The effects of improving fitness characteristics on overall performance in junior golfers

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Abstract

The game of golf is constantly evolving and elite players now use a number of strategies to maximize performance. One of these approaches is an increased focus on physical conditioning including resistance training. This has led to the suggestions that amateur and junior golfers may also benefit from physical conditioning.

Analysis of golf reveals that there is substantial physiological demand placed on the body in order to repeat a consistent and accurate high-speed golf swing. Junior golfers are potentially susceptible to poor golf swing mechanics and potential risk of injury if they lack the required strength and mobility to produce and control force and maintain posture during the golf swing.

Therefore the purpose of this research was to 1) establish what has been published in the literature relating to strength and conditioning programs designed to improve golf-related fitness characteristics and golf performance, and 2) design and evaluate a 12-week resistance-training program for adolescent golfers designed to enhance strength characteristics and golf performance.

The findings from the review suggest that strength and conditioning programs can have a positive effect on the golf swing and fitness characteristics. However there is large gap in regards to the development of junior golfers. As golf is a high skill sport, habits formed during the development years can impact performance both positively and negatively at a later stage, which can influence long-term success in the sport.

The intervention study used a quasi-experimental design where junior golfers (n= 30) were recruited and allocated to either an intervention (n = 20) or a control (n = 10) group for the 12-week study period. Sessions were ran twice a week for the intervention period with each session focusing on the full body and including exercises that utilised body weight and/or elastic resistance apparatus. Physical assessments consisting of single leg squat, modified push-ups, side bridge hold, sit and reach, and shoulder mobility were conducted at baseline and 12-weeks. Individual handicap was used as a measure of on-course golf performance.

The intervention resulted in strength increases with all variables showing high to moderate effect sizes ($d = 0.64$ to $0.96$). There was a moderate reduction in golf handicap for the intervention group ($d = 0.42$). Therefore showing resistance training programs can positively affect strength characteristics in junior golfers, which may influence golf handicap.
This is one of the first studies to investigate the effects of resistance training on junior golfers’ fitness and performance. This study found that an entry-level resistance-training program is beneficial to junior golfers with no prior resistance training. Future studies are needed to examine the effects of more advanced training programs for golfers with more resistance-training experience. Further investigation of the relationships between increases in physical fitness and a range of golf performance measures is also required. Also, investigation is necessary to establish physical fitness parameters for junior golfers and the impact this has on performance. Best practice in terms of strength and conditioning programs for the junior golf athlete is yet to be established and requires further investigation.
Preface

Results from this dissertation have been published in scientific journals as well as presented at a scientific conference.

Publications

Peer reviewed papers


Smith, C. J., Callister, R., & Lubans, D. R. The effects of resistance training on junior golfers’ physical and on-course performance (Currently under review by the International Journal of Golf Science)

Abstract of paper presented at conference

Statement of Declaration

I hereby certify that this thesis is submitted in form of a series of papers of which I am a joint author. I have included as part of the thesis a written statement from each of the co-authors: and endorsed by the Faculty Assistant Dean, attesting to my contribution to the joint publications.

(Signed).........................................................

Christopher John Smith

Co-Authors Statement

I Robin Callister and David R Lubans, attest that the Research Higher Degree candidate Christopher J Smith contributed to the publications outlined below.

(Signed).........................................................

Professor Robin Callister

(Signed).........................................................

Associate Professor David R Lubans
Statement of Candidates contribution

The author conducted the analysis for the systematic review; designed, co-ordinated and conducted the assessments and training sessions for the intervention study, analysed the data, drafted the manuscripts and wrote chapters 1 and 4 of the Masters thesis.

The role of both supervisors (co-authors) with regards to the published paper and manuscript under review presented in this thesis is outlined below:

Christopher Smith conducted all research and data analysis and wrote both manuscripts.

Professor Robin Callister provided guidance and assisted with project design. Robin also provided numerous comments and was involved in the editing process during the preparation of the two manuscripts.

Associate Professor David Lubans provided guidance and assisted with project design. David also provided numerous comments and was involved in the editing process during the preparation of the two manuscripts as well assisting with the statistical analysis.

Overall the work for this thesis was undertaken in collaboration with supervisors as well as the contributions of graduate research assistants who assisted with the collection of data (physical assessments under my direct supervision). The works for publication include the following:


Smith, C. J. (70%), Callister, R. (15%), & Lubans, D. R. (15%). (Currently under review by the International Journal of Golf Science) The effects of resistance training on junior golfers’ physical and on-course performance (see Chapter 3)
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To my supervisors Robin and David – I really cannot thank you enough for your time, effort and patience. This has been a very long process due to a number of unforeseen circumstances but the guidance and knowledge is second to none and I am forever grateful for that.

I would also like to thank Belmont Golf Club junior committee and the Central Coast Academy of Sport for their assistance through the intervention study, this work would not be possible without your involvement.

Finally to my wife and family, thank you for having the patience to support me through this process, I really cannot thank you enough.
Chapter 1. Introduction

1.1 Background

I have a longstanding interest in the sport of golf. Following the completion of my degree in Health and Physical Education at the University of Newcastle in 2008, I have spent the last five years developing my expertise as a strength-and-conditioning coach for golfers. Unlike many sports, fitness training for golf is relatively new and has developed largely as a consequence of the success of a small number of professional golfers such as Tiger Woods, who incorporated fitness training into their golf training strategy. Scientific evidence for the effectiveness of strength and conditioning programs for golfers is in its infancy, and it was this lack of scientific base, particularly for junior golfers, that led me to embark on the project presented in this thesis.

1.2 Thesis aims and outline

The first aim of this project was to establish what has been published in the literature relating to strength and conditioning programs designed to improve golf-related fitness characteristics and golf performance. The second aim was to design, implement and evaluate a 12-week resistance-training program for adolescent golfers designed to enhance strength characteristics and golf performance.

It was hypothesised that the resistance-training program would enhance junior golfers’ strength qualities. It was also hypothesised that changes in foundation strength would be inversely associated with changes in golf handicap.

This thesis consists of four chapters. Chapter 1 provides an introduction and describes the study aims. Chapter 2 consists of a comprehensive literature review that looks at the outcomes and effectiveness of strength and conditioning programs for golfers as well as the study quality of previous studies. Chapter 3 describes the development, implementation and outcomes of an exercise-training program for junior golfers. Finally, Chapter 4 provides a
discussion of strength and conditioning for golfers, particularly junior golfers, bringing
together findings from the systematic review and project. It also discusses the limitations of
my research and makes suggestions for future projects and practical application.

1.3 Overview of Chapter 1

This chapter describes the nature and objectives of golf. It provides a perspective on the
physiological characteristics that contribute to success in golf, junior golf development and
briefly describes the potential benefits of conditioning programs for junior golfers. Finally, a
brief justification and significance of the project as well as the aims and hypotheses are
outlined.

1.4 What is golf?

Golf is an intermittent sporting activity that consists of substantial moderate paced walking,
interspersed with short periods of standing in golf posture and striking the golf ball, often
with high force, in a controlled manner, with the objective of landing the ball in a very
precise location. Successful golf performance is dependent on a golf swing that is highly
predictable for the required shot and provides for appropriate distance and direction
(accuracy)(1-3).

Golf is played outdoors on a course that usually consists of 18 holes (targets where the ball
must finish). Players progress from hole to hole, which vary in their distance apart and the
terrain encountered. Each hole is rated in a way that results in a recommendation for the
number of shots (hits of the golf ball) that is reasonable for a golfer to take to cover the
distance from the tee (starting point of first shot on each hole) to the end target for that
hole. The sum of the number of recommended shots for each hole results in a number for
the course as a whole and is described as par.
The aim of golf is to cover each hole and the course as a whole in the least number of shots. For elite professional and amateur players, the lowest total score for the tournament (usually four rounds of 18 holes of golf) wins. For these golfers, performance can be monitored objectively over a season by an individual’s ranking, scoring average or money earned. For recreational golfers, the lowest gross or net (gross score minus handicap) wins the day’s event. For amateur (including recreational) golfers, success can be measured objectively by monitoring the change in their handicap. Handicap is a number that represents the average number of strokes relative to par the individual plays the course in; for example, having a handicap of 5 means that golfer averages 5 shots over par or a score of 77 on a par 72 course. Handicap is recalculated after every completed round in competition. As the individual player improves, their handicap will be reduced.

1.5 Overview of what contributes to successful golfing performance and how it can be monitored

Golf is a sport in which a wide range of factors contribute to success, including players’ motivation and arousal levels, weather conditions, ability of opponents, golf course set-up, technique, shot making ability, energy and fitness levels (4). Having the ability to minimise the effect of internal factors on performance is what separates the best players from the rest of the field. It is for these reasons that a holistic approach must be taken in order to improve golf performance. Six key areas must be considered when developing a player improvement program; i) Technical – the swing, ii) Tactical – the course, iii) Physical – the body, iv) Psychological - the mind, v) Personal - the individual, and vi) Professional – the golfer (2). A well-designed holistic program will address all of these areas, but may place greater focus on specific areas during different stages. For example, more emphasis will need to be placed on physical and technical development in junior golfers aged 13-18. This is due firstly to lack of physical development as well as it being the optimal time to begin physical development and work towards building a sound technique, but secondly the level
of mental maturity required to develop the other areas. Each developmental area clearly impacts on the other and must be developed if the individual is hoping to achieve ultimate success in golf (5, 6).

Although golf handicap is considered to provide an objective measure of success in golf for amateur players, other measures of performance are commonly used. One such method is the monitoring and collection of golfing sub-skill statistics during a round of golf (4) including driving, putting, chipping, pitching and iron accuracy. Information on total number of putts, driving distance and accuracy, and greens in regulation amongst many more can be gathered and analysed in order to review players strengths and weaknesses and monitor performance (4). During a round a player is required to hit a number of different types of shots including drives, iron shots, chipping and pitching and putting. The more proficient the player becomes in each of these areas the greater the potential the player has to hit lower scores and become a more successful golfer. This is clearly shown in the correlations between the statistical categories mentioned above and scoring average (4).

1.6 The importance of physical conditioning for golf

1.6.1 Physiological demands of golf

Golf may not appear to be the most physically demanding sport however careful analysis of the game indicates its physical demands are substantial. Golfers are on the course anywhere between 4-6 hours, and skilled golfers will make on average around 30-40 full swings and 30-40 short controlled shots (chipping/pitching putting) per round; in a tournament situation this is then repeated each day over a four-day period. The number of repetitions of the golf swing is then increased through practice whereby players hit numerous balls during skill refinement as well as during practice rounds when preparing for tournaments. The number of balls hit and time spent practicing is specific to the individual and will depend on what the particular player is working on and what form they are in.
During periods of play the distance walked is somewhat longer than the total measured length of the golf course; on average it is about 38% longer equating to approximately 8.5-10.5km with some studies reporting up to 72% more, which means walking up to 12km (6).

Table 1.1 was taken from Smith (6), where he collated the energy demands of golfers walking the course carrying their own bags for 18 holes from numerous references.

### Table 1.1: Physical demands of walking a golf course

<table>
<thead>
<tr>
<th>Performance Variable</th>
<th>Value/Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\text{VO}_2$ (mL/min/kg)</td>
<td>22.4</td>
</tr>
<tr>
<td>$\text{VO}_{2\text{max}}$ (%)</td>
<td>35-46</td>
</tr>
<tr>
<td>Heart rate response (beats/min)</td>
<td>95-120</td>
</tr>
<tr>
<td>$\text{HR}_{\text{max}}$ (%)</td>
<td>52.1-67.4</td>
</tr>
<tr>
<td>Ventilatory response (L/min)</td>
<td>50.8</td>
</tr>
<tr>
<td>Respiratory exchange ratio</td>
<td>0.87</td>
</tr>
<tr>
<td>Lactate response (mmol/L)</td>
<td>0.8-1.1</td>
</tr>
<tr>
<td>Total energy expenditure (Kcal)</td>
<td>960-1954</td>
</tr>
<tr>
<td>Energy expenditure (Kcal/min)</td>
<td>6.0-11.8</td>
</tr>
<tr>
<td>Distance covered in excess of course distance (%)</td>
<td>27-72</td>
</tr>
</tbody>
</table>

$\text{HR}_{\text{max}} = \text{maximal heart rate}; \text{VO}_{2\text{max}} = \text{maximal } \text{VO}_2; \text{VO}_2 = \text{oxygen uptake}.$

Reference: (6)

In comparisons to other sports, these results confirm that golf is not the most physically demanding sport, however it is the long duration of play that must be taken into consideration. These values would also change based on the environment of the course (e.g., number of hills). The more physically prepared a golfer is the less he/she will experience the negative effect of fatigue and therefore will be able to make better decisions and achieve optimal golf swing mechanics and on-course performance (6).

In a recent review, Smith (6) outlined the many physical and physiological components that can influence golf performance such as neurological function, proprioceptive response,
immune response, thermoregulatory response, peripheral fatigue processes, aerobic capacity/endurance, segmental mobility and stability, muscular strength and power, and body structure. All of these factors have the potential to impact on technical, tactical and mental performance (6). Importantly, all the factors above can be influenced by physical development and can potentially be trained. This suggests that improving physical fitness may improve golfing performance by developing an athlete that can endure long periods of play and practice, under stress and differing environmental conditions, and is resistant to fatigue, which is detrimental to performance.

1.6.2 The dynamics of the golf swing

The golf swing is a rotational and side-to-side movement. More specifically, it requires an element of trunk flexion (not spinal flexion), and spinal and hip rotation that causes the golfer’s centre of mass to shift slightly toward the trail leg on the back swing and then the lead leg during the downswing through impact and into follow-through (Figure 1.1) (7).

![Figure 1.1: Positions and movements of the golf swing](image)
1.6.3 Increasing driving distance

The modern game of golf has seen male and female athletes hitting the ball further. This has been the result of swing modifications brought about by changes in golf ball and equipment manufacturing, knowledge of biomechanics and the need to hit it further as a result of the golf courses being lengthening to cope with the changes in equipment. In 1997, the top ten players on the US PGA tour had a mean club head speed of 150km.h\(^{-1}\) with only some players reaching higher speeds. In comparison over the 2012 season the top ten players (money earners) had a mean club head speed of 185km.h\(^{-1}\) (8, 9). The player with the fastest club head speed on the US PGA tour for 2012 had a mean club head speed of 200km.h\(^{-1}\) and a mean ball speed of 297km.h\(^{-1}\), resulting in a mean driving distance (carry distance) of 288m (8). It is evident from these results that professional players over the years have been able to increase their ability to increase rotational angular velocities, which in combination with improved equipment has resulted in the ball travelling further. The golf swing has evolved over time to allow players to better utilise the stretch-shortening cycle and ground reaction forces (7). Players attempt to reduce the amount of pelvic rotation of their backswing but maximise torso rotation. This creates a resistance between the upper and lower body segments known as X-factor, which then allows for the storage of potential energy (7, 10, 11). This is then further stretched during transition of the backswing and downswing (X-factor stretch) whereby the downswing is initiated with the lateral shift in the golfers centre of mass towards the lead leg and unwinding of the hips, which then leads to a set sequence of accelerating and decelerating body segments in order the maximise angular rotational velocity peaking just prior to impact (7, 10, 11). The modern golf swing also maximises the use of ground reaction forces, as with all striking and throwing sports a projectile’s velocity is maximised when the athlete’s momentum is travelling towards the intended target (7). The trail leg is loaded in the back swing where the golfers centre of mass shifts slightly towards the trail leg resulting in more pressure through the trail foot, this then
shifts through transition of the backswing and downswing to the lead leg. Importantly, it is not only the magnitude of the pressure that is imparted on the ground but also the timing of how the pressure changes between the feet during the swing (7). It is important that the swing follows this set sequence of movements with correct timing, to allow for the utilisation of the ground reaction forces (GRF) and the muscles stretch-shortening cycle (SSC) leading to the summation of segmental velocities and the efficient use of the kinetic chain to produce force, which is then applied to the ball (12). Knowing how power and speed are produced in the golf swing allows training methods that enhance SSC and GRF utilised in other sports to be put in place to improve these qualities. Specific movement drills can be introduced in parallel to assist with the transfer of these adaptations to the golf swing, thus potentially enabling the golfer to increase their club head speed, ball speed and driving distance.

1.6.4 Physical characteristics and capabilities of skilled golfers

This set sequence of movements of loading and unloading of body segments has been shown to be vital for optimal swing mechanics and results in maximising club head speed and ball speed as well as decreasing shot dispersion (7). However for optimal kinematics or movement to occur, one must develop appropriate levels of joint mobility and stability, strength and movement patterns. If this does not occur then the individual golfer may develop movement compensations to make up for a particular physical limitation or poor swing concept resulting in ineffective swing mechanics and compromised ball striking as well as increasing injury risk. Research has shown through physical assessment that highly skilled players possess superior values of hip (gluteus maximus and medius specifically), trunk and shoulder strength; knee, pelvis, spine (specifically the lumbar spinal segment), scapula and elbow stability; and shoulder (glenohumeral), hip (coxal) joint and spinal (specifically the thoracic spinal segment) range of motion relative to lesser skilled players (Figure 1.2) (7, 13-15). Possessing higher values of these physical characteristics or what could be termed golf-
related physical characteristics (16), combined with good golf swing concepts and coordination is what allows highly skilled players to generate more controlled speed in the swing and as a result improve performance. Importantly all the physical variables mentioned above are trainable and therefore can be improved, strengthening the argument that golfers should be involved in physical preparation training when participating in a development program aimed at improving performance.

**Figure 1.2: Physical characteristics of a successful golf swing**

1.6.5 Injury prevention

During the golf swing, there are forces acting on the body which can be categorised into: downward compression, side to side bending and sliding, and back to front shearing (17). Downward compressive loads during the swing have been shown to be 8-times body weight (17). In addition, lead hip internal rotational velocities of 227.8 deg/s and trail hip external rotation velocities of 145.3 deg/s have been measured in higher skilled golfers during the downswing phase (18), whilst these are not as high as those seen in the throwing arm of baseball pitches, the golf swing is a closed chain skill whereby the foot stays fixed and the golfer rapidly rotates around the hip; this may be a potential injury mechanism to surrounding soft tissue (18). Also if the individual player lacks adequate hip and ankle
mobility they will be predisposed to knee problems. Due to these velocities and the transfer of the golfers centre of mass towards the lead leg in the downswing, the lead leg sustains large lateral and vertical compression forces (133N and 950N, respectively) and large rotary torques post impact (23Nm) (7). Therefore, the golfer experiences a high level of force throughout the swing showing that it is vital that the golfer is strong, has good stabiliser control, and is supple enough to endure and absorb these loads repetitively to avoid injury, especially around the spine and hips, but also the knees, shoulders, elbows and wrist considering most golf-related injuries are related to overuse (9, 17, 19). This is especially the case for the wrist, elbow and shoulder where the club comes into impact and strikes the ground; high loads are experienced frequently through these joints (9, 17). If the player does not have adequate stability around the scapular/glenohumeral joint or has poor patterning in their swing then the loads experienced through the downswing and impact cannot be absorbed or distributed efficiently, which combined with high numbers of repetitions predisposes these areas to injury.

