Effectiveness of avoiding collision with an object in motion – virtual reality technology in diagnostic and training from perspective of prophylactic of body injuries

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

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Abstract

Background and Aim: People older than 60 years, with dysfunctions of musculoskeletal or motor system, impaired vision or hearing etc. are in a group of higher risk of collisions with objects in motion, which suddenly are heading towards their body (cyclists, runners, thrown an object, intentional punch or kick etc.). This study aims to verify compensation possibilities of this category of threats by a person who is cumulating a few factors of higher risk of collision with an object in motion heading toward his head, but on the other hand, having a longstanding adaptation for this kind of threats.

Material and Methods: Two men have been subjected to the study: a man A 68-years-old and man B 27-years-old. Measurements have been performed with the use of MVN Biomech System (XSENS). Application projects a ball with a diameter of 12 cm, which fly with constant velocity (three trials; 10-, 6- and 3 m/s) alongside axis perpendicular to a frontal plane on the height the head and legs of the participant in an initial moment.

Results: Man **B** avoided collision head with an object in motion three times. Man **A** avoided it only with a velocity of 3 m/s. Mean time of reaction of man **A** was 0.407 ±0.27s and was 35% longer than man **B** (0.263 ±0.05s). Man **A** performed body rotation faster (0.870 ±0.636s) than **B** (1.133 ±0.054s); moves his centre of mass more efficiently in the frontal plane (5.953 ±0.034deg) and sagittal plane (6.185 ±0.959deg) than man **B** (9.825 ±2.909deg) and (13.001 ±0.451deg). Man **A** managed to avoid collision with a ball with a diameter of 12 cm for the left knee at the highest velocity (10 m/s). Man **B** did not avoid collision nor for the left or right knee in the same circumstances. Kinematic trajectory for following velocities registered for 27 years old man differs significantly.

Conclusion: Positive adaptation effects for 68 years old man (most of the analysed time graphs of kinematics quantities were similar) is an empiric proof, that some category of "life sports" guarantee an optimal level of motor safety to a late elderly. Furthermore, adequately adapted virtual reality technology could be an effective and attractive tool for enhancing training of avoiding collisions on small space (in the apartment, garage etc.) despite weather or other circumstances.

Key words: health-related training • life sports • motor safety • prophylactic and therapeutic agonology • martial arts • safe fall

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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***) [19].

Sabaku – to move to an advantageous position. Also called ***tai-sabaki*** (body movement) and ***ashi-sabaki*** (footwork) [19].

Tai-sabaki – body movement [19].

INTRODUCTION

Alongside with falls and collisions with a ground or vertical objects, collisions with objects in motion belongs to one of the most common causes of body injuries or death. Group of these issues belongs to the most neglected areas of public health in both exploratory and application areas, especially in body injuries prevention. Differences are seen on a level of epidemiology monitoring of such phenomena. Most of the reports are about risk factors, directs causes and results of falls [1-4]. A few studies provide information about numbers and results of collisions of men with vertical objects and objects in motion [5, 6].

Similar to falls, both categories of collisions, have direct relation with ***motor safety*** (is consciousness of the person undertaking to solve a motor task or consciousness the subject who has the right to encourage and even enforce from this person that would perform the motor activity, who is able to do it without the risk of the loss of life, injuries or other adverse health effects [7]). It is hard to question an assumption that optimal adaptation for protection of one's body during a fall and collisions should be expected from people who are combat sports, martial arts and games. This division is too general to acknowledge those athletes as a homogenous group in a meaning of effective prevention. Following athletes should be better adapted to fall: judokas, wrestlers, sumotori etc., and handball, hockey, rugby, soccer players etc. To avoid collisions better: boxers, fencing, karate, taekwondo athletes etc.

Although falls cannot be eliminated (everybody has felt at least once before becoming an adult and may fall at least once during rest of his life), collisions can be limited in the human population. For example, people older than 60 years, with dysfunctions of musculoskeletal or motor system, impaired vision or hearing etc. are in a group of higher risk of collisions with objects in motion, which suddenly are heading towards their body (cyclists, runners, thrown object, intentional punch or kick etc.) [8, 9]. Compensatory factors of such threat are solid adaptation effects, mostly acquired by longstanding health-related training basic on (independently from "life sports") combat sports, martial arts, self-defence, games etc.

This study aims to verify compensation possibilities of this category of threats by a person who is cumulating a few factors of higher risk of collision with an object in motion heading toward his head, but on the other hand, having a longstanding adaptation for this kind of threats.

