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Comparative Kinematical Analysis of Forward Roll Fall, Side Fall, and Forward Break Fall in Individual Kinematic Model

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Key words: combat sports, martial arts, Gubitz model, biomechanics of falling techniques

Abstract

Introduction. In martial arts and combative sports the fall technique is frequently described. Fall techniques are taught in particular martial arts and combative sports differently. We empirically assume that some fall techniques have similar movement structure. There is a supposed possibility of transfer of one movement skill to another in the process of education. Three fall techniques are mentioned under this circumstance: forward roll fall, side fall, and forward break fall. Forward break fall arises from a combination of forward roll fall and a final position with suppression of fall energy. **Aim.** Comparative kinematical analysis of selected fall techniques and description of common characteristics in individual kinematic model. **Material and methods.** As a theoretical base for kinematical analysis a 4-phase model of fall techniques was chosen. This model includes an initiation phase, falling phase, impact phase and a phase of after all position. The examined subject was a teacher of martial arts (4. dan aikido, 2. dan judo, 2. dan iaido) and of self-defence. For the kinematical analysis we used a SIMI Motion 3D system. Thirteen points were monitored – head, left and right shoulder, left and right elbow, left and right wrist, left and right knee and left and right ankle. Gubitz model was used for calculation of gravity centre. **Results.** In the phases of initiation and falling in forward roll fall and forward break fall certain congruence was found. However, forward break fall is very often used in a fall with a phase of flying and in a fall with an indistinct motion in x-axis. In this case the similarity between forward roll fall and forward break fall is debatable. Further on, congruence in phases of after fall position in side fall and forward break fall was discovered. On the contrary, we found significant differences in side fall and forward break fall in the initiation phase. The differences were marked mainly in spatio-temporal characteristics. However, it is the initiation phase that is crucial for prevention of an injury caused by a fall.

Introduction

The basic principle of models and modelling is preservation of isomorphism that can be complete in an ideal case. It means that a model and reality are similar or even the same in their structure. It is clear, as Fery [1967] states that models are always understood as certain representation. Iconic model has a similar appearance (from the point of view of general human perception) as the represented, individual features are easily recognizable. In the case the model is described in specific (e.g. mathematical) symbols we call it a symbolic model. If it is possible to represent the symbolic model fully (or sufficiently) in an iconic way, which is a case of motor skills, we use a special transitive icon-symbolic model. Thus a model is considered to be a norm of technique and from a certain point of view – because of used techniques of model creation – to be partly an idealized copy of the original. A model is a description of an ideal performance of motor skill. Biomechanical methods of modelling of movement techniques are very often used in kinanthropology [Baláž, Olejár 2005; Slamka, Moravec 2000] or even in connection to diagnostics of motor skills [Psalman, Zvonař 2007]. This is useful mainly in situations where there are constant conditions for skills and where the motor skills can be defined with kinematic and dynamic description. Modern methods can be used in an entirely non-invasive way and without any impact on behaviour of measured object, since visual record of the object not the object itself is being analysed. Advantages of this method were proven for instance in athletics [Sebera *et al.* 2008, 2007].

Aim

Comparative kinematical analysis of selected fall techniques and description of common characteristics in individual kinematic model.

Materials and methods

As a limiting condition in a choice of an author representing the model of fall technique we chose a conception of theoretical sensitivity according to Glaser and Strauss [Strauss, Corbin 1999]. Theoretical sensitivity can be gained from more sources:

Literature - theoretical sensitivity was reached by creating a pre-model of fall techniques on the basis of theoretical research. We contrasted all available sources until saturation of movement pattern as well as movement dispersion of this pattern were not reached.

Professional experience - the presenting person is a teacher dealing with training of fall techniques in different groups of sportsmen, in self-defence, for the purposes of physical education teachers etc.

