ORIGINAL ARTICLE

Biomechanics research on martial arts – the importance of defensive study

Authors' Contribution:
A Study Design
B Data Collection
C Statistical Analysis
D Manuscript Preparation
E Funds Collection

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Abstract

Background & Study Aim: Martial art is a self-defence art. Nevertheless, most martial art biomechanics studies have concentrated more on the offensive rather than on the defensive aspect of it. An in-depth study of defensive techniques is equally important since the real application of self-defence requires an individual to defend first and counter-attack second. The disproportionate trend of current studies needs to be validated to support future research. The purpose of this paper are trend of research and publications pertaining to defensive techniques in martial arts biomechanics.

Material & Methods: A systematic survey of research publications was conducted in the field of martial art biomechanics. Advanced search was opted to retrieve and filter scientific articles published in four databases which include SportDiscuss, ScienceDirect, Web of Science and ProQuest. An analysis was conducted on the aforementioned publications in order to categorize them based on the martial arts' classifications for offensive and defensive techniques.

Results: The results show that 89.1 percent of the publications in Martial Arts Biomechanics studies had focused on offensive techniques, compared to only 11 percent on defensive techniques.

Conclusions: Research in martial arts biomechanics is expanding, nevertheless it portrays a similar trend that tends to focus on offensive techniques. Supposedly, defensive techniques are of equal importance in martial arts. Therefore, more biomechanics investigations pertaining to defensive techniques in martial arts should be carried out. In addition, the data presented in this review could provide significant knowledge to support future research in martial arts biomechanics.

Keywords: bibliometrics • defensive action • offensive action • scientific journals

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Fend off – is a technique that permits the practitioner to repel/avert an attack. This kind of technique is observed in an established Malay Martial Art known as *Seni Silat Cekak*.

Evade – avoid the strike and apply counter attack.

Grab – catch a strike using hands.

Makan gerak – intuitive counter manoeuvre, when the enemy attacks, attack faster than the enemy.

Block – avoid a strike by stopping it.

Martial arts – referring to any combat and self-defence practices that combine offensive and defensive techniques.

INTRODUCTION

Martial arts are among one of numerous cultural activities practiced by males and females to protect themselves from physical and emotional harm initiated by attackers [1,2]. By applying certain techniques, the practitioner would be able to express his internal strength so that he can use it to defend himself. In fact, martial arts practitioners can rely on such techniques to disable their opponents [3]. More importantly, the practitioner may be able to defeat bigger and stronger opponents if they can apply the proper technique upon their opponents [4].

Martial arts are not necessarily a medium for the practitioner to become remarkable. Demonstrations that display the prolonged version of martial arts' various techniques, in order to impress the audience, i.e. in documentaries on television, is not the best way to reveal the systematic beauty of such techniques. Each technique itself must be characterized as concise, easy and precise. The main intention for each practitioner is to settle the confrontation as quickly as possible. Martial art is classified as a highly dangerous sporting career as almost all martial arts practitioners have experienced some form of injuries during practice [5].

Technically, martial art is an affiliation of systematic techniques designed to effectively avoid an attack, to kill or disable the enemy [6,7]. Based on the history of humanity, people tend to be aggressive in order to have an advantage over others. Threats of piracy, colonialism and expansionism made some form of martial arts relevant at the time. As a result, martial arts lessons were available in almost every part of the world, producing thousands upon thousands of different martial arts practices [8]. Local cultures may have affected the different forms of martial arts which have resulted in the arts' various styles, techniques and ideologies. However, the diverse martial arts techniques have remained true to two fundamental elements; the art to evade an attack and the art to incapacitate the attacker, as indicated in Figure 1. Both elements complement each other, thus practitioners are required to master them both in order to rely on the martial arts as self-defence tools. The battle situation sometimes requires someone to apply an attack and vice versa.

One martial arts practitioner may differ from another in the arts of application and body coordination when applying any technique. However, due to networking through friendships, intermarriages and business affairs, similarities among certain types of martial arts are observed as well [7,8]. In fact, physical similarities may have limited the disparity of movements even though human limbs have multi-degreed flexibility. The best examples are the punch and the kick in martial arts. There are various names to represent them and yet, in the end, they still remain just different types of a punch or a kick.

