SHORT COMMUNICATION

Changes in strength and jump performance over a 10 week competitive period in male collegiate golfers

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As with most structured training programs to enhance performance, a reduction in resistance training volume is seen during competitive periods and an emphasis is placed on technical and tactical training. For that reason, it is important to know where priorities should be placed during times of reduced physical preparation training and if the sport itself allows for the maintenance of neuromuscular qualities.

Objective: Thus, the purpose of this investigation was to examine changes in strength and jump testing over a competitive period of 10 weeks.

Methods: 11 male NCAA Division I completed this investigation. Each participant was tested before and after the competitive fall season. Testing consisted of countermovement jump and isometric mid-thigh pull. Paired samples t-tests were used to determine if statistical differences were present between testing sessions.

Results: Significant increases in jump height ($p = 0.002$) and RSIm ($p = 0.013$) were seen in the post competitive season jump testing. Force at each time epoch was significantly reduced from pre to post-testing ($p < 0.001$ at each time epoch).

Conclusion: Performing countless repetitions of the golf swing during the competitive season provided a stimulus sufficient to maintain dynamic task performance. The results of this investigation point to the need for practitioners to take a complete examination of variables when analyzing performance testing. When taking into account the entirety of the test, reductions in force at task-relevant time epochs would lead to more precise programming to address needs.

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Key words: golf performance ■ force-time analysis ■ athletic performance

INTRODUCTION

Numerous sports require athletes to express physical attributes such as strength and power to have high levels of success. Recently, several studies have investigated the relationship between strength and power in golf-specific performance.[1-3] A recent systemic review identified both strength and power of the upper and lower body as physical attributes that demonstrated positive correlations to clubhead velocity (CHV).[4] Within this review jump height and power were the two measures of lower body power assessed. The between-study variance shown in the correlation values has been suggested to result from differing jump assessments technique (jump mat, vertec, and force platform). This has then resulted in a more thorough analysis of the correlation between CHV and jump performance resulting in stronger relationships such as concentric impulse during the countermovement jump (CMJ) and CHV.[5,6] In a similar manner lower body strength has a wide array of assessment techniques again leading to inconsistent findings as to the strength of the relationship between lower body strength relates to CHV. As the golf swing is performed quickly, especially the downswing which is the phase of the swing where clubhead acceleration occurs, it has been suggested that the isometric midthigh pull (IMTP) would provide a more sport-specific assessment over the traditional 1-repetition maximal (1RM) testing. However, Ehlert[4] found that the 1RM back squat exercise had a stronger relationship to CHV than the general lower body strength.

In a recent review of the strength and conditioning practices within golf, it has been suggested that practitioners use the CMJ using force platforms and the IMTP to monitor training outcomes and assess golf athletes.[7] This is in large part due to the additional information obtained from the force platform during the CMJ and the time-specific nature of analysis in the IMTP.[1,8] Force-related variables specifically have been shown to relate to clubhead velocity while field-based jumps tests have had mixed results.[1,3,9] As this body of evidence continues to develop it is also important to investigate changes in strength and power over the course of competitive periods as this could have an impact on sport-specific performance.

Previous investigations using collegiate golfers have shown that improvement in strength (1RM back squat) coincided with greater driving distance and CHV over periods of train-

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ing ranging from 8 to 18 weeks.[10,11] Doan et al[10] showed that when combining data from both men and women participating in the training protocol increased CHV, however when stratified by sex neither the men nor women statistically improved CHV. Though significant strength gains were present in the 1RM squat and significant increases in medicine ball throw velocity. Oranchuk et al[11] showed improvement in the CHV after partaking in high-load strength and power based while a low-load rotational-based training program displayed a reduction in CHV. While this again points to the utility of strength and power training to improve performance, the low-load group also saw improvement in strength over the course of the eight weeks of training. Thus, the direct transfer of strength gains to improvement in sport-specific changes may be limited and require further investigation. It has also been shown over a shorter six-week period where changes in strength (bench press and leg press) while CHV and vertical jump showed no change after training.[12]

