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# Kinematics Comparison between Dominant and Non-Dominant Lower Limbs in Thai Boxing

William Trial

# Kinematics Comparison between Dominant and Non-Dominant Lower Limbs in Thai Boxing

William Trial

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Dr. Tong-Ching Tom Wu, Thesis Director
Dr. Edward A. Braun, Committee Member
Dr. Pamela J. Russell, Committee Member

## Abstract

Muay Thai, also known as Thai Boxing, is Thailand's national sport, and it involves athletes using different stand-up striking and clinching techniques. There are a limited number of research studies that have examined Thai Boxing skills and specifically none have examined the kinematics of the dominant and non-dominant legs while in a double collar or double underhook clinching position. The purpose of the study was to investigate the kinematics of the dominant (right) and non-dominant leg (left) between the double collar and double underhook Thai Boxing clinching positions. Participants executed six continuous knee strikes with the dominant leg and non-dominant leg in each of the two clinching positions for twelve knee strikes. A standard two-dimensional video motion analysis was conducted. The results revealed statistical significant difference at the hip joint angle between both clinching positions ($p$ = .013) but not at the knee and ankle joints. There were no statistical significant differences in the joint angular velocity and acceleration for the hip, knee, and ankle joint between both clinching positions. However, there was a statistical significant difference found in the joint angular velocity for the knee joint ($p$ = 0.00) between the dominant and non-dominant leg. Lastly, there was a significant correlation of the joint angle ($r$ = 0.65 and 0.63; double collar and double underhook) and the angular velocity ($r$ = 0.76 and 0.67; double collar and double underhook) for the left and right knee between both clinching positions. In addition, there was a significant correlation of the joint angle between the left and right hip ($r$ = 0.66) for the double collar position but not for the double underhook position. This study demonstrates the importance of hip joint flexibility and the angular velocity of the knee between the dominant and non-dominant leg. Future

research studies investigating the impact of the knee at the point of contact in the Thai Boxing clinch positions among group of elite mixed martial arts athletes are warranted.

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Thai Boxing is the national sport of the Kingdom of Thailand. The sport originated during the second and third centuries (B.C.) from Indian-Buddhist Monks whom were originally sent to find the Suvarnabhumi, the land of gold, in modern-day central Thailand (Junlakan and Prayukvong, 2007). The monks 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 (Junlakan and Prayukvong, 2007). 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) used in Western Boxing. The length of a match is dependent on the weight class of the fighter. The length of each round is five minutes, 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 (Green, 2010).

Ambidexterity is the state of being equally adept in the use of both left and right appendages (legs) and is an important factor in athletic performance and injury prevention. Specifically in combat sports when fighters may choose to face their opponent with either the left shoulder forward in a right-handed stance (orthodox) or the right shoulder forward in a left-handed stance (south-paw), thus a degree of cross dominance is useful. Currently, there are minimal number of studies that have analyzed kinematic differences and the ambidexterity of the hip, knee, and ankle between the Thai

Boxing clinching positions. However, there has been lower-limb kinematic research analyzing the biomechanical differences of the dominant and non-dominant leg in soccer and rugby (Dorge, Anderson, Sorensen, and Simonsen, 2002; Bauer, 1988; Ball, 2011).

The question regarding ambidexterity has been recommended in training for both dominant and non-dominant limbs within sports that involve unilateral movements, such as Thai Boxing (Turner, 2009). The question that this research study has addressed is that were there significant differences between the joint angles, angular velocities, and accelerations of the hip, knee, and ankle for both clinching positions between the dominant and non-dominant lower limb. This study hypothesized that there was a significant kinematic difference in regards to the joint angle and angular velocity of the hip. With these factors stated, the current study provided a comprehensive understanding about the knee striking motion within two Thai Boxing clinching positions so that an improved strength training and technical program can be developed.