Whilst lower skilled golfers show similar downward compressive forces to higher skilled golfers, the lower skilled golfers show higher rates of spinal lateral bending and shear loads, so together these forces increase the potential for a joint to break down under load (9, 17). This commonly occurs at the lumbar spine region, which accounts for 23.7-34.5% of all golfing related injuries (17). Studies have shown that golfers who experience low back pain have poor pelvic positioning (hyperlordotic), reduced hip rotational range of motion on the lead leg, thoracic spine rotation and trunk musculature strength (20-22). Therefore increasing hip, trunk and lower limb strength combined with improved pelvic control, hip (coxal) and thoracic mobility may assist in reducing the amount of lateral shift or sliding of the pelvis through the swing providing it is combined with good technical concepts, thereby reducing the degree of ‘crunch factor’ (lateral bend with axial rotation) in the lumbar spine
during the downswing (9), resulting in an improved rotation and club delivery position in the
downswing.

1.6.6 Summary

It is evident that golf professionals have become more athletic to maximise driving distance
and improve the ability to play and reduce the effects of fatigue. This is supported by the
literature with a number of recent reviews showing that physical conditioning can increase
club head speed and as a result improve driving distance (4, 6, 7, 16). As previously
described, the golf swing is a complex movement that involves the production of a large
amount of force in order to increase angular rotational velocity with precision, which is why
golfers should be involved in a well constructed strength and conditioning program to
develop: adequate joint mobility and stability, foundational movement efficiency and
competency, strength-endurance followed by max-strength then speed-strength utilising the
SSC and enhancing GRF whilst maintaining overall flexibility (23).

1.7 A perspective on the physical development of junior golfers

Research has shown that the process of excelling in any skill can take anywhere from 8-12
years; this is also known as the 10,000 hour or 10 year rule (24). In terms of golf, this does
not mean hitting thousands of balls from a young age, but rather building foundations that
will assist in skill/technical, tactical and physical development. The developmental pathway
or continuum is outlined in the long-term athlete development model (LTAD), which aims to
match longitudinal athlete development with biological and chronological development (24).
This model supports the need to develop sound foundations early and provides a framework
to assist in the progressive development of athletes (24-26). The model aims to
progressively build foundations by avoiding early emphasis on competition in order to better
prepare athletes for when competition really matters in the latter years of athletic
development, which for golfers would be elite amateur competition, tour school and professional tournaments. There are six stages, as follows:

**Table 1.2: Stages of the long-term athlete development model**

<table>
<thead>
<tr>
<th>Stage of development</th>
<th>Age bracket (y)</th>
<th>Training focus</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stage 1: Fundamental stage</td>
<td>6-9</td>
<td>Develop fundamental movement skill (FMS) competence</td>
</tr>
<tr>
<td>Stage 2: learning to train</td>
<td>8-12</td>
<td>Further develop FMS and begin sport skill development</td>
</tr>
<tr>
<td>Stage 3: training to train stage</td>
<td>11-16</td>
<td>Build aerobic and strength foundations</td>
</tr>
<tr>
<td>Stage 4: training to compete</td>
<td>15-17</td>
<td>Optimise fitness/ strength specific to the sports needs</td>
</tr>
<tr>
<td>Stage 5: training to win</td>
<td>17 &gt;</td>
<td>Maximise fitness/ strength specific to the sports needs</td>
</tr>
<tr>
<td>Stage 6: Retirement</td>
<td></td>
<td>Retain involvement in sport, (ie; coaching, administration etc)</td>
</tr>
</tbody>
</table>

Reference: (24-26)

These stages and what they encompass provide the framework for programs designed to improve an individual’s technical, tactical and physical development. Junior golfers should begin to build fundamentally sound skill and physical foundations early. Habits formed during childhood and adolescents strongly impact on skill, movement and physical capabilities during late adolescence and adulthood (27).

As children enter the game of golf they are encouraged to build competence in striking skills and develop their hand-eye coordination. As they progress they can begin to learn the fundamentals of the golf swing (grip, stance posture), which then progresses to skill refinement, including speciality shots, and the ability to compete and play under pressure (26). During this process junior golfers should be constantly improving fundamental movement skills which can be described as multi-joint, multi-directional and multi-plane
foundation movements such as squatting, lunging, pushing, pulling, rotating and bracing which form the base for all sports-specific skills (28). Building competence in these movements as well as developing sound sports-specific skills allows for the development of physical literacy which arms junior golfers with the neuromuscular processes required to adapt and continue to learn thus potentially improving athletic development and performance (24, 25, 28). As they age, junior golfers can begin to establish movement consistency whereby movement technique can be maintained as they develop strength-endurance and maintain or even improve mobility/flexibility and stability (29), as well as introducing golf movement related drills. It is not until the later stages of junior development, and once they have adequate physical competence, that more advanced physical development strategies such as max-strength and speed-strength development should be addressed as well as advanced sports-specific skills.
Chapter 2. Systematic literature review

2.1 Overview of chapter 2 - Systematic literature review

As part of my project, I conducted a systematic literature review titled “A systematic review of strength and conditioning programs designed to improve fitness characteristics in golfers”. The primary aim of this review was to evaluate conditioning programs and their effectiveness on measures of golf-related fitness and golf performance with the secondary aim of the review evaluating the quality of existing studies and its impact on the interpretation of results using the Consolidated Standard of Reporting Trails (CONSORT) statement. The review has been published (16) and is provided below. Also, it informed the design of the study described in Chapter 3.

2.2 Introduction

Golf is an intermittent activity that combines moderate paced walking, standing in golf posture and ball striking. Golf performance is highly dependent on a successful golf swing that is repeatable and allows for maximum distance, distance control and accuracy. Increased professionalism has contributed to golfers, especially elite golfers, adopting a more holistic or multi-dimensional approach to improving performance (3, 5, 6). Both McMaster et al. (5) and Smith (6) clearly establish the importance of taking an integrated approach to player development and the relationships each component within such a framework have on one another. This approach allows both player and coach to optimise performance as highly specific individual programs can be developed knowing that technical, tactical, psychological, physical and lifestyle factors all influence one another (5, 6). Strength and conditioning training has been identified as one of the components of a multidimensional approach essential for optimising golf performance. Strength and conditioning training, when combined with technique refining, has been identified as an
important strategy for improving swing positions due to an increased proficiency of body mechanics (30-32).

Physical fitness characteristics including strength, flexibility, balance and coordination impact on the golfer’s ability to produce force and coordinate movement. Studies have shown through physical fitness assessment that highly skilled golfers have superior values of these characteristics, specifically hip, core and shoulder strength; knee, pelvis, spine (specifically the lumbar spinal segment), scapula and elbow stability; and shoulder (glenohumoeral), hip (coxal) joint and spinal (specifically the thoracic spinal segment) range of motion relative to lesser skilled players (7, 13, 14). These attributes can be referred to as golf-related fitness characteristics and provide successful golfers with more effective swing and body mechanics (13, 33). This allows successful golfers to consistently produce higher club-head speeds (CHS) and deliver the club head squarely to the ball producing longer and more accurate shots, which assist in achieving lower scores. Additionally golfers need to be physically fit to withstand the repetitive strain placed on their muscles and joints. The golf swing requires acceleration and deceleration of body segments combined with compression, rotational torsion of the spine and shearing of the joints (6). When we consider how many swings a golfer makes during a round, over a competitive tournament (72-holes), or on the practice range, it is easy to understand why it is important for golfers to participate in physical conditioning (6).

Three previous reviews (3, 6, 7) examined the effects of physical conditioning on golfers and performance development. Hellstrom (3) clearly identified the physiological and biomechanical factors that contribute to success among elite golfers. Similarly, Hume et al. (7) comprehensively described the role of biomechanics in increasing driving distance and accuracy. Hume and colleagues also identified the effects of physiology and physical conditioning on maximising distance. Smith (6) provides a comprehensive review of the role physiology plays in performance development. He clearly establishes why golfers need to be
fit and the links between physiology and performance as well as the importance of taking a multi-dimensional approach to improving performance. All three reviews clearly establish that physical conditioning has the potential to improve performance indicators such as driving distance and swing mechanics as well as showing that highly skilled golfers have superior fitness characteristics than those of lesser skilled golfers. However, neither review addressed the specificity of the strength and conditioning program on golf-related fitness or golf performance or the quality of the existing studies.

It is important to define golf-specific training. Golf-specific exercises are those that activate the muscles used in golf with comparable patterns of motor coordination between agonist, antagonist and synergist muscles; are conducted in similar planes of movement to the golf swing; require golf-specific speed of movement through the kinetic chain; place a load on postural muscles to develop their endurance; and facilitate maintenance of an appropriate range of motion about specific joints. By designing a conditioning program based on addressing these needs, golfers have the potential to improve their body’s performance during the golf swing, which then has the potential to improve swing mechanics and as a result, golfing performance. Also, it is important that this is built on a strong foundation of functional physical fitness in order to tolerate the training load, reduce injury risk and adapt appropriately.

Consequently, the primary aim of this systematic review was to evaluate conditioning programs and their effectiveness on measures of golf-related fitness and golf performance. The secondary aim of this review was to evaluate the quality of existing studies and the impact of study quality on the interpretation of results.
2.3 Methods

2.3.1 Identification of studies

A systematic search of studies that have used strength and conditioning intervention programs to improve golf performance were sourced via four electronic library databases, including SPORTDiscus, Pub Med, SCOPUS, and Ovid Medline. No year restrictions were placed on the search. The search terms used to find the studies used combinations of the following; golf* and strength or “physical fitness” or “strength and conditioning” or conditioning or physiology or flexibility or “range of motion” or “resistance training” or exercise or balance or fitness. The review was conducted in three stages. The first stage consisted of a database search where articles were included or excluded based on their title or abstract. The second stage involved full-text review and assessment of relevance. Reference lists of the full-text articles were checked for additional articles in the final stage. Conference proceedings from the World Scientific Congress of Golf were included; abstracts and poster presentations from other conferences were not.

2.3.2 Criteria for inclusion

All three authors independently assessed the eligibility of the studies based on the following inclusion criteria: (i) Participants were golfers (ii) Included an evaluation of a strength and conditioning program (iii) Study design was experimental (iv) Included baseline and post intervention assessments (v) Published in English (vi) Published in a peer-reviewed journal or proceedings from the World Scientific Congress of Golf. The Quality of Reporting of Meta-analyses (QUOROM) statement (34) was consulted and provided the structure for this review. The flow of studies through the review process is reported in figure 2.1.
Figure 2.1: Flow of studies through the review process
2.3.3 Criteria for assessment of study quality

All three authors independently assessed the quality of the included studies in reference to the Consolidated Standard of Reporting Trails (CONSORT) Statement. A formal quality score for each study was completed on an 8-point scale assigning a value of 0 (absent or inadequately described) or 1 (present or explicitly described). The following questions were used to assess study quality: (1) Did the study include a non-training group? (2) Were participants randomly allocated? (3) Were the groups comparable on measures at baseline? (4) Did the authors report an indicator of reliability for study assessment techniques ($r > 0.70$)? (5) Was the program adequately described in the methods section? (6) Did the authors report a power calculation to detect hypothesized changes? (7) Was the study adequately powered to detect changes in outcomes? (8) Did the study report effect sizes? Low quality scores were those that received less than two points, medium quality was 3-5 points and high quality studies were those that received 6-8 points.

2.4 Results

2.4.1 Summary of programs

A total of 948 articles were identified through the database searches; of these 911 were initially culled based on title and abstract relevance. Thirty-seven full text articles were assessed with another four being added through searching article reference lists. At the completion of the search process 13 studies in 12 articles met the inclusion criteria and were included in the review (Table 2.1). Participants were predominately middle to older age male recreational golfers (29-79yrs of age). Four studies included younger and more skilled players (30, 32, 35) (16-29yrs, handicap males: 0-5.5, females: 5-10). Four of the 13 studies recruited both male and female golfers (30, 36-38).

The durations of the strength and conditioning programs ranged from 5-11 weeks, with the exception of Lennon (35) study B, which was a 12-month periodised program. Participants
were generally required to complete 3-4 sessions per week with each session lasting 40-90 minutes. Each program included one of or combined resistance and flexibility training (concurrent training) with the exception of Latella et al., (36) who used a number of proprioception exercises aimed at improving physical limitations in the golf swing. Lennon (35) study B also incorporated aerobic cross-training as well as proprioception training and golf drills into the periodised training program.

The majority of programs used generic resistance and flexibility training activities, and included using machine weights, free weights, bar-bells, dumb-bells and static stretching. All studies that incorporated resistance training reported progressive overload. Programs were progressed via increasing sets, reps and load (4.5-5kg or 5%), lowering sets and reps but increasing the load, or by adding new more difficult exercises. The progressions were made after a set period of time or at the discretion of the trainer/researcher once the participant was showing signs of improvement.

2.4.2 Effectiveness of intervention programs

Club head speed. All but one study measured CHS (35). The majority of studies that assessed CHS reported statistical significant increases ranging from 1.5 to 9.5%. Only one study did not report statistical significant differences in CHS between the treatment and control group (37). The two studies that used younger more skilled golfers had smaller increases in CHS of 1.6% (30) and 1.5% (32). Fradkin et al. (39) and Jones (40) recorded the highest increases in CHS (9.5 and 7.2%) respectively.

Strength and explosive strength. Strength was assessed in 10 of the 13 studies reviewed. Isokinetic and isometric tests using dynamometers and isoinertial one and ten repetition maximum (1RM & 10RM) tests were used to assess performance on various resistance-training exercises. All studies that assessed strength reported statistically significant increases (30, 31, 35-38, 41-43). The only study to assess explosive strength was Doan et al.
They assessed trunk rotational force using a seated 2kg medicine ball throw. Release velocity was calculated for three trials and statistically analysed. Medicine ball release velocity increased significantly from baseline to post-test (19.9%).
<table>
<thead>
<tr>
<th>Study</th>
<th>Sample</th>
<th>Design</th>
<th>Measures</th>
<th>Intervention Programs</th>
<th>Results</th>
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<tbody>
<tr>
<td>Latella et al. (2008)</td>
<td>N=17</td>
<td>One group pre-post test</td>
<td>CHS, BV, CD, TD. STR-isokinetic. ROM-goniometer. BA-single leg force plate. SK-3D motion analysis</td>
<td>8-week program using proprioception exercises aimed at addressing physical limitations of golfers. Used movements specific to the golf swing using apparatus such as swiss balls, dura disc, and foam rollers.</td>
<td>CHS, CD, TD, BV all significantly increased (2.98, 6.59, 6.69, 3.95%). All physical fitness parameters significantly improved. Significant differences were also noted in swing mechanics.</td>
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<td>Lephart et al. (2007)</td>
<td>N=15</td>
<td>One group pre-post test</td>
<td>CHS, BV, CD, TD, RD, LA, BS. STR-isokinetic. ROM-goniometer and active tests. BA-single leg force plate. SK-3D motion analysis</td>
<td>8-week conditioning program aimed at increasing lower body stability and upper body mobility. Static and dynamic stretches were performed at the beginning of each session. Conditioning exercises were completed using therabands performed in a similar motion the golf swing, and balance exercises with a foam roller were performed at the end.</td>
<td>CHS, CD, TD, BV all significantly improved (5.2, 7.7, 6.8, 5.0%). Of the thirty-eight STR, ROM and BAL assessments carried out twenty-one significantly improved. All ROM of variables significantly improved, compared with five strength and only two balance variables significantly improving. Upper torso axial rotation and X-factor velocity significantly improved.</td>
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<td>Thompson et al. (2007)</td>
<td>N=18</td>
<td>EXP-2 groups randomisation INT or CON</td>
<td>CHS. fitness variables assessed using the “Senior Fitness Test battery”</td>
<td>A three phase systematically periodised program was used over an 8-week period. Exercises were based around functional fitness, which aimed at developing spinal stabilisation, neuromuscular development, strength, flexibility, balance and speed/power.</td>
<td>CHS significantly increased (4.9%). All fitness variables did improve however not all were statistically significant. Leg strength and all flexibility variables assessed in the study improved significantly.</td>
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<td>Doan et al., (2006)</td>
<td>N=16</td>
<td>One group pre-post test</td>
<td>CHS, FA, LA. STR- 1RM, hand grip dynamometer, medicine ball throw. ROM-Active test. Qualitative swing analysis</td>
<td>8-week conditioning program, combining strength training, plyometrics (medicine ball training), trunk muscular endurance and flexibility.</td>
<td>All fitness variables assessed improved significantly. CHS significantly increased (1.62%). FA and LA as well as putting distance control did not change significantly. Qualitative swing analysis showed no consistent trends in changes to swing mechanics, however some subjects did show some signs of improved mechanics. A significant correlation was found between CHS</td>
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<tr>
<td>Study</td>
<td>N</td>
<td>Age (±SD)</td>
<td>Intervention Details</td>
<td>Results</td>
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<td>Fletcher and Hartwell</td>
<td>11</td>
<td>29 ± 7.4  years</td>
<td>EXP-2 groups randomisation INT or CON CHS, CD. 8-week combined strength and plyometric program. Free weight exercises were conducted as well as medicine ball rotations and throws.</td>
<td>A significant difference was noticed between CON and INT for CHS and CD with the INT significantly improving their CHS and CD (1.5 &amp; 4.3%)</td>
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<td>Fradkin et al.</td>
<td>20</td>
<td>39.6 years</td>
<td>N=20 EXP-2 groups similar pair randomisation CHS. 5-week flexibility training program.  The program consisted of three sections, four dynamic exercises of a rotary nature, nine static exercises focused around the major golf muscles and finally 30 seconds of air swings with a golf club. This was performed 4-5 times per week and before play or practice.</td>
<td>A significant difference was evident between the control and treatment group. CHS significantly increased from week 1 to week 2 showing that a warm-up does increase CHS. A conditioning effect was found over the 7-week with CHS significantly increasing from baseline to post-test (before a warm-up) (9.5%).</td>
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<td>Thompson &amp; Osness</td>
<td>31</td>
<td>64.8 ± 6.1 years</td>
<td>EXP-2 groups randomisation INT or CON CHS. STR- 10RM. ROM-goniometer 8-week generic weight training circuit program using machines, a flexibility component was also conducted which consisted of both dynamic and static stretching exercises.</td>
<td>All strength and ROM variables significantly improved except for internal hip rotation for the treatment group. CHS also significantly increased from baseline to post-test (2.7%).</td>
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<td>Reyes et al.</td>
<td>19</td>
<td>32-84 years</td>
<td>N=19 QEXT- 2 groups matched pairs INT or COM CHS, BV, CD. STR maximal isometric holds 6-week generic strength training exercises. The method of training was termed maximal static contractions, which involved lifting the weight and holding it for approx ten seconds without allowing it to fall, weight was increased once the weight could be held for twenty seconds.</td>
<td>Mean CHS from baseline to post-test did not significantly differ between the treatment and control group. The treatment group did improve their strength over 6-weeks.</td>
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<td>Jones</td>
<td>16</td>
<td>58.0 ± 9.0 years</td>
<td>One group pre-post test design CHS. ROM-goniometer. 8-week flexibility training program using PNF stretching. Focused on the hip and shoulder muscles bilaterally and the spine.</td>
<td>All ROM variables did improve as a result of the PNF training. CHS significantly increased from baseline to post-test (7.2%).</td>
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<td>Lennon</td>
<td>14</td>
<td>18 ± 7</td>
<td>N=14 EXP-2 groups TD. STR-unspecified. ROM-sit and reach, 8-week conditioning program performed four times per week. (Details)</td>
<td>From baseline to post-test the treatment group noted statistically</td>
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<tr>
<td>Study</td>
<td>Age: ± years</td>
<td>Description</td>
<td>Intervention</td>
<td>Results</td>
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<td><strong>Study A</strong></td>
<td>16 ± 0.4</td>
<td>Shoulder rotation. Aerobic endurance-Unspecified</td>
<td>Study included strengths, pivot, flexibility exercises as well as golf drills.</td>
<td>Significant changes in body mass, all strength and ROM variables as well as 5-iron skill test. The control group showed no changes from baseline to post-test.</td>
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<td><strong>Lennon</strong></td>
<td>N=28</td>
<td>Professional &amp; Elite amateur golfers</td>
<td>Full year periodised program which included aerobic work (cross-training), strength, pivot, flexibility exercises as well as golf drills and proprioceptor training. (Details of specific exercises and drills were not reported). The program was split into 4-month periods each focussing on specific training variables.</td>
<td>Significant improvements occurred in subjects physical condition, statistically significant improvement in dynamic flexibility occurred (p&lt;0.05). All golfers recorded their best ever performances on tour and throughout the season that year.</td>
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<td><strong>Hetu et al.</strong></td>
<td>N=17</td>
<td>Age: 52.4 ± 6.7 years</td>
<td>8-week generic strength and flexibility program. Plyometric exercises were also added, these involved medicine ball rotations and throws.</td>
<td>All strength and ROM variables significantly increased, as well as CHS from baseline to post-test (6.3%).</td>
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<td><strong>Westcott et al.</strong></td>
<td>N=17</td>
<td>QEXT- 2 groups INT or COM</td>
<td>8-week generic strength and flexibility program. Fifteen exercises were performed using either machine or free weights and a stretch mate apparatus.</td>
<td>All strength and ROM variables significantly increased. CHS significantly increased (6.0%). No negative effects on the golf swing were reported during the following season.</td>
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*BA = Balance; BS = Backspin; BV = Ball velocity; CD = Carry distance; CHS = Club head speed; COM = Comparison group; CON = Control group; EXP = Experimental study design; FA = Face angle; HC = Handicap average number of strokes over par; INT = Intervention group; LA = Launch angle; PNF = Proprioception neuromuscular facilitation; QEXP = Quasi-experimental design; RD = Roll distance; RM = Repetition maximum; ROM = Range of motion; SK = Swing Kinematics; STR = Strength; TD = Total distance.*
Range of motion. Range of motion was assessed in 10 of the 13 studies reviewed, mostly using standard passive goniometry. Other flexibility tests included sit and reach tests and active flexibility testing with the assistance of video analysis. Shoulder and hip range of motion as well as trunk rotation and hamstring flexibility were assessed in most studies. Most range of motion variables assessed reported statistically significant improvements as a result of the intervention programs (30, 31, 35, 36, 38, 40-43).

