The effect of a seven-week exercise program on golf swing performance and musculoskeletal measures

Olivier, Mico H.; Horan, Sean A.; Evans, Kerrie A.; Keogh, Justin W L

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THE EFFECT OF A SEVEN WEEK LONG, ONE SESSION PER WEEK EXERCISE PROGRAM ON GOLF SWING PERFORMANCE AND MUSCULOSKELETAL MEASURES

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Mico H Olivier

Faculty of Health Science and Medicine

Bond University

University Drive

Gold Coast 4016

Ph: +61 7 559 54469

Email: mico.olivier@student.bond.edu.au

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Running head: Golf swing exercise program

Authors:

Mico H. Olivier[1], Sean A. Horan[2], Kerrie A. Evans[2], Justin W. L. Keogh[1,3,4]

[1]Faculty of Health Science and Medicine

Bond University

Gold Coast, Queensland

Australia

[2] School of Allied Health Sciences

Menzies Health Institute Queensland

Griffith University, Gold Coast

Queensland

Australia

[3]Sport Performance Research In New Zealand (SPRINZ)

AUT University,

Auckland

New Zealand

[4] Cluster for Health Improvement,

Faculty of Science, Health, Education and Engineering

University of the Sunshine Coast

Sippy Downs, Queensland

Australia

Corresponding author:

Mico H Olivier

Faculty of Health Sciences and Medicine

Bond University, University Drive

Gold Coast 4026

Ph +61 7 559 54469

Email: mico.olivier@student.bond.edu.au

ABSTRACT

As most golf exercise studies have involved two or three sessions per week, the present study investigated the effects of a supervised exercise session performed once a week for seven weeks on golf swing variables and musculoskeletal screening measures. Forty-three golfers from the Professional Golfers Association of Australia International Golf Institute (PGA-IGI) with a mean ± SD handicap of 8.6 ± 8.3 participated in the study. Each golfer performed 10 musculoskeletal tests and a standardised 60-shot golf performance test (TrackMan, Vedbaek, Denmark) on separate days before and after the seven-week program. Significant improvements in a number of musculoskeletal tests (i.e. left leg bridging, thoracic extension, right thoracic rotation, and right and left single leg squat) were observed ($p < 0.05$), however, no significant differences were observed for any golf swing variables. Further research is required to determine whether alternative training protocols may improve golf performance.

Keywords: Clubhead speed, TrackMan, movement screening, muscular endurance, launch monitor.

INTRODUCTION

Golf has traditionally been viewed as a skill based sport that is not overtly physical and has a low risk for injury. However, this view is in contrast to elite golf practice with recent reviews finding high levels of lower body, trunk and upper body muscle activity during the golf swing [1], relatively high physiological stress during match play [2] and relatively high injury rates to areas such as the lower back, shoulder and wrist [3-5]. Most golf-related injuries are thought to result from the large number of practice hours golfers perform, the asymmetrical nature of the golf swing or biomechanical-related swing inefficiencies.

Several interventions studies have looked at the effects of exercise programs on physical characteristics and found significant improvements following the intervention programs in muscular strength, power, endurance and range of motion in golfers of various ages and skill levels [6-12]. The study by Doan et al. [6] assessed highly skilled golfers before and after 11 weeks of resistance training, assessing their golf performance, muscular strength and flexibility. They reported significant improvements in all strength, power and flexibility measurements, with relative strength gains and flexibility ranging from 7-24% and 7–16% respectively. Similarly, Lephart et al. [10] investigated the effects of an eight-week exercise program on less skilled and older athletes in comparison to the above mentioned study. Their results showed statistically significant increases in all ROM tests as well as for club head velocity, ball velocity, carry distance and total distance. The majority of previous intervention studies have ranged between 8-18 weeks and typically involved 2-3 exercise sessions per week. In contrast, the training programs of Larkin et al. [11] and Reyes [12] only went for three and seven weeks, respectively. Following on from this, a recent study by Lamberth et al. [13] utilised a 6-week combined resistance and functional training program with the aim of eliciting improvements in golf performance. Lamberth et al. [13] found significant improvements in one-repetition maximum bench press and leg press, but no significant change in club swing speed.