# Review of the Literature

## Previous Thai Boxing Research Studies

There is a paucity of research studies (Sidthilaw, 1997 and Trial and Wu, in press) 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 8 to 48 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 = 0.86 and r = 0.79, respectively) but they were not significantly related to leg strength. Sidthilaw (1997) further indicated that the Thai Boxing roundhouse kick could generate sufficient 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 during an actual Thai Boxing match among amateur Thai Boxing fighters. Contrastingly, Trial and Wu (in press) analyzed the hip motion within two Thai Boxing clinching positions (double collar and double underhook). The authors observed a significant statistical difference at the hip joint angle ($p$ = 0.00, $p < 0.05$,) and a significant statistical correlation for the hip angular velocity and acceleration ($r$ = 0.94 and 0.85, <0.05, respectively). This study indicated that the double collar-tie clinching position technique uses less hip flexion than the double underhook clinching technique. Thus, the double collar clinching technique may be more suitable for striking a lower target in relation to the striker's knee position. Lastly, other Thai Boxing research studies have focused on the physiologic aspects. Crisafulli, Vitelli, Cappai, and Milia (2009), Silva, Del Vecchio, Picano, Takito, and Franchini (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. Kim, Kim, and Im (2011) analyzed the kicking joint kinematics of the kicking leg in Taekwondo. They indicated that the back kick utilized a combination of hip and knee extension and was characterized by a push like movement. Contrastingly, the thrashing and turning back kick utilized a greater degree of hip abduction than the roundhouse kick and back kick, and was characterized by a push-throw movement. Hwang (1987) conducted a preliminary kinematic analysis of the Taekwondo front kick with three amateur Taekwondo athletes who were instructed to execute kicks at and without a target. 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 without a target condition, and the maximum foot velocities of both conditions were between 11.6 m/s and 13.4 m/s. 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; 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 Skill of the Thai Boxing Clinch**

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, the athlete can also throw their opponent to the ground from the clinch. Throwing the opponent to the ground, however, 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 on the head or one hand on the neck and the other on the top of the head, 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 injury.

