

# Biomechanical methods applied in martial arts studies

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## Abstract

Martial arts are practiced in both amateur and in high professional level, stimulating scientific research in several areas of knowledge, including biomechanics. The main purpose of this review is to present the biomechanics methods used in the study of martial arts. The great importance of this study is the compilation of information science of what has already been analyzed under the biomechanics aspects related to martial arts and how this has been done. The methodology was directed to the revision of literature starting from articles, books, and seminars. From the collection of bibliographic surveys, it has been concluded that depending on the parameters studied *e.g.*: reaction time, speed, strength, power, among others, there is the need to apply one or more methods since there are situations in which only one biomechanical method will not be enough to answer the pointed question. It is also concluded that the investigated studies in the presented review showed the character of a descriptive examination, not directly applied to the development of techniques used on different modalities.

**Keywords:** martial arts, biomechanics, instrumentation on biomechanics, sport biomechanics, kinesiology.

## 1 Introduction

Martial arts, nowadays, are practiced by children and adults of both genders, in several societies and with different purpose (DEL'VECCHIO and FRANQUINI, 2006). The most practiced modalities involving competitive manner, both professional and amateurs are karate, taekwondo, judo, jiu-jitsu, and kung-fu (CORREIA and FRANCHINI, 2010). The amateur practitioners aim good health and apprenticeship of techniques conceded by the modality, but not the high yield (CARVALHO, 2004). At the professional environment martial arts are practiced as a sporting modality aiming high performance (PIMENTA and MARCHI JUNIOR, 2009).

Some of these modalities such as judo since 1972, in Monique, Germany and the taekwondo since 2000, in Sidney, Australia are considered as Olympic modalities (FALCO, ÁLVARES, CASTILHO et al., 2009; DRIGO, OLIVEIRA and CESANA, 2006). The investments to promote tournaments, mainly connected by television and radio programs surge the interest in the various modalities of martial arts (PIMENTA and MARCHI JUNIOR, 2009). With the professionalism, it became imperative the improvement of the techniques through training (OLIVEIRA, MOREIRA, GODOY et al., 2006), making it necessary researches which potentially help technicians, coaches and professors of martial arts in planning these trainings in order to give to the athlete the best chance to use his ability completely developed, fully fledged. It is found in the literature biomechanical studies of several modalities that analyze capabilities such as strength, power, reaction time, speed, agility and balance, among other elements. Many of these parameters which had been established are analyzed based on techniques of punching and kicking. These

analyses are obtained through biomechanical methods of kinemetry, dynamometry, and electromyography (AMADIO and DUARTE, 1996). Considering the importance of biomechanical parameters of martial arts as a link to improve techniques used, as well as to evaluate performance, the present review aims to exhibit the biomechanical methods used in the studies of martial arts.

## 2 Material and methods

The PubMed ([www.pubmed.nl](http://www.pubmed.nl)) and MEDLINE databases were used to conduct a literature search using keywords without restrictions. In this systematization, a search was conducted using the keywords: biomechanics, martial arts.

## 3 Results

Martial arts are a compound of corporal practices derived from war techniques. The martial term means “Marte – War Roman God” (FRANCHINI, TAKITO, RODRIGUES et al., 1996). The term “art” means expression, invention, imagination, playful and creation (FRANCHINI, TAKITO, RODRIGUES et al., 1996).

As to Reid and Croucher (1983), martial art is a compound of techniques, philosophy and combat traditions. Each martial art is an heiress of a determined tradition and constitutes coherence at all events in a way that all techniques are duly assembled by basic philosophical concepts and by traditional rituals. Martial arts were born many centuries ago aiming high at self defense. The fights among tribes led the warriors to understand the importance of training to face sudden outbreaks in order to get the best results

in the combats (HIRATA and DEL'VECCHIO, 2006). Owing to the big interest in the martial arts by professional practitioners as well as amateurs (PIMENTA and MARCHI JUNIOR, 2009; CARVALHO, 2004), researches are made in this area looking for the best way to improve the combat techniques. Biomechanics has been used through its high methods aiming to study the physics of martial arts.

