THE RELATIONSHIP BETWEEN FORCE-TIME METRICS AND CLUBHEAD SPEED IN NCAA DIVISION II GOLF ATHLETES

BY

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THESIS

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Abstract

The primary purpose of this study was to examine the relationship between clubhead speed (CHS) and force-time metrics during the isometric mid-thigh pull (IMTP) using a hexagonal trap bar. The study also investigated the differences in force-time metrics during the IMTP performed using the hexagonal trap bar and the straight barbell. NCAA Division II collegiate golf athletes participated in a cross-sectional study to assess anthropometry, CHS, and IMTP force-time metrics, including measures of peak force and time specific force produced at 50, 100, 150, 200, and 250ms. The IMTP was assessed using a hexagonal trap bar and a straight barbell. The study's primary findings showed a strong, significant correlation between maximal CHS and peak force (r = .802, p = .05). The results showed a strong correlation between CHS and force at 200ms and 250ms with moderate correlations shown at 100ms and 150ms. Peak force during the IMTP was significantly higher when using the hexagonal-trapbar (1,973.90 ± 551.07N) compared to the straight barbell (1,723.10 ± 445.86N, t(9) 3.12, p = .006). These results demonstrated a relationship between CHS and force-time metrics from the IMTP when using a hexagonal trap bar as well as a difference in force production during the IMTP when using the hexagonal trap bar compared to the straight barbell.

Chapter One: Introduction

Golf is one of the few sports that is enjoyed by people of all ages, from playing golf leisurely to competing in the PGA Championships. According to a 2024 survey conducted by the National Golf Foundation (NGF), a total of 47.2 million Americans aged six years and older participated in golf, both on- and off-course (NGF, 2025). Strength and conditioning can benefit golf players by increasing their ability to produce force and power for a more consistent and accurate clubhead speed (CHS).

Improving the force production for any rotational athlete is important for improving athletic performance (Han et al., 2019; Leary et al., 2012; Wells et al., 2024). It is well known that strength, power, and speed are among the most important components for improving the golf swing (Oranchuck et al., 2020). A crucial metric that golf players, coaches and practitioners monitor is CHS. Previous literature suggests the higher the force generated, the greater the CHS (Johansen et al., 2023; Leary et al., 2012; Miller et al., 2022; Wells et al., 2019). Specifically, CHS has been shown to positively correlate with isometric mid-thigh pull (IMTP; Comfort et al., 2019; Johansen et al., 2023; Shaw et al., 2024). Thus, the greater the CHS, the greater the force produced during the IMTP. Isometric strength training protocols have been found to increase strength and power in a safe manner; therefore, it may be plausible for strength coaches to implement isometric training for their athletes (Coughlan et al., 2020; Shaw et al., 2024; Lum et al., 2022; Oranchuk et al., 2020). According to Miller et al. (2022), positive associations were observed between one-repetition maximum deadlift and force-time metrics (r = .459 – .635, p < .001 – .027).

Most studies show a positive relationship between CHS and force-time metrics during the IMTP utilizing a straight barbell (Comfort et al., 2019; Johansen et al., 2023; Shaw et al., 2024).

In many strength and conditioning settings, the hexagonal trap bar has become a popular equipment option, often used in conjunction with various training methods, including isometric variations in the training programs. The hexagonal trap bar has not been widely used in golf studies. Although similar, there are potential differences in using the straight barbell and the hexagonal trap bar during the IMTP. This study examined those differences.

Purpose

The primary purpose of this study examined the relationships between CHS and force-time metrics during the IMTP performed using a hexagonal trap bar. This study also examined the differences in force-time metrics during the IMTP performed using a straight barbell versus a hexagonal trap bar.

Research Hypotheses

1) The relationships between CHS and force-time metrics during the IMTP performed using a hexagonal trap bar will be significant, positive, and moderate.
2) The force-time metrics during the IMTP when performed using a hexagonal trap bar will be significantly higher than the force-time metrics during the IMTP when performed using a straight barbell.

Null Hypotheses

1) There is no relationship between CHS and force-time metrics during the IMTP performed using a hexagonal trap bar.
2) There is no difference in force-time metrics during the IMTP performed using a straight barbell when compared to a hexagonal trap bar.

Limitations

This study had several limitations that must be acknowledged. There could be a lack of effort, as the participants may not have given their full effort during the CHS and IMTP. The encouragement protocol included during testing should allow the participants to give their full effort. There was a possibility of a mechanical error, in which the technology failed to function correctly. Recalibration prior to each trial helped to overcome mechanical error. The study involved a specific golf population. It is worth noting that participants with a history of injuries may impact the performance of the CHS test or IMTP test.

Delimitations

This study had delimitations that must be considered. The researcher employed a cross-sectional study approach to investigate the relationship between CHS with the use of a driver golf club and IMTP force-time metrics. It would be impossible to determine whether one variable directly impacts the other due to data collection at a single point in time, given the correlational design. The CHS was assessed by using the participant's driver golf club. The isometric contraction was assessed using the isometric mid-thigh pull by using two types of bars: straight barbell and a hexagonal trap bar. The study is also delimited to Division II collegiate golf athletes.

Assumptions

It was assumed that all participants gave their full effort during the CHS and IMTP assessment(s). Another assumption is that a relationship existed between isometric force production and dynamic force production.

Operational Definitions

- *Clubhead Speed*: The velocity at which the clubhead travels before impact with the golf ball (Brennan et al., 2023).
- *Ground Reaction Force:* A reaction to the force the body exerts on the ground (Wells et al., 2019).
- *Impulse*: The effect of an object force acting over a period of time (McGinnis, 2020).
- *Isometric Contraction*: When the muscle does not change length during muscle contraction (Haff & Triplett, 2016).
- *Kinetic Energy:* The energy an object has due to movement (McGinnis, 2020).
- *Newton's Second Law of Motion:* The more force an object produces, the faster it will move (McGinnis, 2020).
- *Peak Power:* The maximum amount of power (force/time) that a muscle can produce (McGinnis, 2020).
- *Peak Velocity:* The maximum speed reached during the concentric phase (Weakley et al., 2021)
- *Rate of Force Development:* The speed at which a muscle can generate force from a resting state (Haff & Triplett, 2016).
- *Stretch Shortening Cycle:* When the muscle lengthens (eccentric contraction) and then shortens (concentric contraction) for muscle action (Haff & Triplett, 2016).
- *X-Factor:* The relationship between the shoulders and the pelvis during the golf swing (An et al., 2013).

Summary of Introduction

There is a relationship between CHS and IMTP force-time metrics (Comfort et al., 2019; Johansen et al., 2023; Shaw et al., 2024;); however, a straight barbell is mainly used for IMTP assessment instead of a hexagonal trap bar. Additional research could help determine which type of isometric training protocols would be most beneficial for improving force-time metrics in rotational athletes.

Chapter Two: Review of the Literature

Introduction

The golf swing is an angular motion-dominated sport movement that generates high clubhead speed (CHS) primarily through the angular motions of the golf club. To achieve a fast CHS, the golfer must produce substantial external momentum using ground reaction forces and transfer sufficient angular momentum from the body to the club (Madrid et al., 2020). The purpose of the golf swing is to exert force to produce kinetic energy in the clubhead, which is then transmitted to the ball by impact (Nesbit & Serrano, 2005). The swing is a decisive stretch-shortening cycle in which the lower, midsection, and upper body muscles rapidly stretch before shortening (Hume, Keogh, & Reid, 2005).