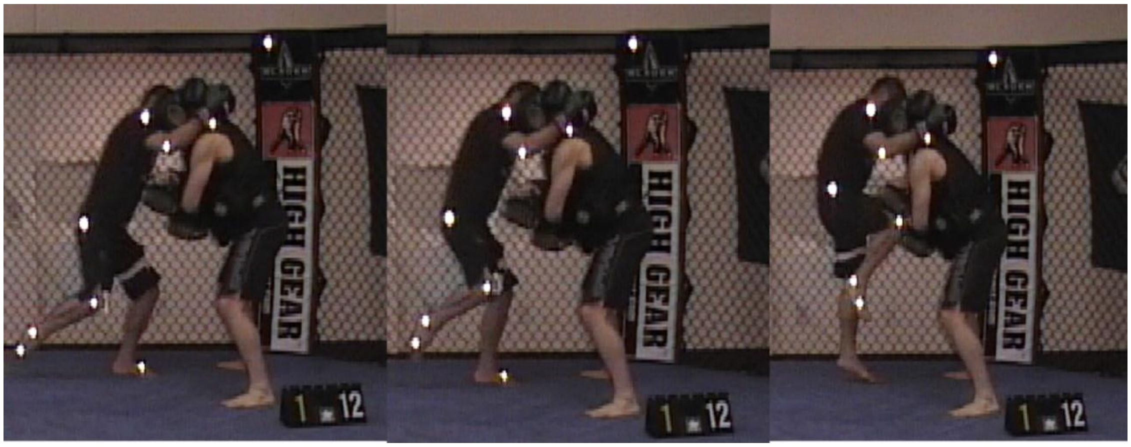


*Figure 1*: The progression of the double collar Thai Boxing clinching position

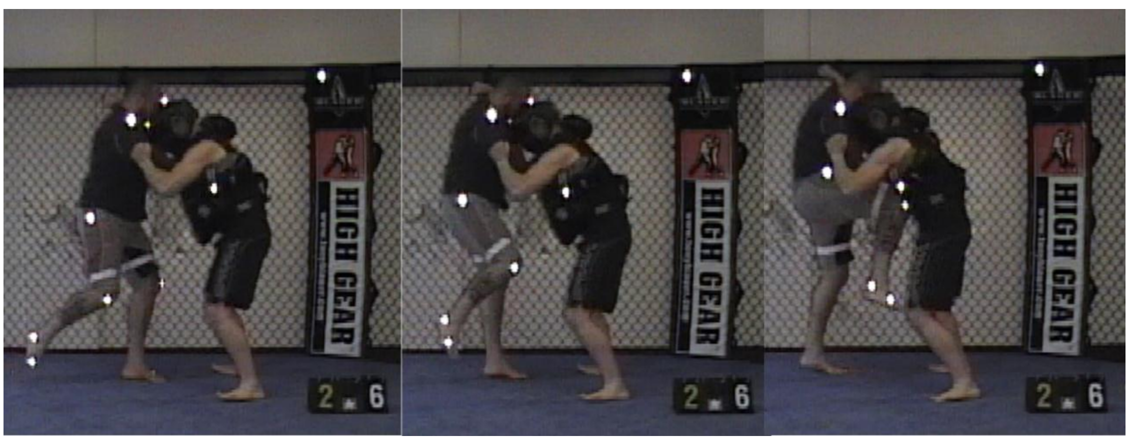


*Figure 2*: The progression of the double underhook Thai Boxing clinching position

**Ambidexterity**

In a study conducted by Dorge et al. (2002), they examined ball velocity in maximal instep kicking with the preferred and the non-preferred leg among seven skilled soccer players. The velocity of the ball was related to biomechanical differences observed during the kicking action. They found that higher ball speeds were achieved with the preferred leg because of higher foot speeds and a higher coefficient of restitution at the time of impact compared with the non-preferred leg. Dorge et al. (2002) concluded that the difference in maximal ball speed between the preferred and non-preferred leg is caused by a better inter-segmental motion pattern and a transfer of velocity from the foot to the ball when kicking with the preferred leg.

Contrastingly, Ball (2011) examined the differences between the preferred (right) and non-preferred (left) leg kicking in the drop punt kick of professional male rugby players (n =17). The authors determined that foot speed, knee, and shank angular velocity at ball contact and hip range of motion were significantly larger for the preferred leg while, hip and thigh angular velocity at ball contact and hip range of motion were significantly larger for the non-preferred leg. It was concluded that the preferred-leg kicks (right) made greater use of the pelvis, knee, and shank while non-preferred leg kicks (left) relied more on the hip and thigh for ball speed. In a similar study, Bauer (1982) investigated and measured the kinematic and electromyographic parameters of the rugby punt among professional male rugby athletes (n =13) when performed for maximum distance using the preferred and non-preferred kicking leg. The results indicated a lack of coordinated muscle contraction and inferior performances of non-preferred kicking legs of all subjects. Bauer (1982) concluded that the necessary kinematic segmental sequencing processes were not maintained when subjects performed the rugby punt with the non-preferred foot. Lastly, failure to control segmental motion affected momentum transfer through the limb segments and the final momentum transfer to the ball at impact, resulting in decreased ball speeds.

From a motor learning perspective, Cular, Miletic, and Miletic, (2010) investigated the motor abilities of Taekwondo martial arts techniques among male and female athletes (10 ± 2 years). They determined that motor abilities such as grip strength, frequency of alternate leg movements, and alternate hand movements for male athletes measured on the right and left sides of the body were defined with a strong correlation with Taekwondo basic techniques' performance to both sides of body. Likewise, Teixeira, Correa, Olivera, and Romano (2009) compared adult soccer players with 12 ± 4.16 years of experience and non-soccer players (n = 11) on leg performance on motor tasks requiring general and soccer-specific movements and body-balance stabilization. Their results revealed that the preferred-leg (right) is used for soccer-specific movement abilities and the non-dominant leg is used for general balance and stabilization abilities. Conversely, Morris, Newby, Wininger, and Craelius (2009) examined the inter-limb transfer in the lower-limbs of subjects who learned to move a cursor towards target in 0.8 seconds using ankle movements: plantar/dorsi-flexion and inversion/eversion. The results revealed that tasks using the left foot (non-dominant limb) but not tasks using the right foot (dominant limb) experienced significant inter-limb transfer of directional as well as positional information, reflective of the different functional roles played by the upper and lower limbs (Morris, Newby, Wininger, and Craelius, 2009). Thus, inter-limb transfer occurred from the non-dominant (left) to the dominant (right) foot, but not vice versa.

# Methods

## Participants

Ten amateur martial arts athletes volunteered to participate in the study. The mean age, height, weight and experience with 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 a local mixed martial arts training club. Two Thai Boxing cotton hand wraps (4.6 m) and two standard Thai Boxing gloves (0.34 kg) were provided to each participant for wrist protection and simulating both double-collar-tie and double underhook clinching positions.

