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Susceptibility to injury during falls in men practicing combat sports

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Dictionary:

Technique – specific procedures to move one's body to perform the task that needs to be accomplished [79].

Contact sport – *noun* any sport in which physical contact between players is an integral part of the game, e.g. boxing, rugby or taekwondo [79].

Ukemi – the term for breakfalls designed to process the body when thrown [80].

Kup – a term used to denote denote one's technical level in taekwondo (preceding dan level, i.e. black belt).

Kyu –*noun* a level of proficiency in some martial arts [79].

INNOAGON – (innovative agonology) is an applied science dedicated to promotion, prevention, and therapy related to all dimensions of health and the optimization of activities that increase the ability to survive (from micro to macro scales) [69, 70].

Abstract:

Background and Study Aim: The recommended prophylaxis of falls most often involves training muscle strength and balance. However, there are both people who, despite regular physical activity, suffer bodily injuries as a result of an unintentional fall, and those who, in such circumstances (despite the lack of professional preparation for safe fall), are able to cushion the impact with the ground and protect the distal parts of the body. The cognitive aim of this study was knowledge about the possibilities of protecting distal parts of the body during a fall by people practising combat sports and in non-practising men.

Material and Methods: 241 men were studied. Group 1 comprised 107 practitioners of combat sports; Group 2 comprised physically active persons (n = 66); and Group 3 comprised physically inactive persons (n = 66). The susceptibility test to the body injuries during the fall' (STBIDF) was used. We base our analysis on the primary evaluation criteria of the SFI (susceptibility to bodily injuries during a fall) phenomena. However, we use a modified name for the overall STBIDF results index (SFI Index) – the sum of the points informing about the mistakes made during the three motor tasks: 0 low; 1–3 average; 4–8 high; and 9–14 very high.

Results: The persons who practised combat sports achieved a significantly lower overall SFI Index (2.27 points) than the non-practising persons (5.32, $p<0.001$). The overall score obtained in the test by the physically active persons (Group 2) was 4.82; while the inactive persons (Group 3) obtained an overall score of 5.79. Taking all of the studied persons into consideration (n = 241), a significant positive correlation was observed between the SFI Index and the number of declared injuries ($r = 0.364$, $p<0.001$).

Conclusions: The practitioners of combat sports committed fewer mistakes while performing the STBIDF and sustained fewer injuries during falls before tests. Combat sport training (especially judo, ju-jitsu and wrestling) is a good example of preventing bodily injuries during a fall. Frequent, unintentional falls (as a result of the competitor's effective actions during training and tournament fights), but also during repeated throws during technical training sessions, are the elements that teach the specific ability to protect one's own body during a collision with the ground.

Keywords: contact sports, safe falls, ukemi

1. Introduction

Falls could occur in all stages of life, more often among children and people above 65 years old. These constitute the main cause of permanent injuries in the elderly population. Injuries caused by falls even often lead to death [1]. It has been estimated that among people over age 65, some 40% of them fall at least once a year. However, with age, this proportion grows. The result of nearly half of the falls are injuries such as broken bones, dislocation of joints or soft tissue contusions. Most injuries involve the hands (wrist joints), elbows, knees and spine. In the elderly (over 75 years old) the effect of falls is 100% fractures of the forearm, 90% of fractures proximal femur, and about 25% fractures of the spine [1, 2].

Most of the methods that have been developed so far for preventing falls have focused on risk assessment, the elimination of risk factors, the improvement of the functioning of organs and systems, and supplements of calcium and vitamin D. The suggested prophylaxis involves, in particular, training muscle strength and balance [1].

However, these actions are mainly aimed at preventing falls, without addressing the issue of preventing or reducing the consequences of falls, e.g. teaching a person how to fall safely, to protect one-self and to avoid collisions [3-9]. The ability to protect one's own body during a fall could be the most effective method of preventing negative consequences. Therefore, developing a motor habit of proper falling could significantly reduce the number of injuries and the resulting mortality, especially in the population of elderly and disabled persons [2].

Without a doubt, a healthy lifestyle, and especially regular physical activity, helps a person to maintain independence and the ability to function. Physical exercise improves postural stability and balance, and increases or maintains strength and endurance [10-17]. Furthermore, in some sport disciplines, the ability to protect oneself and to collide with the ground or the opponent safely is one of the aims of training. This particularly concerns contact sports, including combat sports [18, 19].

