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A kinematic analysis of the Thai boxing clinch

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Abstract. The purpose of the study was to investigate the kinematics between the double collar-tie and double underhook Thai Boxing clinching positions. Ten amateur mixed martial arts athletes executed six knee strikes for both clinching positions with their dominant limb directed towards a target. A standard two-dimensional video motion analysis was conducted, and the results showed a statistical significant difference at the hip joint angle and the angular acceleration of the knee and ankle. Within both clinching positions, there was a statistically significant correlation between the hip and knee joint angles, hip and knee angular velocities, and hip angular acceleration. Between both clinching positions, there was a statistically significant correlation at the knee joint angle, knee angular velocity, and hip angular acceleration. This study demonstrates the importance of the hip and knee joint movements in both clinching positions, which implies the applications of strength training and flexibility at these joints for sports performance and injury prevention. It is suggested that future studies analyzing the non-dominant leg are warranted to fully understand the Thai Boxing clinch.

Keywords: boxing; clinch; kinematics; lower extremity; martial arts

1. Introduction

Thai Boxing is a national sport of the Kingdom of Thailand. The sport originated during the second and third centuries BC from Indian-Buddhist Monks whom were originally sent to find the Suvarnabhumi, the land of gold, in modern-day central Thailand (Junlakan 2007). They trained with equal rigor in the arts of meditation and self-defense, on the premise of believing that a strong body leads to a strong spirit. During the late 20th century, Thai Boxing gained popularity, and under a unified governing body, the sport spread to 110 countries with five continental federations. In addition, Thai Boxing has multiple applications in other sports such as American and European kickboxing, karate (multiple forms), and mixed martial arts. The sport requires the use of punches, kicks, and strikes, directing towards eight points of contact (hands, feet, elbows, and knees) instead of two points of contact (hands) as in Western Boxing. The duration of a match is based on the weight class of the fighter. The length of each round is five minutes in duration, with two-minutes of recovery scheduled in between each round, for five rounds. Similar to boxing, the outcome of a match is decided either by knockouts, technical knockouts, or points, based upon a system adapted from the Queensbury Rules (MUAY THAI 2010).

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From a biomechanical perspective, basic Thai Boxing skills and techniques utilize the principles of velocity, force, and torque to produce powerful striking movements. Furthermore, there are a limited number of research studies that have examined the kinematics of Thai Boxing. Sidthilaw (1997) examined the kinetic and kinematic characteristics of Thai Boxing roundhouse kicks at different height with ten male Thai Boxing athletes. These athletes had eight to forty eight months of training experience. From this study, the results showed the middle-level kick generated the greatest peak force and impulse while the high-level kick involved the least amount of force and impulse. The amount of peak force and impulse were directly related to the final velocity of the ankle (r = .86 and r = .79), but they were not significantly related to leg strength. Sidthilaw (1997) further indicated that the Thai Boxing roundhouse kick could generate sufficient enough force to cause neurological impairment, skull fractures, facial bone fractures, and rib fractures. Additionally, Gartland, Malik, and Lovell (2005) determined that the head is the most common site of injury with amateur Thai Boxing fighters. Lastly, other Thai Boxing research studies have focused on the physiologic aspects. Crisafulli, Vitelli and Cappai (2009), Silva, Del Vecchio, and Picano (2011), and Turner (2009), have suggested that Thai Boxing requires the use of both anaerobic and aerobic energy systems. Specifically, anaerobic glycolysis, which is the intermediate energy system used for activities that last from thirty seconds to two minutes, is recruited during the first round and the recovery period while, aerobic glycolysis, which in the energy system used for activities longer than two minutes in duration, is the primary energy system during the second and third rounds.

