METHOD TO VISUALIZE AND ANALYZE SIMILARITIES OF MOVEMENTS – USING THE EXAMPLE OF KARATE KICKS

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Most sports movements are very complex. In order to estimate similarities between the movements many biomechanical parameters are necessary. This impairs the clearness of the classification of similar movements. Another variant is the use of nonlinear procedures which allow the consideration of the movement on the whole. But a connection to the single biomechanical parameters is not given. The aim of this paper is to introduce a procedure to visualize the movement coordination to get a visual impression of the whole movement, and in addition further analyses by means of statistical tools to confirm similarities and variabilities between the movements were presented using the example of Mae-Geri.

KEYWORDS: coordination, karate, visualization, movement similarity

INTRODUCTION: Because sports movements are very complex, biomechanical analyses contain many parameters including their characteristic curves. For this reason it is frequently problematic to identify similarities and differences between the movements. Yet, the sports practice requires the identification of movement modifications. Therefore, various holistic approaches and methods have been used (Haken 1996; Yamada, 1995; Newell et al., 2007; Perl 2004; Schmidt et al., 2009; Witte et al., 2003; Witte et al., 2009). The problem with the recent methods is that they demand a decision between the analysis of the whole movement and movement details in the form of biomechanical curves or parameters. Based on this, it is the aim of this study to present a method which meets the following requirements: subjective impression of the total movement coordination with a visual pattern, quantitative analysis of biomechanical parameters and curves and application of statistical methods or tools to find similarities and differences between the movements.

METHOD: The generation of the visual movement patterns includes the following steps: selection and normalization of biomechanical parameters relevant to movement (e.g. body angles, angular velocities, and forces) temporal normalization, construction of a matrix containing movement parameters in discrete time-lags, and visualization by means of contour plots in colour or gray scales. After this, statistical methods or tools can be applied to the biomechanical time series. The researched Mae-Geri is a front kick which belongs to the karate sport (Figure 1). Five karatekas (age between 13 and 18 years) of high national level participated in this study: two male subjects: Chr and Joh and three female subjects: Lui, Mar and Nad. Each technique was performed ten times. Chudan (jap. Solar plexus) was defined as the target area. The movement analysis was accomplished with a VICON system (12 cameras MX 13, 250 Hz, Nexus V 1.01). For the movement patterns, the time courses of body angles were exported. Table 1 shows an overview of the movement specific body angles. The selection resulted from our own empirical findings and practical experiences of long-time karatekas. The angle normalization can be accomplished with the following determinants: angle maximum is 0 and angle minimum is 1. For the absolute time scale of each movement the following temporal standardization was computed: 0.0, 0.1, 0.2,…, 1.0. In this paper the results of the subjects Chr, Lui and Nad are presented. Afterwards, a matrix containing movement parameters in discrete time-lags was constructed and visualized by contour plots in gray scales. To research similarities between the movements Euclidean distances were calculated. To estimate similarities between the single trials and the single angles, coefficients of variation and correlation (Pearson) and the Euclidean Distance were used. Euclidean Distance for the single angles between the executions for each subject were calculated and similarity levels were defined (Table 2).

Figure 1. Technique of the Mae-Geri Chudan

Table 1. Body angles of Mae-Geri using for the movement pattern plots and statistical analyses recording to the Plug-in-Gait model by VICON

Short cut	angle
W1	HipX: Hip angle (Flexion)
W2	Knee: Knee angle (Flexion)
W3	Ankle: Ankle angle (Dorsiflexion)
W4	Spine: Spine angle (Flexion/Dorsiflexion)
W5	PelX: Dorsiflexion of pelvic
W6	PelZ: Internal Rotation of pelvic

Table 2. Definition of similarity levels on the basis of the Euclidean Distance

Similarity level	Range of the Euclidean Distance
I	0,0 – 0,2
II	>0,2 – 0,4
III	>0,4 – 0,6
IV	>0,6 – 0,8
V	>0,8 – 1,0
VI	>1,0