The goal of training during competitive seasons for many sports is to maintain the physical adaptations from previous training blocks, as both technical and tactical training takes priority. Golf is no different in terms of where training priorities are placed and in many cases is more complicated as competitions span multiple days over a week with competitions taking place on weekly basis. With the dense competition schedule of collegiate golf, resistance training is often sporadic and inconsistent. There is a lack of evidence as to how the physical performance variables associated with golf performance change over the course of a season. This information is important for practitioners to understand where the emphasis should be placed when training takes occurs. As mentioned previously the use of the 1RM as a measure of strength has its limitations and the use of IMTP has been recommended even though it too has its limitations. While the vertical jump is commonly used to assess lower body power, the use of force platforms in assessing the change in performance with golfers is limited. Using a force platform may provide insight into the neuromuscular changes that occur over a competitive period while changes in jump height may not be present.[13] Rather than using variables such as jump height and 1RM strength that only provide a small insight into changes that occur over a competitive season it is important to investigate changes using a more robust approach. Thus, this investigation aimed to examine strength and vertical jump performance changes over 10 weeks of competition during the fall season in NCAA Division I male golfers.

METHODS

11 NCAA Division I male golfers between the ages of 18 and 23 completed this observational study (age 20.72 ± 0.67 years, height 179.67 ± 3.75 cm, body mass 74.97 ± 5.73 kg). All participants had been cleared for sports participation by the university's sports medicine staff and were free of injury during the time data was collected. Each participant provided written informed consent before any testing was conducted. Participants completed two testing sessions. The first testing was conducted the week before the first fall competition and the second session was at the end of the fall semester with ten weeks between testing sessions.

All participants engaged in all team activities (weight training and practice sessions) during the ten weeks. One or two resistance training sessions took place each week (16 total sessions). All participants performed the same resistance training regimen during each session. Sessions consisted of both upper and lower body movements such as deadlifts, squats, lunges, bench presses, rows, and pull-ups. (Table 1) Training progressively overloaded during the ten weeks through manipulation of sets, repetitions, and load.

Table 1 Example of Resistance Training Program During the 10 Weeks of Competition

Day 1	Week 1	Week 2	Week 3	Week 4
Trap Bar Deadlift	3×5	3×5	3×5	3×5 (deload)
Band Pull Through	2×10	2×10	2×10	1×10
DB Bench Press	3×8	4×4	4×4	3×3
Band T Spine Rotations	3×5 each	3×5 each	3×5 each	3×5 each
Single Leg Squat	3×3 each	3×3 each	3×3 each	3×3 each
DB Goblet squat	3×8	3×8	3×8	3×4
Single Leg PB Curl	3×6 each	3×6 each	3×6 each	3×6 each
Chest Supported Row	3×10	3×10	3×10	3×6
½ Kneeling Face Pull	3×15	3×15	3×15	3×15
Day 2				
Medicine Ball Rotation Toss	3×5 each	3×5 each	3×5 each	3×3 each
Medicine Ball Granny Toss	3×3	3×3	3×3	3×2
DB ¼ Squat Jumps	3×5	3×5	3×5	3×3
Band Assisted Jumps	3×5	3×5	3×5	3×3
Shoulder Mobility Circuit				
Medicine Ball Chest Pass	3×5	3×5	3×5	3×3
Medicine Ball Russian Twist	3×8each	3×8each	3×8each	3×8each
Twist				

Participants self-selected the load used for a given exercise and the certified strength and conditioning professional overseeing the training monitored proper progression in loading over the 10 weeks.

Jump Testing:

Vertical jump testing was conducted during both the pre and post-testing sessions using a countermovement jump. All jumps were performed on a portable force platform (AMTI, Watertown, MA, USA). Each jump was performed with a 1.83 m polyvinyl chloride pipe placed across the upper back. Participants were allowed to use a self-selected foot position and to go to a self-selected depth. Instructions were given to jump as high as possible while maintaining contact with the dowel throughout the duration of the jump. Before the initiation of movement, one second of quiet standing was used to calculate body mass for future analysis. Two trials were collected with thirty seconds given between each trial.

