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Original research

A randomized trial of traditional and golf-specific resistance training in amateur female golfers: Benefits beyond golf performance

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ABSTRACT

Objective: Compare golf-specific resistance training (GSRT) with traditional resistance training (TRAD) with regard to golf performance and other outcome measures.
Design: Randomized controlled study.
Setting: Outpatient gym.
Participants: 45 female golfers were randomized into TRAD or GSRT, both of which targeted muscles active during the golf swing. Participants performed supervised training 3d·wk^{-1} for 10 weeks.
Outcome Measures: Golf performance, bone density, body composition, and physical performance tests.
Results: 29 individuals (58.1 ± 2.1y; 15 TRAD, 14 GSRT) completed training. Completers were older ($p = 0.048$) and played golf more frequently than non-completers ($p = 0.002$), but were not otherwise different. Training decreased whole body fat mass ($p = 0.013$) and visceral fat mass ($p = 0.033$) across groups, but did not influence lean mass ($p = 0.283$) or bone mineral density ($p = 0.205$). Training increased driver speed ($p = 0.001$), driver distance ($p = 0.020$), and 7I distance ($p < 0.001$), but not 7I speed ($p = 0.160$), but no group or interaction effects were present. Training increased all physical performance tests ($p \leq 0.005$) regardless of group, but the seated medicine ball throw was most related to baseline driver speed ($r^2 = 0.384$), and also most responsive to training ($r^2 = 0.250$).
Conclusion: 10 weeks of supervised TRAD and GSRT provided similar improvements in body composition, golf performance, and physical performance in amateur female golfers.

1. Introduction

According to the National Golf Foundation report on golf participation in the United States, 24.7 million people played one or more rounds of golf in 2013 (Golf Participation in the United States, 2014). One sector where the game of golf continues to grow is with females, 5.3 million of whom played one or more rounds of golf in 2013. Although an exact number is not known, many of these female participants will engage in resistance training in an effort to improve their golf game.

A number of studies have found that resistance training benefits golf performance, generally measured by changes in club head speed or driving distance. Early research in this realm concentrated on traditional resistance training and flexibility, with reports of 2.5–6.3% improvements in club head speed (Hetu, Christie, & Faigenbaum, 1998; Thompson & Osness, 2004). Improvements in club head speed and driving distance were also noted when plyometric training was combined with traditional weight training (Fletcher & Hartwell, 2004). More recent studies, which have focused on targeting factors known to be associated with golf performance and incorporating sport-specific movements, have also reported similar improvements in golf parameters in collegiate athletes (Doan, Newton, Kwon, & Kraemer, 2006), middle aged males (Lephart, Smoliga, Myers, Sell, & Tsai, 2007), and senior citizens (Thompson, Cobb, & Blackwell, 2007).

While studies have shown that both a traditional resistance training program and a golf-specific training program can improve

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golf performance, there is a lack of literature comparing these two training programs using golf-specific outcomes. Only one golf training study has included a comparison of traditional versus golf-specific training, and this was performed as part of a periodized program in young low-handicap male golfers, and resistance training volume greatly differed between groups (Alvarez, Sedano, Cuadrado, & Redondo, 2012). Furthermore, this study is typical with regard to gender in that most of what is known about strength training pertains to male golfers despite the fact that there are sex-specific differences in the golf swing (Horan, Evans, & Kavanagh, 2011) as well as the metabolic requirements (Zunzer, von Duvillard, Tschakert, Mangus, & Hofmann, 2013) and psychological components of golf (Hayslip & Petrie, 2014; Kim, Park, Kim, Jun, Park, & Kim, 2010).

Therefore, the primary purpose of this study was to compare the effects of a 10-week traditional resistance training program to a functional, golf-specific resistance training program on golf performance parameters, specifically driver and 7-iron club head speed and shot distance, in recreational female golfers. In addition, we aimed to determine whether these training programs improved selected health-related outcomes, including bone density and body composition, and whether there was any relationship between physical performance tests and golf performance parameters. Our main hypothesis was that there would be no between group differences for golf performance, physical performance, and health-related outcomes but both groups would show improvement.

2. Materials and methods

2.1. Participants

Amateur female golfers were recruited through postings at local country clubs and public golf courses, as well as through emails to state and local women's golf associations. Inclusion criteria were: females $\geq$18 years of age, and an official handicap or completion of at least 5 rounds of golf within the last year. Exclusion criteria were current episode of musculoskeletal pain, unable to stand and swing a golf club independently, systemic disease including but not limited to rheumatologic disease or cancer, or psychological or other cognitive impairment. This randomized, prospective, longitudinal study was approved and conducted under xxx University IRB protocol.

