentional) [1-10]. The assumption of motor modifications of subsequent tasks of the tests used is to create circumstances with two opposite properties: those that facilitate subconscious reduction of collision errors of some body parts with the ground during a simulated backward fall; those that make the simulated fall more difficult [4, 7, 8, 10].

Recommendations from authors of recent studies of the SFI phenomenon highlight the possibility of more accurate evaluation and propose secondary analysis of the results of previous observations [7, 8]. Observations documented by video recording are the most valuable. We just now have this form of documented results for the use of the 'test-retest' procedure of the susceptibility test to the body injuries during the fall, STBIDF [6], as well as STBIDF-M [8]. In this work, we perform a secondary analysis of the STBIDF results developed from the revised evaluation criteria – see 'material and methods' section for a description.

The aim of the study is the cognitive value of motor modifications used in the basic test measuring the SFI phenomenon in relation to the movement habits of young adults.

2. Materials and Methods

Participants

Secondary analysis was performed on observations of 35 physiotherapy students participating in the 'test-retest' (21.3 ±0.8 years of age). The sample was selected from 45 males and females undertaking their first-degree studies during the fifth semester of 2017–2018 at Podhale State College of Applied Sciences (PSCAS) in Nowy Targ, Poland. The following inclusion criteria were applied: an adequate health state, voluntary participation, and gender (female). The exclusion criteria were: a lack of consent for participation in the study, pregnancy, and dysfunctions making it impossible to undergo the test. All participants were informed in detail about the aim of the study prior to participation.

The study was accepted by the Bioethics Committee at the Regional Medical Chamber in Gdansk, Poland, Resolution KB – 17/17 [6].

Study design and tools

The 'retest' procedure of STBIDF was repeated after 7 days from 'test' [6]. The analysis was based on modified (more precise) criteria for observing the SFI phenomenon in three external circumstances: Task 1 a simulated fall backwards on soft ground involved adopting as quickly as possible to a horizontal stance from a vertical stance after a GO command; Task 2 before repeating the task and the GO command, the person was instructed to clap their hands and press the sponge against their upper torso with their chin; Task 3 activities identical to Task 2 preceded by a backwards jump from a 20 cm platform after a GO command.

The novelty is: a) abandoning the separation of type II errors during the evaluation of the lower and upper limbs; b) separating in the analysis repeated simulations of a backward fall on the same level (Tasks 1 and 2) and a backward fall from a height with feet down (Task 3); c) recognition the cause of the hip error during Tasks 1 and

2 as improper cushioning of the fall by the lower limbs; d) documenting errors of each hand separately.

The consequence is an increase from 14 to 15 points of the extremely negative test result (Index SBIDF) – the sum of errors of each of the five observed body parts (legs, hips, each hand separately, head) during three simulated backward falls. Two modifications (pressing the sponge with the chin to the torso and clapping during a simulated backward fall) during Tasks 2 and 3 provide information either about resistance to these modifications, or about the tendency to increase the number of errors, or about sensitivity, the effect of which is subconscious reduction of errors during the collision with the ground. One modification (Task 3) cumulates the mentioned cognitive values of these modifications with knowledge about the motor (often also mental) effects of the necessary backward jump (from a platform of about 20 cm) preceding the simulated fall from a height with the feet down.

The novelty is basing the measurement on the 'zero-one' formula of five body parts: legs, hips, each hand separately, head. This modification means: a) giving up the separation of second-degree errors during the evaluation of the lower and upper limbs; b) evaluation of the lower limbs during each Task (and not only during Task 3); c) considering the cause of the hip error during Tasks 1 and 2 as improper cushioning of the fall by the lower limbs; d) documenting errors of each hand separately.

A lower limb error during each Task was considered to be a collision with the ground of the buttocks or immediately of the back in the absence of an acute angle between the thighs and shins at the moment of contact of the body with the ground, and during Task 3 instead of jumping off the platform descending, or after jumping stopping instead of continuing the squat, etc. The finding of these errors implies a risk to the hips as well (which, in an evaluative sense, equate to a risk of injury to the entire torso) and is documented with 1 point under the headings 'legs' and 'hips'.

Similarly, in both of these boxes, it is documented that the buttocks hit the ground or rotate to the side when the body makes contact with the ground – this is evidence of insufficient cushioning of the falling body by the lower limbs.

A hand(s) error is simultaneous or preceding contact with the ground of the body and similarly for the head.

Errors in stopping clapping or holding the sponge with the hand, but without touching (hitting) the head on the ground and similarly with the hands, are recorded in the test documentation (with symbols 'C', 'S' respectively), but not qualified as indicators of the likelihood of damage to these body parts during a fall under adverse circumstances.

The consequence is an increase from 14 to 15 points of the extreme negative test score (Index SBIDF) – the sum of the errors of each of the five observed body parts (legs, hips, each arm separately, head) during three simulated backward falls. Invariably, as in the basic version of the STBIDF [1, 2], one evaluation criteria takes into account the overall risk of injury according to the number of simulated falls, the other takes into account each of the isolated body parts and also takes into account the number of falls. Any application of the STBIDF in its traditional form means that the estimation of the risk of injury includes summing up the errors (or lack thereof) of hips, hands and head three times and legs only once (however, alternatively either 0, 1 or 2 points).

In the corrected evaluation method, each of the five observed body parts is evaluated according to a 'zero-one' formula. Hence, each time observations from a subsequent simulated test fall are added, the maximum number of errors (i.e. each of the five parts identified) is increased by 5 conventional points (Table 1).

Table 1. Criteria for evaluating a person's overall risk of injury in relation to the number of simulated falls and ground impact errors of the five body parts evaluated.

Risk indicator	Qualitative evaluation criteria (verbal and %) based on the sum of errors (SFIpoints) during one to six simulated falls					
subscript after S: number of falls	extreme E	very high VH	high H	average A	low L	very low VL
			1 fall (actually: number of body part)			
S_1FIpoints	**5**	**4**	**3**	**2**	**1**	**0**
S_1FI%	*100*	*80*	*60*	*40*	*20*	*0*
			2 falls			
S_2FIpoints	**10**	**9**	**8-7**	**6-4**	**3-1**	**0**
S_2FI%	*100*	*90*	*80-70*	*60-40*	*30-10*	*0*
			3 falls			
S_3FIpoints	**15-14**	**13-12**	**11-10**	**9-6**	**5-2**	**1-0**
S_3FI%	*100-93*	*87-80*	*73-67*	*60-40*	*33-13*	*7-0*
			4 falls			
S_4FIpoints	**20-19**	**18-16**	**15-13**	**12-8**	**7-2**	**1-0**
S_4FI%	*100-95*	*90-80*	*75-65*	*60-40*	*35-10*	*5-0*
			5 falls			
S_5FIpoints	**25-24**	**23-21**	**20-16**	**15-10**	**9-3**	**2-0**
S_5FI%	*100-96*	*92-84*	*80-64*	*60-40*	*36-12*	*8-0*
			6 falls			
S_6FIpoints	**30-28**	**27-24**	**23-19**	**18-12**	**11-3**	**2-0**
S_6FI%	*100-93*	*90-80*	*77-63*	*60-40*	*37-10*	*7-0*

However, when two falls are observed, the score, e.g. S2FI points = 2, may be derived from the summation of two errors from several possible compilations: the person may have made two errors with two different body parts either during the first fall, or during the second fall, or one of each fall with the same body part or with different ones. These possible compilations do not change the qualitative interpretation of the result in terms of the overall risk of injury from a fall – it is low (20%). However, when the errors involve the same body part, the risk will be extreme (100%) (Table 2).

