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The Effects of Vertically-Oriented Resistance Training on Golf Swing Performance Variables

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ABSTRACT

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The purpose of this study was to examine the effects of vertically-oriented resistance training on golf driving performance. Ten Division-I collegiate golfers completed 2 resistance training sessions per week for 10 weeks during the fall tournament season. Pre- and posttraining assessments of strength-power and golf performance were compared. To assess strength-power, jump height, peak force, and peak power (PP) were measured from static and countermovement (CMJ) vertical jumps; peak force and rate of force development from 0-250 ms were measured from an isometric mid-thigh pull. Golf performance was assessed in terms of ball launch speed (BS), spin rate, carry yardage (CY), and total yardage (TY), averaged from 5 shots using a driver. Following training, all measures of strength-power improved, with CMJ PP improving significantly ($p<0.00625$). The golf performance assessment indicated significant increases ($p<0.0125$) in BS, CY, and TY. These results suggest that vertically-oriented resistance training can improve golf driving performance.

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CHAPTER 1

INTRODUCTION

Golf has become very popular, with participation estimations ranging from 35 to 55 million (Farrally et al., 2003; Geisler, 2001). An abundance of public courses, easily accessible equipment, time spent outside, and the fun of a good challenge are just a few of the reasons why so many enjoy the game. The purpose of golf is to hit a small ball into a series of 18 holes using several different kinds of clubs. The level of precision inherent to this task demands a tremendous amount of skill and practice. Those displaying superior proficiency in golf skill may have the opportunity to play the game competitively at the club, high school, or college level. Success at these levels can even result in an opportunity to play professionally. At these levels of competition school reputations, scholarships, and millions in purse money can be on the line. For this reason it is not surprising that a great deal of inquiry has gone into understanding and improving golf performance.

Research from a variety of subfields in science have vastly expanded our understanding of the central component of the game of golf: the swing. Much of the knowledge gained on the golf swing has come from the field of biomechanics. The contributions of golf biomechanics in maximizing golf swing performance and driving distance are summarized in a comprehensive review by Hume, Keogh, and Reid (2005). These authors define golf biomechanics as the application of the principles and technique of mechanics to the structure and function of the golfer in an effort to improve golf technique and performance (Hume et al., 2005). As a better understanding of the kinematics and kinetics of golf shots has developed, practitioners have been able to improve golf performance by improving several of the physical characteristics associated with golf performance, such as flexibility and strength.

Watanabe, Kuroki, Hokari, and Nishizawa (1998) analyzed the swings of 22 amateur golfers and reported that better players with lower scores produced greater club head velocity, higher ball launch angles, less variation in ball velocity, and faster body-twist angular velocity (Watanabe et al., 1998). Club head velocity seems to be a particularly effective tool for differentiating golfers of varying abilities. Fradkin, Sherman, and Finch (2004) reported a high negative correlation (r = -0.95) between club head speed and a golf handicap (Fradkin et al., 2004). Accordingly, the improvement of club head speed and, consequently, driving distance has become a common endeavor in golf training studies. Improvements have been successfully achieved through various flexibility (Jones, 1999), strength (Landford, 1976), and combined training programs (Alvarez, Sedano, Cuadrado, & Redondo, 2012; Doan, Newton, Kwon, & Kraemer, 2006; Fletcher & Hartwell, 2004). Torres-Ronda, Sanchez-Medina, and Gonzalez-Badillo (2011) provide an overview of the research conducted on muscle strength and golf performance. In this critical review these authors identify a variety of limitations in the current literature. Among these are lack of control groups, inappropriate performance assessments, and failure to account for differences in age and skill level (Torres-Ronda et al., 2011). Furthermore, most research involves recreational golfers, which do not adequately represent golfers at more elite levels. These limitations leave practitioners dealing with golfers at the college and professional level with very little direct evidence that can be used to determine best-practice. Thus, more research is needed using more elite populations. The purpose of this study is to examine the influence of a 10-week, vertically oriented resistance training program on golf driving performance variables in Division-I male golfers.

Definitions

1. Golf Handicap: A scoring index used and regulated by the United States Golf Association to evaluate golf skill ability. The system uses a formula to approximate how many strokes above or below par a player might be able to play on any given USGA course.
2. Ground Reaction Force (GRF): The force exerted by the ground on the body in contact with it.
3. Isometric Force-Time Curve: The tracing that results from plotting a series of instantaneous readings from a force plate over time. Several variables can then be calculated from this tracing using algebra and calculus.
4. Isometric Peak Force: The highest ground reactions force measured by a force plate during an isometric exercise, calculated from the force-time curve and generally measured in Newtons (N).
5. Kinematics: The branch of biomechanics focusing on movements.
6. Kinetics: The branch of biomechanics focusing on the forces underlying movement.
7. Rate of Force Development (RFD): The rate of rise of contractile force during muscle contraction. This is calculated from any segment on a force-time curve and is expressed in Newtons per second (Aagaard et al., 2002).
8. Specificity: The degree of association, including bioenergetics, kinetics, and kinematics, between a training exercise and a physical performance (Stone et al., 2007, p. 171).
9. Stretch-Shortening Cycle: a muscle action sequence in which an eccentric muscle action is followed immediately by a concentric contraction (Komi, 2000).
10. X-Factor: The differential between hip and shoulder turn at the top of the backswing in golf, typically measured in degrees.

Purpose

The purpose of this study is to examine the influence of a 10-week, vertically oriented resistance training program on golf performance variables in male Division-I golfers.

Assumptions

1. All of the equipment used in our study provided accurate and reliable results
2. A maximum effort was given in all strength-power and golf assessments
3. The golfers at East Tennessee State University (ETSU) represent other low-handicap golfers at the college and professional level.

Delimitations

Volunteers for this study had to be members of the men's varsity golf team at ETSU. These golfers all had golf handicaps ≤ 3. Subjects also had to participate in the Sports Performance Enhancement Consortium (SPEC) program at the Center of Excellence for Sport Science and Coach Education (CESSCE) at ETSU.

Limitations

1. No control group was used in this study
2. No assessments in flexibility were conducted before or after training

CHAPTER 2

REVIEW OF THE LITERATURE

The popularity of the sport of golf and performance-related interests reached the scientific community decades ago. Such interest, combined with advances in technology, have resulted in a large body of research related to the sport. A large portion of this research has aimed to expand the capacity to better understand and improve the golf swing.

Phases of the Golf Swing

A number of classification schemes have been used to describe the phases of the golf swing. Hume and colleagues (2005) subdivide the swing into four phases: the set-up, backswing, downswing, and follow-through. The following description of the phases of the golf swing follow this model. As with most sports, there is much debate between coaches with regard to the finer points of optimal swing mechanics. The following descriptions of each phase will remain as general as possible while recognizing that a range of possibly conflicting opinions are held on several of the topics discussed.

Set-Up

The set-up is the starting position of the golf swing. Geisler (2001) suggests this position should accurately align the golfer with the target, establish dynamic and static balance, exhibit sound “golf posture,” and provide an effective grip on the club. Grips are categorized by the direction and extent of hand rotation on the club. To achieve a strong grip, a right-handed player would rotate the hands clockwise from neutral. This grip increases potential club head speed by allowing for greater wrist cocking and release on the downswing phase, but it also complicates swing timing and increases the risk of an off-line shot. A weak grip maximizes club-face control by minimizing hand movement but not without sacrificing potential club head speed (Geisler, 2001). At the 1994 World Scientific Congress of Golf, Barrentine, Fleisig, and Johnson reported that to maximize both power and control, 50%-60% of the golfer's weight should be on the back foot, and knee flexion should be between 20-25°. The trunk should be flexed to approximately 45° at the hips. The golfer should laterally flex the spine to achieve a shoulder tilt of approximately 16°. Because the right hand is lower on the club, there will be slight depression and downward rotation of the right arm and scapula. Once this position is achieved, the player can initiate the swing with the backswing.

