The golf swing is a complex full body movement during which the spine and shoulders are highly involved. 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. Most injuries are the result of overuse and poor swing mechanics. 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).

A number of studies have found that resistance training benefits golf performance, generally measured by changes in club head speed or driving distance. 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. 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 during golf swing than high handicap golfers \(^12,13\). 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 \(^14\). 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 \(^3-8\). 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 \(^3-8,10,12\). 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 \(^10\) (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