INNOVATIVE STRATEGIES TO IMPROVE POSTURE IN GOLF

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Declaration

I, the undersigned, hereby declare that the work contained in this thesis is my own original work and has not previously, in its entirety or partially, been submitted at any university for the purpose of obtaining a degree.

Signature Date

Abstract

Posture is generally defined as the position of the limbs and the body as a whole, whether in static or dynamic situations. Although there may be postures that are common to a variety of sports, posture is considered to be sport-specific. Optimal posture in golf provides a good base from which a golfer can apply maximum effort to the golf ball with the least amount of energy. Optimal posture is also regarded as a factor that can reduce the incidence of injury. A recognition of the importance of posture in golf led to the general question that initiated this study: If posture improves, will golf performance improve?

The purpose of this study was to determine the effectiveness of a golf-specific postural training programme, on selected postural variables and on 5-iron hitting distance, accuracy and ball flight. Eighteen novice female golfers were randomly assigned to either a control (n=9) or an intervention group (n=9). Video analysis was used to assess the postural variables of static balance and postural consistency, while the one-minute lying lift, one-minute walkout and overhead medicine ball throw were used to assess the postural variables related to core stability. The Modified Benson Golf Test was used to assess the golf skill of the participants, as measured by 5-iron distance, accuracy and ball flight. The experimental group was placed on a six-week programme consisting of two, sixty-minute sessions a week. Using a repeated measures ANOVA (Analysis of Variance), significant improvements in core stability and 5-iron distance and accuracy were achieved ($p<0.05$). Although Improvements in static balance and postural consistency were also found, they were not significant. It was concluded that core stability training can improve the power dimension of the 5-iron shot of novice golfers, a postural training programme has potential for helping novice golfers improve their golf performance.

Opsomming

Postuur, in dinamiese sowel as statiese situasies, word gedefinieer as die posisie van die lemematе en die liggaam as 'n geheel. Postuur word beskou as sportspesifiek, alhoewel daar 'n algemene postuur vir sommige verskillende sportsoorte is. Optimale postuur in gholf verskaf aan 'n gholfspeler die geleentheid om die gholfbal met maksimum krag en minimum energie te slaan. Optimale postuur kan ook 'n bydrae lewer tot die voorkoming van beserings. Die belangrikheid van postuur in gholf was die motivering vir hierdie studie en het gelei to die algemene vraag: Indien postuur verbeter, sal prestasie in gholf verbeter?

Die doel van die studie was om die effektiwiteit van 'n gholfspesifieke postuurprogram op 'n aantal postuurveranderlikes, 5-yster afstand, akkuraatheid en vlug van die bal te bepaal. Agtien beginner gholfspeelsters is ewekansig na of 'n kontrole groep (n=9) of 'n eksperimentele groep (n=9) toegeken. Video-analise is gebruik om die postuurveranderlikes naamlik balans en konstantheid van postuur te onleed. Om rompstabiliteit ("core stability") te meet is die "one-minute lying leg lift", "one-minute walkout" en "overhead medicine ball throw" toetse gebruik. Die "Modified Benson Golf Test" is gebruik om afstand, akkuraatheid en vlug van die bal te meet. Die eksperimentele groep het 'n ses-weke program gevolg. Die program het bestaan uit twee, sestig-minute sessies 'n week. Statisties betekenisvolle verbeteringe ($p<0.05$) in rompstabiliteit ("core stability") en 5-yster afstand-akkuraatheid is gevind met die herhaaldelike metings ANOVA (Analise van Variansie). Alhoewel verbeteringe in balans en konstantheid van postuur gekry is, was die veranderinge nie statisties betekenisvol nie. Die gevolgtrekking is dat rompstabiliteitsoefeninge 'n positiewe effek op krag ten opsigte van die 5-yster hou het en dat 'n oefenprogram gefokus op postuur die potensiaal het om die prestasie van beginner gholfspeelsters te verbeter.

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Chapter One

Setting the Problem

Farrally, Cohran, Crews, Hurdzan, Price, Snow and Thomas (2003) completed a review of the development of golf. They determined that at the beginning of the 21st Century, there were 30 000-golf courses and 55 million people playing golf worldwide. The value of golf club memberships sold in the 1990s in the USA alone, was US$3.2 billion. In part because of this sustained development of golf as an international industry, there have been increasing numbers of people conducting research and applying science to golf in order to develop the game. Since 1990, the World Scientific Congress of Golf has reported 311 papers at four world congresses. Scientific papers have also been published in discipline-specific peer-reviewed journals, while the two governing bodies of golf (Royal and Ancient Golf Club of St. Andrews and the United States Golf Association) has sponsored research, and, of course, equipment manufacturers have supported research on product design and production.

Research about Golf

Farrally et al. (2003) associated the significant increase in prize money in the late 1980's, which encouraged greater professionalism among players, with the willingness of players to turn to sports scientists, especially golf psychologists, to improve their performance. They noted that research about equipment and the human factors that affect golf, have been areas of focus.

Equipment (Clubs and Balls)

When comparing golf clubs and balls to those of 20 and more years ago, titanium drivers have replaced wooden woods, graphite and steel shafts in irons and woods are the norm and most irons have cavity backs. Farrally et al. (2003) found that the improvements in performance have been so significant that there are those that feel that the technology is making the game too easy. They are in favour of stricter rules on equipment in order to limit the effect of technology.

Farrally et al. (2003) stated that they found that the area where technology has had the most significant effect on performance in the last few years, has been the development of the large-headed titanium driver. With a large head and titanium as the material, golfers have been able to increase the length of their drives by an average of nine meters. Another significant benefit of these large-headed drivers is the reduced loss of distance when hitting a shot off-centre.

In terms of golf ball technology, manufacturers are constantly trying to develop a ball that will give maximum distance when hitting with the driver, and maximum spin when hitting with irons (Farrally et al., 2003).

Human Factors and Golf Performance

Farrally et al. (2003) found that 27 different factors related to the golfer were identified at the Futures of Golf Congress in 2001 (see Table 1). The conclusions from this conference indicated there is still much research to be done with regards to human factors of golf. The areas that have attracted recent attention include motor learning, biomechanics, vision in golf, exercise and nutrition, prevention and treatment of injuries and sport psychology.

Motor Learning and Control

Knight (2004) defined expert performance as a level of proficiency that is acquired through many years of focused training, during which the cognitive ability to control and monitor performance is refined. Although years of intense practice are needed to achieve the level of expert performer, practice alone is not sufficient. For example, Zaickowsky and Morris (2001) studied the effect of family influences on male professional golfers when they were learning the game. They found that differences in golfers' early experiences in terms of family support were important determinants to the development of excellence in golf, in addition to opportunities for practice and competition.

According to Schempp, McCullik, Pierre, Woorons, You and Clark (2004), practice sessions must be structured to promote retention and transfer of motor skills to the performance environment. They recommended variability

Table 1

Areas of study associated with the human factors that affect golf performance (Farrally et al., 2003)

Golfers	Golf game	Related fields
Professional issues	Swing biomechanics	Alternative therapies
Minority golf	Short game	Sport psychology
Golf and the brain	Club-fitting	Personality and golf
The junior golfer	Putting	Science and philosophy
Vision and golf		Motor learning
Coaching		Measurement in golf
Performing under stress/the yips		Performance enhancement practice
Aging and conditioning		Golf injuries/rehabilitation
Adherence		Exercise and nutrition
Women in golf		Statistics
Instruction		
Great golfers		

of practice with controlled contextual interference and intermittent feedback provided by a coach. Selective use of blocked practice was recommended as a means to accelerate learning. They also supported instructional strategies that would encourage the players to be cognitively involved in the learning process, which they predicted would results in improved independence/self-management when performing on the golf course.

Farrally et al. (2003) reviewed studies that explored the role of observational learning (modelling) in learning golf. They found evidence that self-models were the most effective models for improving performance. In golf, this would mean that watching recordings of one's own swing should have a greater potential to improve performance than viewing the recording of an expert's swing.

Swing and Club Analysis

Although the classic mechanical analysis of the ideal swing was completed by Cochran and Stobbs (1996), individual golfers may have a collection of unique characteristics that makes it difficult to perform the ideal swing. Video analysis of the golf swing is a growing tool used by professional golf instructors and computer simulations of the golf swing and recording of data from instrumented clubs are used to attempt to produce a perfect "fit" between a golfer and his/her clubs (Farally et al., 2003).

Vision in Golf

Perkins-Ceccato, Passmore and Lee (2003) investigated the effects of verbal and video feedback in learning a basic golf stroke. The results indicated that the video and video plus verbal groups outperformed the verbal group on post-test accuracy distance.

Vickers (2001) studied vision in golf from a motor control perspective and has developed the concept of the "quiet eye" to improve performance in golf putting. The "quiet eye" refers to the control of gaze maintained by expert golfers immediately before and during the putting stroke.

Another visual skill that influences golf performance is the ability to read greens (Pelz, 1994) as well as the ability to align the putter correctly (Potts & Roach, 2001). Proper alignment of the clubs for all of the shots is an area that has received little research attention.

Flexibility and Mobility

Despite the interest in improving strength and flexibility to increase the distance of drives, the physical demands of golf are not completely understood in terms of their interdependence. For example, there is a lack of literature on the relationship between flexibility and performance. One of the few studies found indicated that highly skilled golfers rotate their shoulders in relation to their hips more than less skilled golfers do during the downswing (Cheetam, Martin, Morttram & Laurent, 2001). This would suggest that greater trunk mobility might benefit performance. Verstegen (2001) emphasized the importance combining core stability and individualised strength and flexibility programmes with nutrition to enhance performance. They identified an increase in power in the golf-specific muscles that are activated in the golf swing as a focus for improving performance. However, researchers are still trying to determine workable guidelines that will promote the design of physical training programmes that can address each individual player's weaknesses (Chettle & Neal, 2001).

Aerobic Fitness

In a study by Crews, Sherreffs, Thomas, Krahenbuhl and Helfrich (1986), it was found that the aerobic fitness of some female United States Tour professional players might be low enough to have a negative impact on their performance. Unfortunately, there has been no recent research to determine whether the interest in physical conditioning during the last few decades has improved this situation. Carlson, McKay, Selig and Morris (2001) suggested that in addition to supporting physical performance on the golf course, aerobic training could reduce the response to stress and have the potential to improve concentration. Two meta-analyses of studies in the sport and exercise literature support these suggestions (Etnier, Salazar, Landers, Petruzello, Han & Nowell, 1997; Crews & Landers, 1987). Even for older recreational golfers, golf has an aerobic component (Stauch, Liu, Giesler & Lehamann, 1999) and there are clear health benefits from improved aerobic fitness for older adults (Broman, 2001; Magnusson, 1999).

Physiological Stress

Physiological stress from the environment is another factor that affects golf performance. McLellan's (2001) overview of the physical and physiological factors governing heat exchange between the body and the environment and provided recommendations for optimising golf performance in hot environments. Manore (2001) investigated the importance of fluid intake to minimize the chances of dehydration, one of the physiological stressors that commonly inhibits performance in golf. He recommended ingesting carbohydrates every three hours to fuel the brain and nervous system as a way to reduce the impact of physiological stressors.

Prevention and Treatment of Injuries

Surveys have shown that injuries in golf are relatively common (Therialt & Lachance, 1998; Finch, Sherman & Jones, 1994; McNicholas, Nielsen & Knill-Jones, 1994). The most common injuries occur in the back (Sugaya, Tsuchiya, Moriya, Morgan & Banks, 1994) and the wrist (Dalgleish, Vicenzino & Neal, 2001). Correction of postural imbalances has been found to contribute to injury prevention (Draovitch, 2001). Teaching golfers about injury prevention techniques may improve adherence to exercise programmes among golfers (Freedberg, 2001).

Sport Psychology

Bandura's (1977; 1982) work on self-efficacy and its influence of psychological variables such as persistence, effort, task choice, goal setting and attrition, is often cited in research on the psychology of golf. Other topics in sport psychology with specific applications for golf have included the following:

- Anxiety (Hardy & Mullen, 2001).
- Pre-performance routines (Kingston & Hardy, 2001; Feltz & Landers, 1983).
- Mood state (Mathers & Cox, 2001).
- Personality (Graham, 2001).
- Attention (Crews & Landers. 1993).
- Imagery (Beauchamp, Bray & Albinson, 2002; Taylor & Shaw, 2002; Grove, De Prazer, Weinberg & Pitcher, 2001).

Psychological stress also has been studied in the terms of "choking" (Linder, Lutz, Crews & Lochbaum, 1998) and "the yips" (Smith, 2001). Kingston, Madill and Mullen (2002) have suggested, for example, that a holistic approach is needed when working with golfers afflicted with "the yips". Troesch (2001) even suggested that periodisation of mental training was just as important as the periodisation of physical training for golf.

Purpose of the Study

The purpose of this study was to design and implement an innovative exercise programme aimed at the postural development of novice golfers. The programme was premised on the assumption that hitting distance, accuracy and ball flight could be improved if novice golfers were given the opportunity to develop their core stability, balance and posture. The innovative dimension of this programme was that it used minimal amounts of commonly available equipment and no technology, so that if successful, the programme could be implemented within all communities in South Africa without concerns about either funding or access to electricity.

Significance of the Study

Although many golfers and golf coaches may look to cutting-edge technologies to improve performance, the instructional and fitness dimensions of golf still deserve attention from sport science researchers. This study will explore how participation in postural training exercises may contribute to real improvements in performance on the golf course. An effort was made to keep the exercises as functional as possible in order to maximise transfer to the golf swing. If novice golfers can improve their distance, accuracy and ball flight as a result of working on their core stability, balance and posture, then a low-tech, low-cost method will have been discovered that can be used by all aspiring golfers, regardless of their access to sophisticated technology. This kind of research has the potential not only to add to the body of scientific information about golf, but also to make scientifically sound training practices available to a broader population.

Research Questions

The study was designed to establish whether it is possible to show improvements in posture during the golf swing following a six-week functional posture programme. The following research questions guided this investigation:

1. Were there any changes in the postural variables of core stability as measured by leg lifts, walkouts and medicine ball throw, following a six-week intervention programme?
2. Were there any changes in static balance, as measured by posture in the address position, following a six-week intervention programme?
3. Were there any improvements in consistency of posture, as measured by the change in knee angle as well as change in body angle, following a six-week intervention programme?
4. Were there any changes in golf skill as measured by distance, accuracy and ball flight of a 5-iron shot, following a six-week intervention programme?

Methodology

This study followed a repeated measures design. As an experimental study, a random assignment of subjects to experimental and control groups was implemented. Care was taken to try to conduct pre- and post-tests under identical conditions. To make sure there were no significant differences between the pre-values of the experimental and control groups, independent t-tests were conducted on each of the dependent variables. In order to determine pre- posttest changes, a repeated measures analysis of variance (ANOVA) was run for each of the dependent variables.

The Publication Manual of the American Psychological Association (American Psychological Association, 2001) was followed as the style of reference for this thesis.