Isometric Mid-Thigh Pull

Isometric mid-thigh pulls were performed using a portable force platform (AMTI, Watertown, MA, USA). Participants were first familiarized with the correct starting position and instructions. Knee and hip joint angles were manually measured using a goniometer using the recommendations of Comfort et al[14] with knee angles between 125 and 145 degrees and 140 and 150 degrees at the hip. After being placed into the correct start position verbal instructions were given to drive their feet as "hard and fast as possible into the ground." Force-time data for each trial was visually inspected to ensure that a countermovement was not performed. If a countermovement was detected, an additional trial was performed. Two successful trials were collected with sixty seconds given between each trial.

Data Analysis

All vertical ground reaction force data were collected at 1000Hz. All raw force data was exported into a custom excel spreadsheet for further analysis. Jump data was broken into three distinct phases (unweighting, braking, and propulsive) as defined by McMahon et al.[15] A body mass plus 5SD method was used in determining movement onset, and the end of the propulsive phases was identified as the first sample of vertical ground reaction force below 10 N. Variables of interest for the jump included jump height and reactive strength index modified (RSIm), time to take off, phase duration, mean propulsive force and mean braking force. IMTP force data was again exported into a custom excel spreadsheet. Similar to the CMJ procedures a body mass plus 5SD method was used to determine movement onset which has previously been suggested.[16] Variables of interest included peak force, mean force, and force at 100, 200, and 300 milliseconds.

Statistical Analysis

A Shapiro-Wilk test of normality was used on each variable of interest. The reliability of the variables of interest was assessed using the coefficient of variation (CV) and interclass correlation coefficients (ICC). High reliability was determined as CV $\leq$ 5% and an ICC of greater than $\geq$ 0.9. Acceptable reliability was deemed to occur with a CV between 5% and 10% and an ICC of between 0.9 and 0.8.[17] Paired samples t-tests were used to determine if differences existed between testing sessions. Statistical significance was determined using an a priori alpha level of $p \leq 0.05$. Effect sizes were calculated as Hedges g and interpreted using the criteria of trivial (< 0.2), small (0.2 – 0.49), moderate (0.5 – 0.79), and large (> 0.8).

Additionally, single-subject analyses were performed on each variable of interest to determine if the changes seen were outside the individual variability exhibited during the pretest. Variability was assessed using pretest CV values. All statistical analyses were performed using SPSS (v25.0, SPSS Inc., Chicago, IL, USA).

RESULTS

Reliability data is presented in Table 2. All CMJ variables displayed acceptable levels of reliability. IMTP peak force and force @ 300ms displayed acceptable reliability. Means

Table 2 Intraclass Correlation Coefficients (ICC) and Coefficient of Variation (CV)

	ICC (95% Confidence Interval)	CV (95% Confidence Interval)
Peak Propulsive Force (N)	0.97 (0.89 – 0.99)	4.0 (1.5 – 6.5)
Mean Propulsive Force (N)	0.98 (0.94 – 0.99)	3.6 (2.6 – 4.7)
Propulsive Duration (ms)	0.96 (0.84 – 0.99)	3.8 (2.7 – 4.9)
Loading Duration (ms)	0.90 (0.62 – 0.97)	6.4 (2.5 – 10.3)
Time to Take-off (ms)	0.90 (0.62 – 0.97)	5.1 (2.4 – 7.7)
Jump Height (cm) *	0.96 (0.85 – 0.99)	2.8 (0.7 – 4.8)
RSIm*	0.88 (0.55 – 0.97)	6.4 (3.3 – 9.4)
IMTP Peak Force (N)	0.96 (0.85 – 0.99)	7.5 (3.3 – 11.7)
IMTP Average RFD (N/s)	0.99 (0.96 – 0.99)	14.5 (5.3 – 24.5)
IMTP Force @ 100ms (N)**	0.92 (0.71 – 0.98)	17.0 (7.9 – 26.2)
IMTP Force @ 200ms (N)**	0.75 (0.08 – 0.93)	16.6 (9.9 – 23.3)
IMTP Force @ 300ms (N)**	0.95 (0.80 – 0.99)	9.3 (5.1 – 13.4)