Golfers must possess the physical attributes to withstand the increased stresses of the swing and reduce the risk of injury. CHS improvements alone are insufficient because clubhead kinematics determines the interaction between CHS, ball speed, and driving distance (Coughlan et al., 2020). Shaw et al. (2024) found a significant difference between peak force (PF) for IMTP ($g = 1.29 - 2.06$, $p < .05$), countermovement jump peak power ($g = 0.66 – 0.73$, $p < .05$), and jump height ($g = 1.07$, $p < .05$). The strength and power training group significantly positively improved their CHS and carry distance ($p < .05$, $g = 0.41 – 1.64$). The purpose of this literature review was to determine the athletic performance attributes that are required for the golf swing.

Literature Review Methodology

Search Strategies

A comprehensive assessment of the literature was conducted to evaluate how biomechanics (forces, torques, kinetics, muscle force, and acceleration) affect golf performance (hitting distance and clubhead speed). Key terms used were "golf" AND "clubhead speed" AND "golf grip strength" AND "isometric" OR "overcoming isometrics" OR "isometric mid-thigh pull" AND "stretch-shortening cycle" OR "x-factor" AND "ground reaction forces" OR "vertical forces" OR "horizontal forces" OR "torque forces" AND "rate force development" AND "deadlift" OR "hex trap bar deadlift" OR "barbell deadlift."

Inclusion and Exclusion Criteria

The following inclusion criteria was used to determine the appropriate use of this thesis: (a) reference “golf” in relation to the isometric mid-thigh pull test; (b) the improvement of sport(s) performance in relation to the golf swing; and (c) studies included of any age, gender, or activity level. For this review of literature, there were no exclusion criteria.

Analysis of Golf Swing

The golf swing requires whole body awareness and the coordinated effort of all the muscle groups. The muscles are activated during four distinct phases of the golf swing. During the first phase, the backswing involves a clockwise or counterclockwise rotation of the pelvis and trunk, depending on the athlete. Throughout the downswing, the pelvic rotation is reversed at the start of the downswing, and then the trunk rotation is reversed. The downswing takes an average of 0.23 seconds for professional golfers making a drive (Hume et al., 2005). While the trunk and pelvic rotation are reversed, the third phase, the impact phase, involves a point at which the golf ball and the clubhead make contact. Lastly, the "follow-through" phase occurs at the end of the golf swing (Loock et al., 2013). Throughout the phases of the golf swing, a significant correlation exists between lower body strength, grip strength, and clubhead speed (An et al., 2013; Brown et al., 2011; Cummings et al., 2017; Hellstrom, 2008; Sheehan et al., 2019).

The lower body provides stability, allowing the relationship between the upper and lower body segments to transfer kinetic energy to the ball efficiently. A steady base that allows the upper body and trunk to rotate efficiently is necessary for an efficient golf swing (Sheehan et al., 2019). Power production may benefit more by increasing the rate of force development and the short duration of the downswing. While power production may benefit the rate of force development, maximal torso rotational velocity develops maximum acceleration during the downswing and ball velocity (Sheehan et al., 2019). In other words, the obliques and erector spinae require high muscle activation during the acceleration phase. The term "x-factor" describes the relationship between the shoulders and the pelvis during the golf swing. To generate a high CHS, the x-factor angle at the top of the backswing must be greater to generate power before the club increases impact and the ball carries distance, greater torque is applied to the club (An et al., 2013); power production starts producing force into the ground, which transfers kinetic energy to the lower body for stability.

While the lower body is important for producing power and stability, the golf swing is primarily driven by the upper body (You et al., 2023). The ability to generate force at a faster rate is crucial for increasing CHS. At the same time, the lower body weight must be shifted, and the upper body muscles must be adequately recruited to achieve maximal acceleration during the downswing (Sheehan et al., 2019). Commings (2017) examined the effects of various grip diameters during an 8-week resistance training protocol on Division I male (n = 10) golfers. The resistance training program consisted of linear periodization, involving three sessions per week, each lasting 45 minutes. Each session consisted of a squat or deadlift variation and a grip-strengthening exercise for both the wrist flexor and extensor muscles. Both groups followed similar protocols; however, the fat grip training group performed all movements with a Fat Gripz model attached to every bar used during the training session. As a result, the Fat Gripz model training group showed significant increases in ball speed, carry distance, and drive distance ($p \leq .05$) while only the left-hand grip strength significantly increased ($p = .022$) from pretest to posttest after eight weeks of resistance training (Cummings et al., 2017). Utilizing a Fat Gripz model during training could increase golf swing performance compared with a standard straight barbell diameter.

Additionally, Hellström (2008) found that only right-hand grip strength is moderately, significantly positive correlated ($r = .36$ $p > .05$) with CHS. Furthermore, Brown et al. (2011) found that only left-hand grip strength correlates with CHS ($r = .54$, $p < .05$). In a population of rotational athletes, such as those in golf, softball/baseball, or tennis, exposure to resistance training with an emphasis on grip strength exercises may improve swing performance. There is still a lack of evidence to support the relationship between hand grip strength and clubhead speed.

Physical Requirements of Golf Swing

Golfers generate significant amount of forces during the complete swing to reach greater speeds. Therefore, golfers must also have the physical attributes to withstand increased stress throughout the swing and reduce the risk of injuries. CHS improvements alone are insufficient because clubhead kinematics determines the interaction between CHS, ball speed, and driving distance (Coughlan et al., 2020). Elite players experience spinal compressive forces over 7000 Newtons and shear force up to 600 Newtons during each swing (Bishop et al., 2022). Improving golf swing performance variables such as CHS and carry distance is strongly associated with golf handicap (Shaw et al., 2024). Strength and power are two of the main physical components of the golf swing. Given the forceful nature of the swing and the correlation between strength, power, and CHS, skilled golfers are expected to exhibit higher strength and power metrics. Oranchuk et al. (2020) suggested that increasing muscular strength and power, such as through exercises like the power clean, back squat, and countermovement jump, could increase CHS.

Oranchuk et al. (2020) conducted an eight-week strength training program to determine the effects of a strength and power resistance training program on improving CHS. Collegiate golf athletes ($n = 6$ male, $n = 6$ female) were randomly placed into two groups. The control group completed an eight-week resistance training program focusing on low-load rotational exercises. In contrast, the experimental group underwent an eight-week strength and power training program, with an emphasis on high-load weightlifting and powerlifting movements. Both groups continued to participate in regular team events and golf practice. One-repetition back squat, deadlift, clean, and peak countermovement jump (CMJ) height were assessed to measure CHS. Oranchuk et al. (2020) found a positive relationship between CHS with power clean ($r = .70$, $p = .012$), back squat ($r = .64$, $p = .025$), deadlift ($r = .54$, $p = .068$), and counter movement jump ($r = .73$, $p = .007$). The strength and power training group showed significant improvement in average CHS ($p = .024$, 95% CI [1.01, 9.43], ES = 0.20). In contrast, the low-load, unilateral, and rotational resistance training group showed a negative decrease in average CHS ($p = .028$, 95% CI [-13.41, -0.054], ES = 0.20). This suggests that incorporating high-load, heavy strength, and power training programs can positively increase CHS.