The Backswing

According to Hume and colleagues (2005) the purpose of the backswing is to position and align the golfer's hub center and club head so that the golfer can execute an accurate and powerful downswing, to provide a base link for the downswing's kinetic chain, and to stretch the muscles and joint structures that are responsible for generating power. Cochran and Stobbs (1968) found that elite golfers accomplish all this in less than a second (0.82 seconds) for drive shots.

To initiate the backswing the golfer begins to pull the club head away from the ball along an imaginary line perpendicular to the toes while retaining the triangle formed by the arms and chest for the first 40-60cm (Cochran & Stobbs, 1968; Wiren, 1990). The shoulders and hips continue to rotate while the arms move upward. As the hands reach hip height, the right elbow flexes as the arm abducts and outwardly rotates. The left arm adducts and inwardly rotates, but remains straight. At the top of the backswing, an average shoulder rotation between 78-102° and hip rotation between 47-55° have been reported, with better golfers exhibiting greater flexibility (Adlington, 1996; Burden, Grimshaw, & Wallace, 1998; McTeigue & Anderson, 1996). The left leg now bears approximately 40% of the bodyweight and is passively externally rotated because of the right pelvic rotation (Barrentine et al., 1994). The backswing of most players is characterized by rotation around a fixed point; however, it is believed that a lateral weight shift can contribute to higher club head speeds by taking advantage of the larger muscle groups in the hips and legs. The extent of the lateral weight shift that should occur during this phase is highly controversial (Ball, Best, Dowlan, & Brown, 2002). According to Milburn (1982), the hips and torso produce only about 10% of the total linear velocity in the downswing in skilled golfers. For this reason, many coaches argue that the risk of diminished swing control due to the center of mass moving outside the base of support would discourage the use of this technique. However, when Burden (1998) studied the swings of sub-10 handicap players, it seemed that the speed of the swing benefited by the center of mass shifting exclusively in the intended direction of ball flight. Research providing insight into the optimal extent of lateral weight-shift remains equivocal. Consequently, a variety of opinions are held by coaches on this topic.

The Downswing

The downswing returns the club head to the ball in the desired plane while maximizing velocity on impact. This is the fast, powerful portion of the swing, and only takes elite golfers about 0.23 seconds to complete on a drive shot (Chochran & Stobbs, 1968). Jobe, Moynes, and Antonelli (1986) further divide the downswing into two subphases: the “forward swing phase,” which initiates the downward motion of the club, and the “acceleration phase,” which accelerates the club downward. Chochran and Stobbs (1968) described a model swing as having a fixed axis of rotation (near the sternum) with a two-lever, one-hinge moment arm to impart force on the ball. In a right-handed golfer the upper lever is formed by the left arm; the lower lever consists of the club shaft; and the wrist joint serves as the hinge. Okuda, Armstrong, Tsunezumi, and

Yoshiike (2002) have stated that the downswing sequence is initiated by the eccentric action of the trunk muscles. Electromyographic (EMG) analysis by Bechler, Jobe, Pink, Perry, and Ruwe (1995) has shown that the right hip extensors and abductors and the left adductor magmus initiate left pelvic rotation to begin the forward swing, which actually begins before the arms have completed the backswing. The left subscapularis and latissimus dorsi are very active early in the forward swing with the pectoralis major becoming more active in the acceleration phase (Jobe et al., 1986). In the right arm these authors found that the right subscapularis, pectoralis major, and latissimus dorsi are all very active throughout the forward and acceleration phases. EMG analysis of the trunk muscles by Pink, Perry, and Jobe (1993) indicated that the erector spinae and abdominal oblique muscles on the right side of the body maintain body posture early in the downswing, with both muscle groups becoming very active in the acceleration phase. An efficient and power downswing requires more than the aforementioned muscle groups producing large magnitudes of force. To achieve maximum club-head speed, golfers must conserve angular momentum by allowing torque generators to commence in sequential order from proximal to distal (Milburn, 1982; Sprigings & Neal, 2000). This principle is described as the summation of sequential forces. If kinetic energy is conserved, as force is produced and travels up the kinetic chain from the legs and hips, followed by the trunk and shoulders, and finally the hands and wrists, the angular velocity of each segment should be greater than the previous segment. Geisler (2001) confirmed this principle by recording the angular velocities for professional golfers for the hip (498°/sec), shoulder (723°/sec), arm (1,165°/sec), and club head (2,090°/sec). Of particular importance is the cocking and release of the wrists. Evidence suggests that professional players exhibit a greater degree of wrist cocking in later phases of the swing than amateurs. In a correlation study of swing characteristics and club-head velocity, Robinson (1994) used linear regression analysis and found that of 15 kinematic and kinetic swing variables assessed, the degree of wrist-cocking was the strongest determinant of club-head velocity, accounting for 60.3% of the variance between golfers of varying ability. Finally, it is worth noting that during and immediately following impact, considerable vertical compression forces (up to 80% body weight) and large rotatory torques (23 Nm) are sustained by the front leg (Barrentine et al., 1994).

The Follow-Through

The follow-through uses eccentric muscle actions to decelerate the body and club head (Pink et al., 1993). The hands continue along the swing path. Once they reach shoulder height, both elbows flex to decelerate the speed of the arms, while the trunk maintains postural stability. The golfer should finish in a balance position with the trunk facing the target and the hands behind the left ear (Hume et al., 2005).

Determinants of Swing Performance

Overall golf performance is dependent on the development of a myriad of technical and tactical abilities to minimize the number of strokes the golfer must take to complete a round. Most relevant to this investigation, this section is focused on aspects of driving performance. Golf performance literature has consistently supported that more skilled golfers with lower scores produce higher club head velocities and consequently longer driving distance than less successful players (Watanabe et al., 1998; Wells, Elmi, & Thomas, 2009). Fradkin et al. (2004) reported a high negative correlation (r = -0.95) between club head velocity and golf handicap, suggesting that club head velocity can be a useful tool for measuring golf performance in laboratory and field settings

The displacement of a drive shot is a direct function of the linear velocity of the club-head (Wallace, Otto, & Nevill, 2007). We know that architecture and intrinsic properties of the muscle form the basis for all human movement. Given that a golfer possesses the technical biomotor abilities necessary to accurately return the club-head back to the ball, the distance of a drive shot is then determined by the capacity to powerfully contract the muscles involved in the swing. The role of muscular strength and power is well established in the scientific literature in both cross sectional (Thompson, 2002; Wells et al., 2009; Wiren, 1968) and prospective studies (Alvarez et al., 2012; Landford, 1976; Reyes, 2002).

Although the golf swing is often thought of as a rotational movement dominated by the upper body, a portion of the force imparted on the ball is provided by the lower body and is more vertical in nature. Several studies highlight the importance of producing considerable GRF if club head velocity is to be maximized (Barrentine et al., 1994; Gatt, Pavol, Parker, & Grabiner, 1999; Koenig, Tamres, & Mann 1994). In the review by Hume and colleagues (2005), these authors identify that magnitudes of GRF recorded in studies examining shots using a driver or 5-iron are comparable to those encountered while running at a velocity of approximately 4 m/sec.

A capacity for the rapid production of large magnitudes of force is important but only provides the raw potential for long drive shots. In order to take full advantage of this ability, the golfer must also be able to precisely coordinate and time the production of these forces throughout the kinetic chain during the swing. This concept was previously discussed as the summation of sequential forces. Cheetham, Martin, Mottram, and Laurent (2000) identified three components to optimizing the kinematic sequence of the swing: 1) all segments should accelerate and decelerate before impact (except for the club, which should peak at ball impact); 2) the order in which the segments reach peak velocity should be the pelvis, torso, arm, then club; and 3) the peak velocity of each segment should exceed the previous segment.

In the modern golf swing the backswing involves the rapid lengthening of the muscles of the lower, mid-section, and upper body, followed immediately by the forceful contraction of these muscles in the downswing. This type of muscle action, in which the concentric portion of contraction is enhanced from immediately following an eccentric action, is described as the stretch-shortening cycle (SSC). While the mechanisms of the SSC remain controversial, possibly factors include the reutilization of stored elastic energy, a myototic reflex, muscle-tendon interactions allowing for a more optimal length, and optimization of the muscle activation pattern (p. 58, Stone, Stone, & Sands, 2007). Regardless of the mechanism, professional players seem to better use the SSC than their amateur counterparts. Studies have shown that professional players generally use longer backswings and complete the backswing in less time, resulting in greater backswing velocity and a more vigorous stretch as they transition into the downswing (Cochran & Stobbs, 1968; McTeigue et al., 1994).