RSIm = Reactive Strength Index modified, IMTP = isometric midthigh pull

Table 3 Changes in CMJ and IMTP Performance

	Pre	Post	*g*	% Change
Peak Propulsive Force (N)	918.14 ± 164.51	943.55 ± 173.74	0.15	↑ 2.8
Mean Propulsive Force (N)	639.01 ± 125.95	681.37 ± 146.46	0.31	↑ 6.6
Propulsive Duration (ms)	303.77 ± 42.90	302.77 ± 48.09	0.01	↓ 0.3
Loading Duration (ms)	638.36 ± 101.69	615.91 ± 161.01	0.16	↓ 3.5
Time to Take-off (ms)	941.55 ± 132.93	918.68 ± 191.45	0.14	↓ 2.4
Jump Height (cm) *	28.18 ± 4.51	32.29 ± 3.80	0.98	↑ 14.6
RSIm*	0.30 ± 0.06	0.36 ± 0.06	0.96	↑ 20.0
IMTP Peak Force (N)	1426.51 ± 329.06	1279.80 ± 217.67	0.52	↓ 10.3
IMTP Average RFD (N/s)	1525.00 ± 1379.53	1068.73 ± 757.65	0.40	↓ 29.9
IMTP Force @ 100ms (N)**	650.82 ± 334.71	424.90 ± 195.67	0.82	↓ 34.7
IMTP Force @ 200ms (N)**	952.42 ± 256.38	750.62 ± 268.16	0.77	↓ 21.2
IMTP Force @ 300ms (N)**	1133.96 ± 265.37	879.25 ± 231.97	0.94	↓ 22.5