MATERIALS AND METHODS

Two men have been subjected to the study: a 68-years-old scientist (**A**), who has been training judo and other combat sports for over than fifty years and is professionally involved in teaching people how to fall down safely and avoided collision (with diagnosed type 2 diabetes, sight defect and burdensome degeneration of left ankle joint); a 27-years-old physiotherapist (**B**), who trains judo as an amateur, has completed specialist course on safe falling and avoided collision used those exercises in his kinesiotherapy practice (including patients with mental disorders).

Measurements have been performed with the use of MVN Biomech System (XSENS), which is composed of 17 sensors placed on different body parts (based on internal sensors equipped with accelerometer, gyroscope and magnetic field sensor) and mobile 3D projection system Oculus Rift. In virtual reality environment, an application which simulates object in motion was designed. Application projects a ball with a diameter of 12 cm, which fly with constant velocity (three trials; 10-, 6- and 3 m/s, starting from the fastest) alongside axis perpendicular to a frontal plane on the height the head of the participant in an initial moment. In this pilot study experiment during the first trial, (projectile fly with 10 m/s) man **A** was not aware of the necessity of a focus on a task (effect of surprise). Before other trials, head of the project (Robert Michnik) gave such information to tested men.

RESULTS

Collision in head

Man **A** avoided it only with a velocity of 3 m/s (Table 1, Figure 1a). Man **A** performed body rotation faster (0.870 ±0.636s), so he even has taken into account a situation with an element of surprise. He diverged a trunk in a frontal and sagittal plane at the lesser angle (Figure 1a,b,c). Except for purposely arranged situation with an element of surprise, he reacts to approaching an object in similar reaction time to a man 41 years younger. Mean time of reaction of man **A** was 0.407 ±0.27s and was 35% longer than man **B** (0.263 ±0.05s).

Man **B** avoided collision with an object in motion three times (Table 2). Performed body rotation slower (1.133 ±0.054s); moves his centre of mass less efficiently in frontal (9.825 ±2.909deg) and sagittal plane (13.001 ±0.451deg) than men **A** (respectively 5.953 ±0.034deg; 6.185 ±0.959deg).

The average minimal distance of flying project from a centre of mass of a head L_{min} in a case of man **A** was two times smaller than in a case of man **B**. Man **A** also in a smaller range shifted his centre of mass in frontal plane x_{min}. From one side, these assessment data indicates flawless technique of body control in a danger of collision with an object in the motion of a man **A** (Figures 1a, 1b, 1c). On the other hand, it justifies more hits to a head (with a velocity of 3 m/s it was just a scratch).

For man **B** kinematic trajectory for following velocities differs significantly (Table 2) and this inconsistency is identified on a level of direct observation (Figures 2a, 2b, 2c).

Biomechanical description of avoiding collision with the object for the highest velocity (10 m/s) for both men (Table 1 and 2) and visualisation of avatars (Figure 1a and Figure 2a), as well as verbal characteristics (Table 3), fulfils time-lapse photos in the same time function. The frame of reference (head to ceiling lights; legs to operator's desk etc.) reveals differences in quality of body movement in favour of the man A (Figure 3).

Collision with legs

Man **A** managed to avoid collision with a ball with a diameter of 12 cm for the highest velocity (10 m/s) with the left knee. Man **B** did not avoid collision nor with the left or right knee in the same circumstances (Table 5). Both men (in accordance with methodology) perform dodge by simultaneous retraction of left leg and rotation of 180° on the right leg.

Table 1. Biomechanics characteristic of avoiding head collision with object in motion in laboratory conditions by man A

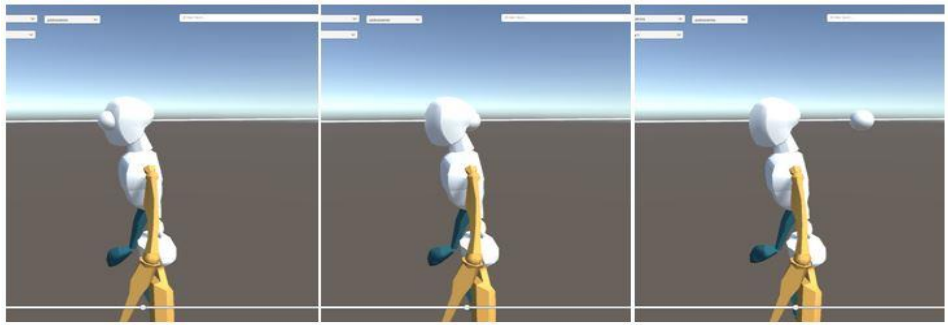
Variable	v	t_r	L_{min}	t_m	α	ß	x_{max}
Indicator	m/s	ms	m	ms	deg	deg	m
				Results			
collision	10	0.720	0.065	0.900	5.2488	5.103	0.0748
collision	6	0.230	0.0482	0.833	6.1215	6.5185	0.1555
avoided	3	0.270	0.1586	0.875	6.4872	6.932	0.251