Table 2. Alternative criteria for evaluating the risk of injury to one part of the human body in relation to the number of simulated falls under observation, or monitoring that is not a motor simulation but a fixed event(s) in circumstances not arranged by the research subject.

Risk indicator	Qualitative evaluation criteria based on sum of errors (SFIpoints) during one to six simulated falls					
	extreme E	very high VH	high H	average A	low L	very low VL
				1 fall		
S_1FIpoints BP	**1**					**0**
S_1FI% BP	*100*					*0*
				2 falls		
S_2FIpoints BP	**2**			**1**		**0**
S_2FI% BP	*100*			*50*		*0*
				3 falls		
S_3FIpoints BP	**3**		**2**		**1**	**0**
S_3FI% BP	*100*		*67*		*33*	*0*
				4 falls		
S_4FIpoints BP	**4**		**3**	**2**	**1**	**0**
S_4FI% BP	*100*		*75*	*50*	*25*	*0*
				5 falls		
S_5FIpoints BP	**5**	**4**	**3**	**2**	**1**	**0**
S_5FI% BP	*100*	*80*	*60*	*40*	*20*	*0*
				6 falls		
S_6FIpoints BP	**6**	**5**	**4**	**3**	**2**	**1-0**
S_6FI% BP	*100*	*83*	*67*	*50*	*33*	*17-0*

There is some analogy when interpreting qualitative assessments of the risk of injury to individual body parts according to the number of observed falls of the same person. However, motor and/or external circumstance simulations (e.g. falling backwards after jumping off a platform with a height that does not pose a potential risk to the individual) can be compiled according to the purpose of the diagnosis and the specifics of the person tested (Table 2). Using the accepted symbols for the qualitative assessments and the corrected interpretation of the STBIDF results (as used in this research), an example record for legs could take this form: Task 1 E; Task 2 E; Task 3 VL. Sticking to the original evaluation criteria (legs only assessed during Task 3) such an interpretation is not possible.

Also new are the assumptions regarding: firstly, the extension of the quantitative and qualitative analysis to six consecutive simulated back falls; secondly, the dependence of the procedure for summation of results from identical 'test-retest' motor simulations on the statistical properties of the initial comparisons (notwithstanding the already proven reproducibility of STBIDF raw results over a short time interval [6]); thirdly, we take as an initial criterion for quantitative-qualitative analysis the possible fractions of individuals, selected on the basis of the number of errors made with fixed body parts during Task 1 (they fall on a continuum from 0 to 5).

Therefore, for ease of perception of the results, we have replaced the empirical data from the 'retest' procedure corresponding to each STBIDF Task with the names: Fall 4; Fall 5; Fall 6.

An individual indicator profile for a sequence of six simulated falls during the STBIDF 'test-retest' procedure and based on modified criteria may, for one body part, take the form: Task 1 VL; Task 2 VL; Task 3 E; Fall 4 VL; Fall 5 VL; Fall 6 E, for another: Task 1 E; Task 2 E; Task 3 VL; Fall 4 VL; Fall 5 VL; Fall 6 VL. This would mean that the extreme risk of injury to the former body part is for falls from a height with the feet down. The profile for the second body part, from the example above, mandates the interpretation that the person, with the acquisition of experience regarding falls, is able to drastically reduce the risk of damage to this body part regardless of external circumstances, even before undertaking a professional safe fall course.

Statistical analysis

Minimal differences in errors of individual body parts during simulated backward falls during the STBIDF 'test-retest' procedure mandated the summation of the results of the two observations (Figure 1). Thus, the model of probable risk of injury (in %) for men and women aged 21.3 ± 0.8 years is based on observations of 210 falls under safe laboratory conditions in three different external circumstances. Each of these circumstances was simulated again after 7 days.

During each simulated fall (Task or Fall according to the accepted rules for documenting observation results), it was possible for the 35 students tested to make 175 errors with five body parts. When summing up the results in pairs of repeated circumstances (which we called 'mirror': Task 1 Fall 4; Task 2 Fall 5; Task 3 Fall 6), the total is 350 errors. For the 'test' and separately 'retest' procedures, 525 errors each. Taking into account all observations from the six simulated falls, it was possible for the students tested to make 1,050 errors. The empirical basis for the overall probability of injury risk during a fall under various external and internal circumstances (their assessment is related to the quality of motor responses to the arranged external circumstances) by this sample of the population is the proportion (in %) of errors made relative to the theoretical value calculated above.

3. Results

The overall probability of risk of injury during a fall under different external and internal circumstances, verified on the basis of very similar results of repeated observations (Figure 1), is located at the borderline of average and high (S6FI% = 61.05). The physiotherapy students in the population sample (n = 35) made one more error during the 'retest', further demonstrating that the motor experience of one week ago did not, in a general sense, influence either the reduction of errors or their escalation during the repeat experiment. Students made the most errors in the circumstances of a backward fall from a height with feet down, when the hands and head were engaged in various manipulative activities (S2FI% = 71.14, high risk). They made the least during a backward fall on the same level when the hands and head were engaged in different manipulative activities (S2FI% = 48.57, average risk) (Figure 1).