## Protocols and Experimental Set Up

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 for five minutes to increase core muscular temperature and muscular force production to reduce the risk of potential injury. 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 black shorts to provide better contrast between the markers and clothes for video analysis.

Participants executed six continuous knee strikes with the dominant (right) leg and non-dominant leg (left) in each of the two clinching positions for a total of twelve knee strikes. Since the knee strikes were performed in a continuous motion, participants attempted to simulate real fight-like movement. Each participant had three minutes break between both clinching positions to avoid the influence of fatigue. For each knee strike, the participant directed the kick towards an experienced Thai Boxing athlete who was equipped with a belly pad, two standard Thai Boxing pads, a groin protector, and a mouth guard to insure safety. Since the target was well protected and experienced with the sport, risk of injury was minimal. Lastly, the order of the clinching positions and the legs were 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 over the duration of an hour for each participant. Data were analyzed on four knee strikes from each leg from knee contact to 20 frames after, with the first and last knee strikes being discarded to ensure consistency of the knee striking motion. Mean angular positions, velocities, and accelerations were calculated over these 20 frames (equaled 0.34 seconds).

**Instrumentation and Statistical Analysis**

A two-dimensional video analysis was 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. A Digital filter was applied at 8 Hz to filter the data. The video was transferred onto a computer in the Biomechanics Lab and analyzed with Ariel Performance Analysis System (version 13.3.3) software (Ariel Dynamics Inc., Trabuco Canyon, California) A two-way (2 clinching techniques x 2 legs) repeated measures ANOVA ($\alpha = 0.05$) was conducted on the kinematic variables of the lower extremity and followed by a post-hoc t-test comparison with Bonferroni adjustment if a significant difference was found. In addition, Pearson's product-moment correlations were conducted with SPSS (version 18) software (IBM Corporation, Armonk, New York).

## Results

Descriptive statistics for the lower extremity joints of each testing condition were reported in Table 1,2, and 3. Results showed only a statistical significant difference ($p$ = .013) at the hip joint angle between both clinching positions (109.0° ± 15.0° and 88.9° ± 13.3°; right double collar and double underhook and 109.0° ± 13.5° and 99.0° ± 20.6°; left double collar and double underhook). No significant differences were found at the hip joint angle ($p$ = 0.14) between the dominant and non-dominant leg. In addition, no interaction effect (2 legs x 2 clinching positions) were found at the hip joint angle ($p$ = 0.34). There were no significant differences at the knee joint angle ($p$ = 0.34) between both clinching positions. No significant differences were found at the knee joint angle ($p$ = 0.31) between the dominant and non-dominant leg. In addition, no interaction effect (2 legs x 2 clinching positions) was found at the knee joint angle ($p$ = 0.37). There were no significant differences at the ankle joint angle ($p$ = 0.17) between both clinching positions. No significant differences were found at the ankle joint angle ($p$ = 0.50) between the dominant and non-dominant leg. Lastly, no interaction effect (2 legs x 2 clinching positions) was found at the ankle joint angle ($p$ = 0.92).

Table 1

*Descriptive statistics of average joint angular displacement in each condition*

| Clinching Position | Hip (°) | Knee (°) | Ankle (°) |
|---|---|---|---|
| Right Double Collar | 109.0 ± 15.0 | 66.1 ± 12.4 | 118.4 ± 11.0 |
| Right Double Underhook | 88.9 ± 13.3 | 68.7 ± 15.9 | 113.7 ± 11.3 |
| Left Double Collar | 109.0 ± 13.5 | 71.4 ± 13.7 | 114.0 ± 12.7 |
| Left Double Underhook | 99.0 ± 20.6 | 147.4 ± 249.5 | 109.8 ± 20.6 |