Despite growing evidence that exercise offers golfers significant performance benefits [6-10], the specific type and frequency of physical conditioning programs to achieve optimal outcomes is still unknown. Adhering to time-intensive exercise programs may be challenging for collegiate golfers who are studying full-time, working part-time and trying to maintain relatively high amounts of golf practice and match play. These demands may mean that it is difficult for these golfers to apportion enough time to be able to perform 2-3 supervised exercise sessions per week as has been performed in previous intervention studies [6-10, 14]. Additionally, with the collegiate golf programs requiring students to pass academic, playing and industry components away from the course, program instructors need to be mindful of student load when scheduling exercise sessions into the program. As very little research has examined the effects of a reduced physical conditioning training duration and/or frequency on collegiate golfers, such research appears warranted. Previous studies that have examined reduced training frequency [15-17] have demonstrated that relatively untrained older adults can significantly improve muscular strength, power and/or endurance with one exercise session per week. Furthermore, significant body composition and physical performance gains can be observed in as little as four weeks of training in professional rugby union players [18]. It would therefore appear feasible that even one resistance exercise session per week may induce significant improvements in muscular strength, power and endurance that may subsequently improve musculoskeletal screening test outcomes and/or golf performance in collegiate golfers with little to no physical conditioning experience.

Strength and conditioning coaches and physiotherapists frequently employ musculoskeletal screening assessments [19-24] to assess physical fitness deficiencies and movement dysfunctions thought to contribute to reduced performance or an increase injury risk in athletes. Screening protocols, such as the Functional Movement Screen (FMS) [19-22, 25, 26], Movement Competency Screen (MCS) [24] and the Conditioning Specific Movement Tasks (CSMT) [23] have gained substantial attention over recent years because of their proposed potential to identify dysfunctional movement patterns that may reduce performance and predispose athletes to greater risks of injury. From a performance perspective, Parsonage et al. [23] investigated elite adolescent rugby players and divided them into 3 groups based on four CSMT. Results showed that the two groups who performed better on movement competency tests, thought to be specific for rugby, were significantly faster over 10, 20 and 40m, jumped significantly higher, and covered significantly greater distances on the Yo-Yo intermittent recovery level 1 than the group who scored lower on these movement competency tests. Kiesel et al. [26] and Cowen et al. [27] have also observed significant improvements in FMS scores after an exercise program designed to improve the movement deficiencies identified by baseline assessments.

However, some limitations still exists with the common screening assessments. First, there is currently limited evidence as to the efficacy of these screening protocols in reducing the risk of injury. Secondly, these screening approaches appear quite generic and appear to be focused on athletes competing in running-based sports. On this basis, a more “golf specific” musculoskeletal test protocols referred to as the *Ten Test On Range* (The Golf Athlete, Brisbane, Australia) assessment protocol have been developed. This screening tool involves a series of tests designed to specifically test physical parameters thought to be important for golf and thus was adopted in this study [28]. While commonly used in by many Australian golf professionals and physiotherapists, there is limited research on this screening tool.

Therefore, the aim of the current study was to investigate the effects of a short duration (i.e. seven week) exercise program comprising one exercise session per week on musculoskeletal test scores and golf swing performance. It was hypothesised that the exercise program would result in improvements in both musculoskeletal screening scores and golf swing performance.

METHODS

PARTICIPANTS

Forty three golf students (7 females and 36 males, mean ± SD age 24 ± 8.9 years) volunteered to participate in the study (handicap, 8.6 ± 8.3 strokes). All students were enrolled in a Diploma of Golf Management at the PGA-IGI (Professional Golf Association – International Golf Institute), which is a full-time, one year golf management course. All participants had a minimum of one years' golf experience, and little if any previous experience with a golf-specific exercise program. Written consent was obtained prior to data collection and approval to conduct the study was given by the relevant institutions' ethics committees.

OVERVIEW OF EXPERIMENTAL DESIGN

The current project was a single-group based intervention study involving a pre post design. Prior to the seven-week exercise intervention, participants completed assessments of musculoskeletal screening and golf performance across two testing sessions. At the first session, participants were asked to perform a series of 10 selected musculoskeletal screening tests [28], while at the second session participants performed a standardised, field based golf performance test which included 60 golf shots (Combine Test, TrackMan, ISG A/S, Denmark). Following baseline testing, all participants undertook a once weekly, seven-week golf specific exercise program consisting of muscular strength and endurance exercises. Following completion of the exercise program, all participants repeated the same musculoskeletal screening and golf swing performance tests performed at baseline.