Stretch-Shortening Cycle

The average CHS for elite golf players is 108.6 ± 7.8 mph (Brožka et al., 2023). The golf movement sequence is referred to as the stretch-shortening cycle (Cole & Grimshaw, 2015). Golfers stretch the primary muscle groups during the eccentric phase (backswing) before transitioning to the concentric phase (downswing). The importance of the golf swing is to finish a round of golf with the fewest strokes possible. The actual CHS average scores for the driver, 5-iron, and pitching wedge were 49.4 ± 2.1 m/s (110.4 ± 4.8 mph), 42.1 ± 1.8 m/s (94.2 ± 4.0 mph), and 38.2 ± 1.9 m/s (85.5 ± 4.3 mph), while the average normalized CHS were 26.8 ± 1.3 BH/s, 22.7 ± 1.1 BH/s, and 20.6 ± 1.2 BH/s (Madrid et al., 2020). The CHS is associated with shorter downswing phases, larger backward/downward on-plane rotations, a larger x-factor, delayed backswing angular velocity peaks, and backswing-to-downswing transitions. Golfers who can produce more impulse during a slow stretch-shortening cycle might have an athletic advantage if they can transfer the kinetic energy to the clubhead (Wells et al., 2018). The stretch-shortening cycle enhances the athlete's performance and minimizes the transition from backswing to downswing.

Isometric Contraction

The muscle length remains constant during isometric muscle activation because the contractile and resistive forces are equal (Haff & Triplett, 2016). Examples include a plank or a wall sit, because the muscle does not change length. It had been suggested that isometric training resulted in less fatigue (Baily et al., 2025) compared with dynamic training (Reblo et al., 2025). The reason for the decreased fatigue response is most likely that isometric contraction consumes less energy (Bailey et al., 2025), due to less cross-bridge cycling and adenosine diphosphate hydrolysis (Delmotte et al., 2020).

Isometric Mid -Thigh Pull

According to research, highly talented golfers initiate their downswing from the ground up (Hume et al., 2005), with energy being transferred to the clubhead through the body's kinetic chain (Nesbit & Serrano, 2005). One of the most effective ways to assess a golfer's ability to generate force from the ground to the clubhead is from the straight barbell isometric mid-thigh pull (Comfort et al., 2019; Johansen et al., 2023; Shaw et al., 2024). When compared with one-repetition maximal testing, isometric mid-thigh pull (IMTP) is safer to administer during strength training sessions and less fatiguing while allowing measurement of force characteristics (Comfort et al., 2019).

Athletes with a fast CHS should demonstrate better peak force (PF) and rate force development (RFD) during the IMTP in comparison to individuals with slow CHS. In a cross-sectional design, Johansen et al. (2023) examined the relationships between CHS and selected physical performance variables. The cohort was divided into top and bottom quartiles based on their CHS for comparison between players with fast CHS (n = 7) and those with slower CHS (n = 7). Johansen et al. (2023) reported a significant positive correlation between golf handicap and CHS (r = .59, p = .005). In addition, the golf handicap (p = .04) and CHS ($p \leq .0001$) were 11.3% higher for fast CHS group than for slow CHS group. Furthermore, it was observed that CHS and straight barbell IMTP (r = .82, $p \leq .0001$) had a very strong correlation. As a result, it is indicated that golf handicap and CHS are significantly positive relationship with the straight-barbell IMTP force-time metrics.

Another cross-sectional design study conducted by Wells et al. (2019) investigated thirty-one male European Challenge Tour golfers (mean age: 26.9 ± 5.4 years) to determine the prediction of CHS from a CMJ and IMTP variables. The IMTP PF as well as RFD from 0 - 150ms and from 0 - 200ms. Wells et al. (2019) indicated that while all variables contributed the prediction of CHS; CMJ was the only significant contribution to the prediction (β = .525, p < .01). The straight barbell IMTP is commonly used in various studies (Bishop et al., 2023; Bliss, 2021; Hume et al., 2005; Johansen et al., 2023; Leary et al., 2012; Shaw et al., 2024; Wells et al., 2019; Wells et al., 2020).

Malyszek et al. (2016) conducted a comparison study of the IMTP between straight barbell and the hexagonal trap bar. Twenty resistance-trained men participated over a three-day period. Upon arriving the first day, body mass and height were obtained using an electronic scale and a stadiometer. A dynamic warm-up was performed before testing. Once the dynamic warm-up was completed, the participants performed a warm-up consisting of five pulls at 50%, three pulls at 75%, and one pull at 90% effort, with one minute of rest in between sets and three minutes in between conditions until a steady effort was demonstrated. During day two and day three, the participants carried out the same warm-up procedures that were on day one. After that, the participants used the hexagonal trap bar or the straight barbell to complete three trials of an IMTP or deadlift. Between trials, the resistance-trained men were given a one-minute rest, and between conditions, three minutes. On day three, they used the lift that had not been assessed on day two, using the same protocols. While the study found a difference in peak ground reaction forces between the IMTP (3,186.88 ± 543.53 N) and the deadlift (2,501.15 ± 404.04 N; $p < .05$), no differences were observed for RFD and ground reaction force between the straight barbell and the hexagonal trap bar ($p > .05$).

Straight Barbell Deadlift vs. Hexagonal Trap Bar Deadlift

During a strength training program, it is common for a strength and conditioning coach to program various lifts, such as a hexagonal trap bar deadlift, straight barbell deadlift, and IMTP, to examine performance and adaptation to training stimuli (Comfort et al., 2019). A correlational study conducted by Miller et al. (2022) was implemented to determine the relationship between one-repetition maximum hexagonal trap bar IMTP force-time characteristics. College-aged students (male = 13, female = 10) participated over a period of three days. During the first visit, a medical history questionnaire and informed consent were obtained before the start of the protocol(s). Anthropometric measures and one-repetition maximum hexagonal trap bar deadlift were assessed during visits one and two, while isometric pulls were performed during visit three. Throughout the first two visits, separated by 24-hours, visits two and three were separated by a minimum of 72-hours. Impulse was measured at 100-300J, while rate of force development was measured at 0-250ms. Peak force was also measured at 50ms, 100ms, 150ms, 200ms and 250ms to determine the maximum amount of force exerted during each time-specific area of the force-time curve. Miller et al. (2022) determined that one-repetition maximum hexagonal trap bar deadlift was positively correlated with impulse (r = .575 - .635, p < .004), PF (r = .695 - .652, $p \leq$ .001), and RFD at 0 - 250ms (r = .459 - .594, p < .027). Miller et al. (2022) assessed correlation relationships between PF and RFD (r = .695 – .879, $p \leq$ .001) of the IMTP are significantly and positively correlated with one-repetition maximum deadlift performance.

