ANALYSIS OF PERFORMANCE OF THE KARATE PUNCH (GYAKU-ZUKI).

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Variation in the movement sequence of the reverse punch (Gyaku-zuki) could affect kinematic variables such as punch time, distance and joint velocities. The reverse punches of nine elite Malaysian karate athletes were imaged in 3D at 150 Hz for two conditions (Jodan and Counter-chudan). Based on the linear resultant joint velocities of the shoulder and elbow two clusters are identified. One cluster is characterized by a more simultaneous movement sequence and the other by a more sequential movement sequence. The first cluster is mostly associated with female performances (87%) and the second cluster mostly with male performances (83%). It is found that the mostly male cluster achieved longer punch distance and higher peak linear resultant joint velocities for shoulder, elbow and wrist. Furthermore subgroups within the two clusters are identified and are associated with Jodan and Counter-chudan punches. The mostly female cluster achieves longer punch distance and higher peak linear resultant velocities in the subgroup associated with Jodan punches. However, the mostly male cluster achieves similar results for the subgroup associated with the Counter-chudan. Conclusion: the females tend to punch with a simultaneous sequence and men tend to punch with a sequential sequence with regard to the shoulder and elbow movements. Additionally women and men seem to have optimal performances in terms of punch distance and peak linear resultant joint velocities in different punching conditions.

KEY WORDS: reverse punch, elite karate athletes, cluster analysis, kinematic analysis.

INTRODUCTION: The Gyaku-zuki, also known as the reverse punch, is a technique commonly used in karate kumite, a form of competitive fighting (Emmermacher et al., 2005; Hofmann et al., 2008). The objective of a punch is to hit the opponent at a controlled distance in as little time possible (Emmermacher et al., 2005; Hofmann et al., 2008). Punching consists of the rapid execution of a sequence of body movements (Stull et al., 1988).

Only a few biomechanical studies have examined the technique of karate punching. Stull et al. (1988) investigated the relative timing sequence of peak joint velocities of the reverse punch by four different martial arts practitioners. They digitized multiple joint velocities (ankle, knee, hip, shoulder, elbow and wrist) from film (100 Hz) and found for example that the peak shoulder velocities of the shoulder occurred between 53% and 84% of total movement time. Variations in the sequence could affect kinematic variables such as total punch time, distance covered and joint velocities. Some researchers (Emmermacher et al., 2005; Hofmann et al., 2008 and Stull et al., 1988) measured one or more of these variables, but not in relation to any variation in the sequence of movements. Sforza et al. (2000) used 3 dimensional analyses of multiple joints to measure the repeatability (standard deviation) of karate punches (choku-tsuki and oi-tsuki). They found a larger standard deviation for horizontal motions than vertical motions.

The purpose of this research paper is to examine the reverse punch movements and variations in technique of elite Malaysian karate exponents. Two variants of the reverse punch or conditions were studied, the Jodan and Counter-chudan. Differentiating the variation in movement sequences was done by cluster analysis of the linear resultant joint velocities of the shoulder and elbow.

METHODS: The subjects were 8 full time Malaysian national karate athletes (4 males age 26.5±5.4 years; mass 65.0±11.5 kg and 4 females age 25.8±3.3 years; mass 55.7±7.3 kg). They had a minimum of 2 years experience in the national program. All subjects regularly practised the reverse punch, especially the Jodan variant where they punch the opponents head and the Counter-chudan variant where they punch an approaching opponent's trunk.

The punching movement was captured using 6 infra-red Motion Analysis Corporation Eagle cameras and a Kistler force plate. Force data were sampled at 1000 Hz and the camera frame rate was 150 Hz. Calibration and collection of data was done with the EVaRT 5.0 software application. The measurement error was less than 0.0005m.

Subjects completed a 10 minute warm up session before testing. Four reflective markers were placed on the hip (iliac crest), shoulder (acromion), elbow (lateral epicondyle) and wrist (ulnar styloid) of the preferred punching side. Subjects were instructed to position their back foot on the force plate when performing the punch. To simulate fighting a training partner acted as an opponent and stood at a desired distance set by the subject. Both the Jodan and Counter-chudan were executed 3 times each. There was a rest period of at least 15 seconds between each punch.

EVaRT was used to smooth the data with a butterworth filter at 12 Hz. After which the data was further analysed using Matlab 7.0 software. Computations of kinematic variables such as punch time, punch distance and linear resultant joint velocities were calculated. The athletes were allowed to move before executing the punch. Therefore the start of each punch is defined as the time of peak ground reaction force (GRF). The end of the punch is defined as the time of maximum elbow extension. Punch distance is defined as the horizontal position of the wrist at the end of the punch minus the horizontal position of the hip at the start of the punch.