Limitations

The following limitations must be acknowledged when considering the results of the study:

1. The number of subjects used in this study was small (N = 18), which constitutes a limitation in terms of generalizations to larger populations.

2. All the subjects in the study were female and were university students. The results of this study may have been different if the subjects came from a different population.

3. A number of different variables were measured, which made it difficult to determine the contribution of each to the post-test performance of the subjects.

4. Ball flight was measured subjectively, using a simple yes-no rating. There was no control for error in assigning a score to ball flight.

5. The effectiveness of the intervention programme was affected by the level of motivation of the subjects in the experimental group. Although subjects appeared to apply themselves during practice sessions, their level of motivation was not assessed.

Summary

Research about golf has drawn increased attention over the past few decades. Although equipment manufacturers continue to search for the perfect club and ball, it is unlikely that changes in equipment alone will produce major changes in performance. The limits imposed by the rules and by the laws of physics, lead to the conclusion that the main factor contributing to longer driving distances, especially by professionals, will continue to be club head speed. In most cases, increases in club head speed will be attributed to bigger, stronger, fitter and technically-better players. According to Farrally et al. (2003), the club head speeds of elite players have increased by eight to 10% over the last 25 years. If one converts this to distance, it is an increase of nine to 13 metres on the drive off the tee.

There is an increase in interest surrounding the human factors that influence golf performance, and it is from future research on these topics that techniques are more likely to be developed that will raise performance standards. At all levels of the game, improved teaching methods and training activities are being developed. This study will attempt to develop and implement an innovative approach to the development of postural control for the golf swing, specifically for the 5-iron shot. This approach is premised on the assumption that optimal postural control is an essential part of each golfer's optimal swing. Finding the optimal swing may also be regarded as a factor in injury prevention, and may contribute to a golfer's interest and ability to stay active in the game for a number of years.

Chapter Two

Review of Literature

Golf is a rotation sport where the golfer wants to transfer the greatest possible amount of kinetic energy from the body and the club to the ball (Carlsoo, 1967). Chek (2001) stated that golfers who want to reach their potential must be able to create explosive repeated and effective rotation. This chapter will orient the reader to the physical dimensions of the golf swing by providing first a general analysis of the swing, followed by literature about posture, balance, physical fitness and examples of innovative ways of training to improve golf.

General Analysis of the Golf Swing

During rotation of the trunk, there is tremendous load on the spine as well as the spinal cord. According to Chek (2001), the stress of gravity on the spinal cord when supine is 30lb/inch, while in a standing position the stress can range from 190 to 200 lb/inch. Muscle balance is critical to the integrity of the spine during rotation. Vertebrae that are aligned to the vertical axis execute normal motion, while vertebrae whose centers of motion have deviated from the vertical axis execute abnormal motion. Rotation may cause the affected vertebrae to displace from the normal position.

Check (2001) emphasized that when the pelvis, trunk and head are aligned vertically and the spinal curvatures are optimal, minimum muscular contraction is required to keep the body from falling. If the golfer deviates from the ideal spinal alignment, there will have to be an increase in postural compensations, causing performance to decrease and increasing the risk for injury.

When looking specifically at the golf swing, there is minimal activity of the trunk muscles during the backswing and relatively high and constant activity in these muscles throughout the forward swing (Draovitch & Westcott, 1999; Watkins, Uppal, Perry, Pink & Dinsay, 1996). Horton et al. (2001) found that the abdominal muscles contribute significantly to the generation of power during the acceleration phase of the golf swing.

Draovitch and Westcott (1999) highlighted the role of rotator cuff muscles at the end ranges of motion. They described the swing in terms of the activation of internal shoulder rotators during acceleration and the anterior shoulder muscles during the swing and follow-through movements. The middle and posterior shoulder muscles on the lead arm were extremely active in stabilising the shoulder girdle throughout the swing.

Slater-Hammel (1948), in one of the earliest pieces of research on the mechanics of the golf swing, stated that only the triceps brachii of the right and left arm, right latissimus dorsi, right pectoralis major and posterior fibers of the left deltoid contributed to the acceleration of the golf club. Draovitch and Westcott (1999) found that peak muscle activity of the hip and knee during the golf swing was recorded before the peak muscle activity of the trunk and shoulders region. This justifies the importance of the sequential actions of the different components of the body for generating power.

It is clear from these research findings that a successful golf swing depends on the performance of a complex sequential action involving the feet and knees, rotation of the hips, trunk and shoulders, and movement of the arms, wrists and hands (Fletcher and Hartwell, 2004; Richards, Farrel, Kent & Kraft, 1985). The lower limbs act as stabilisers to allow torque to be applied to the club head (Fletcher & Hartwell, 2004; Watkins et al., 1996). This is the basis for Draovitch and Westcott's (1999) statement that to obtain the greatest benefit from proper sequencing of the swinging action, a golfer must have strong leg, thigh and hip muscles to generate driving power. These lower-body forces must then be transferred through well-conditioned midsection muscles to the upper body.

Posture in Golf

Posture is the position of the limbs or carriage of the body as a whole (Dirckx, 2001). Rochon (2004) defined good posture as the ability to maintain the normal spinal curves. According to Uetake, Ohtsuki, Tanaka and Shindo (1998), optimal posture in sport refers optimal musculoskeletal balance in the specific positions and during the actions of a specific sport. In other words, both static posture and dynamic posture must be considered in the performance context of a particular sport.

Static Posture in Golf

Chek (2004a) defined static posture as the position from which movement begins and the position in which it ends. It was his opinion that if a golfer has poor posture in the address position, he/she would likely maintain poor posture throughout the entire swing. Optimal posture in the set-up position will have a profound influence on the quality of the body motion and balance. Rochon (2004) identified optimal posture in the set-up position as a factor contributing to :

- Maintaining optimal spinal alignment throughout the golf swing.
- Having more efficient movement.
- Decreasing the risk of injury.
- Improving muscle recruitment.
- Producing more power at ball strike.

Norkin and Levangie (1992) recommended that a plumb line be used to assess static posture in a normal standing position:

When viewed from a sagittal (side) view:

- Slightly anterior to a midline through the knee.
- Approximately in line with the greater trochanter of the femur.
- Midway between the back and abdomen as well as the front and back of the chest.
- Through the shoulder joint.

- Through the lobe of the ear.

When viewed from anterior or posterior view:

- The body should be well-aligned, resembling three stacked inverted pyramids.

- The pelvis, shoulders and head should sit level with a straight spine.

According to Chek (2001) if scoliosis (lateral curvatures in spine) is present, the golfer should bend forward. If the scoliosis remains during this forward bending and the ribs appear elevated on one side, he remarked that this could indicate a structural scoliosis and that further evaluation by a doctor is necessary. If the spine straightens when bending forward it indicates functional scoliosis, he suggested that a full length/tension assessment should be done to provide regular stretches. He stated that it is important that this kind of misalignment in static posture must be corrected first, because the associated length/tension imbalances will disrupt dynamic posture.

Posture in the Address Position

Posture during the address position is regarded as the key to an efficient golf swing. Theriault and Lachance (1998) identified the starting posture as a critical consideration if maximum potential kinetic energy is to be generated with the club.

- Chek (2001) suggested that the ideal address posture is to address the ball as though one were sitting on a stick. The initial bend should come from the knees, which should be supple, yet at the same time maintain sufficient tension to be steady.

- Chek (2001) also stated that the shoulders should not be excessively protracted as this leads to increased thoracic kyphosis and encourages forward head posture, which will limit spinal rotation.

- Koslow (1994) described the position as one in which the weight should be more toward the heels than the balls of the feet, so that the golfer could lift his/her toes inside the shoes.

- Williams and Cavanagh (1983) specified that footwear should facilitate the role of the lower extremity in providing a solid base of support to enhance the production of force, as well as providing comfort and relief from strain.

- Lindsay and Horton (2002) observed that care should be taken to avoid flexing the spine too much at address. Too much flexion was a common characteristic found in golfers who were suffering from chronic low back pain. A plumb line dropped from the golfer's shoulder should bisect the base of support. It is important not to round the upper back when looking down at the ball and the head only needs to tip downward from the upper cervical joints.

Gender Differences in Posture

Rehling (1955) noted that many golfers have unique postures, which means coaches must be very careful assuming that there is one method of hitting the golf drive that can be called "the correct method". One source of each golfer's unique posture is the anatomical gender difference. For example, men's hip sockets are created in a more vertical position that tends to limit a natural hip turn. This means that careful attention needs to be paid to the golfer's width of stance. For men, too wide a stance can restrict hip movement, leading to the loss of flexibility, and a loss of balance (www.golfsupport.com/Tips/bernadetttip5.htm).

Leetun, Ireland, Willson, Ballantyne and Davis (2004) supported these observations. They found that structural differences between males and females could produce different movement patterns. Applying this to golf, it means that men may need to turn their feet outward in order to achieve more hip turn and to create more stability. The more the feet are turned outward, the more the hips will turn. Women may want a wider stance (more than shoulder width), with the feet turned less outward. Some women over-swing their backswing due to a small width of stance. Over-swinging causes imbalance, promotes "yanking" of the club at the top of the backswing which can result in an "ax chop" back down towards the ball, and also eliminates a proper weight transfer in the golf swing (www.golfsupport.com/Tips/bernadetttip5.htm).

Dynamic Posture in Golf

Chek (2004a) defined dynamic posture as the ability to maintain an optimal axis of rotation in any combination of movement planes at any time in space. He identified swing and ball control factors such as swing plane, angle of attack, clubface alignment and hitting the sweet spot, as factors that are all directly related to one's dynamic posture.

Dynamic posture for the swing in golf includes the backswing, downswing and follow-through. According to Chek (2001), a golfer initiates movement of the club with the arms, as though to sweep a second ball away. As the arms rise, they follow an imaginary swing-plane running from the top to of the shoulders to the ball. The torso, followed by the pelvis, completes the sequence that ends when the golfer's club is parallel to the ground at the top of the backswing.

As the backswing takes place, 75% of the golfer's weight is transferred to the forward leg. The leg should not shift laterally. A proper weight distribution is a critical component of the golf swing as it allows significant force transference to the club face at the point of impact with the ball as well as injury prevention (Koslow, 1994; Richards, Farrel, Kent & Kraft, 1985; Carlsoo, 1967). As the arms, trunk and pelvis rotate (coil), there should be a minimal shift of the axis of rotation. Excessive shift can easily be identified as excessive lateral movement of the head in relationship to the ball, and if this occurs, the chances of achieving optimal swing factors and ball flight will be minimal.

Chek (2001) suggested that with optimal muscle balance and flexibility, the golfer should be able to perform the backswing with a dual rotational axis (between the spine and the right hip). As the coiling action takes place and weight shifts toward the forward leg, the rotational axis moves toward the hip joint. As this coiling action reaches its end point, the action quickly changes direction and the rotational axis progressively shifts to the opposite side during the downswing and throughout the follow-through.

In terms of posture during the swing, a plumb line dropped from the butt end of the club shaft should fall on a line bisecting the golfer's feet at any point during the golf swing. The position of the head, especially during the backswing, is critical to maintain optimal weight distribution as well as optimal visual focus. Chek (2001) explained that if there is any restricted motion in the upper cervical, lower cervical and upper thoracic spine, it could lead to one of two things:

- Compensation by the rest of the body, which would affect swing consistency.
- If the body is unable to compensate effectively, a momentary pulling of the from the ball, which will disrupt head and body control, and thus the swing.

In Koslow's (1994) description, the ideal follow-through should end in a well-balanced, upright posture. The reverse C follow-through posture should be avoided at all costs as it places a tremendous amount of sheer forces on the lumbar spine, which has been found to be clinically related to back pain in golfers.

Muscle Balance

Norkin and Levangie (1992) identified the function of the postural muscles as more for stability and endurance than for strength or power. They stated that the main role of these muscles is to hold the skeletal system and joint structures in proper alignment so that the larger and potentially "stronger" muscles can produce the desired body movements with appropriate force.

An incorrect golf swing can be associated with muscle imbalances. These imbalances might not be obvious until they cause a disruptive physical problem. Draovitch and Westcott (1999) listed the following common sources of error and their impact on the swing:

- Reduced neck rotation, which can make it difficult to focus on the ball during the swing.
- Insufficient trunk strength, which can interfere with maintaining a proper spine angle as well as the transfer of force from the lower body to the upper body.
- Tight hamstrings, which may make it difficult to achieve an effective address position.
- Reduced range of hip motion, which can compromise swing patterns.
- Decreased trunk rotation, which can limit shoulder turn and cause movement sequencing problems between the hips and trunk region.
- Insufficient shoulder strength, especially in the rotator cuff, which can lead to poor club control, including decreased club head speed and difficulty controlling deceleration of the club.

Richards et al. (1985) defined the ability to maintain a functional trunk position for each shot as a skill, which he referred to as "maintaining spine angle". A stable spine serves as an efficient, rigid lever that facilitates the transfer of energy from the lower body to the upper body. If spinal stability is a weakness, increasing the stability of the spine and the muscles that support it, could produce improvements in one's game.

Muscle balance is critical for maintaining optimal posture during performance (Draovitch & Westcott, 1999). Wallace and Reilly (1993) determined that playing a round of golf produces loading on the spine due to the postural strain of the address posture and putting actions, the compressive loading of the spine due to walking the course and the rotational stress caused by the golf swing. Horton, Lindsay and MacIntosh (2001) pointed out that due to the fact that golf is an assymetrical sport, it may create abnormal stresses on the lumbar spine, which could lead to pain and/or injury. Bending the spine places unnecessary stress on the lower back muscles and joints. It also reduces the ability to transfer power from the lower body to the upper body, which means a decrease in clubhead speed. For example, when the upper back is bent forward and hunched over, extra stress is created on the shoulders and neck, causing the rotator cuff muscles to work in an abnormal position. This undesirable posture places the muscles at a mechanical disadvantage that can lead to tendonitis, muscle strain, and/or joint strain. This position also limits the movement range of the swing (Draovitch & Westcott, 1999).

Conclusions about Posture in Golf

Good postural alignment when sitting or standing does not guarantee that the same postural parameters will be maintained in sport, for example, when addressing a golf ball or swinging a golf club. According to Chek (2001) the postural attitude in any given situation is part of the motor memory of past experiences of the same task. Thus in order to achieve a healthy postural awareness, attention needs to be given to both static and dynamic postural control when learning golf and when designing golf-specific fitness programmes.

Balance

Hudson (2004) identified balance as the first consideration in acquiring skillful movement. According to Sanders, Fairweather and Rae (2004), one of the primary functions of the head is that it houses important sensory systems responsible for maintaining balance and controlling movement. These systems include the vestibular (balance) system and the visual control mechanisms. The vestibular system provides critical ongoing information that clearly defines the position of the head relative to the line of gravity and its motion. Therefore, it provides information to help control balance. This information can be subdivided into two forms. There is information regarding the position of the body at any particular time called static information and there is information about the movement of the body called dynamic information.