Swinton et al. (2011) conducted a cross-sectional study to compare the kinematics and kinetics of the deadlift exercise performed with the straight barbell and hexagonal trap bar. Nineteen male power lifters performed one-repetition maximum and submaximal testing with the straight barbell and the hexagonal trap bar. During the one-repetition testing protocol, the competitive power lifters performed a series of warm-up sets and up to five maximal attempts. Two to four minutes of rest periods were provided between maximal attempts with the heaviest load lifted. The participants performed in a randomized order with a 30-minute rest period between the straight barbell deadlift and the hexagonal trap bar deadlift. During the submaximal testing, subjects performed their own specific warm-up. Once the warm-up was completed, the straight barbell deadlift and the hexagonal trap bar deadlift performed in a randomized order with a sub maximum of two repetitions performed in each repetition with maximal effort. A minimum of two-minutes rest period between trials was necessary to produce maximum performance. Swinton et al. (2011) determined that there was significant difference with straight barbell deadlift 244 ± 39kg and the hexagonal trap bar deadlift was 265 ± 41.8kg ($p < .05$).

Studies reported that the biceps femoris, gluteus maximus, and erector spinae were activated during the straight barbell deadlift and hexagonal trap bar deadlift (Andersen et al., 2017; Camara et al., 2016). Andersen et al. (2017) reported that the straight barbell deadlift activation of the biceps femoris was 28% higher than that of the hexagonal trap bar deadlift ($p = .001$), while no significant difference was displayed for gluteus maximus and erector spinae activations. Furthermore, the bicep femoris activation in the concentric phase of the movement was 39% higher for the straight barbell deadlift compared with the hexagonal trap bar deadlift ($p = .002$).

Camara et al. (2016) reported both the concentric (1.199 ± .22 mV) and eccentric (.879 ± .31 mV) phases of the hexagonal trap bar deadlift, which yielded greater electromyography values from the vastus lateralis compared to the straight barbell deadlift concentric phase (.968 ± .22 mV). In contrast, greater electromyography values were significantly greater for the biceps femoris during the concentric phase (.835 ± .19 mV) during the straight barbell deadlift when compared to the hexagonal trap bar deadlift (.723 ± .20 mV). In addition, with the electromyography values, the hexagonal trap bar deadlift showed greater PF (2,553.20 ± 371.52 N) and peak power (1,871 ± 451.61 W) when compared to the straight barbell deadlift dynamic effort. The hexagonal trap bar deadlift may be more effective in increasing force and power production. Although the long-term training effects are unknown, it is essential to note that these recommendations are based on studies examining the acute effects. The hexagonal trap bar may be a better barbell selection due to its ability to evenly distribute the load and reduce the moment at the lumbar spine, which can help prevent lower-back injuries or pain (Camara et al., 2016).

Force - Time Metrics

The only external forces that could change the golfer-club system momentum are the ground reaction forces and the ground reaction momentum acting on the golfers' feet (Han et al., 2019). According to recent studies, highly skilled golfers use ground reaction forces to redirect their momentum back towards the target at the mid-backswing and late backswing (Wells et al., 2024). You et al. (2023) did a systematic review and a meta-analysis and discovered that because golf clubs come in different lengths and sizes, they may influence a player's posture and swing power. The ground reaction force produced by the lead foot is greater than that of the trail foot.

Leary et al. (2012) conducted a cross-sectional examination to investigate the relationship between average CHS, maximum CHS and IMTP. In the study, the participants (n = 12 recreational golfers) participated in three-day testing sessions over two weeks at the end of the golf season. Leary et al. (2012) measured PF at 30ms to 250ms, the RFD from 30 - 250ms, and the peak rate of force development. Leary et al. (2012) found that handicap was moderately correlated with average CHS (r = -.52, p = .04) and maximal CHS (r = -.45, p = .07). Force at 30 - 250ms during the IMTP test was moderately significantly correlated with average CHS (r = .04 - .36, p > .07) and PF (r = .19, p > .07). Moderate significant correlations were also found between the RFD from 0 - 250ms with average CHS (r = .08 - .38, p > .07). Force at 30 - 250ms during the IMTP test was moderately significantly correlated with maximal CHS with correlation coefficients ranging from -.08 to + .36 (p > .07). This indicates that average CHS and maximal CHS are positively but not significantly correlated with the IMTP. When attempting to maximize CHS and improve golf performance, Leary et al. (2012) suggested that all training activities and practices should target positive RFD and PF outcomes

Summary of Literature Review

According to Newton's second law of motion, impulse is directly proportional to the change in momentum. Since a golfer's mass does not change from shot to shot, the velocity is affected during the downswing by increasing the force or the duration of force (Wells et al., 2019). Examining the relationship between the ground reaction force and the golfers foot location during the swing is important for practitioners to consider. Planning a strength program for golfers suggests that kinematics and biomechanics play a significant role in swing mechanics. The golf swing, IMTP, hexagonal trap bar deadlift, and straight barbell deadlift are whole-body movements that involve the upper extremities, including the biceps, wrists, and forearms, as well as the lower extremities, such as the bicep femoris, gluteus maximus, and erector spinae. Depending on the focus of the strength training, both barbell variations may be beneficial.

To generate CHS, the backswing, downswing, and follow-through create a kinetic chain that produces a large amount of force at impact with the golf ball. The IMTP is an assessment of strength that increases force production in areas such as peak ground reaction force, peak power, PF, RFD, and impulse. Exercise selection is a crucial consideration for enhancing athletic performance. Furthermore, it is currently unclear if the hexagonal trap bar IMTP is beneficial in a golf strength and conditioning program. Therefore, this thesis aims to determine whether CHS correlates with force-time metrics during the IMTP using a hexagonal trap bar. It also aims to determine if force-time metrics during the IMTP are different when using hexagonal trap bar compared to the straight barbell.

Chapter Three: Methodology

Participants

Ten NCAA Division II College athletes (female = 7; male = 3) aged 18 years and older participated in this study. Participants were required to sign an informed consent document, complete a physical activity readiness questionnaire, and be free from any injury that might impact their ability to participate in the study.

Required sample size for the primary research question was estimated using G*Power (Faul et al., 2007). The literature on the relationship between clubhead speed (CHS) and peak force (PF) reports correlation coefficients ranging from r = .20 - .88 (Sanders et al., 2021; Leary et al., 2012). This resulted in sample size estimates ranging from 6 to 262. The upper end of that range is unrealistic for a study of this nature making our goal to recruit as many participants as possible.

Recruitment

Participants were recruited from University of Central Oklahoma. Permission was obtained from the Athletics Department to recruit athletes on the men and women golf teams. The recruitment was conducted via an email blast and an announcement before team lifts.

Pre-Participation Screening

The participants were asked to sign an informed consent document (Appendix A) when they agreed to participate in the study. Participants were also asked to complete a physical activity readiness questionnaire (PAR-Q; Appendix B) to ensure their readiness to participate in the study. Any participants who had answered “yes” to any of the questions on the PAR-Q were required to be cleared by the team’s medical doctor. This thesis was approved by the University of Central Oklahoma Institutional Review Board (#2025-093).

Procedures

A cross-sectional correlation study approach was employed to investigate the association between CHS with the driver and isometric mid-thigh pull (IMTP) force-time metrics in collegiate Division II golfers. The IMTP force-time metrics, measured as peak force and force at 50ms, 100ms, 150ms, 200ms, and 250ms were selected to replicate the reported duration of the downswing (Leary et al., 2012; Wells et al., 2019). Data collection took place across three testing sessions, a minimum of 24-hours apart. Due to confidentiality, individualized appointments were scheduled on day one to collect demographic information, followed by CHS testing. On testing days two and three, participants completed IMTP assessment using the hexagonal trap bar and the straight barbell in random order.