Other research studies have analyzed lower-limb kinematic variables in similar martial arts such as Karate and Taekwondo. Hwang (1987) conducted a preliminary kinematic analysis of the Taekwondo front kick with three amateur Taekwondo athletes who were instructed to execute kicks at both with a target and without it. Hwang (1987) determined that the absolute linear foot velocities were between 10.3 m/s and 11.7 m/s for with a target condition and between 0.8 m/s and 11.7 m/s for without a target condition. The maximum foot velocities in both conditions were between 11.6 m/s and 13.4 m/s for with a target and without it, respectively. In regards to angular velocity, Pozo, Bastein, and Dierick (2011) determined that there were significant differences in several lower-limb joint angles with angular velocity peaks occurring earlier in the kick for the Shotokan karate kick Mae-Geri. Wasik (2011) also determined that there is a correlation between the maximum knee and foot velocities for the Taekwondo side kick (r = 0.72) because higher knee velocities can contribute to the increase in foot joint angular velocity. Kong, Luk, and Hong (2000) conducted a research study to examine the relationship between the front and back legs of the Taekwondo roundhouse kick, and the authors determined that movement time of the kick executed by the front leg was 12% shorter than the back leg. The maximum linear velocity of the roundhouse kick executed by the back leg was greater than the front leg by 38% and 62% for the ankle and knee joints, respectively.

The Thai Boxing clinch is not a unique Thai invention but rather is a common Greco-Roman wrestling maneuver (Pedreira 2009). In the clinch, athletes may attack their opponents with punches, elbows, and most commonly, knees. On the other hand, athletes can also throw their opponents to the ground from the clinch. However, this tactic does not score any points but it fatigues and demoralizes the opponent. The most commonly associated clinching position in the sport of Thai Boxing is the double-collar (Pedreira 2009). The main objective of the double-collar clinching position is to hold the opponent's head with both hands on the back of the head, or one hand on the neck and the other on the top of the head while keeping the elbows tightly together. This maneuver presents a significant advantage to the athlete because it provides full control of the opposition's head and neck movements. Contrastingly, the objective of the double underhook clinch is to project both arms underneath the opponent's armpits while lifting the opponent slightly off their feet (Hewitson 2012). At this moment, the opponent does not have a strong base of support which makes them vulnerable to a variety of knee strikes. From both positions, it is paramount that the opponent attempts to escape in order to prevent serious injuries. Since both clinching techniques are different, it would be crucial to understand which type of clinching technique would be more effective to perform and how to perform it correctly and safely. Therefore, the purpose of this study was to examine the lower limb kinematics between the double collar-tie and double underhook Thai Boxing clinching positions of amateur mixed martial artists.

2. Methods

Ten amateur martial arts athletes volunteered to participate in the study. The mean age, height, weight and experience in mixed martial arts were 23 ± 5 yrs., 1.8 ± 0.1 m, 73.3 ± 11.4 kg, and 5.9 ± 5.4 yrs., respectively. Participants were recruited from local mixed martial arts training clubs. The institutional research ethics review was approved and written informed consent was obtained from each participant prior to the study. In addition, each participant completed a PAR-Q and a questionnaire, which indicated their cardiovascular health, fitness history, and experience participating in the sport. All participants arrived at the Biomechanics Laboratory or local mixed martial arts training clubs. Two Thai Boxing cotton hand wraps (4.6 m) and two standard Thai Boxing gloves (.34 kg) were provided to each participant for wrist protection and simulating both double collar-tie and double underhook clinching positions.