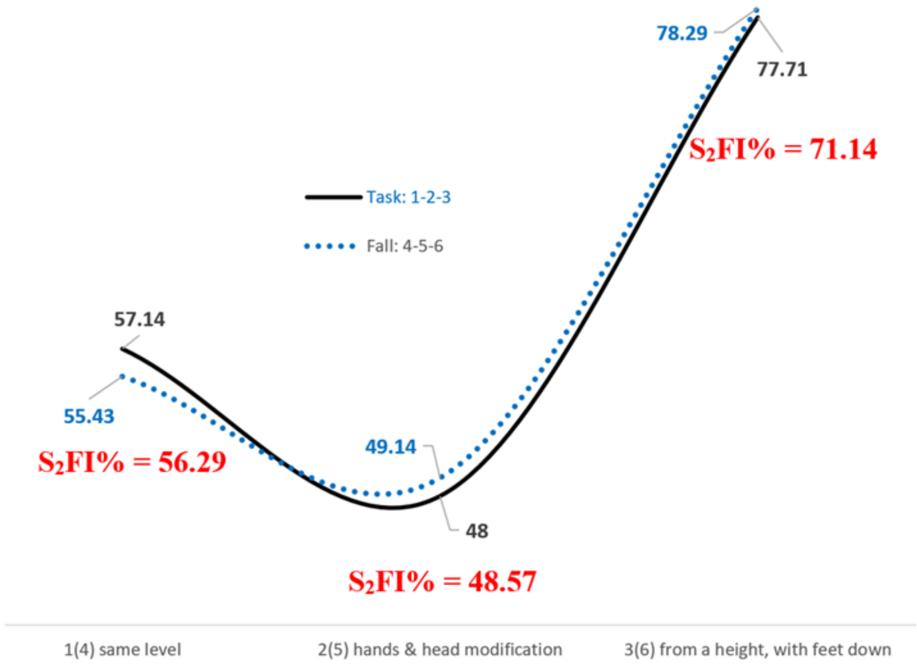


Figure 1. Risk of injury (%) during 6 simulated backward falls under different external experimental circumstances by 35 physiotherapy students (3 falls repeated after a one-week break – retest).

Of the body parts identified, very high risk (S6FI% = 88.57) applies to the head. High risk of injuries to each arm separately (S6FI% = 72.86). S6FI% BP for legs and hips respectively, is 36.19% each, indicating low risk, but close to average (Figure 2).

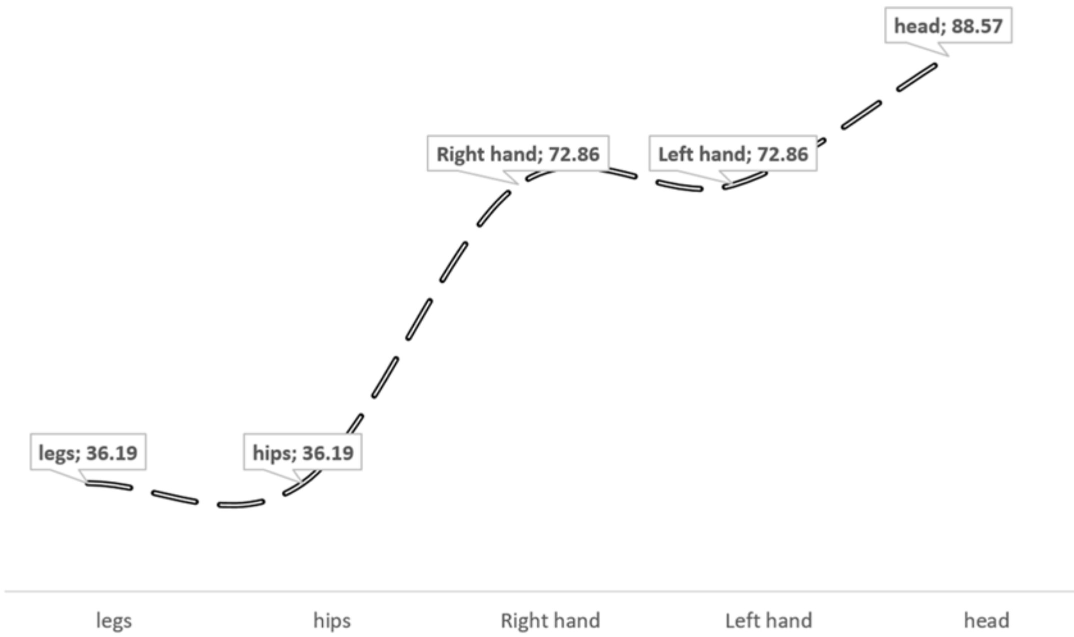
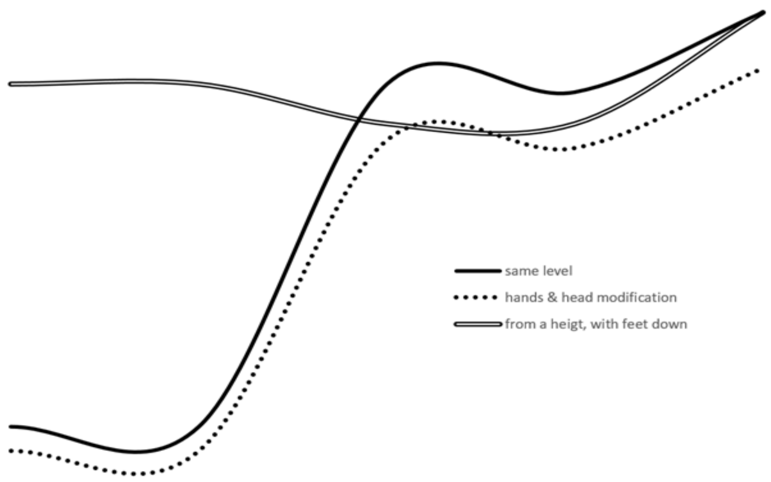


Figure 2. Probable injury risk model (in %) based on summation of identified body-to-body collision errors from observations of 210 simulated backward falls in laboratory conditions.

The highest risk of multi-organ damage is associated with a fall from a height with the legs down (S2FI% = 78.29), even when there is little difference in the levels at which the fall was initiated and completed. In such circumstances, the risk of injury to the head is close to extreme (91.43%), to the legs and hips (torso) high (78.29%), the left and right arms also high (71.43% each). The risk of injury due to falling at the same level on which young adults move or stand is close to extreme for the head, but high for the upper limbs. The positive effect of the applied motor modifications during Task 2 (when upper limbs and head are at this point engaged in motor activities easy to repeat in other experimental circumstances) became apparent relative to the results of the first of the test falls. These activities repeated during Task 3 provide evidence that only hand clapping is conducive to sustaining the tendency to reduce hand hands (Figure 3).



legs	hips	R hand	L hand	head
17.14	17.14	78.57	77.14	91.43
12.86	12.86	68.57	67.146	81.43
78.57	78.57	71.43	71.43	91.43

Figure 3. Risk of injury to various body parts by young adults (n = 35) based on the results of a simulated backward fall under three external circumstances and concomitant motor modifications of increasing coordination difficulty.

These general trends are even significantly modified over the course of the repeated two cycles of test falls, but within the fractions identified on the basis of Task 1. The most numerous (n = 20, representing 57.14% of the population sample) are those who made errors with three body parts and, for the purposes of the results presented here, are coded F-3. This is a very highly homogeneous group in terms of the profile of these errors. Only one student (5% of them) made a legs, hips and head error during the first test fall. The others (95%): right hand, left hand and head. At the same time, with the exception of the third test fall (Fall 4), when again all made a head error, they reduced these errors by an average of 10%. Hands errors were slightly more effective (by 12%), however, the risk of damaging them calculated from the five test falls is borderline high and very high (83%). The risk of damage to legs and hips increased dramatically (relative to the score from Task 1) during a backward fall from a height with feet down. The rate of S5FI%BP increased by 5.2% in relation to the S1FI%BP for Task 1, which is evidence that the tendency to increase the overall risk of multiple organ injuries during falls in different circumstances prevailed in this fraction (Table 3).