One final aspect of the backswing-downswing transition that warrants discussion is the X-factor stretch. McLean (1992) was the first to suggest that the differential between hip and shoulder rotation at the top of the backswing was actually more important for driving performance than the degree of shoulder turn alone. Later, Cheetham and colleagues (2000) would further support McLean's proposal. They examined the X-factor stretch between 10 professional and 9 amateur golfers. Although they found that the X-factor stretch at the top of the backswing was 11% greater in the professional group, this percentage did not reach statistical significance. They did find that in the early stages of the downswing, the X-factor stretch was significantly greater (19%) in the professional golfers. In sum, research suggests that while the

X-factor at the top of the backswing may contribute to greater driving distance, the magnitude of X-factor stretch seen in the early phase of the downswing may be of even greater importance in maximizing driving distance.

In sum, research suggests that maximizing driving distance involves the production of considerable magnitudes of GRF, the summation of sequential forces, optimizing the contribution of the SSC, and maximizing the X-factor early in the downswing.

Training Studies from Golf Performance Literature

The majority of the previously discussed studies indicate associations between golf performance and various physical characteristics through correlations or regression analysis. These relationships are helpful in understanding golf performance, but we know that correlation does not indicate causation. For this reason studies examining golf performance before and after various training modalities are necessary to draw better conclusions. A considerable volume of research has been conducted for this purpose. Sato, Kenny, and Dale (2013) recently provided a review paper on current golf performance literature and its application to training. Several physical characteristics vital to the improvement of golf performance are identified, including flexibility, stability, and strength-power. While research on balance and stability is limited, studies designed to improve flexibility and strength-power have been prevalent for decades.

Research conducted as early as 1976 has suggested a positive influence on golf driving performance following a resistance training (RT) program (Lanford, 1976). Studies isolating RT in the intervention have been rare. Following 7 weeks of RT-only, Reyes (2002) reported an increase in mean strength but found no correlation between subjects' improvements in strength and driving distance. Given that the training protocol used in the study consisted of isometric strength training, the likelihood of the strength gains transferring to sport performance were rather low based on the concept of specificity.

The golf community has been known to emphasize the importance of flexibility over strength. It is, of course, important to be mindful of flexibility, as it plays a crucial role in golf performance. Increases in club head velocity up to 7.2% have been observed after 8 weeks of flexibility-only training using proprioceptive neuromuscular facilitation (Jones, 1999). Albeit, no control group was used and the subjects represented an older population (58 ± 9 years). Nonetheless, many players and coaches are cautious toward strength training for fear of compromising flexibility. Though such ideologies are contrary to the weight of scientific evidence on RT, reservations still persist. To address these concerns and ensure that range of motion (ROM) is maintained, almost all training studies to date have included some type of flexibility to supplement the strength training. From a research standpoint, this makes it more difficult to directly attribute performance improvements to strength gains. A common way researchers have addressed this issue has been to include data on changes in strength and changes in driving performance. With very few exceptions (Pinter, 1992; Reyes, 2002), when improvements in strength have been observed, improvements in club head speed (1.62%-6.3%) have always followed regardless of the type of RT (Doan et al., 2006; Hetu, Christie, & Faigenbaum, 1998; Lennon, 1999; Thompson & Osness, 2004; Westcott, Dolan, & Cavicchi, 1996). Similarly, 4%-5% increases in driving distance have been reported (Fletcher & Hartwell, 2004; Lephard et al., 2007). These studies employed a variety of training modalities including isometric RT, free weights, machines, medicine ball exercises, plyometrics, elastic tubing, balance, and flexibility routines. Due to the diversity in research design, training modality, and subject profiles, results from each study are not necessary quantitatively comparable to other studies. Even so, it does seem that RT has an overwhelmingly positive impact on golf driving performance.

Methodological Issues in Training Studies

When taken collectively the available research makes a strong overall case for the importance of physical training in maximizing performance. However, analysis of studies at the individual level for the purpose of comparing findings to other studies or determining best-practice for training is problematic due to various methodological issues. Torres-Ronda and colleagues (2011) identify many of these issues in a critical review on golf performance literature. One common limitation is lack of a control group. Among published training studies only four used a randomized control group (Fletcher & Hartwell, 2004; Lennon, 1999; Thompson, 2007; Thompson & Osness 2004). Without a control group it is difficult to conclude that improvements in performance are directly attributable to the training intervention. Even when statistically significant improvements are observed, naturally occurring changes, learning effect on assessments, or biological maturation (in the case of young populations), could all contribute to improvements.

Another theme is that, with very few exceptions (Lanford, 1976; Reyes, 2002), RT is never isolated as the independent variable. All other studies employ a RT program alongside concurrent flexibility, plyometric, balance, or endurance training. Evidence supports the importance of all of these physical characteristics, but for the purpose of research a mixed methods approach makes it difficult to delineate the effects of individual aspects of the training program. Practitioners wanting to determine the relative contribution of the RT in a mixed-methods design can only make assumptions based on the degree of strength improvements relative to the observed improvements in performance. This is difficult for two reasons. First, some studies do not report changes in strength (Fletcher & Hartwell, 2004; Pinter, 1992; Seiler, Skaanes, Kirkesola, & Katch, 2006). Second, changes in strength between studies are not necessarily comparable because there is very little consistency between strength assessments between studies. Analyses of strength changes may be isometric, isokinetic, isointernal, or rotational. Similar variation is observed in instrumentation and may include dynamomentry, isokinetic machines, force platforms, 3D electromagnetic motion analysis system, or digital video cameras. Taken collectively, the diversity may reinforce the importance of the role strength and power play in golf performance, but it also makes comparing results of these studies to one another nearly impossible.

Another source of limitation from current research is participant characteristics. Resulting confounders can generally be divided into two categories: age and skill. The age range for highly competitive golfers is approximately 18-35 years, yet participants in this age range are rarely recruited. Many studies have recruited younger participants (Doan et al., 2006; Lennon, 1999; Seiler et al., 2006), while others opted for seniors-only (Hetu et al., 1998; Thompson, 2002; Thompson et al., 2007; Thompson & Osness, 2004; Westcott et al., 1996). Still, others used participants exhibiting age ranges of 38 (Landford, 1976) to 52 years (Reyes, 2002). The physiological differences between a teenager and a senior can profoundly impact external validity, especially for coaches making decisions pertaining to college or professional golfers.

The other area of concern with regard to participant characteristics is skill. In golf skill is generally described in terms of golf handicap. Because groups of highly skilled golfers are hard to find and even harder to assemble, most studies have used low-skilled subjects (Fletcher & Hartwell, 2004; Lephart, Smoliga, Myers, Sell, & Tsai, 2007; Wiren, 1998) or groups of varying skill levels. Some authors have not reported any measure of skill at all (Hetu et al., 1998;

Thompson, 2002; Thompson et al., 2007; Wells et al., 2009; Westcott et al., 1996). Excluding unpublished masters theses, only one training study to date has been published using golfers with an average handicap ≤ 5 (Alvarez et al., 2012). This is problematic because estimated gains in recreational athletes may not apply to more elite golfers because evidence suggests that achieving measurable performance adaptations in highly skilled athletes can require more intense training (Hopkins, Hawley, & Burke, 1999). This phenomenon has been previously observed in golf training literature. For instance, Hetu and colleagues (1998) reported a 6.3% increase in CHS following an 8-week RT, plyometric, and flexibility program. Using more advanced golfers with an average handicap of 5.5 ± 3.7, Fletcher and Hartwell (2004) only observed an increase of 1.5% in CHS, even though a similar 8-week RT, plyometric, and flexibility program was implemented. This further reinforces the need for more research using highly skilled populations.