MUSCULOSKELETAL SCREENING ASSESSMENTS

The present study employed 10 musculoskeletal screening tests to examine flexibility, muscular endurance and movement competency of all participants. The testing sessions were conducted at a Country Club, with each of the musculoskeletal screening sessions lasting ~one hour, whilst each Combine performance test taking ~45 minutes. An experienced Exercise Scientist, 2 experienced sports physiotherapists, 10 post-graduate physiotherapy students and a Master of Science student conducted the musculoskeletal testing sessions at the Country Club. The Combine test was performed on the golf range under the supervision of a Master of Science student with the assistance of a golf lecturer at the Country Club. Table 1 provides a description and rationale of the musculoskeletal screening tests utilised in this study.

Insert Table 1 about here

GOLF SWING PERFORMANCE AND VARIABLES

Golf swing performance was measured using a Doppler Radar system, namely the TrackMan (TrackMan IIIe, Vedbaek, Denmark). This device is valid and reliable [29] and is commonly used by Australian golf coaches and on the USPGA and European PGA tours [30]. Using this device enables participants to complete a field based golf performance test called the

‘Combine Test’ (TrackMan Performance Studio Version 3.0, TrackMan, Denmark), which involved 60 shots to 10 standardised targets. For each shot, the software provides a score from 0-100 based on distance from the target along the target line and lateral deviation from the target line. The lowest score for a shot equates to 0 and the highest 100. Distance markers were placed at 50, 100 and 150 metres, with the markers measured using a golf laser range finder (Bushnell Medalist, Overland Park, United States). The distance markers were placed in a line, providing each golfer with a target line to hit towards. All testing was performed on an outdoor driving range (150 × 300 metres), with each participant hitting shots from an artificial grass mat. Environmental conditions were similar on all testing days, with temperatures between 24 – 28 degrees Celsius and light winds between 10 – 20 km/h. The golf balls used were range balls (Srixon, Sydney, Australia), which generally travel ~80% of the distance of a standard competition ball. The TrackMan device was set up approximately 1.5 – 2.0 m behind the ball and in line with the target line similar to the recommendations of Robertson et al. [31].

Following a warm-up and familiarisation period of 15-20 minutes which included shots with a selection of clubs (i.e. self-selected), participants undertook the Combine Test. The test requires the golfer to hit shots using their club of choice (except the maximum distance shot where a driver is used) to distances along a target line at 65, 75, 85, 95, 105, 125, 145 and 165 metres, as well as a shot for maximum distance with the driver club. At each distance the golfer hits three shots starting at the 65 metre distance, followed by three shots to each subsequent distance thereafter. At the completion of these 30 shots, the process is repeated a second time until a total of 60 shots is completed. In the current study, participants were instructed to hit the ball as straight and close as possible to the target distance, except for the driver where participants were instructed to hit the ball as far and straight as possible. In addition to a score for each shot and an overall score out of 100, the TrackMan device allows for the measurement of other performance variables. In the current study, the measurements we were interested in were club head speed (CHS), ball speed, carry distance, total distance, carry side (lateral deviation distance) and smash factor (ball speed / clubhead speed). A description of the variables is given in Table 2.

Insert Table 2 about here

EXERCISE PROGRAM

All participants were asked to complete one supervised exercise class per week for a seven week period. The exercise program (see Table 3) was developed through consensus moderation between all researchers (all of which were trained exercise scientists or physiotherapists), with consideration given to the biomechanics and physical requirements of the golf swing, common injury sites of golfers, as well as the practicalities of the exercise facility and time available per class. The classes were held in a group exercise room and supervised by an experienced sports physiotherapist and a Master of Science student. The available equipment consisted of bikes, step-up boxes, a smaller barbell and weight plates up to 5kg. Each class ran for approximately 60 minutes which included a 5 minute warm-up and cool-down component. Consequently, the exercise program consisted of several traditional muscular endurance exercises as well as more golf specific movements involving rotational movements of the hips, torso and shoulders [1]. Exercises were adapted and progressed or alternatively regressed to suit the physical levels of each participant as determined using the baseline musculoskeletal screening assessment.

Insert Table 3 about here

STATISTICAL ANALYSIS

As assumptions of normality were met for all outcomes based on the Shapiro-Wilks test, means and standard deviations were used as measures of centrality and spread. A repeated measures ANOVA was performed to evaluate pre-post differences in all outcomes for the entire group. However, because of considerable variation in the number of exercise sessions attended by some participants, a secondary analysis was performed comparing the training response of those completing 6 or greater sessions ($n = 11$), those who completed 4 sessions ($n = 6$) and those who completed 2 or less sessions ($n = 8$). The three groups were referred to as the High, Medium and Low adherence groups, respectively. Given many of the outcomes for this sub-group analysis did not meet the assumptions of normality according to the Shapiro-Wilks tests, a Mann-Whitney U test was performed to compare the pre-post change scores between the sub-groups for all outcome measures. All statistical analyses were performed in SPSS Version 20, with significance set at $p < 0.05$.