### 3.1 About biomechanics methods

Biomechanics is one of the sub disciplines of kinesiology (HALL, 2000) and by definition it is the study of the application of mechanics to biological systems (HAMIL and KNUTZEN, 2008). The Biomechanics performance-related areas include measurement and motor control of human locomotion, sports, clinics and rehabilitation, orthopedics, among others (AMADIO and DUARTE, 1996). Biomechanics is structured with areas of cinemetry, dynamometry, anthropometry and electromyography to describe and exhibit a mathematical model of the human movement as a special fact (AMADIO and BARBANTI, 2000; CARPENTER, 2005; WINTER, 1990).

### 3.2 Biomechanical methods used in the studies of physics on martial arts

Biomechanical methods are used in the studies of physics of the martial arts and now some studies will be presented showing how these studies have been made. In a study about karate, Rodrigues and Rodrigues (1984) measured the reaction time and the movement time in the frontal kicks (mae-geri) and circular (mawashi-geri), to check the correlation between these two variables. The results pointed to the fact that independently of the technique used, the reaction time is superior to the movement time Layton (1993) measured the reaction and movement time of four techniques: straight blow (shoku-zuki), reverse blow (gyaku-zuki), frontal kick (mae-geri) and circular kick (mawashi-geri) of karate-shotokan, executed by both sides of the body. The results showed that except for the application of kata techniques the individuals executed the blows within the same reaction and movement time, independently of the side of the body that acts with the technique. Saltzberg, Hondzinski and Flanders (2001) used a system of videos to check five volunteers without any experience on martial arts aiming to describe the process of apprenticeship of an unknown movement involving the whole body. The results showed that the individuals, through practice, changed the angles of torsion and inclination of the trunk, facilitating both the postural and the adjustment of the kicking. Pinto Neto, Magini, Sabba et al. (2008) compared, using a high speed camera (1000 Hz), values of strength, power and efficiency of the palm blow of kung-fu among experienced and amateurs individuals. Viana, Andrade and Belmonte (2005) checked the correlation among the reaction time, flexibility and speed of the lower limbs. The authors concluded that there were not significant positive correlations among the researched variables. Esteves, Nascimento, Moreira et al. (2007), using a triple-axial speedometer coupled together to the back of the ankle of the individual, studied the taekwondo's kick called bandal tchagui. The results showed that owing to the high sharp of deceleration during the impacts, the structure of the foot becomes susceptible to injuries. Sforza (2002) performed a three dimensional analysis of the karate kicking

mae-geri-keage through an optical-electronic instrument. Thirteen reflexive markers were placed on anatomic. The reproducibility of the technique was measured. It was concluded that greater reproducibility was observed in the horizontal plan and it was still noticed smaller deviation in the hip and head. Movements in the ankle and knee joints showed high variability in the dominant member. Nien, Chang and Tang (2007) investigated the effects of speed in the movements of the taekwondo kicking roundhouse in two situations, *i.e.*, kicking a target the quickest possible and repeating the same task without a target. Using a high speed video camera it was concluded that the maximum speed of the toe and the ankle joint considering the existence of a target, was significantly higher than it would be without the target, and further, the angular speed of the hip, knee and ankle did not present significant difference among the situations kicking with or without a target. In these studies the method of cinemetry was used. Pinto Neto and Magini (2008) described the issues of electrical activation of the *biceps brachialis*, *brachioradialis* and *triceps brachialis* muscles as well as the kinematic characteristics of the upper limb during a Kung-fu fight action striking with the palm of the hand. It was observed that individuals did not make total stretching of the elbow at the end of the blow, and the first muscle to be activated was precisely the m. *biceps brachialis*. The *biceps brachialis* and *brachioradialis* muscles displayed less activity before the hand hit the target, whereas the *triceps brachialis* presented, in this connection to other muscles, larger wideness in the first half of the movement. Castro (1994) compared the action of the *biceps braquialis* muscle of both the extremity members in the kicking's dolha chagui and tuit chagui considering 20 athletes of taekwondo black-belt category. For this research he used electromyography aiming to register the electrical activity of the investigated muscles, and also a video-camera to record the kicking's divided in five phases. The conclusion was that the support limb showed higher muscle activation during striking of dolha chagui compared with tuit chagui kick. Pucsok, Nelson and Ng (2001) analyzed and compared the horizontal and vertical reaction forces of the support leg and the horizontal and vertical speed of the sweeping leg during the execution of the throwing technique (harai-goshi) of judo wrestlers both amateurs and advanced, utilizing a force plate and video cameras. The authors concluded that there was a positive correlation between the horizontal reaction force and horizontal speed of the sweeping leg and a significant difference of the horizontal reaction force of the support leg among beginners and advanced competitors. Fernandes (2009) made biomechanical analysis of the kicking ap bal ap dolio tchagui of taekwondo on 13 elite athletes. In this study the electrical muscle activation pattern for four lower limb and two trunk muscles were identified. It was also measured the electrogoniometry of the knee used for kicking and the horizontal and vertical accelerometry of the lower limb that performed the strike. The results allowed to conclude that all the muscles studied are activated before the movement of the knee, except for the *vastus medialis* muscle. It was also found that *biceps femoris* and lateral *gastrocnemius* are recruited in phase, the left and right *erector spinae* are pre-activated, maximal knee joint extension occurred approximately 10% of the movement prior to the foot/sand bag contact.

