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Research article

Wavelet transform analysis of electromyography Kung Fu strikes data

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Abstract

In martial arts and contact sports strikes are performed at near maximum speeds. For that reason, electromyography (EMG) analysis of such movements is non-trivial. This paper has three main goals: firstly, to investigate the differences in the EMG activity of muscles during strikes performed with and without impacts; secondly, to assess the advantages of using Sum of Significant Power (SSP) values instead of root mean square (*rms*) values when analyzing EMG data; and lastly to introduce a new method of calculating median frequency values using wavelet transforms (WMDF). EMG data of the deltoid anterior (DA), triceps brachii (TB) and brachioradialis (BR) muscles were collected from eight Kung Fu practitioners during strikes performed with and without impacts. SSP results indicated significant higher muscle activity ($p = 0.023$) for the strikes with impact. WMDF results, on the other hand, indicated significant lower values ($p = 0.007$) for the strikes with impact. SSP results presented higher sensitivity than *rms* to quantify important signal differences and, at the same time, presented lower inter-subject coefficient of variations. The result of increase in SSP values and decrease in WMDF may suggest better synchronization of motor units for the strikes with impact performed by the experienced Kung Fu practitioners.

Key words: Martial arts, combat sports, Kung Fu, EMG, wavelet transform, impact.

Introduction

Despite the progress made in the biomechanics of martial arts for the past three decades, there is still much work that needs to be done in order to improve the understand the complexity of these ancient arts (Neto et al., 2008b). In martial arts and contact sports strikes are performed with and without impact at near maximum hand speeds. For that reason, electromyography (EMG) analysis of such movements is non-trivial. Studies about EMG of martial arts strikes are rare. Neto et al. (2008a) reported a kinematical and EMG analysis of Kung Fu Yau-Man Palm strikes without impact. An empirical model applied to data obtained by a high-speed camera (1000 Hz) described the kinematical characteristics of the movement. The authors analyzed the EMG signals of the triceps brachii (TB), biceps brachii (BB) and brachioradialis (BR) muscles during the strikes in the time and frequency domains. The EMG results showed a well developed muscle coordination of the practitioners in agreement with kinematical results. In a similar study, Neto et al. (2007b) evaluated the coordination between agonists and antagonists muscles of the arm in a movement of Kung Fu performed by trained and untrained subjects. The authors demonstrated, using wavelet transforms to analyze the data in the frequency domain through time, that the untrained subjects presented much higher undesired co-contractions during the strikes. Neto et al. (2007a) compared the EMG activity of the TB, BB and BR during palm strikes with and without impacts. EMG analyses were done in the time and wavelet domains. Morlet wavelet power spectra were obtained and an original method was used to quantify statistically significant regions on the power spectra (SSP). The results both in the time (root mean square – *rms*) and frequency domains (SSP) indicated higher TB and BR muscle activity for the strikes with impacts. No significant difference was found for the BB in the two different scenarios.

This paper has three main goals. Firstly, to investigate the differences in the EMG activity of muscles during strikes performed with and without impacts. Secondly, to confirm some of the advantages, reported by Neto et al. (2007a), of using SSP values instead of *rms* values when analyzing EMG data. Finally, to introduce a new method of calculating median frequency values (MDF) using wavelet transforms.

Methods

Eight KF Yau-Man practitioners with 4.5 year average training experience of were selected to participate in the experiment. Each participant performed one palm strike without impact and one strike with impact targeting a training shield held by their KF instructor. A detailed description of the palm strike movement can be found on Neto et al. (2007c). Surface EMG signals were obtained from the anterior deltoid (DA), TB and BR of their striking hand. The subjects were allowed to position themselves in relation to the target and to adjust its height as they wished.

The methodology was approved by the University of Vale do Paraiba Ethics in Research Committee (Protocol #: H226/2007/CEP) and the subject provided his informed written consent.

Materials

The surface EMG signals were obtained using a four-channel module (model EMG400C, EMGSystem, Brazil) with a total amplifier gain of 2000 and sampled at 1000 Hz. A 12 bits AD converter digitalized the analogue signals with a sampling frequency of anti-aliasing of 2.0 kHz for each channel and an input range of 5mV. After shav-

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ing and cleaning the skin with alcohol, bipolar surface EMG electrodes were placed according to standard procedures with an inter-electrode distance 0.2 cm (Hermens and Freriks, 2000) and guided by bone prominences and the route of the muscle fibers.