RESULTS

Thirty six of the original 43 participants completed baseline and post testing and the data from these 36 participants are presented in Tables 4-5. Adherence data was also recorded for every exercise session, with a mean attendance rate of 55% (i.e. an average of 3.8 out of 7 sessions was attended by the whole group). As shown in Table 4, significant improvements in a number of musculoskeletal screening tests was observed for the entire group including: left leg bridging ($p = 0.024$); combined elevation (thoracic extension) ($p = 0.013$); right thoracic rotation ($p < 0.001$); and right and left single leg squat performance ($p = 0.012$ and $p = 0.001$ respectively). In contrast, no significant changes in any of the golf performance measures were observed for the entire group (see Table 5).

Insert Table 4 about here

Insert Table 5 about here

Results of the Mann-Whitney U test for the effect of attendance on outcome measures revealed a small number of significant between-group effects. These included an improved overhead squat and single right leg squat for the High versus the Moderate group ($p = 0.008$, and $p=0.033$ respectively); an improved left side bridge holding time squat for the High versus Low group ($p = 0.011$); and no significant changes for the Moderate versus the Low group ($p > 0.05$). For golf swing performance measures (i.e. Combine Test overall scores, clubhead speed, ball speed, driving distance, smash factor and carry side) no significant between-group differences in change scores were observed between the three attendance groups.

DISCUSSION

The main findings of this study were that significant improvements were observed in several musculoskeletal screening tests including the left leg bridging lift, combined elevation test, right thoracic rotation, and right and left single leg squat performance. However, no significant improvements were observed for any of the golf swing performance variables. Additionally, Mann-Whitney U test results demonstrated no significant differences in the change scores between the three attendance groups for any of the golf swing performance measures, although more frequent training was associated with greater improvements in a number of the musculoskeletal screening tests including the left side bridge and overhead squat.

Improvements in a number of the musculoskeletal screening tests as a result of the exercise intervention provides partial support for our first hypothesis. Such findings are consistent with several previous investigations, all of which found significant improvements in strength and range of motion outcomes when golfers engaged in a regular exercise program [6, 8-10]. For example, Doan et al. [6] assessed one-repetition maximum (1-RM) strength for the bench press, shoulder press, lat pulldown, and squat exercises which are well-known global exercises typical of strength training, and reported significant improvements in all these tests following an 11-week exercise intervention. A different approach was used by Lephart et al. [10] assessing strength of the torso, shoulders and hip muscle using a Biodex System III Multi-Joint testing and Rehabilitation System. Following the eight-week exercise intervention, Lephart et al. [10] reported significant improvements in torso rotational and hip abduction strength as well as all range of motion variables.

A unique feature of the current study was the one exercise session performed each week. Previous studies that have examined the effect of a single exercise session per week on previously untrained older adults found significant improvements in a range of physical qualities including muscular endurance and functional performance [15-17]. Similarly, we found improvements in several range of motion and movement competency tests (single leg bridging, thoracic rotation, thoracic extension and single leg squat performance) in younger, untrained collegiate golfers. Despite improvements in physical competency, this current study along with Lamberth and colleagues [13] observed no translation into improved golf performance, which is in contrast to the observed increases in both physical qualities (leg strength, core strength, range of motion) and CHS reported in previous studies [6-10, 14].

The most plausible explanation for the discrepancy, is that most previous golf specific exercise programs have utilised 2 – 3 sessions per week over 8 – 18 weeks, whereas our study consisted of only 1 session per week for seven weeks. Limited improvement in golf performance may reflect a minimum dosage effect, whereby a greater training duration might be required if the frequency is only once per week. This view is partially supported by the results of the sub-analysis comparing the High, Medium and Low attendance groups, whereby greater improvements were observed for multiple musculoskeletal screening tests for those who attended more exercise sessions.