Table 3. Injury risk profiles of the largest fraction of students (F-3; n = 20) in relation to the five body parts identified (row scores) and in an overall sense (column scores: 'Total') – the corresponding differences are calculated between Task 1 scores and the arithmetic mean (M) of the results of falls two to six.

Body part	For simulated falls in various external circumstances						For body part	
	S_1FI%BP						S_5FI%BP (M)	differences
	Task 1	Task 2	Task 3	Fall 4	Fall 5	Fall 6		
head	**100**	80	90	100	90	90	**90**	**–10%**
Left hand	**95**	80	80	95	75	85	**83**	**–12%**
Right hand	**95**	75	85	95	75	85	**83**	**–12%**
hips	**5**	0	95	5	0	75	**35**	**+30%**
legs	**5**	0	95	5	0	75	**35**	**+30%**
Total								
		S_1FI%					**(M)**	**differences**
(M)	**60**	47	89	60	48	82	**65.2**	**+5.2%**

The other factions each have five people (14.29% of the total). The code F-5 is assigned to those who made errors with each of the five body parts. However, only the students in this fraction revealed a consistent tendency to reduce their errors during successive test falls with four body parts (except the head). The severity of this trend is not constant, however: they reduced errors by 24% when they fell for the third, fourth and fifth time, and by 8% during the second and sixth test falls. The S5FI% for falls two to six is 82.5, meaning that students in this fraction reduced errors by –17.5% (Figure 4).

Table 4. Injury risk profiles of fraction F-5 students (n = 5) in relation to the identified five body parts (row scores) and in an overall sense (column scores: 'Total') the corresponding differences are calculated between Task 1 scores and the arithmetic mean (M) of the results of falls two to six.

Body part	For simulated falls in various external circumstances						For body part	
	S_1FI%BP						S_5FI%BP (M)	differences
	Task 1	Task 2	Task 3	Fall 4	Fall 5	Fall 6		
head	**100**	100	100	100	100	100	**100**	**0**
Left hand	**100**	100	80	100	100	100	**96**	**–4%**
Right hand	**100**	100	80	100	100	100	**96**	**–4%**
hips	**100**	80	60	40	40	80	**60**	**–40%**
legs	**100**	80	60	40	40	80	**60**	**–40%**
Total								
		S_1FI%					**(M)**	**differences**
(M)	**100**	92	76	76	76	92	**82.5**	**–17.5%**

Coded F-2 are students who made errors with two body parts. The initial profiles of this fraction are the most diverse: two made right hand and head; one left hand and head; one right hand and left hand; one legs and hips. They increased their risk of injury during repeated test falls (+9.6% on average), although this average result is partly offset by reduced upper limps errors (Table 5).

Table 5. Injury risk profiles of F-2 students (n = 5) in relation to the identified five body parts (row scores) and in an overall sense (column scores: “Total”) – the corresponding differences are calculated between Task 1 scores and the arithmetic mean (M) of the results of falls two to six.

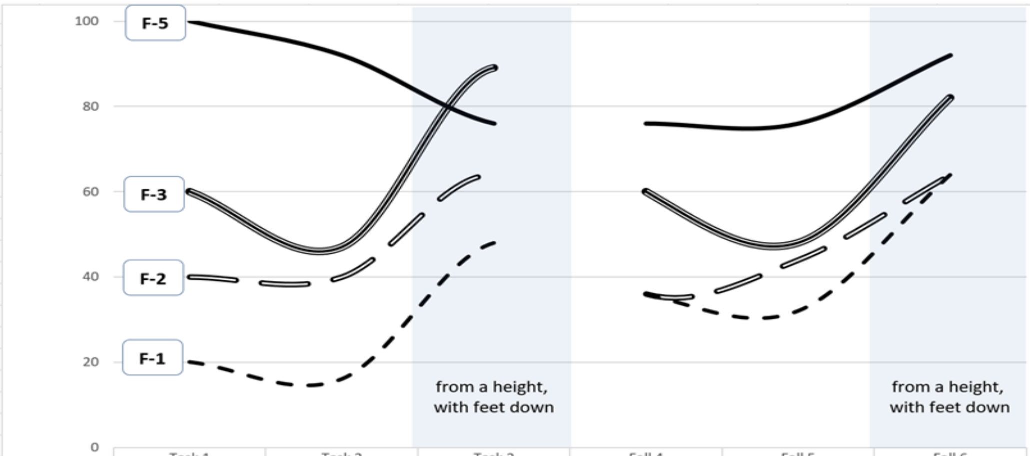
Body part	For simulated falls in various external circumstances						For body part	
	$S_1FI\%BP$						$S_5FI\%BP$ (M)	differences
	Task 1	Task 2	Task 3	Fall 4	Fall 5	Fall 6		
head	**60**	60	60	40	80	80	**64**	**+4%**
Left hand	**40**	40	40	20	40	40	**36**	**–4%**
Right hand	**60**	60	60	40	60	40	**52**	**–8%**
hips	**20**	20	80	40	20	80	**48**	**+28%**
legs	**20**	20	80	40	20	80	**48**	**+28%**
Total								
		$S_1FI\%$					(M)	differences
(M)	**40**	40	64	36	44	64	**49.6**	**+9.6%**

The initial profiles of the F-1 fraction are uniform: everyone made a head error. Some reduced it three times during repeated test cycles of falls. However, on two occasions, including the last of the simulated falls, all bore witness to their inability to keep their head from colliding with the ground in the circumstances of a backward fall from a height with feet down. From the second of the simulated falls onwards, at least one of the students in this fraction made a left-hand ground collision error. The increase in the risk of damage to individual body parts from +20% to +40%, irrespective of the reduction of the head (–20%), is important empirical evidence that it is only the variety of simulated external circumstances of a fall that reveals the intrinsic inadequacies of humans regarding their ability to protect their own bodies during unintentional and intentional falls (Table 6).

Table 6. Injury risk profiles of fraction F-1 students (n = 5) in relation to the identified five body parts (row scores) and in an overall sense (column scores: ‘Total’) – the corresponding differences are calculated between Task 1 scores and the arithmetic mean (M) of the results of falls two to six.