Testing Day 1

During the first day, demographic information, anthropometric data, and CHS were collected. After signing informed consent and completing the PAR-Q, participants completed a demographic information form (Appendix C).

Anthropometry Protocol. All measurements were conducted with the participants wearing comfortable clothes with no shoes (Johansen et al., 2023). With the participant standing (90° shoulder flexion, full elbow extension, and pronation of the forearm), the length of both arms and both legs were measured using a generic soft measuring tape. Arm length was measured as the distance between the lateral edge of the scapula acromion and the most distal aspect of the third finger (Johansen et al., 2023). Leg length was measured as the distance between the greater trochanter of the femur and the lateral malleolus (Johansen et al., 2023). Arm and leg length were reported as the mean of two trials.

Pre-Testing Warm-Up. The purpose of the warm-up was to reduce the risk of injuries, increase blood flow, increase muscle temperature, and enhance performance (Vadher et al., 2024). Each participants completed three minutes of cycling following by dynamic stretches. Dynamic stretches were performed for six repetitions and included glute bridges, hinge into a squat, scapular push-ups, lateral lunge to thoracic rotations, double-leg pogo hops, and double-leg broad jumps (Bliss, 2021; Johansen et al., 2023; Wells et al., 2019). The warm-up protocol was developed using the principles cited in Bliss et al. (2021) and examples from other studies (Johansen et al., 2023; Leary et al., 2012; Wells et al., 2019). Once the standardized warm-up procedures were completed, subjects performed a minimum of three warm-up golf swing protocols, as described by Bliss et al. (2021).

Clubhead Speed Assessment. CHS was measured using a TrackMan 4 launch monitor collected using a dual doppler radar (Interactive Sports Games, Denmark). Prior to each data collection, the launch monitor was recalibrated. The TrackMan 4 launch monitor is demonstrated to be reliable and accurate in measuring peak force (ICC = 0.60 - 0.99; Brennan et al., 2024). Bliss et al. (2021) recommended bringing and using their own driver due to the participants appendicular limbs. The golf ball was positioned at the same tee spot for every shot to maintain consistency in the distance between the launch monitors. According to the manufacturer guideline(s), the TrackMan was positioned eight to ten feet behind the tee so that the system aligns with the target. For every testing session, the launch monitor was calibrated and set to a "normalized setting," which is advised for indoor use. Participants were instructed to retake the shot if the TrackMan failed to record measurements (Brennen et al., 2024).

Standardized instructions were given to the participants: “give the best fast golf swing and hit the golf ball as hard as possible” for each of the maximal effort trials. The participants completed a minimum of five accurate (in-play) trials. The longest accurate shot was used for analysis. Verbal encouragement was given with each bout of encouragement lasting about 5 seconds. The highest CHS was recorded.

Testing Day 2 & 3

Isometric Mid-Thigh Pull. The participants performed the same warm-up protocol as completed on the first day of testing. Three minutes after the standardized warm-up procedures were completed, subjects performed an IMTP. IMTP was conducted using dual force plates, sampling at 1,000 Hz (Hawkin Dynamics, Westbrook, ME, USA). The force plates were recalibrated prior to each data collection. The Hawkin Dynamics force plate is reliable when measuring the force-time metrics within (ICC = .98 and .97) and between sessions (ICC = .89; De Witt et al., 2018; Johansen et al., 2023). Comfort et al. (2019) suggested that before the start of the IMTP, the height of the bar should be used to determine the body position to achieve optimal knee (125–145°) angles, which were recorded using a universal goniometer. The participants stood at the center of the force plate, approximately hip-width apart. The participants gripped the straight barbell with a pronated grip. While using the hexagonal trap bar, the participants maintained a neutral grip, with their palms facing toward their body. For the IMTP, the hand positioning should result in a balanced, even bar (Haff & Triplett, 2016).

The participants were instructed to grab the bar and pull against the J-hooks of the weight rack with an upright torso, slight flexion in the knees, shoulder girdle retracted and depressed, shoulders slightly above or slightly centered under the bar, feet roughly centered under the bar, approximately hip width apart (Comfort et al., 2019). Prior to the start of the IMTP measurement(s), it was important to remove any “slack” from the J-hooks because this would result in a change in joint angles during the IMTP attempts. To give the individual a sufficient warning to be ready to give a maximum effort to the pull, a countdown of “3, 2, 1, Pull!” was given. Participants completed a minimum of two trials, with a one-minute rest period between each trial. Additional trials were performed if the difference between trials was greater than 250N (Comfort et al., 2019).

Statistical Analysis

All statistics were performed using SPSS version 28 (SPSS Inc., Chicago, IL, USA). Means and standard deviations were calculated to describe the participant characteristics of the sample. Pearson’s Product Moment Correlation Coefficients were used to examine relationships between clubhead speed and force-time metrics during the isometric hexagonal trap bar mid-thigh pull ($\alpha = .05$). Force characteristics include peak force and force at 50, 100, 150, 200, and 250ms.

A secondary analysis was performed to determine if differences existed in force-time metrics between the two types of bars used to perform the isometric mid-thigh pull (straight barbell vs. hexagonal trap bar). The independent variable was the type of bars used during the isometric mid-thigh pull (straight barbell vs. hexagonal trap bar). The dependent variables were the force characteristics, including peak force and force at 50, 100, 150, 200, and 250ms. Paired samples t-tests were used to test for differences in force characteristics between the two types of bars ($\alpha = .05$).

Chapter Four: Results

The main aim of the study was to analyze the correlation between clubhead speed (CHS) and force-time metrics from an isometric mid-thigh pull (IMTP) using the hexagonal trap bar. The secondary aim was to compare the force-time metrics during the IMTP performed using two different types of bars. Ten highly skilled Division II golf athletes took part in this study (age = 20.00 ± 1.25 years). The average weight was 69.53 ± 10.18 kg and the average height was 167.99 ± 9.07 cm. The average time participating in strength training was 5.10 ± 1.45 years. Additional descriptive statistics are presented in Table 1.

Table 1

Descriptive Statistics of the Study Sample

	N	Minimum	Maximum	Mean	Std. Deviation
Age	10	18	22	20.00	1.25
Golf Years	10	3	16	8.20	3.80
ST Years	10	3	8	5.10	1.45
Weight (kg)	10	58.51	88.45	69.53	10.18
Height (cm)	10	157.48	190.30	167.99	9.07
RUL (cm)	10	27.30	98.30	71.08	19.14
LUL (cm)	10	27.20	98.20	70.96	19.16
RLL (cm)	10	32.50	100.00	78.61	28.94
LLL (cm)	10	32.50	100.00	78.73	28.99

Note: ST = Strength Training; RUL = Right Upper Limb Length; LUL = Left Upper Limb Length; RLL = Right Lower Limb Length; LLL = Left Lower Limb Length

Table 2 shows the descriptive statistics for CHS and force-time metrics during an IMTP performed using a hexagonal trap bar and straight barbell. The mean clubhead speed was 101.36 ± 15.09mph. Peak force during the IMTP when using the hexagonal trap bar was 1,973.90 ± 551.07N. Peak force during the IMTP when using the straight barbell was 1,723.10 ± 445.86N.