2.2. Protocol overview

After providing their written informed consent, subjects completed a medical and golf history questionnaire. Golf-specific information gathered via the history form included self-reported number of years playing golf, handicap, frequency of play, and frequency of practice. Baseline testing in the human biomechanics and physiology laboratory followed, consisting of measurement of height and weight using a stadiometer, bone density and body composition using dual energy X-ray absorptiometry (DXA), 7-iron and driver club speed and total ball distance using a golf simulator (High Definition Golf, Interactive Sports Technologies, Vaughan, Ontario), and physical performance tests. The golf simulator calculates distance through the use of overhead cameras that monitor the club-ball contact zone and high speed cameras that monitor ball flight from impact to screen. The system captures multiple frames from the cameras producing a ball velocity measurement that is combined with launch angle and spin measurements in a proprietary formula that calculates distance. Participants were then randomly assigned by choosing a sealed envelope that contained group assignment: traditional resistance training group (TRAD) or golf-specific resistance training group (GSRT). The research assistants then opened the sealed envelopes so that subjects remained masked to their assignment. Resistance training was conducted 3 days per week for 10 weeks. Each training session was directly supervised by at least one of the researchers, such that correct technique and appropriate resistance could be monitored. Following the 10 weeks of training, participants repeated the testing procedures under similar conditions as baseline testing.

2.3. Training programs

Both groups focused on training muscles that electromyography studies have identified as being highly active during the golf swing including the erector spinae, abdominal obliques, pectoralis, latissimus dorsi, levator scapulae, rhomboids, gluteus medii, hamstrings, and wrist flexors (Marta, Silva, Castro, Pezarat-Correia, & Cabri, 2012). The TRAD group completed traditional resistance training techniques to strengthen these muscle groups. These exercises predominantly involved the use of unidirectional resistance with stability provided by the apparatus on which the lifting was conducted. The GSRT group completed strengthening exercises for these same muscle groups that incorporated dynamic movement, balance and stability, and multi-plane resistance. The exception to these exercises was the shoulder shrug, used in both groups to target the levator scapulae. Both groups completed 3 sets of 9 exercises in each session. A complete description of the exercises performed by each group is found in Appendices A and B. The target number of repetitions for each set was 10. Participants recorded the weight and number of repetitions for each exercise into a personal log. When the participant was able to complete 3 sets of 10 at a given resistance, the resistance was increased so that the participant could not complete 10 repetitions for the third set.

2.4. Testing procedures

2.4.1. Health-related outcomes

Body composition and bone mineral density were measured using DXA (Discovery W, Hologic Inc., Bedford MA). All DXA procedures were performed in accordance to manufacturer recommendations. Daily calibration was performed using a manufacturer-supplied phantom with components of known density. Height and body mass were measured on a digital stadiometer and scale system (284, Seca GMBH, Hamburg). A whole body scan was performed, during which participants were requested to lie motionless in the supine position. The images of all scans were then visually evaluated by one of the research team members to ensure there were no issues that could lead to error (e.g., metallic objects, altered body positions, etc.). Analysis of exams was performed in Hologic Apex v4.0 software using NHANES reference standards.

2.4.2. Golf-performance

For determination of 7-iron and driver club speed and total ball distance, participants were allowed 5 warm-up hits with each club and then completed 5 trial hits with each club using the golf simulator and their own golf clubs. Participants were allowed to choose which club (7-iron or driver) they wanted to be tested with first. This same order was then used during the post-test. Participants were informed that the mean of the three trials with the longest distance for each club would be used for analysis. Because the reliability of the golf simulator used has not been previously evaluated, data were gathered initially and again within 48 h to determine the reliability of the swing parameters. Club speed was selected as a key dependent variable because it may be considered a golf-specific indicator of human performance independent of club-ball interactions (e.g., site of contact between club head and ball, angle of contact, spin rate). Total ball distance was selected as the second key dependent variable of golf performance since it takes into account club-ball interactions and therefore, likely incorporates both physical ability and skill.

2.4.3. Physical performance

To determine the musculoskeletal performance of the golfers, physical performance tests were performed at baseline and following the training intervention period. Physical performance tests were chosen as a proxy measure of golfer function and these particular measures were chosen to capture the power and movement associated with golf. The following performance tests were conducted:

2.4.3.1. Standing broad jump. Participants stood with their toes on the starting line, squatted and jumped using their arms to assist in propelling them as far forward as possible. All participants performed three warm-up jumps, followed by three recorded trials. The mean jump distance from these three trials served as a dependent variable.

2.4.3.2. Seated weighted ball throw. Participants were seated on a bench inclined to 45° with their feet on the floor. Participants held a six-pound medicine ball against their chest and were instructed to launch the ball with both hands as far as possible using a chest pass motion. All participants had three warm-up throws followed by three recorded trials. The mean of the three trials was used to score the test. This test has previously reported as reliable with an ICC of 0.92 (Clemons, Campbell, & Jeansonne, 2010).

2.4.3.3. Standing rotational weighted ball throw. Participants stood as if readying to take a golf swing while holding a six pound medicine ball in both hands. Participants then moved the ball away from the target line in a backswing motion, then forward to launch the ball as far as possible. Participants had three warm-up throws followed by three recorded trials. The mean of the three trials was used to score the test. This test has previously reported as reliable with an ICC of 0.89 (Gordon, Moir, Davis, Witmer, & Cummings, 2009).