Prior to the warm-up, all participants were instructed how to properly wrap their hands with the Thai Boxing cotton hand wraps. After they were fitted and tied with the standard Thai boxing gloves, the participants performed a dynamic warm up to increase core muscular temperature and muscular force production to prevent against potential injuries. Joint reflective markers were placed on the right side of the following joint locations: lateral malleolus of the fibula (ankle), base of the fifth metatarsal (toe), lateral epicondyle of the femur (knee), greater trochanter (hip), greater tubercle (shoulder), lateral epicondyle of the humerus (elbow), styloid process of the radius (wrist), and on the chin and forehead. Each participant wore a tight-fitting black shirt and shorts to provide better contrast between the markers and clothes for video analysis. Participants executed six continuous knee strikes with their dominant leg (right) in each of the two clinching positions (double collar-tie and double underhook) for a total of twelve knee strikes, Fig. 1. Since the knee strikes were performed in a continuous motion, the participants attempted to simulate real fight-like movement. Each participant had three minutes break between both two clinching positions to avoid the influence of fatigue. For each knee strike, the participant directed the kick towards an experienced Thai Boxing athlete whom was equipped with a belly pad, two standard Thai Boxing pads, a groin protector, and a mouth guard to insure maximum safety of the athlete. Since the target was well protected, the risk of injury was minimal. Lastly, the order of the clinching positions was randomized to reduce any order effect.

Following all twelve knee strikes, the participant performed five minutes of static stretching for cool down and recovery. In addition, each participant had the opportunity to view video trials of their kicking movement which enabled them to have a better understanding about the mechanics of their own clinching technique. Data collection was conducted in one hour over the duration of one day. Data was recorded on all twelve knee strikes. A-two dimensional video analysis was

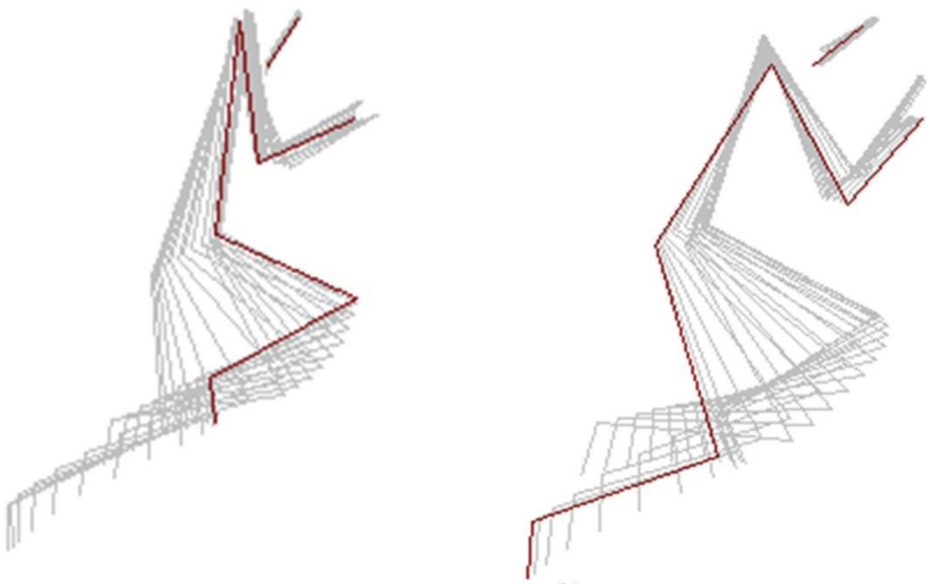

Fig. 1 Two types of clinching technique: (a) stick figure of double collar-tie, and (b) stick figure of double underhook

conducted with a JVC video camera (model: GR-D371V, JVC America, Wayne, New Jersey) which captured sagittal motion at 60 Hz with 650W artificial lighting. Digital filter was applied at 8 Hz to filter the data. The video was transferred onto a computer in the Biomechanics Lab. Dependent sample t-tests ($\alpha = 0.05$) and Pearson's product-moment correlations were conducted with SPSS (version 18) software (IBM Corporation, Armonk, New York).

3. Results

A dependent sample t-test ($p < 0.05$) was conducted between the double collar-tie and double underhook clinching positions at the hip, knee, and ankle joints. The joint angular displacements, velocities, and acceleration of each joint were calculated and compared between the two positions. The results showed a statistical significant difference at the hip joint angular displacement between double collar-tie and double underhook at 103.2 ± 13.4° and 88.4 ± 12.4° ($p = 0.00$), respectively, but there were no statistical significant differences at the knee and ankle between both clinching positions, Fig. 2. Additionally, there were no statistical differences between the joint angular velocity of the hip, knee, and ankle.