The detection of static and dynamic information is critical to maintaining balance during movement. In golf, the problem of maintaining body posture in a balanced position is challenged by the transfer of weight away from the ball on the backswing and then towards and beyond the ball during the downswing and follow-through. The vestibular and visual systems provide information about the position and motion of the head and body during the golf swing, and are linked to pressure receptors in the feet. This interaction among the senses enables coordinated movement without losing balance. The common coaching point to "keep your head still" when learning the golf swing, may be linked to the combined roles of the vestibular, visual and proprioceptive systems involved in maintaining balance (Sanders et al., 2004).

All of these senses function much better when there is a stable frame of reference, that is, when the head is still. Sanders et al. (2004) stated that the comparison of important sensory information between shots in golf, is facilitated by a consistent frame of reference. This may be the reason why many novice golfers try to keep their head still during the golf swing in an attempt to hit the golf ball without losing balance.

Head Movement and Balance

Vision is recognised as a dominant source of sensory information for maintaining balance (Sanders et al., 2004). If the head is rotated to facilitate the body's range of motion, then this rotation may prevent the golfer's eyes from being fixed on the ball, which can simultaneously reduce the quality of vestibular and proprioceptive inputs. Thus, head movement may increase the likelihood of balance problems. By keeping the head relatively still during the backswing, the novice player may have an easier task in maintaining balance. However, evidence suggests that novices show relatively greater head movement through the ball contact zone (Sanders et al., 2004). This means that head movement during the swing could contribute to a loss of balance.

Sanders et al. (2004) confirmed that the performance of complex actions involving both visual and motor coordination is improved when the head is momentarily prevented from excessive rotation. In order to restrict challenges to balance during the backswing, the novice may create greater difficulties in maintaining balance at the ball contact phase and during the follow-through. In novices, a lack of development of an appropriate postural muscle reaction to weight transfer could lead to problems when attempting forward weight transfer that includes movement of the head with the spine. The implication for coaches is that time should be given during practice to develop the necessary postural muscle reactions to head movement and weight transfer.

Sanders et al. (2004) advised that by learning to keep his/her head still, the novice player may inhibit the development of a more advanced and effective golf swing. Sanders and Owens (1992) supported this by suggesting that coaching novices to keep their heads still in order to swing about a fixed point should be given up because it may limit the natural lateral movement of the head that is a characteristic of elite golf players.

Balance and Stability

Shumway-Cook and Woolacott (1985) isolated the development and maintenance of what they called "stability" as critical in performing complex motor skills. There are two types of stability: static and dynamic. Chek (2001) provided the following definitions:

> Static stability: the ability to remain in one position for a period of time without losing good structural alignment. It is also known as postural stability (p. 86).
>
> Dynamic stability: the ability to keep each and all working joints in optimal alignment during any given movement, such that the efficiency of the movement is facilitated and injury is prevented. (p. 86)

Rochon (2004) defined dynamic stability with reference to golf as "maintaining a desired alignment (the spinal angle) against external forces and loads (golf club, impact with ball) throughout an entire movement (the whole swing)." He explained that dynamic stability cannot be developed without first developing static stability. The golfer cannot expect to deliver the necessary strength and power for any golf shot if his/her body is unstable. Even putting consistently is impossible. Therefore it is very important to develop static stability as the platform on which strength and power can be developed.

In addition to the assessment of static posture, Chek (2001) recommended the assessment of "postural sway". Within the context of golf, Chek (2004b) defined sway as the subtle shifting of weight. Excessive postural sway is related to faulty pivot relationships and produces abnormal ball trajectories, erratic timing and poor balance. As a golfer's postural alignment and joint stability improves, the magnitude of postural sway decreases. When the postural muscles have been strengthened and there is optimal joint alignment, the golfer can maintain any given position for long periods of time.

Improving postural stability in order to control sway is important for every golfer. If the golfer has inadequate postural stability and excessive postural sway, he/she will have difficulty reproducing good shots. By reducing postural sway, the golfer increases his/her chance of reproducing an optimal club path, because postural strength and stability create a more perfect and reliable axis of rotation, and allow more precise integration of the legs and arms with the trunk.

Conclusions about Balance

Balance is one of the golfer's key fitness components. When the ball lies uphill, downhill, level or side hill, above or below the feet, poor balance definitely can contribute to a poor shot from an imperfect lie. If these factors are combined together with an inability to maintain proper trunk position throughout the swing, it increases the chances of both a poor shot and an injury (Draovitch & Westcott, 1999). The goal of the postural exercise programme developed for this study will be to improve both static and dynamic balance for the purpose of developing functional stability during the swing.

Mobility and Stability

According to Draovitch and Westcott (1999), the most important aspect of any functional movement is the principle of maintaining an optimal balance between mobility and stability. Golf is a sport of both accuracy and distance. According to Spence, Caldwell and Hudson (2004), distance is enhanced by greater mobility, while accuracy is associated with greater stability and lesser mobility. Therefore it is very important to be aware of the fine line that exists between mobility and stability in the stance and golf swing.

If the golfer has too much flexibility, or flexibility that he or she is unable to control during the functional part of the golf swing, it no longer works as a benefit. On the other hand, if the golfer is tight-jointed and stable but do not have enough mobility to produce a functional golf swing, he or she will be unable to preload the muscle, resulting in lack of power. Therefore, the golf swing requires a good balance between mobility and stability (Draovitch & Westcott, 1999). Stretching in creating the balance between mobility and stability. Draovitch & Wescott (1999) recommended that the golfer needs to participate in a combination of different flexibility/stretching activities in order to achieve the best results. These activities will help the golfer achieve an optimal relationship between mobility and stability, which will ensure that flexibility does not become the most neglected fitness component in the exercise programme.

Physical Fitness

Golf is a game in which a small advantage in one performance aspect can mean the difference between finishing first or finishing 20^{th}. If one takes a look at the professional tour statistics one finds that the difference between a golfer ranked first in a tournament and the golfer ranked 20^{th}, could be as small as a .25 shot difference in scoring average over one round. Multiply this by four rounds per tournament, and this small advantage can be the difference between either winning or losing by one shot. Fitness training for golf is one of these performance aspects that has the potential to improve the standard of golf (Horton et al., 2001).

In addition to enhancing golf performance, physical fitness also can contribute to injury prevention. Horton et al. (2001) identified a lack of strength and/or endurance of the trunk muscles as risk factors in the occurrence of chronic low back pain in golfers. They found that the abdominal muscles fatigued more quickly than the lower back muscles in those people suffering from chronic low back pain. Cosio-Lima, Reynolds, Winter, Paolone and Jones (2003), as well as Horton et al. (2001), submitted that abdominal muscular endurance and strength and torso balance are important for trunk stability, appropriate posture, and body movements during all sports.

Watkins et al. (1996) suggested that trunk muscle strength as well as trunk coordination is important for both power generation as well as injury prevention in professional and amateur golfers. Strong chest, back, and shoulder muscles allow greater acceleration of the club, while maintaining control through trained arms and forearms. There are few other single actions that require more overall muscular strength, joint flexibility and movement coordination than a correctly executed golf swing.

Strength and Muscle Endurance

Mullane and Reed (2000) discovered that very few amateur golfers associated improvement in physical conditioning with improvements in golf performance. Watkins et al. (1996) found that many people do not view golf as a vigorous sport and that training for golf is not as seen to be very important. One reason many golfers said that they did not engage in strength training was that they thought it would reduce flexibility and cause stiffness, which would have a negative affect on their golf performance (Fletcher & Hartwell, 2004; Faigenbaum, 1998).

Parziale's (2002) research revealed that 25% of the golfers in the United States were 65 years or older. The conclusion can be made that novice golfers may well be older individuals with relatively low rates of participation in other forms of physical activity. Burdorf, Tromp-Klarens and van der Steenhoven (1996) found that physical inactivity was associated with reduced strength of the muscles of the trunk as well as a direct correlation between inactivity and chronic lower back pain.

Chappius and Johnson (1995) proposed that strengthening exercises be implemented to help golfers gain muscle endurance and avoid injuries. Massey (2004) supported the need to develop strength and muscle endurance for golf, by stating that although golf looks like a relatively slow-moving activity, it places a lot of strain on the body. Faigenbaum (1998) documented that the golf swing can reach clubhead speeds of up to 160 km/h. Pink, Jobe, Yocum and Mottram

(1996) provided further support with their conclusion that although individual swings may seem to be low in stress/load, the accumulation of swings can result in trauma of several different regions of the body unless the golfer is in good physical condition.

Participation in a strength-training programme can reduce the golfer's physical limitations and help to optimize their swing pattern. Training enables more efficient transfer of momentum, which translates into improved ball striking capability and increased club head speed at impact. Fletcher and Hartwell (2004) found that golfers increased club head speed and driving distance significantly after following an eight-week weight training and plyometric training programme.

Traditional Training

Traditional strength and muscle endurance training in a gymnasium using weights is often thought of in terms of the development of the musculature associated with body-building and weightlifing. The development of exercise machines and techniques for lifting that focus on isolating muscles and stimulating them to grow are typical in this traditional approach to building strength. According to Chek (2004c) doing exercises on a machine ignores the functional requirements of most sports, and can involve minimal activation of postural muscles, minimal activation of stabilizer and neutralizer muscle functions. Machines also eliminate the need to continuously maintain balance (centre of gravity over base of support), a constant challenge in the functional approach to strength and muscle endurance training.

Functional Training

Conditioning for golf should be based on the principles of functional training that is designed to establish muscular balance, strength and coordination in relation to the movement requirements of a specific sport. According to Cosio-Lima et al. (2003) functional training enhances the ability of the neuromuscular system to initiate and control dynamic concentric, eccentric, and isometric stabilisation contractions in response to gravity, ground-reaction forces and momentum. They also stated that functional training could enhance the body's ability to improve stability and balance because the core muscles stabilise the axial skeleton. An example of functional training is a Swiss ball exercise programme, which increases the priopriоceptive demands of performing an exercise as well as developing the strength of the core muscles that are important for balance and stability.

Physical fitness for golf should be developed through participation in a functional training programme. Chek (2001) based his approach to functional training on the relationship between the brain and the body. The brain controls the muscles, and the brain does not "think" in terms of individual or isolated muscles, but recruits groups of muscles in uniquely programmed sequences. Therefore, for an exercise programme to improve function, it must be designed to integrate the whole body. He recommended that five key components be included in a functional training programme:

1. Customised flexibility exercises.

   Rather than follow a general stretching programme Chek (2001) recommended that an individual assessment be completed to determine which stretches and stretching techinques are most likely to benefit the golfer, based on the range of motion (ROM) of his/her joints. The specific requirements of golf must be compared against the golfer's own joint ROM so that specific stretches can be identified, and a programme designed and followed.

2. Maintenance of center of gravity over base of support.

   Exercises in the programme should enhance the golfer's ability to maintain his/her balance. Golf is a sport of repetitive explosive actions that challenge a golfer's ability to maintain his/her centre of gravity over his/her feet (the base of support). If a golfer has problems with balance, he/she will also have problems maintaining an optimal swing axis and swing path (Chek, 2001).

3. Building on generalised motor programmes.

   Generalised motor programmes have been proposed to exist for different classes movements that display the same relative timing (Schmidt & Lee, 1999). For example, a squat and a two-foot vertical jump may have the same relative timing, although they are predominantly different in over-all speed and amplitude of movement. This is proposed as one reason why the squat exercise may improve vertical jumping performance. According to Chek (2001), for an exercise to be golf-specific it should resemble one of the generalized motor programmes that support the performance of golf skills. For example, a movement that includes actions that following the relative timing sequence and movement used to create the full golf swing, would be recommended for a functional training programme.

4. Selection of open and closed chain exercises.

   In golf, the upper extremities act in an open chain environment, while the legs work in a closed chain environment. In a functional training programme, for example, the selection of exercises requiring the correct resistance and recruitment pattern for the upper body will also be in an open chain environment (Chek, 2001).

5. Promotion of optimal posture.

   In an effort to automate optimal postural control, Chek (2001) is adamant that attention be given to the static and dynamic postures manifested in all functional training programmes.

Comments about Power

Rubenstein (2002) defined power in terms of force in relation to time. It is how quickly a load is moved over a given distance that determines power. Correct, functional posture has a positive influence on power production. His research supports the observation that functional posture plays an important role in the swinging action and lets the golfer impart far more force at impact.

How Power is Generated in the Golf Swing

According to Colby (2004), the motion of the backswing begins the process of creating elastic and chemical energy. As the backswing progresses, the legs act as pistons creating a rotational force on the hips. This motion stops the lower body from moving in the clockwise direction of the backswing and then accelerates it in the counterclockwise direction of the downswing. At this point the upper torso continues moving in the clockwise direction. As this happens, the shoulders stop moving in the clockwise direction of the backswing and begin to accelerate in the counterclockwise direction, following the lead of the lower body. Now each segment (hips, shoulders, arms and club) continue to move in a coordinated fashion until all are accelerating in the counterclockwise direction of the downswing.

The muscles now begin a process of shortening in a coordinated fashion beginning with the trunk, the first link between the hips and the shoulders. As this happens the hips begin to decelerate which in turns transfers momentum to the shoulders. When this happens, there is a large increase in speed of the shoulders. At the same time, the muscles of the link between the shoulders and the arms begin to shorten. Now, the shoulders begin to decelerate which transfers momentum to the arms. The result is large increase in speed of the arms segment. The same coordinated action occurs between the arms and the club with the end result being a large increase in velocity and maximal club head speed through impact (Colby, 2004).

Chek (2001) recommended that if a golfer wants to develop golf power attention must be paid to two principles:

1. Specificity of exercise.
2. Specific adaptation to imposed demands (S.A.I.D principle).

This means that in order to develop golf power golfers must select the exercises with a high carry-over to the game of golf. The S.A.I.D principle indicates that the body will have a specific adaptation to demands imposed upon them by the selection of training exercises.

Power and Ball Flight

Chek (2001) isolated four factors that influence the flight of the ball:

1. Swing plane.
2. Club face alignment.
3. Angle of attack.
4. Club head speed.

Power is the only variable that has a physical influence on club head speed. The golfer needs to develop a base of static and dynamic stability and functional strength in order to control the first three factors. Achieving these three factors will lead to improved accuracy and consistency and very importantly serve as the foundation for developing golf power.

Summary of Physical Fitness

To improve performance, a fitness programme that develops balance, co-ordination, speed, strength and power in a functional way is recommended. Chek and Walsh (2004) also noted that developing functional fitness will help prevent injuries as well as assist in lower back stabilization. According to Chek (2001), functional exercises must focus on the development of power in the trunk, hips and rotator cuff. Performing these exercises may also significantly reduce the chances of injury. This may be due to the optimal use of the core, hips and rotator cuff, which could decrease the need for compensatory movements by other parts of the body.

Innovative Ways of Training for Golf

Despite technological improvements in equipment, the average handicap in North America, for both men and women, has remained at about 19 to 20 for more than a decade (http://www.virtuallyperfectgolf.com). This may be one reason why there is a great interest in innovations in golf instruction. Because this study is an effort to develop an innovative postural training programme that can contribute to improved swing performance, a brief overview of selected innovative approaches is presented to demonstrate the receptiveness of golfers and golf coaches to new ideas about training and instruction, and their eagerness to find inexpensive techniques to help improve performance.