2.4.3.4. Seated rotation range of motion. This test was modified from its original description (Frohm, Heijne, Kowalski, Svensson, & Myklebust, 2012) due to the inability of many of the older participants to easily sit on the floor with legs crossed. Participants sat upright on a bench so that their spine was aligned with a goniometer taped to the floor. While keeping their pelvis stable, participants rotated their torso in one direction as far as possible. Three practice rotations were performed, and their range of motion was then recorded on the fourth rotation. The process was then repeated rotating in the opposite direction.

2.5. Statistical analysis

2.5.1. Power analysis

An *a priori* power analysis was performed, using data from Doan et al. (2006) regarding pre-vs. post-training changes in club speed in female collegiate golfers. The power analysis was performed in Gpower (Faul, Erdfelder, Buchner, & Lang, 2009), using $\alpha = 0.05$, a power of 0.95, and the effect size of 0.67 for a difference between two dependent means (matched pairs) statistical test. This analysis resulted in a suggested total sample size of 26.

2.5.2. Normality tests

Preliminary assessment of normal distribution was performed using a combination of the Shapiro–Wilk test and visual examination of histograms and quantile–quantile (Q–Q) plots. All data were normally distributed and were analyzed with parametric statistics unless otherwise noted.

2.5.3. Completers vs. non-completers

To determine if there were baseline differences in demographics, physical performance, or golf performance between individuals who completed the training program versus those who dropped out of the study, a one-way ANOVA was performed for each dependent variable. Completion status (completer versus non-completer) was the independent variable. Completers were defined as those participants who completed both baseline and post-training evaluations. Handicap and weekly sessions of practice and play were not normally distributed, and therefore compared using the Mann Whitney U test with exact probabilities.

2.5.4. Descriptive statistics for completers

A one-way ANOVA was used to determine if there were any baseline differences in age, height, body mass, health-related outcomes, self-reported handicap, frequency of play, and frequency of practice between training groups using data from those who completed the study. Handicap and weekly sessions of practice and play were not normally distributed, and therefore compared using the Mann Whitney U test with exact significance.

2.5.5. Reliability and precision of golf performance measurements

Two-way random average measures intraclass correlation coefficients ($ICC_{2,k}$) of absolute agreement were computed for each golf performance variable (club speed and total distance). The standard error of the mean (SEM) was then computed as a measure of precision (Weir, 2005). All individuals who completed both baseline testing sessions were included in reliability and precision measurements, whether or not they completed the 10-week training program.

2.5.6. Change in golf performance

A linear mixed effects model was used to determine whether golf dependent variables were influenced by group (TRAD vs. GSRT training), time (baseline vs. post-training), or the interaction between group and time. Group and time served as fixed effects and subject served as a random effect. Multiple models were fit using various repeated measures covariance structures, and the model with the lowest Akaike's Information Criteria was selected as the final model. Adjusted mean differences within groups and between groups were computed using a single analysis of covariance (ANCOVA) for the change in each dependent variable using group as a fixed factor and baseline value as the covariate. Statistical significance was set at $p < 0.05$ *a priori*.

2.5.7. Relationship between physical performance and golf performance

To determine the relationship between baseline physical performance and baseline golf performance for all participants enrolled (including completers and non-completers), stepwise linear regression models were constructed for each golf performance variable. Linear regression models were also constructed to determine the relationship between training-related changes in physical performance and changes in golf performance using data from completers.

For each linear regression model, physical performance tests (seated weighted ball throw, weighted ball golf throw, seated rotation, broad jump) served as potential independent variables to be entered into the model. Independent predictor variables were entered using a probability of $F < 0.05$, and removed using a probability of $F > 0.10$. Separate models were made using each golf performance variable as a dependent variable.