Personal experience – the presenting person is an active trainer of combative sports and self-defence (4. dan aikido, 2.dan judo, 2. dan aikido toho iai, 1st class trainer), with 25 years of practice. Table 1 presents characterization of the subject.

Analysis *per se* – verification and 3D kinematic analysis was performed by SIMI Motion system [Zvonař, Sebera 2007]. Simi Motion 3D captures movements with two of high-speed cameras. The 3D data of selected points) were calculated from the recorded videos and illustrated in diagrams synchronized with the video.

Three executions of all falling techniques were provided. But only one execution per each falling technique was examined. The execution was selected upon agreement of both researchers and performer as the best one.

In cooperation with the technician we recorded fall techniques performed by the presenting person on high frequency digital cameras calibrated for 3D analysis of movement (Fig. 1). The gained data were further processed by specific Simi Motion software for high-end motion analysis and analysing kinetic features. Since just a two-camera system was employed, it happened exceptionally that the monitored point was hidden beyond other body parts and was invisible on the record. In such case the movement was interpolated, rarely estimated. Eleven points were monitored - head, left and right shoulder, left and right elbow, left and right wrist, left and right knee and left and right ankle. Gubitz [1978] model was used for calculation of gravity centre. In a description of individual models of fall techniques we come out of biomechanical structure of fall techniques. The individual phases are initialization, falling, impact and after- fall position.

Model of a forward roll fall

Etiology

The fall technique reminding gymnastic roll performed over one shoulder idealizes a transition from the stand over reversed position on the ground back into the stand. From this point of view it is an ideal example of kitó principles (defined in Japanese *kitó ryú*).

Conditions of the model and its description

The fall is performed with step forward from the stand over roll on a slightly pronated right arm and the back into falling position lying down sideward on the hip. Coming into the fall position is started with dynamic stoppage – quick movement of a stretched arm down to the mat. In Fig. 1 we display the course of perpendicular distances of individual body segments from the mat. Notice the fluent, harmonic passing of the curves. The movement fluently continues over reversed position into the stand. The fall moment is marked with a vertical line. In Fig. 1 we display the course of the perpendicular distance between the centre of gravity - calculated by Gubitz model – and the mat in a forward roll fall and forward break fall. Since the fall phase there is an apparent difference in its course between both fall techniques.

Similarly the comparison of absolute velocity of the centre of gravity documents the difference in Fig. 4. We can see harmonious transition of all segments. Subject is completely upside-down in the 1.6 s (Fig 7b). Then he returns thru single kneeling position to standing position. Technique is done without hard impact, and can be easily perform also on hard surface.

Model of a side fall

Etiology

The side fall does not offer many varieties. In literature only break fall is described. This motion is a response to a loss of balance on a sagittal level.

Tab. 1. Characterization of the subject

Age	Years of practice	Weight	Height	Body Mass Index	Percentage of body fat
37	25	85	175	27	13.7

[source: own research]