Practicing Golf Swings Under Water

Smith (2004) reported on the benefits of practicing golf swings under water (head remains above water). It was claimed that this is an effective way to demonstrate how leverage helps generate speed in the swing. It is also presented as an effective exercise for strengthening the hands, arm and trunk muscles in a functional manner. The source of the benefit of this type of training is identified as the resistance provided by the water, combined with the feeling of near weightlessness that can help golfers "feel" the dynamic motion of their golf swings. The splashes and bubbles created during swinging under water enables the golfer to visualise abstract concepts such as swing planes, torque and leverage in action. In relation to posture, golfers can get immediate feedback on errors. For example, if golfers only swing with their hands and arms, or if they pull out of their posture, their head will sink under water.

Using a Torch to Teach Correct Swing Path

Beginners can practice the correct swing path by building themselves a very simple training aid (Johnson 2004). One first connects the back of two small Mag torches together with a bungee cord that has been passed through a 60cm section of small PVC pipe. This creates a pipe with a light at each end. Then, a length of ribbon is anchored on the ground to simulate the target line that a club should follow when hitting a ball toward a target. The golfer addresses an imaginary ball on the ribbon by shining one torch on the spot where the ball is lying. The beam from the torch on the club head end of the pipe should shine on the ribbon on the golfer's backswing. The beam from the torch on the grip end of the pipe should hit the ribbon as the golfer hinges his/her wrists halfway back. The golfer should trace the target-line ribbon with the club head beam as he or she swings down and through impact. The goal with this drill is to practice precision, not speed. Once golfers can follow the ribbon with the torch beams using a slow swing, they should work their way up to faster ones. This exercise is intended to "groove" and promote consistency.

Virtually Perfect Golf

Virtually Perfect Golf (http://www.virtuallyperfectgolf.com) is advertised as computer technology for personalised and professional golf instruction. It is a combination of 3D, real-time, virtual reality technology with audio instruction methodology. The technology is designed to allow a golfer to feel he/she has "stepped inside the body" of a computer-engineered model player who has an ideal golf swing. The model has the integral elements of a sound golf swing, allowing the golfer to try to make the best possible swing by effectively connecting an ideal starting position to an ideal finishing position.

With the use of virtual-reality glasses, the model guides the golfer through the perfect swing time after time. The golfer tries to match the movement of the computer-generated model. This is done by trying to keep his/her swing inside the image of the model that overlays the image of the golfer. Through this real-time image in the virtual-reality glasses, the golfer can immediately tell whether they are moving within the ideal parameters. This provides him/her with immediate feedback. The combination of seeing and feeling oneself making the perfect golf swing over and over is supposed to enhance the learning process and accelerate improvement. The benefit of this approach is that it eliminates the problem of practicing incorrect motions over and over. With the Virtually Perfect Golf (VPG) system, the golfer practices swinging correctly every time.

These virtual practice sessions do not include hitting golf balls. The potential advantage of this is that it forces the golfer to focus on the process of swinging. Many golfers may be so concerned about where the ball goes that they neglect to focus on the quality of their movement. By using virtual practice, the focus is shifted towards the process of the golf swing i.e. the motion involved in making the ideal golf swing.

Practice sessions includes pre-programmed drills, video and audio clips as well as monitoring by a VPG professional. Adherence with this system is reported to be high because golfers can watch themselves making a perfect swing over and over. This is supposed to increase their commitment to follow the programme.

Using a R5-coin to Determine Balance When Swinging

According to Bishop (2004) one of the most common problems among amateurs is poor balance during the golf swing. Poor balance influences the golfer's swing plane, which may be the cause of many poor shots. He described a quick, easy and inexpensive way to find out if a golfer is swinging in balance.

Place a R5 coin on the toe of the left shoe for the right-handed golfer or right shoe for the left-handed golfer. Then, take a normal golf swing and try to keep the coin on the shoe. After swinging, take a look to see if the R5 coin is still there, or if it has fallen off.

- If the coin has fallen to the inside part of the foot, it indicates that the golfer rolled his/her front foot on the backswing. This means that too much weight moved back during the swing, which makes it very difficult to move the weight forward again. The result is an ineffective weight transfer.

- If the coin falls directly in front of the toe, then the golfer lifted his/her front foot too far off the ground during the backswing. This also means that too much weight moved back during the backswing.

- If the coin has fallen to the outside, then the golfer rolled too far to the outside of the foot or has fallen back to finish on his/her heel.

The goal of this exercise is to finish with the weight solidly over the transverse arch of the front foot, with the hips facing toward the target and the R5-coin still on the foot.

Women Golfers Taking a Wider Stance

Steinbach (2004) remarked that if one takes a look at the most successful players on the Ladies Professional Golf Association (LPGA) tour, one will see that they set up with a stance slightly wider than their shoulders. She suggested that it is these players that are better balanced. The reason for this is that women have wider hips than men, which means that they are more flexible in the hip area. The result is that during the backswing, a women's hips would turn more easily and naturally. Therefore women golfers need more stability to control their bigger hip turn and to create better resistance.

If a woman takes the commonly prescribed shoulder width stance it may lead to balance problems during the swing, as it does not provide stability for sufficient weight shift. Very often a narrow stance also promotes a reverse weight shift, which is a very common among women golfers. According to Koslow (1994), this improper weight shift will result in an open clubface during ball contact which will cause the ball to fade or slice. A stance that is wider than shoulder width allows for a more dramatic weight shift back and away from the ball.

The reason why men can get away with taking a narrower stance is because they do not turn their hips as much or as freely on the backswing. They have a higher center of gravity and one-third more muscle mass in their upper bodies. Men are usually built with shoulders that are wider than their hips. In comparison women have a lower center of gravity, which means that they naturally use more of their lower bodies to generate the power in their swings. By simply making this one change at address position, a woman's golf game might benefit (www.golfsupport.com/Tips/bernadetttip5.htm).

GolfFins

GolfFins I and II (http://resistancetrainer.com//promo2/) are golf swing trainers designed to strengthen and loosen the muscle groups involved in a golf swing while maintaining proper swing tempo. Initially they were designed to attach to the driver for the purpose of warming up before tee-off on the first tee.

However, during the testing stage they proved to be valuable tools to use on every tee just before driving. After making three or four practice swings with the fins on, the driver feels very light and the swing feels effortless during the actual stroke.

The advantage of this product is that proper swing tempo is maintained whereas the use of ordinary swing weights can lead to improper swing tempo when swinging the club. With GolfFins, the amount of resistance felt is related to how hard the golfer is swinging the club. Therefore, the golfer controls the amount of resistance with the speed of the swing. The golfer can warm-up by using slow, easy swings and progress to higher swing speed, which will increase the resistance. By keeping the swing tempo in check, this product will prevent the golfer's hands and arms from getting ahead of the body.

An advantage is that GolfFins are small and attach/detach very easily from the club. When folded up, they fits in one's pocket, which means the golfer can take them anywhere in order to practice the swing. There are two different models: the GolfFins I "Butterfly" and the GolfFins II. Both models are approximately 200 g, expand to 575 cm^{3}. The surface wind resistance is approximately seven times the wind resistance of a standard driver.

The GolfFins helps to keep the backswing slower and more controlled because of the weight and wind resistance. They are advertised to train the muscles to work harder at times when power is actually generated i.e. the downswing and release point.

One of the most important contributors to hitting long drives is called the release. The release is the point just before striking the ball, where the golfer "breaks" his/her wrists. When a golfer practices swinging with the GolfFins, the greatest wind resistance occurs at the time where the club head speed is at its greatest, which should be at the release point. It takes extra effort to break the wrists at this point due to the resistance. Using the GolfFins for three or four practice swings are supposed to help the golfer feel how much easier it is to release at the time of maximum club head speed once the GolfFins are removed.

Squaring the Clubface with the Help of a Ruler

Gough (2003) identified a square left-wrist position at the top of the backswing as one of the key cues for an effective swing, because this wrist position has a direct influence on whether of not the clubface is square, which in turn determines the direction on the flight of the ball. A square wrist and clubface position runs parallel to the left forearm. This position will be negatively affected by a grip that is too strong or weak. If a golfer's wrist and forearm are in one line and the clubface is open or closed, he/she should check his/her grip.

There are two common wrist faults a golfer can make. First, there is the cupped wrist. This is the more common of the two wrist faults and it leads to an open clubface and high, weak and left-to-right ball flight. This breakdown in the wrist at the top also leads to over-swinging. Second, there is the bowed wrist. This is a less common mistake and will lead to a stronger, more penetrating, drawing or hooking ball flight, as the bowing left wrist will lead to a closed clubface. To fix both of these problems, Gough (2003) suggested attaching a ruler across the left wrist with the help of a golf glove. When swinging the club, make sure that the ruler attached to the left wrist and the left forearm are close to parallel at the top of the backswing. This observation may be easier if the swing is practiced in front of a mirror.

Using Baby Powder for Solid Contact

Making consistently solid contact with the ball is difficult for many amateur players. Problems include hitting the ball off the top of the club head, the bottom of the club head, the toe or the heel of the club. Haney (2003) suggested dusting the face of the driver with baby powder before striking the ball. The mark left on the club face provides the golfer with accurate and immediate feedback about the quality of their shots in terms of point of contact with the ball. This can help to identify the golfer's problem so that he/she can focus on correcting it.

For example, if a golfer tends to hit the ball off the heel of the club, the problem could be twofold. First, a faulty swing path could be the cause. That is one where the golfer takes the club too far inside the target line on the backswing, and then swings it outside the line on the way down. This causes the heel of the club to be further away from the golfer than what it was at address. Second, poor balance through impact could also be the cause. This is caused by the golfer dipping his/her upper bodies toward the ball during the swing (Haney, 2003).

To improve swing path, focus should be on moving the club up and a little straighter back on the takeaway. This makes it less likely that the club will move outside on the downswing. To improve balance, the golfer should ask a friend to hold a club against his/her forehead during the swing. Slight lateral movement of the head is allowed, but movement up or down should be resisted (Haney, 2003).

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Curing the "Yips"

All over the world golfers, from amateurs to some professionals struggle with the "yips", either putting, chipping or driving the golf ball (Haney, 2004). The "yips" is a slang expression used to describe the unexplainable sudden muscular actions that cause deviations in a golf stroke. Golfers are often told that it is all in their head, caused by nerves or pressure.

Haney (2004) reported that a team of German scientists and golf teaching professionals wanted to discover exactly when the yips happened in a stroke. They developed what they called the Super Science and Motion (SAM) Putting Opimiser machine. It provides a complete record of the putting or chipping stroke, measured with ultrasound.

Basically, the SAM tracks the location of the club head in space. When a swing is made with the putter or wedge, a small wand attached to the shaft of the club sends information to the base unit, which is connected to a laptop computer. SAM reports on more than 24 characteristics of the stroke, including tempo, swing path, face angle and loft at impact. From this information, it can be determined whether the golfer has a mechanical problem with his/her form. If not, then the deviation is attributed to the "yips".

Simply being able to look at a visual representation of their stroke maybe a powerful treatment tool for some golfers struggling with the yips. For example if the Super SAM machine indicates that the problem area is at impact for chip shots, the goal for this golfer should be to be less impact-conscious. One way to do this is to hit chip shots with light foam balls. They do not provide any resistance at impact so the hands feel different sensations during the swing. SAM can be used for regular check ups to measure progress.

Conclusions about Innovative Techniques

There have been minimal improvements in golf handicaps over the years. The market is open for new ideas about how to improve golf performance. This study will attempt to present a new idea about how to train to improve postural control in golf. Such a programme is intended to increase novices' hitting distance, accuracy and ball flight. The long-term benefits, which are not measured here, also could include an improvement in subjects' physical condition, a factor in injury prevention.

Conclusions from Chapter Two

Fletcher and Hartwell (2004) reported that golf is often viewed as a game of technical, tactical and mental skill that requires less physical exertion than most other sports. Hagerman (2002) viewed golf as a game of precision, timing and agility. These characteristics need to be trained in order for a golfer to play to his/her full potential.

The golf swing is a complex, explosive, and physically stressful action. The body must be prepared both to produce and to withstand the forces required for powerful drives. A golfer may be able to improve several important aspects of his/her swing through functional fitness training, and that training may also contribute to his/her driving distance. Draovitch & Westcott (1999) stated that:

1. Club swing range can be increased by improving joint flexibility.
2. Club swing speed can be increased by developing muscle strength.
3. Club swing power can be increased by training dynamic postural balance and segmental coordination.

According to Chek (2001) the following four physical factors must be addressed in order to be able to provide the four key components necessary to control ball flight (clubface alignment, swing path, angle of attack and speed):

- Muscle balance and flexibility.
- Static and dynamic postural stability.
- Strength.
- Power.

Chek (2001) emphasized that it is very important that these factors are addressed in the correct order. Flexibility must be addressed first. Flexibility of the appropriate areas should be restored to ensure that the musculoskeletal system is balanced. The next step will be to achieve static and dynamic postural stability. Stability is important as a stable body creates a solid framework for all movements and activities. A stable body is also less likely to get injured. Strength will be the next target. It is essential that functional movement pattern be used for building up strength to ensure maximum transfer to the golf swing. Strength is also a key component of power. The last step in the progression will be to develop power.

In golf, technique is more important than strength for producing power, but with more strength golfers can optimise their technical ability to produce the amount of power they need (Rubenstein, 2002). The more power a golfer can transfer from his/her body through the club to the ball, the further he/she will be able to drive the ball. The focus on the innovative training programme implemented in this study is to develop sufficient postural control in terms of strength, balance and posture, to enable novice golfers to achieve improvements in the distance, accuracy and ball flight of their 5-iron shot.

Chapter Three

Methodology

A repeated measures design was followed because the approach used in this study involved the comparison of scores from pre- and posttests of an experimental and a control group. The study also used field-based assessments that relied only on inexpensive equipment. This chapter is a description of the methods of assessment, procedures and data analysis applied in this study.

Methods of Assessment

Pre- and posttests were selected to assess the postural variables of core stability and consistency in posture, as well as golf skill in terms of hitting distance, accuracy and ball flight of a 5-iron shot. The score sheets for these assessments are in Appendix A.

Assessment of Postural Variables

Posture was recorded using the Dartfish® video analysis software and a Panasonic NV-DS30 video camera. Golf posture during the address position was recorded while each subject was completing the Benson Golf Test (for hitting distance and accuracy). The camera was placed five metres directly behind the subjects, in line with the target line. All of the shots were recorded.

With the help of the Dartfish® Analyzer feature and the drawing tools, consistency of posture was measured in terms of body angle and knee angle, and posture in the address position was measured as an indicator of static balance (see Figures 1 and 2). All 20 golf swings were recorded and the video record of the best shot (distance minus accuracy) was then compared to the video record of the worst shot to arrive at the following measures.

Assessment of Core Stability

Core stability was assessed using three field tests: the overhead medicine ball throw (directly backward), the one-minute modified lying leg lift (legs at 90º) and the one-minute walkout test.