Balance. Only two studies assessed balance (31, 36). Both studies used a Kistler force plate where participants were required to perform a single leg balance. Participants in Latella et al. (36) made statistical significant improvements for both left (8%) and right (13%) legs. Of the balance variables assessed by Lephart et al. (31) only left anterior-posterior sway eyes open and closed (-18.3 and -29.4%) and right medial-lateral sway eyes open (-24.8%) showed statistical significant improvements.

Swing Kinematic Analysis. Two studies conducted kinematic swing analyses (31, 36). Three-dimensional biomechanical analyses were carried out using an eight-camera set up, two force plates and analysis software. Lephart et al. (31) found a statistically significant decrease in pelvis axial rotation at the top of the backswing and increased upper torso axial rotational velocity and X-factor velocity (rate of change in X-Factor) during acceleration. No statistical significant change in X-factor was evident at the top of the backswing. Latella et al. (36) found statistical significant decreases in body weight distribution on the front (lead) foot at the top of the backswing (-4.5%), 6.4° decrease in forward tilt during the entire swing, and 1.9° decrease in torso side bending throughout the downswing.

Golf ball launch conditions. Five studies assessed golf ball launch and club head conditions at baseline and post training in addition to CHS (30-32, 36, 37). These variables included ball velocity, carry distance, total driving distance, launch angle, backspin, and face angle. Lephart et al. (31) and Latella et al. (36) found statistical significant improvements in ball
velocity (5.0 & 3.9%), carry driving distance (7.7 & 6.6%) and total driving distance (6.8 & 6.7%) post intervention. Both Doan et al. (30) and Lephart et al. (31) reported no statistical significant changes in launch angle, backspin or clubface deviation (face angle at impact). Fletcher and Hartwell (32) found a statistical significant increase in total driving distance from baseline to post-test (4.3%).

2.4.3 Study quality

After the initial individual review of study quality there was a 94% agreement among the reviewers, with full consensus being met after discussion. Five studies had low quality scores, six studies had medium quality scores and two studies had high quality scores (Table 2.2). Only five of the studies included a true control group (32, 35, 39, 41, 42). Two other studies had a comparison group (37, 43), and the remaining six studies failed to include a control or comparison group. Only four studies reported an indicator of reliability for their assessment protocols (31, 32, 40, 41). Two studies reported a power calculation (30, 32), but only one study reported effect sizes (42). Only one study was not adequately powered to detect changes in outcomes (37). Four studies did not adequately describe the training program used as part of the intervention in the methods section of the study report (35, 36, 39).

2.5 Discussion

2.5.1 Effectiveness of intervention programs

The primary aim of this systematic review was to evaluate conditioning programs and their effectiveness on measures of golf-related fitness and golf performance. Most studies used generic or partly generic resistance training and flexibility programs incorporating small elements of golf-specific exercises (eg: medicine ball plyometric exercises, theraband resistance exercises similar to the movements used during the golf swing). Changes in
appropriate fitness characteristics were assessed and generally reported improvements. All but two of the studies assessed changes in CHS and reported increases. The findings from this review suggest that strength and conditioning programs can have a positive effect on golf-related fitness characteristics, CHS and driving distance.

The secondary aim of this review was to evaluate the quality of existing studies and the impact of study quality on results. The mean study quality scores for the 13 studies was 3.2, indicating that the studies had a medium quality overall score. This suggests that there is considerable room to improve the quality of future strength and conditioning studies for golfers and this can be achieved by adhering to more rigorous study designs and adequate reporting of protocols and results (e.g. CONSORT).

As shown in the results section, strength, flexibility and balance improved among participants from baseline to post-test. However, the participants included in these studies were predominately middle to older aged males and recreational golfers. Research has shown that almost any training stimulus will elicit adaptation in untrained individuals or those with lower athletic abilities (44, 45), and as the golf swing is a dynamic movement that requires strength, range of motion and balance, a generic training program is likely to assist this population in increasing their physical fitness characteristics and as a result increase their CHS. If these same programs were to be implemented in a higher skilled group of golfers the results may not be as pronounced (44, 45). In elite or higher skilled athletes, training programs need to be highly specific in order to achieve maximum transfer of training adaptations (44-46). This is evident from comparing the studies that involved collegiate golfers (30, 32) to the other studies in the review; although collegiate golfers achieved a significant increase in CHS it was considerably less improvement than that of the participants in the other studies. If the collegiate golfers in these two studies were to participate in training programs designed using the principles outlined in the introduction to recruit and activate golf appropriate motor units, perform exercises within golf-specific
planes of motion, maintain correct joint angles and work at appropriate speeds then such
golfers may not only have the potential to further increase their CHS but also improve their
swing mechanics and consistency as they are employing the appropriate motor patterns in
their training (7, 44-46).

Both Lephart et al. (31) and Latella et al. (36) utilised some golf-specific exercises in their
training programs using resistance bands, foam rollers, dura disc and exercise (Swiss) balls.
Doan et al. (30), Fletcher and Hartwell (32) and to a lesser degree Hetu et al. (38)
incorporated plyometric medicine ball exercises into their programs, and participants were
required to complete rotational exercises and various types of throws. This can be a good
method of training the stretch-shortening cycle and increasing rotational strength, however
if performed with poor technique or trying to replicate the golf swing there is concern this
may disrupt swing mechanics.

Programs ranged from 5-11 weeks in duration. This is a relatively short period of time for
muscular adaptations to take place (47). In short duration programs the majority of strength
gains can be attributed to neural adaptations through increased motor unit recruitment and
firing patterns (47). Morphological adaptations such as increased cross-sectional muscle
area tend to take longer to develop depending on the individual, training type, intensity and
volume (45, 47). With the studies only running programs for approximately eight weeks it is
not known how golf swing performance would be impacted with longer periods of training
when larger morphological adaptations are allowed to take place. Also, it is not known
whether the use of generic training programs would allow for further improvements in CHS
or swing mechanics. Once the participants have developed those initial adaptations, to
induce further developments it is likely the participants would need to participate in more
specific training programs to allow for more specific adaptations that may not only further
increase CHS but also improve swing mechanics and consistency.
Only one study, Lennon (35) study B, required participants to participate in a physical conditioning program for a full season (1 year). The participants were elite golfers, both professional and elite national team amateur golfers, who participated in an individualised periodised training program four times per week. It is difficult to comment on the exercises used in the training programs as they were not reported, but individual participants were given specific drills to strengthen their weaker sides and specific golf drills and exercises were used for strength, muscular endurance, movement speed, cardiovascular endurance and proprioception. The programs were periodised to make sure the participants were progressing and working on specific performance variables at different stages of the year. As a result of the program participants in this study not only significantly improved their physical condition and swing mechanics but they also recorded their best ever season in terms of results and money won on tour. This study not only shows that physical conditioning over extended periods of time can induce adaptations both physically and technically for golfers, but that the program must be progressive and specific to the needs of the game of golf and to the individual golfer in order to get the most out of the training program and improve and maintain performance.

Lennon (35) study B was the only study to incorporate any type of cardiovascular conditioning into their training program. Golf does not require a high level of cardiovascular fitness even over a four day tournament (48), however poor cardiovascular fitness has been shown to lead to fatigue which can have a detrimental effect on concentration and decision making which are two vital components of golf (48, 49). Improved cardiovascular fitness can assist golfers in preventing skill deterioration through decreased fatigue and increased concentration, recovery from practice and playing, as well as with weight loss and control (48). Although Lennon (35) did not assess cardiovascular fitness, the participants in the study significantly improved their performance across the season, suggesting they were better able to sustain performance throughout a tournament and also from tournament to
tournament; this could potentially be due to increased mental alertness and concentration levels which allowed for improved decision making. This is one aspect of a golf-specific conditioning program that does not have to be specific to the movement patterns of the golf swing. However, it is important to follow the correct recovery principles following cardio training to prevent tight muscles and joints which may negatively impact golf swing performance (48).
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<th>Quality Criteria</th>
<th>Latella et al., 2008</th>
<th>Lephart et al., 2007</th>
<th>Thompson et al., 2007</th>
<th>Doan et al., 2006</th>
<th>Fletcher &amp; Hartwell, 2004</th>
<th>Fradkin et al., 2004</th>
<th>Thompson &amp; Osness, 2004</th>
<th>Reyes et al., 2002</th>
<th>Jones, 1999</th>
<th>Lennon, 1999 (study A)</th>
<th>Lennon, 1999 (study B)</th>
<th>Hetu et al., 1998</th>
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<td>1. Did the study include a true control group?</td>
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<td>2. Were participants randomly allocated?</td>
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<td>4. Did the authors report an indicator of reliability (&gt;0.70)</td>
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<td>5. Was the program adequately described in the methods section?</td>
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<td>6. Did the authors report a power calculation</td>
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<tr>
<td>7. Was the study adequately powered to detect changes in outcomes?</td>
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<td>8. Did the study report effect sizes?</td>
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<tr>
<td>Score / 8</td>
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<td>3</td>
<td>5</td>
<td>3</td>
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<td>3</td>
<td>3</td>
<td>1</td>
<td>2</td>
<td>2</td>
</tr>
</tbody>
</table>
2.5.2 Study quality

Twelve of the 13 studies were adequately powered to detect changes from baseline to post-intervention testing; this allows conclusions to be made about whether strength and conditioning programs have the ability to bring about positive changes to a golfer’s swing mechanics and overall performance. However these conclusions are strongly affected by the quality of the reporting and study design. Only seven of the 13 studies reviewed included a control or comparison group. The remaining studies were one group pre-test post-test study designs rather than being a true experimental design (randomised controlled trial) or quasi designs (50). This makes it difficult to truly assess the cause and effect relationships of the intervention programs and performance since clear conclusions cannot be made in regards to what elicited the improvements in the treatment groups (7, 50).

Only two studies recorded high quality study scores, the remaining studies could have improved their quality by simply improving the way in which they report or design their studies. Suggestions for improving the quality of the studies include reporting power calculations and effect sizes, reporting reliability data such as typical error and the 95% limits of agreement (51, 52) of testing procedures, including a randomised control group, and adequately describing the training program that the participants undertake.

Only one study reported effect sizes (42). As statistical significance is highly dependent upon sample size, and since the mean sample size across the 13 studies was 18, this suggests that it is important to report effect sizes and discuss findings in relation to practical significance with respect to any meaningful differences from baseline to post intervention (53-55). We have calculated effect sizes for all variables where enough information was provided in the 13 studies. It was found that CHS effect sizes ranged from small to moderate ($d=0.2-0.70$) with fitness, swing kinematics and golf ball launch condition variables demonstrating small to large effects (range $d=0.00-2.09$, mean $d=0.56$).
Not only does this make the studies easier to read and gain an understanding of the effectiveness and conclusions made, it allows the intervention programs to be implemented in a way where it is possible to achieve similar results.

2.5.3 Practical implications

Future studies should focus on improving the assessment of golf performance, so distance control, accuracy and short game skills are assessed in conjunction with CHS. This would give a better indication of how overall golf performance is effected by strength and conditioning. Training specificity is another major area that needs to be addressed. Most studies used generic strength and conditioning programs and elicited positive improvements in both fitness and swing variables suggesting these programs could be used to provide functional foundations; what remains to be explored is the extent to which golf-specific training programs contribute to further improvements in golf-related fitness and golf performance. The effectiveness of longer-term periodised programs could be another important area to be further investigated. The quality of reporting research and study design in this area is one aspect that if improved would allow for a better understanding of the effects of physical conditioning on golfing performance and also allow the intervention programs to be put into practice.

Through improving assessment and training methods it will allow golfers both elite and non-elite to potentially reach their playing goals by ensuring they are receiving the most effective training and practice plans that can be integrated into a multi-dimensional framework such as that explained by McMaster et al. (5) and Smith (6).

2.5.4 Conclusion

The available evidence suggests that physical conditioning can positively influence CHS and swing mechanics in golfers. Further research must be carried out to establish what constitutes the most effective golf-specific conditioning program and the effectiveness of these programs to see if further
improvements can be made in relation to golf-related fitness characteristics and swing mechanics. Furthermore, evidence needs to be provided as to whether golf-specific conditioning influences overall golf performance rather than fitness characteristics and CHS alone. In spite of the quality of the studies and the use of generic strength and conditioning programs, evidence suggests conditioning has the potential to improve golfing performance and warrants the need for more specific and higher quality research in this field.
Chapter 3. Intervention study

3.1 Overview of chapter 3 - Intervention study

Based on the findings of the systematic review, it was evident that there was a gap in the literature in relation to the effects of resistance-training programs for junior golfers. This chapter describes the methods and results of a 12-week resistance-training program designed to improve strength characteristics and golf performance in junior golfers. These findings have been submitted for publication to the International Journal of Golf Science.

3.2 Introduction

Physical preparation programs are an integral part of athlete development in a wide variety of sports. Golfers have been slow to recognise the importance of strength and conditioning due to myths suggesting strength training will have negative effects on the golf swing (32). This trend is changing, especially at the elite level, with both professionals and elite amateur golfers utilising physical preparation programs, including resistance training, as part of their training and practice schedules (4). Also, recent research has provided support for the importance of physical development for improving the golf swing and on-course performance (4, 6, 7, 16, 56).

Golf requires precise execution of powerful coordinated movements in order to produce a mechanically effective swing, which must be repeated 40-50 times during a single round of golf, then reproduced over extended periods of time depending on the length of a tournament, usually four rounds of 18 holes. Furthermore, golfers must have sufficient strength and stability together with the flexibility to achieve the desired ranges of motion and allow the golfer to withstand and absorb the forces produced during the golf swing to avoid musculoskeletal injuries (57). Consequently golfers need to have adequate levels of coordinated strength and explosive power, as well as strength-endurance and mobility.

The golf swing is a rotational and side-to-side movement (7, 58, 59). Performing this activity at high speed with adequate control is difficult, especially for junior golfers, as they rarely possess the strength or structural stability to withstand the forces produced during the swing. In these
circumstances players typically develop compensatory movements to execute the swing with some coordination, which not only reduces the performance of their golf swing, but also increases the potential for injury (9, 17). Players who can attain the appropriate strength attributes are better able to tolerate these loads, reduce their risk of injury, and improve their golf swing performance and potentially on-course results.

Resistance training can have a positive effect on health and sports performance related outcomes in both adolescent non-athlete and athlete populations (60-62). Resistance training programs tend not to be prescribed to children and adolescent populations due to fear of injury, however research clearly shows that when resistance training programs that follow age-appropriate guidelines pose no more risk of injury than any other sports or physical activities (63). Entry-level resistance training programs should initially concentrate on developing movement competence then movement resilience (endurance) by focusing on basic human movements whereby children and adolescents develop their ability to produce and reduce force as well as stabilise and control their own body weight (25, 29). This can be achieved by using a basic resistance-training program that centres on squatting, upper body pushing and pulling, and trunk stabilisation and rotation. Golfers must be able to control and stabilise their own body segments in a sequential movement. Resistance training has the potential to develop the appropriate strength and control to potentially enhance junior golfers’ ability to swing the golf club effectively. Few studies have explored the impact of resistance training on performance among junior golfers. Considering the injury risks involved in golf and the inherent physical demands of the game (17), physical preparation for junior golfers should be a vital component of any development program designed to enhance technical efficiency and overall performance.