Regardless of the validity of the above recommendations, individual people are extremely susceptible to bodily injury during a fall (unintentional or intentional) in identical external circumstances. Gąsienica-Walczak and Kalina [20] assigned the symbol SFI (susceptibility for fall injuries) to this phenomenon. It has been empirically proven many times that there are both people who, despite regular physical activity, suffer bodily injuries as a result of an unintentional fall, and those who, in such circumstances (despite the lack of professional preparation for safe fall), are able to cushion the impact with the ground and protect the distal parts of the body [21-31].

Therefore, the cognitive aim of the study was knowledge about the possibilities of protecting distal parts of the body during a fall by people practising combat sports and in non-practising men.

The effect of the decomposition of the goal into research tasks is three questions: Is there were a correlation between the declared location of fall injuries among people with different physical activities, including practicing different combat sports, and the rates of collision errors with the ground by individual body parts under laboratory observation conditions? What were the most common locations of body injuries after falls? Which combat sports is the most suitable for injury prevention?

2. Materials and Methods

The study encompassed 241 healthy men aged 17-35 years. Group 1 (experimental) comprised 107 sportsmen who practised judo (n = 36), taekwon-do (n = 23), ju-jutsu (n = 17), karate (n = 17), and wrestling (n = 14) – total 107. Group 2 (active, n = 66) comprised persons who did not practise combat sports, but who engaged in other sport disciplines or forms of activity (for a minimum of two times a week). Group 3 (inactive, n = 66) comprised persons who did not engage in regular, organised physical activity (Table 1 and Table 2). The criteria for inclusion in the experimental group were as follows: active participation in trainings and competitions; possessing a valid sportsperson's licence for an appropriate sports association; a minimum of four years of training experience (in combat sports); and a minimum 2nd kyū in judo, jujutsu and karate and 4th kup in taekwondo.

Table 1. Characteristic of examined persons.

Group	Age [years]	Body mass [kg]	Body height [cm]
1 combat sports (n = 107)	24.15 ±6.21	79.37 ±14.15	177.84 ±6.93
2 active (n = 66)	22.19 ±2.56	80.61 ±12.67	181.14 ±6.13
3 non-active (n = 68)	22.22 ±2.67	77.21 ±10.18	180.67 ±6.84

Table 2. Characteristic of combat sports competitors (Group 1) – order variable from the largest to the smallest (if equal, alphabetical order of names).

Combat sport	Age [years]	Body mass [kg]	Body height [cm]	Training experience [years]	Frequency of training [n/week]
Judo (n = 36)	21.27 ±3.78	74.31 ±13.11	176.72 ±6.91	10.23 ±5.12	5.33 ±1.06
Taekwondo (n = 23)	26.56 ±5.23	81.52 ±16.27	178.22 ±7.26	9.69 ±5.66	4.27 ±0.87
Ju-jitsu (n = 17)	27.08 ±5.38	83.29 ±10.88	180.94 ±6.42	6.88 ±4.42	5.66 ±1.48
Karate (n = 17)	23.78 ±6.91	77.08 ±13.50	176.14 ±6.87	5.51 ±2.09	4.11 ±0.70
Wrestling (n = 14)	25.78 ±4.44	86.21 ±13.57	177.57 ±5.98	12.64 ±5.99	4.64 ±1.18

Criteria for evaluating the SFI phenomenon

The SFI was evaluated with 'the susceptibility test to the body injuries during the fall' (STBIDF) [32, 21]. The test comprises three motor tasks that are performed on an exercise mattress. The safe, motor simulation of a backward fall under laboratory conditions is preceded by a pre-test (performing a deep squat several times with the hands resting on the hands of the researcher [33]). In this simple way, the ability to cushion the change from vertical to horizontal posture with the lower limbs is verified (lying down as quickly as possible on the back on a soft surface is each time this simulated fall). Two motoric modifications during Tasks 2 and 3 provide information either about resistance to these modifications, or about the tendency to increase the

number of mistakes, or about sensitivity, the effect of which is subconscious reduction of errors during the collision with the ground.