Overhead Medicine Ball Throw

The subject started with her back to the direction of the throw, heels comfortably apart and behind the starting line (http://www.volleyball.ca/files/tcvc-wtesting protocol.pdf). The medicine ball was held in both hands. The subject then crunched while lowering the ball between the legs, then drove upwards to throw the ball over their head. A three-kilogram medicine ball was used. Each subject had two attempts with the best score recorded. This test measures power and coordination. An increase in core stability is linked to the generation of power as it will enable more effective and efficient transfer of forces from the legs through the trunk to the upper body.

One-minute Modified Lying Leg Lift

An aneroid sphygmomanometer (CE 0483) in a modified cuff was used in this original test designed by Kroff (2005). The cuff was strapped around the subject's waist so that the bladder was positioned on the most curved part of the lumbar spine. The subject had to lie on her back, with her hips and knees at 90º angles and her lower legs parallel to the floor. Her arms and hands were placed behind her head, and her head was tilted forward and upwards (starting position). The pressure cuff was inflated up to 100 mmHg. The subject had to lower her legs, by extending her hips and keeping her knees at a 90º angle, until her heels touched the floor, and then returned to the starting position. Throughout the movement, the subject had to push her lower back into the floor. The number of repetitions in one minute was recorded. A repetition was not counted if the pressure in the cuff dropped below 60 mmHg. The subject was allowed to look at the pressure gauge during the test. . Core strength in the golf swing is critical as it provides trunk stability. Trunk stability is essential for maintaining proper posture and achieving properly coordinated movements during sports (Cosio-Lima, 2003).

One-minute Walkout Test

In this test, also designed by Kroff (2005), the subject had to position herself in the prone position, with her upper legs on the top of a stability ball and her hands on the floor and her arms straight, perpendicular to the floor. A line was drawn with masking tape on the floor at the tips of the subject's middle fingers (starting position). The subject rolled forward on the ball until her shins were on the top, middle part of the ball. A line with masking tape was drawn on the floor, at the back of the hands of the subject (end position). The subject was instructed to move back and forth between the starting and ending positions as quickly as possible, without losing her balance on the ball. The number of repetitions in one minute was recorded. A repetition was not counted if the subject's hands were either not behind the tape at the starting position, or not over the tape at the end position. A repetition was also not counted if it was done with poor posture. The test was terminated if the subject rolled off the ball. Like the one-minute lying leg lifts this test also measures core strength. This means that an improvement in one-minute walkout will have the same benefits as an improvement in one-minute leg lifts.

Assessment of Consistency of Posture

Consistency of posture was determined by looking at variations in a subject's static balance in the address position, and variations between strokes in her body angle and knee angle.

Static Balance

The static balance of each subject was equated with her ability to hold the "ideal posture" in the address position. A vertical line was drawn through the centre of shoulder, front of knees and into balls of feet for each subject on the visual image of her best shot and her worst shot (see Figure 1). Each image was scored as a "yes" if the vertical line was considered acceptable, and "no" if it was not. These determinations were made by the researcher. Subjects received two scores on this test: one for their best shot and one for their worst shot.

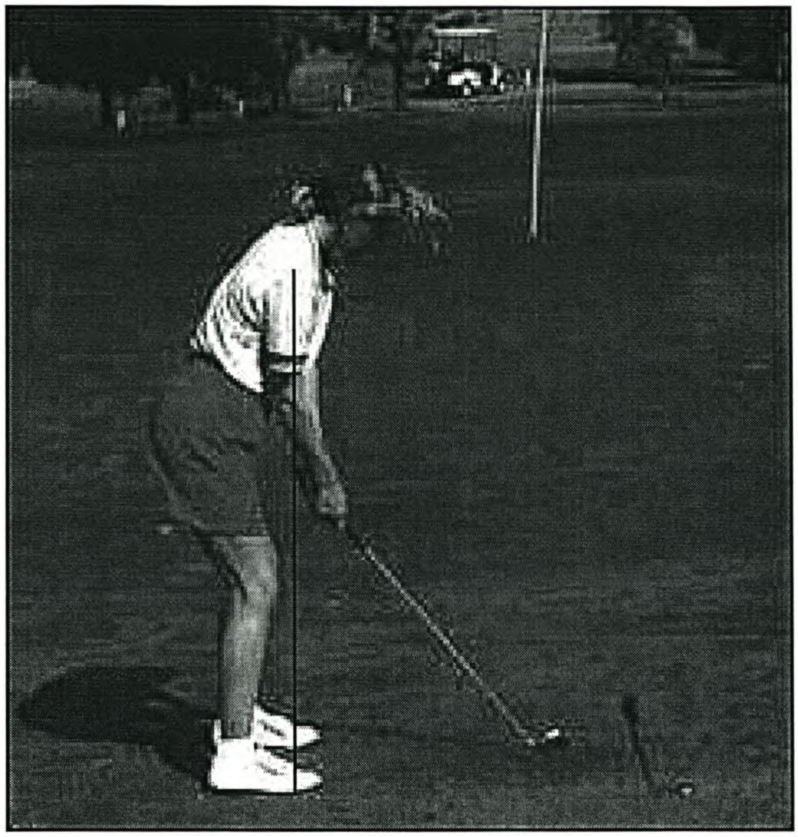

Figure 1

Assessment of balance at address

Body and Knee Angles

The body angle of each subject was determined as the angle formed between the line from the most lateral border of the acromion to the lateral border of the iliac crest, and the line from the lateral border of the iliac crest to the femoral condyle (see Figure 2). To arrive at a score, the body angle of the worst shot was subtracted from the best shot. The difference became the subject's score on this item.

The knee angle was determined as the angle formed between the line from the lateral border of the iliac crest to the lateral border of the femoral condyle, and the line from the femoral condyle to the lateral malleolus (see Figure 2). To arrive at a score, the body angle of the worst shot was subtracted from the best shot. The difference became the subject's score on this item.

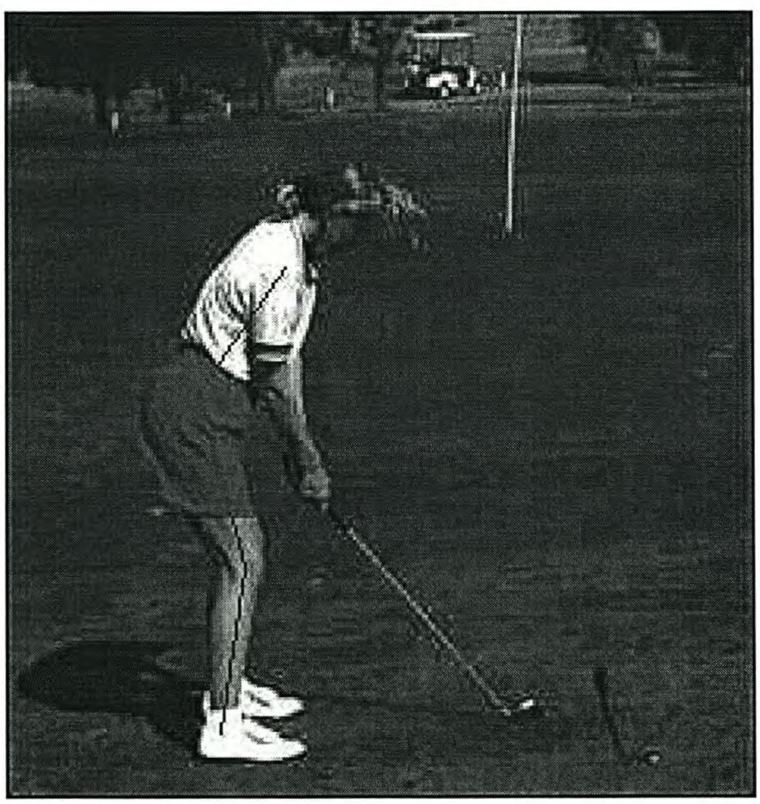

Figure 2

Body angle and knee angle at address

Golf Skill (Hitting Distance, Accuracy and Ball Flight)

The Modified Benson Golf Test (Strand and Wilson, 1993) was used to evaluate golf skill. It measured the ability to hit a five iron in golf. Strand and Wilson reported that a validity coefficient of 0.94 was obtained by correlating actual golf scores with distance and flight deviation scores, and a reliability coefficient of 0.90 was computed using the odd-even approach.

The Benson Test was used in this study because in addition to its high validity and reliability, it is easy to administer and requires only two people as test administrators. One person spots and calls where each ball lands and the second person records the scores. The equipment needed for this test is a five-iron golf club, golf balls, a measuring tape and marking materials. Scoring equipment includes scorecards and pencils. The testing area should be approximately 150m by 100m. Distance markers were placed in line every 25m between the hitting line and the 150m line. On the 150m line, two deviation markers were placed 20m each side of the midpoint.

Subjects stood behind the hitting line with 25 golf balls each. Using a five-iron, they took five practice shots. Following the practice, 20 shots were taken and scored. The person taking scores were located behind the hitters, in line with the 150m line. For each of the 20 shots two numbers was recorded. One is the accuracy of the ball (deviation from the midline) subtracted from the distance the ball traveled in flight and secondly a subjective score for ball flight is given. With regards to ball flight, a score of 0 was given if the subject misses the ball, a score of 1 if the ball traveled along the ground, a score of 3 for a shot hit with the perfect trajectory and a score of 2 for a shot that was not hit with the perfect trajectory but did not travel along the ground. Each subject's test score was the average for the 20 shots.

Procedures

Recruitment of Subjects

It was considered important that subjects in this study be volunteers, since their willingness to participate sincerely as members of either the experimental or control group was critical to the integrity of this research. In order to recruit volunteers as subjects, the following sequence was followed:

- A meeting with all potential subjects (second year female sport science students) was held, where general information was provided about the purpose of this study and the nature of the intervention programme. The general criteria for participation in the study was presented: all subjects had to be female novice golfers. For this study, a novice golfer was defined as someone who had played fewer than five rounds of golf in her life.

- Those who were interested in participating and who met the criteria, were asked to attend a second meeting, where more detail about the study was given. These included a detailed description of the assessment methods, the intervention programme to be followed, how much time per week each subject would be required to train, as well as what was expected from the members of the control group.

- A total of 18 subjects volunteered to participate in the study. They put their names on a list, and then were randomly assigned to either the experimental or the control group.

- A third meeting was held, where subjects were informed about the group to which they were assigned. Letters of Consent were distributed, signed and returned (Appendix A).

- A schedule for pre-testing of the experimental and control groups was organised. Training times for members of the experimental group were also organized to avoid interference with the subjects' academic classes. It was explained to all subjects in the experimental group that they had to attend all 12-exercise sessions prior to the posttests if their results were to be used in this study.

- Subjects in both the experimental and control groups were also asked not to alter their usual physical activity levels during the period of this study. If they were already involved in physical activity, they were asked to maintain their usual forms of participation.

Pre-test

Once the subjects were identified, a date was set and the pre-testing began. The subjects were tested at the facilities of the Stellenbosch University Department of Sport Science. On arrival, each of the subjects signed an indemnity form. The tests described above were then completed in the following order:

1. Assessment of posture (core stability): the Overhead Medicine Ball Throw, the One-minute Modified Lying Leg Lift and the One-minute Walkout Test.

2. Assessment of posture (body and knee angle) and hitting distance, accuracy and ball flight: the Benson Test with simultaneous video taping of address position for later analysis.

Intervention Programme

Each subject who was assigned to the experimental group attended two 60-minute golf-specific training sessions per week for six weeks. The first session started the week after the baseline testing. The sessions were scheduled to accommodate the study schedule of the subjects. The researcher was the instructor for the programme. All the exercises were done under supervision of the researcher.

The training programme consisted of innovative exercises intended to develop posture in golf, with special attention to the development of the functional strength of the muscles of the trunk section (the core). It was intended that the development of postural strength from the core region outward, would have a positive impact on subjects' hitting distance and accuracy (Draovitch & Wescott, 1999)

The bi-weekly training programme was presented as two complementary daily programmes with progression incorporated every two weeks. This made it possible to adapt the programme to each individual's needs and capabilities. The "day one" programme each week focused on posture and balance training, while the "day two" programme focused on the development of core strength and power. Tables 2 and 3 present a summary of the exercises included in an example of a Week 1 programme, as well as the repetitions of each exercise. Sample programmes for Weeks 3 & 4, and Weeks 5 & 6, are presented in Appendix B.

Posttest

The posttest was completed for subjects in both the experimental and the control groups, the day after the last training session. The same test administrators who administered the pre-tests were responsible for the posttests. The same test protocols were followed in the same facility, in the same order, with the same equipment. This was done in order to increase the reliability of the test results.

Debriefing of Subjects

After all tests were completed and results analysed, a printout of the results were made available to the subjects. Subjects could have a look at their results and discuss them with the researcher in their own time. Subjects who were part of the control group were also offered a copy of the training programme that the experimental group followed, and offered the opportunity to try the programme under the supervision of the researcher.

Table 2

Example of Weeks 1 & 2: Day 1 programme

Day 1: Posture and balance training		
Exercise	**Sets**	**Repetitions**
Step ups/skipping	1	2 min
Swiss ball lower body rotation	2	10
Swiss ball side flexion (hold position)	3	30 sec
Swiss ball kneeling	3	30 sec
Swiss ball Russian twist	2	15
Prone cobra	3	15
Stork stands	3	1 min
Wobble boards	2	1 min
Seated chop	3	15
Seated lift	3	15
Eccentric abdominals (legs pushdowns)	3	15
Heavy baseball swing (slow response)	2	20 swings
Light golf club swing (slow response)	2	20 swings
Heavy baseball swing (short response)	2	20 swings
Light golf club swing (short response)	2	20 swings
Frisbee in hands with marbles	2	15
Golf ball toss to target	2	10

Table 3

Example of Weeks 1 & 2: Day 2 programme

Day 2: Strength and power			
Exercise	**Weight**	**Sets**	**Repetitions**
Step ups/skipping		1	2 min
Dead lifts		3	8
Underhand medicine ball throws		3	8
Walking lunges + rotation (w/swiss ball)		3	8
Dumbbell bench press (on swiss ball)		3	8
Chest pass (standing in golf posture)		3	8
Swiss ball hamstrings		3	8
Dumbbell squats (hands above shoulders)		3	8
Standing rows (with elastics in golf posture)		3	8
Flat cross extensions		3	8
Rotator cuff isometrics		3	8
Medicine ball side pass		3	8
Sideways tripod: hip abduction		2	5
Sideways tripod: hip adduction		2	5
Calf raises (a, b, c)		2	8
Dumbbell curls (concentric)		2	8
Dumbbell overhead triceps extension (concentric)		2	8
Dumbbell curls (eccentric)		2	8
Dumbbell overhead triceps extension (eccentric)		2	8
Wrist curls		3	8
Reverse wrist curls		3	8
Wrist pronaton/supination		3	8

Treatment of the Data

The programme SPSS was used to process all of the data. An independent t-test was used to determine whether there were any significant differences between the experimental and control group for any of the variables at the start of the study. As this is a 1-factorial measures design, a repeated measures ANOVA (Analysis of Variance) was run for each dependent variable to see whether there was any significant improvement following the intervention programme. Normal probability plots of the residuals were used to check if the assumption of normality was violated. Two outliers were found and they were excluded from the analysis. The ANOVA was repeated and the results did not differ to when they were included. Therefore results for the entire sample is reported. McNemar tests were used to check whether the balance variables (ordinal data) changed from pre-test to posttest in either of the two groups. The alpha level of significance for all analyses was set at $p<0.05$.