Developing successful athletes is a slow process and requires progressing through a number of stages and windows of specific skill development opportunities as outlined by Balyi and Hamilton (24) in the Long Term Athlete Development model. This model suggests that junior athletes should
go through specific training progressions focussed on development rather than competition in the early stages to give the young athlete the tools to develop the appropriate skills and attributes for their chosen sport. Developing junior golfers into elite golfers needs to follow the same process and their physical preparation is an important factor to be considered. Providing junior golfers with a progressive entry-level resistance-training program aimed at building physical competence and strength-endurance will assist in preparing junior golfers for more advanced training programs in the future, potentially allowing them to further improve their golf swing mechanics and as a result their playing ability.

Considering the limited number of studies that have examined the physical development of junior golfers and the potential for such programs to improve performance in these athletes, the aim of this study was to investigate the effects of a 12-week entry-level resistance-training program on strength characteristics and golf performance in junior golfers.

3.3 Methods

3.3.1 Participants

Junior golfers aged 12-18 years were recruited from two local junior development squads. Squad A (n=12) consisted of junior members of a particular club, however the club-mandated condition of their participation was that they were all allocated to the intervention group. Squad B (n=18) consisted of junior athletes from a local Academy of Sport where members were part of a golf-performance-based selective junior development program. Members of squad B were non-randomly allocated to either the intervention group (n = 8) or a wait-list control group (n = 10) by the program organiser with no input from the research team. Overall this provided an intervention group of 20 (n=12 Junior Club, n = 8 Selective academy) and a control group of 10 (n=10 Selective academy).
3.3.2 Study design

The study used a quasi-experimental design (Figure 3.1). The intervention group was provided with twice weekly resistance training sessions for 12 weeks. Regardless of group (intervention/control), participants were advised to maintain their normal golf practice and playing routines over the 12-week study period. All participants attended a weekly golf coaching session as part of involvement in their squads. The technical coaching sessions were conducted by accredited PGA teaching professionals, these sessions addressed long and short-game technique as well as game strategy improvement. Individual strength and flexibility characteristics were assessed at baseline and 12 weeks. Handicap record was monitored over the 12-week period using golflink. The study was approved by the University Human Research Ethics Committee and each participant provided written parental/guardian consent prior to participation.
Figure 3.1: Intervention study design
3.3.3 Physical characteristics

Each participant completed a pre-exercise health-screening questionnaire (Appendix IV) at baseline. The baseline and 12-week strength and mobility assessments took place at participating golf clubs where the squads held their regular coaching sessions. The participants completed three strength-related assessments (one each for lower, middle and upper body segments) and two mobility/flexibility-related assessments. The entire test battery utilised portable equipment for feasibility and ease of transportation between venues.

3.3.4 Strength-related outcomes

a) A progressively difficult single leg squat test was used to assess unilateral lower limb and hip strength and neuromuscular coordination (64). As mentioned in chapter 1 the golf swing requires elements of lower body function or more specifically adequate combinations of strength and balance and coordination. This test was chosen predominately on its practicality but also on its ability to provide a general measure of an individual’s level of lower limb & pelvic strength and control (specifically gluteus group, VMO and pelvic/trunk stabilisers) as well as ankle and hip mobility. Low levels of these specific qualities can impact on an individual’s ability to maintain posture and balance during the swing in addition to imparting force into the ground.

Participants performed this test without shoes. The participant stood on a 15° decline wedge which was placed on a 30cm box, hands were placed out in front of the sternum with the non-support leg directly out in front of the body. Once ready the participant attempted to squat down touching their buttock to their heel before returning to the starting position. If successful the wedge was reduced by 5° after each successful attempt; if successful at 0° (box only), the wedge was reversed to incline and was increased by 5° after each successful attempt with 15° incline being the final level. The participant was given two attempts at each level until a level could not be completed. Both left and right sides were assessed and the mean between the two sides was the final score. The scoring
b) A timed side bridge test was used to assess torso strength-endurance (65, 66). This test was chosen for a number of reasons: lateral trunk strength-endurance has been shown to be a good predictor of low back pain in golfers (65, 66), as well as it being an important aspect of maintaining posture and assisting with weight transference in the swing therefore providing information for programming from both an injury prevention and performance point of view. The timed side bridge test is easily implemented and has been shown to have strong reliability (r=0.96-0.99)(65).

Participants started by lying on their right side, with the right elbow placed directly under the right shoulder, both legs extended with the left leg (top leg) placed over the top of the right with heel and toe touching. The participant raised their pelvis off the testing surface, aligned ears, shoulders, hips and knees, then attempted to hold this position for as long as possible. The tester started the timer once the pelvis was off the testing surface and stopped it once the pelvis returned to the surface. The test was repeated on the contra-lateral side, and the mean of the left and right sides used for analysis.

c) A modified push-up (kneeling) test was used to assess upper limb and shoulder girdle strength-endurance as well as trunk integrity control. This protocol has been shown to be reliable to use in the adolescent population as well as being easy to implement (67). From a golf performance point of view, adequate upper body and shoulder strength assist in the maintenance of posture and swing arc as well as force production through the impact zone of the golf swing. The test also shows the individual participant’s ability to maintain trunk and lumbar-pelvic control. The test was modified to cater for the differences in strength abilities across all participants. Participants started lying in a prone position with the hands placed directly under the shoulders and knees bent to approximately 45-90°. The participants then attempted to complete 30 push-ups to a metronome set at 40 beats per minute (20 push-ups per minute). The up position was characterised by full extension of the
elbow and the down position was characterised by 90° of flexion at the elbow. The test ended if they completed 30 push-ups, could no longer complete a push-up, could not keep to the set cadence, or could no longer maintain correct posture (head drops, hips drop, failure to reach full arm extension). The number of push-ups completed was recorded.

3.3.5 Mobility/Flexibility-related outcomes

a) A shoulder and wrist mobility test was used to assess shoulder girdle and wrist mobility (specifically flexion, horizontal external rotation and wrist extension). This test provided information regarding the individual participants shoulder girdle and wrist range of motion. This is an important quality to assess in golfers as upper limb and spinal movement restrictions may lead to compensations in the golf swing and potentially decreased performance. Whilst improving flexibility was not a primary goal of the program, it provided information on whether the RT intervention caused any changes in upper limb and spine mobility. The tester first measured the participant’s shoulder width (left-right acromion) and arm length (right acromion to most distal phalanx). The participant adopted a prone lying position with arms extended holding a piece of dowel with hands shoulder width apart, and was required to lift (vertical lift) the dowel as high as possible above the ground allowing them to fully extend the wrist, keeping their nose and forehead on the ground. The distance from the bottom of the dowel to the ground was measured. The shoulder and wrist mobility score was calculated by subtracting the vertical lift from the arm length (lower score indicates superior mobility).

b) A back-saver (single leg) sit and reach test was used to assess unilateral posterior lower limb (hamstring flexibility), lumbar and hip flexibility (68-70). Although the standard double leg sit and reach test has been shown to be more valid in providing information on hamstring extensibility, scores achieved on the back saver sit and reach test have been shown to not be significantly different to that of the standard sit and reach test (68, 69). The benefit of using the back-saver sit and reach was that it provided an ability to assess lower limb posterior chain flexibility symmetry as
well as hip flexibility (69, 70). Since golf in a unidirectional sport this may provide some useful insight into the effect of unidirectional movement on lower limb flexibility symmetry. In addition the is the back saver sit and reach has been shown to be highly reliable \( (r = 0.96-0.99) \)(68) and it provides a simple objective measure. Participants completed this test with shoes off. Participants started sitting with the left foot against the sit and reach box, the right heel placed against the medial side of the left knee and hands together placed on top of the box. The raised leg could be moved laterally to allow the torso to move past. When ready the participant slowly moved the leaver on the box forward attempting to move it as far as possible before holding for three seconds. Both left and right sides were measured and the mean between the two was calculated for analysis.

3.3.6 Golf performance

Golf performance was monitored using handicap change over the 12-week period. A golf handicap is an indication of how many strokes over or under par an individual requires to complete the course on average. Handicap will change (increase or decrease) according to how well the individual is playing over a period of time. As an individual improves their performance their handicap will decrease since they are able to consistently shoot lower scores. Handicap was monitored using Golflink (www.golflink.com.au), which is a system that monitors the handicap of every golfer in Australia who is a member of a golf club. The participants provided their golf link ID numbers, which allowed the handicap data to be obtained. Handicap provides an objective measure of a player’s performance, whilst it may not provide an indication of how the player is developing in different areas of the game (technical, tactical, mentally, etc), it shows how a player is scoring which is potentially influenced by improvements in these areas, this is why it has been used as a performance indicator in this study.

3.3.7 Training program

Participants in the intervention group were provided with two instructor supervised resistance-training sessions a week for 12 weeks. Intervention sessions (approx. 45-50 min) consisted of a 5-
min dynamic flexibility and movement preparation warm-up, 30-35 min of resistance training and 5-10 min cool-down, which included mobility and flexibility exercises. The training sessions were designed in accordance with youth resistance training guidelines, and were conducted by a qualified strength and conditioning coach (63). Body weight and soft-resistance equipment (tubing and elastic bands of different resistance) were used throughout the strength training sessions. Participants in the control group continued their usual practice/training routine and were offered the resistance-training program at the completion of the study.

After a needs analysis considering the golf-swing, junior athletes and the common needs of junior golfers, a 12-week periodised resistance-training program was developed. The participants had a low baseline training age for resistance training, so developing good postural awareness and movement competence was important for progressing and achieving positive adaptations. These needs resulted in the program being organised into three phases (mesocycles). Phase 1 (weeks 1-4) focussed on developing postural awareness and movement competence; Phase 2 (weeks 5-8) focussed on strength-endurance; and Phase 3 (weeks 9-12) focussed on dynamic movements and body segment control. This was then further broken down into six 2-week microcycles, where the volume (sets and reps), and/or intensity (resistance) or a combination of both was increased, adhering to the progressive overload principle (63).

Exercises for each body segment were included in each session (lower/middle/upper) and were designed to assist the participants develop the ability to produce and reduce force as well as stabilise and control body movement. The lower body segment exercises concentrated on building lateral stability and increasing general hip and leg strength. Middle body segment exercises focussed on developing pelvic control and trunk strength with rotational control exercises progressively introduced. Upper body segment exercises were focussed on building shoulder girdle strength-endurance and control using pushing and pulling movements. This was progressed during the final weeks whereby the body segments were integrated using exercises that required the participants to
utilise the entire kinetic chain, requiring them to stabilise one segment whilst the other moves. This forms a key part of physical development for golfers as the golf swing is built on the premise that to create speed there must be a series of coordinated and sequential movements. Also, the program was designed to establish a strong movement foundation that will be beneficial in more advanced exercises in later programs.

3.3.8 Statistical Analysis

Statistical analyses were completed using PASW Statistics 17 (SPSS Inc. Chicago, IL) software and alpha levels were set at $p = <0.05$. All variables were checked for normality and log transformed where necessary (raw values provided in tables). Independent samples t-tests were used to compare intervention and control groups on baseline characteristics and outcomes. Linear mixed models were fitted with an unstructured covariance structure to compare groups for continuous variables. Mixed models were used to assess the impact of group (intervention or control), time (treated as categorical with levels baseline and 12-weeks) and the group-by-time interaction. Mixed models are robust to the biases of missing data and include all participants assessed at baseline regardless of whether they completed post-test assessments. A per-protocol analysis was conducted to determine the effect of the intervention among participants who completed ≥60% of sessions. Change scores were created by subtracting baseline values from post-test scores and bivariate correlation was used to examine the relationship between changes in fitness parameters and handicap. We tested gender by time interactions for all outcomes and found there were no moderation effects for any of the variables (time * gender) ($p = > 0.25$ for all outcomes). As statistical significance is highly dependent upon sample size, researchers are encouraged to report effect sizes and levels of precision (e.g. Cohen’s D and 95% confidence intervals) particularly when studying athletic groups. Cohen’s $d$ was used to determine the intervention effect sizes ($d=(M_1 - M_2) / SD_{pooled}$). Cohen’s thresholds were used to show magnitude of change or difference and were defined as trivial ($d<0.2$), small ($d >0.2 - \leq 0.5$), moderate ($d >0.5 - \leq 0.8$) or large ($d>0.8$) (75-77). Hopkins Correlation coefficient
thresholds were used to show magnitude of correlation, these were defined as trivial ($r > 0.0 - <0.1$), small ($r > 0.1 - < 0.3$), moderate ($r > 0.3 - < 0.5$), large ($r > 0.5 - <0.7$), very large ($r > 0.7 - <0.9$) or practically perfect ($r > 0.9$) (78).

3.4 Results

Thirty junior golfers were recruited for the study (Male N=26, Female N=4). Table 3.1 shows the participants’ mean age, height, weight and golf handicap. No significant differences were found between the intervention and control groups for age, physical characteristics or handicap at baseline.

Table 3.1: Participant’s physical characteristics

<table>
<thead>
<tr>
<th></th>
<th>N</th>
<th>Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>Participant Age (yrs)</td>
<td>30</td>
<td>15 ± 1.36</td>
</tr>
<tr>
<td>Participant height (cm)</td>
<td>30</td>
<td>170.55 ± 11.51</td>
</tr>
<tr>
<td>Participant weight (kg)</td>
<td>30</td>
<td>61.60 ± 14.18</td>
</tr>
<tr>
<td>Participant Handicap baseline</td>
<td>30</td>
<td>15.49 ± 9.01</td>
</tr>
</tbody>
</table>

3.4.1 Physical performance characteristics

Table 3.2 shows the mean changes from baseline to 12-weeks for both the intervention and control groups, as well as the group by time effect ($p$-value) and effect sizes (Cohen’s $d$). The intervention program resulted in moderate to large effect sizes ($d = 0.64-0.96$) for all strength variables (i.e. single leg squat, side-bridge and modified push-ups). A small increase was observed in shoulder mobility ($d=0.25$) whereas a trivial change was seen in sit and reach scores ($d=-0.12$).
3.4.2 Golf performance

Although the difference between groups was not statistically significant ($p = 0.27$), a small difference between the groups was evident ($d = 0.42$). The reduction in handicap within the intervention group was 2.9 strokes whereas the control group recorded a reduction of 1.6 strokes. After conducting a per-protocol analysis where participants in the intervention group who attended <60% of the training sessions were excluded ($n = 2$), the mean within group change in handicap for the intervention group improved to 3.3 strokes.
Table 3.2: Changes in physical performance characteristics

<table>
<thead>
<tr>
<th>Outcome</th>
<th>Intervention (n = 20)</th>
<th>Control (n = 10)</th>
<th>Mean adjusted difference between groups&lt;sup&gt;1&lt;/sup&gt; (95% CI)</th>
<th>Group *Time (p-value)</th>
<th>Effect Size (Cohen’s d)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Baseline</td>
<td>Post study</td>
<td>Baseline</td>
<td>Post study</td>
<td></td>
</tr>
<tr>
<td>Single Leg Squat (level)</td>
<td>0.70 (-0.08, 1.48)</td>
<td>1.20 (0.21, 2.19)</td>
<td>2.20 (1.09, 3.30)</td>
<td>1.54 (-0.16, 3.24)</td>
<td>1.16 (-0.25, 2.57)</td>
</tr>
<tr>
<td>Side Bridge (s)</td>
<td>69.25 (58.56, 79.92)</td>
<td>85.62 (74.01, 97.24)</td>
<td>84.59 (69.49, 99.70)</td>
<td>70.32 (46.81, 93.84)</td>
<td>30.65 (6.10, 55.20)</td>
</tr>
<tr>
<td>Modified Push-ups (reps)</td>
<td>18.60 (14.92, 22.28)</td>
<td>22.03 (18.44, 25.62)</td>
<td>25.40 (20.20, 30.60)</td>
<td>18.60 (14.92, 22.28)</td>
<td>8.64 (-0.62, 17.90)</td>
</tr>
<tr>
<td>Sit and reach (cm)</td>
<td>2.69 (0.39, 4.99)</td>
<td>3.13 (1.07, 5.19)</td>
<td>-2.45 (-5.70, 0.80)</td>
<td>-1.34 (-5.34, 2.67)</td>
<td>-0.67 (-4.93, 3.58)</td>
</tr>
<tr>
<td>Shoulder Mobility (cm)</td>
<td>40.02 (35.02, 45.01)</td>
<td>37.65 (32.14, 43.17)</td>
<td>46.35 (39.29, 53.41)</td>
<td>41.43 (31.96, 50.87)</td>
<td>2.56 (-5.46, 10.58)</td>
</tr>
<tr>
<td>Handicap</td>
<td>15.20 (10.38, 20.03)</td>
<td>12.27 (7.88, 16.66)</td>
<td>15.26 (8.44, 22.09)</td>
<td>13.65 (7.44, 19.86)</td>
<td>-1.32 (-3.72, 1.08)</td>
</tr>
</tbody>
</table>

<sup>1</sup>Mean adjusted difference = [(Intervention (Post – Base) – Control (Post – Base)]
3.4.3 Relationships between changes in fitness characteristics and handicap

Table 3.3 shows the correlations between the changes in handicap with changes in physical fitness characteristics. There were moderate inverse associations between changes in handicap and changes in side-bridge ($r = -0.48$), modified push-ups ($r = -0.44$) and shoulder mobility ($r = -0.38$).

Table 3.3: Relationships between change in fitness measures and change in handicap

<table>
<thead>
<tr>
<th>Fitness Measure</th>
<th>Pearsons Correlation ($r$)</th>
<th>Significance ($p$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Single leg Squat</td>
<td>0.115</td>
<td>0.545</td>
</tr>
<tr>
<td>Side bridge</td>
<td>-0.479</td>
<td>0.007*</td>
</tr>
<tr>
<td>Sit &amp; Reach</td>
<td>-0.122</td>
<td>0.522</td>
</tr>
<tr>
<td>Shoulder mobility</td>
<td>-0.375</td>
<td>0.041*</td>
</tr>
<tr>
<td>Modified push-ups</td>
<td>-0.442</td>
<td>0.014*</td>
</tr>
</tbody>
</table>

* Correlation significant at $p = 0.05$

3.5 Discussion

3.5.1 Main findings

The resistance training program used in this study resulted in moderate to large improvements in upper body, core and lower body/hip strength, and trivial to small increases in mobility/flexibility. Importantly there was no substantial loss of mobility/flexibility during the intervention as this may have been detrimental to golf-swing performance. Over the 12-weeks, the intervention group reduced their handicap by an average of 2.9 strokes, while those in the control group reduced their handicaps by an average of 1.6 strokes showing a small to moderate effect. Our findings suggest that combining technical and physical development programs may result in greater improvements in golf performance.
The training program elicited moderate to large improvements in strength parameters. The program targeted strength development in the lower, middle and upper body segments as strength gains in these segments have been shown to positively influence club-head speed and force production and reduction during the golf swing (13, 23, 79). Exercises that require the integration and coordination of all three-body segments were also implemented in the later stages of the program to assist with force transfer via the kinetic chain. This has been shown to be an important attribute for increasing club head speed and force production in the golf swing (16).