RESULTS: Figure 2 shows two examples for the three subjects for visual movement patterns as contour plots. At first sight and with respect to the temporal successions of gray scales, substantial similarities are visible for the subjects Chr and Lui. For example, the subjects Chr and Lui exhibit analogical characteristics for the first angle W1 (Hip. Greater differences within an athlete are observable for the angle PelX (W5) for the subject Nad. Generally, in comparison to the other subjects, more variable movement patterns can be found for the athlete Nad. To quantify the body angles for each subject, coefficients of variation were calculated as shown in Figure 3. The procedure was that at each normalized time point (in sum 11 time points) per angle, the coefficient of variation was computed. The time-averaged coefficient of variation for each angle and each subject is presented in Figure 2. It can be detected that the angles for each subject have a different behaviour of variability. Thus, for the athlete Chr the angle of the ankle (W3) is the most stable one. In contrast, Lui and Nad displayed the most stable knee angle (W2). This implies that the ankle and knee angle can be replicated the most. As distinguished from these the PelX (W5) for Chr and Nad is the angle with the highest variability. When comparing all coefficients of variation between the subjects, it can be concluded that the kicks of Lui show the least variability and the most variable movements can be found for Nad. The next outstanding problem was to detect which temporal angle curves show the greatest similarities. Therefore the coefficients of correlation (Pearson) between all five subjects for each angle were determined and from this the mean values were calculated. It could be found that the lowest mean correlations (the greatest variations) exist for the angles PelX W5 (r=0.16), Ankle W3 (r=0.75) and Spine W4 (r=0.73). From this it can be assumed that for the Mae-Geri the hip angle, the knee angle and the rotation of pelvis (here only a small amplitude is realized) are the most important angles. As a further method to identify similarities, the determination of the Euclidean Distance was used. From this the most stable angle for a subject can be concluded. In Figure 4 the percentage frequencies of the appearance of the similarity levels for each angle are represented. So it can be established that for Chr and Lui the similarity level I for W1 occurs most frequently. W1 (Hip) is characterized by relatively low variability. The high frequencies of similarity levels greater than II for the subjects Nad show that these angles don't reproduce stable. The finding of high movement variability for subject Nad conforms to the other results. It must be assumed that no explicit correlations between Euclidean Distance and coefficient of variation exist.

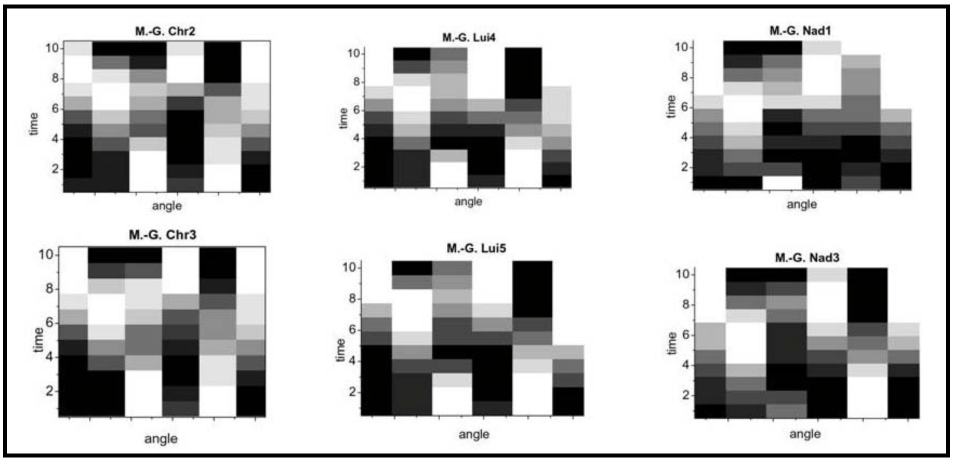

Figure 2. Visualized contour plots of movement pattern of Mae-Geri for 3 athletes, two trials per athlete. White: angle-maximum, black: angle-minimum. From left to right the angles W1(Hip), W2 (Knee), W3 (ankle), W4 (Spine), W5 (PelX), W6 (PelZ) (s. table 1).