There were several limitations that warrant acknowledgement in this study. Firstly, no control group was used during the study. Second, exercise program adherence rates were lower than previous studies, with a mean adherence rate of 55% for the whole group over the seven-week period. This is likely to have decreased the overall effectiveness of the intervention. Lastly, while individualised training programs were considered, they were deemed not to be feasible due to limitations in access to the training facility and the prohibitive cost of providing individual supervised sessions. Consequently, we utilised groups sessions that contained individually focussed exercises, which may have diluted the overall effectiveness of the program.

CONCLUSION

Our results indicate that although exercising once a week for seven weeks leads to no significant improvement in golf performance as assessed by the Combine test, it did result in significant improvements in several musculoskeletal screening tests. In relation to the wider golfing strength and conditioning literature, our results suggest that in relatively untrained golf populations some improvements in physical characteristics may occur with short duration, once a week training, but a longer duration or frequency of exercise is needed to improve golf swing performance. Future research should directly compare variations in exercise duration or frequency using randomised controlled trial designs to better elucidate the effect of manipulating exercise prescription variables on musculoskeletal screening and golf performance outcomes.

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Table 1: A Description of the Musculoskeletal Screening Tests

Musculoskeletal Screening Test	Structures Assessment	Protocol
Side bridge	Challenges the muscles of the anterolateral chest wall (lateral trunk flexors), the quadratus lumborum, external and internal obliques.	Participants laid on their side on the floor, with their forearm and feet supporting their weight. The elbow joint of the support arm flexed at 90°, with the opposite arm placed across their chest and legs extended. Participants then elevated their hips and kept a straight line with their whole body for maximum time, as assessed by a stopwatch [32, 33].
Front plank	Challenges the muscles of the anterior abdominal muscles.	Participants were prone, placing their hands and elbows in front of them on the ground. Participants had to elevate their bodies to start the test, using their hands and toes as pivots whilst maintaining a straight, neutral body position where time taken was in seconds and participants were encouraged to maintain this for as long as possible.
Combined	Global measure of the flexibility of the	Participants were prone on the floor, arms extended out in front of them with hands

elevation (thoracic extension)	upper back and thoracic spine	pointing forward, palms facing down and thumbs touching. Participants kept their chins on the floor, looking up at their thumbs with their chest, hips and feet kept on the floor during the test. They had to then lift up their arms slowly and as far as possible whilst keeping thumbs touching. The vertical distance from their hands to the floor was taken with a tape measure.
Hip Internal Rotation	Global measure of hip internal rotation movement	Participants were supine on a plinth, a belt was around their hips at the anterior superior iliac spine to stabilise their pelvis. The non-test leg was kept straight and the stretching leg was in 90° hip flexion. The assessor inwardly rotated the knee which outwardly rotated the foot until resistance. The stationary arm of the goniometer was in line with trunk and the movable arm in line with tibia. The COR was at the central patella tendon/inferior pole (central knee joint). This was repeated on the other leg.
Hip External Rotation	Global measure of hip external rotation movement	Participants were supine on a plinth, a belt was placed around their hips at the anterior superior iliac spine to stabilise their pelvis. With one leg straight, the other leg was at 90 degrees hip flexion. Their foot was outwardly rotated which inwardly rotated the hip until resistance. The stationary arm of the goniometer was in line

		with trunk and the movable arm in line with tibia. The COR was at central patella tendon/inferior pole (central knee joint). This was then repeated on the other leg.
Straight Leg Raise	Global measure of the flexibility of the hamstring muscle group	Participants were supine on a plinth with hands by their sides. One instructor lifted the test leg extended into hip flexion, keeping the knee extended until resistance was felt or pain initiated. The opposite leg and pelvis was kept straight by another instructor. An inclinometer was placed on the anterior part of the tibia, measuring the degrees of flexibility.
Thoracic Rotation	Global measure of the flexibility of the cervical & thoracic spine	Participants sat upright in a chair. A golf club was placed behind their backs for them to cradle the club in their elbows and maintaining club-spine contact. Participants kept knees, feet and hips facing forward. Participants rotated to one side as far as possible until club-spine contact was no longer maintained. A goniometer measured degrees of rotation by placing the stationary arm above the participants head with the moving arm in line with the leading shoulders direction and shaft direction. This was repeated on the other side.
Overhead squat	Global measure of upper back, hip and ankle mobility	Participants stood feet shoulder width apart, and were instructed to squat down until thighs were parallel to the floor. They had to keep the golf club above their