The greatest gains in strength for adolescents have been shown to occur at the time of peak height velocity (PHV) (24, 80). Whilst gains may be attributed in part to normal growth patterns, evidence suggests that strength training can induce significant strength gains superior to normal growth and development (62, 81). Two previous meta-analyses showed mean effect sizes of 0.57 and 0.75 for strength gains in resistance-training programs in youth populations (82, 83). Research has also shown strength gains of 30-74% after short-term resistance training programs (8-20 weeks) (62). These findings are consistent with those observed in our study.

The Long Term Athlete Development (LTAD) model is a theoretical model that outlines the progressive development of the athlete from a junior sports participant through to an elite athlete. It also outlines the types and frequency of training and competition recommended for athletes in each stage of their development. The mean age of the participants in this study was 15.0 (±1.4) years, which according to the LTAD places the participants in stage 3, i.e., the ‘training to train’ stage (24). This stage is characterised by less emphasis on competition and more focus on training and developing sport-specific skills and physical characteristics (24). As shown by the results, the resistance training program had a positive effect on measures of strength and can be said to be assisting develop the participants’ physical foundations and preparedness to practice and compete therefore aligning with the model. It must be noted that the LTAD is a theoretical model and more evidence is required to clearly establish the periods or windows regarding the best time for strength
adaptations to occur or be targeted (84). It was beyond the scope of this study to assess each participant’s growth and maturation levels. This information may assist in further tailoring training programs for individual adolescents and is recommended for future studies.

Links between physical development and golf performance are beginning to be established (4, 6, 7, 56). In the current study, moderate inverse correlations between changes in strength (i.e., modified push-ups, side bridge), flexibility (shoulder and wrist mobility scores) and handicap. However, our findings should be interpreted with some caution due to the multiple determinants of golfing handicap over a 12-week period (e.g., weather, course set-up, familiarity with golf course played and frequency of play). While it is plausible to suggest that improving physical characteristics may have a positive effect on technical golf swing parameters and preparedness for the physical demands of golf, it is unlikely that increasing an athlete’s physical attributes will result in an immediate reduction in handicap or improved performance; it must be aligned with clear and individualised technical development, i.e. coaching. Further study of the impact of strength and fitness improvements on golf performance is clearly warranted.

3.5.2 Limitations

A major limitation to the study was that the samples size was small and therefore the study was not adequately powered to detect statistically significant changes in handicap. This influences the confidence with which the impact of the combined resistance training and practice program on golf performance in comparison to the control group who only practiced can be asserted. The study was adequately powered to detect statistically significant changes in the side bridge strength test but no other strength or mobility tests were statistically significant, leaving the study as a whole underpowered. This problem of a small sample size was addressed in part by using effect sizes (Cohen’s $d$) to identify changes in variables across the intervention period.

Limited access to resources was a major limitation to the study. We used cost-effective portable equipment and field tests to assess physical fitness qualities. Ideally, analysis of swing mechanics,
dynamic movement, force-output levels and on-course workloads could have been undertaken with access to appropriate equipment, potentially providing a more comprehensive investigation into the effects of improving physical characteristics on the golf swing and relationships to on-course golf performance. This would provide a better understanding of the requirements for an effective physical training program for not only junior golfers but all golfers.

The duration of the program was a minor limitation; the intervention program was 12 weeks in duration, and although this was possibly long enough to see neural changes in strength it was perhaps not long enough to see peripheral or morphological changes in muscle structure and force producing properties, especially considering the types of loading that were used (47).

Another element that would have strengthened the study was to closely monitor anthropometric changes across the course of the intervention period. This would have provided information on change in stature and weight during this rapid time of growth for most of the participants involved. This may have provided a more in depth look into how growth impacts on strength and or mobility/flexibility.

3.5.3 Practical application and future research

Resistance training can have a positive effect on golf swing and on-course performance (16). A number of recommendations can be made for future research and the implementation of the training programs for junior golfers. Different training modalities and program designs should be investigated to determine whether significant changes in max strength, speed-strength, and mobility contribute to improved golf performance in comparison to improved strength-endurance. Motor coordination and body segment control drills/exercises provided by a physiotherapist or golf coach need to be included in parallel to a strength development program to ensure increased efficiency of movement, which would assist in the transfers of strength gains to the golf swing. Regardless of the sport, more research is required to establish the effect of resistance training and conditioning on performance in junior athletes as there are so many factors that contribute to performance (62).
3.5.4 Conclusion

Evidence from this study suggests that a well-designed resistance-training program has the potential to assist in improving strength-endurance and physical preparedness to compete and play which may in turn improve on-course golf performance in junior golfers. This study shows the effectiveness of implementing an entry-level resistance-training program designed to provide baseline physical foundations. Further research will need to establish how different types of training modalities/programs can impact on the physical development of golfers and the impact this has on performance. Further research will also improve the quality and effectiveness of training programs and allow for a greater understanding of the relationship between technical and physical capabilities and how these changes influence skill level and on-course performance.
Chapter 4. Discussion

4.1 Main Findings

The first aim of this project was to identify the types of strength and conditioning programs that have been implemented with golfers of all levels and their effectiveness by undertaking a systematic review of the literature as described Chapter 2. This review illustrated the importance of structured strength and conditioning programs for golfers to improve their golf-related fitness. The evidence suggests that club head speed (CHS), and driving distance, can be increased by undertaking a strength and conditioning program, however, just improving a golfer’s strength or physical characteristics will not guarantee significant gains in CHS or overall golf performance. The systematic review also revealed that the majority of research carried out on golfers involved middle-aged male recreational golfers, with few studies investigating the effects of physical development or preparation with more highly skilled collegiate golfers. In contrast, there was a gap in the literature regarding best practice for developing golf-related fitness for junior golfers and the subsequent implications for golf performance. This is a very important area to continue researching in order to develop the evidence for best practice, especially considering the less than optimal lifestyle and health status of many children and adolescents today.

The second aim of this project was to evaluate the effects of a resistance-training program for junior golfers on strength-endurance and golf performance as described in Chapter 3. The results of this intervention study found that such a program may have small to large positive effects on strength characteristics and golf performance (operationalised as a positive effect on the participants handicaps) over the course of the intervention period.

4.2 Overview of Chapter 4

This chapter will further discuss the findings from my systematic review and the empirical component of my dissertation. This chapter will also identify the limitations that were experienced over the course of the project and explore the practical implications of this study and provide
recommendations for future junior development programs. Finally, suggestions for future research will be discussed.

4.3 Effectiveness of the intervention program

Chapter 3 clearly outlines the implementation of the training program for the intervention group and the effectiveness of the program.

4.3.1 Study design and Implementation issues

As described in Chapter 3, the 12-week resistance-training program was evaluated using a quasi-experimental study design. Getting a sample size large enough to adequately power the intervention was always going to be a challenge as there are not a large number of junior golfers in the local area that play in regular competitions. With an already small pool to select from it was difficult to conduct a randomised trial, as groups (clubs) were unwilling to participate if there was a possibility they would be allocated to the control group. It was also not possible to randomise within clubs due to the potential for contamination and non-compliance with group assignment. This was overcome in Squad B by the squad organisers getting the intervention group participants to stay an extra hour after squad practice after the participants in the control group had gone home.

The intervention program was run over a 12-week period, and it was unfortunate that the 12 weeks chosen included a school holidays period, which impacted adversely on program adherence. As shown in Chapter 3 by the per-protocol analysis, there was a clear impact on change in handicap for those participants with better attendance at training. Future studies should be timed so that school terms are a key component of the program structure, as during school terms junior athletes are in a routine of going to school, training before or after school, and competing on weekends (85). In contrast, during school holidays many junior golfers are away competing in junior tournaments or away on family holidays.
The facilities used to run the training sessions were unequipped open spaces available within the local golf clubs where the squads trained. This meant that portable training equipment such as resistance bands and body weight resistance exercises were used. This was good from a logistical standpoint because the participants were already at the facility and as soon as they finished their golf practice sessions they would walk straight in and train. What remains to be seen is whether these results would be different if the sessions were run in a fully equipped strength and conditioning gymnasium. This may have potentially provided additional stimulus and lead to larger gains due the option of additional loading or vary exercises for those junior athletes who were deemed ready to load a certain movement pattern.

4.3.2 Physical assessment

The physical assessments measured participants’ lower, middle and upper body strength and control, as well as shoulder and wrist mobility and posterior chain flexibility as described in Chapter 3. This testing protocol allowed for a basic movement and strength profile to be established for the intervention group, which assisted in the creation of the physical development program.

As mentioned in Chapter 3 the testing protocol used was practical and user friendly as well as age appropriate. Due to the varying ages in participants throughout the groups (12-17), it was important to choose tests that would allow all participants to achieve some type of score for analysis purposes. For example, the push-up protocol was modified so that the participants had to complete them in a kneeling position in time with the metronome. This did make it easier for some to complete the test but it also allowed those younger or weaker participants to complete some repetitions. The protocol allowed for the collection of objective data that could then be analysed in terms of changes in performance both physical and game based.

Future testing protocols may include some type of movement screen and force producing capacity assessment looking at rate of force development and max force generated (1RM testing upper and lower body push/pull). These types of testing protocols may assist with providing more in depth
information as to why a golfer moves a particular way, makes particular compensations or their ability to produce adequate speed in the swing, which can then assist with programming for the individual.

4.3.3 Programming

Chapter 1 describes the physical characteristics that have been established as necessary for an effective and precise golf swing that allows for maximal transfer of force with accuracy and control together with the physiological requirements of playing the game of golf. This research formed the needs analysis that allowed me to design the intervention program. As stated in Chapter 3, exercises were progressed from creating postural awareness and base strength to building coordinated movement patterns and strength-endurance to finally moving to more rotation based exercises utilising the entire body. This type of training progression or sequence may assist in getting the junior athlete firstly to set up correctly allowing for effective movement patterns, and secondly to assist with allowing the body to stabilise one body segment whilst another is moving due to improved coordination and awareness of movement as well as increased strength; this is vital for sports performance where transfer of force from the body to an implement is required (kinetic chain) (7, 12). All three body segments were trained both in isolation and as an integrated unit to allow for initial gains in strength and control before increasing the difficulty of exercises, such as those that require full-body coordination. This three-phase program allowed for effective progress of the participants by firstly building foundational strength and body awareness, which helped later in the program and made the coaching process a lot easier. Appendix I clearly shows the exercises used and how they were progressed. Exercises included bridging, squatting, upper body pushing and pulling utilising a number of different variations to bring about different adaptations, change joint angles and add variety to the program. The volume of training aligned with the National Strength & Conditioning Association (NSCA) guidelines of 1-3 sets of 6-15 repetitions (some exercises were slightly outside of this if deemed appropriate) and progressively increased (61, 63). This repetition
range allowed me to get the strength-endurance gains I was looking for but it also allowed for adequate practice doing quality repetitions and assist motor learning. Intensity or resistance was in the form of body weight or soft resistance in accordance with the Australian Strength and Conditioning Association (ASCA) and NSCA youth resistance training guidelines (63, 86). It was progressed by either changing the joint angle or body position or changing the resistance of a band. The effectiveness of the use of this type of resistance is three fold; firstly it allows for the safe introduction of resistance training and decreases the risk of injury during the exercise, secondly it teaches body control and awareness which is necessary for more advanced lifting exercises, and finally the equipment is portable and inexpensive which makes for easy implementation.

As mentioned above with the implementation of the intervention, it did not allow the use of hard or heavy external resistance apparatus such as dumbbells, barbells or medicine balls. Whether further gains could have been achieved using these different apparatus and training programs is not known, although this type of strength program would provide more scope for added resistance and increased force output demands; however as stated numerous times throughout the thesis, it is paramount that junior athletes have adequate movement competency before moving with external load. This is where I believe the program that was utilised in the intervention worked well as it provided participants with initial postural awareness, strength-endurance and control particularly with the training age of the participants in the intervention where some even struggled to control their movement using soft resistance such as elastic resistance bands, and resulted in moderate to large improvements for all strength variables ($d = 0.64-0.96$).

The training program did not include exercises that required the participants to set-up in golf posture and make resisted golf swings with tubing or heavy implements. This can quite often be more detrimental than beneficial due to the additional external load that does not allow for the perfect execution of the movement pattern (44, 87). The program utilised exercises that could be termed golf-related as they allowed the individuals to build strength, control, and mobility in the
areas of the body that are needed for the golf swing. The program involved general movement patterns that trained large muscle groups to work in conjunction with one another specifically and non-specifically for the golf swing. This meant that the exercises were progressed to having participants on their feet, challenging them to transfer force and stabilise themselves in lateral movements. Some exercises required golf specific postures to be assumed to assists in building postural endurance and control in the posture required for golf. Again as stated in Chapters 1 and 2, the golf swing requires the transfer of force via the kinetic chain and which utilises ground force reactions and the stretch shortening cycle as well as having the endurance to maintain posture in movement over an extend period of time and under fatigue, physical training for golf should focus on developing these qualities and the specifics should be developed during skill practice in the form of specific swing and movement pattern drills and actually hitting the ball. By training the qualities that are related to golf swing performance, completing specific skill drills and practicing hitting shots and playing and practicing under varied pressure conditions is what can be considered as best practice for training for golf and covers the training principle of specificity, simply mimicking the movement with additional load does not make training specific (87).

4.3.4 Relationships between changes in physical fitness and performance

A small positive effect on handicap was found over the intervention period giving an indication that golf performance improved as a result of completing the resistance and mobility exercises over the intervention period. Moderate inverse \((r = >0.3 - <0.5)\) correlations were found between handicap and upper body and trunk strength and shoulder and wrist mobility/flexibility. More advanced golf swing assessment protocols would have allowed for better insight into the impact the program (both technical and physical) had on golf swing dynamics, which would then allow for a greater insight into the effects physical conditioning combined with technical development has on junior golfers golf swing and preparedness to play.
As mentioned in Chapter 1 golf requires an adequate level of fitness and strength qualities in order for an individual to play and perform to the best of their ability and then be able to consistently repeat this performance (16). Improvements in trunk and upper body strength-endurance may assist the junior golfer in developing a better foundation to move on as well as the endurance to consistently repeat the movement. Improvements in shoulder and wrist mobility could potentially reduce limitations or blocks in golf swing technique, which are brought about by compensations due to joint and limb movement restrictions (7, 13). The less restrictions there is in the mobility-stability joint-by-joint sequence the less movement is restricted meaning the individual golfer can swing the club on a more optimal path potentially leading to improved performance. But again more in-depth analysis needs to be carried out in order to establish these relationships.

Handicap change over the intervention period was used to monitor changes in golf performance. Handicap provides an objective measure of a player’s performance, and although it does not provide an indication of how the player is developing in different areas of the game (technical, tactical, mentally, etc), it shows how a player is scoring, which is potentially influenced by improvements in these areas, and this is why it has been used as a performance indicator in this study. It was beyond the scope of my study to collect skill data; handicap monitoring was used as an objective measure of monitoring performance. However it must be considered that using handicap as a monitoring tool over a short term period (12-weeks) can be problematic as a large number of uncontrollable variables can impact on an individuals golfers score such as weather, course set-up, period of technical change, nutrition/hydration, mental engagement etc. If handicap is going to be used as a monitoring tool in future research then the number of games each participants competes in must also be monitored. The accuracy of handicap improves with the greater amount of rounds included in the calculation. If the individual plays more and sees improvements then this can strengthen conclusions made in regards to what is influencing change.
4.4 Limitations

There were a number of limitations encountered during the study that impacted on the effectiveness of the intervention program. The main limitation was the attendance of participants at weekly training sessions. Mean attendance was 73% but was as low as 27% for some participants. Poor attendance, especially during the school holiday period, limited participants’ training adaptations due to a reduction in training stimulus. Evidence of this can be seen by the per protocol analysis, where the results were substantially better once those who attended <60% of training sessions were excluded.

As mentioned in Chapter 3 a major limitation of the intervention study was that it was not adequately powered to detect meaningful change between the intervention and control groups over the 12-week intervention period. This is why effect sizes (Cohen’s $d$) was used to identify changes in variables over the intervention period.

Limited access to resources was another limitation of the study. We used cost-effective portable equipment and field tests to assess physical fitness qualities. Ideally, analysis of swing mechanics, dynamic movement, force-output levels and on-course workloads could have been undertaken with access to appropriate equipment, potentially providing a more comprehensive investigation into the effects of improving physical characteristics on the golf swing and then on on-course golf performance. This would provide a better understanding of the requirements for an effective physical training program for not only junior golfers but also all golfers.

4.5 Future research

A recent search for new literature since the publication of my systematic review resulted in no new papers specifically relating to physical conditioning and strength training interventions for golfers. A review by Torres-Ronda et al., (56) has since been published which explored the importance of muscle strength on golf swing performance. This review is consistent with the findings of previous
published reviews, which clearly state the importance of physical development and strength training for golfers and the positive effects it can potentially have on performance (4, 6, 16). Common areas of research that still exist are coaching philosophy and skill acquisition, psychology, biomechanics and injury prevention.

Future research should look at the implication of more advanced strength and conditioning programs that aim to increase power and speed, different training programs and methods of assessment for different age groups of non-elite and elite golfers, periodisation for elite golfers and tournament versus non-tournament training programs, and finally develop a greater understanding of the implications of the strength and speed adaptations of specific biomechanical variables within the golf swing.

An area that needs to be further investigated is to what extent longer duration intervention programs have on golf swing and on-course performance. A longitudinal program would potentially allow for further development and consolidation of skills as well as increased time for neural and morphological neuromuscular changes to take place. This could then be combined with the tracking and monitoring of load for elite golfers. This would potentially assist in gaining an understanding into how to minimise the effect of overuse injuries and maximise performance through correct recovery and training modification strategies.

### 4.6 Practical applications

The information and results from this intervention study can be applied to training junior golfers. The important key aspects to take from the study are: always undergo a physical assessment protocol before commencing a training program and relate findings from the assessment to the needs of the sport; make sure that all junior athletes have a sound movement foundation and take time to develop this before moving onto more advanced training programs. What remains to be seen is exactly how much impact participating in physical development programs has on overall
performance not only the full golf swing. The intervention does show this to a degree but a more in-depth overall analysis is required to clearly establish this finding.