Gorgy, Vercher and Goyle (2008) used force plate in order to study the effect of practicing the chinese martial arts tai-chi-chuan, pa-koua and shing-hi-chuan in the postural control, using external perturbation with the practitioners in orthostatic position. In the experiment, the force plate was unexpectedly middle-laterally moved. This maneuver was performed with the volunteers keeping the eyes opened or closed. The sample was composed by practitioners of martial arts and practitioners and non-practitioners of sports. It was assayed the center of mass displacement and postural muscles amplitude and onset. It was concluded that the practice of martial arts influence upon the balance, lessening the displacement of the center of mass and pressure, as well as increasing the use of the ankle strategy to deal with the perturbation. However, there were not changes in the temporal patterns of the electromyographic signals of the investigated muscles. Santos, Esteves, Reis et al. (2005) measured the ground reaction forces from judo athletes when applying “ukemies” in different types of surface. Oliveira (2006) identified the palm pressure strength on jiu-jitsu athletes of competitive level using a hydraulic dynamometer and concluded that the jiu-jitsu athletes did not present raised values of palm pressure strength compared with athletes of others martial arts modalities. Borges Junior, Domenech, Silva et al. (2009) compared the maximal isometric palm pressure strength among practitioners of aikido, jiu-jitsu, judo, rowing and non-practitioners. The results showed that there are greater values of maximum strength when the practiced sport is jiu-jitsu, followed by judo, rowing, aikido, and non-practitioners. In this study dynamometry as used. Gulledge and Dapena (2008) compared the ability to unbalance the opponent by applying a direct or a reversal punch. Ground reaction forces, force transducers connected to the opponent body, and digital cameras (to measure kinematic parameters) were used. The results showed that the reverse punch is twice as stronger than the direct punch. However, the direct punch was more efficient considering that the goal was to unbalance the opponent. This is a good example of a complex biomechanical setup used to answer a direct question in martial arts.

#### 4 Conclusion

Owing to the great interest in the martial arts, many researches and developments are carried through biomechanics. The present study proposing a review of the literature aiming the investigation of which biomechanics methods are used in the studies of martial arts, brought the matter forward showing that depending on the variables studied, i.e., reaction time, speed, power, potency, among others, there is the necessity to use one or more methods, since there are situations in which only one biomechanical method is not enough to answer the proposed question. Another question to be pointed out is related to the investigation of existing literature about this subject, as it has not been perceived, that one single variable is more habitually studied than others. It is obvious that each study is concerned at the investigation of its variables, not seeming visible the possibility that one variable may be more important than the other. In relation to the techniques

checked, i.e. punch, kicking, balance, among others, it was not also perceived that there are techniques more studied in comparison to others. Another point to be mentioned refers to the fact that most of the studies investigated in this research cover all aspects of purely descriptive research not being directly directed to the development of techniques.