Legend: v velocity of an object; t_r reaction time; L_{min} minimal distance between an object and a target; t_m time of body rotation; α maximal angel of trunk divergence in frontal plane; ß maximal angel of trunk divergence in sagittal plane; x_{max} maximal shift lengthwise transversal axis.

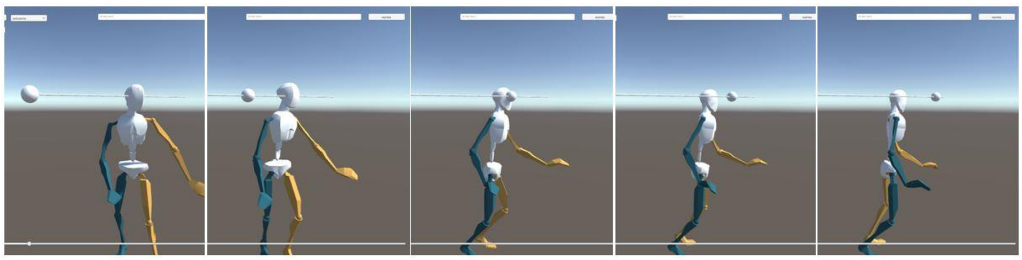
Table 2. Biomechanics characteristic of avoiding collision with object in motion in laboratory conditions by man B.

Variable	v	t_r	L_{min}	t_m	α	ß	x_{max}
Indicator	**m/s**	**ms**	**m**	**ms**	**deg**	**deg**	**m**
				Results			
avoided	10	0.210	0.1626	1.183	8.5005	12.8296	0.1879
avoided	6	0.310	0.164	1.141	7.7679	12.6609	0.263
avoided	3	0.270	0.2463	1.075	11.8825	13.5124	0.228

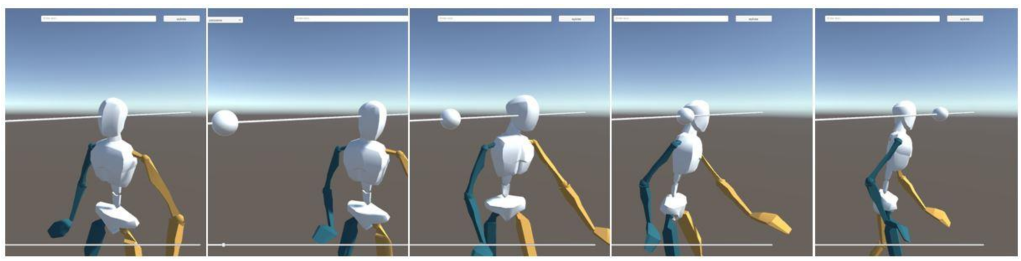
Legend (see Table 1)



1a (10 m/s)



1b (6 m/s)

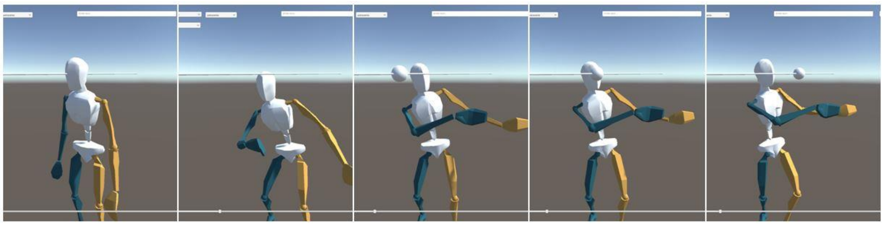


1c (3 m/s)

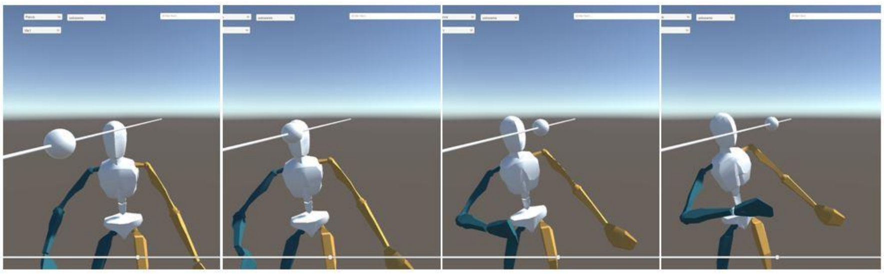
Figure 1. The way of avoiding collision with object in motion in laboratory conditions by man A (a 10 m/s; b 6 m/3; c 3 m/s).