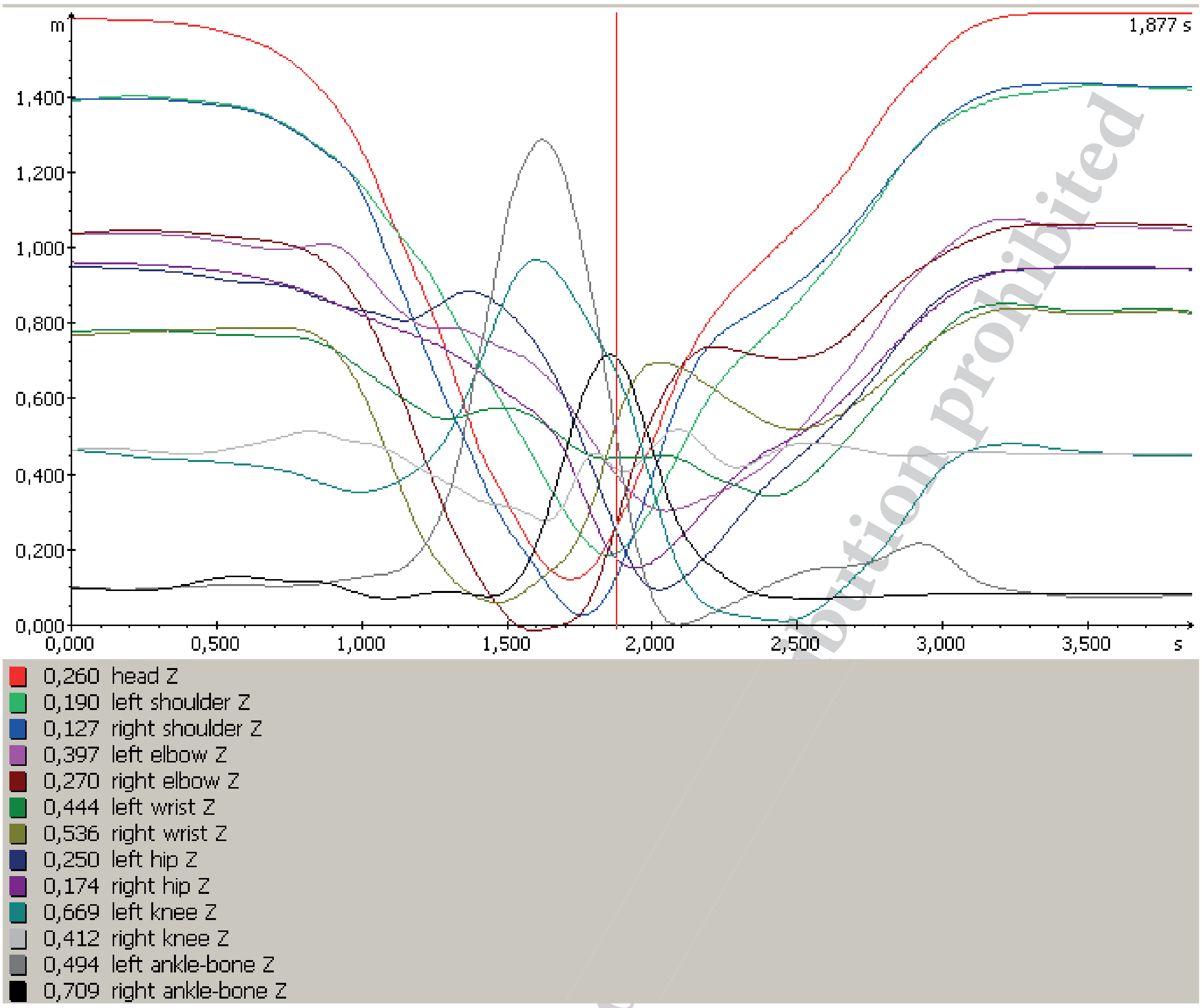

Fig. 1. Course of perpendicular distances of body segments to the mat in a forward roll fall
[source: own research]

Conditions of a model and its description

The basic side fall is realized out of stepping sideward in forward direction. Figure 2 illustrates the course of perpendicular distances of individual body segments (measure points) from the mat based on the measurement with SIMI Motion system. The fall was recorded in 1.3s. Thus the phase of falling is shorter than in fall techniques described above, because there is no roll. The stoppage is anticipated by preparatory arm movement upward and against the fall direction. This movement happens also in order to balance partly the imbalance of falling body. The upward movement of lower limbs and hips after the fall is also interesting. Attenuation of fall energy is therefore spread in time as seen in Fig. 3 from 1.3s to 1.9s (peak in 1,51s). The increase of potential energy lowers kinetic energy. After-fall position (Fig. 7d) shows same kinematic characteristics as after-fall position in forward break fall.

Model of a forward break fall

Etiology

Forward break fall is an idealized motion pattern for usually intuitively solved way of movement dealing with the loss of balance in the forward motion. In combative sports it is the most employed fall technique. This fall is well described in the literature. However, the created model is different in some details from other descriptions.