Task 1 involves moving from a vertical (standing) position to a horizontal position (lying on the back) on a mattress as quickly as possible, with the lower limbs, buttocks, back, upper limbs and head touching the ground (contact of the hands and head with the ground while adopting a horizontal posture is classified as a mistake).

Task 2 is a modification of the first task, where the participant moves from a vertical posture to a horizontal posture (lying position), but additionally presses an exercise pouch with the chin to the sternum and claps with the hands.

Task 3 is similar to the second task, with the exception that the movement to the lying position is preceded by jumping upwards as high as possible (or jumping from a 20 cm platform).

Each participant began each task at a signal. In the second and third tasks, the participant stopped clapping at the command 'stop'. All of the participants were instructed to start and perform each task as quickly as possible as the first priority, and then secondly to focus on the precision of the performed movements. Each task was evaluated by the researcher. The evaluation criterion consisted of the protection of the body parts that were the most exposed to damage (the legs, hips, arms and head) during a fall. All mistakes (where the specified body part touched the ground incorrectly) were noted down as one or two points in an observation sheet.

We base our analysis on the original evaluation criteria [32, 21]. However, we use a modified name for the overall STBIDF results indicator (SFI Index) [20, 30]. That is the sum of the points informing about the mistakes made during the three motor tasks: 0 low; 1–3 average; 4–8 high; and 9–14 very high [8].

In Task 1, the mistakes involved: colliding with the mattress with the buttocks (1 point); maintaining a right or an obtuse angle between the thighs and the lower legs (1 point); supporting oneself with the hands at the back or at the level of the hips (1 point for a one-hand support and 2 points for a two-hand support); colliding with the ground with the elbows (1 point for one arm and 2 points for two arms), and keeping the head tilted backwards or colliding with the ground with the head (1 point). However, it was considered as correct to support oneself with the hands at the front by performing a squat prior to rolling onto one's back [8].

In Task 2, addition mistakes involved: losing, or holding the pouch with the hand (1 point); lack of control over the pouch while lying down (1 point); and interrupting the clapping during the task (1 point). The remaining criteria were the same as in Task 1[8].

Additional mistakes in Task 3 included: landing without bending the knees (2 points); and landing on one leg (1 point) [8].

The studied persons also completed an author's survey that included information concerning, e.g. their practised discipline, training experience, number of falls, and the number and kinds of injuries they had experienced due to falling.

The research related to human use has complied with all the relevant national regulations and institutional policies, has followed the tenets of the Declaration of Helsinki. The study was approved by the Research Ethics Committee of the Józef Pilsudski University of Physical Education in Warsaw (No. SKE 01-38/2023).

Statistical analysis

The empirical data was analysed using standard statistical methods – arithmetic means (M), standard deviations (SD or ±). The relationships between the individual variables were determined with the Pearson product-moment correlation. The significance of differences between the experimental Group (1) and the control Groups (2 and 3) was evaluated with the Mann-Whitney U test. Additionally, analyses with the Kruskal-Wallis test were con-ducted to assess the differences between the sportsmen from the different groups and combat sport disciplines. The minimal level of significance was assumed at $p<0.05$. The calculations were conducted with the use of MS Excel and Statistica 10 software.

3. Results

The persons who practised combat sports obtained a significantly lower overall score in the test documented by Index SBIDF 2.2 than the non-practising persons (5.32, $p<0.001$). This result indicates that they committed fewer mistakes while performing the test. The overall test result (Index SBIDF) for the physically active persons (Group 2) equalled 4.89; while the result obtained by the physically inactive persons (Group 3) was 5.87 (Table 3). Both of these results were significantly higher ($p<0.001$) than the results achieved by the practitioners of combat sports. The most common mistakes made by the study participants from all groups was placing one's arms incorrectly. However, the practitioners of combat sports made the fewest mistakes with respect to the position of the head. In both control groups, the fewest mistakes were committed with the legs. Significant differences between Group 1 and the other groups were observed in each category of the mistakes, with the highest differences noted with respect to the "Head" category. Overall, the most mistakes were observed in Task 3, and the fewest in Task 2. The differences between the results of the practitioners of combat sports and the study participants from the control groups were significant ($p<0.001$) and concerned every task.