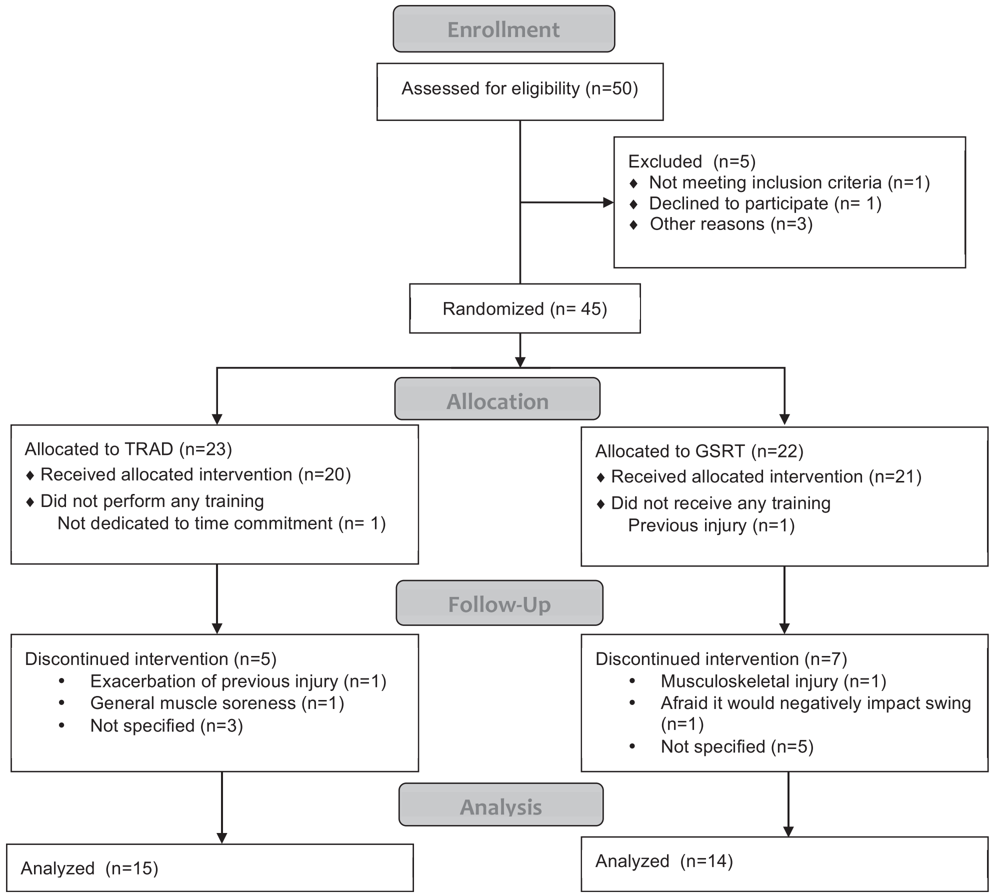

Fig. 1. CONSORT patient flow diagram.

3. Results

3.1. Completers vs. non-completers

Forty-five individuals enrolled in the study, while 29 individuals completed the study (Fig. 1). One individual allocated to TRAD and three individuals allocated to GSRT did not start any training sessions. Of the remaining non-completers who did begin training, TRAD ($n = 5$) completed a median of 16 (interquartile range = 11) training sessions, and GSRT ($n = 7$) completed 11 (10) training sessions. A Mann–Whitney U test revealed no significant differences in number of training sessions completed between training groups within the non-completers ($p = 0.755$).

Completers were significantly older than non-completers ($p = 0.048$), but there were no significant differences in height ($p = 0.763$) or body mass ($p = 0.935$) (Table 1). Completers played golf significantly more than non-completers ($p = 0.002$), but did not differ in practice sessions ($p = 0.255$) or handicap ($p = 0.558$). There were no differences in Dual Energy X-ray Absorptiometry (DEXA), golf performance, or physical performance characteristics between completers and non-completers (Supplemental Table 1).

3.2. Descriptive baseline statistics for completers

At baseline, there were no significant differences in age ($p = 0.824$), height ($p = 0.163$), or body mass ($p = 0.074$) between training groups (Table 1). GSRT had a significantly lower handicap ($p = 0.019$) than TRAD, but weekly practice ($p = 0.070$) and play (0.112) sessions were not different between groups (Table 1).

For baseline DXA measurements, the TRAD group had significantly greater whole body BMD ($p = 0.010$) (Supplemental Table 2). In addition, baseline driver ($p = 0.038$) and seven iron ($p = 0.018$) shot distance was greater in GSRT than in the TRAD group, but club speed was not significantly different between groups for the driver

Table 1
Baseline demographics.

	Age (y) [SD] (95%CI)[a]	Height (m) [SD] (95%CI)	Mass (kg) [SD] (95%CI)	Median practice sessions/Week [IQR]	Median play/ week [IQR][a]	Median handicap [IQR][b]
TRAD (n = 15)	58.5 [2.1] (54.0, 62.9)	164.7 [1.3] (162.0, 167.4)	72.8 [4.1] (64.1, 81.6)	1 [1]	3 [1]	22 [6.3]
GSRT (n = 14)	57.6 [3.7] (49.7, 65.6)	161.0 [1.8] (157.2, 164.8)	66.8 [4.7] (56.7, 76.8)	1 [1]	2 [1]	14 [8.2]
All completers (n = 29)	58.1 [2.1] (53.9, 62.)	162.9 [1.1] (160.6, 165.2)	69.9 [3.1] (63.4, 76.2)	1 [1]	3 [1]	20 [11.3]
Non-completers (n = 16)	48.8 [4.9] (38.3, 59.3)	163.5 [1.8] (159.8, 167.3)	69.5 [3.7] (61.7, 77.3)	2 [1]	2 [1]	14.5 [12.6]

CI = Confidence Interval; GSRT = Functional weight lifting group; IQR = Interquartile Range; SD = Standard Deviation; TRAD Traditional weight lifting group.
[a] Significant differences between completers and non-completers.
[b] Significant difference between TRAD and GSRT.