Assessments of Strength and Power in Sport Science

As previously discussed, the importance of physical characteristics like muscular strength and power for superior golf performance is well-established in the scientific literature. This creates a need for accurate and reliable means of measuring the strength and power capabilities of golfers. Such information is crucial in guiding decisions for golf coaches, sport scientists, and strength and conditioning professionals as they design and implement training programs for golfers at the national and international levels of competition.

Assessments of Strength

Strength describes muscles' ability to produce force. A number of ways to measure this force have been established. The most widely accepted and used assessment of maximum strength in both research and strength and conditioning settings is the one-repetition maximum (1RM) test (Baechle, Earle, & NSCA, 2000). Common exercises tested using this assessment are the back squat, bench press, deadlift, and power clean. There is an abundance of research to support its use as an assessment of strength changes throughout a training program (Kraemer et al., 2003; Stone, Potteiger, & Pierce, 2000; Willougby, 1993). Despite overwhelming popularity, there are a number of concerns that should be considered when choosing the appropriate strength assessment for a situation. 1RM tests have a high metabolic cost, induce substantial fatigue, carry a risk of injury due to very heavy loads, and require a high level of skill to safely and accurately assess the strength of an athlete.

Isometric Force Production and Strength Testing. A common approach to assessing maximal strength, while avoiding some of the disadvantages of 1RM testing, is isometric strength testing—an approach that has been used in exercise science for over half a century (Wilson & Murphy, 1996). High levels of reliability have been established in both single-joint (Haffajee, Moritz, & Svantesson, 1972) and multi-joint conditions (Haff et al., 1997). However, it should be noted that reliability for peak force have been greater than RFD (Wilson & Murphy, 1996). Although limited by the extent of task-specificity, external validity for isometric strength testing has been established as well. Kawamori and colleagues (2006) had eight male collegiate weightlifters perform a series of isometric (IMPT) and dynamic mid-thigh pulls (MTP) while standing on a force plate. Significant relationships were found between the IMTP and dynamic MTP. This relationship seems to carry over into weightlifting performance. Haff and colleagues (2005) showed that peak force and RFD from IMTP testing produce strong to moderate correlations with competition snatch, clean and jerk, and competition total for elite weightlifters. This is not surprising due to the similarity of these movements, but further research has found similar relationships for more general measures of force production, including testing under dynamic conditions. Kraska and colleagues (2009) sought to establish the association between isometric and dynamic measures of force production. They compared values from static (SJ) and countermovement (CMJ) jumps to IMTP testing in 63 collegiate athletes and found moderate to strong positive correlations between isometric force characteristics and jump height. Even with evidence suggesting a strong relationship between static and dynamic characteristics of force production, there is still a need for dynamic strength-power testing.

Assessments of Power

Where isometric measures of force production are designed primarily to assess maximum force production, dynamic assessments are better suited to assess power. Power is one of the most important force characteristics in all of sports. Stone and colleagues (2007) describe power as a work rate and propose the following derived equations: Power = Work / Time = Force × Velocity (p. 171). Work rate and RFD are critical to performance because the movements of many sports place restrictions on the time the athlete has to produce force. For instance, as previously discussed, the downswing on a drive shot of an elite golfer takes only 0.23 seconds. This means that even for golfers with high levels of maximal force production the only force production relevant to golf performance is what can be produced in two-tenths of a second. This is where power and RFD becomes paramount.

Most power testing that occurs in athletic and research settings involves some form of jump assessment. Several vertical jump testing protocols do not require special equipment, and data have shown that good validity and reliability can be achieved without familiarization trials (Moir, Button, Glaister, & Stone, 2004). This gives coaches an extremely cost-effective option for assessing basic measures of power. In cases where more detailed performance data are desired, more sophisticated methods may be necessary.

Newton and Kraemer cite two mechanical properties of muscle that are crucially important in determining explosive muscular power; 1) the ability to create significant force in a short time interval (RFD) and, 2) the ability of the muscle to continually produce high forces as the muscle's shortening velocity increases (Newton & Kraemer, 1994). Jump height alone can be a good indicator of basic muscular power capabilities, but it is insufficient in evaluating an athlete's ability to display characteristics like those mentioned above. When more detailed insight into complex mechanical properties of muscle is desired, it is common practice to conduct vertical jump testing on force plates. Instantaneous force throughout a jump can then be plotted over time to form a force-time curve. This allows the practitioner to calculate several variables like peak force (PF), peak power (PP), peak velocity (PV), and RFD at various phases of the jump. In many sports, particularly at elite levels, the margins determining competition performance are very slim. When milliseconds or centimeters can determine whether or not an athlete makes the podium, having data like this can provide an edge in making training decisions.

The relationship between jump performance and other measures of isometric and dynamic strength is well established in the literature. Stone and colleagues (2003) demonstrated that jump performance is highly correlated with 1RM squat values. Nuzzo, McBride, Cormie, and McCaulley (2008) expanded on this research by investigating relationships between the CMJ performance and isometric and dynamic measurements of strength. In this study 10 NCAA Division I-AA male athletes completed CMJ testing, isometric strength tests (MTP and squat), and dynamic strength tests (squat and power clean). Results indicated significant ($p=\leq 0.05$) positive correlations between dynamic strength (squat and power clean) and CMJ height, relative PP, and PV. Additionally, a significant positive correlation was found between the IMTP and CMJ height when isometric data were scaled for body weight (Nuzzo et al., 2008). In collegiate settings where adequate instrumentation and staffing are available, a test battery using these types of assessments may offer more detailed information and avoid the disadvantages of 1RM testing.

Application to Golf

Many of the aforementioned tests have been used in golf performance research as well as strength and conditioning settings for collegiate golf teams. A review on muscle strength and golf performance by Torres-Ronda and colleagues (2011) indicated a broad spectrum of strength assessments in determining changes in strength across studies included in the review. While the validity of several of these assessments was only assumed, others had backing from the literature. Thompson (2002) had 31 older, recreational golfers complete a 10RM test for several exercises and found a significant relationship between club head speed and chest press, leg press, shoulder press, lat pulldown, seated row, and biceps curl. Hellstrom (2009) found that results from vertical jump testing were highly correlated with club head speed ($r = 0.60$). Leary and colleagues (2012) investigated the relationship between isometric force-time curve characteristics and club head speed in 12 recreational level golfers. Subjects completed testing that included SJ, CMJ, and IMTP tests as well as measurements of average and maximal club head velocities from a series of 10 drive shots. Golf handicap was moderately correlated with average maximal club head speed. From the IMPT assessment both force at 150 milliseconds and RFD from 0 to 150 milliseconds were moderately correlated with average and maximal club head speed. Finally, a moderate correlation between average club head speed and peak RFD from SJ assessment approached significance (Leary et al., 2012).

CHAPTER 3

THE EFFECTS OF VERTICALLY-ORIENTED RESISTANCE TRAINING ON GOLF PERFORMANCE VARIABLES

Original Investigation

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Abstract

The purpose of this study was to examine the effects of vertically-oriented resistance training on golf driving performance. Ten Division-I collegiate golfers completed two resistance training sessions per week for ten weeks during the fall tournament season. Pre- and post-training assessments of strength-power and golf performance were compared. To assess strength-power, jump height, peak force, and peak power (PP) were measured from static and countermovement (CMJ) vertical jumps; peak force and rate of force development from 0-250 ms were measured from an isometric mid-thigh pull. Golf performance was assessed in terms of ball launch speed (BS), spin rate, carry yardage (CY), and total yardage (TY), averaged from five shots using a driver. Following training, all measures of strength-power improved, with CMJ PP improving significantly (p<0.00625). The golf performance assessment indicated significant increases (p<0.0125) in BS, CY, and TY. These results suggest that vertically-oriented resistance training can improve golf driving performance.

Introduction

Golf is widely practiced both as a sport and as a popular recreational activity, with the most conservative estimations of worldwide participation around 35 million (Geisler, 2001). Such popularity, in addition to substantial incentives for competitive performance at the collegiate and professional level have led to considerable scientific inquiry to better understand and improve golf performance. Historically, the majority of investigation has focused on the analysis and improvement of swing mechanics. In the last two decades, more research has become available and has contributed to a greater understanding and awareness of the role physical characteristics such as strength, flexibility, and balance play in optimizing swing mechanics and golf performance.