4.7 Conclusions

The main aim of thesis was to establish whether improving strength and physical fitness could have a positive effect on overall golf performance. The results of the systematic literature review in Chapter 1 revealed that physical preparation (strength training and conditioning) can positively influence golf swing performance such as increasing club head speed and improved kinematics and sequencing. The results of the intervention program in Chapter 3 suggest that strength and conditioning has the potential to have a positive effect on on-course golf performance, whether this is linked to improved golf swing technique or a preparedness to play remains to be seen, but performance was still positively influenced by those involved in the intervention program. This then provides some evidence that suggests physical preparation and development plays a significant role of an overall game improvement plan (technical, tactical, psychological & physical) designed to develop and maximise performance. The findings clearly warrant further investigation into what is best practice in terms of physical development and preparation for elite and non-elite golfers. A bank of evidence is starting to be built that establishes the importance of physical development for golfers of all ages and that the development of the golfing athlete needs to start early and be gradually progressed to achieve excellence in performance.
References


37. Reyes MG, Munro M, Held B, Gebhardt WJ, editors. Maximal static contraction strengthening exercises and driving distance Science and Golf IV Proceedings of the world scientific congress of golf; 2002 4-8 July; St Andrews: Routledge.


### Appendix I. Intervention training 12-week periodised program and warm-up

#### Phase 1: Exercises (Posture & base strength)

<table>
<thead>
<tr>
<th>Exercise</th>
<th>Sets x Reps (wks 1-2)</th>
<th>Resistance</th>
<th>Sets x Reps (wks 3-4)</th>
<th>Resistance</th>
<th>Rest Periods</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>LBS</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Box steps</td>
<td>2 x 20</td>
<td>Black mini band</td>
<td>3 x 30</td>
<td>Black mini band</td>
<td>30-45sec</td>
</tr>
<tr>
<td>Hip bridge</td>
<td>2 x 15</td>
<td>Black mini band</td>
<td>3 x 20</td>
<td>Black mini band</td>
<td>30-45sec</td>
</tr>
<tr>
<td>Crab walks to squats (10 steps / 5 squats)</td>
<td>3 x 15</td>
<td>Black mini band</td>
<td>3 x 20</td>
<td>Black mini band</td>
<td>30-45sec</td>
</tr>
<tr>
<td>Supine pelvic silts</td>
<td>2 x 10</td>
<td>BW</td>
<td>3 x 10</td>
<td>BW</td>
<td>30-45sec</td>
</tr>
<tr>
<td><strong>MBS</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Quadruped pelvic tilts</td>
<td>2 x 10</td>
<td>BW</td>
<td>4 x 8</td>
<td>BW</td>
<td>30-45sec</td>
</tr>
<tr>
<td>1/2 side bridge hip raises</td>
<td>2 x 10</td>
<td>BW</td>
<td>2 x 15</td>
<td>BW</td>
<td>30-45sec</td>
</tr>
<tr>
<td>Angel wings</td>
<td>2 x 30sec</td>
<td>Black TUB</td>
<td>3 x 30sec</td>
<td>Black TUB</td>
<td>30-45sec</td>
</tr>
<tr>
<td><strong>UBS</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1/2 kneeling rows</td>
<td>2 x 10</td>
<td>Yellow PB</td>
<td>3 x 15</td>
<td>Yellow or Orange PB</td>
<td>30-45sec</td>
</tr>
</tbody>
</table>

**Volume** 157  **Volume** 350

#### Phase 2: Exercises (Coordination & endurance)

<table>
<thead>
<tr>
<th>Exercise</th>
<th>Sets x Reps (wks 5-6)</th>
<th>Resistance</th>
<th>Sets x Reps (wks 7-8)</th>
<th>Resistance</th>
<th>Rest Periods</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>LBS</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Single leg balance with upper torso rotations</td>
<td>2 x 30sec</td>
<td>BW</td>
<td>3 x 30sec</td>
<td>BW</td>
<td>30-45sec</td>
</tr>
<tr>
<td>Split squat (focus on technique)</td>
<td>6 x 6</td>
<td>BW</td>
<td>3 x 15</td>
<td>BW</td>
<td>30-45sec</td>
</tr>
<tr>
<td>Resisted side stepping</td>
<td>3 x 15</td>
<td>Orange PB</td>
<td>3 x 20</td>
<td>Orange or Red PB</td>
<td>30-45sec</td>
</tr>
<tr>
<td><strong>MBS</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Quadruped arm-leg extensions</td>
<td>3 x 20</td>
<td>BW</td>
<td>4 x 20</td>
<td>BW</td>
<td>30-45sec</td>
</tr>
<tr>
<td>1/2 side bridge with lateral kicks</td>
<td>2 x 10</td>
<td>BW</td>
<td>3 x 15</td>
<td>BW</td>
<td>30-45sec</td>
</tr>
<tr>
<td>High plank hip rotations</td>
<td>2 x 10</td>
<td>BW</td>
<td>3 x 15</td>
<td>BW</td>
<td>30-45sec</td>
</tr>
<tr>
<td>Tall kneeling single arm presses</td>
<td>3 x 10</td>
<td>Yellow PB</td>
<td>3 x 15</td>
<td>Yellow or Orange PB</td>
<td>30-45sec</td>
</tr>
<tr>
<td><strong>UBS</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Golf posture &quot;X&quot; band holds</td>
<td>3 x 20sec</td>
<td>Black mini band &amp; Black TUB</td>
<td>3 x 45sec</td>
<td>Black mini band &amp; Black TUB or Yellow PB</td>
<td>30-45sec</td>
</tr>
</tbody>
</table>

**Volume** 216  **Volume** 326

#### Phase 3: Exercises (Rotation & body segment control)

<table>
<thead>
<tr>
<th>Exercise</th>
<th>Sets x Reps (wks 9-10)</th>
<th>Resistance</th>
<th>Sets x Reps (wks 11-12)</th>
<th>Resistance</th>
<th>Rest Periods</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>LBS</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lateral resisted split squat</td>
<td>3 x 10</td>
<td>Orange PB</td>
<td>3 x 15</td>
<td>Orange or Red PB</td>
<td>30-45sec</td>
</tr>
<tr>
<td>Lateral step squats to leg drive</td>
<td>3 x 6</td>
<td>BW</td>
<td>4 x 8</td>
<td>BW</td>
<td>30-45sec</td>
</tr>
<tr>
<td>Lateral bounds</td>
<td>3 x 6</td>
<td>BW</td>
<td>4 x 6</td>
<td>Black mini band</td>
<td>30-45sec</td>
</tr>
<tr>
<td>Resisted cross-pattern crawling</td>
<td>3 x 20</td>
<td>Yellow or Orange PB</td>
<td>4 x 20</td>
<td>Orange or Red PB</td>
<td>30-45sec</td>
</tr>
<tr>
<td>60° Seated torso rotations</td>
<td>3 x 14</td>
<td>BW</td>
<td>3 x 20</td>
<td>BW</td>
<td>30-45sec</td>
</tr>
<tr>
<td>Lying lower body rotations (Arm across chest)</td>
<td>3 x 14</td>
<td>BW</td>
<td>3 x 20</td>
<td>BW</td>
<td>30-45sec</td>
</tr>
<tr>
<td><strong>MBS</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Palloff Presses</td>
<td>3 x 10</td>
<td>Yellow PB &amp; Black mini band</td>
<td>3 x 15</td>
<td>Yellow or Orange PB &amp; Black mini band</td>
<td>30-45sec</td>
</tr>
<tr>
<td><strong>UBS</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Standing single arm press and rotate</td>
<td>3 x 10</td>
<td>Yellow PB</td>
<td>4 x 10</td>
<td>Yellow or Orange PB</td>
<td>30-45sec</td>
</tr>
<tr>
<td>Standing single arm pull and rotate</td>
<td>3 x 10</td>
<td>Yellow or Orange PB</td>
<td>4 x 10</td>
<td>Orange or Red PB</td>
<td>30-45sec</td>
</tr>
</tbody>
</table>

**Volume** 300  **Volume** 426

**Key**
- **LBS** = Lower body segment
- **MBS** = Middle body segment
- **UBS** = Upper body segment
- BW = Body weight
- PB = Power band 41" loops
- yellow = light resistance, orange = medium resistance, red = strong resistance
- TUB = Theraband tubing (light resistance)
- Mini band = Small band to go around knees (black = medium/strong resistance)
# Warm-up for golf, practice and training

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>½ kneeling extension and rotations</td>
</tr>
<tr>
<td></td>
<td>Stretch up tall, keep the lower body still rotate the upper body</td>
</tr>
<tr>
<td>2.</td>
<td>Angel wings</td>
</tr>
<tr>
<td></td>
<td>Hands by your side, pull shoulder blades down, narrow waist step slowly</td>
</tr>
<tr>
<td>3.</td>
<td>Split stance rotations</td>
</tr>
<tr>
<td></td>
<td>Golf posture, take one leg back, perform 5-10 rotation keeping most of your weight on the front foot</td>
</tr>
<tr>
<td>4.</td>
<td>Golf posture rotations</td>
</tr>
<tr>
<td></td>
<td>Golf posture, bouncing through the feet, rotate into the right side (left for left handers), shift weight then rotate through, 5-10 rotations</td>
</tr>
<tr>
<td>5.</td>
<td>Cross over golf exercise drill</td>
</tr>
<tr>
<td></td>
<td>Standing tall, hold the club infront of the torso, take across the body whilst rotating the lower body the opposite direction, 5-10 rotations</td>
</tr>
<tr>
<td>6.</td>
<td>Air swings</td>
</tr>
<tr>
<td></td>
<td>Feeling a comfortable yet solid set-up, complete 10-15 swings to help ingrain feels ready for play or practice</td>
</tr>
</tbody>
</table>

Appendix II: Ethics application statement of approval

HUMAN RESEARCH ETHICS COMMITTEE

Acknowledgement of Receipt of Submission

To Chief Investigator or Project Supervisor: Associate Professor Robin Callister
Cc Co-investigators / Research Students: Doctor David Lubans
                                                Mr Christopher Smith
Data: 12-May-2010
Reference No: H-2010-1088

Thank you for your Initial Application submission to the Human Research Ethics Committee (HREC) seeking approval in relation to the above protocol.

Your submission will be considered under L2 Low Risk Research Expedited review by the HREC Panel at the earliest opportunity and you will be advised of the outcome.

The time taken to review and respond to applications will depend on the number of applications received. However, the aim is to provide a response within the following timeframes:

- L1 low risk research: 1 to 2 weeks
- L2 low risk research: 2 to 4 weeks
- L3 full review by HREC: Within 10 days of the HREC meeting.

Your protocol reference number is H-2010-1088. Please use this in any correspondence with the HREC in relation to this protocol.

Enquiries regarding progress with this submission can be directed to Human-Ethics@newcastle.edu.au or 492 18999.

For advice on ethical conduct in human research please refer to a Research Ethics Advisor in your Faculty. Details are available from the Human Research Ethics website.

Human Research Ethics Administration

Research Services
Research Office
The University of Newcastle
Callaghan NSW 2308
T +61 2 492 19999
F +61 2 492 17154
## Notification of Safety Implications

<table>
<thead>
<tr>
<th>To:</th>
<th>Safety Administration</th>
</tr>
</thead>
<tbody>
<tr>
<td>Re Chief Investigator or Project Supervisor:</td>
<td>Associate Professor Robin Callister</td>
</tr>
<tr>
<td>Co-investigators / Research Students:</td>
<td>Doctor David Lubans Mr Christopher Smith</td>
</tr>
<tr>
<td>Date:</td>
<td>12-May-2010</td>
</tr>
<tr>
<td>HREC Reference No:</td>
<td>H-2010-1088</td>
</tr>
</tbody>
</table>

An application to the Human Research Ethics Committee (HREC) has indicated that the above protocol has the following safety implications. The researchers have been advised by way of their application to the HREC that they will need to make a submission to the University’s Health and Safety Team.

- Cash payments to participants - N
- Fieldwork - Y
- Recombinant DNA - N
- Genetically modified organisms - N
- Biologically hazardous micro-organisms - N
- Chemically hazardous materials - N
- Human body fluids or tissue - N
- Radioisotopes / unsealed sources - N
- Ionising radiation - N
- Non-ionising radiation - N
- Other safety issue - N

### Human Research Ethics Administration

Research Services  
Research Office  
T +61 2 492 13999  
F +61 2 492 17164  
Human-Ethics@newcastle.edu.au
Response Required

To Chief Investigator or Project Supervisor: Professor Robin Callister
Cc Co-investigators / Research Students: Doctor David Lubans
Mr Christopher Smith
Date: 21-Jun-2010
Reference No: H-2010-1088

Thank you for your Initial Application submission to the Human Research Ethics Committee (HREC) seeking approval in relation to the above protocol.

Your submission was considered under L2 Low Risk Research Expedited review by the HREC Panel on 18-Jun-2010.

The status of your submission is Conditional Approval. Before it can be considered further, you are asked to provide a response to the following matters:

Researchers are commended on the submission of a very well prepared application.

1. What is the situation if the club agrees to participate but the golf professional does not? If club participation cannot go ahead without club/golf professional agreement would it be clearer to provide just one Information Statement for the club with consent requiring sign off by both club representative and golf professional? Note that while the club professional was asked to complete a consent form this was not included with your application.

2. Amendments to all Participant Documents.
   a. Please remove occurrences of the bracketed 'type text' from the documents.

3. Amendments to Information Statements.
   a. Indicate that the physical assessment sessions will be conducted at the University of Newcastle.
   b. Under 'How will the information collected be used?' please state that the data will contribute to the student researcher’s thesis.
   c. The student researcher should consider amending the format of his email address so that he is not identifying his student number (eg, FirstName.LastName@uon.edu.au). This will also decrease the likelihood of emails being misdirected due to a keying error.
d. For Junior Committees / Club Professionals - Under ‘What do you need to do to participate?’ - where it mentions that clubs might want to use a different dissemination route from the one proposed, they should be alerted that they cannot provide a mailing list for the researchers due to privacy issues (unless the parents have consented to their contact details being provided for this purpose).

e. For Juniors/Parents:
i. Under 'Who can participate?' amend the final sentence to "...also be ineligible if you currently have...".

ii. Under 'What choice do you have?' amend the end of the 2nd sentence to "...relationship with the University of Newcastle or your golf club."

iii. Please ensure the complaints statement occurs only on this document and does not carry over to the associated consent form as the information statement must be retained by participants and the complaints information is important detail.

4. Consent Form.
Consider including a request for contact details to enable provision of individual and overall feedback.

Response:
Please respond by letter with one copy of any amended documentation requested. The letter must be submitted by the chief investigator or project supervisor. In your letter ensure you address each of the above issues.

For ease of review, please:

- Highlight amendments to the documents and update the version number and date.
- Do not resubmit the application form itself unless you are specifically requested to do so.
- Where the research is the project of a student, ensure the response is submitted to the HREC by the project supervisor.

Application Expiry:
Your application will remain valid for six (6) months from the date of the above decision. If you do not respond within that time the application will be cancelled and you will need to submit a new application if you wish to pursue the research.

This research must not commence until you receive written confirmation of full approval.

Associate Professor Alison Ferguson
Chair, Human Research Ethics Committee

For communications and enquiries:
Human Research Ethics Administration
Appendix III: Participant Information statement and consent form

Research Project: The effects of golf-specific conditioning on overall golf performance in junior golfers

Child/Parent information sheet

Dear Junior golfer/Parent

You are invited to participate in the research project identified above which is being conducted by Prof Robin Callister, A/Prof David Lubans and Mr Chris Smith from the University of Newcastle.

The research is part of Mr Chris Smith’s study at the University of Newcastle, supervised by Associate Professor Robin Callister from the School of Biomedical Science and Pharmacy and Dr David Lubans The School of Education, University of Newcastle.

Why is this research being done?

Strength and conditioning is an integral part of athlete development; however this has not been the case for golf until recently. Strength and conditioning programs are now an important aspect of many leading professional golfers’ weekly training schedule. The aim of this study is to evaluate the effectiveness of a golf-specific screening procedure and conditioning program for junior golfers that may assist them build the correct habits from an early age and improve their future performance in golf.

What is involved in this study?

If you agree, you will be invited to participate in the University of Newcastle golf-specific conditioning program, which will be based at Belmont Golf Club. All testing and conditioning sessions will be run at the golf club. The conditioning program will run for 12-weeks and will involve the components and evaluation strategies listed in Table 1.

Table 1: Golf-specific conditioning program components and evaluation strategies

<table>
<thead>
<tr>
<th>Program components</th>
<th>Evaluation of program</th>
</tr>
</thead>
<tbody>
<tr>
<td>24 x 45-60min conditioning sessions, participants will attend two conditioning sessions per week for 12 weeks focussing on posture, flexibility, strength/power specific to the golf swing.</td>
<td>Height: using a portable stadiometer. Weight: using a calibrated scale. Waist circumference: using non-extensible steel tapes. Posture: New York posture rating scale Range of Motion: standing side bend, seated torso rotation, shoulder lateral rotation with abduction 90° with 90° of elbow flexion</td>
</tr>
</tbody>
</table>
Each conditioning session will incorporate a variety of exercises using resistance bands and body weight exercises. During the 12-week program participants will learn about the importance of maintaining a healthy and well conditioned body and the positive influences this has on their golf swing but their overall golf performance and general health. Participants will also receive a golf fitness kit, which includes a number of resistance bands, and exercise cards, which can be used during and after the program.

Following baseline assessment participants will be randomly allocated to start the program immediately or to wait 12 weeks for the program to commence.

Who will be responsible for delivering and administering the program?

Chris Smith is an experienced golf conditioner and will deliver the program. One member of the junior committee or parent will be asked to observe all testing and training sessions to aid in the supervision of the junior members. An outline of the program administration and delivery is provided below:

- The physical assessments (baseline and post-test) will be conducted by members of the research team
- The 24 x golf-specific conditioning sessions will be run by the student researcher and observed by a member of the junior committee.

Who can participate in this research?

Junior golfers aged 12-18 years of age who are full junior members of a golf club will be eligible to participate in this study. If you are not junior members of a golf club or are still only part of an introductory program such as cadets you will not be eligible for the study. You will also be ineligible if you currently have a medical condition or physical injury preventing testing or training.

What choice do you have?

Participation in this research is entirely your choice, if you do agree to participate, you may withdraw from the study at any time without giving a reason. A decision not to participate or discontinuation of involvement in the study will not jeopardise your relationship with the University of Newcastle or your golf club. Similarly, junior members at your club will be included in the study only after you and your parents/guardians have signed a consent form. If you initially agree to participate, you can choose to withdraw from the study at any time without giving a reason.
What are the risks of participating?
Trained staff will conduct the testing and the golf-specific conditioning sessions will be developed by the research team and monitored by the student researcher. Based on previous youth based resistance training studies, participants will have no greater chance of injury by participating in these programs in comparison to other sports and physical activities.