An offensive technique is meant to result in injury, pain and inability to the opponent. The attacker would disable the opponent by aiming at his soft vital areas such as the eyes, throats, ears and joints [7]. The attacks are normally in the form of punches, kicks, smashes and smacks. Thus, this review has divided the offensive techniques into two sections according to the body segments involved in the execution which is the upper limb and the lower limb.

On the other hand, the defensive aspects in martial arts deal with the effort on placing the defender in a safe situation when there is an unwanted incoming force attempting to hurt them. Thus, what is to be observed is the line of action of the incoming force [9]. The defender must be aware of the line of attack and the options available to overcome the situation which is: I) replace the target (in this case, the defender's body) or II) deflect and neutralize the attacker's movement .

The defensive methods in most martial arts have been classified into five types of movements; grab, evade, block, fend off and *makan gerak*. These classifications were made based on personal observations and experiences in martial arts. The defensive moves in this article refer to the preliminary move taken as a response towards the striking force. All these techniques are widely used and are considered as the initial steps which are included in the whole technique.

Grab is a technique with which the defender catches the attacker's limb that is being used to apply the force. The defender would normally utilize the momentum of the attacker to complete the defensive formation. Even though more than one style of martial art uses the grab technique, it is more commonly observed among Judo practitioners when they apply the throw technique.

Evade is a defensive action against an offensive move by an attacker. The defender steps his feet inside or outside the line of attack in order to remove himself from the target point. Evade is normally combined with either a grab, a block or a fend off technique to complete the defensive move. Blocking and fending off an attack represent the acts of avoiding the striking forces. Blocking in martial arts represents the act of avoiding the strike by stopping the opponent's

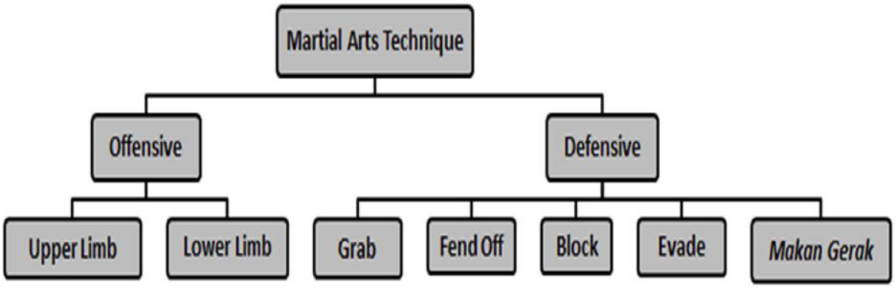

Figure 1. General Martial Arts Composition

attack while fending it off by deflecting the attacking force(s).

Fending off relies on a minimum repelling force executed by the defender to deflect the incoming force. The defender would utilize the flexibility of the hand and arm movements to fend off an attack. A systematic fending off technique is observed in the indigenous traditional Malay Martial Art called *Seni Silat Cekak Malaysia*. All the *buah* (lockdown or takedown techniques) in this Malay Martial Style is rooted from four fending off techniques known as *Kaedah A*, *Kaedah B*, *Kaedah C* dan *Kaedah D* [10].

The final classification for defensive techniques is *makan gerak*. Unfortunately, there is no appropriate English term that may represent the Malay term for *makan gerak*. The term *Makan gerak* refers to a situation where the defender can predict the attacker's next moves and acts faster than the attacker. Normally, an experienced practitioner would be able to apply this kind of technique.

The complexity and variety of martial arts techniques have further increased curiosity among researchers. Therefore, various researches have been conducted to scientifically study the mechanical aspects behind martial arts. Among the huge numbers of scientific areas, biomechanics is observed as having the closest resemblance to human movements in martial arts.

Biomechanics was chosen because it is an area of study that involves the application of mechanical principles towards the anatomical and the physiological aspects of living systems [11]. It is also based on the availability of proper biomechanical methods that could measure the efficiency of martial arts. Furthermore, biomechanics studies have wide applications that are reliable in sports performance enhancement (tennis, soccer, cricket bowling, baseball) [12–15].