Chapter Four

Results and Discussion

The following were the results of this study, based on an analysis of the data collected.

Descriptive Data

The sample consisted of 18 subjects of whom nine were in the experimental group and nine in the control group. Table 4 is a summary of the descriptive data.

Table 4

Descriptive data for the subjects participating in the study

Variable	**Experimental group (n = 9)**				**Control group (n = 9)**			
	Pre-tet		**Post-test**		**Pre-test**		**Post-test**	
	Mean	**SD**	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**
Golf Skill								
Dist - acc	17.72	16.34	25.13	18.09	25.49	21.76	21.55	25.39
Flight	1.16	0.64	1.84	1.24	1.43	0.72	1.0	0.68
Postural Variables: Core Stability								
Leg lifts	7	11	15	12	8	12	7	12
Walkouts	13	7	22	8	15	9	16	9
Med ball throw	7.01	1.04	6.83	1.71	7.8	1.78	6.47	1.36
Consistency in Posture								
Knee diff	1.62	9.1	0.91	1.4	0.32	8.85	0.88	4.93
Body diff	4.22	3.21	0.92	2.45	0.76	9.15	0.8	11.7
Postural Variables: Balance								
Balance	**Best**	**Worst**	**Best**	**Worst**	**Best**	**Worst**	**Best**	**Worst**
	2	2	3	3	1	0	0	0

A comparison of scores for all the variables between the experimental group and the control group at the beginning of the study was done to determine whether or not there were significant differences between the two groups with regards to any of the variables before the intervention programme was started. An independent t-test was used to determine this. Table 5 displays the results of the independent t-test comparing the pre-test variable scores of the two groups. As expected, there were no significant differences between the scores of the two groups at the beginning of the study.

Table 5

Comparison of pre-test scores of the experimental and control group at the beginning of the study

	t-test for Equality of Means		
	t	df	Sig. (2-tailed)
distance	-0.705	16	0.491
	-0.705	15.303	0.491
accuracy	0.346	16	0.734
	0.346	14.560	0.734
distacc	-0.856	16	0.405
	-0.856	14.846	0.405
flight	-0.832	16	0.418
	-0.832	15.752	0.418
medball	0.257	16	0.801
	0.257	12.885	0.801
leglifts	-0.262	16	0.797
	-0.262	15.921	0.797
walkouts	-0.320	16	0.753
	-0.320	15.482	0.753
bknee	0.153	16	0.880
	0.153	15.158	0.880
wknee	-0.476	16	0.640
	-0.476	15.651	0.640
bbody	1.320	16	0.205
	1.320	13.109	0.209
wbody	0.456	16	0.655
	0.456	15.970	0.655

The following four sections are organised to answer each Research Question. Graphs are used as the primary method of presentation. A table of the raw data used to generate these graphs is presented in Appendix C.

Research Question One

Were there any changes in the postural variables of core stability as measured by leg lifts, walkouts and medicine ball throw following a six-week intervention programme?

The results of this study demonstrated that a golf-specific postural development programme can be an effective modality for improving the core stability of female novice golfers.

A repeated measures ANOVA (Analysis of Variance) was done for each of the core stability variables in order to determine whether the experimental group improved their core stability after following a golf-specific posture programme for six weeks. The test was repeated for the control group. Figures 1 to 3 graphically present the results of this repeated measures ANOVA. The experimental group significantly improved their core stability as measured by leg lifts ($p = .00003$), walkouts ($p = .00251$) and medicine ball throws ($p = .01793$), whereas the control group experienced no significant improvement in any of the core stability variables.

One-minute Modified Lying Leg Lifts

There was a significant improvement in the score for the one-minute lying leg lifts of the experimental group (from 7 on the pre-test to 15 on the post-test), while there was a decrease in score for the control group (from 8 on the pre-test to 7 on the post-test).

This test measures core strength. Core strength in the golf swing is critical as it provides trunk stability. Trunk stability is essential for maintaining proper posture and achieving properly coordinated movements during sports (Cosio-Lima, 2003). Well conditioned core muscles also provides a stable base from which to swing as well as helping to maintain proper spinal alignment throughout the swing (Chek, 2001). According to Horton (2001) poorly conditioned core muscles is a major risk factor for the development and occurrence of chronic low back pain in golfers. Watkins et al. (1996) supported this by finding that well conditioned trunk muscles are critical for injury prevention as well as power generation. Therefore, the intervention programme in this study was effective in strengthening the core muscles, which provides the golfer with a better base to swing from, generate more power during the golf swing and decreasing risk of injury (especially the lower back).

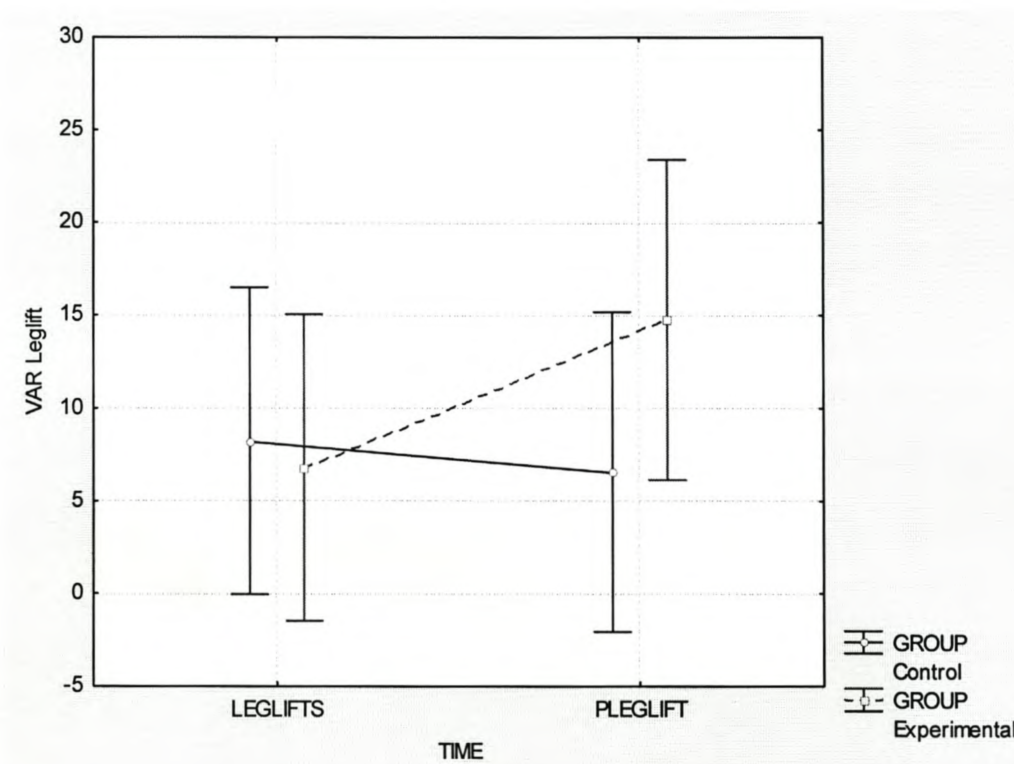

Figure 3

Comparison between the leg lift scores of the experimental group and the control group before and after the intervention programme

One-minute Walkouts

There was a significant improvement in the score for the one-minute walkout of the experimental group (from 13 on the pre-test to 22 on the post-test), while there was no significant improvement for the control group (from 15 on the pre-test to 16 on the post-test). Like the one-minute leg lift, this test is also a measure of core strength.

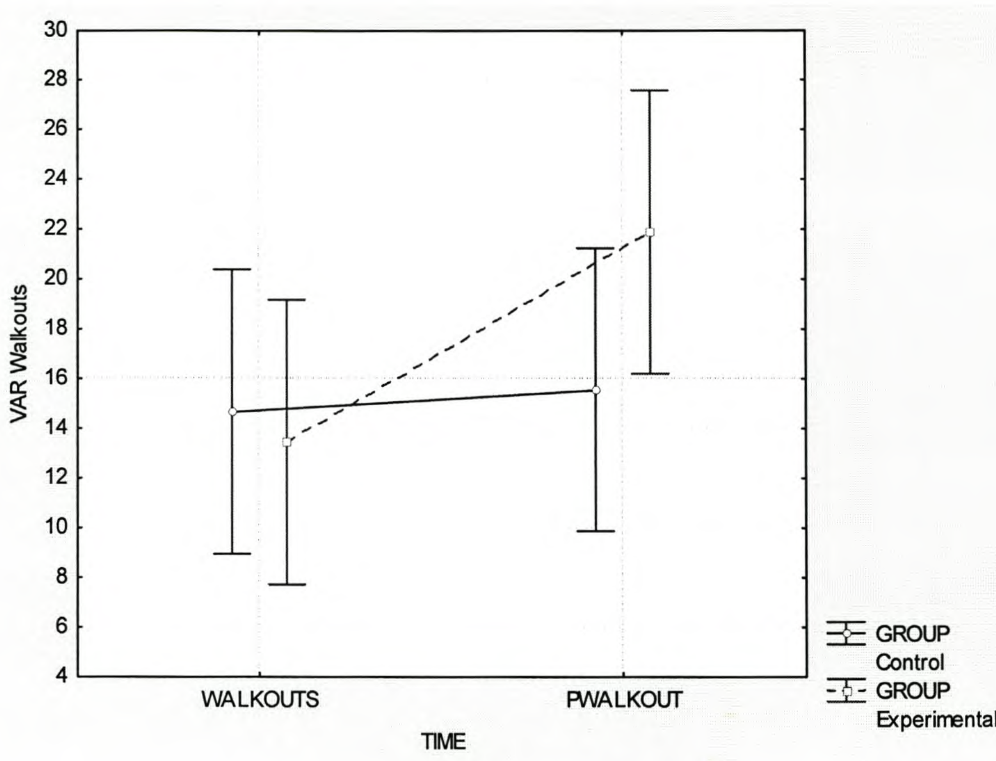

Figure 4

Comparison between the walkout scores of the experimental group and the control group before and after the intervention programme

Overhead Medicine Ball Throws

There was a significant improvement in the score for the overhead medicine ball throw of the experimental group (from 7.01m on the pre-test to 7.8m on the post-test), while there was a decrease in score for the control group (from 6.83m on the pre-test to 6.47m on the post-test).

This test measures power and coordination. Power in golf is critical for driving distance. The more power golfers can transfer from their bodies to the club the greater their driving distance will be. Proper coordination between all the muscles involved in the golf swing is also critical as this will assist in maximum power being transferred from the golfer's body to the ball as well as assisting in injury prevention. Of course, in order to develop golf-specific power, exercises must have a similarity to the game of golf (Chek, 2001). As can be seen from these results, the practice activities in the intervention programme were at least successful in improving power. The experimental group improved significantly with regards to overhead medicine ball throws.

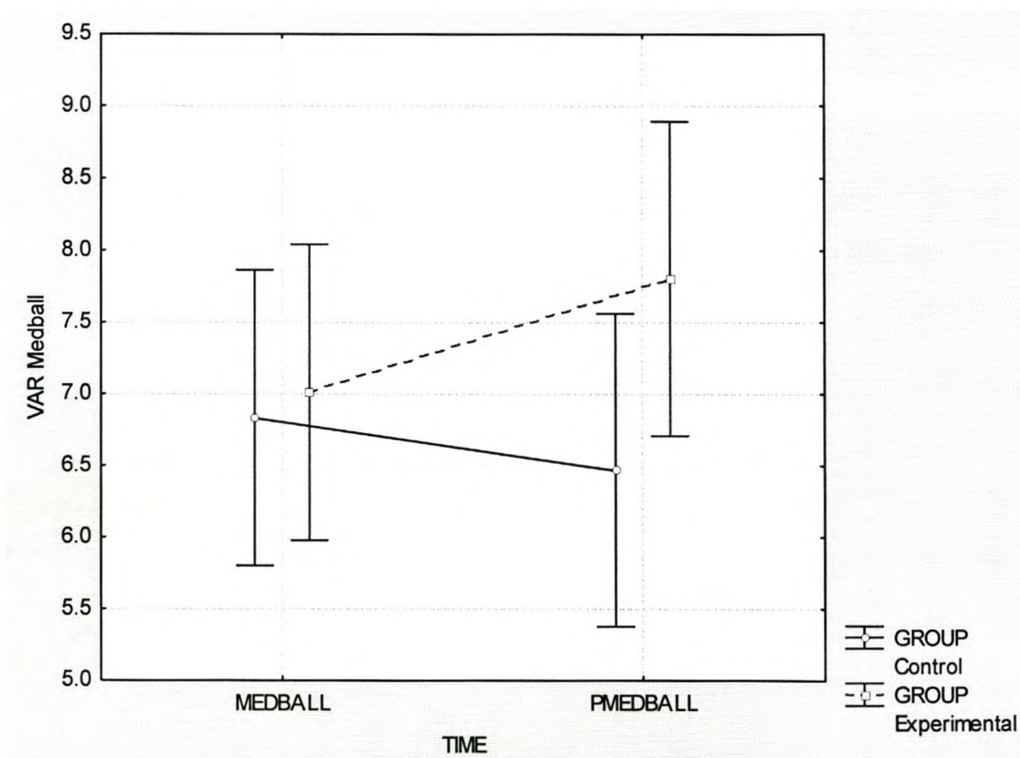

Figure 5

Comparisons between the overhead medicine ball throw scores of the experimental group and the control group before and after the intervention programme

Research Question Two

Were there any changes in static balance, as measured by posture at address position, following a six-week intervention programme?

The results of this study demonstrated that female novice golfers did not show any significant changes with regard to balance in the address position, following a six-week golf-specific posture programme (see Table 6). McNemar tests (suitable for ordinal data) were used to determing whether the balance variables changed from pre-test to post-test in either the experimental group or the control group. The results indicated that neither the experimental group nor the control group experienced any significant changes. In fact, there was absolutely no change in the worst balance post-test score compared to the pre-test score of the control group.

Table 6

The results of a McNemar test to indicate whether the balance variables of the experimental group changed from pre-test to post-test

Test Statistics[b,c]

	bBalance & pbalance	wbalance & pwbalance
N	9	9
Exact Sig. (2-tailed)	1,000[a]	1,000[a]

a. Binomial distribution used.

b. McNemar Test

c. Group = 1,00

Research Question Three

Were there any improvements in consistency of posture, as measured by the change in knee angle as well as change in body angle, over a period of hitting 20 golf balls following a six-week intervention programme?