The statistical comparisons for the hip, knee, and ankle between the double collar-tie and double underhook positions were -9.4 ± 86.8 °/s and -10.1 ± 76.9 °/s ($p = 0.94$), 17.6 ± 147.4 °/s and 58.5 ± 117.8 °/s ($p = 0.17$), and -1.8 ± 99.2 °/s and -56.0 ± 52.3 °/s ($p = 0.23$), respectively. For the joint angular acceleration, there was a statistical significant difference observed between the double collar-tie and double underhook for the knee at 5083 ± 4422 $°/s^2$ and 1981 ± 2707 °/s2 ($p =$

0.03), respectively, and for the ankle at 631 ± 1371 °/s2 and 2581 ± 2191 °/s2 (p = 0.02), respectively, Fig. 3. There was no significant difference observed at the hip joint between both clinching positions

Further, a two-tailed Pearson's product-moment correlation was conducted for the hip, knee, and ankle joints in both clinching positions, Tables 1-3. Within both clinching positions, there was a statistically significant correlation only between the hip and knee joint angles. There was no correlation between the hip and ankle and the knee and ankle joints. Further, correlations of the angular displacements, velocities, and accelerations of the hip, knee, and ankle between two clinching positions were conducted, Table 4. Between both clinching positions, there was a significant correlation observed at the knee joint angle, hip and knee angular velocities, and hip angular acceleration.

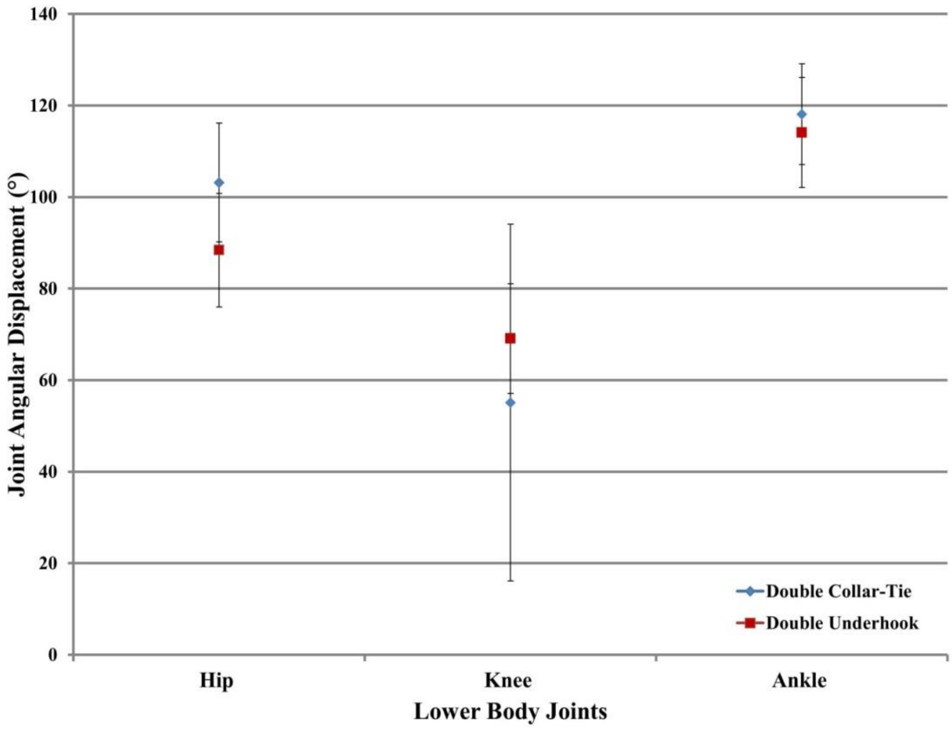

Fig. 2 Angular displacement between clinching positions in each joint

Table 1 Correlation of joint angular displacement in each clinching position

Joint	Double Collar-Tie	Double Underhook
Hip vs. Knee	0.72*	0.94**
Hip vs. Ankle	0.20	0.19
Knee vs. Ankle	0.21	0.03