Previous literature have proven that biomechanical studies are reliable and capable of exhibiting the quality of any martial arts [16,17]. Biomechanics was of great assistance in this study by focusing on how to enhance a practitioner's performance and to reduce injury while applying various techniques [18]. However, most biomechanics characterizations have focused more on offensive classifications and techniques. As a result, publications and references regarding defensive aspects of martial arts are very limited.

Therefore, the following pages offer information regarding biomechanics researches in Martial Arts. Considering the importance of making Martial Arts Biomechanics (MAB) researches more comprehensive, this review offers updated information regarding the current scenario of MAB researches. It aims to exhibit the status of scientific investigations towards defensive techniques in martial arts as well. This information is expected to be used in identifying any research gap for future study.

MATERIALS AND METHOD

This study adopts the systematic survey on research publication as a methodological approach to review the existing literature regarding Martial Arts Biomechanics to identify knowledge gaps pertaining defensive techniques in Martial Arts Biomechanics for future research agenda.

Literature searching strategy

In this study, keywords "Martial Arts" and "biomechanics" were used to retrieve scientific publications from four databases (SportDiscuss, ScienceDirect, Web of Science and Proquest) which were accessed via Universiti Teknologi MARA library's online databases. The Boolean operators 'and' between the keywords was used to ensure that both terms were

included in each article. The search was refined to academic journals or scholar journals in each database, with the exception of the following: letters, editorials and book reviews. The selected scientific publications were then exported in Mandeley Reference Manager to handle the duplication issue.

Literature selection

Some of the selected papers which do not match the aims of study but adhere to the search keywords are likely contained. Therefore, it is essential to make further efforts to screen and filter the selected articles. The screening and filtering was conducted by considering the inclusion criteria (articles on biomechanics investigations towards Martial Arts Technique) and yet the review papers were excluded.

Classification Scheme & Trend analysis

The filtered scientific publications were classified into two major categories, offensive technique or defensive technique based on the general martial arts composition (Figure 1). After the aforementioned scientific publications were classified the trend analysis was performed: (1) to identify the status of biomechanics investigations pertaining to defensive techniques in martial arts and (2) to see the development of Martial Arts Biomechanics since year 1989.

RESULTS

Based on preliminary search, it is found that 338 scientific articles have been published and retrieved using keywords 'Martial Arts' AND 'Biomechanics'. Upon filtering, only 54 articles have fulfilled the inclusion criteria involving investigation about specific offensive/defensive techniques (Table 1).

Table 1. Numbers of articles published using keywords 'Martial Arts' AND 'Biomechanics'

Database	Retrieved articles in preliminary search (number of papers)	Selected articles (number of papers)
Web of Science	25	13
ScienceDirect	231	16
Sport Discuss	47	21
ProQuest	35	4

Duplicates were inevitable among these papers, owing to adoption of overlapping databases [19]. Seven articles were found duplication analysed databases. A Venn diagram is plotted to depict and help identify the duplication (Figure 2).