There were no statistical significant differences in the joint angular velocity for the hip joint ($p$ = 0.27) between both clinching positions. No significant differences were found in the joint angular velocity for the hip joint ($p = 0.37$) between the dominant and non-dominant leg. In addition, no interaction effect (2 legs x 2 clinching techniques) was found in the joint angular velocity for the hip joint ($p = 0.92$). There were no statistical significant differences in the joint angular velocity for the knee joint ($p = 0.59$) between both clinching positions. There was a statistical significant difference ($p = 0.00$) found in the joint angular velocity for the knee joint between the dominant and non-dominant leg (22.9°/sec ± 185.1°/sec and 44.8°/sec ± 111.2°/sec; right double collar and underhook and 115.6°/sec ± 141.6°/sec and 124.8°/sec ± 125.6°/sec; left double collar and double underhook). In addition, no interaction effect (2 legs x 2 clinching positions) was found in the joint angular velocity for the knee joint ($p = 0.83$). There were no statistical significant differences in the joint angular velocity for the ankle joint ($p = 0.26$) between both clinching positions. No significant differences were found in the joint angular velocity for the ankle joint ($p = 0.74$) between the dominant and non-dominant leg. In addition, no interaction effect (2 legs x 2 clinching techniques) was found in the joint angular velocity for the ankle joint ($p = 0.20$).

Table 2

*Descriptive statistics of average joint angular velocity in each condition*

| Clinching Position | Hip (°/s) | Knee (°/s) | Ankle (°/s) |
|---|---|---|---|
| Right Double Collar | -3.5 ± 88.8 | 22.9 ± 185.1 | 8.9 ± 104.3 |
| Right Double Underhook | -12.4 ± 88.9 | 44.8 ± 111.2 | -62.1 ± 36.1 |
| Left Double Collar | 29.4 ± 106.6 | 115.6 ± 141.6 | -41.2 ± 106.8 |
| Left Double Underhook | 17.8 ± 129.4 | 124.8 ± 125.6 | -30.1 ± 112.0 |

There were no statistical significant differences in the joint angular acceleration for the hip joint ($p = 0.70$) between both clinching positions. No significant differences were found in the joint angular acceleration for the hip joint ($p = 0.92$) between the dominant and non-dominant leg. In addition, no interaction effect (2 legs x 2 clinching techniques) was found in the joint angular acceleration for the hip joint ($p$ = 0.92). There were no statistical significant differences in the joint angular acceleration for the knee joint ($p$ = 0.08) between both clinching positions. No significant difference was found in the joint angular acceleration for the knee joint ($p$ = 0.08) between the dominant and non-dominant leg. In addition, no interaction effect (2 legs x 2 clinching positions) was found in the joint angular acceleration for the knee joint ($p$ = 0.85). There were no statistical significant differences in the joint angular acceleration for the ankle joint ($p$ = 0.35) between both clinching positions. No significant differences were found in the joint angular acceleration for the ankle joint ($p$ = 0.06) between the dominant and non-dominant leg. In addition, no interaction effect (2 legs x 2 clinching techniques) was found in the joint angular acceleration for the ankle joint ($p$ = 0.18).

Table 3

*Descriptive statistics of average joint angular acceleration in each condition*

| Clinching Position | Hip (°/s$^2$) | Knee (°/s$^2$) | Ankle (°/s$^2$) |
|---|---|---|---|
| Right Double Collar | 8750.5 ± 4408.2 | 4032.8 ± 3970.1 | 487.96 ± 1546.7 |
| Right Double Underhook | 8358.5 ± 4645.9 | 2209.0 ± 2244.7 | 3014.66 ± 2312.9 |
| Left Double Collar | 7984.9 ± 3353.7 | 4166.8 ± 3369.4 | 915.04 ± 2306.1 |
| Left Double Underhook | 8093.2 ± 3583.5 | 2648.3 ± 2685.3 | 681.55 ± 3852.3 |

Further, a two-tailed Pearson's product-moment correlation was conducted for the hip, knee, and ankle joint displacements, velocities, and accelerations between both dominant and non-dominant legs for each clinching position (Table 4-9). The results showed a statistically significant correlation in the joint angle and angular velocity between left and right knee for the double collar ($r$ = 0.65 and 0.76, respectively) and double underhook clinching positions ($r$ = 0.63 and 0.67, respectively). In addition, there was a significant correlation of the joint angle between the left and right hip ($r$ = 0.66) for the double collar position but not for the double underhook position. There were no further correlations of the joint angle for the left and right ankle and the angular velocity of the left and right hip and ankle between both legs. Lastly, there were no significant correlations for the angular acceleration at the hip, knee, and ankle of both legs between both clinching positions.