** Correlation is significant at the 0.05 level*
*** Correlation is significant at the 0.01 level*

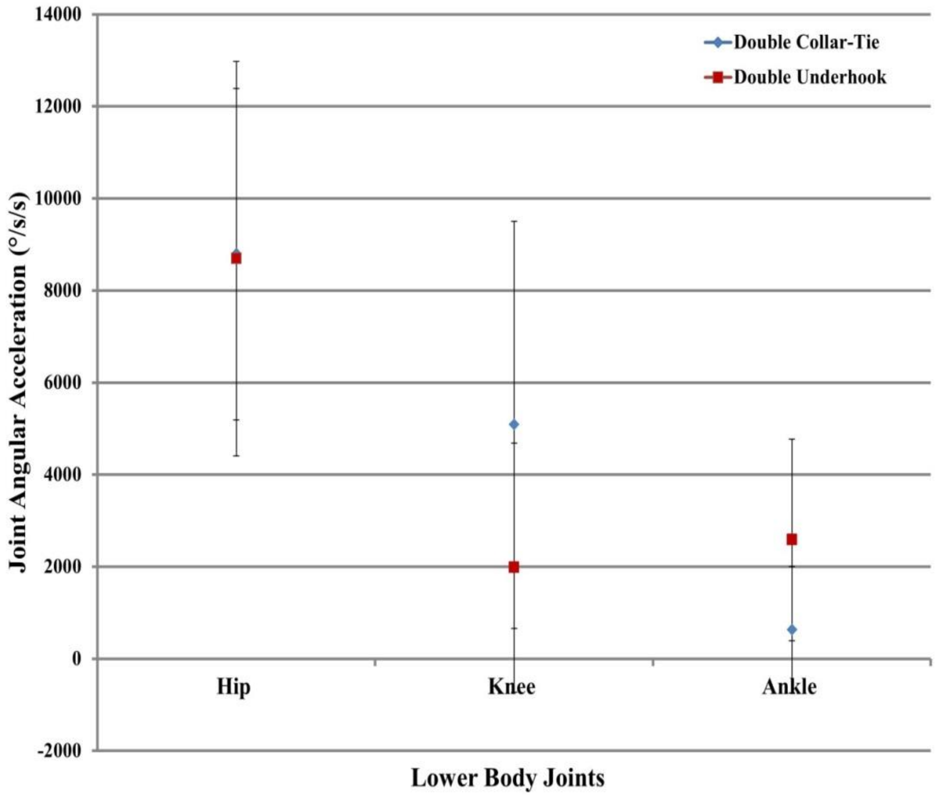

Fig. 3 Angular acceleration between clinching positions in each joint

Table 2 Correlation of joint angular velocity in each clinching position

Joint	Double Collar-Tie	Double Underhook
Hip vs. Knee	-0.57	-0.37
Hip vs. Ankle	0.72*	-0.45
Knee vs. Ankle	-0.88**	0.22

** Correlation is significant at the 0.05 level*
*** Correlation is significant at the 0.01 level*

Table 3 Correlation of joint angular acceleration in each clinching position

Joint	Double Collar-Tie	Double Underhook
Hip vs. Knee	0.08**	0.73*
Hip vs. Ankle	-0.36	-0.28
Knee vs. Ankle	0.10	-0.03

** Correlation is significant at the 0.05 level*
*** Correlation is significant at the 0.01 level*

Table 4 Correlation of joint angle, velocity, and acceleration between double collar and double underhook

Double collar vs. Double underhook			
Joint	Angular displacement (°)	Angular velocity (°/s)	Angular acceleration (°/s^2)
Hip	0.55	0.94*	0.85**
Knee	0.84**	0.81**	0.54
Ankle	0.51	-0.49	0.39