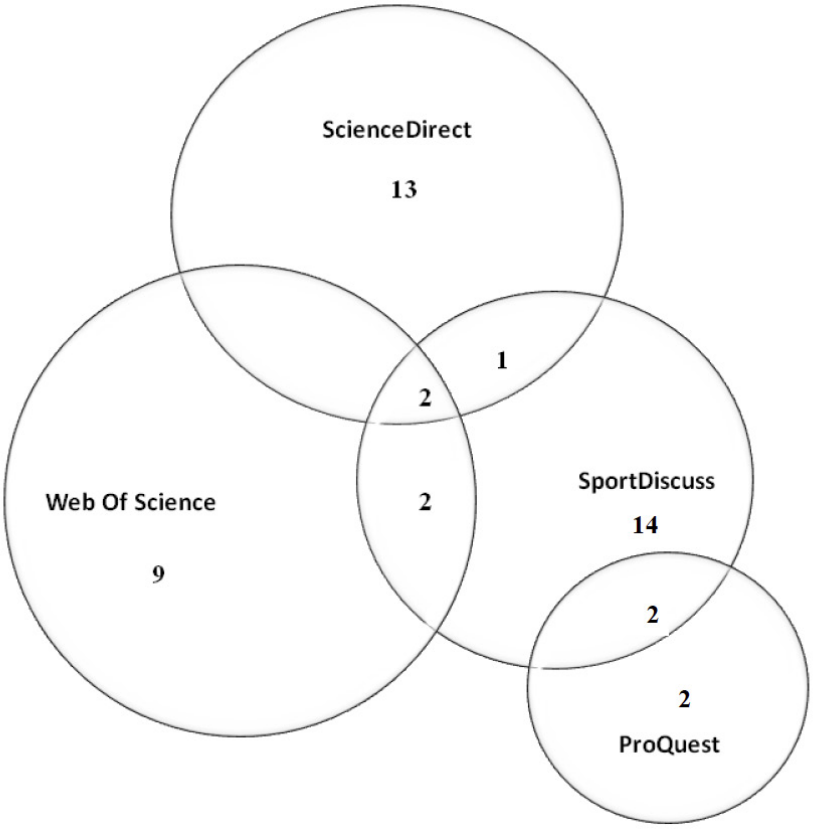

Figure 2. Venn diagram of related articles in each database

Table 2. Selected Publications on Martial Arts Offensive Techniques (Lower Limb)

Author	Methods /Apparatus	Measured Effects	Technique
Wąsik 2010 [20]	Complex Movement Analysis system (Smart-D)	Speed	Roundhouse Kick *(Dolio Chagui)*
Falco et al. 2009 [21]	Force Platform	Distance, execution time & impact force	Roundhouse Kick *(Dolio Chagui)*
Machado et al. 2010 [22]	Electromyography, Isokinetic Dynamometer	Muscular enhancement, power & torque capacity	Kick
Estevan et al. 2011 [23]	Force Platform, A/D Micro Controller, Pressure Sensors, Statistical Analysis	Time (reaction, execution & total response), max impact force	Roundhouse Kick *(Dolio Chagui)*
Pozo J et al. 2011 [24]	Force Plate, High Speed Camera	Impact force	*Mae-geri*
Koh et al. 2002 [25]	Videotape Analysis	Frequency of multiple impact, frequency & reaction to head blow	Axe Kick and Roundhouse kick *(Naeryeo Chagui and Dolio Chagui)*
Estevan et al. 2012 [26]	Force platform, LEDs, analogue-to-digital (A/D) microcontroller	Kicking height	Roundhouse Kick *(Dolio Chagui)*
Estevan et al. 2013 [27]	3D force plates, motion capture system	Execution time, velocity of thigh & shank	Roundhouse Kick *(Dolio Chagui)*
Fife et al. 2013 [28]	Tri-axial accelerometer, Qualysis Track Manager	Foot Velocity	Taekwondo Kicks *(Chagui-Dolio Chagui, Twi-myo Dwi Chagui, Dwi Hureo Chagui)*
Falcó et al. 2011 [29]	--	Impact force, execution time	Roundhouse Kick *(Dolio Chagui)*
Zvonar et al. 2012 [30]	Image Processing (film analysis)	Velocity, acceleration	Front Kick *(Mae-geri)*
Fife et al. 2013 [31]	A Hybrid II Crash Dummy head (H2D), tri-axial accelerometer.	Head linear acceleration (RLA), head injury criterion (HIC) data	Taekwondo Kicks *(Chagui -Dolio Chagui, An Chagui, TwioTuit Chagui, Twio Tuit Dollyo Chagui)*
Estevan et al. 2013 [32]	Force platform, LEDs, analogue-to-digital (A/D) microcontroller	Impact force, reaction time, execution time	Roundhouse kick *(Dolio Chagui)*
Zong-xiang et al. 2008 [33]	High-speed testing method	Kinematic data of body links	Horizontal Taekwondo Kick *(Kaunde Chagui)*
Quinzi et al. 2013 [34]	Surface electromyography (sEMG)	EMG data	Roundhouse kick *(Dolio Chagui)*
Nien et al. 2006 [35]	Motion Analysis System	Kinematic data, peak joint velocity	Taekwondo Kick *(Chagui)*
Quinzi et al. 2013 [36]	Stereophotogrammetric system	Coordinative patterns	Karate kick *(Geri)*
Serina et al. 1991 [37]	High-speed Video	Velocity, energy	Four types of kicks *(Chagui)*
Thibordee et al. 2014 [38]	Electrogoniometer sensors, Surface EMG	Kinematic, kinetic, EMG data	Roundhouse kick *(Dolio Chagui)*
Wu et al. 2007 [39]	3D Motion Analysis System, Bio-Pac System	Velocity	Whip kick *(Bian Tui)*
Kim et al. 2010 [40]	Three-dimensional video motion analysis	Linear displacements of the pivot hip and orientation angles of the pelvis, trunk, right thigh, and right shank	Roundhouse kick *(Dolio Chagui)*

