The Effects of Resistance Training on Junior Golfers’ Strength and On-Course Performance

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The aim of this study was to examine the effect of resistance training on strength characteristics in junior golfers and observe the effect this has on golf performance. The study used a quasi-experimental design. 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. Assessments were conducted at baseline and 12 weeks. The primary outcome was change in strength over the intervention period. Effects on handicap were also assessed. No significant differences were found between groups at baseline for handicap or physical fitness variables. The intervention resulted in strength increases with all variables showing moderate to high effect sizes (d = 0.64–0.96). There was a moderate effect size for handicap (d = 0.42). Resistance-training programs can positively affect strength characteristics in junior golfers, which may influence golf performance.

Keywords: golf, resistance training, adolescents and golf handicap

Physical preparation programs are an integral part of athlete development in a wide variety of sports. Golfers have been slow to recognize the importance of strength and conditioning due to myths suggesting strength training will have negative effects on the golf swing (Fletcher & Hartwell, 2004). This trend is changing, especially at the elite level, with both professionals and elite amateur golfers utilizing physical preparation programs, including resistance training, as part of their training and practice schedules (Hellstrom, 2009). In addition, recent research has provided support for the importance of physical development for improving the golf swing and on-course performance (Hellstrom, 2009; Hume, Keogh, & Reid, 2005; Smith, Callister, & Lubans, 2011; Smith, 2010; Torres-Ronda, Sánchez-Medina, & González-Badillo, 2011).
Golf requires precise execution of powerful coordinated movements to produce a mechanically effective swing, which must be repeated 40–50 times during a single round of golf. It is then reproduced over extended periods of time depending on the length of a tournament, two to 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 (Brandon & Pearcend, 2009). 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 (Hume et al., 2005; Okuda, Gribble, & Armstrong, 2010; Yungchien, Sell, & Lephart, 2010). 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 (Cabri, Paulo, Kots M, & Barreiros, 2009; McHardy, Pollard, & Kehui, 2006). 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 nonathlete and athlete populations (Faigenbaum, Corbin, Pangrazi, & Franks, 2003; Harries, Lubans, & Callister, 2012). Resistance training programs tend not to be prescribed to children and adolescent populations due to fear of injury; however, research clearly shows that resistance training programs that follow age-appropriate guidelines pose no more risk of injury than any other sports or physical activities (Faigenbaum et al., 2009). Entry-level resistance training programs should initially concentrate on developing movement competence and then movement resilience (endurance). This is done by focusing on basic human movements whereby children and adolescents develop their ability to produce and reduce force, as well as stabilize and control their own body weight (Giles, 2006, 2011). This can be achieved by using a basic resistance-training program that centers on squatting, upper body pushing and pulling, and trunk stabilization and rotation. Golfers must be able to control and stabilize 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 (McHardy et al., 2006), 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 (2004) in the Long Term Athlete Development model. This model suggests that junior athletes should go through specific training progressions focused 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.

**Methods**

**Participants**

Junior golfers aged 12–18 years who were full members of a golf club and free from injury or medical conditions that would prevent them from participating in exercise testing and training 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 nonrandomly allocated to either the intervention group \( n = 8 \) or a wait-list control group \( n = 10 \) by the program organizer 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).

**Study Design**

The study used a quasi-experimental design. The intervention group were 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 before participation.

**Physical Characteristics**

Each participant completed a preexercise health-screening questionnaire 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. Portable equipment was used which allowed for easy transportation between venues.

### Strength-Related Outcomes

A progressively difficult single leg squat test was used to assess unilateral lower limb and hip strength and neuromuscular coordination (Miller, 2011). 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 stabilizers) 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 30 cm box, hands were placed out in front of the sternum with the nonsupport 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 system was as follows: unsuccessful 15° decline = 0; successful at 15° decline = 1, 10° decline = 2, 5° decline = 3, 0° = 4, 5° incline = 5, 10° incline = 6 and 15° incline = 7.