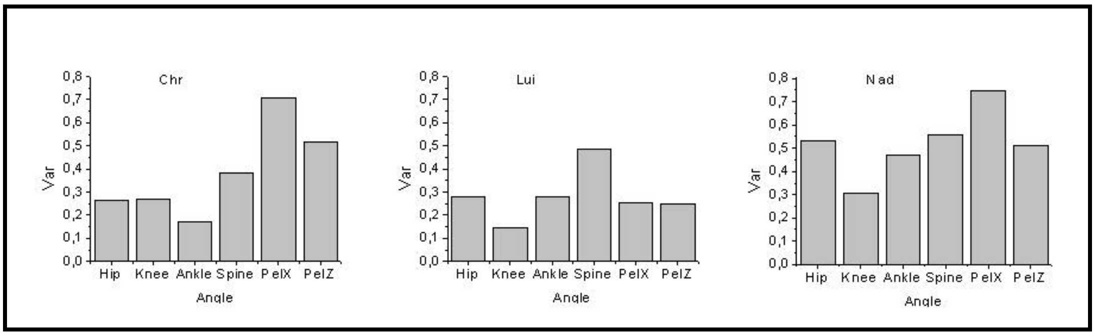

Figure 3. Averaged coefficients of variation for each angle over all executions per subject

DISCUSSION: By means of visualized movement patterns in form of contour plots it was possible to recognize movements with clear differences in the biomechanical characteristics with strong movement artefacts. The discrete angle- time-series could also be used for other analysis: determination of averaged coefficients of variation for each angle over all executions per subject, determination of averaged coefficients of correlation for the single angles over all subjects and calculation of the percentage frequency of the appearance of the similarity levels on the basis of the Euclidean Distance. Generally, the results of these methods are in accordance with the subjective impression of the visual movement patterns. By means of the procedure of the visual movement pattern and the using of the statistical methods some special results recording the similarity of karate kick Mae-Geri could be found. The subjects were able to repeat the movement, with a similar coordination, differently.

Angles which were very stable during repetition (HipX, Knee, PelZ) and angles with a high variability (Ankle, PelX) could be found. From this it is assumed that stable angles are important for the learning process of this movement. The determination of mean coefficients of correlation for the single angles over all subjects confirmed this. The calculation of the percentage frequency of the appearance of the similarity levels on the basis of the Euclidean Distance allows an individual and detailed analysis of the variation of the single angles.

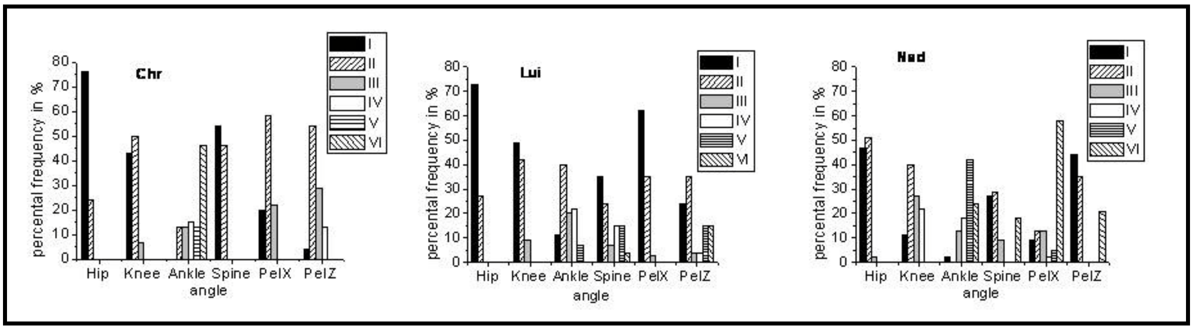

Figure 4. Percentage frequency of the appearance of the similarity levels I – VI for the single angles

CONCLUSION: In summary it can be found that the presented procedure of visualized movement patterns allows a subjective impression of the total movement coordination. Statistical methods of determination of variation provided detailed analyses for the single angles which were used for contour plots for each athlete. From this, expected advice for optimization of the training process can be made.

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