Finally the number of the compiled MAB scientific articles publications was reduced to 44 (defined as selected articles), where 39 articles focused on offensive techniques and the rest (5 articles) on defensive techniques. Out of 39 articles related to offensive techniques, 21 articles studied about the lower limb (Table 2), 16 articles studied about upper limb (Table 3) and the remaining 2 articles studied about both upper and lower limb (Table 4). For defensive techniques, all 5 articles studied about upper limb, where only pushing technique (*Tui Shou*) has been published (Table 5). This is interesting because as described earlier, defensive techniques cover jabbing, evading, blocking, fending off and grabbing, where much more studies should have been conducted.

Further analysis on time trends of publications each year reveals that the Martial Arts Biomechanics is currently attracting more attention from the scientific community. The results (Figure 3) show that the numbers of publications in the four databases: SportDiscuss, ScienceDirect, Web of Science and ProQuest increase significantly and consistently for the past four years compared to the previous year.

Numerical differences between MAB publications on offensive versus defensive techniques are found to be 89:11 (Figure 4). Based on this figure, it is obvious that publications on offensive techniques far surpass the defensive by 78.2%.

DISCUSSION

The study found that research related to MAB has not been vigorously explored. This is because there is still a lot more to discover, especially comprehensive studies related to defensive techniques. The results obviously exposed that the current research patterns (offensive versus defensive) in MAB is significantly imbalanced. Hence, it is worth to discuss the possibility of contributing to the obvious disparity (offensive biased).

MAB research is commonly conducted for sporting

Table 3. Selected Publications on Martial Arts Offensive Techniques (Upper Limb)

Author	Methods /Apparatus	Measured Effects	Technique
Neto et al. 2006 [41]	High-speed Cameras	Velocity, acceleration	Kung fu strike
Imamura et al. 2006 [42]	Video Cameras, Motion Analysis software	Momentum, resultant impulse	Hip throw, hand throw, leg throw *(Koshi-Waza, Te-Waza, Ashi-Waza)*
Neto et al. 2007 [43]	High-speed Video Analysis	Hand speed	Palm strike
Neto et al. 2007 [44]	Electromyography	EMG data	Palm strike
Neto et al. 2007 [45]	High-speed Video	Mass, Hand Speed	Palm strike
Mcgill et al. 2010 [46]	Electromyography	EMG data	Strike
Piorkowski et al. 2011 [47]	Motion Analysis System	Impact force, contact speed	Punch
Koshida et al. 2011 [48]	Motion Analysis System Force Platform	Kinetic & kinematic data	Kendo strike
Ferreira et al. 2012 [49]	Electromyography	EMG Data	Punch
Neto et al. 2012 [50]	High-speed Cameras	Mean impact force	Palm strikes
Zaggelidis et al. 2012 [51]	Force Plate	Ground force reaction	Throwing technique *(Nage-Waza)*
Wąsik et al. 2013 [52]	Complex Movement analysis system (Smart-D)	Speed, acceleration	Straight Punch *(Ap Jirugi)*
Flanagan 2000 [53]	--	Force of punch	Twisting punch, Vertical punch
Cesari et al. [54]	Photocells, Force Platform	Limb velocity, CoP displacement, punch impulse	Karate punch *(Tsuke-Waza)*
VencesBrito et al. 2011 [55]	Electromagnetic sensors, EMG signals, System Ascension Technology, Software, Motion Monitor	Kinematic, EMG Data	Straight punch *(ChokuZuki)*
Imamura et al. 2007 [56]	Three-dimensional Motion Analysis System	Velocity for Center of Mass	Sweeping Hip throw *(Harai Goshi)*