A timed side bridge test was used to assess torso strength-endurance (Evans, Refshauge, Adams, & Aliprandi, 2005; McGill, Childs, & Liebenson, 1999). 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 (Evans et al., 2005; McGill et al., 1999), 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 ($r = .96–0.99$)(McGill et al., 1999). 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 contralateral side, and the mean of the left and right sides used for analysis.

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 (Lubans et al., 2011). 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 characterized by full extension of the elbow and the down position was characterized 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.

**Mobility/Flexibility-Related Outcomes**

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 participant’s 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. While 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).

A back-saver (single leg) sit and reach test was used to assess unilateral posterior lower limb (hamstring flexibility), lumbar and hip flexibility (Chillon et al., 2010; Hartman & Looney, 2003; Miñarro, Andújar, & García, 2009). 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 (Hartman & Looney, 2003; Miñarro et al., 2009). 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 (Chillon et al., 2010; Miñarro et al., 2009). Since golf is a unidirectional sport this may provide some useful insight into the effect of unidirectional movement on lower limb flexibility symmetry. In addition the back saver sit and reach has been shown to be highly reliable \((r = .96–0.99)\) (Hartman & Looney, 2003) 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.

**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. While 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.

**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 (Faigenbaum et al., 2009). 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 (see Table 1). 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 organized into three phases (mesocycles). Phase 1 (weeks 1–4) focused on developing postural awareness and movement competence; Phase 2 (weeks 5–8) focused on strength-endurance; and Phase 3 (weeks 9–12) focused 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 (Faigenbaum et al., 2009).

Exercises for each body segment (lower/middle/upper) were included in each session and were designed to assist the participants develop the ability to produce
<table>
<thead>
<tr>
<th>Phase 1 Exercises (Posture &amp; base strength)</th>
<th>Sets × Reps (wks 1–2)</th>
<th>Resistance</th>
<th>Sets × Reps (wks 3–4)</th>
<th>Resistance</th>
<th>Rest Periods</th>
</tr>
</thead>
<tbody>
<tr>
<td>LBS Box steps</td>
<td>2 × 20</td>
<td>Black MB</td>
<td>3 × 30</td>
<td>Black MB</td>
<td>30–45sec</td>
</tr>
<tr>
<td>Hip bridge</td>
<td>2 × 15</td>
<td>Black MB</td>
<td>3 × 20</td>
<td>Black MB</td>
<td>30–45sec</td>
</tr>
<tr>
<td>Crab walks to squats (10 steps / 5 squats)</td>
<td>3 × 15</td>
<td>Black MB</td>
<td>3 × 20</td>
<td>Black MB</td>
<td>30–45sec</td>
</tr>
<tr>
<td>MBS Supine pelvic tilts</td>
<td>2 × 10</td>
<td>BW</td>
<td>3 × 10</td>
<td>BW</td>
<td>30–45sec</td>
</tr>
<tr>
<td>Quadruped pelvic tilts</td>
<td>2 × 10</td>
<td>BW</td>
<td>4 × 8</td>
<td>BW</td>
<td>30–45sec</td>
</tr>
<tr>
<td>1/2 side bridge hip raises</td>
<td>2 × 10</td>
<td>BW</td>
<td>2 × 15</td>
<td>BW</td>
<td>30–45sec</td>
</tr>
<tr>
<td>UBS Angel wings</td>
<td>2 × 30sec</td>
<td>Blue TUB</td>
<td>3 × 30sec</td>
<td>Black TUB</td>
<td>30–45sec</td>
</tr>
<tr>
<td>1/2 kneeling rows</td>
<td>2 × 10</td>
<td>Yellow PB</td>
<td>3 × 15</td>
<td>Yellow or Orange PB</td>
<td>30–45sec</td>
</tr>
</tbody>
</table>