Model conditions and its description

The unifying principles of fall techniques were already published. These should be followed in individual phases according to the possibilities of their application. In this fall we do not employ kinetic fall energy for standing up again. It is because the fact that forward break fall in the basic version is finished in falling posture lying on the hip. In the methodical material written earlier [Reguli, Voldán, Vít 2006] we show a fall technique in motion along with preparative exercises used in the training.

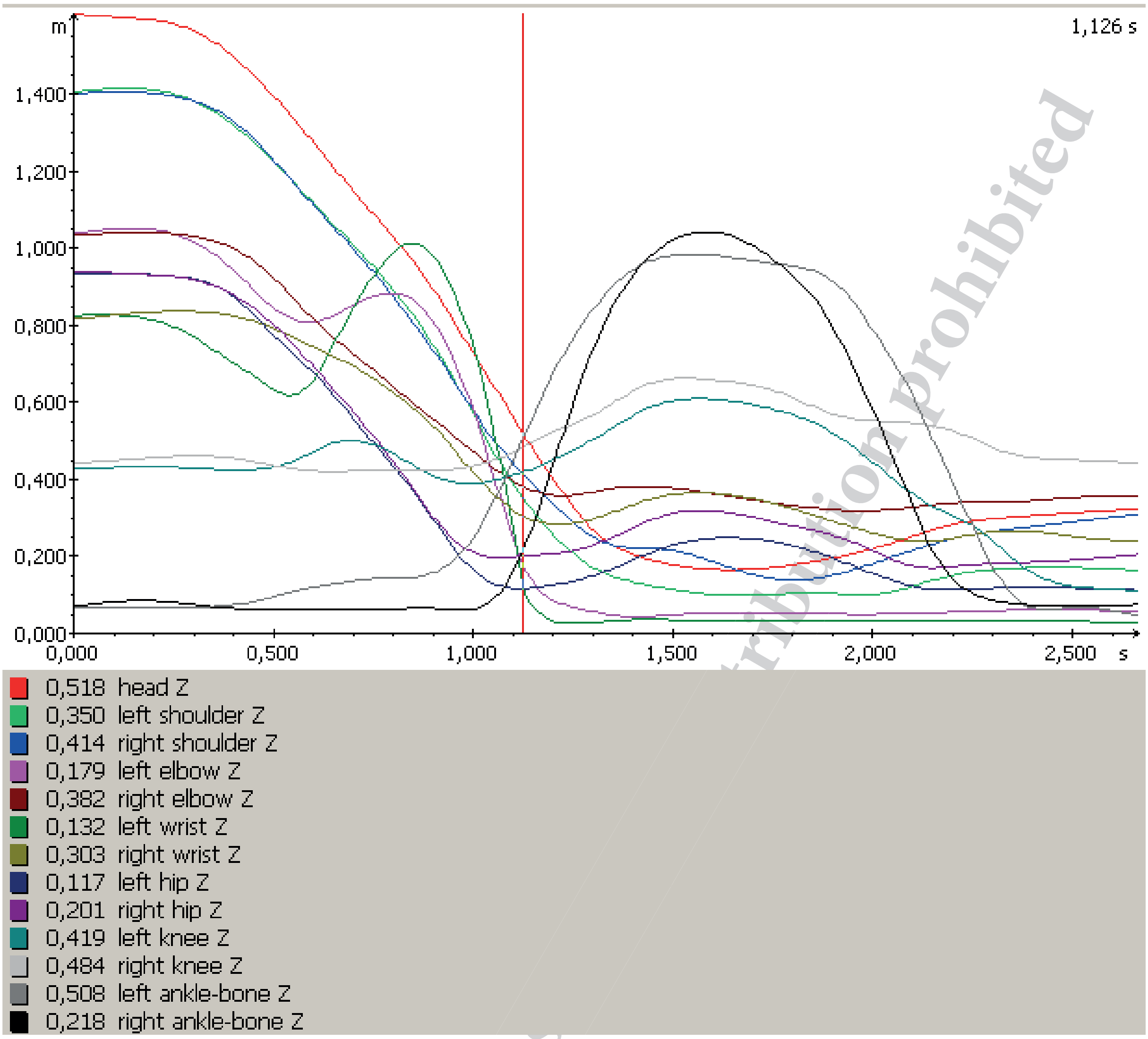

Fig. 2. Course of perpendicular distances of body segments to the mat in a side fall
[source: own research]

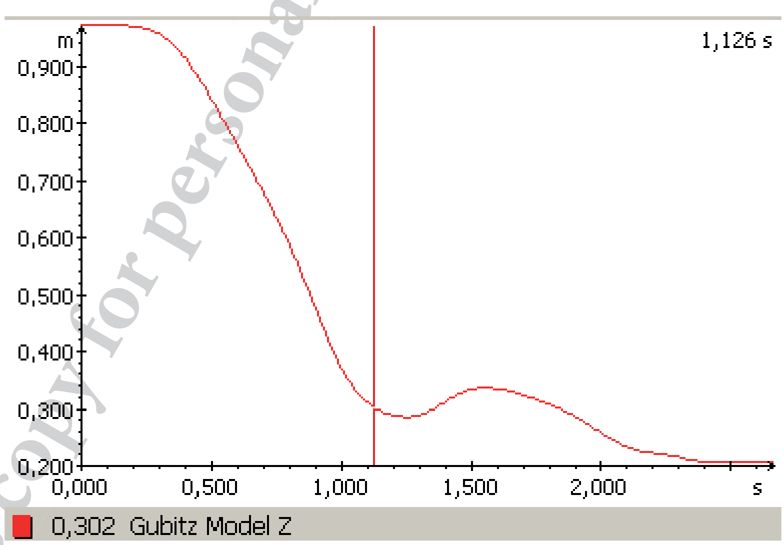

Fig. 3. Course of perpendicular distances of gravity centre to the mat in side fall
[source: own research]