** Correlation is significant at the 0.05 level*
*** Correlation is significant at the 0.01 level*

4. Discussion

Little is known about the kinematic characteristics of the Thai Boxing Clinch. The purpose of the study was to examine the joint angular displacement, velocity, and acceleration of the hip, knee, and ankle between the double-collar and double underhook Thai Boxing clinching positions. The results revealed a significant statistical difference at the hip joint angle between both clinching positions and at the knee and ankle joint for the angular acceleration. In a previous Taekwondo research study, Kim *et al.* (2010) observed a significant difference in the peak hip flexion for the roundhouse kicking leg. In this study the hip flexion for the double-collar tie and double underhook clinching positions were 103.2˚ ± 13.4˚ and 88.4 ˚± 12.4˚, respectively. One of the main factors that may explain a statistical significant difference for the joint angular difference at the hip between both clinching positions was the hip's linear distance from the target. This interpretation corresponds with Kim *et al.* (2010) who determined that the target distance had an influence on hip flexion and pelvic rotation. From the qualitative video analysis, the hip was farther away from the target for the double collar-tie position than for the double-underhook position. This factor might have allowed the athlete to achieve a greater hip flexion in this research study. In regards to the knee and ankle, there was no statistical significant difference between both joints. The results may imply that the hip joint is the primary joint for executing the clinch position, and the knee and ankle joints are the secondary joints which help to stabilize the hip and trunk movements.

There was no significant difference in the hip and knee for the angular velocity between both clinching positions. However, there was a high standard deviation observed at each joint which indicates that participants executed the knee striking motion with different angular velocities. Some of the reasons why each participant performed the knee striking motion at different angular velocities could be attributed to recruitment of fast-twitch muscle fibers, muscle fiber composition, muscular strength, and technique. When comparing this study to other martial arts studies, Pozo *et al.* (2010) also did not find significant differences in the hip and knee joints for the peak angular velocities for the Shotokan Karate Mae-Geri kick between international and national athletes. While this may be true, lower values were obtained for knee flexion (784˚/s and 698˚/s) while higher values were obtained for hip flexion (721˚/s and 605˚/s) for the international and national athletes, respectively. The findings of this study are congruent with Pozo *et al.* (2010), which knee joint angular velocities (double collar: 17.6 ± 147.4 ˚/s and double underhook: 58.5 ± 117˚/s) were higher than the hip joint angular velocities (double collar-tie: -9.4 ± 86.8˚/s; double underhook: -10.1 ± 76.9˚/s) in both clinching positions. Our finding is also consistent with Tang, Chang, and Nien (2007) who also reported higher average knee angular velocities and lower hip angular velocities (1737 ± 322 ˚/s vs. -533 ± 79 ˚/s) for the right leg. It may be concluded that the knee plays a significant factor when determining the mean angular velocity of a knee strike in the skill of the Thai Boxing clinch. Interestingly, Sorensen, Zacho and Simonsen (1996) suggest that motion-dependant moments from lower leg angular velocity may cause thigh deceleration during the martial arts front kick. In this study thigh deceleration was not observed in each kick, and the results for the hip joint angular acceleration were significantly higher than the knee and ankle accelerations. However, there was a high correlation between the hip and knee accelerations in both clinching positions but not for the ankle. Thus, Sorensen *et al.* (1996)'s finding is not supported in the research study.

The Pearson product-moment correlation coefficient revealed a statistical significant strong correlation in joint angular displacement between the hip and knee joints in both clinching positions. Further, there was also a statistically moderate correlation in joint angular velocity at the hip and knee joint, and hip joint angular acceleration. The correlation results may suggest that there is a high transferability of skill and that by training one clinching technique may be beneficial for another clinching technique, specifically at the knee and hip joints. There was not a significant correlation for knee and ankle joint angular displacement, ankle joint angular velocity, and knee and ankle joint angular acceleration. This finding indicates that the ankle movement has a minimal influence in both clinching positions.