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

<p>| Volume                                       | 197                    | Volume     | 326                    | Volume     | 326           |</p>
<table>
<thead>
<tr>
<th>Phase 3 Exercises (Rotation &amp; body segment control)</th>
<th>Sets × Reps (wks 9–10)</th>
<th>Resistance</th>
<th>Sets × Reps (wks 11–12)</th>
<th>Resistance</th>
<th>Rest Periods</th>
</tr>
</thead>
<tbody>
<tr>
<td>LBS</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lateral resisted split squat</td>
<td>3 × 10</td>
<td>Orange PB</td>
<td>3 × 15</td>
<td>Orange or Red PB</td>
<td>30–45sec</td>
</tr>
<tr>
<td>Lateral step squats to leg drive</td>
<td>3 × 6</td>
<td>BW</td>
<td>4 × 8</td>
<td>BW</td>
<td>30–45sec</td>
</tr>
<tr>
<td>Lateral bounds</td>
<td>3 × 6</td>
<td>BW</td>
<td>4 × 6</td>
<td>Black MB</td>
<td>30–45sec</td>
</tr>
<tr>
<td>MBS</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Resisted cross-pattern crawling</td>
<td>3 × 20</td>
<td>Yellow or Orange PB</td>
<td>4 × 20</td>
<td>Orange or Red PB</td>
<td>30–45sec</td>
</tr>
<tr>
<td>60° Seated torso rotations</td>
<td>3 × 14</td>
<td>BW</td>
<td>3 × 20</td>
<td>BW</td>
<td>30–45sec</td>
</tr>
<tr>
<td>Lying lower body rotations (Arm across chest)</td>
<td>3 × 14</td>
<td>BW</td>
<td>3 × 20</td>
<td>BW</td>
<td>30–45sec</td>
</tr>
<tr>
<td>Pallof Presses</td>
<td>3 × 10</td>
<td>Yellow PB &amp; Black MB</td>
<td>3 × 15</td>
<td>Yellow or Orange PB &amp; Black MB</td>
<td>30–45sec</td>
</tr>
<tr>
<td>UBS</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Standing single arm press and rotate</td>
<td>3 × 10</td>
<td>Yellow PB</td>
<td>4 × 10</td>
<td>Yellow or Orange PB</td>
<td>30–45sec</td>
</tr>
<tr>
<td>Standing single arm pull and rotate</td>
<td>3 × 10</td>
<td>Yellow or Orange PB</td>
<td>4 × 10</td>
<td>Orange or Red PB</td>
<td>30–45sec</td>
</tr>
<tr>
<td>Volume</td>
<td>300</td>
<td>Volume</td>
<td>426</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

MB = Mini knee band, TUB = Tubing, PB = 41’ Power band
and reduce force as well as stabilize and control body movement. The lower body
segment exercises concentrated on building lateral stability and increasing gen-
eral hip and leg strength. Middle body segment exercises focused on developing
pelvic control and trunk strength with rotational control exercises progressively
introduced. Upper body segment exercises were focused 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 use the entire kinetic chain, requiring
them to stabilize one segment while 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. In
addition, the program was designed to establish a strong movement foundation that
will be beneficial in more advanced exercises in later programs.

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 posttest
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 posttest scores and bivariate cor-
relation was used to examine the relationship between changes in fitness param-
eters 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)(Batterham & Hopkins, 2006;
Hopkins, Marshall, Batterham, & Hanin, 2009; Moher et al., 2010) particularly
when studying athletic groups. Cohen’s $d$ (1988) was used to determine the inter-
vention 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 ($d \leq 0.2$), small ($d>0.2–≤0.5$),
moderate ($d>0.5–≤0.8$) or large ($d>0.8$) (Cohen, 1988; Cohen, 1992). 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 ($r = >0.9$) (W G Hopkins, 2002).

Results
Thirty junior golfers were recruited for the study (Male $N = 26$, Female $N = 4$).
Table 2 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.

Physical Performance Characteristics

Table 3 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).

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.

Relationships Between Changes in Fitness Characteristics and Handicap

Table 4 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 = -.48), modified push-ups (r = -.44) and shoulder mobility (r = -0.38).