Table 4

*Correlation of average joint angular displacement between the left and right legs for the double collar position*

| Joint | Left Hip | Left Knee | Left Ankle |
|---|---|---|---|
| Right Hip | 0.66* | 0.75* | 0.32 |
| Right Knee | 0.28 | 0.65* | 0.00 |
| Right Ankle | 0.06 | -0.11 | -0.46 |

*Note.**Correlation is significant at the 0.05 level

Table 5

*Correlation of average joint angular displacement between the left and right legs for the double underhook position*

| Joint | Left Hip | Left Knee | Left Ankle |
|---|---|---|---|
| Right Hip | 0.51 | 0.72* | 0.07 |
| Right Knee | 0.31 | 0.63* | -0.23 |
| Right Ankle | 0.20 | 0.40 | 0.15 |

*Note.**Correlation is significant at the 0.05 level

Table 6

*Correlation of average joint angular velocity between the left and right legs for the double collar position*

| Joint | Left Hip | Left Knee | Left Ankle |
|---|---|---|---|
| Right Hip | 0.00 | -0.14 | 0.23 |
| Right Knee | 0.14 | 0.76* | 0.03 |
| Right Ankle | -0.10 | 0.39 | 0.36 |

*Note.**Correlation is significant at the 0.05 level

Table 7

*Correlation of average joint angular velocity between the left and right legs for the double underhook position*

| Joint | Left Hip | Left Knee | Left Ankle |
|---|---|---|---|
| Right Hip | -0.56 | -0.60 | 0.54 |
| Right Knee | 0.71* | 0.67* | -0.13 |
| Right Ankle | 0.24 | -0.01 | -0.04 |

*Note.**Correlation is significant at the 0.05 level

Table 8

*Correlation of average joint angular acceleration between the left and right legs for the double collar position*

| Joint | Left Hip | Left Knee | Left Ankle |
|---|---|---|---|
| Right Hip | -0.25 | -0.26 | -0.06 |
| Right Knee | 0.09 | 0.17 | 0.01 |
| Right Ankle | -0.54 | -0.32 | -0.09 |

*Note.**Correlation is significant at the 0.05 level

Table 9

*Correlation of average joint angular acceleration between the left and right legs for the double underhook position*

| Joint | Left Hip | Left Knee | Left Ankle |
|---|---|---|---|
| Right Hip | -0.16 | 0.12 | -0.03 |
| Right Knee | -0.26 | 0.21 | 0.13 |
| Right Ankle | -0.58 | -0.25 | -0.52 |

*Note.**Correlation is significant at the 0.05 level

## Discussion

Little is known about the kinematic relationship between the dominant and non-dominant legs of the Thai Boxing Clinch. The purpose of the study was to examine the joint angular displacement, velocity, and acceleration between the dominant and non-dominant legs at the hip, knee, ankle joints for the double-collar and double underhook Thai Boxing clinching positions. The results revealed a statistical significant difference at the hip joint angle between both clinching positions. In a previous Taekwondo research study, Kim, Kwon, Kwon, and Yenuga (2010) observed a significant difference in the peak hip joint angle for the roundhouse kicking leg. Trial and Wu (in press) also observed a significant difference at the hip joint angle between both clinching positions (103.2° ± 13.4° and 88.4° ± 12.4°; double collar and double underhook) for the dominant limb (right) in the Thai Boxing Clinch. In the current study, the average hip flexion angles for the dominant and non-dominant limbs for the double-collar tie position were 109.0° ± 15.0° and 109.04° ± 13.5°, respectively. In addition, the average hip flexion angles for the dominant and non-dominant limbs for the double underhook clinching position were 88.9° ± 13.3° and 99.04° ± 20.6°, respectively. From an empirical analysis, the average hip flexion angles for the dominant and non-dominant limb were similar in the double collar position and comparable in the double underhook position. This finding indicates that the double collar clinching technique may be more suitable for striking a lower target in relation to the striker's knee position. In comparison, Sachlikidis and Salter (2007) observed more lead hip flexion at maximum knee lift in the speed throws than the accuracy throws for both arms. They also reported that the mean lead hip flexion angle for the dominant arm throws was also significantly greater than that for the non-dominant arm throws for both throw conditions. However, Ball (2011) found no significant statistical differences at the thigh joint angle between the preferred and non-preferred leg at ball contact during the rugby punt kick. The average joint angle for the thigh was 62° for both the preferred and non-preferred limb. Therefore, the findings of Sachlikidis and Salter (2007) and Ball (2011) are incongruent and do not support the findings of this study.