Table 4. Selected Publications on Martial Arts Offensive Techniques (Combination of Upper & Lower Limbs)

Author	Methods /Apparatus	Measured Effects	Technique
Kuragano et al. 2012 [57]	Electromyography	EMG Data, Punch Force & Electrical Potential (Muscle)	Punch & Kick *(Tzuki & Geri Waza)*
Fife et al. 2013 [58]	Hybrid II Crash Dummy, tri-axial accelerometer	Linear Head acceleration, Head Injury Criterion, peak head velocity, fist & foot velocity	Boxing punch (Knock Punch, Jaw Punch, Uppercut,Forehead) & Taekwondo kick *(Dolio Chagui, Chiko Chagui, Naeryeo Chagui, Dwi Huryeo Chagui, Dwi Chagui)*

Table 5. Selected Publications on Martial Arts Defensive Techniques

Author	Methods /Apparatus	Measured Effects	Technique
Chen et al. 2010 [59]	Motion Analysis Systems, Force Plate, Electromyography	EMG data, Center Of Mass Displacement, Muscle Activities	Pushing Technique *(Tui Shou)*
Chang et al. 2010 [60]	Kistler Force Plate, VICON motion capture system, Visual 3D, Matlab	Ground Force reaction, COM displacement	Pushing Technique *(Tui Shou)*
Huang et al. 2006 [61]	Motion Analysis Systems	COP trajectories	Pushing Technique *(Tui Shou)*
Liu et al. 1989 [62]	--	--	Pushing Technique *(Tui Shou)*
Wong et al. 2007 [63]	Video Camera, Motion Analysis software (Peak Motus)	Resistance force	Pushing Technique *(Tui Shou)*

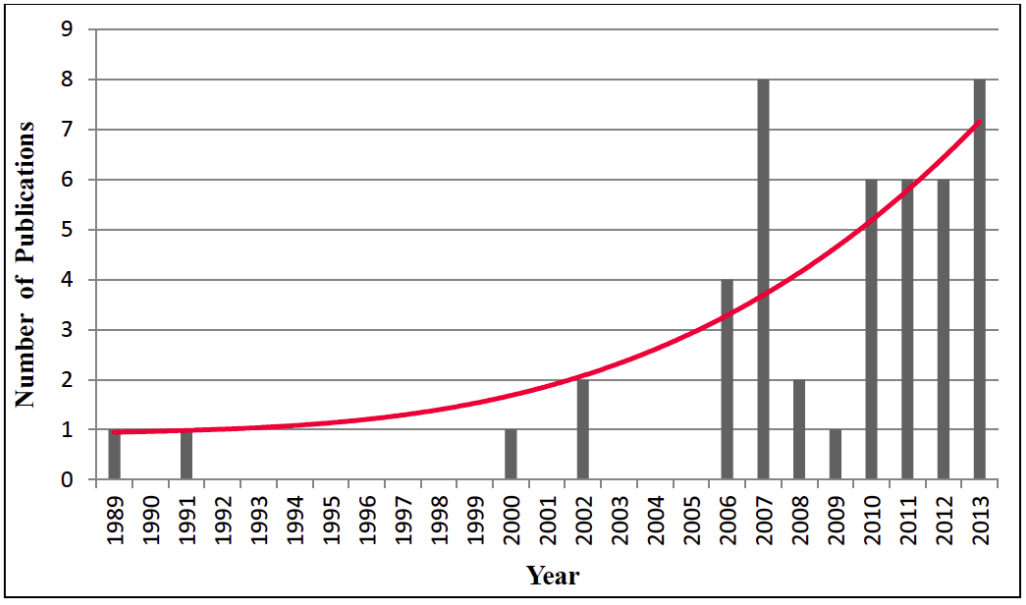

Figure 3. Year Profile of publications (till 2013)

purposes. This could the main possibility as in sports, the striking formation is biomechanically characterised to provide information and improve offensive techniques. For example, the output from an MAB study is expected to assist athletes in strategizing offensive tactics in martial art competitions.