g = Hedges effect size
* = p < 0.05
** p < 0.01

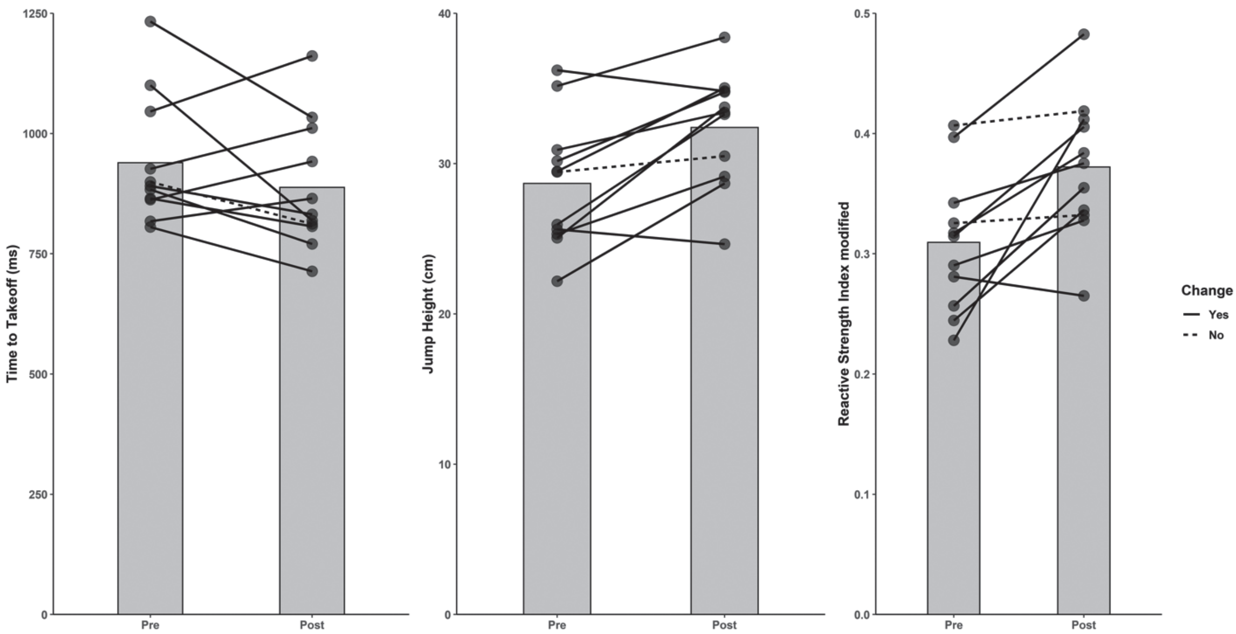

Figure 1 Group and individual change over the 10 weeks of competition.

and SD for all CMJ variables are reported in Table 3. In the vertical jump, both jump height (p = 0.002, *g* = 0.98) and RSIm (p = 0.013, *g* = 0.96) was statistical greater during the postseason testing session. No other jump data saw statistical differences. Means and SD for all IMTP variables are reported in Table 3. Force at each time epoch was statistically reduced during the postseason test. While not statistically different moderate effect sizes were present in peak force (p = 0.12, *g* = 0.52).

When using the single subject analysis each variable displayed an individual response, where both positive and negative changes were seen as well as no change. Six individuals saw an increase in CMJ peak force, while one displayed a reduction. Seven participants displayed an increase in CMJ mean force with two participants having a reduction. Four participants had a reduction in propulsive duration while two had an increase. Loading duration and time to takeoff were reduced in six participants, and four saw an increase in time. Jump height was increased in eight participants while two individuals saw a reduction. Lastly, RSIm was increased in eight participants and reduced in one.

IMTP peak force was increased for one individual over the 10 weeks while a reduction was seen in six individuals. Average RFD was decreased in six individuals and increased in two individuals. For each of the time epochs used in the IMTP analysis, eight individuals saw reductions in force. One participant had an increase of force @ 100ms while no increases were seen for the other two epochs.

DISCUSSION

The goal of this investigation was to examine changes in strength and power over a 10-week collegiate golf competitive period. The main findings of this investigation were reduced force during the IMTP and increased jump height and RSIm in the CMJ. These results provide new evidence to aid in the training of collegiate golfers. Findings from this investigation are similar to those seen across other sports with reductions in strength and maintenance of vertical jump abilities.[18-21] Additionally, this investigation sought to use a single-subject analysis to identify if group means were caused by a large shift from single participants as golf is an individual sport. We found that general trends existed for each variable of interest however, each variable also displayed individuals having opposing changes over the course of the ten weeks.

The reductions in IMTP performance are of interest within this particular study. Wells et al[1] have shown that the rate of force development at 150 and 200 ms is associated with clubhead velocity in high-level golfers.[1] The current investigation saw reductions in force at each of these time epochs. Force at given times was utilized rather than RFD in the present study. This was based on changes in RFD at a given time epoch would be a result of changes in the force level at the given time as time is constant in the calculation.[14,22] While the variables used are different between this study and the previous one, both variables are assessing the same quality. It should be noted, reliability values (CV) for the force at the given time epochs (100 and 200 ms) were high suggesting finding meaningful change outside of an individual's CV would be potentially difficult. However, individuals still had meaningful change with reductions in force production with pretesting CV values as high as 33.88. The one individual that saw an increase in peak force over the 10 weeks saw reductions in force at each of the three time epochs. The one participant that had an increase in force @ 100 ms saw no change in peak force or force at 200 ms and a reduction in force @ 300 ms. Thus, reductions in force-generating capacities appear to be of concern and should be addressed in training. Clubhead velocity was not assessed in the current study, thus making assumptions about how the reduced force output impacted golf performance difficult and should be considered in future investigations.