Table 2

Descriptive Statistics of Clubhead Speed and Force-Time Metrics

	N	Minimum	Maximum	Mean	Std Deviation
CHS (mph)	10	84.65	129.59	101.36	15.09
TPF (N)	10	1,292.00	2,976.00	1,973.90	551.07
TF50 (N)	10	1,049.00	1,836.00	1,268.00	226.34
TF100 (N)	10	1,102.00	2,245.00	1,447.40	313.30
TF150 (N)	10	1,194.00	2,473.00	1,555.80	362.61
TF200 (N)	10	1,149.00	2,743.00	1,629.50	441.06
TF250 (N)	10	1,200.00	2,790.00	1,675.20	449.73
BPF (N)	10	1,317.00	2,803.00	1,723.10	445.86
BF50 (N)	10	1,031.00	1,585.00	1,268.00	214.26
BF100 (N)	10	1,148.00	1,943.00	1,399.60	276.35
BF150 (N)	10	1,219.00	2,265.00	1,468.60	328.38
BF200 (N)	10	1,220.00	2,305.00	1,483.40	335.56
BF250 (N)	10	1,143.00	2,358.00	1,506.70	356.37

Note: CHS = clubhead speed; TPF = hexagonal trap bar peak force; TF50 = hexagonal trap bar force at 50 milliseconds; TF100 = hexagonal trap bar force at 100 milliseconds; TF150 = hexagonal trap bar force at 150 milliseconds; TF200 = hexagonal trap bar force at 200 milliseconds; F250 = hexagonal trap bar force at 250 milliseconds; BPF = straight barbell peak force; BF50 = straight barbell force at 50 milliseconds; BF100 = straight barbell force at 100 milliseconds; BF150 = straight barbell force at 150 milliseconds; BF200 = straight barbell force at 200 milliseconds; BF250 = straight barbell force at 250 milliseconds

Clubhead Speed and Hexagonal Trap Bar IMTP

The primary aim of this study was to examine the correlation between CHS and force-time metrics from an IMTP using the hexagonal trap bar (Table 3). When using the hexagonal trap bar, significant positive correlations were observed between CHS and peak force (r = .802, p = .005), force at 100ms (r = .662, p = .037), force at 150ms (r = .764, p = .010), force at 200ms (r = .815, p = .004), and force at 250ms (r = .820, p = .004). The correlation between CHS and force at 50ms (r = .507, p = .135) was non-significant. The results showed strong correlations observed between CHS and peak force, force at 200ms and 250ms and moderate correlations at 100ms and 150ms.

Table 3
Intercorrelations of Clubhead Speed with Force-Time Metrics During the Isometric Mid-Thigh Pull Using a Hexagonal Trap Bar

	1	2	3	4	5	6	7
1. CHS (mph)	1						
2. TPF (N)	.802**	1					
3. TF50 (N)	.507	.704*	1				
4. TF100 (N)	.662*	.804**	.973**	1			
5. TF150 (N)	.764*	.844**	.926**	.979**	1		
6. TF200 (N)	.815**	.869**	.895**	.961**	.993**	1	
7. TF250 (N)	.820**	.865**	.878**	.945**	.984**	.991**	1

Note: CHS = clubhead speed; TPF = hexagonal trap bar peak force; TF50 = hexagonal trap bar force at 50 milliseconds; TF100 = hexagonal trap bar force at 100 milliseconds; TF150 = hexagonal trap bar force at 150 milliseconds; TF200 = hexagonal trap bar force at 200 milliseconds; F250 = hexagonal trap bar force at 250 milliseconds;
*p < .05. **p <. 01

Clubhead Speed and Straight Barbell IMTP

Although not the primary objective, the relationship between CHS and force-time metrics during the IMTP using a straight barbell were also examined for comparison with the results when using the hexagonal trap bar. When using the straight barbell, CHS and peak force showed a significant, strong, positive correlation (r = .826, p = .003; Table 4). A significant, moderate, positive correlation was seen between force at 100ms (r = .641, p = .046), force at 150ms (r = .742, p = .014), force at 200ms (r = .686, p = .029) and force at 250ms (r = .712, p = .021). The correlation between CHS and force at 50ms ($r = .541$, $p = .106$) was not significant. These results are consistent with those found when using the hexagonal trap bar (Table 3).

Table 4

Intercorrelations for Clubhead Speed & Straight Barbell Isometric Mid-Thigh Pull

	1	2	3	4	5	6	7
1. CHS (mph)	1						
2. BPF (N)	.826**	1					
3. BF50 (N)	.541	.706*	1				
4. BF100 (N)	.641*	.841*	.903**	1			
5. BF150 (N)	.742*	.925**	.808**	.947**	1		
6. BF200 (N)	.686*	.922**	.775**	.955**	.976**	1	
7. BF250 (N)	.712*	.919**	.808**	.936**	.975**	.976**	1

Note: CHS = clubhead speed; BPF = straight barbell peak force; BF50 = straight barbell force at 50 milliseconds; BF100 = straight barbell force at 100 milliseconds; BF150 = straight barbell force at 150 milliseconds; BF200 = straight barbell force at 200 milliseconds; BF250 = straight barbell force at 250 milliseconds

$^{*}p < .05$. $^{**}p < .01$

Differences Between Straight Barbell IMTP and Hexagonal Trap Bar IMTP

To examine the secondary purpose of this study, a paired-samples t-test was conducted to compare the force-time metric during the IMTP when using the hexagonal trap bar and the straight barbell (Table 5). Peak force during the IMTP was significantly higher when using the hexagonal trap bar (1,973.90 ± 551.07N) compared to the straight barbell (1,723.10 ± 445.86N, $t(9)$ 3.12, $p = .006$). Force was also significantly higher when using the hexagonal trap bar at 200N (Mean Diff = 146.10 ± 247.26N, $t(9)$ 1.87, $p = .047$) and 250 N (Mean Diff = 168.50 ± 242.99N, $t(9)$ 2.19, $p = .028$. No significant differences were observed between force-time metrics when using the hexagonal trap bar and straight barbell for force at 50ms (Mean Diff = 0.00 ± 227.73N, t(9) .000, p = .50), force at 100ms (Mean Diff = 47.80 ± 231.79N, t(9) .65, p = .265) and 150ms (87.20 ± 208.85N, t(9) 1.32, p = .110). For all force metrics except force at 50N, force was higher when using the hexagonal trap bar to perform the IMTP. For force at 50ms, the mean was the same when using the two different bars.