Data analyses

All EMG data was processed off-line with Matlab 7.0.1 (MathWorks Inc). The EMG signals were treated in two different ways. First, the EMG signals were analysed following standard procedures in the time and frequency domains. For the time domain analysis the EMG signals were full wave rectified and then linear smoothed using a low pass Butterworth order 4 filter with a cut frequency of 14 Hz. The mean amplitude for this linear envelope was determined and it was used to normalize the EMG signals from which *rms* values were calculated. For the frequency domain, the median frequency of the signals were found using Fourier Transform (FMDF).

Second, EMG signals were normalized by the standard deviation and treated using *Morlet* wavelet transform as in Neto et al. (2007a) using a base algorithm developed by Torrence and Compo (1998). Sum of the significant power values (SSP) on the wavelet power spectra were calculated as in Neto et al. (2007a), and an algorithm was developed in Matlab 7.0.1 (MathWorks Inc.) to determine the MDF associated to the wavelet significant power values (WMDF).

Statistics

A balanced analysis of variance (ANOVA) was performed for the variables *rms*, FMDF, SSP and WMDF with one random factor (Subject) and two different crossed fixed factors (Impact and Muscle), followed by dependent t tests with Bonferroni corrections post hoc analyses. Pearson's Correlation analysis was used to investigate possible linear associations between the variables. Inter-subject (IECV) coefficients of variation for each muscle with and without impact were also calculated for each variable. All statistical tests were done using the Minitab (MINITAB® 14.12.0, Minitab Inc.) software; values of p smaller than 0.05 were considered significant.

Results

The least squares mean for *rms* was 0.23 for the strikes with impact and 0.21 for the strikes without impacts. ANOVA for the *rms* demonstrated that only the factor Subject as significant (Table 1).

Table 1. Analysis of Variance for *rms*

Source	DF	SS	MS	F-test	p
Subject	7	.25022	.03575	3.19	.010
Impact	1	.00476	.00476	.42	.519
Muscle	2	.06314	.03157	2.82	.073
Impact*Muscle	2	.03131	.01565	1.40	.261
Error	35	.39223	.01121		
Total	47	.74166			

rms = root mean square;, DF = degrees of freedom, SS = sum of squares, MS = mean square. * represents interaction.

The least squares mean for FMDF was 126.5 Hz for the strikes with impact and 124.1 Hz for the strikes without impacts. ANOVA for the FMDF demonstrated no significant factors (Table 2).

Table 2. Analysis of Variance for FMDF.

Source	DF	SS	MS	F-test	p
Subject	7	5007	715	1.31	.276
Impact	1	71.5	71.5	.13	.720
Muscle	2	2017	1008	1.84	.173
Impact*Muscle	2	768.7	384	.70	.502
Error	35	19146	547		
Total	47	27010			

FMDF = Fourier median frequency, DF = degrees of freedom, SS = sum of squares, MS = mean square. * represents interaction.

The least squares mean for SSP was 31931 V^2 for the strikes with impact and 22750 V^2 for the strikes without impacts. ANOVA for the SSP demonstrated only the factor Impact as significant (Table 3). Mean SSP was significantly higher (p = 0.023) for the strikes with impact (31931 ± 18153 V^2) than for the strikes without impacts (22750 ± 4987 V^2).

Table 3. Analysis of Variance for SSP.

Source	DF	SS	MS	F-test	p
Subject	7	1010256978	144322425	.80	.589
Impact	1	1011452408	1011452408	5.64	.023
Muscle	2	578958091	289479046	1.61	.214
Impact* Muscle	2	284925300	142462650	.79	.460
Error	35	6277408226	179354521		
Total	47	9163001004			

SSP = sum of significant power, DF = degrees of freedom, SS = sum of squares, MS = mean square. * represents interaction.

The least squares mean for WMDF was 80.5 Hz for the strikes with impact and 93.5 Hz for the strikes without impacts. ANOVA for the WMDF demonstrated that all three factors, Subject, Impact and Muscle were significant (p = 0.022; p = 0.007; p = 0.005, respectively) (Table 4). Mean WMDF was significantly lower (p = 0.007) for the strikes with impact (80.5 ± 24.3 Hz) than for the strikes without impacts (93.5 ± 12.7 Hz).

Table 4 - Analysis of Variance for WMDF.

Source	DF	SS	MS	F-test	p
Subject	7	4720	674	2.76	.022
Impact	1	2028	2028	8.29	.007
Muscle	2	2989	1495	6.11	.005
Impact*Muscle	2	990	495	2.02	.147
Error	35	8560	245		
Total	47	19287			

WMDF = wavelet median frequency, DF = degrees of freedom, SS = sum of squares, MS = mean square. * represents interaction.