The execution time, reaction time, and target distance may have an influence in executing a knee strike in both clinching positions. Pozo *et al.* (2011) conducted a research study on Shotokan karate kick mae-geri, and the authors examined the performance characteristics of the mae-geri kick on execution time, lower limb kinetics, and kinematics, and their respective repeatability with national and international karate athletes. This study showed that the international karate athletes demonstrated higher knee angular velocities than the national karate athletes for all phases of the mae- geri kick. Pozo *et al.* (2011) concluded that the repeatability of execution time and the lower limb kinematics are particularly important for karate athletes, and the same may be assumed for Thai Boxing athletes. In a similar study comparing execution, reaction and total-response time, Falco, Estevan, and Vieten (2011) compared five commonly used taekwondo kicks (roundhouse, front leg axe, clench axe, jump spin back, and jump spin hook). The results of their study indicated that swing kicks (roundhouse and jump spin hook) have a faster execution and total response time than the thrust kicks (front leg axe and clench axe). There were no differences in reaction time among the five kicks. All knee strikes executed from both clinching positions can be classified as thrust kicks in which they have slower execution rates in comparison to Thai swing kicks such as the Roundhouse kick. In reference to the reaction time of all the knee strikes, all participants started and ended when instructed, so the reaction time did not play a significant factor in this study.

Burke, Protopas, and Bonato (2010) suggest that approximately thirty-eight hours are required to learn offensive and defensive martial arts techniques. Layton (1993) observed that the speed of the Shotokan Karate kick does not have a significant correlation with age. The primary factor to maintain the speed of Shotokan Karate kick is through physical training and experience. In a previous research study, Sbriccoli *et al.* (2010) reported higher values for peak angular velocity reached in elite karate athletes during knee flexion (1,470 ± 84˚/s) was statistically higher than amateurs (1110 ± 26˚/s). Further, Falco *et al.* (2007) also found a significant difference between national (elite) and recreational (amateur) taekwondo athletes for foot and hip reaction times and movement of the upper body. In this study participants had approximately 5.9 ± 5.4 years of experience and were approximately 23 ± 5 years of age. Since most of the participants compete in mixed martial arts, Thai Boxing fundamentals have already been learned and are close to being mastered. However, only amateur mixed martial arts athletes were used in this study instead of elite martial arts or actual Thai Boxing athletes. Therefore, it can be derived that elite mixed martial arts athletes have more refined movements and may be more efficient in regards to their technique in comparison with amateur mixed martial arts athletes. However, since elite mixed martial arts or Thai Boxing athletes were not available for this study, the results of this study may only be applicable to amateur mixed martial arts athletes.

5. Conclusions

This study provides an important understanding on the kinematics of the Thai boxing clinching positions in the dominant (right) leg for both the double collar-tie and double underhook techniques. Ten amateur mixed martial arts athletes participated in this study and each athlete performed six knee strikes in each clinching position. The results showed a statistical significant difference at the hip joint angles between both clinching positions, but there were no significant differences between the knee and ankle between both clinching positions. There were no statistical differences in the joint angular velocity of the hip, knee, and ankle. For the joint angular accelerations, there was a significant statistical difference observed only for the knee and ankle joints and within both clinching positions, there was a statistically significant correlation at the hip and knee joint angles. Lastly, there was a significant correlation at the knee joint angle, hip and knee angular velocities, and hip angular acceleration between both clinching positions.

This study indicates that the double collar clinching position technique has a lesser hip flexion angle than the double underhook clinching technique. Thus, the double collar-tie clinching technique may be more suitable for striking a lower target in relation to the striker's knee position. Interestingly, the significant statistical difference for knee and ankle joint acceleration suggests that both joints accelerate at a similar rate in both clinching positions while the hip does not. Lastly, this study may suggest the importance of strength training and flexibility at the hip and knee joints. Future studies are warranted to analyze the non-dominant leg to have a comprehensive understand about the Thai Boxing clinch.

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