Discussion

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.
<table>
<thead>
<tr>
<th>Outcome</th>
<th>Intervention (n = 20) Baseline</th>
<th>Intervention (n = 20) Post study</th>
<th>Control (n = 10) Baseline</th>
<th>Control (n = 10) Post study</th>
<th>Mean adjusted difference between groups¹ (95% CI)</th>
<th>Group *Time (p-value)</th>
<th>Effect Size (Cohen’s d)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Single Leg Squat (level)</td>
<td>(0.70, 1.20)</td>
<td>(1.09, 1.54)</td>
<td>(1.16, -0.16, -0.25)</td>
<td>(1.54, -0.25, 2.57)</td>
<td>0.10</td>
<td>0.002</td>
<td>0.96</td>
</tr>
<tr>
<td>Side Bridge (s)</td>
<td>(69.25, 85.62)</td>
<td>(84.59, 70.32)</td>
<td>(30.65, 6.10, 55.20)</td>
<td></td>
<td>0.002</td>
<td>0.96</td>
<td>0.96</td>
</tr>
<tr>
<td>Modified Push-ups (reps)</td>
<td>(18.60, 22.03)</td>
<td>(25.40, 18.60)</td>
<td>(8.64, -0.62, 17.90)</td>
<td></td>
<td>0.002</td>
<td>0.71</td>
<td>0.71</td>
</tr>
<tr>
<td>Sit and Reach (cm)</td>
<td>(2.69, 3.13)</td>
<td>(-2.45, -1.34)</td>
<td>(-0.67, -4.93, 3.58)</td>
<td></td>
<td>0.74</td>
<td>-0.12</td>
<td></td>
</tr>
<tr>
<td>Shoulder Mobility (cm)</td>
<td>(40.02, 37.65)</td>
<td>(46.35, 41.43)</td>
<td>(2.56, -5.46, 10.58)</td>
<td></td>
<td>0.51</td>
<td>0.25</td>
<td></td>
</tr>
<tr>
<td>Handicap</td>
<td>(15.20, 12.27)</td>
<td>(15.26, 13.65)</td>
<td>(-1.32, -3.72, 1.08)</td>
<td></td>
<td>0.27</td>
<td>0.42</td>
<td></td>
</tr>
</tbody>
</table>

¹Mean adjusted difference = [(Intervention (Post—Base) — Control (Post—Base)]
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 (Chettle & Neal, 2001; Sell, Tsai, Smoliga, Myers, & Lephart, 2007; Wells, Elmi, & Thomas, 2009). 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 (Smith et al., 2011).

The greatest gains in strength for adolescents have been shown to occur at the time of peak height velocity (PHV) (Balyi & Hamilton, 2004; Philippaerts et al., 2006). While 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 (Faigenbaum et al., 2009; Zatsiorsky & Kraemer, 2006). Two previous meta-analyses showed mean effect sizes of 0.57 and 0.75 for strength gains in resistance-training programs in youth populations (Falk & Tenenbaum, 1996; Payn, Morrow, Lynne, & Dalton, 1997). Research has also shown strength gains of 30–74% after short-term resistance training programs (8–20 weeks) (Faigenbaum et al., 2009). 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 (Balyi & Hamilton, 2004). This stage is characterized by less emphasis on competition and more focus on training and developing sport-specific skills and physical characteristics (Balyi & Hamilton, 2004). 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

<table>
<thead>
<tr>
<th>Fitness Measure</th>
<th>Pearson 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 \( p < .05 \)
targeted (Ford et al., 2011). 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 (Hellstrom, 2009; Hume et al., 2005; Smith, 2010; Torres-Ronda et al., 2011). In the current study, moderate inverse correlations were found 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 individualized technical development, i.e., coaching. Further study of the impact of strength and fitness improvements on golf performance is clearly warranted.

Limitations

A major limitation to the study was the small sample size 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 with 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.

The study used a nonrandomized quasi-experiment design. Ideally the study would have been randomized, however this could not occur due to Squad A mandating that to be included in the study they would need to be included in the intervention group. Due to already having a small sample size the experimental design had to be amended.

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.

Handicap change over the intervention period was used to monitor changes in golf 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 individual golfer’s 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 participant 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.

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 (Folland & Williams, 2007).

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.

**Practical Application and Future Research**

Resistance training can have a positive effect on golf swing and on-course performance (Smith et al., 2011). 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 with 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 (Faigenbaum et al., 2009).

**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 is needed 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.
References