There is now ample evidence indicating that one of the major facets of golf performance that can be influenced by these physical characteristics is driving distance. Cross sectional research has consistently supported that more skilled golfers with lower scores produce higher club head velocities and consequently longer driving distance than less successful players (Watanabe et al., 1998; Wells et al., 2009). Fradkin et al. (2004) reported a high correlation (r = 0.95) between club head velocity and golf handicap, suggesting that club head velocity can be a useful tool for measuring golf performance in laboratory and field settings. Longitudinal studies have further supported these findings by showing that improvements in flexibility (Jones, 1999), muscular strength (Thompson & Osness, 2004), and power (Doan et al., 2006) can improve driving performance. This knowledge has made it commonplace for golfers at the collegiate and professional level to maintain some type of strength training regimen. Research efforts have now shifted toward optimizing the effectiveness of resistance training programs. In a recent critical review of muscle strength and golf performance, Torres-Ronda et al. (2011) found that many studies present methodological errors in their design; lack direct assessment of changes in strength, fail to account for differences in age and skill, and rarely involve elite level golfers. These limitations in the available literature make it difficult for coaches to take an evidence-based approach when determining best-practice in training programs for highly skilled golfers. Consequently, decisions regarding training must often rely more heavily on general training principles established in sport science.

A central focus of any sport-specific training program should be to maximize the transfer-of-training effect, or the extent to which training adaptations improve sport performance (Stone at al., 2007). As “sport-specificity” has gained more attention in the field of strength and conditioning, some have inadvertently placed undue restraints on the concept. One such restraint is a bias toward or overemphasis on *mechanical* specificity. This results in judging the utility of an exercise solely based on the extent to which the exercise replicates the movements of the sport. In golf, such an approach would involve mimicking the golf swing while using bands or cables as resistance. This practice has been moderately effective with untrained recreational golfers (Lephart et al., 2007), but there is no scientific evidence suggesting that this approach would improve the performance of competitive golfers that have already achieved a higher skill level and training base.

A more effective approach would be to allow knowledge of the kinematics and kinetics of the golf swing established in biomechanics research to guide decisions in exercise selection and training. Hume et al. (2005) provide a comprehensive review on the role of biomechanics in maximizing driving distance. These authors present a deterministic model of the golf swing showing biomechanical factors related to the distance of a drive shot. While many of these factors, such as gravity and air-resistance, are beyond the control of the golfer, others can be modified through physical training. These include; 1) the utilization of the stretch-shortening cycle (SSC), 2) the use of sequential summation of forces principle, and 3) the production of relatively high ground reaction forces (GRF) (McTeague et al., 1994; Neal, Lumsden, Holland, & Mason, 2007; Vaughan, 1982). If the goal is to optimize specificity and achieve the greatest transfer-of-training effect, a resistance training program designed to augment the aforementioned force characteristics would seem to be the most appropriate, evidence-based approach to improving golf driving performance. The purpose of this investigation is to examine the influence of a 10-week, vertically-oriented resistance training program on golf driving performance in NCAA Division-I golfers.

Methods

Participants

Members of the East Tennessee State University (ETSU) men's golf team were asked to participate in this study. Researchers met with student-athletes and coaches at the beginning of the fall semester to explain experimental procedures and possible risks. Ten golfers agreed to participate and signed an informed consent document. Physical examination by the university's sports medicine staff verified participants' health status and ensured golfers were free of injury that could compromise their safety or performance for any of the testing procedures. Anthropometric data for participants can be found in Table 3.1 on the next page. All golfers participating in this study had handicaps under 3. This study was approved by the East Tennessee State University Institutional Review Board. Informed consent documents can be found in Appendix A.

Table 3.1

Participant Characteristics

Age Range (years)	18 - 22
Height (cm)*	183.50 ± 5.35
Body Mass (kg)*	71.38 ± 6.85
Body Fat (%)*	10.63 ± 6.17

*values expressed as mean ± SD

Laboratory Testing Procedures

Anthropometric Testing. Height was measured to the nearest 0.5 cm using an electronic stadiometer (Cardinal Scale, Model DHRWM, Webb City, MO) with the participants' feet together, toes slightly out, and a neutral head position. Body mass was determined to the nearest 0.1 kg using a calibrated and certified digital scale (Tanita BF-350, Arlington Heights, IL). Body composition was determined via skin folds measured at 7 sites in a private room to the nearest 0.5 mm using Lange medical grade skin fold calipers (Beta Technology, Inc., Cambridge, MD). These measurements were then placed into the Siri equation to estimate body fat percentage.

Warm Up. Before vertical jump and mid-thigh pull tests were conducted, participants were led through a standardized warm-up protocol specifically designed for the testing battery. This protocol consisted of 25 jumping-jacks, a single set of 5 dynamic pulls from the mid-thigh position with a 20 kg Olympic bar, then 3 sets of 5 repetitions of the same exercise with a load of 60 kg. One minute of rest was given between all exercises and sets.

Vertical Jump Testing. Following completion of the warm-up, participants performed a series of static jump (SJ) and countermovement jump (CMJ) assessments on a 91.4 x 91.4 cm force plate (RoughDeck HP, Rice Lake Weighing Systems, Rice Lake, WI). All jumps were performed holding a polyvinyl chloride bar on the shoulders to eliminate the contribution of arm swing. Warm-up trials at 50% and 75% of perceived maximum effort were performed prior to the first recorded SJ and CMJ to ensure adequate physical preparation and to allow for familiarization. For SJ testing, participants descended into a squat position until a 90° knee angle was reached. This angle was verified using a handheld goniometer. Once the proper position was assumed, a "3-2-1-jump" command was given. A key feature of the SJ is the elimination of the SSC in an effort to more accurately reflect concentric strength and power. Consequently, if a countermovement or "dip" was observed by the laboratory technician during a SJ, the jump was not counted and the test was repeated until two jumps were performed from a static starting position. For CMJ testing, participants began from a standing position and were asked to jump as high as possible using a self-selected depth. Once a participant indicated that he was ready, a "3-2-1 jump" command was given. Jump testing was complete when data had been collected from two properly-executed SJ and CMJ tests.

Isometric Mid-Thigh Pull (IMTP) Testing. For isometric strength testing, participants were placed in a custom built power rack positioned over a similar force plate. The design of the rack utilizes a series of locking pins and hydraulic jacks to allow the bar to be positioned with precision at any height. Bar height was adjusted to achieve the "peak power position," similar to the position of the second pull in weightlifting movements. This position is characterized by straight arms, a vertical trunk, a neutral spine, and a knee angle between 120-130°, which was also verified using a handheld goniometer. A photographic representation of the set-up for an IMTP test is given in Figure 3.1 on the next page.

Figure 3.1. Photographic representation of an isometric mid-thigh pull

Once this position was achieved, the participants' hands were secured to the bar using weightlifting straps and athletic tape to eliminate the possibility of grip strength being a limiting factor for GRF produced. Participants then performed a warm-up pull at 50% and 75% of perceived maximum effort. Prior to recorded attempts, instructions were given to pull as fast and as hard as possible to encourage maximal rate of force development (RFD) and peak force (PF) (Bemben, Clasey, & Massey, 1990). Verbal encouragement was also provided to help ensure a true maximal effort was given (McNair, Depledge, Brettkelly, & Stanley, 1996). At least 3 minutes of recovery were given between recorded pulls. If the PF from the two pulls differed by >250 N, an additional pull was performed. PF was then recorded from the average of the two best trials. All data collected from the two trials were saved as force-time curves to be analyzed for RFD. All force plate data was collected using custom LabView software (Version 10.0, National Instruments Co., Austin, TX) at a sampling rate of 1,000 Hz and low pass filtered with a Butterworth filter and a cutoff frequency of 100 Hz.