There was not a statistically significant difference between the angular displacement of the knee and ankle between both clinching positions. The results may imply that the hip joint is the primary joint for executing the clinch position, and the knee and ankle joints serve a secondary purpose. 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 qualitative video analysis, Trial and Wu (in press) determined that the leg 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 degree of hip flexion in this research study. Thus, the double collar clinching technique may be more suitable for striking a lower target in relation to the striker's knee position.

Ball (2011) indicated that the preferred leg produced significantly larger knee and shank angular velocities at ball contact and exhibited greater pelvic range of motion during the soccer leg kick. In contrast, the non-preferred leg produced significantly larger hip and thigh angular velocities and employed greater hip range of motion. Lastly, Ball

(2011) suggested that rugby players make better use of the pelvis, knee, and shank with their preferred leg but made more use of the thigh and hip for non-preferred leg kicks. However, from this study there were no significant statistical differences at the hip, knee, and ankle for the angular velocity between both clinching positions. There was a statistical significant difference found in the joint angular velocity for the knee joint between the dominant and non-dominant leg. This finding indicates that the dominant leg produced significantly slower knee flexion angular velocity than the dominant leg, which is quite interesting since one would expect the dominant leg to produce a higher knee flexion angular velocity than the non-dominant leg. From a close data inspection on each participant's dominant leg knee angular velocity, it was observed that some participants demonstrated a positive knee angular velocity (knee extension movement), and some participants showed a negative angular velocity (knee flexion movement). This variability caused the dominant leg to have a lower knee angular velocity than the non-dominant leg. A possible explanation may be because participants were quite efficient in using their dominant leg, so they were comfortable striking their target either flexing or extending their knee at contact. More research studies are needed to validate this finding.

Cular et al. (2010) analyzed the gender-specific (n = 57; 39 males and 18 females) influence of dominant laterality of motor abilities on Taekwondo techniques performed to the left and right body side and the quality of performance of Taekwondo leg technique (front kick and roundhouse kick) among youth athletes. The authors indicated that gender differences in regards to Taekwondo technique acquisition and flexibility defined the body asymmetry differences of motor abilities assessed by the following variables: grip strength, frequency of alternate leg movements, and alternate hand movements. Secondly, motor abilities measured on both the left and right side of the body were defined with a strong correlation with basic Taekwondo kicks performed to both sides of the body for the male athletes (r = .75-.81), while in female athletes, motor abilities measured on the right side of the body were not significant. Starosta (1988) also determined that the higher efficiency of shots at goal, demonstrated by elite soccer players, were performed by left-footed players, resulting from different motor abilities to which the right-footed players were unable to adapt themselves rapidly enough. While analyzing the inter-limb transfer of ankle movements, Morris et al. (2009) determined inter-limb transfer occurred from the non-dominant (left) to the dominant (right) foot, but not vice versa. Lastly, van Hedel, Biedermann, Erni, and Dietz (2002) studied the ability of the leg to avoid obstacles during treadmill walking. They determined that movements at the knee, learned on the treadmill are transferred from one leg to another, non-preferentially. Although the motor and inter-limb transfer abilities of the participants were not recorded within the current study, the participants produced similar hip joint angles in each clinching position ($p$ =0.013, $p$ <0.05). In addition, a statistical significant correlation was observed for the joint angular displacement between the left and right hip ($r$ = 0.66) and the left and right knee ($r$ = 0.65) between both the dominant and non-dominant limb within the knee strikes. Furthermore there was a correlation of the joint angular velocity for the left and right knee (r = 0.67) between both clinching positions. Therefore, it may be assumed that a combination of motor and inter-limb transfer abilities partially contributed to the results.