Table 5
Comparison of Force-Time Metrics Between the Two Bars

	Mean Diff (N)	*r*	*t*	*df*	*p*
TPF - BPF	250.80	.891	3.12*	9	.006
TF50 - BF50	0.00	.467	0.00	9	.500
TF100 - BF100	47.80	.698	0.65	9	.265
TF150 - BF150	87.20	.822	1.32	9	.110
TF200 - BF200	146.10	.831	1.87*	9	.047
TF250 - BF250	168.50	.843	2.19*	9	.028

Note: TPF = hexagonal trap bar peak force; TF50 = hexagonal trap bar force at 50 milliseconds; TF100 = hexagonal trap bar force at 100 milliseconds; TF150 = hexagonal trap bar force at 150 milliseconds; TF200 = hexagonal trap bar force at 200 milliseconds; F250 = hexagonal trap bar force at 250 milliseconds; BPF = straight barbell peak force; BF50 = straight barbell force at 50 milliseconds; BF100 = straight barbell force at 100 milliseconds; BF150 = straight barbell force at 150 milliseconds; BF200 = straight barbell force at 200 milliseconds; BF250 = straight barbell force at 250 milliseconds
*p < .05

Chapter Five: Discussion

The aim of the study was to examine the relationships between clubhead speed (CHS) and force-time metrics during the isometric midthigh pull (IMTP) when using a hexagonal trap bar. We observed that, in general, the greater the CHS, the greater the force-time metrics during the IMTP when using the hexagonal trap bar. Additionally, the secondary purpose was to compare the force-time metrics during the IMTP between the hexagonal trap bar and the straight barbell. Peak force (PF), force at 200ms, and force at 250ms was significantly higher when using the hexagonal trap bar ($p < .05$).

Correlation Between Clubhead Speed and Hexagonal Trap Bar Peak Force

Often, sports performance coaches will focus on maximum effort strength and use that as their benchmark for athletic performance. The main finding of the present study was that maximal CHS was a strong, significantly correlated with PF during the IMTP when using the hexagonal trap bar in the present group of Division II golf athletes ($r = .802$, $p = .005$).

Our findings were like previous literature, which also agree that CHS is strongly correlated with force-time metrics (Johansen et al., 2023; Sanders et al, 2012). Johansen et al. (2023) reported a strong positive correlation between CHS and PF ($r = .82$, $p \leq .001$) in highly skilled national-level male golfers. Similarly, Sanders et al. (2021) showed a significant positive correlation between CHS and PF in a group of high level-youth golfers ($r = .88$, $p < .001$). Although, the literature consistently showed a positive correlation between CHS and PF, in at least one study, the correlation was much weaker. Among recreational golfers, Leary et al. (2012) reported a weak positive correlation between CHS and force-time metrics ($r = .20$, $p = .27$).

While CHS and PF do positively correlate, certain studies show a weaker correlation than others. All studies previously published on this topic use a straight barbell to perform the IMTP. To the knowledge of the authors, our findings provided the first evidence of a relationship present between CHS and PF when using the hexagonal trap bar to perform the IMTP among highly skilled collegiate golfers. The significance of developing maximum strength among golfers seems to be supported by the association between CHS and PF when using either the hexagonal trap bar or the straight barbell.

Straight Barbell vs. Hexagonal Trap Bar Force-Time Metrics

In the IMTP, an athlete applies their maximum effort to a stationary bar during a static position. In the current investigation, a higher PF was achieved during the IMTP when using the hexagonal trap bar (1,973 ± 551.07N) than when using the straight barbell (1,723.10 ± 445.86N). To our knowledge, Malyszek et al. (2016) was the only other study that examined a direct comparison between the two barbells when using the IMTP. However, the present study differs from Malyszek et al. (2016) findings as they found no difference in RFD and peak ground reaction forces between the two bars ($p > .05$). Thus, further study of the two bars is warranted when performing the IMTP.

In studies of methods other than the IMTP to assess PF, dynamic effort 1-repetition maximum is the most common reported. Among competitive powerlifters, the hexagonal trap bar showed greater PF in comparison to the straight barbell when performing a deadlift. Swinton et al. (2011) found significant difference between straight barbell deadlift and hexagonal trap bar deadlift with overall heavier loads observed when using the hexagonal trap bar ($p < .05$). In contrast, Camara et al. (2016) showed no significant difference in 1-repetition maximum values between bars in the deadlift despite showing significant differences in electromyography values.

Camara et al. (2016) reported significantly greater electromyography amplitude values for both the concentric (1.199 ± .22 mV) and eccentric (.879 ± .31 mV) phases for the hexagonal trap bar from the vastus lateralis than in correspondence with the straight barbell value ($p \leq .05$). On the other hand, the concentric (.835 ± .19 mV) phase of the straight barbell from the bicep femoris had significantly greater normalized electromyography amplitude values than the hexagonal trap bar value ($p \leq .05$). According to Andersen et al. (2017), there was no significant difference in the activation of the gluteus maximus and erector spinae, but the straight barbell deadlift activation of the biceps femoris was 28% higher than of the hexagonal trap bar deadlift ($p = .001$). Additionally, the straight barbell deadlift activated the bicep femoris 39% more during the concentric portion of the exercise than the hexagonal trap bar deadlift ($p = .002$). Although there is some evidence that greater force is produced when using the hexagonal trap bar, there is still a need for further research comparing the two barbells, especially when assessing force-time metrics during the IMTP.

Study Limitations

While the current study offers new insights into the connection between swing performance in collegiate golfers and force-time metrics, methodological considerations should be considered when comparing results to other studies. First, the current study did not investigate how maturation or gender affected force-time metrics and swing performance. Second, this study was only open to Division II collegiate golfers. Third, an unequal number of female and male golfers participated in this study. Results should be interpreted considering these study limitations.

Future Study

Additional studies of the relationship between CHS and force-time metrics when using the hexagonal trap bar in rotational sports, including golf, should be conducted to confirm these results. Future studies should also focus on the training intervention, specifically using isometric training techniques, to improve force production, CHS, and performance.

Practical Applications

From a pragmatic perspective, these associations provide evidence regarding the kinds of resistance training equipment that could be advantageous for incorporation into the golf training program such as the hexagonal trap bar. Therefore, when trying to increase CHS and enhance golf performance, exercise equipment selection is an important consideration when designing a resistance training program. When paired with appropriate program variables, chosen equipment such as the hexagonal trap bar could activate the targeted muscles and offer a proper biomechanical stimulation.

Conclusion

To the best of the authors' knowledge, our results offer the first evidence of the relationship between clubhead speed and force-time metrics during the IMTP when using the hexagonal trap bar. The findings revealed strong positive correlations with PF, force at 200ms, and force at 250ms and moderate positive correlations with force at 100ms and force at 150ms. Force-time metrics during the IMTP appeared to be greater when using a hexagonal trap bar than when using a straight barbell. This evidence suggests that the hexagonal trap bar can be used as an appropriate, possibly superior, substitute for the straight barbell.

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Appendices

Appendix A – Informed Consent Document

Research Title: The Relationship Between Ground Reaction Forces and Clubhead Speed in NCAA Division 2 Golf Athletes: A Comparison of the Isometric Mid-Thigh Pull Using a Barbell and a Hexagonal Trapbar

Researchers: Xavier Obregon, B.S., CSCS, PES

Melissa Powers, Ph.D.

Purpose:
The primary purpose of this study is to examine the relationship between clubhead speed and ground reaction forces during the isometric mid-thigh pull performed using a barbell and a hexagonal-trapbar. The study will also examine the difference in ground reaction forces during the isometric mid-thigh pull performed using a barbell when compared to a hexagonal-trapbar.

Procedures:
You will be asked to read and complete the PAR-Q+ form prior to participation in this study. If medical clearance is indicated from this form, you must be cleared by the team doctor to participate in this study.