How will the information collected be used?
The data collected from this study will contribute to the student researcher’s thesis and also used for journal publications, conference presentations and to inform future practice for the design of valuable, evidence-based golf-specific conditioning programs.

How will privacy be protected?
Any personal information provided by parents/guardians and junior members will be confidential to the researchers. The results of the study will be published in general terms and will not allow the identification of individuals or clubs. Once the data has been collected and entered into an electronic data file and verified, the recording sheets will be destroyed. The electronic data files will be retained for at least 5 years but no person will be identifiable in the data files or published reports.

What do you need to do to participate?
If you are willing to participate in this study, could you please complete the accompanying Consent Form and return it to the selected representative from your junior committee before the study begins.

Further information
Following the completion of the study, the junior committee will be sent a dissemination report describing the findings of the study. It is suggested that the findings are disseminated to you and your parents/guardians via a report or similar method. Individual results will be given to you, which you may choose to give to their relative coaches.

If you would like further information please do not hesitate to contact Mr Chris Smith. Thank you for considering this invitation.
Junior golfer/Parent consent sheet

Chief Investigators: Prof. Robin Callister, A/Prof David Lubans and Mr Chris Smith

I have been given information about the project identified above. I understand that if I consent to my child’s involvement in the project, my child will be invited to participate in the Golf-specific conditioning study. He / She will participate in a 12-week golf-specific conditioning program and also complete the following assessments: height, weight and waist circumference, posture, functional movement, range of motion, muscular strength/endurance and power, golf skills test where they will be required to hit a set number of golf balls with different clubs at a number of targets. During the golf skills test their swings will be recorded and analysed.

I have had an opportunity to ask Mr Chris Smith questions about the research. I understand that my child’s participation in this research is voluntary and he/she is free to withdraw from the research project at any time. Their refusal to participate or withdrawal of consent will not affect my relationship with the University of Newcastle.

By signing below I am indicating my consent for my child to participate in the clubs junior development program to be invited to participate in this research project conducted by Mr Chris
Smith, as it has been described to me in the Information Statement, a copy of which I have retained.

Student name: ____________________________________________________

Junior golfers Signature: __________________________ Date: _______________

Parent/guardian name: _____________________________________________

Signature: __________________________ Date: _____________________

Please sign the completed consent letter and return with your child’s Junior Committee representative
Appendix IV: Participant pre-exercise screening and injury history

Junior Golf Fitness Pre-exercise Screening Questionnaire

Name: ____________________________ Age: ____________________________

Please answer the following questions as accurately as possible.

<table>
<thead>
<tr>
<th>Question</th>
<th>No</th>
<th>Yes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Have you recently been hospitalized or undergone any surgeries that might prevent you from completing physical activity?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Do you have high blood pressure?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>If YES, do you take any medications to control it?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Do you have diabetes (Type I or Type II)?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>If YES, do you have trouble controlling your diabetes?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Do you have a history of seizures?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Do you have any bone/joint/muscle disorders that could be aggravated by a change in your physical activity?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Do you experience unusual fatigue or shortness of breath with usual activities?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Do you have asthma?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>If YES, do you take any medication for it?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Do you perform more than 150 minutes of moderate physical activity per week, or do extensive resistance training?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Do you have any physical reason or medical condition that the people conducting this exercise test need to be aware of for your safety or that could prevent you from undertaking exercise during the testing?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>If YES, please provide details below:</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Other medical conditions or injuries (please indicate whether they are golf related injuries by placing G next to the injury):

__________________________________________________________________________________
__________________________________________________________________________________
__________________________________________________________________________________
__________________________________________________________________________________
A systematic review of strength and conditioning programmes designed to improve fitness characteristics in golfers

CHRISTOPHER J. SMITH¹, ROBIN CALLISTER¹, & DAVID R. LUBANS²

¹School of Biomedical Sciences and Pharmacy, The University of Newcastle, Callaghan, NSW, Australia and ²School of Education, The University of Newcastle, Callaghan, NSW, Australia

(Accepted 9 March 2011)

Abstract
It has been suggested that conditioning programmes have the potential to improve golf performance through fitness adaptations. The primary aim of this systematic review was to evaluate the effectiveness of conditioning programmes on measures of golf-related fitness and golf performance. Four electronic library databases were searched and the quality of the studies was assessed using criteria adapted from the Consolidated Standard of Reporting Trials statement. Thirteen studies satisfied our criteria for inclusion. Nine studies involved middle-aged to older male recreational golfers and four studies used younger more skilled golfers. Conditioning programmes involved the use of machine weights, free weights, medicine balls, and elastic bands, and most studies included a flexibility component. Most studies assessed changes in fitness characteristics and generally resulted in improvements. All but two of the studies assessed changes in club head speed and reported increases. The findings from this review suggest that strength and conditioning programmes can have a positive effect on the golf swing and fitness characteristics of golfers. The majority of studies in this review evaluated the effects of generic conditioning programmes on fitness characteristics and club head speed. Future studies should investigate the effects of more golf-specific strength and conditioning programmes to improve fitness and overall golf performance.

Keywords: Golf, strength, strength and conditioning, flexibility, range of motion, physiology, resistance training, exercise, balance, physical fitness

Introduction
Golf is an intermittent activity that combines moderate paced walking, standing in golf posture, and ball striking. Golf performance is highly dependent on a successful golf swing that is repeatable and allows for maximum distance, distance control and accuracy. Increased professionalism has contributed to golfers, especially elite golfers, adopting a more holistic or multidimensional approach to improving performance (Hellstrom, 2009; McMaster, Herbert, Jameson, & Thomas, 2001; Smith, 2010). Both McMaster et al. (2001) and Smith (2010) clearly established the importance of taking an integrated approach to player development and the relationships each component within such a framework have on one another. This approach allows both player and coach to optimize performance, as highly specific individual programmes can be developed knowing that technical, tactical, psychological, physical, and lifestyle factors all influence one another (McMaster et al., 2001; Smith, 2010). Strength and conditioning training has been identified as one of the components of a multidimensional approach essential for optimizing golf performance. Strength and conditioning training, when combined with technique refining, has been identified as an important strategy for improving swing positions due to an increased proficiency of body mechanics (Doan, Newton, Kwon, & Kraemer, 2006; Fletcher & Hartwell, 2004; Lephart, Smoliga, Myers, Sell, & Tsai, 2007).

Physical fitness characteristics including strength, flexibility, balance, and coordination impact on the golfer’s ability to produce force and coordinate movement. Studies have shown through physical fitness assessment that highly skilled golfers have superior values of these characteristics, specifically hip, core, and shoulder strength; knee, pelvis, spine (specifically the lumbar spinal segment), scapula, and elbow stability; and shoulder (glenohumeroal), hip (coxal) joint, and spinal (specifically the thoracic spinal segment) range of motion (Hume, Keogh, &
Reid, 2005; Keogh et al., 2009; Sell, Tsai, Smoliga, Myers, & Lephart, 2007). These attributes can be referred to as golf-related fitness characteristics and provide successful golfers with more effective swing and body mechanics (Sell et al., 2007; Zheng, Barrentine, Fiesig, & Andrews, 2008). This allows successful golfers to consistently produce higher club head speeds and deliver the club head squarely to the ball producing longer and more accurate shots, which assist in achieving lower scores. In addition, golfers need to be physically fit to withstand the repetitive strain placed on their muscles and joints. The golf swing requires acceleration and deceleration of body segments combined with compression, rotational torsion of the spine, and shearing of the joints (Smith, 2010). When we consider how many swings a golfer makes during a round, over a competitive tournament (72 holes), or on the practice range, it is easy to understand why it is important for golfers to participate in physical conditioning (Smith, 2010).

Three previous reviews (Hellstrom, 2009; Hume et al., 2005; Smith, 2010) examined the effects of physical conditioning on golfers and performance development. Hellstrom (2009) clearly identified the physiological and biomechanical factors that contribute to success among elite golfers. Similarly, Hume et al. (2005) comprehensively described the role of biomechanics in increasing driving distance and accuracy. Hume and colleagues also identified the effects of physiology and physical conditioning on maximizing distance. Smith (2010) provides a comprehensive review of the role physiology plays in performance development. He clearly establishes why golfers need to be fit and the links between physiology and performance as well as the importance of taking a multidimensional approach to improving performance. All three reviews clearly establish that physical conditioning has the potential to improve performance indicators such as driving distance and swing mechanics as well as showing that highly skilled golfers have superior fitness characteristics compared with lesser skilled golfers. However, none of the reviews addressed the specificity of the strength and conditioning programme on golf-related fitness and golf performance, or the quality of the existing studies.

It is important to define golf-specific training. Golf-specific exercises activate the muscles used in golf with comparable patterns of motor coordination between agonist, antagonist, and synergist muscles; are conducted in similar planes of movement to the golf swing; require golf-specific speed of movement through the kinetic chain; place a load on postural muscles to develop their endurance; and facilitate maintenance of an appropriate range of motion about specific joints. By designing a conditioning programme that addresses these needs, golfers have the potential to improve their body's performance during the golf swing, which then has the potential to improve swing mechanics and, as a result, golfing performance. Also, it is important that this is built on a strong foundation of functional physical fitness in order to tolerate the training load, reduce injury risk, and adapt appropriately.

Consequently, the primary aim of this systematic review was to evaluate conditioning programmes and their effectiveness on measures of golf-related fitness and golf performance. A secondary aim was to evaluate the quality of existing studies and the impact of study quality on the interpretation of results.

Methods

Identification of studies

A systematic search of studies that have used strength and conditioning intervention programmes to improve golf performance were sourced via four electronic library databases: SPORTDiscus, PubMed, SCOPUS, and Ovid Medline. No year restrictions were placed on the search. The search terms used to find the studies used combinations of the following: "golf" and "strength", "physical fitness", "strength and conditioning", "conditioning", "physiology", "flexibility", "range of motion", "resistance training", "exercise", "balance" or "fitness". The review was conducted in three stages. The first stage consisted of a database search where articles were included or excluded based on their title or abstract. The second stage involved full-text review and assessment of relevance. Reference lists of the full-text articles were checked for additional articles in the final stage. Conference proceedings from the World Scientific Congress of Golf were included; abstracts and poster presentations from other conferences were not.

Criteria for inclusion

All three authors independently assessed the eligibility of the studies based on the following inclusion criteria: (i) participants were golfers; (ii) included an evaluation of a strength and conditioning programme; (iii) study design was experimental; (iv) included baseline and post-intervention assessments; (v) published in English; (vi) published in a peer-reviewed journal or proceedings from the World Scientific Congress of Golf. The Quality of Reporting of Meta-analyses (QUOROM) statement (Moher et al., 1999) was consulted and provided the structure for this review. The flow of studies through the review process is reported in Figure 1.
Criteria for assessment of study quality

All three authors independently assessed the quality of the included studies with reference to the Consolidated Standard of Reporting Trails (CONSORT) statement. A formal quality score for each study was completed on an 8-point scale assigning a value of 0 (absent or inadequately described) or 1 (present or explicitly described). The following questions were used to assess study quality: (1) Did the study include a non-training group? (2) Were participants randomly allocated? (3) Were the groups comparable on measures at baseline? (4) Did the authors report an indicator of reliability for study assessment techniques ($r > 0.70$)? (5) Was the programme adequately described in the methods section? (6) Did the authors report a power calculation to detect hypothesized changes? (7) Was the study adequately powered to detect changes in outcomes? (8) Did the study report effect sizes? Low-quality studies were those that received less than 2 points, medium-quality studies received 3–5 points, while high-quality studies were those that received 6–8 points.

Results

Summary of programmes

A total of 948 articles were identified through the database searches, of which 911 were initially culled based on title and abstract relevance. Thirty-seven full-text articles were assessed with another five being added through searching article reference lists. At the end of the search process, 13 studies in 12 articles met the inclusion criteria and were included in the review (Table 1). Participants were predominately middle to older age male recreational golfers (29–79 years of age). Four studies included younger and more skilled players (Doan et al., 2006; Fletcher & Hartwell, 2004; Lennon, 1999) (16–29 years; handicap males: 0–5.5; handicap females: 5–10). Four of the 13 studies recruited both male and female golfers...
Table I. Summary of study characteristics and results.

<table>
<thead>
<tr>
<th>Study</th>
<th>Sample</th>
<th>Design</th>
<th>Measures</th>
<th>Intervention programmes</th>
<th>Results</th>
</tr>
</thead>
<tbody>
<tr>
<td>Latella et al. (2008)</td>
<td>N = 17 Age: 43.3 ± 12 years, HC: 12.5 ± 7.9</td>
<td>One group pre/post test design</td>
<td>CHS, BV, CD, TD, STR: isokinetic. ROM: goniometer. BA: single leg force plate. SK-3D motion analysis</td>
<td>8-week programme using proprioception exercises aimed at addressing physical limitations of golfers. Movements specific to the golf swing using apparatus such as Swiss balls, dura disc, and foam rollers</td>
<td>CHS, CD, TD, BV all increased significantly (2.98, 6.59, 6.69, 3.95%). All physical fitness parameters improved significantly. Significant differences were also noted in swing mechanics</td>
</tr>
<tr>
<td>Lephart et al. (2007)</td>
<td>N = 15 Age: 47.2 ± 11.4 years</td>
<td>One group pre/post test design</td>
<td>CHS, BV, CD, TD, RD, LA, BS. STR-isokinetic. ROM: goniometer and active tests. BA: single leg force plate. SK: 3D motion analysis</td>
<td>8-week conditioning programme aimed at increasing lower body stability and upper body mobility. Static and dynamic stretches were performed at the beginning of each session. Conditioning exercises were completed using therabands performed in a similar motion to the golf swing, and balance exercises with a foam roller were performed at the end</td>
<td>CHS, CD, TD, BV all significantly improved (5.2, 7.7, 6.8, 5.0%). Of the 38 STR, ROM, and BAL assessments carried out, 21 improved significantly. All ROM of variables improved significantly, compared with five strength and only two balance variables. Upper torso axial rotation and X-factor velocity improved significantly</td>
</tr>
<tr>
<td>Thompson et al. (2007)</td>
<td>N = 18 Age: 70.7 ± 7.1 years</td>
<td>EXP - 2 groups randomization INT or CON</td>
<td>CHS. Fitness variables assessed using the “Senior Fitness Test” battery</td>
<td>A three phase systematically periodized programme was used over an 8-week period. Exercises were based around functional fitness, aimed at developing spinal stabilization, neuromuscular development, strength, flexibility, balance, and speed/power.</td>
<td>CHS increased significantly (4.9%). All fitness variables did improve, although not all significantly so. Leg strength and all flexibility variables assessed in the study improved significantly</td>
</tr>
<tr>
<td>Doan et al. (2006)</td>
<td>N = 16 Age: 19.3 ± 1.5 years, HC: 0–10</td>
<td>One group pre/post test design</td>
<td>CHS, FA, LA, STR: 1-RM, hand grip dynamometer, medicine ball throw. ROM: Active test. Qualitative swing analysis</td>
<td>8-week conditioning programme combining strength training, plyometrics (medicine ball training), trunk muscular endurance, and flexibility</td>
<td>All fitness variables assessed improved significantly. CHS increased significantly (1.6%). FA and LA as well as putting distance control did not change significantly. Qualitative swing analysis showed no consistent trends in changes to swing mechanics, although some participants did show some signs of improved mechanics. A significant correlation was found between CHS and medicine ball throw velocity</td>
</tr>
<tr>
<td>Fletcher and Hartwell (2004)</td>
<td>N = 11 Age: 29 ± 7.4 years, HC: 5.5 ± 3.7</td>
<td>EXP - 2 groups randomization INT or CON</td>
<td>CHS, CD</td>
<td>8-week combined strength and plyometric programme. Free weight exercises were conducted as well as medicine ball rotations and throws</td>
<td>A significant difference was noted between CON and INT for CHS and CD with the INT significantly improving their CHS and CD (1.5 and 4.3%)</td>
</tr>
<tr>
<td>Fradkin et al. (2004)</td>
<td>N = 20 Age: 39.6 years, HC: 19.8</td>
<td>EXP - 2 groups similar pair randomization</td>
<td>CHS</td>
<td>5-week flexibility training programme consisting of three sections, four dynamic exercises of a rotary nature, nine static exercises focused around the major golf muscles and, finally, 30 s of air swings with a golf club. This was performed 4–5 times per week and before play or practice</td>
<td>A significant difference was evident between the control and treatment group. CHS increased significantly from week 1 to week 2 showing that a warm-up does increase CHS. A conditioning effect was found after 5 weeks of conditioning with CHS increasing significantly from baseline to post-test (before a warm-up) (9.5%)</td>
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(continued)
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<thead>
<tr>
<th>Study</th>
<th>Sample</th>
<th>Design</th>
<th>Measures</th>
<th>Intervention programmes</th>
<th>Results</th>
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<tr>
<td>Thompson and Oness (2004)</td>
<td>$N = 31$ Age: 64.8 ± 6.1 years</td>
<td>EXP – 2 groups randomized INT or CON</td>
<td>CHS, STR: 10-RM, ROM: goniometer</td>
<td>8-week generic weight training circuit programme using machines; a flexibility component was also conducted, which consisted of both dynamic and static stretching exercises</td>
<td>All strength and ROM variables improved significantly except for internal hip rotation for the treatment group. CHS also increased significantly from baseline to post-test (2.7%)</td>
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<tr>
<td>Reyes et al. (2002)</td>
<td>$N = 19$ Age: 32–84 years HC: 2–40</td>
<td>QEXT – 2 groups matched pairs INT or COM</td>
<td>CHS, BV, CD, STR: maximal isometric holds</td>
<td>6-week generic strength training exercises. The method of training was termed maximal static contractions, which involved lifting the weight and holding it for ~10 s without allowing it to fall; weight was increased once the weight could be held for 20 s</td>
<td>Mean CHS from baseline to post-test did not differ significantly between the treatment and control group. The treatment group did improve their strength over the 6 weeks</td>
</tr>
<tr>
<td>Jones (1998)</td>
<td>$N = 16$ Age: 58.0 ± 9.0 years HC: 18 ± 7</td>
<td>One group pre/post test design</td>
<td>CHS, ROM: goniometer</td>
<td>8-week flexibility training programme using PNF stretching. Focused on the hip and shoulder muscles bilaterally and the spine. Aerobic endurance was unspecified</td>
<td>All ROM variables did improve as a result of the PNF training. CHS increased significantly from baseline to post-test (7.2%)</td>
</tr>
<tr>
<td>Lennon (1999, study A)</td>
<td>$N = 14$ Age: 16 ± 0.4 years</td>
<td>EXP – 2 groups</td>
<td>TD, STR: unspecified. ROM: sit-and-reach, shoulder rotation. Aerobic endurance: unspecified</td>
<td>8-week conditioning programme performed four times per week. Details of the programme were not reported</td>
<td>From baseline to post-test the treatment group noted statistically significant changes in body mass, all strength and ROM variables, as well as 5-iron skill test. The control group showed no changes from baseline to post-test</td>
</tr>
<tr>
<td>Lennon (1999, study B)</td>
<td>$N = 28$ Professional and elite amateur golfers</td>
<td>One group pre/post test design</td>
<td>Static and dynamic physical assessment: unspecified. Dynamic flexibility during the golf swing</td>
<td>Full year periodized programme that included aerobic work (cross-training), strength, pivot, flexibility exercises, as well as golf drills and proprioceptor training (details of specific exercises and drills were not reported). The programme was split into 4-month periods each focusing on specific training variables</td>
<td>Significant improvements were observed in participants’ physical condition, as well as dynamic flexibility (P &lt; 0.05). All golfers recorded their best ever performances on tour and throughout the season that year</td>
</tr>
<tr>
<td>Hetu et al. (1998)</td>
<td>$N = 17$ Age: 52.4 ± 6.7 years</td>
<td>One group pre/post test design</td>
<td>CHS, STR: 1-RM and hand grip dynamometer. ROM: sit-and-reach and total body rotation test</td>
<td>8-week generic strength and flexibility programme. Piometric exercises were also added, which involved medicine ball rotations and throws</td>
<td>All strength and ROM variables increased significantly, as well as CHS from baseline to post-test (6.3%)</td>
</tr>
<tr>
<td>Westcott et al. (1996)</td>
<td>$N = 17$</td>
<td>QEXT – 2 groups INT or COM</td>
<td>CHS, STR: 10-RM, ROM: electric goniometer</td>
<td>8-week generic strength and flexibility programme. Fifteen exercises were performed using either machine or free weights and a stretch mate apparatus</td>
<td>All strength and ROM variables increased significantly. CHS increased significantly (6.0%). No negative effects on the golf swing were reported during the following season</td>
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Note: BA = balance; BS = backspin; BV = ball velocity; CD = carry distance; CHS = club head speed; COM = comparison group; CON = control group; EXP = experimental study design; FA = face angle; HC = handicap average number of strokes over par; INT = intervention group; LA = launch angle; PNF = proprioception neuromuscular facilitation; QEXP = quasi-experimental design; RD = roll distance; RM = repetition maximum; ROM = range of motion; SK = swing kinematics; STR = strength; TD = total distance.
(Doan et al., 2006; Hetu, Christie, & Faigenbaum, 1998; Latella, Yungchien, Yung-Shen, Seii, & Lephart, 2008; Reyes, Munro, Held, & Gebhardt, 2002).