No significant linear association was found between the values of *rms* and SSP (R = -0.028, p = 0.849) and FMDF and WMDF (R = 0.270, p = 0.063).

Table 5 shows the *rms*, FMDF, SSP and WMDF mean values and IECV values for each muscle with and without impact. The mean and coefficient of variations (in percentage) considering all data for the values of *rms*, SSP, FMDF and WMDF were: 0.22 (56%); 125.3 Hz (19%); 27340 V^2 (51%); and 87.03 Hz (23.3%), respectively.

Table 5. ***rms*, FMDF, SSP and WMDF mean values and IECV values for each muscle with and without impact.**

		Deltoid Anterior		Triceps Brachii		Brachioradialis	
Variable	**Impact**	**Mean**	**IECV**	**Mean**	**IECV**	**Mean**	**IECV**
rms	with	.1675	73.74	.2106	53.90	.3132	41.23
	without	.1905	77.48	.2196	56.54	.2215	44.55
FMDF	with	115.72	14.82	135.00	28.91	128.91	20.76
	without	122.56	11.29	133.55	17.44	116.21	11.64
SSP	with	23742	18.71	35662	77.06	36389	38.14
	without	21339	15.54	22016	15.01	24895	28.87
WMDF	with	92.67	18.29	85.40	35.08	63.50	23.64
	without	97.71	7.67	93.67	9.24	89.21	21.13

rms = root mean square, FMDF = Fourier median frequency (Hz), SSP = sum of significant power (V^2), WMDF = wavelet median frequency (Hz), IECV = inter-subject coefficient of variation (%).

Discussion

Although the least squares mean for *rms* was higher for the strikes with impact, ANOVA results did not demonstrate Impact to be a statistically significant factor. On the other hand, considering the SSP variable, Impact did demonstrate to be a statistically significant a factor. In a similar study, Neto et al. (2007a) found significant differences in the results of both *rms* and SSP between strikes with and without impact. In their work, however, each subject performed much more strikes than in the current study. The higher number of strikes increased the chance of finding statistically significant results. The comparison between the IECVs found for *rms* and SSP confirmed the results obtained by Neto et al. (2007a) that SSP results present lower IECV's than *rms* results. This fact was also evident in the ANOVA analyses, which showed that Subject was a significant Factor for the variable *rms* and not for the variable SSP. Contrary to what happen in Neto et al. (2007a) no significant correlation was found between the values of *rms* and SSP. In conclusion, SSP seems to be more sensitive than *rms* to quantify important signal differences and, at the same time, presents lower IECVs, which thereby can facilitate EMG's usage as a diagnostic or biofeedback tool.

FMDF data presented lower coefficient of variations than WMDF data. In this case however, lower coefficient of variations does not indicate a superiority of the method. Mathematically, Fourier transform methods are only valid when the signal may be considered as a stationary stochastic process. Although the recorded EMG signal during certain conditions may be considered as such, in dynamic conditions such as the one being studied the EMG signal may not (Hostens et al., 2004). No significant correlation was found between the values of FMDF and WMDF. Only through WMDF, it was found that the median frequencies for the strikes with impact were lower than the strikes without impact. The result of increase in SSP values and decrease in WMDF may suggest better synchronization of motor units for the strikes with impact performed by the experienced Kung Fu practitioners (Ricard et al., 2004). It may happen that strikes with impact are associated with higher hand speeds. Further studies with high-speed videos and EMG data collected simultaneously should be done to confirm these speculations.

At last, this study suggests that wavelet transform methods to analyze EMG data may be important in future studies of combat sports and martial arts strikes, where standard EMG analyses procedures (*rms*, Fourier transform) may not be reliable or precise. Furthermore, strike training against heavy bags or pads should not be neglected, since strikes performed with impact may present important muscle activation differences from strikes performed without impacts.

Conclusion

This paper investigates the differences in the EMG activity of muscles during palm strikes performed by Kung Fu Yau-Man experienced practitioners with and without impacts. SSP results presented higher sensitivity than *rms* to quantify important signal differences and, at the same time, presented lower inter-subject coefficient of variations. The results show higher SSP values and lower WMDF values for the strikes with impact compared to the strikes with no impact, suggesting better synchronization of motor units for this type of strike when performed by Kung Fu Yau-Man experienced practitioners.

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Key points

- The results show higher muscle activity and lower electromyography median frequencies for strikes with impact compared to strikes without.
- SSP results presented higher sensitivity and lower inter-subject coefficient of variations than *rms* results.
- Kung Fu palm strikes with impact may present better motor units' synchronization than strikes without.

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