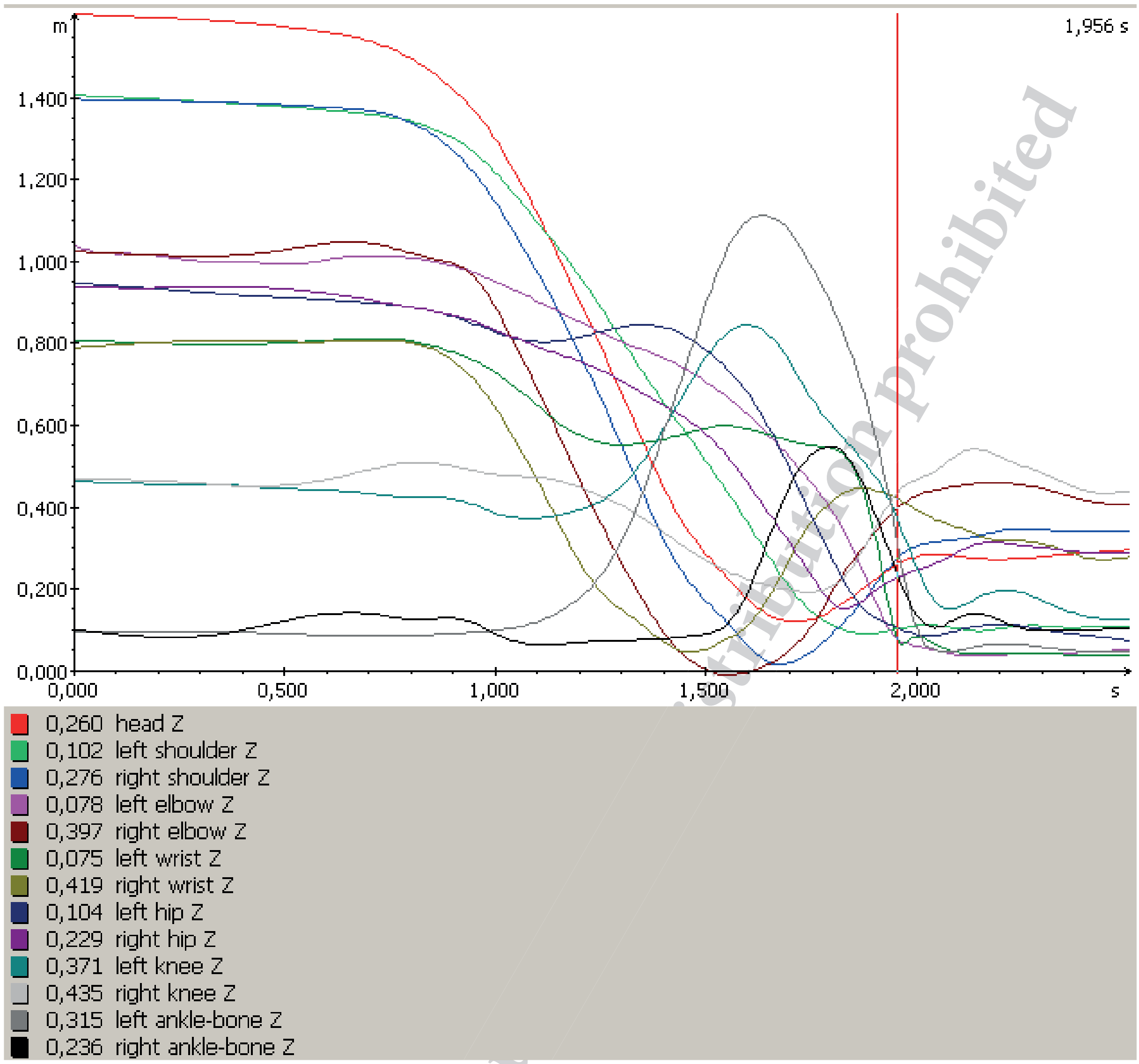

Fig. 4. Course of perpendicular distances of body segments to the mat in a forward break fall
[source: own research]

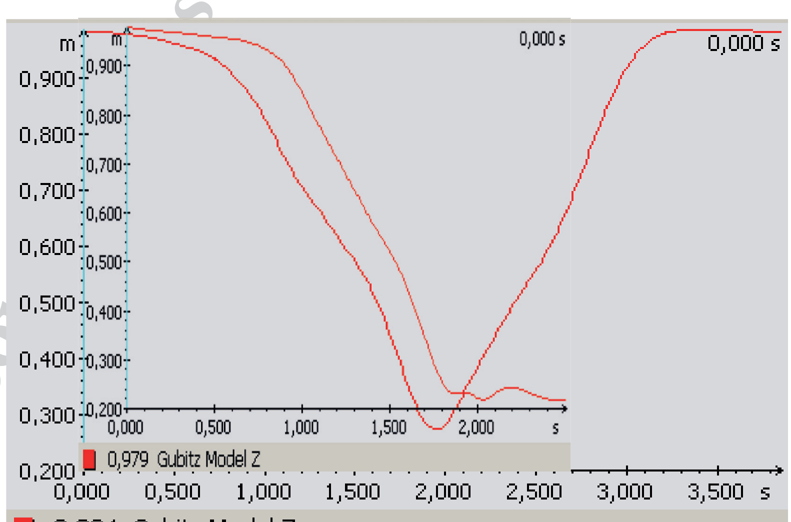

Fig. 5. Course of perpendicular distances of gravity centre to the mat in a forward roll fall and forward break fall
[source: own research]