Golf Performance Testing

Golf driving performance data were measured and recorded at the ETSU golf facility using a TrackMan™ radar system (TrackMan II, TrackMan USA, Brighton, MI). This device uses radar and internal software to measure, calculate, and display several variables of golf driving performance. Before collecting data from maximal-effort drives, participants were instructed to follow the warm-up routine they are accustomed to performing when preparing for practice or playing a round of golf. This routine involves a dynamic warm-up followed by a series of golf shots, beginning with smaller irons and progressively working up to the driver. The TrackMan™ radar system then collected and displayed data from a series of five maximal effort drive shots performed by each participant. Variables recorded for the purposes of this study included: 1) ball speed (BS), 2) launch spin rate (SR), 3) carry yardage (CY), and 4) total yardage (TY). These measures comprised the golf performance variables.

Training

Participants followed a vertically-oriented resistance training program under the supervision of qualified strength and conditioning coaches. This was an evidence-based, periodized program specifically designed to improve physical characteristics identified in the scientific literature as important for improving golf performance (Sato et al., 2013). Table 3.2, below, presents the specific programming, along with a brief description of the training phase and goal. It should be noted that intensity was prescribed as "set-rep best," which is not equivalent to 1-repetition maximum (1RM) percentages. Set-rep best percentages represent the approximate percentage of the weight an athlete feels he or she is capable of completing for the assigned number of repetitions. For instance, if an athlete feels confident in completing 5 repetitions on back squat with a load of 100 kg, then an intensity of 70% for 3 sets of 5 repetitions would be completed with a load of approximately 70 kg.

Table 3.2

Training Programming

	Sets x Reps	Intensity*	Phase	Targeted Adaptation
Week 1 - 4	3 x 5	65-70%	Strength	Development of basic strength
Week 5 - 7	3 x 8	75-80%	Overreaching	Increased work capacity from exposure to higher volume-loads
Week 8	3 x 5	65%	Deload	Maximize recovery-adaptation from overreaching phase
Week 9	3 x 3	85-90%	Strength-Power	Translation of strength adaptions into power
Week 10	3 x 2	85-90%	Power	Optimization of power output

*Intensity is based on percentage of "set-rep best"

Table 3.3

Training Exercises

	Week 1 - 4, 8	**Week 5 - 7**	**Week 9-10**
Push Day	Overhead Squat Back Squat DB Bench Press DB Shoulder Press	Overhead Squat Back Squat Bench Press Push Press Step-ups	Overhead Squat Back Squat Bench Press Push Press Step-ups*
Pull Day	Mid-thigh Pull Clean Pull from Knee Supine DB Pullover 1-Arm DB Row	Mid-thigh Pull Clean Pull from Below Knee Supine DB Pullover Bent-over Bar Row DB Reverse Fly	Mid-thigh Pull Clean Pull from Knee Supine DB Pullover Bent-over Bar Row**

*Week 9 only
**1-Arm DB Row was re-introduced in place of this exercise for week 10
DB = dumbbell

Table 3.3, above, presents the primary exercises performed throughout the resistance training program. Participants completed two training sessions per week for 10 weeks for a total of 20 training sessions during the fall golf season. Exercises were organized into “push” and “pull” days. In addition to the primary exercises prescribed, 5 to 10 short sprints (10-20m) were performed on push days during some weeks as part of the golfers’ conditioning program. This program also involved various mid-section or “core” exercises performed on pull days at various phases of the training program. Once the 10-week training period was complete, participants repeated all testing procedures to allow pre- and post-training values to be compared.

Data Analysis

Force-time data from jump and IMTP assessments were considered laboratory testing variables. From SJ and CMJ testing data, the following were analyzed and recorded: jump height (JH), peak force (PF), and peak power (PP). Variables from the IMTP data included PF and RFD from 0-250 milliseconds. Values analyzed from the TrackMan™ radar system, including BS, SR, CY, and TY were considered golf performance variables. All data were reported as mean accompanied by standard deviation.

Statistical Analysis

A Paired-samples T-test was used to determine if significant differences in selected variables existed between pre- and post-test values from laboratory testing data. The same data analysis was used to determine if significant differences were present between pre- and post-test values from golf performance data. The alpha level for statistical significance was set at $p \leq 0.05$, but adjusted to a lower value using a Bonferroni Correction since more than one dependent variable was present. In an effort to estimate effect magnitude for pre- and post-training comparisons, Cohen’s *d* effect sizes were included. Effect size estimates were interpreted with the scale created by Cohen (1988), where 0.2-0.49 is small, 0.5-0.79 is moderate, and 0.8 and above is large. All statistical analyses were performed using SPSS Predictive Analytics SoftWare (SPSS Version 22: An IBM company, New York, NY).

Results

Laboratory Performance Assessment

Table 3.4, below, provides a summary of results from the laboratory performance assessments. An increase in the mean values from the pre-training assessment was observed across all variables. After the Bonferroni adjustment was applied, paired sample t-test results indicated that only the increase in CMJPP was found to be statistically significant ($t(1,9)=-2.50$, $p=0.0015$, $d=0.91$).

Table 3.4

Laboratory Performance Assessment

	Pre	Post	% change	*p* value	effect size
	Mean ± SD	Mean ± SD			
CMJ Height (cm)	30.95 ± 5.14	32.70 ± 4.35	5.7	0.0338	0.37
CMJ Peak Force (N)	1549.45 ± 155.80	1654.42 ± 187.69	6.8	0.0174	0.61
CMJ Peak Power (W)	3976.83 ± 434.62	4384.73 ± 458.65	10.3	0.0015*	0.91
SJ Height (cm)	25.92 ± 3.58	26.79 ± 3.59	3.4	0.0146	0.24
SJ Peak Force (N)	1496.63 ± 143.37	1688.93 ± 165.83	12.8	0.0092	1.24
SJ Peak Power (W)	3435.78 ± 614.07	3954.72 ± 570.99	15.1	0.1602	0.88
IMTP Peak Force (N)	3384.38 ± 487.22	3568.66 ± 365.74	5.4	0.5004	0.43
IMTP RFD 0-250ms (N/s)	4231.01 ± 1236.03	5249.38 ± 1774.83	24.1	0.2112	0.68

* indicates significant differences between pre- and post-training results at $\alpha \leq 0.00625$

Golf Performance Assessment

Table 3.5, below, provides a summary of results from the golf performance assessment. Increases in the mean values from pre-training were observed in BS (+1.9%), CY (+2.1%), and TY (+1.4%), while a decrease in SR (-2.0%) was observed. The Bonferroni adjusted paired t-test results indicated statistically significant increases in BS (t(1,9)=-4.53, p=0.001, d=0.66), CY (t(1,9)=-4.09, p=0.003, d=0.57), and TY (t(1,9)=-3.26, p=0.010, d=0.31).

Table 3.5

Golf Performance Assessment

	Pre	Post	% change	*p* value	effect size
	Mean ± SD	Mean ± SD			
Ball Speed (mph)	150.80 ± 4.89	153.70 ± 3.90	1.9	0.001†	0.66
Spin Rate (rpm)	2019.00 ± 186.30	1977.70 ± 190.76	-2.0	0.461	-0.22
Carry Yardage	250.90 ± 10.46	256.10 ± 7.67	2.1	0.003†	0.57
Total Yardage	285.30 ± 13.03	289.20 ± 11.96	1.4	0.010†	0.31

† indicates significant differences between pre- and post-training results at $\alpha \leq 0.0125$

Discussion

As previously discussed, driving performance is a distinguishing characteristic of superior golf performance (Watanabe et al., 1998). Research has collectively shown that maximizing driving distance involves the production of relatively high GRF, the utilization of the SSC, and the summation of sequential forces (Hume et al., 2005). Strength training is a common means by which practitioners seek to augment these physical characteristics, but little research has been conducted on the effectiveness of such training involving golfers at the national or international levels of competition. The aim of the present study was to examine the influence of 10 weeks of vertically-oriented resistance training on golf driving performance in collegiate male golfers.