#### References

- AMADIO, AC. and BARBANTI, VJ. *A biodinâmica do movimento humano e suas relações interdisciplinares*. São Paulo: Estação Liberdade: EEFUSP, 2000. p. 52-54.
- AMADIO, AC. and DUARTE, M., eds. *Fundamentos biomecânicos para a análise do movimento humano*. São Paulo: Laboratório de Biomecânica, EEFUSP, 1996. p. 12-13, p. 22-58.
- BORGES JUNIOR, NG., DOMENECH, SC., SILVA, ACK., DIAS, JA. and SAGAWA JUNIOR, Y. Estudo comparativo da força de prensão isométrica máxima em diferentes modalidades esportivas. *Revista Brasileira de Cineantropometria e Desempenho Humano*, 2009, vol. 11, n. 3, p. 292-298.
- CARPENTER, CS. *Biomecânica*. Rio de Janeiro: Sprint, 2005. p. 19-26.
- CARVALHO, JGR. Sobre trauma e eventos cardíacos na prática de caratê: da realidade à prevenção. *Revista Médica do Paraná*, 2004, vol. 62, n. 2, p. 41-47.
- CASTRO, LOD. *Avaliação eletromiográfica de músculos dos membros inferiores no dolha chagui e tuit chagui do taekwondo*. Rio de Janeiro: Universidade do Estado do Rio de Janeiro, 1994. 34 p. [Monografia de graduação em Educação Física].
- CORREIA, WR. and FRANCHINI, E. Produção academia em lutas, artes marciais e esportes de combate. *Motriz*, 2010, vol. 16, n. 1, p. 1-9.
- DEL'VECCHIO, FB. and FRANCHINI, E. Lutas, artes marciais e esportes de combate: possibilidades, experiências e abordagens no currículo de educação física. In SOUZA NETO, S. and HUNGER, D., org. *Formação profissional em Educação Física: estudos e pesquisas*. Rio Claro: Bibliotética, 2006, v. 1, p. 99-108.
- DRIGO, A. J., OLIVEIRA, P. R. and CESANA, J. O judô brasileiro, o desempenho, e as mídias: caso das Olimpíadas de Atenas 2004 e o mundial do Cairo de 2005. *Conexões (UNICAMP)*, v. 4, n. 1, p. 4, 2006.
- ESTEVES, AC., NASCIMENTO, AS., MOREIRA, FD. and REIS, DC. Impacto no eixo ântero-posterior no chute bandal tchagui do taekwondo. *Revista Digital*, ano 11, n. 10, 2007.
- FALCO, C., ÁLVARES, O., CASTILHO, I., ESTYEVAN, I., MARTOS, J., MUGARRA, F. and IRALDI, A. Influence of the distance in a roundhouse kick's execution time and impact force in Taekwondo. *Journal of Biomechanics*, 2009, vol. 42, p. 242-248. PMID:19124126. <http://dx.doi.org/10.1016/j.jbiomech.2008.10.041>
- FERNANDES, VS. *Análise biomecânica do chute AP bal AP dolio tchagui do tae-kwon-do*. São Paulo: Universidade Sao Judas Tadeu, 2009. [Dissertação de mestrado em Educação Física].
- FRANCHINI, E., TAKITO, MY., RODRIGUES, FB. and MANOEL, EJ. Considerações sobre a inclusão de atividades motoras típicas de artes marciais em um programa de Educação Física. In *Anais do Congresso de Iniciação Científica da Escola de Educação Física da Universidade de São Paulo*, 1996. São Paulo, 1996. v. 1, p. 65-69.