Table 3. Motor characteristic (in a timeline) of avoiding collision with an object in motion in laboratory conditions.

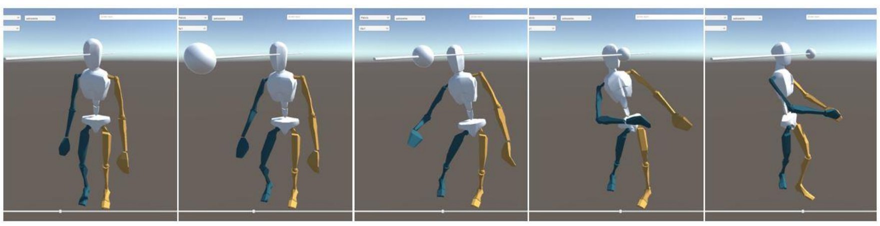
V [m/s]	Man A	Man B
10	result: a direct hit (Figure 1c)	knee flexion; rising of a right upper limb; bending trunk forward; Tilting of a trunk to a right side; putting away right lower limb to a side; result: avoided (crossing of an object at 90-110°) (Figure 2c)
6	knee flexion; head rotation; rising of a left upper limb; turn on a right lower limb; result: scratch of an object at a right side of a head at 120-130°) (Figure 1b)	knee flexion; tilting of a trunk to a right side and backward; rising of a right upper limb; turn on a right lower limb result: avoided (crossing of an object at 80-90°) (Figure 2b)
3	knee flexion; head rotation; rising of a left upper limb; turn on a right lower limb; result: avoided (90°) (Figure 1a)	knee flexion; rising of a right upper limb; tilting of a trunk to a right side and backward; turn on a left lower limb result: avoided (crossing of an object at 90-100°) (Figure 2a)



2a (10 m/s)



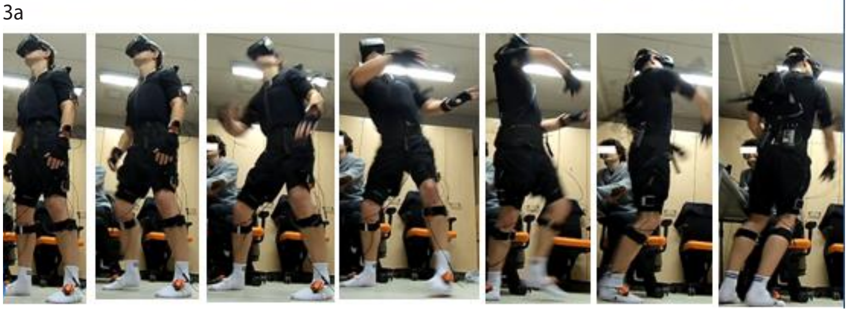
2b (6 m/s)



2b (3 m/s)

Figure 2. The way of avoiding collision with an object in motion in laboratory conditions by manB(a 10 m/s; b 6 m/3; c 3 m/s).

3a



3b

Figure 3. Motor response to man **A** and **B** in the same moments of simulated collision with a ball with a diameter of 12 cm, which moves with a velocity of 10 m/s.

Table 4. Biomechanics characteristic of avoiding legs collision with an object in motion in laboratory conditions by man A.

Variable	v	t_r	L_{min}	t_m	α	ß	x_{max}
Indicator	**m/s**	**ms**	**m**	**ms**	**deg**	**deg**	**m**
Results (knee left)							
collision	10	0.500	0.039	0.883	6.3907	6.2236	0.1883
avoided	6	0.300	0.088	0.808	7.1889	4.3474	0.1529
avoided	3	0.230	0.3226	0.716	7.4872	6.2484	0.0902
Results (knee right)							
avoided	10	0.300	0.1025	0.875	6.0704	4.2544	0.2031
collision	6	0.230	0.0663	0.858	8.0451	8.3971	0.2915
collision	3	0.280	0.0334	0.783	6.4684	8.716	0.1469

Legend (see Table 1)

Table 5. Biomechanics characteristic of avoiding legs collision with an object in motion in laboratory conditions by man B.