The durations of the strength and conditioning programmes ranged from 5 to 11 weeks, with the exception of Lennon (1999, study B), which was a 12-month periodized programme. Participants were generally required to complete 3–4 sessions per week with each session lasting 40–90 min. Each programme included resistance or flexibility training or both (concurrent training) with the exception of Latella et al. (2008), who used a number of proprioceptive exercises aimed at improving physical limitations in the golf swing. Lennon (1999, study B) also incorporated aerobic cross-training as well as proprioceptive training and golf drills into the periodized training programme.

The majority of programmes used generic resistance and flexibility training activities, including using machine weights, free weights, bar-bells, dumb-bells, and static stretching. All studies that incorporated resistance training reported progressive overload. Programmes were progressed via increasing sets, repetitions, and load (4.5–5kg or 5%), lowering sets and repetitions but increasing the load, or by adding new, more difficult exercises. The progressions were made after a set period of time or at the discretion of the trainer/researcher once the participant was showing signs of improvement.

Effectiveness of intervention programmes

Club head speed. All but one study measured club head speed (Lennon, 1999). The majority of studies that assessed club head speed reported significant increases ranging from 1.5% to 9.5%. Only one study did not report significant differences in club head speed between the treatment and control group (Reyes et al., 2002). The two studies that used younger, more skilled golfers reported smaller increases in club head speed of 1.6% (Doan et al., 2006) and 1.5% (Fletcher & Hartwell, 2004). Fradkin et al. (2004) and Jones (1998) recorded the highest increases in club head speed (9.5% and 7.2% respectively).

Strength and explosive strength. Strength was assessed in 10 of the 13 studies reviewed. Isokinetic and isometric tests using dynamometers and isoinertial one- and ten-repetition maximum (1-RM and 10-RM) tests were used to assess performance on various resistance-training exercises. All studies that assessed strength reported significant increases (Doan et al., 2006; Hetu et al., 1998; Latella et al., 2008; Lennon, 1999; Lephart et al., 2007; Reyes et al., 2002; Thompson, Cobb, & Blackwell, 2007; Thompson & Osness, 2004; Westcott, Dolan, & Cavicchi, 1996). The only authors to assess explosive strength were Doan et al. (2006). They assessed trunk rotational force using a seated 2-kg medicine ball throw. Release velocity was calculated for three trials and statistically analysed. Medicine ball release velocity increased significantly from baseline to post-test (19.9%).

Range of motion. Range of motion was assessed in 10 of the 13 studies reviewed, mostly using standard passive goniometry. Other flexibility tests included sit-and-reach tests and active flexibility testing with the assistance of video analysis. Shoulder and hip range of motion as well as trunk rotation and hamstring flexibility were assessed in most studies. Most range of motion variables assessed reported significant improvements as a result of the intervention programmes (Doan et al., 2006; Hetu et al., 1998; Jones, 1998; Latella et al., 2008; Lennon, 1999; Lephart et al., 2007; Thompson et al., 2007; Thompson & Osness, 2004; Westcott et al., 1996).

Balance. Only two studies assessed balance (Latella et al., 2008; Lephart et al., 2007). Both studies used a Kistler force plate and participants were required to perform a single leg balance. Participants in the study of Latella et al. (2008) made significant improvements for both left (8%) and right (13%) legs. Of the balance variables assessed by Lephart et al. (2007), only left antero-posterior sway (eyes open and closed: −18.3% and −29.4% respectively) and right medial-lateral sway (eyes open: −24.8%) showed significant improvements.

Swing kinematic analysis. Two groups conducted kinematic swing analyses (Latella et al., 2008; Lephart et al., 2007). Three-dimensional biomechanical analyses were carried out using an eight-camera set-up, two force plates, and analysis software. Lephart et al. (2007) found a significant decrease in pelvis axial rotation at the top of the backswing and increased upper torso axial rotational velocity and X-factor velocity (rate of change in X-factor) during acceleration. No significant change in X-factor was evident at the top of the backswing. Latella et al. (2008) reported significant decreases in body weight distribution on the front (lead) foot at the top of the backswing (−4.5%), a 6.4° decrease in forward tilt during the entire swing, and a 1.9° decrease in torso side bending throughout the downswing.

Golf ball launch conditions. Five studies assessed golf ball launch and club head conditions at baseline and after training in addition to club head speed (Doan et al., 2006; Fletcher & Hartwell, 2004; Latella et al., 2008; Lephart et al., 2007; Reyes et al., 2002). These
variables included ball velocity, carry distance, total driving distance, launch angle, backspin, and face angle. Lephart et al. (2007) and Latella et al. (2008) found significant improvements in ball velocity (5.0% and 3.9% respectively), carry driving distance (7.7% and 6.6%), and total driving distance (6.8% and 6.7%) after the intervention. Both Doan et al. (2006) and Lephart et al. (2007) reported no significant changes in launch angle, backspin or club face deviation (face angle at impact). Fletcher and Hartwell (2004) reported a significant increase in total driving distance from baseline to post-test (4.3%).

Study quality

After the initial individual review of study quality there was 94% agreement, with full consensus being met after discussion. Five studies had low-quality scores, six studies had medium-quality scores, and two studies had high-quality scores (Table II). Only five of the studies included a true control group (Fletcher & Hartwell, 2004; Fradkin et al., 2004; Lennon, 1999; Thompson et al., 2007; Thompson & Osness, 2004). Two other studies had a comparison group (Reyes et al., 2002; Westcott et al., 1996), and the remaining six studies failed to include a control or comparison group. Only four studies reported an indicator of reliability for their assessment protocols (Fletcher & Hartwell, 2004; Jones, 1998; Lephart et al., 2007; Thompson et al., 2007). Two studies reported a power calculation (Doan et al., 2006; Fletcher & Hartwell, 2004), but only one study reported effect sizes (Thompson & Osness, 2004). Only one study was not adequately powered to detect changes in outcomes (Reyes et al., 2002). Four studies did not adequately describe the training programme used as part of the intervention in the methods section of the study report (Fradkin et al., 2004; Latella et al., 2008; Lennon, 1999).

Discussion

Effectiveness of intervention programmes

The primary aim of this systematic review was to evaluate conditioning programmes and their effectiveness on measures of golf-related fitness and golf performance. Most studies used generic or partly generic resistance training and flexibility programmes incorporating small elements of golf-specific exercises (e.g. medicine ball plyometric exercises, theraband resistance exercises similar to the movements used during the golf swing). Changes in appropriate fitness characteristics were assessed and generally reported improvements. All but two of the studies assessed changes in club head speed and reported increases. The findings from this review suggest that strength and conditioning programmes can have a positive effect on golf-related fitness characteristics, club head speed, and driving distance.

The secondary aim of this review was to evaluate the quality of existing studies and the impact of study quality on results. The mean study quality scores for the 13 studies was 3.2, indicating that the studies had an overall score of medium quality. This suggests that there is considerable room for improvement in the quality of future strength and conditioning studies for golfers, which can be achieved by adhering to more rigorous study designs and adequate reporting of protocols and results (e.g. CONSORT).

As shown in the Results section, strength, flexibility, and balance improved among participants from baseline to post-test. However, the participants recruited in these studies were predominately middle to older aged males and recreational golfers. Research has shown that almost any training stimulus will elicit adaptation in untrained individuals or those with lower athletic abilities (Gamble, 2006; Zatsiorsky & Kraemer, 2006), and as the golf swing is a dynamic movement that requires strength, range of motion, and balance, a generic training programme is likely to assist this population in increasing their physical fitness characteristics and, as a result, increase their club head speed. If these same programmes were to be implemented in a higher skilled group of golfers, the results may not be as pronounced (Gamble, 2006; Zatsiorsky & Kraemer, 2006). In elite or higher skilled athletes, training programmes need to be highly specific to achieve maximum transfer of training adaptations (Baechle & Earle, 2008; Gamble, 2006; Zatsiorsky & Kraemer, 2006). This is evident from comparing the studies that involved collegiate golfers (Doan et al., 2006; Fletcher & Hartwell, 2004) to the other studies in the review; although collegiate golfers achieved a significant increase in club head speed, their improvement was considerably less than that of the participants in the other studies. If the collegiate golfers in these two studies were to participate in training programmes designed using the principles outlined in the Introduction to recruit and activate golf-appropriate motor units, perform exercises within golf-specific planes of motion, maintain correct joint angles, and work at appropriate speeds, then such golfers may not only have the potential to further increase their club head speed but also improve their swing mechanics and consistency, as they would be employing the appropriate motor patterns in their training (Baechle & Earle, 2008; Gamble, 2006; Hume et al., 2005; Zatsiorsky & Kraemer, 2006).
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<tbody>
<tr>
<td>1. Did the study include a true control group?</td>
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<td>3. Were the groups comparable on measures at baseline?</td>
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<td>4. Did the authors report an indicator of reliability (r &gt; 0.70)</td>
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<td>5. Was the programme adequately described in the methods section?</td>
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<td>6. Did the authors report a power calculation</td>
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<td>7. Was the study adequately powered to detect changes in outcomes?</td>
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<td>8. Did the study report effect sizes?</td>
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Both Lephart et al. (2007) and Latella et al. (2008) utilized some golf-specific exercises in their training programmes using resistance bands, foam rollers, dura disc and exercise (Swiss) balls. Doan et al. (2006), Fletcher and Hartwell (2004), and to a lesser degree Héutu et al. (1998) incorporated plyometric medicine ball exercises into their programmes, and participants were required to complete rotational exercises and various types of throws. This can be a good method of training the stretch–shortening cycle and increasing rotational strength, although if performed with poor technique or trying to replicate the golf swing, there is concern this may disrupt swing mechanics.

Programmes ranged from 5 to 11 weeks in duration. This is a relatively short period of time for muscular adaptations to take place (Folland & Williams, 2007). In programmes of short duration, the majority of strength gains can be attributed to neural adaptations through increased motor unit recruitment and firing patterns (Folland & Williams, 2007). Morphological adaptations such as increased cross-sectional muscle area tend to take longer to develop depending on the individual, training type, intensity, and volume (Folland & Williams, 2007; Zatsiorsky & Kraemer, 2006). With the studies only running programmes for approximately 8 weeks, it is not known how golf swing performance would be impacted with longer periods of training when larger morphological adaptations are allowed to take place. Also, it is not known whether the use of generic training programmes would allow for further improvements in club head speed or swing mechanics. Once those initial adaptations had been developed, it is likely that the golfers would need to participate in more specific training programmes to allow for more specific adaptations that may not only further increase club head speed but also improve swing mechanics and consistency.

Only one study, Lennon (1999, study B) required golfers to participate in a physical conditioning programme for a full season (1 year). The participants were elite golfers, both professional and elite national team amateur golfers, who participated in an individualized periodized training programme four times per week. It is difficult to comment on the exercises used in the training programmes as they were not reported, but individual participants were given specific drills to strengthen their weaker sides and specific golf drills and exercises were used for strength, muscular endurance, movement speed, cardiovascular endurance, and proprioception. The programme was periodized to make sure the participants were progressing and working on specific performance variables at different stages of the year. As a result of the programme, participants in this study not only significantly improved their physical condition and swing mechanics but they also recorded their best ever season in terms of results and money won on tour. This study not only shows that physical conditioning over extended periods of time can induce adaptations both physically and technically for golfers, but that the programme must be progressive and specific to the needs of the game of golf and to the individual golfer to get the most out of the training programme and improve and maintain performance.

Lennon’s (1999, study B) was the only study to incorporate any type of cardiovascular conditioning into the training programme. Golf does not require a high level of cardiovascular fitness even over a 4-day tournament (Chettle & Neal, 2001); however, poor cardiovascular fitness has been shown to lead to fatigue, which can have a detrimental effect on concentration and decision making – two vital components of golf (Chettle & Neal, 2001; Wilmore, Costill, & Kenney, 2008). Improved cardiovascular fitness can assist golfers in preventing skill deterioration through decreased fatigue and increased concentration, recovery from practice and playing, as well as weight loss and control (Chettle & Neal, 2001). Although Lennon (1999, study B) did not assess cardiovascular fitness, the participants in the study significantly improved their performance across the season, suggesting they were better able to sustain performance throughout a tournament and also from tournament to tournament; this could potentially be due to increased mental alertness and concentration, which allowed for improved decision making. This is one aspect of a golf-specific conditioning programme that does not have to be specific to the movement patterns of the golf swing. However, it is important to follow the correct recovery principles after cardiorespiratory training to prevent tight muscles and joints that might negatively impact golf swing performance (Chettle & Neal, 2001).

Study quality

Twelve of the 13 studies were adequately powered to detect changes from baseline to post-intervention testing; this allows conclusions to be made about whether strength and conditioning programmes have the ability to bring about positive changes to a golfer’s swing mechanics and overall performance. However, these conclusions are strongly affected by the quality of the reporting and study design. Only seven of the 13 studies reviewed included a control or comparison group. The remaining studies were one-group pre-/post-test study designs rather than being a true experimental design (randomized controlled trial) or quasi designs (Thomas, Nelson, & Silverman, 2005). This makes it difficult to truly
assess the cause and effect relationships of the intervention programmes and performance, since clear conclusions cannot be made as to what elicited the improvements in the treatment groups (Hume et al., 2005; Thomas et al., 2005).

Only two studies recorded high-quality study scores; the remaining studies could have scored higher simply by improving the way in which they were reported or designed. Suggestions for improving the quality of the studies include reporting power calculations and effect sizes, reporting reliability data such as typical error and the 95% limits of agreement (Hopkins, 2000; Nevill & Atkinson, 1998) of testing procedures, including a randomized control group, and adequately describing the training programme that the participants undertake.

Only one study reported effect sizes (Thompson & Osness, 2004). As statistical significance is highly dependent upon sample size, and since the mean sample size across the 13 studies was 18, this suggests that it is important to report effect sizes and discuss findings in relation to practical significance with respect to any meaningful differences from baseline to post-intervention (Hagger & Chatzisarantis, 2009; Jacobson & Truax, 1991; Kirk, 1996). We have calculated effect sizes for all variables where enough information was provided in the 13 studies. It was found that club head speed effect sizes ranged from small to moderate ($d = 0.2 - 0.70$) with fitness, swing kinematics, and golf ball launch condition variables demonstrating small to large effects (range $d = 0.00 - 2.09$, mean $d = 0.56$).

Not only does this make the studies easier to read and gain an understanding of the effectiveness and conclusions made, it allows the intervention programmes to be implemented in a way whereby it is possible to achieve similar results.

**Practical implications**

Future studies should focus on improving the assessment of golf performance, so that distance control, accuracy, and short game skills are assessed in conjunction with club head speed. This would give a better indication of how overall golf performance is affected by strength and conditioning. Training specificity is another major area that needs to be addressed. Most studies used generic strength and conditioning programmes and elicited positive improvements in both fitness and swing variables, suggesting that these programmes could be used to provide functional foundations; what remains to be explored is the extent to which golf-specific training programmes contribute to further improvements in golf-related fitness and golf performance. The effectiveness of longer-term periodized programmes could be another important area of investigation.

The quality of reporting research and study design in this area is one aspect, which, if improved, would allow for a better understanding of the effects of physical conditioning on golfing performance and also allow the intervention programmes to be put into practice.

By improving assessment and training methods, both elite and non-elite golfers would be better able to achieve their playing goals by ensuring that they are receiving the most effective training and practice plans that can be integrated into a multidimensional framework such as that explained by McMaster et al. (2001) and Smith (2010).

**Conclusion**

The available evidence suggests that physical conditioning can positively influence club head speed and swing mechanics in golfers. Further research must be carried out to establish what constitutes the most effective golf-specific conditioning programme and the effectiveness of these programmes to determine whether further improvements can be made in relation to golf-related fitness characteristics and swing mechanics. Furthermore, it needs to be shown whether golf-specific conditioning influences overall golf performance rather than fitness characteristics and club head speed alone. In spite of the quality of the studies and the use of generic strength and conditioning programmes, the evidence suggests conditioning has the potential to improve golfing performance and more specific and higher quality research in this field is warranted.

**References**