Table 3. Susceptibility to injury during falls.

Group	Legs	Hips	Hands	Head	Index SBIDF
1 (n = 107)	0.43 ±0.39	0.71 ±0.46	0.99 ±0.62	0.27 ±0.23	2.20 ±0.96
2 (n = 66)	0.76 ±0.47	1.06 ±0.68	1.71 ±0.78	1.36 ±0.59	4.89 ±2.04
3 (n = 68)	0.97 ±0.48	1.51 ±0.77	1.75 ±0.79	1.63 ±0.69	5.87 ±2.39
differences	0.044	0.021	0.008	0.000	0.000

In the group of sportsmen who practised combat sports, 16 (14.93%) of the practitioners obtained 0 points (no mistakes), which indicates a low susceptibility to injury. In the control groups, no one performed the test without making any mistakes. Moreover, more than half of the persons from Groups 2 and 3 were characterised by a high or very high susceptibility to injury; whereas no participant in Group 1 obtained more than 9 points, i.e. a result that would indicate a very high susceptibility to injury (Table 4).

Table 4. Susceptibility to injury during falls (categories).

Group	Low	Average	High	Very high	Difference
1 (n = 107)	21 (20%)	62 (58%)	24 (22%)	0	
2 (n = 66)	0	22 (33%)	41 (62%)	3 (5%)	0.001
3 (n = 68)	0	12 (18%)	47 (69%)	9 (13%)	

The results of the STBIDF also varied significantly for the practitioners of different combat sports ($p<0.001$). The lowest result was obtained by the judokas, and the highest result was achieved by the taekwondo fighters. The judokas committed the least mistakes in the 'legs', 'hips' and 'arms' categories. The greatest differences occurred for mistakes in the 'head' category (Table 5). The overall score of the judokas was significantly lower than the result achieved by the wrestlers ($p = 0.021$) and taekwondo fighters ($p<0.001$). A significant difference ($p = 0.009$) was also observed between the results achieved by the jujutsu fighters and taekwondo fighters. As far as the location of the mistakes is concerned, the highest number of significant differences was observed in the 'head' category, where the taekwondo fighters obtained a significantly higher result than the sportsmen from the remaining disciplines. However, no significant differences in the actual occurrence of injuries were observed between the practitioners of judo, jujutsu, karate, wrestling and taekwondo.

Table 5. Results of in Group 1.

Sport	Legs	Hips	Hands	Head	Sum
Judo	0.17 ±0.16	0.42 ±0.81	0.69 ±0.78	0.19 ±0.21	1.5 ±1.08
Jujitsu	0.35 ±0.39	0.88 ±1.11	0.71 ±0.69	0	1.94 ±1.52
Karate	0.37 ±0.44	0.62 ±0.59	1.06 ±1.03	0.12 ±0.21	2.05 ±1.12
Wrestling	0.43 ±0.85	1.07 ±1.32	1.29 ±1.2	0.07 ±0.17	2.79 ±1.89
Taekwondo	0.96 ±1.02	1.09 ±1.12	1.61 ±1.34	0.7 ±0.63	3.48 ±1.83
Chi-square	12.809	8.919	9.322	25.168	19.102
Difference [p]	0.005	0.03	0.025	0.000	0.000

Injuries

The studied persons declared 581 injuries (on average, 2.41 per person) that were not related to practising sport. However, the persons from the control groups sustained injuries significantly more frequently than the practitioners of combat sports (Group 1: on average, 1.14 injuries per person; Group 2: 3.14, $p = 0.004$; Group 3: 3.71, $p = 0.002$). Bruises and tendon/ligament ruptures were the injuries that occurred the most frequently (Group 1: 0.56; Group 2: 1.67, $p<0.001$; Group 3: 1.69, $p < 0.001$), while joint dislocations and sprains were less frequent (Group 1: 0.42; Group 2: 1.1, $p = 0.032$; Group 3: 1.67; $p = 0.021$), and bone fractures, the number of which did not differ significantly between the groups, were the least frequent type of injury (Group 1: 0.41; Group 2: 0.37; Group 3: 0.36). As far as the location of injuries is concerned, injuries of the lower limbs were declared the most frequently; and injuries of the head and spine were declared the least frequently. The tarsal joint was the most frequently injured bodily structure (Group 1: 0.26; Group 2: 0.59; Group 3: 1), followed by the knee joint (Group 1: 0.11; Group 2: 0.49; Group 3: 0.72), the fingers (Group 1: 0.27;

Group 2: 0.18; Group 3: 0.52) and the wrist joint (Group 1: 0.15; Group 2: 0.41; Group 3: 0.44).