Body part	For simulated falls in various external circumstances						For body part	
	$S_1FI\%BP$						$S_5FI\%BP$ (M)	differences
	Task 1	Task 2	Task 3	Fall 4	Fall 5	Fall 6		
head	**100**	60	100	80	60	100	**80**	**–20%**
Left hand	**0**	20	40	60	40	40	**40**	**+40%**
Right hand	**0**	0	20	40	20	20	**20**	**+20%**
hips	**0**	0	40	0	20	80	**28**	**+28%**
legs	**0**	0	40	0	20	80	**28**	**+28%**
Total								
		$S_1FI\%$					(M)	differences
(M)	**20**	16	48	36	32	64	**39.2**	**+19.2%**

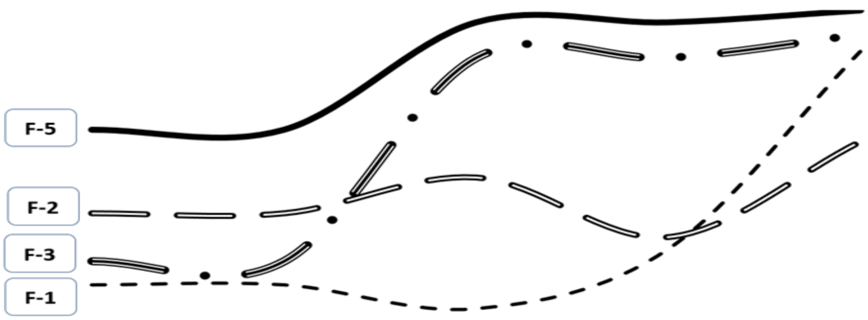
The overall model of motor responses in the changing external circumstances of simulated falls in both cycles, shows both moments that favour reducing the risk of injury from an imminent collision with the ground (orchestrated motor modifications of hands and head) and moments that hinder protection of distal body parts (dominated by a backward fall from a height with feet down). The phenomenon is modified by intrinsic factors of individuals who, under identical initial circumstances of a simulated backward fall on the same level of stable ground, differed in the number of errors of first contact with the ground by five fixed body parts – in this sample from the population, there was no individual who made no error in this phase of the experiment (Figure 4).



	Task 1	Task 2	Task 3	Fall 4	Fall 5	Fall 6
F-5 (n = 5)	100	92	76	76	76	92
F-3 (n = 20)	60	47	89	60	48	82
F-2 (n = 5)	40	40	64	36	44	64
F-1 (n = 5)	20	16	48	36	32	64

Figure 4. Quality of students' motor responses as measured by averaging S1FI% for each fraction over two cycles of simulated falls.

The factor with the strongest differentiation between fractions is right hand S5FI% (range 80%), the least head S5FI% (range 36.67%). The quality of variation in motor responses within the same fraction (range 71.9% between head and right hand) is characterised by students who made only one error at the start of the experiment – a head error. We found the smallest range between the same variables (3.33%) among students of the F-5 fraction (Figure 5).

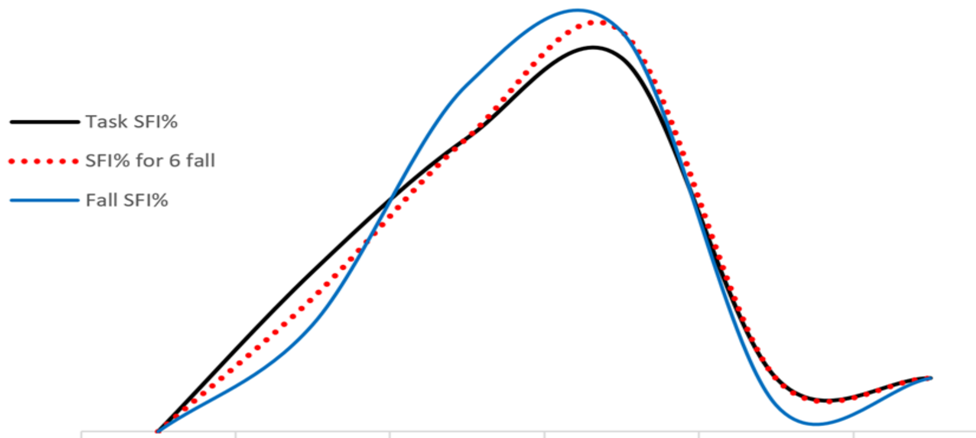


	legs	hips	Right hand	Left hand	head
F-5 (n = 5)	66.67	66.67	96.67	96.67	100
F-3 (n = 20)	30	30	86.83	86.83	93.33
F-2 (n = 5)	43.33	43.33	53.33	36.67	63.33
F-1 (n = 5)	23.33	23.33	16.67	33.33	88.57

Figure 5. S5FI%BP ratios taking into account test falls two to six combined for each fraction.

Distribution of SFI risk in different phases of the experiment and correlations of variables

The probability distribution of single- or multiple-organ injuries (two to five body parts) is close to normal in both phases of the experiment conducted. However, the distributions are slightly negatively skewed: skewness for 'test' –0.171 and for 'retest' –0.240; and for the summed results of observations from both cycles of simulated backward falls –0.207. On the model, this statistical property is illustrated by a slight shift of the apex of the most numerous SFI risk representation (high level) towards higher values of this index (Figure 6).



	very law	law	avarage	hight	very hight	extreme
Task SFI%	0	17.14	31.43	40	5.71	5.71
SFI% for 6 fall	0	14.29	31.43	42.88	5.71	5.71
Fall SFI%	0	11.43	37.15	42.88	2.86	5.71

Figure 6. Distribution of SFI risk among physiotherapy students (n = 35).

The correlations of the 'mirror pairs' SFI points indices are positive and statistically significant: very high Task 2 Fall 5 ($r = 0.788$, $p<0.01$); and high Task 1 Fall 4 ($r = 0.659$, $p<0.01$) and Task 3 Fall 6 ($r = 0.600$, $p<0.01$).

Extremely different external circumstances of simulated falls result in significant modification of motor responses (derived from different compilations of internal factors). The quantitative magnitude of the phenomenon is documented by the proportion of individuals who are stable in terms of the number of body parts at risk of damage during a fall under unfavourable conditions regardless of the degree of coordination difficulty of the motor simulations being compared, to those individuals whose motor responses change under just such experimental conditions. The evidence of a stable motor response (in terms of the number of body parts with which the person incorrectly collided with the ground during the compared falls under laboratory conditions) during Task 1 and Fall 6 concerns 25.51%. The remainder, during the last of the series of experimental falls, either reduced the risk of multi-organ damage or increased it. One of the observed subjects made no mistakes and two increased the risk to four mistakes. The statistical effect of these modifications is a set of possible SFI risk fractions emerged under six repetitions of simulated backward falls under changing external circumstances – three falls each in cycles separated by a seven-day break (Figure 7).

