J Int Acad Phys Ther Res 2019; 10(1): 1706~1710
ISSN 2092-8475

www.iaptr.org
https://doi.org/10.20540/JIAPTR.2019.10.1.1706

Effect of Rehabilitation Exercise for Golfers on the X-factor and Ground Reaction Force according to Phase of the Golf Swing

Background: Despite frequent shoulder injuries of rotator cuff muscle of golfers by the result of overuse and poor swing mechanics, there is little research on shoulder specific rehabilitation exercises for injured rotator cuff muscle and golf swing

Objective: To examined the effect of rehabilitation exercise for golfers on the X factor and ground reaction force (GRF) according to phase of the golf swing.

Design: Crossover study

Methods: The participants were 13 amateur golfers selected for a 4 week rehabilitation exercise for golfers. A rehabilitation exercise for golfers consisting of 5 steps and 4 items (sleeper stretch, full side plank, push up to plank, high plank knee unders) were applied to all participants. A three dimensional motion analyzer and force platform (SMART-E, BTS, Italy) were used to measure the X factor (angle between shoulder and pelvis at top of back swing) and GRF according to phase of the golf swing. All dependent variables were measured before and after exercise. The collected data was analyzed using the paired t test and SPSS 21.0.

Results: The GRF had a statistically significant increase in the impact phase and ratio impact/weight after rehabilitation exercise for golfers ($p<.05$). The X-factor, GRF in top of back swing and finish were no significant differences between before and after exercise ($p>.05$).

Conclusions: These results suggested that rehabilitation exercise for golfers was effective for increasing GRF in the impact phase and ratio impact/weight for amateur golfer.

Key words: *Golf rehabilitation exercise, Ground reaction force, Golf swing phase.*

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Received : 02 December 2018
Revised : 15 February 2019
Accepted : 22 February 2019

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INTRODUCTION

The golf swing is a complex full body movement during which the spine and shoulders are highly involved [1]. Golf injuries can occur at any point during the golf swing, from takeaway through follow-through. Upper extremity injuries can affect the shoulder, elbow, and hands and are usually a result of the golf swing at impact. Injuries are also common in the lower back as well as the lower extremities [2, 3]. Most injuries are the result of overuse and poor swing mechanics [2]. Joeng et al. reported that the number of previous season competitions were significantly associated with injury risk in golfers of Korean Ladies Professional Golf Association (KLPGA) [4].

A number of studies have found that resistance training benefits golf performance, generally measured by changes in club head speed or driving distance [5, 6]. 10 weeks of supervised traditional resistance training (TRAD) and golf-specific resistance training (GSRT) provided similar improvements in body composition, golf performance, and physical performance in amateur female golfers [5]. An 8-week multimodal exercise program on strength, flexibility, and golf performance in 55- to 79-year-old men resulted in significant improvements in muscle strength, selected

range-of-motion (ROM), and golf-club head speed [6]. An 8-week progressive functional training program including flexibility exercises, core stability exercises, balance exercises, and resistance exercises resulted in significant improvements in club head speed and several components of functional fitness [7, 8]. However, little research has been carried out into the golf-specific training related to upper extremity [9]. X-factor has been recognized to be associated with swing speed [10]. Increasing angular separation between the pelvis and thorax has been thought to initiate the stretch shortening cycle and lead to increased increased clubhead speed [11]. In general, more skilled players had higher X-factor values and demonstrated greater and earlier force generation in peak weight transfer during golf swing than high handicap golfers [12-14]. Difference in peak weight transfer and timing based on golf handicap reported that low handicap golfers demonstrated greater and earlier force generation than high handicap golfers [12]. Myers et al. [14] reported that torso-pelvic separation contributed to greater upper torso rotation velocity and torso-pelvic separation velocity during the downswing, ultimately contributing to greater ball velocity.

Despite frequent shoulder injuries of rotator cuff muscle of golfers by the result of overuse and poor swing mechanics [2], there is little research on shoulder-specific rehabilitation exercises for injured rotator cuff muscle and golf swing [2-4]. Most of the studies related to golf fitness have examined golf mechanic changes after exercise, but studies on x-factor and weight shift due to shoulder-specific rehabilitation exercise were lacking [5-8, 10, 11]. Therefore, the purpose of the present study was to examine the effect of rehabilitation exercise for golfers on the X-factor and ground reaction force (GRF) according to phase of the golf swing.

METHODS

Subjects

The participants were 13 amateur golfers selected for a 4-week rehabilitation exercise for golfers. None of the participants had problems with their musculoskeletal, nervous, or cardiovascular systems, and they were able to complete the rehabilitation exercise for golfers according to the instructions given by the researcher. Before participating in this research, all the participants were given an explanation about the content and the procedures of the experiment. They voluntarily participated in the research, and signed an informed consent form. This study was approved by the Institutional Ethics Committee of Namseoul University (No. NSUIRB-201811-003).