Correlations

Taking all of the studied persons into consideration (n = 241), a significant positive correlation was observed between the result of the test (SFI Index) and the number of declared injuries (r = 0.364, p<0.001). Significant correlations were also observed between the Index $_{SBIDF}$ and the number of injuries of the head/spine (r = 0.262, p = 0.001) and the upper limbs (r = 0.319, p<0.001), as well as between the results of each task and the number of injuries, and between each category of mistakes and the number of injuries. There were also significant correlations between Index $_{SBIDF}$ and number of injuries in each group (Table 6).

Table 6. Correlations between the results of STBIDF and number of body injuries.

Group	Localization of body injuries			Sum of injuries
	head / spine	upper limbs	lower limbs	
All (n = 241)	0.262***	0.319***	0.094	0.364***
1 (n = 107)	0.084	0.209*	0.062	0.201*
2 (n = 66)	0.182	0.496***	0.172	0.370**
3 (n = 68)	0.327**	0.409***	−0.060	0.280*

*p<0.05; **p<0.001; ***p<0.001

4. Discussion

Preventing falls is difficult, mostly due to the complexity of their causes; however, it is not impossible. Physical activity, recreation and motor rehabilitation can play an important role in the prevention of falls. Admittedly, studies by Sterkowicz et al. [34] as well as by Syska and Bógdał [35] proved that the ability to protect oneself and to position one's own body correctly during a fall are not related to the overall physical fitness, as even persons characterised by a high level of fitness may not be able to soften the collision be-tween their body and obstacles or the ground, and are consequently exposed to injuries. However, Czerwiński et al. [1] and Tinetti et al. [11 36] pointed out that physical activity should be a basis in the prophylaxis of falls because it increases the osseous mass, improves the functioning of the cardiorespiratory system, increases the range of motion in the joints and the increases muscle mass. Therefore, thanks to physical activity, the level of fitness increases and this minimises the risk of falls and the resulting body injuries [37, 36, 38, 39]. The analysis of the results conducted in this present study leads to similar conclusions. Admittedly, neither the level of physical activity nor physical fitness was investigated directly in this study, but physically active persons performed the motor tasks of the STBIDF better and declared bodily injuries less frequently. The greatest differences in the test results and in the number of bodily injuries were observed between the sportsmen practising combat sports and the persons from the control groups.

Other authors have also reported a beneficial effect of practising combat sports and hand-to-hand combat systems in the prevention of falls [40, 6, 41, 22, 42]. Primarily, they have focused on different aspects of preventing falls and their consequences. One of these aspects is motor coordination: balance and postural stability. Bączkowicz et al. [43] observed a relationship between reduced postural stability and the number of falls in a population of older people. The study by Mraz et al. [10] concerning motor

coordination (the ability to maintain body balance) in physically active young and elderly people did not reveal significant differences between the studied groups; however, the study emphasised a beneficial effect of fitness and physical activity among older people on their balance ability. Famuła et al. [2] reached a similar conclusion while evaluating postural stability on a stabilometric platform, where significantly better results were obtained by the studied persons who declared regular physical activity.

The role of the muscles in softening impact is an important factor in the prevention of falls and the resulting body injuries [44, 45, 28, 20]. As a result, strength exercises (apart from balance exercises) are the main element of falls prevention programmes [1]. Combat sport training is aimed at the optimal development of the motor features, but building strength is also an important part, and the practitioners of these sports are characterised by a high level of muscle strength [46-52]. Strength exercises are also an important element of health training based on combat sports and other hand-to-hand combat systems [53-55]. Importantly, increasing the muscle strength concerns both the postural muscles and the deep muscles. Frequently performing callisthenic exercises additionally forms a sense of self-control and teaches the practitioner how to protect one's own body [56-60].