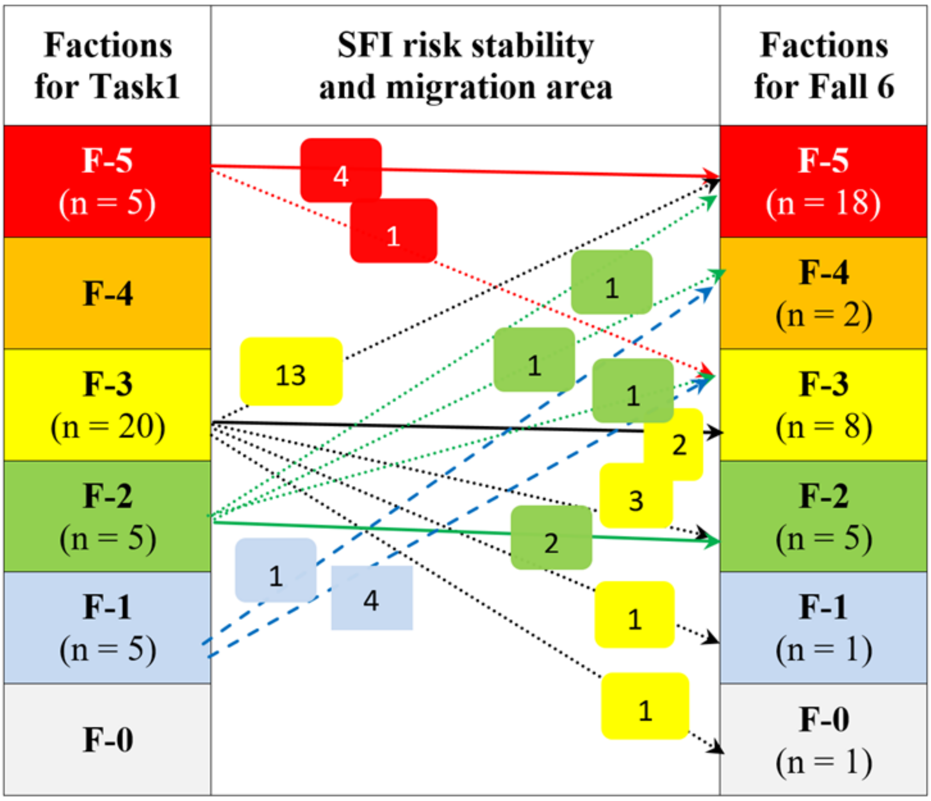


Figure 7. Stability (solid line) and migration (dotted line) model of the SFI risk of physiotherapy students (n = 35) during the first and last of simulated backward falls in two extremely different external circumstances.

A qualitative indicator of these migrations is the correlation coefficient of SFI points between Task 1 and Fall 6. An average positive correlation of r = 0. 345 ($p<0.05$) and R2 0.1190 means that there is less than a 12% probability that a person who makes 2, 3 or 5 errors during a test fall backwards onto the ground on which they are standing or moving will repeat the same number of errors in the circumstances of a backward fall from a height with feet down. We also found an average, slightly higher positive correlation (r = 0.371, $p<0.05$) when correlating SFI points between Task 1 and Task 3, i.e. between the first and third falls of the first cycle. The coefficient of determination R2 = 0.1376 means that the probability discussed above is only 1.86% higher.

The qualitative verbal assessment highlights the finding that none of the five people who made a head error during the first simulated fall (under the least demanding external circumstances) not only failed to reduce it during subsequent motor responses colliding with the ground. Four of them increased the risk of multi-organ damage to three and one to four body parts (Figure 7).

Extreme risk profiles of SFI in the two phases of the experiment

At the poles of the SFI risk continuum are three students, each from a different fraction of the initial distribution. One of them is characterized by complete repeatability of errors in a quantitative sense (he is completely resistant to motor modifications). His profile entered in the document adapted for this purpose (Table 7 to 9) would be filled in by the numbers 1 and 5 alone in the relevant rows and columns provided for quantitative assessments and 100% and code 'E' as qualitative assessments.

One student from the F-3 fraction and one from the F-1 fraction made the fewest errors over the course of the experiment (Index SFI points each = 8; risk low, 26.67%), however, their quality profiles are opposite. The one from the F-3 fraction reduced errors in the second cycle of test falls from 5 to 3, although this lower Index SFI% = 20 still confirms the low risk. His motor responses during the 'mirror' pairs of simulated falls (first and second) are fully correlated. The lack of errors during the last two simulations (Fall 5 and 6) suggest that he is the type with the self-education ability to protect distal body parts in a ground impact situation due to an unintentional fall – like the other participants in the experiment he was not taught professional safe fall either before or between one and the other cycle of these motor simulations (Table 7).

Meanwhile, the student profile from the F-1 fraction is the inverse of that described above. The correlation of motor responses during Task 1 and Fall 4 is negative, average and not statistically significant (r = –0.408). There is no statistical correlation between Task 2 and Fall 5 and between the motor responses of the last pair of 'mirror falls' r = 0.408 (Table 7).

Table 7. Profiles of students with the lowest SFI risk among those surveyed.

	Student from F-5									*Student from F-1*								
Body part	**Task**			**Fall**			**Index S_6FI: BP**			**Task**			**Fall**			**SFI: Body Part**		
	1	**2**	**3**	**4**	**5**	**6**	**pts**	**%**	**code**	**1**	**2**	**3**	**4**	**5**	**6**	**pts**	**%**	**code**
head	1	1	1	1	1	1	**6**	***100***	**E**	1	1	1	0	0	1	**4**	***67***	**H**
L hand	1	1	1	1	1	1	**6**	***100***	**E**	0	0	0	1	0	0	**1**	***17***	**VL**
R hand	1	1	1	1	1	1	**6**	***100***	**E**	0	0	0	1	0	0	**1**	***17***	**VL**
hips	1	1	1	1	1	1	**6**	***100***	**E**	0	0	0	0	0	1	**1**	***17***	**VL**
legs	1	1	1	1	1	1	**6**	***100***	**E**	0	0	0	0	0	1	**1**	***17***	**VL**
S_1FI (Task/Fall)							**Index S_6FI**			**S_1FI (Task/Fall)**						**Index S_6FI**		
points	5	5	5	5	5	5	**30**			1	1	1	2	0	3	**8**		
%	*100*	*100*	*100*	*100*	*100*	*100*	***100***			*20*	*20*	*20*	*40*	*0*	*60*	**26.67**		
code	E	E	E	E	E	E	**extreme**			L	L	L	A	VL	H	**low**		
Phase	**S_3FI**						**Index S_3FI**			**S_3FI**						**Index S_3FI**		
	sane level		**motor modification**		**from height**		**pts**	**%**	**code**	**sane level**		**motor modification**		**from height**		**pts**	**%**	**code**
Task	5 E		5 E		5 E		**15**	***100***	**E**	1 L		1 L		1 L		**3**	***20***	**L**
Fall	5 E		5 E		5 E		**15**	***100***	**E**	2 A		0 VL		3 H		**5**	***33***	**L**

Both students, who reduced the risk of SFI by 4 penalty points during a repeated cycle of simulated backward falls, proved to be simultaneously resistant to motor modifications, which, by design, should help eliminate head-on collision errors in such a situation. In addition, a student from the F-5 fraction confirmed such resistance to hands on four occasions. In the repeated cycle, he no longer made legs and hips errors when simulated falls were performed on the ground on which he was standing before the GO command. The student from the F-3 faction did not make legs and hips errors under such experimental circumstances. Both made errors with these body parts on two occasions when the simulation involved a backward fall from a height with feet down. However, only the student from the F-3 fraction reduced hands errors during the last two simulations (Fall 5 and 6), but the hand clapping initiated before the GO command was disrupted by the abrupt change from vertical to horizontal posture required by the experimental criteria. In his case, there is a full correlation between the motor responses of Task 1 and Fall 4, the two first simulations within the STBIDF (Table 8).