Outcome measures and procedures

A three-dimensional motion analyzer (SMART-E, BTS, Italy) was used to measure the X-factor which is angle between shoulder and pelvis at top of back swing [19] (Figure 1). The motion analyzer has 6 infrared cameras and 2 video cameras (vixta 2 TVC, BTS, Italy). Circular passive markers are used for motion analysis. The kinematic data were sampled at a frequency of 120 Hz and processed using the data analysis program, SMART Analyzer (SMART-E, BTS, Italy). The 6 markers were attached to the C7 spinous process, both acromions, S1 spinous process and both top of iliac crest. A force platform (SMART-E, BTS, Italy) was used to measure the GRF according to phase of the golf swing. The GRF measured in top of back swing, impact, finish and ratio impact/weight [18] (Figure 2).

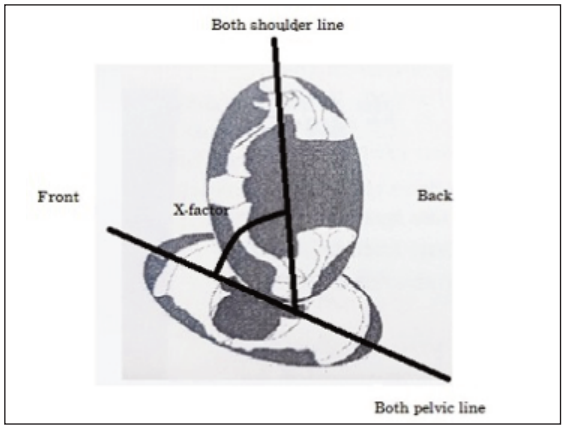

Fig. 1. X-factor measurement

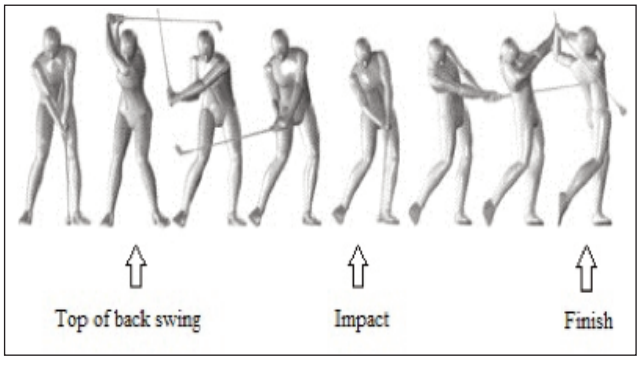

Fig. 2. GRF measurement

A rehabilitation exercise for golfers consisting of 5steps and 4 items which were sleeper stretch, full side plank, push-up to plank, high plank knee-unders were applied to all participants by a single instructor who is a golf rehabilitation specialist with over 10 years of experience [3] (Table 1). A rehabilitation exercise for golfers was completed 3 times a week for 4 weeks. The sleeper stretch was performed for 20 seconds on each side. The full side plank was held for 30 seconds on the left side. It was repeated five times. The right side was performed in the same way as the left side. The push-up to plank and high plank knee-unders were performed for 10 times and 3 sets. Finally, the sleeper stretch was performed to finish the exercise. The rest interval for each time was 20 seconds [3].

Table 1. Rehabilitation exercise protocol for golfers

Rehabilitation exercise	Execution
Sleeper stretch	■ Lie on your right side. ■ Bend your right elbow 90 degrees, and position the elbow at shoulder level. ■ Place your left hand on the back of your right forearm. ■ Push your left arm into the back of the right wrist to lower the right forearm toward the ground ■ When you feel a deep stretch in the right shoulder, pause and hold for 20 seconds. ■ Repeat on the left.
Full side plank	■ Lie on your left side with your right leg on top of your left. Rest on your left forearm with your elbow directly under your shoulder. ■ Push yourself up onto your left forearm and left foot so that your feet, knees, hips, and shoulders are all in one straight line. ■ Maintain this position without dropping your hips or torso, rolling your pelvis backward, or bending at the waist. ■ Hold for 30 seconds, and then perform on the opposite side. ■ Repeat 5 times on each side.
Push-up to plank	■ Start in a push-up position with your hands directly under your shoulders. ■ Lower yourself on arm at a time until your weight is supported by your forearms and toes (like the plank). ■ Try not to have much side to side hip movement through the transitions. ■ Return to the start position by pushing up one arm at a time. ■ Repeat 10 times and 3 sets
High plank knee-unders	■ Start in a push-up position with your hands directly under your shoulders and your elbows straight. Your body is as straight as a plank of wood. ■ Lift your left foot off the ground slowly, and bend your left knee up to your left hip. ■ Slightly push the left knee under the right thigh; pause. ■ Return to the start position. Repeat with the right leg. ■ Repeat 10 times and 3 sets

Data and Statistical Analysis

All the measured data were processed by the program of IBM SPSS Statistics version 21.0. The K-S (Kolmogorov- Smirnov) test was conducted in order to analyze the normal distribution of the measured data and normal distribution was verified. A paired sample t-test was used to compare the X-factor of the participants before and after the rehabilitation exercise for golfers. A paired sample t-test was used to compare the GRF of the participants before and after the rehabilitation exercise for golfers. The level of significance was set at $\alpha=.05$.