Testing Day 1
Due to confidentiality purposes, you will meet one on one with the researcher for your first testing day. You will be asked to complete demographic information form prior to the start of the pre-testing warm-up. Your height, and the length of your arms and legs will be measured. Then, you will complete a short warm-up. Following the warm-up, you will stand on a portable force plate and perform a golf swing using your own driver. For each golf swing, the protocol will require you to assume their golf stance position. You will swing the golf club with three maximal efforts. One minute of rest will be taken between each trial.

Testing Day 2 & 3
You will be randomized into groups to complete testing day 2 and 3 in random order, on one day you will perform the test using the straight barbell and on the other day, you will use the trapbar. A warm-up will be completed before testing. Three minutes after the standardized pre-testing warm-up procedures, you will perform an isometric mid-thigh pull test. For this test, you will stand on portable force plates assuming a pronated grip (straight barbell) and/or neutral grip (trapbar) position with feet placed in approximately shoulder-width position. You will pull the bar up giving your maximum effort for three trials. Two minutes of rest will be taken between each trial.

Expected Time for Participation:
Time for data collection should be approximately no longer than thirty minutes for each session. You are asked to attend three data collection trial assessments.

Potential Benefits:
The information gained from this study will help strength and conditioning coaches develop safe and effective training programs for future athletes.

Potential Risk:
The risk of the study consists of the general risk assumed when completing any athletic or daily task. The testing procedure could result in a muscular strain due to isometric and clubhead speed procedures but is a decreased risk due to the warm-up given for the participant. For safety purposes, a certified CSCS strength and conditioning coach will be on site during all testing.

Researcher Contact Information:
If you have any questions or concerns regarding the study, please contact Xavier Obregon, B.S., CSCS, PES at xobregon@uco.edu or Melissa Powers, Ph.D. at (405) 974-5309 mpowers3@uco.edu. The UCO Institutional Review Board can be reached at irb@uco.edu or (405) 974-5497.

Explanation of Confidentiality:
Your participation in this study is confidential. Your name or other identifying information will not be associated with your data. We will keep a record of your name on a master code sheet which will be stored on a password protected computer separated from your data. All data will be stored on a password- protected computer with access limited to approved research personnel. Your results will not be shared with anyone outside the research team.

Explanation of Photograph:
During the participation of the experiment, the researcher will ask your photograph. Photographs will be taken in such a way that you cannot be identified. You are not required to consent to have your photograph taken. The photograph will be used research presentations publications only.

Assurance of Voluntary Participation:
Participation in this study is voluntary. The participant has the right to withdraw at any time and decline further participation within the study. The decision to leave the study is held solely with the individual participant.

Affirmation of the Participation:
I hereby voluntarily agree to participate in the above listed research project and further understand the above listed explanations and descriptions of the research project. I also understand that there is no penalty for refusal to participate, and that I am free to withdraw my consent and participation in this project at any time without penalty. I acknowledge that I am at least 18 years old. I have read and fully understand this Informed Consent Form. A copy of this consent form has been given to me to keep.

Participant's Printed Name: ____

Participant's Signature: ____________________________ Date: _________________

Consent to Photograph

I understand that the researcher will take photographs throughout the testing procedure and will be used for research purposes.

Participant's Printed Name: ____

Participant's Signature: _________________________________ Date: ____________________

Appendix B – The Physical Activity Readiness Questionnaire for Everyone

PAR-Q+

The Physical Activity Readiness Questionnaire for Everyone

The health benefits of regular physical activity are clear; more people should engage in physical activity every day of the week. Participating in physical activity is very safe for MOST people. This questionnaire will tell you whether it is necessary for you to seek further advice from your doctor OR a qualified exercise professional before becoming more physically active.

GENERAL HEALTH QUESTIONS

Please read the 7 questions below carefully and answer each one honestly: check YES or NO.	**YES**	**NO**
1) Has your doctor ever said that you have a heart condition ☐ **OR** high blood pressure ☐?	☐	☐
2) Do you feel pain in your chest at rest, during your daily activities of living, **OR** when you do physical activity?	☐	☐
3) Do you lose balance because of dizziness **OR** have you lost consciousness in the last 12 months? Please answer **NO** if your dizziness was associated with over-breathing (including during vigorous exercise).	☐	☐
4) Have you ever been diagnosed with another chronic medical condition (other than heart disease or high blood pressure)? **PLEASE LIST CONDITION(S) HERE:** ______	☐	☐
5) Are you currently taking prescribed medications for a chronic medical condition? **PLEASE LIST CONDITION(S) AND MEDICATIONS HERE:** ______	☐	☐
6) Do you currently have (or have had within the past 12 months) a bone, joint, or soft tissue (muscle, ligament, or tendon) problem that could be made worse by becoming more physically active? Please answer **NO** if you had a problem in the past, but it **does not limit your current ability** to be physically active. **PLEASE LIST CONDITION(S) HERE:** ______	☐	☐
7) Has your doctor ever said that you should only do medically supervised physical activity?	☐	☐

If you answered NO to all of the questions above, you are cleared for physical activity.
Please sign the PARTICIPANT DECLARATION. You do not need to complete Pages 2 and 3.

- Start becoming much more physically active – start slowly and build up gradually.
- Follow Global Physical Activity Guidelines for your age (https://www.who.int/publications/i/item/9789240015128).
- You may take part in a health and fitness appraisal.
- If you are over the age of 45 yr and NOT accustomed to regular vigorous to maximal effort exercise, consult a qualified exercise professional before engaging in this intensity of exercise.
- If you have any further questions, contact a qualified exercise professional.

PARTICIPANT DECLARATION

If you are less than the legal age required for consent or require the assent of a care provider, your parent, guardian or care provider must also sign this form.

I, the undersigned, have read, understood to my full satisfaction and completed this questionnaire. I acknowledge that this physical activity clearance is valid for a maximum of 12 months from the date it is completed and becomes invalid if my condition changes. I also acknowledge that the community/fitness center may retain a copy of this form for its records. In these instances, it will maintain the confidentiality of the same, complying with applicable law.

NAME ______________________ DATE ______________

SIGNATURE ______________________ WITNESS ______________

SIGNATURE OF PARENT/GUARDIAN/CARE PROVIDER ______________________

If you answered YES to one or more of the questions above, COMPLETE PAGES 2 AND 3.

Delay becoming more active if:

- You are currently experiencing a temporary illness, such as a cold or fever. It is best to wait until you feel better.
- You are pregnant. In this case, talk with your health care practitioner, physician, qualified exercise professional, and/or complete the ePARmed-X+ at www.eparmedx.com before becoming more physically active.
- Your health changes. Answer the questions on Pages 2 and 3 of this document and/or talk to your health care practitioner, physician, or qualified exercise professional before proceeding with any physical activity program.

Appendix C - Background and Demographic Information

Participant Number: __________

Participant Information:

DOB: _________________________ M/F: _________________________

Please answer the following questions as accurately as possible:

1. What is your current academic classification?

2. Current number of years of sport of golf play.

3. How many years of strength training do you have?

Researcher will collect these values:

Weight (lbs.)__________ Height (cm)__________

Appendicular Limbs:

Right Upper Limb (cm): __________ Left Upper Limb (cm): __________

Right Lower Limb (cm): __________ Left Lower Limb (cm): __________

Clubhead Information

Club size: __________ Clubhead Shaft length (cm): __________

Clubhead Shaft Weight (kg): __________ Brand: ______________________________