In regards to leg preference and interlateral asymmetry of balance stability in soccer players, Teixeira et al. (2011) suggested and revealed that the preferred-leg (right) is used for mobilization abilities and the non-dominant leg is used for balance and stabilization abilities. This may be partially true because the significant statistical difference ($p < .013$) at the hip joint angle (left double collar: 109.1° ± 13.5°; right double collar: 109.0° ± 15.0°) in the double collar position may imply that the dominant and non-dominant limbs may have both been used for mobilization, during the knee-striking phase. During the non-knee striking phase, when the dominant limb switched places with the non-dominant limb, the dominant limb stabilized, and the non-dominant limb was used for mobilization. In the skill of Thai Boxing clinch, the rear leg was used for mobilization while the front leg was used for stabilization and balance. However, the ability of the dominant and non-dominant limb appeared to display reciprocal abilities, and it was evident that both legs switched positions during each knee strike. Although this factor was evident in respect to the hip joint angle, between the dominant and non-dominant limb, in the double collar position, the results of Teixeira et al. (2010) do not relate to any factors between the dominant and non-dominant leg for both clinching positions.

One limitation was that data collection lasted an hour. The results of the study might have been different if a technical training program equally utilizing the dominant and non-dominant limb were prescribed over a longer duration. In turn, the motor abilities and inter-limb transfer of skill may have been more apparent. In an actual sparring match, both contenders are constantly sliding or stepping forward and backwards either to avoid or execute a kick, punch, knee, and elbow strike towards their opponent. However, all knee strikes were conducted in a controlled environment towards a stationary athlete. Therefore, the results of this study do not simulate an actual mixed martial arts or Thai Boxing match, so more realistic conditions may need to be developed for future studies. Lastly, the study only examined male amateur mixed martial arts athletes whom the mean age, height, weight and experience were 23 ± 5 yrs., 1.8 ± 0.1 m, 73.3 ± 11.4 kg, and 5.9 ± 5.4 yrs., respectively. However, elite mixed martial arts or Thai Boxing athletes were not available for this study. Therefore, future studies are needed to employ elite mixed martial arts or Thai Boxing athletes as the participants.

# Conclusion

This study provides an important understanding of the relationship between the dominant (right) and non-dominant (left) limbs for the double collar and double underhook Thai boxing clinching positions. Ten amateur mixed martial arts athletes participated in this study and each athlete performed six knee strikes in each clinching position. The results revealed a statistically significant difference at the hip joint angle between both clinching positions but not at the knee and ankle joints. There were no statistical significant differences for the joint angular velocities and accelerations for the hip, knee, and ankle joint between both clinching positions. However, there was a statistically significant difference found in the joint angular velocity for the knee joint between the dominant and non-dominant limbs. In addition, no significant differences were found for the angular velocity of the hip and ankle between the dominant and non-dominant legs. Further, there were no statistical differences for the hip, knee, and ankle joint angles and accelerations between the dominant and non-dominant legs. Lastly, there was a significant correlation at the joint angle and for the angular velocity at the left and right knee between both clinching positions. In addition, there was a significant correlation of the joint angle between the left and right hip ($r$ = 0.66) for the double collar position but not for the double underhook position.

This study indicates that within the double collar and within the double underhook clinching positions share a similar degree of hip flexion between the dominant and non-dominant legs. In addition, the dominant and non-dominant legs showed different knee angular velocities. An explanation for this factor is that instead of flexing their knee, some of the participants may have extended their knee during the execution of the knee strike at the point of contact. Thus, the participants may have learned the Thai Boxing clinching techniques differently from another at the time of data collection. The impact of the knee at the point of contact may have contributed to the significant difference observed for the knee joint angular velocity between the dominant and non-dominant legs. Therefore, future studies are warranted that analyze the impact of the knee at the point of contact in both clinching positions between the dominant and non-dominant legs.

In regards to training the dominant and non-dominant limbs, Cular et al. (2010) concluded that Taekwondo training should be programmed with more strength and speed exercises done with the weaker body side implying that Thai Boxing and mixed martial arts athletes should do the same. Starosta (1988) also recommended that basic technical elements should be developed symmetrically at all stages of sports instruction. By prescribing symmetrical training of the dominant and non-dominant limb, the knee may be able to flex instead of extending. Secondly, the knee angular velocity may decrease while contributing to the accuracy of a successful knee strike. Training the non-dominant limb should also take place during the off-season and focus on the technical improvement with attention being paid to regularity, proper assignment of the tasks, control, and evaluation of performance (Starosta, 1988). Therefore, Thai Boxing coaches should prescribe technical routines for Thai Boxing athletes that train both the dominant and non-dominant limbs symmetrically for optimal performance.

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