Table 8. Profiles of students who most effectively reduced the risk of SFI (each by 4 penalty points) in the second cycle of simulated falls (pp penalty point; 0 c ceasing to clap).

Student from F-5									
Body part	**Task**			**Fall**			**Index S_6FI: BP**		
	1	**2**	**3**	**4**	**5**	**6**	**pts**	**%**	**code**
head	1	1	1	1	1	1	**6**	***100***	**E**
L hand	1	1	1	1	1	1	**6**	***100***	**E**
R hand	1	1	1	1	1	1	**6**	***100***	**E**
hips	1	1	1	0	0	1	**4**	***67***	**H**
legs	1	1	1	0	0	1	**4**	***67***	**H**
S_1FI (Task/Fall)							**Index S_6FI**		
points	5	5	5	3	3	5	**26**		
%	*100*	*100*	*100*	*60*	*60*	*100*	***86.67***		
code	E	E	E	H	H	E	**very high**		
Phase	**S_3FI**						**Index S_3FI**		
	sane level		**motor modification**		**from height**		**pts**	**%**	**code**
Task	5 E		5 E		5 E		**15**	***100***	**E**
Fall	3 H		3 H		5 E		**11**	***73***	**H**

Student from F-3									
Body part	**Task**			**Fall**			**SFI: Body Part**		
	1	**2**	**3**	**4**	**5**	**6**	**pts**	**%**	**code**
head	1	1	1	1	1	1	**6**	***100***	**E**
L hand	1	1	1	1	0	0	**4**	***67***	**H**
R hand	1	1	1	1	0	0	**4**	***67***	**H**
hips	0	0	1	0	0	1	**2**	***33***	**L**
legs	0	0	1	0	0	1	**2**	***33***	**L**
S_1FI (Task/Fall)							**Index S_6FI**		
points	3	3	5	3	1	3	**18**		
%	*60*	*60*	*100*	*60*	*20*	*60*	**60**		
code	A	A	E	A	L	A	**average**		
Phase	**S_3FI**						**Index S_3FI**		
	sane level		**motor modification**		**from height**		**pts**	**%**	**code**
Task	3 H		3 H		5 E		**11**	***73***	**H**
Fall	3 H		1 L		3 H		**7**	***47***	**A**

Two individuals (one from the F-3 fraction and one from F-1) increased the risk of SFI, each by 4 penalty points. The student from the F-3 fraction cushioned his body's collisions with the ground flawlessly throughout the experiment, resulting in the absence of errors also identified with the ‘hips’. At the same time, he bore witness to a complete resistance to motor modifications that should help eliminate the error of head-on collision with the ground during a fall. There is a complete correlation between his motor responses during Task 3 and Fall 6. For some internal reason, from Task 3 onwards, he was already repeating hands errors by the end of the experiment. The student from F-1 fraction did not make right hand errors throughout the entire experiment. He made legs and hips errors for the first time during the motor response ending the experiment. He started the left hand from Task 2 and this was the only time he pressed the sponge with his chin against his torso and therefore did not hit his head on the ground. He was certainly not helping himself with the left hand at this point. None of this student's motor responses correlated statistically significantly when comparing ‘mirror’ simulated falls (Table 9).

Table 9. Profiles of students who increased their SFI risk the most (each by 4 penalty points) in the second cycle of simulated falls.

Student from F-3									
Body part	**Task**			**Fall**			**Index S_6FI: BP**		
	1	**2**	**3**	**4**	**5**	**6**	**pts**	**%**	**code**
head	1	1	1	1	1	1	**6**	***100***	**E**
L hand	0	0	1	1	1	1	**4**	***67***	**H**
R hand	0	0	1	1	1	1	**4**	***67***	**H**
hips	0	0	0	0	0	0	**0**	***0***	**VL**
legs	0	0	0	0	0	0	**0**	***0***	**VL**
S_1FI (Task/Fall)							**Index S_6FI**		
points	1	1	3	3	3	3	14		
%	*20*	*20*	*60*	*60*	*60*	*60*	***46.67***		
code	L	L	H	H	H	H	**average**		
Phase	**S_3FI**						**Index S_3FI**		
	sane level		**motor modification**		**from height**		**pts**	**%**	**code**
Task	1 L		1 L		3 H		**5**	***33***	**L**
Fall	3 H		3 H		3 H		**9**	***60***	**H**

Student from F-1									
	Task			**Fall**			**SFI: Body Part**		
	1	**2**	**3**	**4**	**5**	**6**	**pts**	**%**	**code**
head	1	0	1	1	1	1	**5**	***67***	**VH**
L hand	0	1	1	1	1	1	**5**	***67***	**VH**
R hand	0	0	0	0	0	0	**0**	***17***	**VL**
hips	0	0	0	0	0	1	**1**	***17***	**VL**
legs	0	0	0	0	0	1	**1**	***17***	**VL**
S_1FI (Task/Fall)							**Index S_6FI**		
points	1	1	2	2	2	4	**12**		
%	*20*	*20*	*40*	*40*	*40*	*80*	**40**		
code	L	L	A	A	A	VH	**average**		
Phase	**S_3FI**						**Index S_3FI**		
	sane level		**motor modification**		**from height**		**pts**	**%**	**code**
Task	1 L		1 L		2 A		**4**	***27***	**L**
Fall	2 A		2 A		4 VH		**8**	***53***	**A**

4. Discussion

In our opinion, the most important findings of this research are relevant from the perspective of improving methods for measuring the risk of injury during a fall. This phenomenon is referred to in the scientific literature as SFI by the experts of the Polish School of Safe Fall – this was the first time this also symbolic name was used by Ukrainian researchers [11].

A secondary analysis of the results of the validation procedure of the first test measuring the SFI phenomenon, based on three tasks (simulated backward fall from a height with feet down), each of increasing coordination difficulty (STBIDF [1, 2]), took into account each time not only the observation of the five body parts, but also an adjustment of the evaluation rules. In the original version of this test, the evaluation of the risk of damage to the lower limbs (criterion: errors made during the required jump off the 20 cm platform during Task 3) was associated with a three-stage scale: either no error (0); first-degree error (1); or second-degree error (2). This digital record of errors during motor responses to arranged backward fall simulations in three modified external circumstances (STBIDF) and in six for STBIDF-M, is otherwise a penalty point. Meanwhile, the errors documented by symbolically recording the variable 'hips' (and it is also about the torso) as 1 penalty point is a consequence of insufficient cushioning of the falling body by the legs. The adjustment is seemingly insignificant in a mathematical sense, as although the Index SFI increases by 1 penalty point for each finding of hips/torso ground impact errors, the maximum Index SFI value can be 15 penalty points (previously 14). Therefore, by one rather than two, although a 'hips' error can be made during Task 1 and Task 2 (when 'legs' were not evaluated) as we have reduced 2 penalty points to 1 point evaluating legs errors during Task 3.