		head. Scoring was done with a 1, cannot get thighs to parallel with arms across chest, to 5, squat with thighs parallel and arms extended above head, scale
Single leg bridging lift	Global measure of hip strength and weight transference	Participants were instructed to lie supine on the floor, place feet apart, and lift their hips off the ground whilst extending one leg and holding it for 10 seconds. Participants were scored on a 1 – 5 scale, with 1 being the inability to straighten the leg and 5 is a steady 10 second hold with no cramping in the hamstring muscles
Single leg squat	Global measure of hip & trunk muscle strength	Participants folded their arms across their chest, stood on one leg with the other leg out in front. Participants were encouraged to do 6 controlled squats whilst aiming to reach 90° knee flexion. A scoring system of 1, significant dropping of hips, knees and losing balance, to 5, performed squat with good control to 90 degrees knee flexion, was used

Table 2: Definitions of multiple golf performance variables as measured by the TrackMan Pro.

Golf performance variables	**Definitions**
Club head speed (CHS)	The speed at which the club head is moving before impact
Ball Speed	The speed of the ball after impact is made
Carry Distance ("flat")	The distance the ball travels through the air
Carry Side (accuracy)	The measurement of where the ball lands in relation to the target line, either left or right of it.
Smash Factor	The ball speed divided by the club speed

Table 3: A List of Exercises Implemented in the Seven-Week Exercise Program.

Body Part	Exercises Progressions	Sets	Reps	Rest between sets
Lower body	Bodyweight lunge	3	8 - 12	45-60s
	Bodyweight Lunges with twist			
	Weighted Lunges with twist			
	Hockey jumps			
Upper push	Bodyweight push ups on knees	3	8 - 12	45-60s
	Bodyweight push ups			
	Dumbbell push ups			
Core	Prone hold	3	45 sec.	45-60s
			1 min	
	Seated Russian twist		10 – 15	
	Barbell woodchop		10 -15	
Upper pull	Prone 1-arm dumbbell rows	3	8 - 12	45-60s
	Renegade row			
Sprints	Resisted band sprints	1	5	walk back to start

Table 4. Changes in Musculoskeletal Screening Test Scores after the Seven Week Training Program

Outcome		Baseline mean ± SD	Post mean ± SD	p - value
Side bridge (sec)	Right	75 ± 34.8	87 ± 34.7	0.146
	Left	75 ± 30.9	93 ± 39.6	0.065
Bridging leg lift (1-5)	Right	4.6 ± 0.7	4.8 ± 0.5	0.570
	Left	4.5 ± 0.7	4.8 ± 0.4	0.024*
Straight leg raise (degrees)	Right	68 ± 11.5	69 ± 12.7	0.691
	Left	69 ± 11.3	70 ± 11.9	0.679
Hip internal rotation (degrees)	Right	27 ± 10.2	26 ± 6.8	0.625
	Left	28 ± 9.1	25 ± 7.8	0.224
Hip external rotation (degrees)	Right	40 ± 10.2	42 ± 12.6	0.553
	Left	39 ± 10.8	39 ± 14.4	0.796
Combined elevation (cm)		8 ± 6.7	13 ± 8.9	0.013*
Thoracic rotation (degrees)	Right	30 ± 6.2	37 ± 7.4	< 0.001**
	Left	31 ± 7.5	30 ± 9.6	0.860
Overhead squat (1-5)		3.8 ± 1.6	4.2 ± 1.2	0.354
Single leg squat (1-5)	Right	2.4 ± 0.7	2.9 ± 0.9	0.012*
	Left	2.4 ± 0.8	3.1 ± 0.8	0.001*
Front plank (sec)		140 ± 69.7	152 ± 79.6	0.507

* Statistical significance level at $p < 0.05$; ** Statistical significance level at $p < 0.001$.

Table 5. Changes in Golf Swing Performance after the Seven Week Training Program

Outcome	Baseline mean ± SD	Post mean ± SD	p - value
Combine test	66.0 ± 12.0	67.1 ± 9.4	0.681
Club head speed ($km.h^{-1}$)	162.1 ± 17.5	162.1 ± 17.0	0.995
Ball speed ($km.h^{-1}$)	225.7 ± 25.7	224.1 ± 24.0	0.773
Smash Factor	1.39 ± 0.05	1.38 ± 0.05	0.391
Driving Distance (metres)	234.6 ± 37.3	220.3 ± 31.1	0.072
Carry Side	0.6 ± 12.4	0.5 ± 13.2	0.718

* Statistical significance level at $p<0.05$