The results of this study demonstrated that the golf-specific posture programme in this study was not effective for improving consistency of posture in female novice golfers. A repeated measures ANOVA (Analysis of Variance) was done for each of the posture variables of knee angle and body angle, in order to determine whether the experimental group improved their consistency of posture. The test was repeated for the control group. Figure 4 and 5 graphically present the results of this repeated measures ANOVA test.

Although the experimental group experienced an improvement in consistency in posture as measured by knee angle (from 1.62° difference at pre-test to 0.92° difference at post-test) and body angle (from 4.22° difference at pre-test to 0.92° difference at post-test), the change was not significant.

In comparison, the control group experienced only small changes from pre-test to post-test (knee angle difference changed from 0.32° at pre-test to 0.88° at post-test, while the body angle difference changed from 0.76° at pre-test to 0.8° at post-test). However, there was a significant difference for the body angle variable when looking at the main effect - group. This means that the experimental and control groups were significantly different irrespective of time. In other words when the pre and post values are combined.

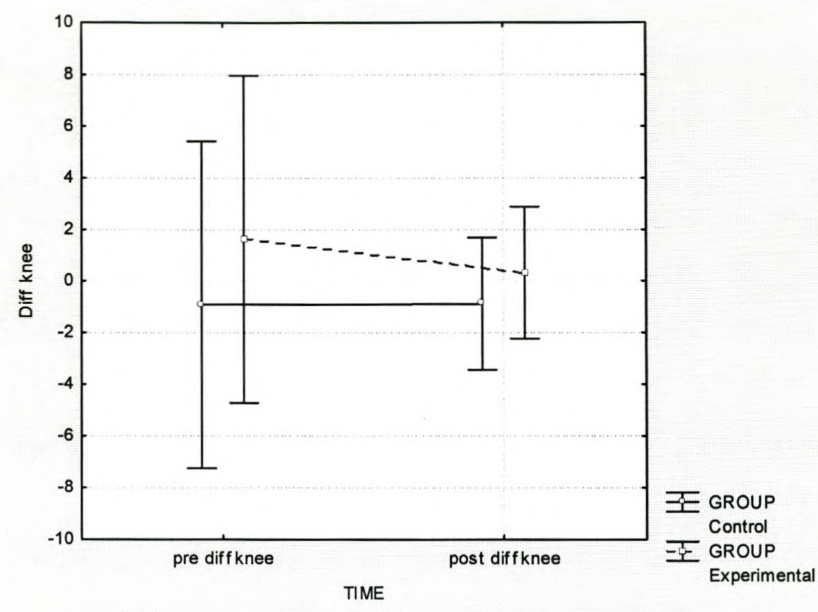

Figure 6

Pre- and Post-test comparisons between the knee angle difference between the best and worst shot of the experimental group and the control group.

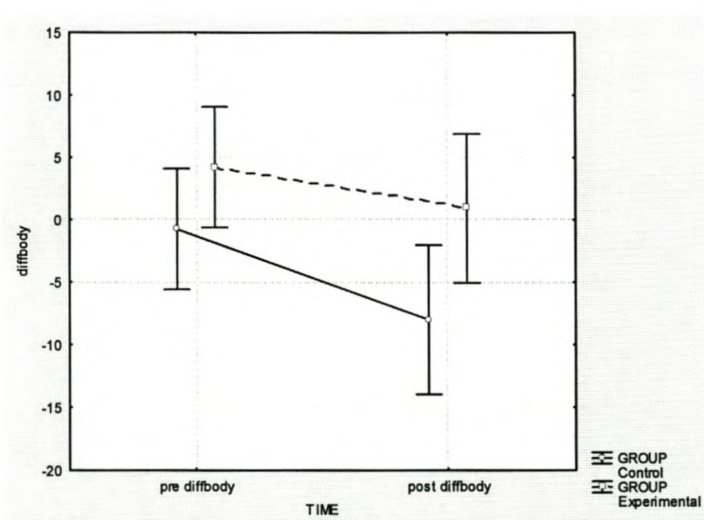

Figure 7

Pre- and Post-test comparisons between the body angle difference between the best and worst shot of the experimental group and the control group.

Research Question Four

Were there any changes in golf skill as measured by distance-accuracy and ball flight following a six-week intervention programme?

The results of this study demonstrated that female novice golfers achieved significant improvements in their 5-iron distance-accuracy by participation in a six-week golf-specific postural training programme. However, following this programme did not result in significant improvements in the ball flight of these golfers.

A repeated measures ANOVA (Analysis of Variance) was completed for both variables of golf skill (distance-accuracy and ball flight) as measured during the Benson Golf Test, in order to determine the effects of the intervention programme on the performance of the experimental and control groups. Figures 6 and 7 graphically present the results of the repeated measures ANOVA test for distance-accuracy. As can be seen from the results, the experimental group significantly improved their distance-accuracy score ($p = .0092$). The control group also experienced no significant improvement with regards to their distance-accuracy scores.

No significant changes were found for ball flight ($p = .077$) for either the experimental or the control group.

Distance-Accuracy

There was a significant improvement in the scores for distance-accuracy of the experimental group (from 17.72m on the pre-test to 25.13m on the post-test), while there was a decrease in score for the control group (from 25.49m on the pre-test to 21.55m on the post-test).

This test produces a combined score of distance and accuracy for each stroke. The manner of scoring adds to the validity of the test, because in golf, it is critical to be able to hit long straight and also straight shots. The intervention programme in this study can be regarded as successful because the experimental group achieved significantly improved distance-accuracy scores and the control group did not.

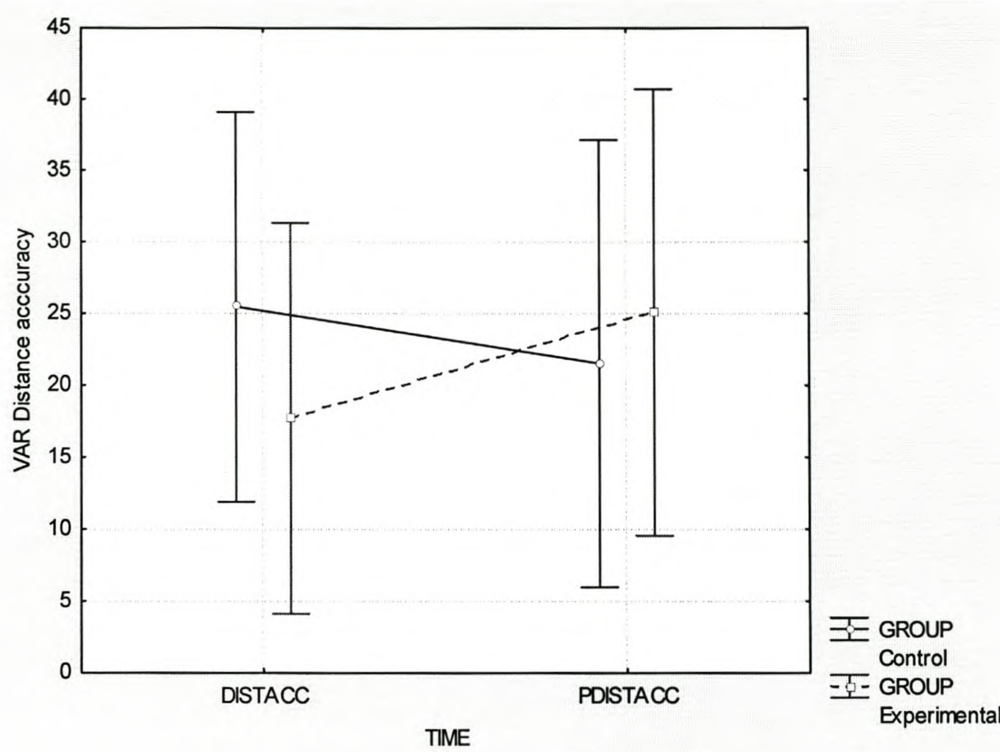

Figure 8

Comparisons between the distance-accuracy scores of the experimental group and the control group before and after the intervention programme

Ball Flight

Although the experimental group showed an improvement in ball flight scores (from 1.16 on the pre-test to 1.84 on the post-test), this improvement was not significant. The control group did not show any improvement in ball flight scores. In fact their scores decreased from 1.43 on the pre-test to 1.3 on the post-test.

The ball flight scores gives an indication of the consistency with which the clubface contacts the ball. Ball flight is a critical variable in determining what happens to the ball once it hits the ground after a stroke is taken. It is a critical variable in successful golf. The source of error for ball flight can be in the grip as well as the swinging pattern.

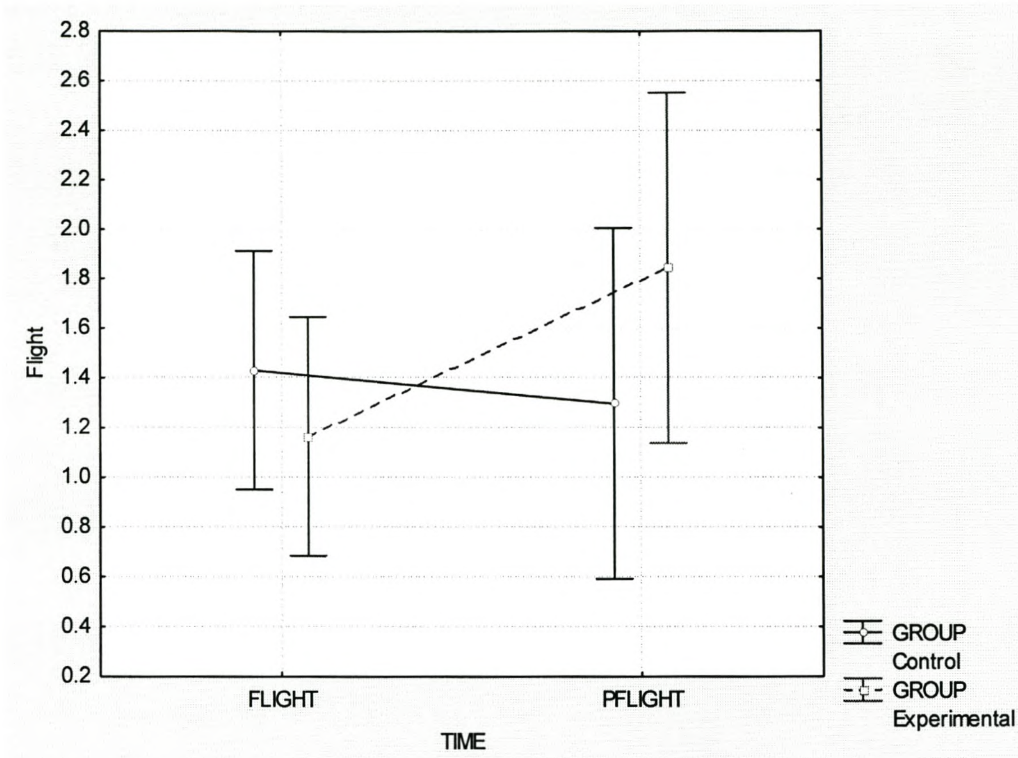

Figure 9

Comparisons between the ball flight scores of the experimental group and the control group before and after the intervention programme

Summary of Results and Discussion

The significant improvements achieved by subjects in the experimental group on the postural variables of core stability and golf skill (hitting distance and accuracy), indicate that novice golfers may benefit from a core stability training programme.

Because the experimental group also showed improvements with regards to the postural variables of balance and consistency, the researcher does not want to "give up" on the possibility that a training programme can be designed that will be able to assist novice golfers with the development of these variables. It is possible that ball flight, the variable of golf skill on which no significant improvement was achieved, may be affected by balance in the address position and consistence in body angle and knee angle during a stroke.

Chapter Five

Conclusions and Recommendations

A wide variety of research topics have been associated with the scientific study of golf. From as early as 1948, there have been studies on the mechanics of the golf swing, although according to Farrally et al. (2003), we are still a long way from fully understanding this complex movement pattern.

This study was focused on selected variables that contribute to postural control during the swing. Although the stated purpose of the study was to discover effective training strategies that would contribute to hitting distance, accuracy and ball flight, the benefits of optimal posture during sport performance have also been related to injury prevention, a critical area for future applications since there has been a steady an increase in the number of injuries to golfers (Theriault & Lachance, 1998).

Conclusions

By following a golf-specific training programme, it was hoped that novice female golfers would show an improvement in their postural control, as measured by their core stability, balance and static posture in the address position, and that these improvements would be accompanied by improvements in golf skill, as measured by ball distance, accuracy and flight. Although changes in balance, consistency in posture and ball flight were not significant for members from the experimental group, significant improvements were found with regards to core stability variables and the distance-accuracy of their 5-iron shot.

The impact of improvements in core stability may be linked to the generation of power in the swing, since core stability may be associated with a more effective and efficient transfer of forces from the legs through the trunk to the upper body. Core stability is also a postural variable because it is the core that is responsible for maintaining spinal angle, and therefore postural stability throughout the swing

(Draovitch & Westcott, 1999). The results of this study demonstrated that the training programme that was followed was effective in terms of improving core stability and power, as measured by improvements in the distance and accuracy of the shot.

The intervention programme also was not found to be effective with regards to improvements in balance in the address position. There are several possible explanations:

- The activities in the programme may not have been appropriate for the development of balance in the address position.
- The programme may have been too short in duration. A 15 or 20 week programme may have been more successful.
- The method of scoring balance was a "yes or no" determination made by comparing the subject's static posture with the ideal posture. This simple categorisation does not allow for degrees of improvement and there is some question that the ideal template does not allow consideration of individual body characteristics.

The intervention programme also was not found to be effective with regards to improvements in consistency in posture in the address position.

- The method for measuring the postural variables may have been too insensitive. For example, an alternative way of measuring posture might have been to analyze the posture for each of the 20 shots and to get the average posture over all 20 shots and to compare the average of the pre-test result with the average of the post-test result. This could have given a better indication of the subjects' ability to maintain a consistent posture, rather than comparing the "best shot" with the "worst shot."

The training programme followed in this study took into account that postural muscles function more for endurance than for strength or power. This led to decisions about the selection of the exercises within the programme, as well as the decision to keep the repetitions high. This was considered appropriate because muscle endurance rather than strength or power, is the primary physical demand on musculature when maintaining posture during the golf swing.

- The goal of the Day One activities in each week was to improve postural control and balance. Exercises provided during this first day of the week were done with light weights and a high number of repetitions because postural muscles respond best to these type of exercises (Draovitch & Westcott, 1999). The muscles of the core were targeted because they are the key muscles in providing postural stability. Postural stability in turn should allow the golfer to maintain the optimal spinal angle throughout the swing. Optimal spinal angle is central for improving consistency in golf. A strong core has the added benefit of allowing more effective transfer of forces from the legs to the upper body, which in turn should lead to longer drives.

  Balance exercises were included in Day One activities, because poor balance can contribute to a poor shot, especially from an imperfect lie (e.g. uphill, downhill, etc.). A combination of poor balance and inability to maintain the proper spine angle throughout the swing increases the probability of a poor shot, and logically could increase the likelihood of injury.