One subject performed the Jodan only and 13 trials of the other subjects were excluded as incomplete trials leaving 39 trials for analysis. The shoulder and elbow linear resultant joint velocity data was normalized for time and passed into the statistical software R v2.6 (www.R-project.org). The data was clustered using the average linkage method within the hclust function from the R-Stat Cluster package. Groups were selected based on the Hubert-Γ score and p-values assigned to the clusters using a bootstrapping technique (Chow et al., 2008).

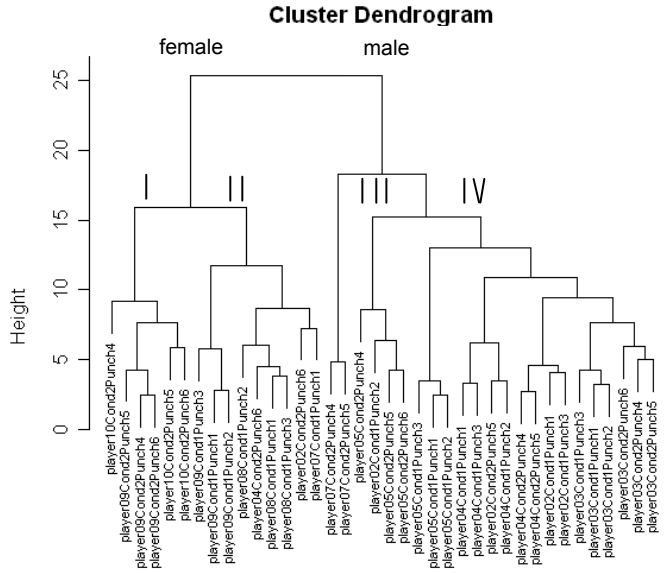

Figure 1: Dendrogram of cluster analysis.

RESULTS: Figure 1 shows that the cluster analysis identified two distinct groups (p=0.14). The first cluster included mostly trials from female subjects (87%) and the second cluster mostly trials from male subjects (83%). Table 1 contains the averaged peak values of kinematic variables of each cluster and the difference between the two clusters. It shows that cluster 2 has on average a longer punch distance and higher peak linear resultant velocities of shoulder, elbow and wrist. Examination of the ensemble average curves for the two clusters revealed that the mostly female group tended to show a simultaneous movement sequence and the mostly male group showed a sequential sequence with regard to movement of the shoulder and elbow. Examplar trials can be seen in Figure 2 and 3. The

sequential sequence is characterized by the peak linear resultant elbow velocity occuring after the peak linear resultant shoulder velocity. The simultaneous sequence is characterized by the peak linear resultant elbow velocity occuring simultaneously with the peak linear resultant shoulder velocity.

Further examination identified two subgroups within each cluster (Figure 1). These four subgroups are mostly associated with the Jodan (subgroup II & IV) and Counter-chudan

Table 1 Average peak values of kinematic variables and the differences between cluster 1 & 2.

N=39	Cluster 1	Cluster 2	Difference
Punch time [s]	0.26 ± 0.04	0.27 ± 0.04	-0.01
Punch distance [m]	1.08 ± 0.16	1.29 ± 0.15	-0.21
Peak hip velocity [m/s]	2.42 ± 0.53	2.44 ± 0.57	-0.02
Peak shouder velocity [m/s]	4.04 ± 0.58	4.61 ± 0.39	-0.57
Peak elbow velocity [m/s]	6.94 ± 1.10	7.36 ± 0.79	-0.42
Peak wrist velocity [m/s]	6.93 ± 1.12	7.65 ± 0.86	-0.72