Variable	v	t_r	L_{min}	t_m	α	ß	x_{max}
Indicator	**m/s**	**ms**	**m**	**ms**	**deg**	**deg**	**m**
Results (knee left)							
collision	10	0.365	0.0278	1.000	4.8758	7.623	0.2154
collision	6	0.210	0.1199	1.250	4.7571	8.890	0.0678
avoided	3	0.210	0.0608	1.125	3.5742	8.0023	0.1764
Results (knee right)							
collision	10	0.260	0.0638	1.175	4.3004	7.0805	0.1168
avoided	6	0.250	0.0747	1.275	6.5454	13.4804	0.1436
collision	3	0.260	0.0569	1.500	5.3945	12.3157	0.1874

Legend (see Table 1)

DISCUSSION

The same men, three years earlier were tested by professional biomechanics team for the quality of specific body parts control during a collision with a floor made from concentrate (fall to the side [10]) moreover, with a concrete wall [11]. Similarly to this experiment, older man controlled his body more effectively in both extreme situations. In an optimally way, he protects his body in such circumstances and functions more effectively in comparison with considerably younger man.

Therefore, there is no place for any doubts, which preliminary assumptions are correct. During youth, learning of effective body protection during a fall, collision with vertical objects as wells as avoiding collision with an object in motion (and when this is impossible, compensating results of collision) in a whole life investment in personal motor safety. Monitoring of results of an experiment via using avatars shows the motoric subtlety of compensating methods of collision results by proper body rotation. Repetition of rotation techniques by man **A** should stimulate the imagination. Maintaining of such skill through a lifetime is possible thanks to attractive health-related training. Those criteria are fulfilled by the pedagogic offer of fun forms of martial arts [12].

The experiment shows how control of surrounding is important. Man **A**, despite proving that in similar circumstances of the risk of collision with an object with a head he more effectively performs defensive movements, in a moment of programmed surprise (trial 1) he was helpless. During formal exercises, the collision of a ball with a head might discourage to continue another repetition. The attractiveness of fun forms of martial arts (guaranteed by competencies of a teacher) is basing on a fact, that participants acquire a high level of concentration on motor tasks and they can perceive different modifications of an environment. In total opposition are motor behaviours of people on the street and in other public places. The Even result of casual observation shocks because of some people busy with using their smartphones etc. Velocities applied in this experiment corresponds to moving cyclist, runner, thrown object etc. Therefore, applied simulation using virtual reality technology is adequate for possible situations, provides safety of trained person and are attractive. In the future, they could be used even in a home, despite weather conditions.

Head director of this experiment (Robert Michnik) did not warn man **A** (did not say "ready" command), which result in surprise effect during the first trial. Man **A**, despite performed motor task in more coordinated way (Figure 3), his reaction time was three-times longer than man **B** (Tables 1 and 2). Even if man **B** would not be able to avoid a collision, differences between the central collision of the moving object with the head and non-central one are so obvious, that no comment is required. This result has very prophylactic significance. It should spread awareness for millions of people, that moving through crowded areas such as streets, railway stations etc., focusing eyes and manipulative action of the hands on a mobile device come with big threat and its consequences could lead to injury or even be fatal.

Next step towards the improvement of assessing the system for this phenomenon based on virtual reality technology, should be differencing between central collisions and non-central collisions. This conclusion was approved by participants of AHFE 2017, which got to know results of this experiment only for head results [13].

Virtual reality technology could be applied further in diagnostic, prophylactic and therapy of people with balance dysfunctions [14]. Alongside with augmented-reality technology [15], these are examples of modern enhancement health-related training, especially during the teaching of unknown techniques of movement. In some way, this could be a bridge between behavioural activation of people (patients) fascinated with modern technology and physically active people unfamiliar with virtual augmented-reality. These new technological possibilities do not have to enhance sedentary lifestyle. Along with getting knowledge about prophylactic and therapeutic agonology [16-18], recommended forms of physical activity (fun forms of martial arts, self-defence training etc.) could create a new, attractive and effective perspective of prophylactic of body injuries. Japanese *budo* offers not only effective but also an attractive form of collision avoidance – *sabaku* and *tai-sabaki* [19].

CONCLUSIONS

Positive adaptation effects for 68 years old man (most of the analysed time graphs of kinematics quantities were similar) is an empiric proof, that some category of "life sports" guarantee an optimal level of motor safety to a late elderly. Furthermore, adequately adapted virtual reality technology could be an effective and attractive tool for enhancing training of avoiding collisions on small space (in the apartment, garage etc.) despite weather or other circumstances.

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