($p = 0.102$) or seven iron ($p = 0.589$) (Table 2). There were no significant differences between groups for physical performance tests (Supplemental Table 3).

3.3. Change in health-related outcomes

Two individuals (one from each training group) were excluded from DXA analysis, as they were too large to scan in a single pass (body mass > 110 kg). One 99.8 kg individual who was successfully scanned served as an outlier, which influenced normal distribution for certain DXA parameters. However, this individual was included in all analyses, as inclusion/exclusion did not have a noteworthy influence on the results. A summary of body composition results is provided in Supplementary Table 2.

There was a significant main effect for training group ($p = 0.017$) on BMD and whole-body lean mass ($p = 0.031$), but not for overall body mass ($p = 0.062$), fat mass ($p = 0.142$), percent body fat ($p = 0.205$), or visceral fat mass ($p = 0.138$). There was a significant main effect for time on whole body percent fat ($p = 0.033$), whole body fat mass ($p = 0.013$), and visceral fat mass ($p = 0.033$), but not for BMD ($p = 0.205$), lean mass ($p = 0.283$), or overall body mass ($p = 0.705$). There were no significant group X time interactions for any body composition variables.

3.4. Reliability and precision of golf performance measurements

All golf performance parameters gathered on the golf simulator demonstrated both reliability and precision (Supplemental Table 4).

3.5. Changes in golf performance

Golf performance data is summarized in Table 2. There was a significant main effect for time (baseline vs. post-training) for driver club speed ($p = 0.001$), driver distance ($p = 0.020$), and 7-iron distance ($p < 0.001$), but not for 7-iron club speed ($p = 0.160$). There was a significant main effect for training group for 7-iron distance ($p = 0.024$) with GSRT greater across both tests, but not for driver distance ($p = 0.077$), driver club speed ($p = 0.115$), or 7-iron club speed ($p = 0.136$). There were no significant two-way interactions between time and training group.

3.6. Changes in physical performance

Physical performance data is summarized in Supplemental Table 3. There was a significant main effect for time for broad jump ($p < 0.001$), seated weighted ball throw ($p < 0.001$), standing rotational weighted ball throw ($p < 0.001$), and seated rotation range of motion to the left ($p = 0.004$) and right ($p = 0.005$). There were no significant group effects for broad jump ($p = 0.158$), seated weighted ball throw ($p = 0.812$), standing rotational weighted ball throw ($p = 0.310$), seated rotation to the left ($p = 0.129$) and right ($p = 0.082$). There were no significant interactions.

3.7. Relationship between physical performance tests and golf performance parameters

The linear regression model relating physical performance to driver club speed included two independent predictor variables. The seated weighted ball throw was selected first ($r^2 = 0.384$; 95% confidence interval [0.160, 0.608]), followed by the broad jump ($r^2 = 0.446$, [0.234, 0.658]). For driver distance, seated weighted ball throw was selected first ($r^2 = 0.327$; [0.101, 0.553]), followed by the weighted ball golf throw ($r^2 = 0.395$; [0.178, 0.612]). The seated weighted ball throw was the only variable entered into the model for 7-iron distance ($r^2 = 0.269$; [0.047, 0.491]) and 7-iron club speed ($r^2 = 0.197$; [−0.012, 0.406]). Change in seated weighted ball throw was selected as the only variable that was related to change in driving distance ($r^2 = 0.250$; [−0.011, 0.511]) and 7-iron distance ($r^2 = 0.299$; [0.032, 0.566]). No performance variables were related to change in club speed regardless of club used. The relationships between seated medicine ball throw and driver distance are displayed in Fig. 2A and B.

Table 2
Golf performance data.

Golf club	Parameter	Group	Baseline	Post training	Adjusted mean differences (Within Group)[d]	Adjusted mean differences (Between Groups)[e]
			Mean [SE] (95% C.I.)	Mean [SE] (95% C.I.)	Mean [SE] (95% C.I.)	Mean [SE] (95% C.I.)
Driver	Club head speed ($m\ s^{-1}$)[b]	TRAD	28.3 [0.8] (26.7, 29.9)	29.0 [0.8] (27.4, 30.6)	1.4 [0.5] (0.3, 2.6)	−0.1 [0.4] (−0.9, 0.7)
		GSRT	30.2 [0.8] (28.5, 31.8)	30.8 [0.8] (29.1, 32.4)	1.3 [0.6] (0.1, 2.4)	
	Distance (m)[a,b]	TRAD	128.7 [5.7] (117.1, 140.2)	136.3 [5.7] (124.7, 147.9)	7.4 [3.2] (1.0, 13.8)	−4.2 [4.7] (−13.8, 5.4)
		GSRT	145.6 [5.9] (133.6, 157.5)	148.4 [5.9] (136.4, 160.4)	3.1 [3.2] (−3.5, 9.8)	
7-Iron	Club head speed ($m{\cdot}s^{-1}$)[b]	TRAD	24.4 [0.8] (22.8, 26.0)	24.2 [0.8] (22.7, 25.8)	−0.3 [0.8] (−1.8, 1.3)	2.2 [1.1] (0.0, 4.4)
		GSRT	24.9 [0.8] (23.3, 26.6)	26.7 [0.8] (25.1, 28.3)	1.9 [0.8] (0.3, 3.4)	
	Distance (m)[a,b,c]	TRAD	85.8 [3.9] (77.9, 93.7)	95.0 [3.9] (87.1, 102.9)	8.5 [2.2] (3.9, 13.1)	−0.2 [3.4] (−7.2, 6.8)
		GSRT	99.5 [4.0] (91.3, 107.6)	107.0 [4.0] (98.8, 115.1)	8.3 [2.3] (3.5, 13.0)	