RESULTS

General characteristics for the subjects

The participants of this study were 13 amateur golfers aged 28.69±10.84 years (Mean±SD) with an average height and weight of 173.69±6.54 cm and 75.46±6.02 kg, respectively.

X-factor and GRF according to phase of the golf swing applying to the rehabilitation exercise for golfers

The GRF in impact and ratio impact / weight were significantly greater after golf rehabilitation exercise than before exercise ($p<.05$). The X-factor, GRF in

Table 2. X-factor and GRF according to phase of the golf swing applying to the rehabilitation exercise for golfers [Unit :N]

X-factor & GRF	Measurement	Mean±SD
X-factor (degree)	Before	34.90±13.88
	After	39.12±9.84
Top of back swing	Before	659.90±54.99
	After	753.25±32.52
Finish	Before	671.77±55.08
	After	759.47±34.79
Impact*	Before	760.15±61.94
	After	887.39±33.30
Ratio impact/weight*	Before	1.03±0.07
	After	1.20±0.02

* $p<.05$

top of back swing and finish were no significant differences between before and after exercise ($p>.05$) (Table 2).

DISCUSSION

In the present study, the GRF in impact and ratio impact / weight were significantly greater after golf rehabilitation exercise than before exercise. These results demonstrate that shoulder-specific rehabilitation exercise for golfers can increase weight shift on impact [9, 15]. Transferring weight during the golf swing is one of the most challenging aspects for all amateur golfers. If golfer's shoulders and arms have too much tension in them at the top of the backswing, weight shifting can not move normally [12, 15]. Rehabilitation exercise (sleeper stretch, full side plank, push-up to plank, high plank knee-unders) for golfers in this study may have helped to release tension on the muscles around the shoulders during the golf swing. The relaxation of the shoulders should have enabled the natural weight shift during downswing at the top of the backswing, and would have increased power on impact [12]. The swing of the golfers can be performed perfectly when the movement of the shoulders and the movement of the lower body occur harmoniously [1, 16]. The slipper stretch of rehabilitation exercise for golfers seemed to increase the torque during golf swing while stretching both shoulder muscles [3, 8, 17]. The full side plank, push-up to plank and high plank knee-unders would have helped to increase the swing power and speed in the golf swing while activating the deep muscles of the trunk as well as the shoulders [3, 8, 17]. The golf swing is not an independent function of upper limb and lower limb [1, 16]. In this study, the increase of the golf swing torque and the increase of the speed, which are the result of the rehabilitation exercise for golfers, can induce the maximum force on impact [12].

After the rehabilitation exercise for golfers, the increase in ratio impact / weight means that the ball was hit with a power greater than the weight of the subject on impact. The muscles of the shoulder and trunk strengthened through the rehabilitation exercise for golfers would make full use of their weight and torque on impact [7, 8]. Therefore, it would have hit the golf ball by using the force which is bigger than the weight of the subject on impact. If you analyze the swing of professional golfers in the US or Korea, you can find that the ratio impact / weight is several times larger than their weight [13, 14]. This suggests that the rehabilitation exercise for golfers performed in this study can increase the ratio impact / weight of the amateur golfer, thus helping to increase the distance for golf swing [5, 6].

A limitation of the present research is that this experiment was conducted using only a small number of amateur golfers who have experience with less than two years. Thus, we may not safely generalize our research results to any other level golfer. Also, it was difficult to completely control the daily activities related to the participants' exercise during the 4 weeks experimental period in which the rehabilitation exercise for golfers was performed. In future studies, it seems that it will be necessary to develop an ideal exercise program for golf which protects the body from golf damage and improves golf performance by applying various level, age, and period of rehabilitation exercise for golfers.

CONCLUSION

The GRF in impact and ratio impact / weight were significantly greater after rehabilitation exercise for golfers than before exercise. The X-factor, GRF in top of back swing and finish were no significant differences between before and after rehabilitation exercise for golfers. In conclusion, the rehabilitation exercise for golfers is effective for increasing GRF in the impact phase and ratio impact/weight for amateur golfer. The rehabilitation exercise for golfers can help golfers improve their performance.

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