Laboratory performance data from this study indicate that the training protocol used can elicit considerable improvements in strength and power after only 10 weeks of training. Although none of the variables from the SJ testing reached statistical significance, increases were observed in all three, and a large effect size was observed for PF (d=1.23) and PP (d=0.88). Effect size is an important consideration because it is often used as a measure of "practical significance." Improvements in SJ performance are relevant to golf performance because recent research has shown that SJ performance is one of the greatest predictors of club head speed (Read et al., 2013). The increases in PP and PF suggest that positive adaptations in the concentric strength of the muscle were made. These increases are likely attributable to improvements in factors related to neuromuscular function since volume-loads prescribed were not high enough to stimulate structural changes in muscle architecture. Such adaptations may include increased motor unit (MU) recruitment (particularly high-threshold MU's), rate coding, synchronization, intra- or intermuscular activation patterns, enhanced inhibition of agonist muscle activity, utilization of the SSC, or any combination of these and other factors.

Increases were observed across all three variables from the CMJ. In addition to statistical significance, the 10.3% increase in PP had a large effect size (d=0.91). The 6.8% increase observed in PF had a moderate effect size (d=0.61). These increases in force production resulted in a 5.7% increase in jump height. The increase observed in PF and PP in the CMJ were both less than that of SJ results. This discrepancy further supports the notion that improvements in SJ performance are attributable to increased contractile capacity of the muscle. Compared to SJ performance, the countermovement in a CMJ adds the elastic component to performance and the proportion of performance attributed to contractile capacity is decreased. Thus, positive adaptations in concentric strength may not have as large of an effect on CMJ performance as it did in the SJ. It is unclear why improvements in jump height were greater in the CMJ than SJ. We speculate that improvements in the utilization of the SSC could play a role, but we are hesitant to draw any conclusions because neither variable exhibited statistically significant changes, and effect sizes for both were small.

In the analysis of force-time curves, PF represents the largest magnitude of force recorded under the conditions of the measurement. Since strength is defined as the ability to produce force, PF is highly representative of maximum strength. Power itself is a work rate. PP is likewise an instantaneous measurement, but in addition to the magnitude of force production, it also accounts for velocity. All of these variables correlate with one another, but PF is most highly representative of maximum strength, whereas PP is more representative of explosive strength since it takes RFD into account. Under this framework, isometric force-time data support that adaptations to the training program may have been more substantial in terms of muscular power than maximum strength because the increase in RFD was almost five-fold greater than PF. The 24.1% increase in RFD from 4241.01 ± 1236.03 to 5249 ± 1774.83 N/s in the IMTP assessment was the largest percentage increase observed among all variables. Statistical significance was lacking due to a relatively large standard deviation, but a moderate effect size was observed (d=0.68). Due to the nature of the golf swing, an increase is RFD is much more relevant to golf driving performance than PF. The average downswing for elite golfers only takes about 0.23 seconds (Chochran & Stobbs, 1968). An increase in PF may still be valuable to coaches in monitoring the effectiveness of a training program, but actual golf performance enhancement will likely be limited to the extent of improvement in force production within the first 230 milliseconds. The importance of RFD is also evident in the effectiveness of studies that sought to improve explosive strength by supplementing strength training with plyometrics. Such research has reported increases in club head speeds ranging from 1.5% (Fletcher & Hartwell, 2004) all the way up to 6.3% in one study (Hetu et al., 1998).

The observation that explosive strength and power may have increased more than maximum strength in the present study is further supported by data from dynamic assessments. In both SJ and CMJ tests, percentage increases in PP exceeded increases in PF. Although the coherence of dynamic and isometric data seem to support this observation, it should be reiterated that CMJPP was the only variable to reach statistical significance, so this may be speculation.

What can be concluded is that the observed improvements in muscular strength and power seemed to carry over into golf performance as three of the four golf performance variables increased. All three of the observed increases were statistically significant, with moderate effect sizes for BS (d=0.66) and CY (d=0.57). The only golf performance that did not increase was SR. However, the 2.0% decrease observed had a very large p value (p=0.46) and a small effect size (d=-0.22), so minimal consideration was given to SR in the interpretation of these results.

The translation of improved strength and power to golf performance is not surprising since the relationship between these characteristics and driving performance is so well-established in the scientific literature. A less obvious factor to the observed transfer of training could be the concurrent strength and technical training. In other sports in which the technical movement depends on the precisely coordinated action of different muscles, some authors have emphasized the importance of combining strength training with technical training to maximize the transfer of gains (Manolopoulos et al., 2004; Sedano et al., 2009). Based on this research, the fact that the participants maintained their regular golf practice and collegiate competition schedule could have played a role in the successful transfer of physical adaptations to golf performance.

Successful transfer of training was also expected since the positive influence of resistance training on golf performance has been well established in recreational populations (Doan et al., 2006; Hetu et al., 1998; Lephart et al., 2007; Thompson et al., 2007). However, estimated gains in recreational athletes do not always apply to more elite level golfers because evidence suggests that achieving measurable performance adaptations in highly skilled athletes can require more intense training (Hopkins et al., 1999). To the knowledge of the authors of the present study, this is only the third research report on the positive influence of strength training on driving performance in highly trained players. The first of these studies reported a 1.5% increase in club head speed after 8 weeks of combined resistance and plyometric training (Fletcher & Hartwell, 2004). This improvement was slightly less than the present study, and it is suspected that the shorter duration of the training program could account for this slight discrepancy.

The second and most recent study reported substantially larger increases in jumping and golf performance (Alvarez et al., 2012). After 12 weeks of maximal and explosive strength training, these authors reported increases of 6.8%, 9.9%, and 8.5% in BS, SJ height, and CMJ height, respectively. A major difference between their study and the present study is that the present study used NCAA Division-I golfers as subjects, and this research took place during the fall golf tournament season. Over the course of the semester, participants were scheduled to compete in up to six collegiate or international competitions. In an effort to manage fatigue and ensure optimal golf performance for these tournaments, the volume-loads and intensities prescribed were much less than the previous study. The primary reason for conducting this research “in-season” is to simulate a typical annual schedule of nationally-competitive golfers.

The “off-season” period for most college and professional golfers is often very brief and rarely exceeds one month in length. Accordingly, most of the resistance training performed by golfers at the collegiate and professional levels must occur in-season. Therefore, these researchers considered it in the best interest of maximizing external validity to conduct this study in-season while the participants were playing in tournaments. The discrepancy in these results suggest that during periods where fatigue is not a major concern, as in a true “off-season” phase, golfers may benefit more from training at higher volume and intensities.

Regarding the concept of specificity, these results indicate that training adaptations can carry over to sport performance when training methods are geared toward improving force production characteristics associated with sport performance. Exercises need not mimic the exact mechanics of the sport. Some authors have suggested that more specific strength training programs might have an even greater impact of driving performance (Westcott et al., 1996), but no research to date has supported this recommendation, especially when dealing with advanced golfers. After 12 weeks of maximum and explosive strength training, Alvarez et al. (2012) included a 6-week period of exclusively “golf-specific” training using resistance bands, but no significant increases in strength or golf performance were observed during this phase.

It should be noted that the present study did not incorporate any assessments of flexibility before or after the RT program. This limitation was largely due to time constraints the NCAA places on student-athletes and lack of standardized golf-specific flexibility protocols. Nonetheless, the authors recognize that the importance of flexibility in golf performance is very well established in the scientific literature in both descriptive and training studies (Hume et al., 2005). Thus, research similar to the present study focusing on the flexibility component of performance in highly-skilled golfers would be beneficial for practitioners attempting to delineate the effects of improved strength-power and flexibility. Similarly, more research conducted with advanced populations is needed to make valid comparisons of training modalities in order to optimize physical training for elite populations.

Conclusion

Research has consistently demonstrated the effectiveness of physical conditioning programs in improving golf performance, yet few studies have attempted to maximize the transfer-of-training effect by catering the training program to improving characteristics identified in the scientific literature to be directly associated with golf performance (Lephart et al., 2007). Two such characteristics are the production of relatively high GRF and the utilization of the stretch-shortening cycle (Hume et al., 2005). The purpose of this study was to examine the effectiveness of a 10-week, vertically-oriented resistance training program on golf performance variables in Division-I male golfers. The findings of this study indicated improvements (3.4-24.1%) across several measures of strength and power under isometric and dynamic conditions. The enhancement of these physical characteristics likely contributed to better golf driving performance, observed as significant improvements (p=0.010-0.001) in ball launch speed (1.9% greater), carry yardage (2.1% greater), and total yardage (1.4% greater). These findings suggest that improving golfers' ability to generate GRF through vertically-oriented resistance training can augment golf performance by increasing driving distance. Further research may seek to evaluate the effectiveness of a similar program in conjunction with flexibility training. Such information could be valuable to strength and conditioning professionals in designing holistic physical conditioning programs for elite level golfers.