In fact, a score of 15 penalty points indicates a three-fold failure of each of the five observed body parts during impact under safe laboratory conditions. This, in turn, represents an extreme risk of multi-organ injury in the unfavourable circumstances of an unintentional fall outside laboratory conditions.

This ultimately small mathematical correction is of momentous evaluative significance in motor simulations with a larger number of repeated falls. As the empirical data from these studies confirm, that although there are small and statistically insignificant quantitative differences, the qualitative indicators reveal the complexity of the phenomenon in various aspects. For example, it is easy to observe both the change in external circumstances and even the details of individual motor responses under identical external circumstances for each of the observed individuals (stepping down rather than jumping off a 20 cm platform, ceasing or continuing to clap hands when changing posture from vertical to horizontal, etc.). However, these motor responses are derived from intrinsic factors (various personality characteristics – to which we again draw attention) and are not subject to direct observation. It turns out that only in some individuals are motor responses statistically significantly correlated in so-called 'mirror circumstances', but the relationship with events separating these circumstances is not clear. In the course of this experiment, the obvious event was the seven-day interval of repeated motor simulations, but the influences of the internal experience from the 'test' procedure stage are still a mystery.

Thus, an obvious question arises: will an extended cycle of simulated falls (as in the case of STBIDF-M up to six [4]) and then repeated seven days apart [8] reveal significant adaptive tendencies (not discovered in the course of these studies) in some proportion of subjects with similar demographic characteristics to those participating in the experiment analysed secondarily in this work?

It is only difficult to predict the answer to this question. What is certain is that we have a videotape of the STBIDF-M 'test-retest' procedure [8], and this means that a secondary analysis based on the evaluation criteria described in this thesis and conducted by the same team of researchers may not be deformed in terms of methodological criteria. Instead, it may produce new findings of a cognitive nature.

With our knowledge of the results of the STBIDF-M 'test-retest' procedure [8], we emphasise that the division into six alternative fractions of observed individuals in terms of establishing initial SFI risk is still in the theoretical realm. However, we believe that this criterion for initial subdivision is appropriate and not in view of the obvious possibility of repeating the study in the future with a much larger sample from the population. In everyday human physical activity, with the exception of professional safe fall training (exercise), such an accumulation of consecutive falls and, on top of that, under dynamically changing external circumstances does not in principle occur.

Most often, however, an unintentional fall occurs when a person is not sufficiently stimulated physically, mentally, emotionally, etc., so that his or her motor response is characterised by the lowest possible risk of injury during a collision with the ground [12-23]. The fact that some adult women and men are able to reduce this risk, without the need for prior education, neither justifies the global dimension of preventive omissions, nor undermines the sense of holding on to the results of this first motor simulation as a preliminary criterion for dividing people into factions due to the potential risk of injury during a fall. Also, precisely because of the far-reaching preventive goals.

This criterion has an important advantage in terms of methodological validity. None of the subjects in the two experiments we are discussing had been previously stimulated, motorically or otherwise, to perform a primary simulated backward fall under safe laboratory conditions that were the same for all. This initial simulation – we deliberately repeat – is a change from a vertical to a horizontal posture on the ground on which the observed person is standing.

We anticipate greater dispersion within the stability and migration of SFI risk (as determined by the Task 1 results of the first cycle) in the course of even more multiplied test falls. However, this preliminary hypothesis is of little significance, with the knowledge that the motor criteria and external circumstances of this first simulation are too liberal to be assigned the valence of even a preliminary predictor of SFI risk.

We therefore draw attention to the simplicity and clarity of the recording of the results of each falls simulation modelled in Tables from 7 to 9. These results documented in simple zero-one notation and read competently meet the criteria of a unique, multivariate predictor of SFI risk. Thus, this individual SFI risk profile of an observed person is sufficiently documented to design an optimal preventive intervention programme. The usefulness of such a profile in combining prevention with therapy in any case of identified traumatic experience having previous falls is not excluded.

The conventionally named "motor response rectangle for SFI risk estimation" is, for this research, based on the results of six simulations and has 6 columns and 5 rows. The number of rows remains constant in every other model, in contrast to the number of columns and the potential variability of the simulated event – with the exception of Task 1. The columns report events repeated as a function of time (because nothing can happen outside of time), and each individual event is a more or less conscious motor response by five body part at a given moment in time. These moments in laboratory conditions of changing from vertical to horizontal posture last in the likeness of the elapsed time from the moment of loss of equilibrium to the collision of the body with the ground in any other non-experimental circumstances.

In this experiment, the ordering was as follows: from the first simulation of a fall under the least demanding circumstances in terms of coordination difficulty (Task 1 STBIDF) to the third, ending the first cycle of simulations and also the most complex in coordination terms (Task 3) and during the 'mirror' simulations in the repeated cycle that ends Fall 6. The 'rectangle' part shaded in blue informs the initiated user that the results of the second cycle were separated by a 7-day break.

The rows (first head, up to the fifth legs) are knowledge carriers about the stability or changing risk of failure of individual body parts as a function of time and due to or arranged external circumstances. The remaining columns and rows are populated with relevant quantitative and qualitative indicators describing the SFI risk phenomenon in the plotted experimental formula.

5. Conclusions

The motor habits established during adolescence, associated with multiple changes of vertical to horizontal posture during the day (tilting the head), and even more often sitting on platforms (chairs, etc.) or the ground, supporting oneself with hands (also when getting up), suppress the positive adaptive potential of the applied motor modifications in STBIDF. These observations, associated with the previous recommendations of the experts of the 'Polish School of Safe Falling', extend the evidence of ignoring necessary interventions starting from preschool education.

This conclusion in complementary terms is justified, among other things, by the results of the analyses presented in this thesis. Extending this knowledge with conclusions from observing the motor responses of similarly aged individuals from the same academic community in the circumstances of multiplied test falls may prove crucial for the development of a universal, equally safe, but even more cognitively valuable tool for measuring the risk of injury during a fall.

Data Availability Statement: The data supporting this study's findings are available from the corresponding author upon reasonable request.

Acknowledgments: The authors thank all coaches and swimmers who participated in the study.

Conflicts of Interest: The authors declared no conflict of interest.

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Citation: Kalina A, Kruszewski A, Gąsienica-Walczak B. Motor modifications versus movement habits in measuring the SFI phenomenon. Arch Budo J Inn Agon 2024, 20: 250-269