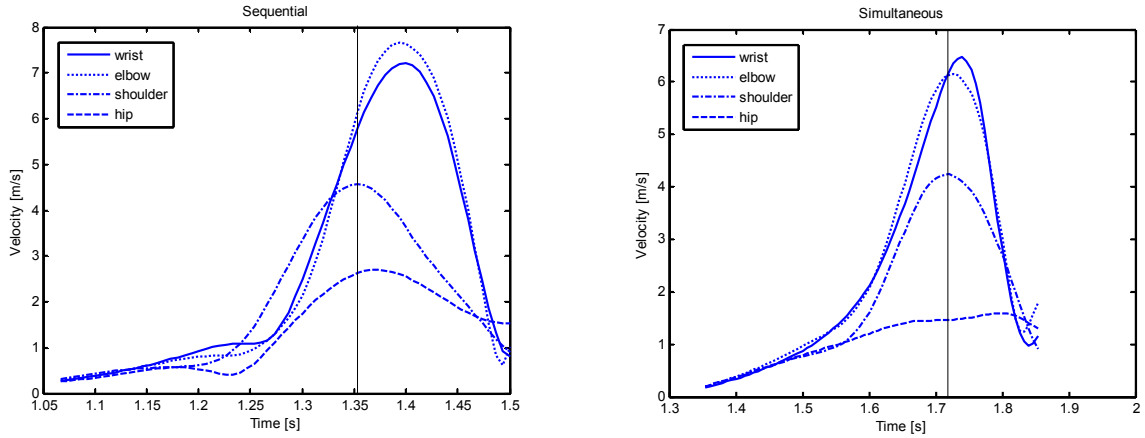

Figure 2 & 3: Exemplar linear resultant velocity curves of sequential (left) and simultaneous (right) movement sequences against time (not normalized).

Table 2 Average peak values of kinematic variables and the differences between the subgroups within cluster 1 & 2.

	Cluster 1			Cluster 2		
Subgroup (n)	Sub I (6)	Sub II (9)	Diff.	Sub III (6)	Sub IV (17)	Diff.
Punch time [s]	0.25 ± 0.04	0.27 ± 0.04	-0.02	0.28 ± 0.03	0.27 ± 0.05	0.01
Punch distance [m]	0.93 ± 0.08	1.19 ± 0.11	-0.26	1.38 ± 0.05	1.25 ± 0.16	0.13
Peak hip velocity [m/s]	2.02 ± 0.25	2.69 ± 0.51	-0.67	3.20 ± 0.33	2.18 ± 0.34	1.02
Peak shouder vel. [m/s]	3.51 ± 0.36	4.40 ± 0.39	-0.89	5.14 ± 0.23	4.42 ± 0.22	0.72
Peak elbow vel. [m/s]	6.10 ± 0.78	7.49 ± 0.93	-1.39	8.11 ± 0.54	7.09 ± 0.70	1.02
Peak wrist vel. [m/s]	6.18 ± 1.04	7.43 ± 0.90	-1.25	8.52 ± 0.43	7.34 ± 0.76	1.18

(subgroup I & III). In subgroup II and IV respectively 78% and 65% are Jodan punches. In subgroup I and III respectively 100% and 83% are Counter-chudan punches. Table 2 contains the averaged peak values of kinematic variables of the subgroups and the difference between the subgroups within each cluster. It shows that subgroup II and

subgroup III have a larger average punch distance and consistently higher averaged peak linear resultant joint velocities within the cluster.

DISCUSSION: The averaged peak linear resultant velocities are similar to those found in previous research by Emmermacher et al. (2005), Hofmann et al. (2008) and Stull et al. (1988). Summarizing the result, cluster 1 showed a more simultaneous movement between the shoulder and the elbow and cluster 2 showed a more sequential sequence. The kinematic results of cluster 2 does reveal larger values for the averaged peak linear resultant velocity of the hip, shoulder, elbow and wrist. Additionally, the average punch distance is larger in cluster 2. However this could be explained as an affect of gender differences. Therefore it is expected that the mostly male cluster have higher punch velocities and longer distance than the mostly female cluster. Logically, within the two clusters the ratio of Jodan and the Counter-chudan punches are alike. In the mostly female cluster 47% are Jodan punches and 53% Counter-chudan. For the mostly male cluster the percentages are 52% and 48% respectively. Interestingly the mostly female cluster achieve higher peak linear resultant joint velocity in the subgroup associated with Jodan whereas the mostly men cluster achieve higher peak linear resultant joint velocities in the subgroup that is associated with the Counter-chudan. However future research with more statistical power is needed to confirm these findings. Now only 8 subject participated and only 38 trials were included in the clustering analysis. Furthermore examining the effect of different punch conditions on kinematic variables could reveal important differences in techniques of male and female karate athletes.

CONCLUSION: The females in this study tend to show a more simultaneous movement sequence and the men show a more sequential sequence with regard to the shoulder and elbow movements. Additionaly their optimal performance is achieved in different punching conditions. The men punch optimal in terms of longer distance and peak linear joint velocities in the subgroup associated wth Counter-chudan punches whereas the women punch optimal in the subgroup associated with the Jodan punches.

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