Another main possibility might be due to general perception of 'the person who can perform the most powerful attack will dominate in a battle'. This perception has encouraged researchers to focus on powerful offensive strikes rather than defensive technique.

The third possibility could be related to the degree of difficulty in conducting research related to offensive or defensive technique. However, experimental setup

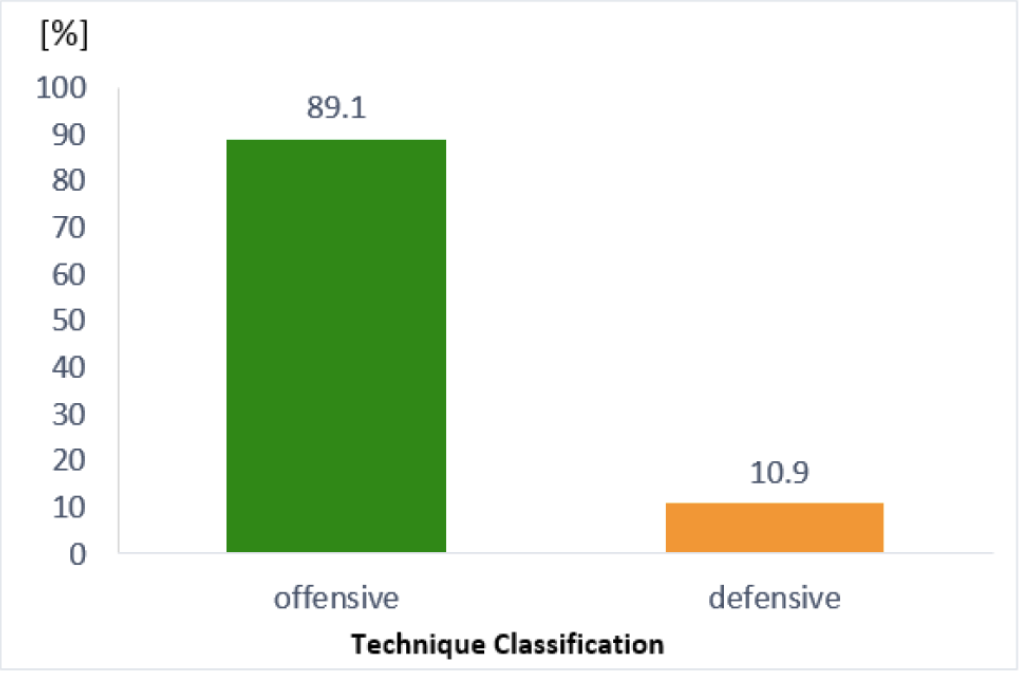

Figure 4. Comparison between offensive and defensive publications

for offensive techniques could be made simpler by striking an imaginary target. On the contrary, defensive techniques require a real attacker and quasi fighting environment. (imaginary strike is not realistic).

CONCLUSIONS

The results show that the main objective of this study has been achieved successfully. Research in Martial Arts Biomechanics is expanding; nevertheless it portrays a similar trend that tends to focus on offensive techniques (89.1% biased). Literatures reviewed the data presented in this review could provide significant knowledge to support future research in Martial Arts Biomechanics. Therefore, it could be concluded that the current study has provided significant knowledge to support future research in Martial Arts Biomechanics. Supposedly, defensive techniques are of equal importance in martial arts. Therefore, more biomechanics investigations pertaining to defensive techniques in martial arts should be carried out.

COMPETING INTEREST

The authors declare that they have no competing interests.

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