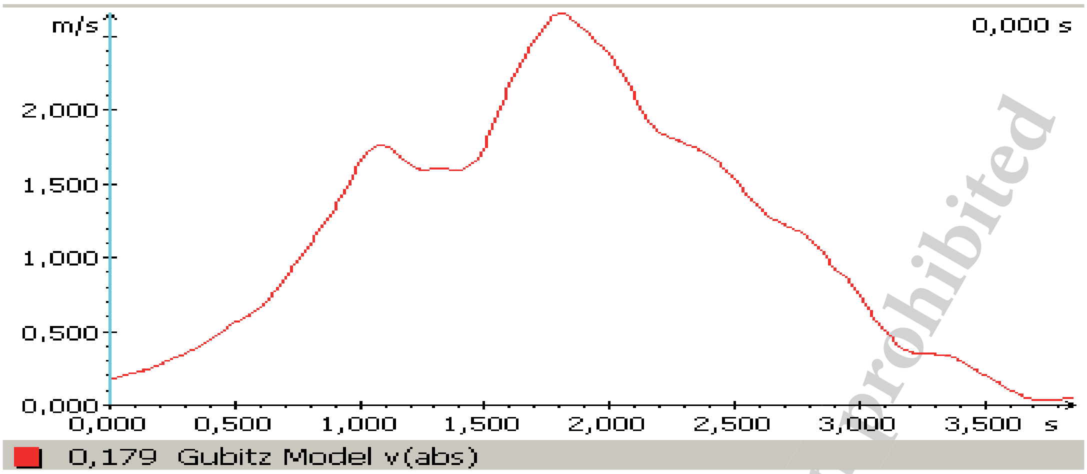

Fig. 6. Course of absolute velocity of gravity centre in a forward break fall and forward roll fall
[source: own research]

Figure 4 illustrates course of perpendicular distances of individual body segments (measured points) from the mat based on measuring with SIMI Motion system. Fluent and harmonic passing of the curves ends with abrupt stop of a movement in after-fall body position v lying on the hip before the 2nd second. Coming to fall posture is initiated by dynamic stoppage – quick movement of a stretched arm aiming to the mat.

Conclusions and discussion

The initialization and fall phase are in forward break fall identical as in forward roll fall. The course of individual segments is the same. The process of the motion of gravity centre on Z-axis in a forward break fall as well as forward roll fall is well illustrated in Fig. 5. In forward break fall vertical movement of the body centre stops in 1.96s, while in forward roll fall centre of gravity continues in harmonious movement. The Figure 6 shows absolute velocity of the centre of gravity. In forward break fall the movement is suddenly abrupt, in forward roll fall the gravity centre slows down steadily together with transition to stand. Similarly we can observe concordance in time characteristics. The fall in forward roll fall was reached in 1.88s. In forward break fall the fall was reached in 1.96s. Managing of the forward break fall leads to lowering of the fall velocity of individual body segments, or of the gravity centre on zero. From the point of view of energy it is transformation of kinetic energy into internal energy of a system of mat and a trainer. On the basis of the 3rd Newton law of action and reaction we know that the trainer forces on the mat with pressure force and the mat reacts the same strength but opposite direction force on them.

The effort is to minimize the deformational effects of the response power on trainer’s body. This power can be spread in two ways: firstly we can prolong the time when the movement of the trainer is retarded, secondly we can enlarge the contact area of the body on which the power of the mat forces.

The after fall position is identical in both forward break fall and side fall (Fig. 7d). In the forward break fall the angle between left hip, left shoulder and left wrist was measured 53.2° in the after fall position (left hip, left shoulder and left elbow 52.0°). In the side fall the angle between left hip, left shoulder and left wrist was 56.6° (left hip, left shoulder and left elbow 55.4°). The difference between the angles is considered negligible. The left arm was extended in both cases.