[a] Significant baseline differences between TRAD and GSRT.
[b] Significant time effect (baseline vs. post-training), regardless of training group.
[c] Significant group effect (TRAD vs. GSRT), regardless of time.
[d] Adjusted mean differences were computed using ANCOVA to control for baseline values. As such, adjusted mean differences differ from difference scores computed by simply subtracting baseline from post-training values within a group.
[e] Adjusted mean difference for GSRT relative to TRAD (positive value represents superior effect for GSRT compared to TRAD).

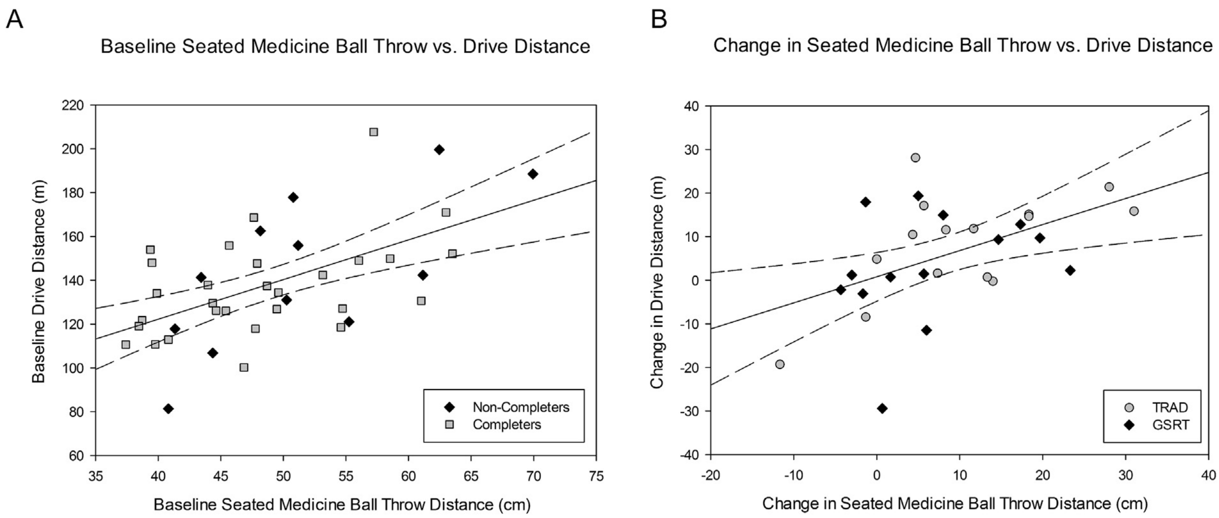

Fig. 2. A. Relationship between seated medicine ball throw and driving distance. B. Relationship between change in seated medicine ball throw and change in driving distance. Dotted lines represent confidence intervals.

4. Discussion

This study is the first to our knowledge to reveal that resistance training, traditional or sport-specific, improves golf-related outcomes in amateur female golfers. The findings of our study are interesting for a couple of reasons. First, driver and 7-iron shot distance and driver club speed improved with training irrespective of group. Despite trends in the golf training industry stressing golf-specific resistance training, we found that both traditional and golf-specific resistance training groups improved. We can only speculate as to why there was no difference between groups in our study. Both programs targeted the muscles known to be active the golf swing: the erector spinae, abdominal obliques, pectoralis, latissimus dorsi, levator scapulae, rhomboids, gluteus medii, hamstrings, and wrist flexors (Marta et al., 2012). Strengthening these muscle groups might be more important than the method by which they are strengthened. Perhaps strength and dynamic stability are both necessary components of the golf swing and are of equal importance/effect size and therefore, both groups improved for different but equally impactful reasons.

Second, our findings are interesting because despite statistically significant gains in golf-related performance measures, the gain in simulator distance was approximately 2 yards. It could be argued that in a group of higher handicap (mean of 20), older (mean age 58) amateurs improved skill or flexibility might be a more important variable in golf performance than improved strength. Also plausible is that resistance training has benefits other than greater distance like greater endurance or injury prevention. Our study certainly has shown other benefits related to physical performance and health, but the effect of different training programs on the rate of injury would be an appropriate topic of future research.