- GORGY, O., VERCHER, JL. and COYLE, T. How does practice of internal Chinese martial arts influence postural reaction control? *Journal of Sports Sciences*, 2008, vol. 26, n. 6, p. 629-642. PMID:18344134. <http://dx.doi.org/10.1080/02640410701670401>
- GULLEDGE, K. and DAPENA, J. A Comparison of the reverse and power punches in oriental martial arts. *Journal of Sports Sciences*, 2008, vol. 26, n. 2, p. 189-96. PMID:17943591. <http://dx.doi.org/10.1080/02640410701429816>
- HALL, SJ. *Biomecânica Básica*. 3th ed. Rio de Janeiro: Guanabara Koogan, 2000. 4 p.
- HAMIL, J. and KNUTZEN, KM. *Bases Biomecânicas do Movimento Humano*. 2th ed. São Paulo: Manole, 2008. 5 p.
- HIRATA, DS. and DEL VECCHIO, FB. Preparação física para lutadores de Sanshou: Proposta baseada no sistema de periodização de Tudo O. Bompá. *Movimento & Percepção*, 2006, vol. 6, n. 8, p. 2-17.
- LAYTON, C. Reaction + Movement-time and Sidedness in shotokan karate students. *Perceptual and Motor Skills*, 1993, vol. 76, n. 3, p. 765-6. <http://dx.doi.org/10.2466/pms.1993.76.3.765>
- NIEN, YH., CHANG, JS. and TANG, WT. The kinematics of target effect during roundhouse kick in elite taekwondo athletes. *Journal of Biomechanics*, 2007, vol. 40, n. S2
- OLIVEIRA, M., MOREIRA, D., GODOY, JRP. and CAMBRAIA, AN. Avaliação da força de prensão palmar em atletas de jiu-jítsu de nível competitivo. *Revista Brasileira de Ciência e Movimento*, 2006, vol. 14, n. 3, p. 63-70.
- OLIVEIRA, SRS., SERASSUELO JUNIOR, H. and SIMÕES, AC. Seleção paulista masculina de judô: Estudos do comportamento das tendências competitivas entre atletas federados. *Revista Brasileira de Cineantropometria & Desempenho Humano*, 2006, vol. 8, n. 4, p. 82-90.
- PIMENTA, T. and MARCHI JUNIOR, W. A constituição de um subcampo do esporte: o caso do taekwondo. *Movimento*, 2009, vol. 15, n. 1, p. 193-215.
- PINTO NETO, O. and MAGINI, M. Electromyographic and kinematic characteristics of kung fu Yau-Man palm strike. *Journal of Electromyography and Kinesiology*, 2008, vol. 18, n. 6, p. 1047-1052. PMID:17499517. <http://dx.doi.org/10.1016/j.jelekin.2007.03.009>
- PINTO NETO, O., MAGINI, M., SABBA, MM. and PACHECO, MT. Comparison of force, power, and striking efficiency for a Kung Fu strike performed by novice and experienced practitioners: preliminary analysis. *Perceptual and Motor Skills*, 2008, vol. 106, n. 1, p. 188-196. PMID:18459367. <http://dx.doi.org/10.2466/pms.106.1.188-196>
- PUCSOK, JM., NELSON, K. and NG, ED. A kinetic and kinematic analysis of the Harai-goshi judô technique. *Acta Physiologica Hungarica*, 2001, vol. 88, n. 3-4, p. 271-80.
- REID, H. and CROUCHER, M. *O caminho do guerreiro*. São Paulo: Cultrix, 1983. 34 p.
- RIBEIRO, SR., TIERRA-CRIOLLO, CJ., MARTINS, RABL. Efeitos de diferentes esforços de luta de judô na atividade enzimática, atividade elétrica muscular e parâmetros biomecânicos de atletas de elite. *Revista Brasileira de Medicina do Esporte*, 2006, vol. 12, n. 1, p. 27-32.
- RODRIGUES, SCP. and RODRIGUES, MIK. Estudo de correlação entre tempo de reação e tempo de movimento no Karatê. *Revista Kinesis*, 1984, n. especial, p. 107-117.
- SALTZBERG, JR., HONDZINSKI, J. and FLANDERS, M. Humans adapt the initial posture in learning a whole-body kicking movement. *Neuroscience Letters*, 2001, vol. 306, n. 1-2, p. 73-76. PMID:12434836. [http://dx.doi.org/10.1016/S0304-3940\(01\)01875-4](http://dx.doi.org/10.1016/S0304-3940(01)01875-4)
- SANTOS, SG., ESTEVES, AC., REIS, DC., MORO, ARP. and MELO, SIL. Força de reação do solo em diferentes segmentos corporais de judocas na realização de “ukemis” em diferentes tipos de tatames. *Revista Brasileira de Ciência e Movimento*, 2005, vol. 13, n. 4, p. 15-24.
- SFORZA, C. Repeatability of mae-geri in traditional karate: A three-Dimensional analysis with black-belt karateka. *Perceptual and Motor Skills*, 2002, vol. 95, n. 2, p. 433-44. <http://dx.doi.org/10.2466/pms.2002.95.2.433>
- VIANA, MS., ANDRADE, A. and BELMONTE, AP. Tempo de reação, flexibilidade e velocidade de membros inferiores de atletas de taekwon do. *Coleção Pesquisa em Educação Física*, 2005, n. 3, p. 198-201.
- WINTER, DA. *The biomechanics and motor control of human gait: normal, elderly and pathological*. 2th ed. University of Waterloo: Waterloo, 1990. 65 p.

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