The peak force values of the IMTP in the current study are substantially lower than those previously reported in competitive male golfers (1456.21 N vs 2093.91 N).[6] This is of importance because the sample used in the present study displayed values indicating a lack of strength at the onset of the competitive season. Reductions in the force-generating capacities when already starting at a low value are of concern and point to the need for practitioners to have an understanding of reference data for their athletes. It should be noted however that the participants in the present study were much younger (20.72 vs 26.9 years).[6] This may have led to a much lower training age and explained the low levels of strength seen in the present study. It is also worth noting that there is a widespread strength within the sample as indicated by the large SD values. This again can be attributed to a sample with a low training age.

CMJ performance as indicated by jump height and RSIm both improved after the 10 weeks. This supports previous investigations that saw lower body power increase over a competitive season.[19,20] Previous investigations have shown that jump height has limited associations with golf performance, in particular clubhead velocity.[3,5] However, other force-related CMJ variables did show significant relationships to clubhead velocity.[1,5,6] The propulsive impulse which is the product of force and time is one such variable that has been significantly associated with golf performance.[1,5,6] In the present study, propulsive time did not change over the course of the 10 weeks, though a slight increase was seen in the mean propulsive force. The propulsive impulse is responsible for jump height. Thus, the increase in force output can explain the increase in jump height. The increase in jump height in part explains the change in RSIm as this is calculated as jump height over time to take-off. Though, time to take-off did not reach statistical significance the reduction seen also would have played a role in the increase in RSIm. As an improvement on either portion of the equation would create an increase in RSIm, the present study saw improvement on both variables used in the calculation of RSIm.

On the individual level, it is interesting to see that each variable assessed during the CMJ had both positive and negative responses over the next weeks. Thus, group changes in jump height and RSIm appear to come from two main causes. First, the number of individuals who saw positive changes outnumbered the negative changes (8 vs 2 jump height and 8 vs 1 RSIm). Secondly, one individual saw positive adaptions in each variable assessed in the CMJ. With an individual increase in jump height from 25.06 cm to 33.75 (34.7% increase) and a reduction in time to take off from 1100.5 ms to 819 ms (25.58% decrease), RSIm nearly doubled. This points to the need to monitor and assesses athletes on an individual level rather than looking at group changes. While the majority of participants showed improvement in CMJ values, significant group changes can largely be attributed to one individual and masked negative changes from others.

Taking into account the changes in both tests, it appears that male collegiate golfers show similar seasonal effects to other sports where explosive lower body movements such as the vertical jump task have been maintained or improved while changes in strength appear to be less consistent.[18-20] Specifically, concerning strength changes, the current study displays this inconsistency. Peak force was reduced to a non-significant level while force at 100, 200, and 300 ms each showed significant reductions. Similar findings have been shown in female volleyball athletes where strength only at particular knee joint angles displayed changes during isokinetic testing for both maximal torque and torque at 150 ms.[19] Furthermore, in a sample of male rugby athletes, no differences were seen pre to post-testing after a 6-week competition block in IMTP peak force.[23] It is important to note that within each study participants performed resistance training thus demonstrating that improvements in strength during the season are difficult with the limited exposures to a training stimulus.

The present investigation is novel in that much of the previous research on collegiate golfers is centered on relationships between golf performance and physical parameters such as vertical jump height and grip strength. While this data is important in understanding how physical traits and attributes relate to performance it is just as important to understand how those targeted variables are impacted during the course of a competitive season as priority is placed on the technical skills of golf rather than training physical attributes. The data presented within this investigation shows that dynamic, coordinated tasks such as the vertical jump are maintained due to the nature of swinging a golf club numerous times over the course of the competitive season. Thus, training emphasis should be placed on maintaining strength as these qualities appear to be negatively impacted by the lack of consistent training. As force-generating capacities have been shown to have positive associations with golf performance and as a variable used to distinguish high and lower-performing golfers, this is importance to maintain during competitive periods.

Conflicts of Interest

The authors declare no conflicts of interest.

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