The results of this study show that the men who practised combat sports performed the motor tasks they were instructed to do much better, and they sustained injuries less often after falling. This may be the result of their ability to fall safely (*ukemi*), which is formed even at the initial stage of the training and is one of its basic elements [4]. Leavitt [61] suggests that learning how to fall safely may help in preventing body injuries sustained during falls in the later period of life. According to Kalina et al. [3], learning the motor habit of falling safely is recommended even for elderly persons, despite the fact that the related exercises may be quite difficult for persons who are less physically fit. However, out of several thousand studied persons who underwent safe fall training based on judo (*ukemi*), bodily injuries occurred only in a few cases (and included no persons over 40 years of age) [3]. The usefulness of safe fall training based on combat sport training techniques has been confirmed by Weerdesteyn et al. [40]. Even a few sessions of safe fall training help to reduce the fear of falling and allow a person to learn the basics of protecting one's own body, which in turn may significantly reduce the risk of falling and the resulting body injuries [40].

Limitations of the study

The limitation of the research is subjective assessment of the. The score is awarded by the researcher. However, the research in this work was conducted by a qualified person with extensive experience in the field of functional assessment. More recent tests, also using the STBIDF-M, use video technology, allowing multiple observations of how a task or the entire test is performed [20, 31].

The STBIDF is used by the researchers and has been described in the literature [6, 21, 62, 19, 38, 7, 22, 23, 13, 50, 24-27, 29, 30]. It is used for athletes, across all disciplines (not only combat sports). Another advantage is its simplicity and the possibility of performing it in anywhere (in sports hall) during the training session, without any special tools.

However, we left out the issue of innovative methods to measure SFI among children aged two to six years old [63, 64].

Directions for further research

The methods of preventing falls that have been developed so far mainly concern improvements to the functioning of the organs and systems, the elimination of risk factors, and supplementing the body with calcium and vitamin D. The recommended prophylaxis involves the training of muscle strength and balance [1]. However, the above-mentioned actions are aimed only at minimising the risk of falling and do not address the issue of preventing or reducing the consequences of falling (e.g. through learning how to fall safely, protect one's own body and avoid collisions). The issue of the ability to cope after a fall was researched by Żak [65] who proved the effectiveness of physical therapy programmes in teaching patients how to get up after a fall by using the method of backward movements. However, none of these programmes has been sufficiently effective (which is proven by an increasing number of falls and the resulting injuries).

The ability to protect one's own body during a fall could be the most effective method of preventing the undesirable consequences of falling. Furthermore, developing the motor habit of proper falling would help to reduce the number of related injuries, especially in children, older people and physically weak persons (persons with illnesses and disabilities), where the risk of falling is considerably higher [66]. Reliable verification of the effectiveness of falls and injury prevention methods should be the main direction of further research activities. All the more incomprehensible is the lack of implementation of the unique achievements of the Polish School of Safe Falling, of which the results of the SFI phenomenon presented in this work are a key element. Breaking mental barriers [67, 68], as well as promoting the new applied science INNOAGON [69-73] from micro to macro scales, are in our opinion the most urgent tasks in fulfilling the social mission of science.

Practical recommendations

The modern lifestyle does not encourage physical activity. Also, because many persons work mostly in a sitting position, have no time for any kind of activity and are often overweight, weaker and less physically active, they are more exposed to falling. With an ageing population, the issue of falls will continue to intensify. This is why it is highly important to develop an effective programme for preventing falls – in a universal sense, as a key element of modern preventive medicine [76-78]. Also, alternative programme that teaches safe falling techniques based on the elements of combat sport training could play a significant part.

5. Conclusions

The practitioners of combat sports committed fewer mistakes while performing the STBIDF and sustained fewer injuries during falls before tests. Combat sport training (especially judo, ju-jitsu and wrestling) is a good example of preventing bodily injuries during a fall. Frequent, unintentional falls (as a result of the competitor's effective actions during training and tournament fights), but also during repeated throws during technical training sessions, are the elements that teach the specific ability to protect one's own body during a collision with the ground.

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

Institutional Review Board Statement: The study was approved by the Research Ethics Committee of the Józef Pilsudski University of Physical Education in Warsaw (No. SKE 01-38/2023).

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