Practical Applications

A comprehensive training plan to improve golf performance and reduce the risk of injury for competitive golfers should be multi-faceted and address the development of flexibility, balance and stability, and strength-power. The primary focus of this investigation was the strength-power component. Data from this study show that 10 weeks of a vertically-oriented resistance training can significantly improve golf driving performance. This information may be useful to golf coaches and strength and conditioning professionals when making decisions pertaining to the physical development of golfers, particularly at higher levels of competitive play.

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CHAPTER 4

CONCLUSION

Research has consistently demonstrated the effectiveness of physical conditioning programs for improving golf performance, yet there have been few attempts to maximize the transfer-of-training effect by catering the training program to improving characteristics identified in the scientific literature to be directly associated with golf performance (Lephart et al., 2007). Two such characteristics are the production of relatively high ground reaction forces (GRF) and the use of the stretch-shortening cycle (Hume et al., 2005). The purpose of this study was to examine the effectiveness of a 10-week, vertically-oriented resistance training program on golf performance variables in Division-I male golfers. The findings of this study indicate improvements in golfers' strength and power observed as higher magnitudes of GRF produced (3.4%-24.1% greater). The observed increase in these physical characteristic likely contributed to improvements in golf driving performance, observed as significant improvements (p=0.010-0.001) in ball launch speed (1.9% greater), carry yardage (2.1% greater), and total yardage (1.4% greater). These findings suggest that vertically-oriented resistance training can be an effective training modality for improving golf driving performance even for nationally competitive golfers.

As the emphasis on the concept of sport specificity continues to increase in the sport industry, coaches and practitioners should be mindful that specificity is not always as obvious as it may seem. Caution should be used against overemphasizing mechanical specificity. Doing so may result in narrowed exercise selection criteria based solely on the extent to which an exercise mimics the movements of the sport. While the replication of the golf swing with the addition of resistance bands has shown to be moderately effective in recreational level golfers (Lephart et al., 2007), these authors caution that such a program may not provide an adequate stimulus to improve performance in more advanced golfers. This study supports that allowing information from golf biomechanics on the kinetics and kinematics of the golf swing to form the basis for exercise selection can be an effective approach in maximizing the transfer-of-training effect in more advanced golfers. Further research may be designed to evaluate the effectiveness of a similar program in conjunction with an extensive flexibility training program. Such information could be valuable to golf coaches and strength and conditioning professionals in designing holistic physical conditioning programs for golfers at higher levels of competitive play.

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APPENDIX

Informed Consent Documents

Principal Investigator: Austin Driggers

Title of Project: The effects of vertically-oriented resistance training on golf swing performance variables

SUBJECT CONSENT FORM FOR PARTICIPATION OF HUMAN SUBJECTS IN RESEARCH

Project Title: **The effects of vertically-oriented resistance training on golf swing performance variables**
Primary Investigator: Austin Driggers, BS, Exercise & Sport Sciences, driggersa@goldmail.etsu.edu
Co-Investigator: Kimitake Sato, PhD, Exercise & Sport Sciences, satok1@etsu.edu

Phone: 325-669-6360

Introduction: This informed consent will explain about being a participant of this research project. Please read this consent carefully and decide if you wish to participate.

Purpose: The purposes of this study are:
a. To determine the effectiveness of the training programs performed by the men's golf team
b. To identify possible relationships between body composition, data from jump and mid-thigh pull tests, and golf driving performance measures like club head speed, ball speed, spin rate, and launch angle.

Duration: This study involves analysis of information from you training and monitoring information for the period from August 2013 to December 2013

Procedures: This study only involves analysis of your data from the monitoring and training programs. This study does not involve any physical procedures. Data to be used from laboratory testing includes age, height, weight, body composition, results from jump testing, and results from the mid-thigh pull test. Golf performance data will include your handicap and numbers recorded from the TrackMan system (club head speed, ball speed, spin, approach angle, and launch angle). Data from your training log will also be used to confirm that you completed 90% of the training program.

Participation rights and alternative procedures: Allowing your information to be analyzed as part of this research project is voluntary. You may decide not to participate in this study. Should you begin participation, you may still decide to stop and withdraw at any time. Your decision will be respected and will not result in loss of benefits to which you are otherwise entitled. Your choice about this research will not affect your participation on the golf team, and will not affect your participation in the monitoring and training programs.

Possible risks/discomforts: Since this study only involves analysis of data, there is a risk of loss of confidentiality of your identifiable data. In order to minimize the risk of displaying identity, your name will be replaced with an assigned number in our computer records. Only the principle and co-investigators will know the name connected with each number when the data are reported. At no point will your name be used for research. For the research purposes of this study, data will always appear based on averages, not individual reports.

Possible benefits: This study seeks to gather as much knowledge as possible from the athlete monitoring program you participate in. More specifically, so see which laboratory tests are most important for golf performance. This knowledge will be passed onto your coaching staff and could lead to better training programs in the future to help maximize individual and team golf performance.

Financial costs and compensation to participants: There are NO financial costs to you, and NO compensation for your participation.

Voluntary participation: Participation in this research is voluntary. You may refuse to continue participation at any time. Should you choose not to participate or choose to withdraw from the study; the benefits to which you are entitled will not be affected. You may withdraw by contacting primary or co-investigators. (phone number listed below)

Contact for questions: If you have any questions, problems or research-related problems at any time, you may call Austin Driggers at 325-669-6360, or Dr. Kimi Sato at 423-439-5138. You may also call the Chairman of the Institutional Review Board at 423-439-6054 for any questions you may have about your rights as a research subject. If you have any questions or concerns about the research and want to talk to someone independent of the research team, or you can't reach the study staff, you may call an IRB Coordinator at 423-439-6055 or 423-439-6002.

APPROVED
By the ETSU IRB
MAR 17 2014
By ___ Chair/IRB Coordinator

DOCUMENT VERSION EXPIRES
MAR 16 2015
ETSU IRB

01/21/13 Page 1 Subject Initials ______

Principal Investigator: Austin Driggers

Title of Project: The effects of vertically-oriented resistance training on golf swing performance variables

Confidentiality: We will take every precaution to protect your identity. We will assign a subject number to you and not use your name in our computer records. Only the principle and co-investigators will know the name connected with a subject number. Any reports involving your data will not use your name. For research purposes, data will be averaged and no individual reports will be made. A copy of the records from this study will be stored in a locked cabinet the sport science laboratory E113, Mini-dome for at least 10 years following this research project. The results of this study may be published and/or presented at meetings and will exclude individual data. Although your rights and privacy will be maintained, the Secretary of the Department of Health and Human Services, the ETSU IRB, and personnel particular to this research have access to the study records. Your records will be kept completely confidential according to current legal requirements and will not be revealed unless required by law, or as noted above.

Having read the above and having had an opportunity to ask any questions, please sign below if you would like to participate in this research.

____
Participant's Signature Date

____
Participant's name (please print)

____
Primary Investigator's Signature Date

APPROVED
By the ETSU IRB
MAR 17 2014
By JO
Chair/IRB Coordinator

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VITA

AUSTIN RYAN DRIGGERS

Education:	M.A. Kinesiology and Sport Studies, East Tennessee State University, Johnson City, Tennessee, 2014
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Professional Experience:	Strength and Conditioning Coach, Kansas City Royals, Springdale, Arkansas, 2013-Present
	Ski/Snowboard Instructor, Angel Fire Ski and Snowboard School, Angel Fire, New Mexico, 2013-2014
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	East Tennessee State University Out of State Tuition Scholarship (2012-2013)
	Wheaton College Dean’s List (Fall 2010, 2011, Spring 2012)
	Ozarka $10,000 Science Scholarship Award (2008)