Both training groups significantly improved all measures of physical performance with no differences between groups. Results from the stepwise linear regression indicated that the seated weighted ball throw is a valid proxy measure for driver and 7-iron club speed and distance. Further, the seated weighted ball throw was the only test responsive to changes in 7-iron and driver distance. This finding is significant since the seated weighted ball throw can be used as a convenient, reliable (Clemons et al., 2010) clinical baseline measure of golf performance that is responsive to training. Physical performance tests that are proven to be reliable, valid, and responsive are extremely rare (Hegedus, McDonough, Bleakley, Baxter, & Cook, 2015; Hegedus, McDonough, Bleakley, Cook, & Baxter, 2015). The strengths of physical performance tests are that they can be performed easily, almost anywhere, and by individuals with a wide range of expertise. The major weakness of these tests is their generally unknown statistical properties creating doubt about the usefulness of their results. This ease of use but lack of usefulness creates a dilemma. Our findings begin to solve this dilemma for those healthcare professionals, trainers, and teaching professionals that work with golfers since we found the seated weighted ball throw to be responsive.

Finally, the results of this study demonstrate that resistance training provides health benefits beyond improved golf and physical performance. Following the 10-week supervised training programs, both groups decreased their body fat percentage, whole body fat mass, and visceral fat mass. Increased visceral fat mass is associated with the development of metabolic disorders, including diabetes mellitus and hyperlipidemia (Fujioka, Matsuzawa, Tokunaga, & Tarui, 1987). Conversely, reduction in visceral fat mass is associated with health benefits like improvements in plasma glucose and lipid metabolism (Fujioka et al., 1991).

4.1. Limitations

One of the limitations of our study was the dropout rate. Statistical analysis showed that dropouts were significantly younger and played golf less, though were not different in terms of body composition, physical fitness, golf swing performance, handicap, or practice. Additionally, there were no group differences in the number of training sessions completed before dropping out, which indicates training type did not influence adherence. Although a power analysis was performed, the data used for it was from a small sample study of intercollegiate female golfers, who may have responded differently to training (Doan et al., 2006). Therefore, it is possible that including a larger sample in this study may have resulted in further statistical significance between groups. However, if a change in a dependent variable was not already significantly different between groups, adding more subjects to reach statistical significance would not likely translate to meaningful differences in golf performance, given that both groups improved considerably and differences in the magnitude of performance between groups appears relatively small.

Next, the ultimate gain in driving distance was 2 yards and because all shots were measured in controlled conditions within the lab using a golf simulator, we cannot comment on the actual gain in distance on the golf course under variable playing conditions.

Further, neither training program incorporated a skill or a flexibility component. Both of these interventions may have improved golf performance but would have potentially clouded the main purpose of the study, which was to compare two different kinds of resistance training. Finally, we did not control for other factors that may have affected body composition, such as dietary changes or aerobic conditioning (Al-Zadjali, Keller, Larkey, Albertini, & Center for Healthy Outcomes in Aging, 2010; Brehm, Seeley, Daniels, & D'Alessio, 2003). Despite not controlling for these factors, we still found that both groups achieved decreased body fat percentage, whole body fat mass, and visceral fat mass.

4.2. Conclusions

This study demonstrated that ten weeks of strength training specifically targeting muscles used during the golf swing is effective in improving golf performance and physical performance in recreational female golfers, regardless of whether weight training mimics motions and positions used in golf or not. Further, there appear to be health benefits associated with strength training for golf including decreased whole body fat percentage and visceral fat mass. Such positive impact on body composition further supports existing research demonstrating the health benefits of golf participation. Given the extensive popularity of golf worldwide, and the growing number of female participants, training programs aimed at enhancing golf performance may serve as a motivator to increase the intensity and volume of physical activity in individuals who would not otherwise do so, and thus, may ultimately have a positive impact on health. Further research should explore the comparative long-term health and performance benefits of different types of golf training across various populations.

Author contributions

All authors contributed to the writing and editing of this manuscript.

Conflict of interest

None declared.

Ethics statement

All work in this manuscript has been conducted in accordance with The Code of Ethics of the World Medical Association (Declaration of Helsinki). All procedures in this study were approved by the university's Institutional Review Board and all participants underwent written informed consent.

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Appendix A. Traditional resistance exercises.