The transition to after fall position in a fall phase is in forward break fall different from side fall. In the fall in forward break fall the shoulder touches the mat after the arm shortly tips the mat.

a) b) c) d)

Fig. 7. Different phases in forward roll fall (from a to c) and side fall (d)
[source: own research]

The shoulder leaning against the mat creates a movable turning edge. Round the shoulder the body rolls away up to the after fall lying position. In the side fall the turning edge is formed by the hip, around which the body is rolled away up to after fall lying position. The opposite orientation of turning edge causes different conditions for the fall deceleration. In the after fall position the trunk is in an oblique position towards the mat. While the angle between shoulder and the mat in after fall position was 41.3° in forward break fall, this was just 22.7° in the side fall.

Forward break fall is not a basic fall technique. It can be considered a connection of initial movement and roll in forward roll fall and after-fall positions in side fall. It is illustrated in Fig 7. We can see transition thru upside-down position in Fig 7a) to c) as it is in forward roll fall. Then impact and discontinuance of falling in Fig 7d) as it is in side fall.

In the motor learning it is recommended to start with training of forward break fall once after managing side fall and forward roll fall [Reguli, Voldán, Vít 2006; Vít 2005, 2009; Bartík 2006, 1999; Štefanovský 2009; Cynarski, Momola 2007; Vít, Šalplachtová 2009].

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Porównawcza analiza kinematyczna padu z przewrotem w przód, padu w bok i padu prostego w przód w indywidualnym modelu kinematycznym

Słowa kluczowe: sporty walki, sztuki walki, model Bubitza, biomechanika techniki upadku

Streszczenie
W sztukach i sportach walki technika padów jest często opisywana. Technik padów naucza się różnie w poszczególnych sportach. Autorzy empirycznie zakładają, iż techniki padów mają podobna strukturę. Istnieje możliwość przeniesienia jednej umiejętności ruchowej do drugiej w trakcie procesu edukacji. W tekście zostały wymienione trzy techniki upadku: pad z przewrotem w przód, pad w bok oraz pad w przód prosty, kołyskowy. Ostatni z padów powstał z kombinacji padu z przewrotem w przód oraz końcowej pozycji z wytłumieniem energii powstałej w czasie padu.
Cel: Celem pracy była kinematyczna analiza porównawcza wybranych technik padów i opis typowych cech charakterystycznych w indywidualnym modelu kinematycznym. **Materiały i metody**: Jako teoretyczną bazę dla kinematycznej analizy wybrano

4-fazowy model techniki padu. Model ten obejmuje fazy: inicjacji, upadku, uderzenia i fazę końcową po zakończeniu poprzedzających faz. Podmiotem badania był nauczyciel sztuk walki (4. dan aikido, 2. dan judo, 2. dan iaido) i samoobrony. W analizie kinematycznej użyto systemu SIMI Motion 3D. Monitorowano trzynaście punktów- głowę, prawe i lewe ramię, prawy i lewy łokieć, prawy i lewy nadgarstek, prawe i lewe kolano oraz prawa i lewą kostkę nogi. W celu obliczenia środka ciężkości zastosowano model Gubitza.

Rezultaty. W fazie inicjacji i upadania, podczas padu z przewrotem w przód oraz padu prostego w przód, stwierdzono pewną zgodność. Jednakże pad do przodu prosty jest często używany z fazą przewrotu w powietrzu i padem z nieznacznym ruchem w osi x. W tym przypadku podobieństwo między padem w przód z przewrotem oraz padem w przód prostym jest sporne. Ponadto odkryto zbieżność w fazach następujących po zakończeniu pozycji padu w padzie bocznym i padzie w przód prostym. Co więcej, autorzy odkryli znaczne różnice w padzie w bok i padzie w przód w fazie inicjacji. Różnice te zaznaczały się głównie w charakterystyce przestrzenno-czasowej. Jednakże to właśnie faza inicjacji ma zasadnicze znaczenie dla zapobiegania kontuzji spowodowanych upadkiem.