- The goal of the Day Two activities was to increase core strength and power. Exercises in the strength workout incorporated general and specific exercises in order to achieve optimal results. A resistance was selected that allowed the subject to complete the given number of repetitions only if they could maintain proper form. In other words, they had to stop the exercise if they began to lose form. Due to the heavier weights repetitions were kept short. According to Draovitch and Westcott (1999), following a progressive strength training programme enhances the contraction capacity of the muscles, thereby increasing the potential to create force.

- The overall goal of the six week programme was to provide some innovative and functional activities that would produce benefits that would transfer to golf performance. Therefore, exercises were often done with subjects standing in the golf address posture. Swiss ball training was designed to increase the proprioceptive demands of actions that stressed the core muscles that are important for balance and stability in sport (Cosio-Lima et al. 2003).

Although the researcher did attempt to customise the exercises and feedback to subjects in the experimental group during exercise sessions, it was necessary for standardisation purposes to follow a similar pattern for all subjects. For example, all subjects were provided with a progression in their programme every two weeks.

- The set-pace for progressions might be one of the reasons why there was not a significant improvement in posture for the experimental subjects, as those who started off at a higher level than the others had to wait two weeks before the progression was introduced.

- It is possible that some of the weights used in the exercises may have been too light of some of the participants. If this were the case, it may have contributed to the fact that no significant changes were found with regards to either balance or postural consistency for the experimental group.

Recommendations

In view of the conclusions drawn as a result of the investigation, the following recommendations are made:

1. The number of subjects in the present study was a limitation, which makes it difficult to generalise broadly from the results. A similar study with more subjects would be needed to confirm the results of the present study.

2. It would have been preferable to have one-on-one supervision of each subject during the training sessions, since specific correction of posture is difficult when working in groups.

3. Although the idea of having subjects observe the technique of their training partner for key points in performance was intended to increase the subjects' understanding of the exercises, cognitive development was not a formal part of the programmes. No literature on cognitive involvement in training was reviewed. This is an interesting feature to introduce into training, and deserves formal investigation.

4. According to Dawes (2005) to hit a golf ball consistently and effectively requires a blend of dynamic flexibility, neuromuscular coordination, strength and power. If a golfer lacks an adequate level of any one of these traits, performance will be affected negatively. Although an effort was made to make the exercises functional and specific to golf, no effort was made to help them on the driving range or on the golf course. A study where a group follows an exercise programme as well as golf instruction training, compared to an exercise-only group and a golf-instruction only group, should be considered should be considered as a follow up to this research.

5. The posture of an adult is a habit. If muscle imbalances have occurred or abnormal postures have been maintained, musculature will have compensated. In this process, poor postural habits and a pre-disposition to injury may already have been created. Correcting errors or weaknesses in posture take time and concentrated effort. If the current study were repeated, but for a longer period of time, significant results with regards to posture consistency might be achieved. In the current six-week study, the trend toward improvement was observed, but these changes were not significant. Another suggestion is to repeat the research, keeping the length of the programme the same but changing the intervention strategies and/or the methods for measuring postural variables.

6. It would be very interesting to repeat the current study with intermediate as well as elite golfers and to compare the improvements made by to each of those groups, with those of the novice golfers. It is suspected that no significant improvements will be made with regards to postural consistency of intermediate and elite golfers, since their postural habits would be even more ingrained that for the novice golfers. However, potential small improvements in posture might lead to improvements in golf skill, and certainly core stability and balance improvements might be possible.

7. A similar study using both females and males is recommended to see how males respond to training. Differences in centre of gravity and/or initial core strength or power, for example, might call for either a different training programme or produce different results.

8. During the present study, progressions for the whole group were introduced every two weeks. It is recommended that the rate and challenges in progressions be individualized for every subject. This more customized approach might lead to more significant improvements in performance.

9. Finally, research focused on fewer variables might provide more definite guidelines for future training of golfers. For example, a core stability training programme by itself, would have narrowed the scope of the programme and allow more specific conclusions about the impact of core stability training on golf skill, posture, etc.

Final Remarks

The innovative postural development strategies presented as the intervention programme in this study were functional, but they did not offer a holistic approach to improving golf performance. Performance itself is integrated, and it is logical that more integrated training with a functional emphasis would transfer more positively to sport than a unilateral training programme would.

The role of core stability in the 5-iron shot was demonstrated, and this has immediate applications for golf instructors who work with novices. The functional fitness of any novice in any sport can be a constraint on their ability to learn a new skill. It is recommended that golf instructors incorporate ways to improve the core stability of novices even as they work on their acquisition of golf skills.

Certainly, this study demonstrated that an effective core stability programme can be implemented that uses minimal and inexpensive equipment, including Swiss balls, medicine balls, elastic bands, dumbbells, skipping ropes, foam pads, golf balls, frisbees, golf clubs and baseball bats. This means that innovative training does not have to mean expensive training, and that even persons with minimal financial resources can gain access to training activities that will help them improve their performance.

Gary Player is famous for his devotion to physical training. His was always aware that his ability to swing a golf club was directly dependent on his body's physical ability to apply what he had learned. By improving one's cores stability, the golfer creates the potential for power in his/her swing. A functional core stability training programme can help develop this potential.

By improving one's posture, the golfer creates a consistent and stable base from which to swing ball after ball. Poor posture at address will lead to poor posture throughout the entire swing, which decreases the chance of hitting a good shot. This study was not able to deliver a succesful golf-specific postural training programme, however some improvements in hitting distance and accuracy were achieved, which provides support for efforts to continue the search for functional training programmes that can complement and accelerate improvement in golf performance.

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Appendix A

Test Score Sheets

Core stability score sheet

Name: Date:

Tel no: Experimental/Control

Group

Overhead medicine ball throw (2 hand – directly backward)

3 kg medicine ball	Distance (m) – pre-test	Distance (m) – post-test
Throw 1		
Throw 2		

One minute Modified Lying Leg Lift (legs remain bent at 90°)

Leg lifts in one minute – pre-test	
Leg lifts in one minute – post-test	

One minute walkout test

No of walks in one minute – pre-test	
No of walks in one minute – post-test	

Benson Golf Test

Name: ____________________________ Date: ______________

Marker: ____________________________ Ball flight judge: __________

Ball	Distance	Accuracy	Dist -Acc	Flight	Body angle		Knee angle		Balance	
					Best	Worst	Best	Worst	Best	Worst
1										
2										
3										
4										
5										
6										
7										
8										
9										
10										
11										
12										
13										
14										
15										
16										
17										
18										
19										
20										
Total										
Ave										

Consent

The results from this testing procedure can reveal some of your physical strengths and weaknesses. In order to permit the tester to compile a summary of your capabilities your complete co-operation and compliance is essential. The results from your test are completely confidential and only the personnel directly involved in the testing will have access to these records.

- I hereby give my written consent to Mario Olivier to conduct the respective tests.
- I indemnify Mario Olivier and all testers involved against any injury or damages, which might stem from my participation.

Participants signature: .... Date: ....

Appendix B

Sample Training Programmes

Example of Weeks 3 & 4:   Day 1 programme.

Day 1: Posture and balance training			
Exercise	**Weight**	**Sets**	**Repetitions**
Step ups/skipping		1	2 min
Swiss ball lower body rotation		2	15
Swiss ball side flexion (hold position)		2	1 min
Swiss ball kneeling		3	1 min
Swiss ball Russian twist		3	15
Swiss ball back extension		3	15
Stork stands (closed eyes)		3	1 min
Wobble boards		2	1 min
Seated chop		3	15
Seated lift		3	15
Eccentric abs (legs pushdowns)		3	15
Heavy baseball swing (slow response)		2	20 swings
Light golf club swing (slow response)		2	20 swings
Heavy baseball swing (short response)		2	20 swings
Light golf club swing (short response)		2	20 swings
Frisbee in hands with marbles		2	15
Golf ball toss to target		2	10

Example of Weeks 3 & 4: Day 2 programme.

Day 2: Strength and Power			
Exercise	**Weight**	**Sets**	**Repetitions**
Step ups/skipping		1	2 min
Dead lifts		3	10
Underhand medicine ball throws		3	10
Walking lunges + rotation (with med ball)		3	10
Dumbbell bench press (on swiss ball)		3	10
Chest pass (standing in golf posture)		3	10
Single leg pelvic lifts		3	10
Dumbbell squats (hands above shoulders)		3	10
Standing rows (with elastics in golf posture)		3	10
Flat cross extensions		3	10
Rotator cuff isometrics		3	10
Medicine ball side pass		3	10
Bankies: hip abduction		3	5
Bankies: hip adduction		3	5
Calf raises (a, b, c)		2	10
Dumbbell curls (conc)		2	10
Dumbbell overhead tricep extension (conc)		2	10
Dumbbell curls (ecc)		2	10
Dumbbell overhead tricep extension (ecc)		2	10
Wrist curls		3	10
Reverse wrist curls		3	10
Wrist pronaton/supination		3	10

Example of Weeks 5 & 6: Day 1 programme.

Day 1: Posture and balance training			
Exercise	**Weight**	**Sets**	**Repetitions**
Step ups/skipping		1	2 min
Swiss ball lower body rotation		2	15
Swiss ball side flexion (hold position)		1	2 min
Swiss ball kneeling		3	10 golf swings
Swiss ball Russian twist with med ball		3	15
Swiss ball back extension		3	15
Stork stands + golf swing		3	15
Wobble boards with golf club (set up + top of backswing)		2	1 min
Seated chop		3	15
Seated lift		3	15
Eccentric abs (legs pushdowns)		3	20
Bosu - Heavy baseball swing (slow response)		2	20 swings
Bosu - Light golf club swing (slow response)		2	20 swings
Bosu - Heavy baseball swing (short response)		2	20 swings
Bosu - Light golf club swing (short response)		2	20 swings
Frisbee in hands with marbles		2	15
Golf ball toss to target		2	10

Example of Weeks 5 & 6: Day 2 programme.

Day 2: Strength and Power			
Exercise	**Weight**	**Sets**	**Repetitions**
Step ups/skipping		1	2 min
Dead lifts		3	12
Underhand medicine ball throws		3	12
Walking lunges + rotation (with med ball)		3	12
Dumbbell bench press (on swiss ball)		3	12
Chest pass (standing in golf posture)		3	12
Dynamic hammies		3	12
Dumbbell squats (hands above shoulders)		3	12
Standing rows (with elastics in golf posture)		3	12
Flat cross extensions		3	12
Rotator cuff isometrics		3	12
Medicine ball side pass		3	12
Bankies: hip abduction		3	8
Bankies: hip adduction		3	8
Calf raises (a, b, c)		2	12
Dumbbell curls (conc)		2	12
Dumbbell overhead tricep extension (conc)		2	12
Dumbbell curls (ecc)		2	12
Dumbbell overhead tricep extension (ecc)		2	12
Wrist curls		3	12
Reverse wrist curls		3	12
Wrist pronaton/supination		3	12

Raw data of the pre-test core variables of the experimental group.

Name	Med ball throw	Leg lifts	Walkouts
Subject A	6.22	0	12
Subject B	7.75	5	15
Subject C	7	1	4
Subject D	7.01	3	28
Subject E	6.12	1	10
Subject F	7.55	3	10
Subject G	6.9	3	11
Subject H	5.5	9	9
Subject I	9.04	36	22
Group Ave	**7.01**	**6**	**13**
Group SD	**1**	**11**	**7**

Appendix C

Raw Data

Raw data of the pre-test postural variables of the experimental group.

Experimental group																
Name	**Knee angle**						**Balance**				**Body angle**					
	Post programme			**Pre programme**			**Post**		**Pre**		**Post programme**			**Pre programme**		
	best	worse	**diff**	best	worse	**diff**	best	worse	best	worse	best	worse	**diff**	best	worse	**diff**
Subject A	164.3	163.6	**0.7**	175.2	165.3	**9.9**	N	N	Y	N	133.7	131.1	**2.6**	141	135.2	**5.8**
Subject B	163.4	163.4	**0**	172.6	189.1	**-16.5**	N	N	N	Y	136.2	137.8	**-1.6**	149.4	151.8	**-2.4**
Subject C	164.7	163.1	**1.6**	172.1	163.7	**8.4**	N	N	N	N	139.5	140.3	**-0.8**	139.5	131	**8.5**
Subject D	164.7	165.3	**-0.6**	159.1	163.5	**-4.4**	N	N	N	N	152.2	152.5	**-0.3**	144.7	140.3	**4.4**
Subject E	156.5	157.3	**-0.8**	159.2	157.2	**2**	N	N	N	N	123.4	123.1	**0.3**	134.2	130.2	**4**
Subject F	165.1	161.8	**3.3**	180	167.5	**12.5**	Y	Y	Y	N	147.6	141.7	**5.9**	151.4	144.4	**7**
Subject G	168.2	169	**-0.8**	170.1	162.8	**7.3**	Y	Y	N	N	134.3	132.2	**2.1**	142.4	136.5	**5.9**
Subject H	155.6	155.2	**0.4**	157	160.4	**-3.4**	Y	Y	N	Y	121.8	120	**1.8**	130.2	127.3	**2.9**
Subject I	165.1	166	**-0.9**	173.4	174.6	**-1.2**	N	N	N	N	136.1	137.8	**-1.7**	156.3	154.4	**1.9**

Raw data of the pre-test golf skill variables of the experimental group.

	Distance			Accuracy			Distance - Accuracy			Ball flight		
Name	**Ave**	**SD**	**Median**	**Ave**	**SD**	**Median**	**Ave**	**SD**	**Median**	**Ave**	**SD**	**Median**
Subject A	16.03	20.93	7.34	3.05	4.94	0.59	12.98	17.93	6.39	1.00	0.93	1
Subject B	53.84	32.84	50.91	9.66	6.91	9.58	44.18	27.13	37.75	1.90	0.74	2
Subject C	9.52	8.94	7.58	2.76	4.05	1.06	6.75	5.72	5.03	0.80	0.56	1
Subject D	3.14	3.50	2.40	0.86	1.24	0.25	2.28	2.97	0.84	0.60	0.51	1
Subject E	14.76	22.48	3.65	1.71	3.00	0.67	13.05	20.34	2.92	0.87	0.92	1
Subject F	52.52	39.14	37.59	7.64	7.10	4.10	44.88	35.91	29.81	2.27	0.88	3
Subject G	1.68	3.02	0.00	0.18	0.45	0.00	1.50	2.85	0.00	0.27	0.46	0
Subject H	23.82	20.46	21.50	9.52	8.50	9.60	12.98	17.93	6.39	1.33	0.65	1
Subject I	24.70	24.42	16.96	3.80	4.37	1.92	20.90	20.30	14.98	1.44	0.88	1
Group Ave	**22.22**	**19.53**	**16.44**	**4.35**	**4.51**	**3.09**	**17.72**	**16.79**	**11.57**	**1.16**	**0.72**	**1.22**
Group SD	**19.26**	**12.44**	**17.51**	**3.65**	**2.70**	**3.88**	**16.34**	**11.22**	**13.46**	**0.64**	**0.19**	**0.83**