Traditional exercise	Description	Photo/Example
Back Extension	Lay face down with legs and pelvis flat on the platform Holding a weight with upper body hanging off the platform, lower until there is a 90 degree angle between legs and upper body Raise back to starting position using buttocks and hamstrings	

(*continued on next page*)

(*continued*)

Traditional exercise	Description	Photo/Example
Wrist Curls	Rest forearm on thigh with wrist hanging off, palm facing up Keeping forearm flat, curl wrist towards body	
Side Plank	Prop on forearm and elbow with feet on the ground. Hold for 30 seconds. Maintain level body position	
Bench Press	Lower bar in a controlled manner until elbows have achieved a 90 degree bend Push bar up until arms are straight again	
Seated Lat Pulldown	Starting with straight arms, pull down handles until they have reached shoulder level squeezing shoulder blades together Raise handles back to starting position using control	

(*continued*)

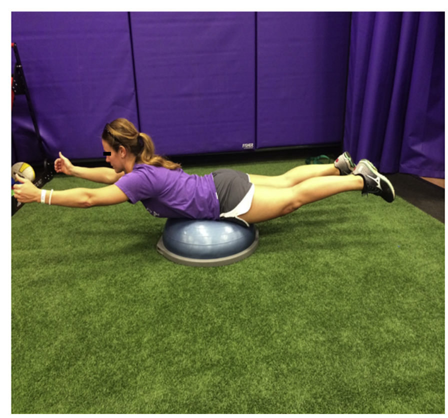
Traditional exercise	Description	Photo/Example
Shoulder Shrugs	Holding weight in both hands, stand with weight at sides Keeping arms straight, raise shoulders towards ears Hold this position for a one-count, then return to starting position	
Bent Over Row	Rest knee and hand on bench with body parallel to ground With back flat, start with opposite hand holding a weight with a straight arm Pull weight up until hand is at trunk height Lower weight back to straight arm position with control	
Hip Abduction Machine	Place arms on rests Place outside of leg at or just above the knee on the pad Keeping leg straight, push against the pad laterally Lower leg with control until just before weight is resting	
Modified Russian Deadlift	Stand with feet at shoulders width apart Keeping legs straight and back flat, bring bar from the safety rests to standing position using buttocks and hamstrings Lower bar back to safety rests using control	

(*continued on next page*)

(*continued*)

Traditional exercise	Description	Photo/Example
Reverse Hyper Hip Extension	Start with torso on platform with legs hanging off Place ankles in straps and keep legs as straight as possible while lifting toward ceiling Lower back to start position with control	 0

Appendix B. Golf-specific resistance exercises.

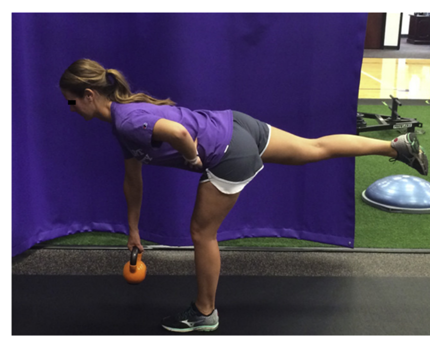
Functional Exercise	Description	Photo/Example
Back Extension	Lay with trunk on Bosu ball and legs and shoulders hanging off Lift legs and shoulders up towards the ceiling simultaneously Lower legs and shoulder back down using control	
Wrist Flexion/ Pronation on Cable Machine	Hold handle at waist height using a golf grip Move trailing wrist from a position of extension and supination to a position of relative flexion and pronation Return to starting position using control	

(*continued*)

Functional Exercise	Description	Photo/Example
Standing Diagonal Chop on Cable Machine	Hold handle at shoulder height with both hands Keeping trunk flexed, pull handle diagonally across body while rotating the torso Return to staring position using control	
1 arm, 1 Leg Cable Bench Press	Stand on one leg and hold handle in opposite hand with elbow bent at 90 degrees Push handle out until arm is straight while maintaining balance Return to a 90 degree elbow bend using control	
Standing Lat Pulldown	Grab handles so that arms are straight Keeping arms straight, pull down on handles until handles are at thighs Return handles to resting position keeping arms straight and using control	

(*continued on next page*)

(*continued*)

Functional Exercise	Description	Photo/Example
Shoulder Shrugs	Holding weight in both hands, stand with weight at sides Keeping arms straight, raise shoulders towards ears Hold this position for a one-count, then return to starting position	
1 arm, 1 Leg Cable Row	Stand on one leg and hold handle in opposite hand with arm straight Pull handle towards body until handle is even with trunk while maintaining balance Return arm to straight position using control	
1 Leg Russian Deadlift	Stand on one leg and hold weight in opposite hand Keeping standing leg and straight and back flat, bend at the waist and touch the weight to the ground Reverse this motion and raise back to standing position using hamstring and buttock	
Lateral Plyometrics	Jump quickly from side to side Land and jump one legged, using left leg on left side and right leg on right side	

(*continued*)

Functional Exercise	Description	Photo/Example
Standing Cable Hip Abduction	Face perpendicular to cable machine and place outside ankle into strap With a straight leg, raise leg away from cable machine Lower leg back towards cable machine with control	

Appendix C. Supplementary data

Supplementary data related to this article can be found at http://dx.doi.org/10.1016/j.ptsp.2016.04.005.

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