GROUND REACTION FORCES DURING THE GOLF SWING USING DIFFERENT GOLF CLUBS IN FEMALE GOLFERS

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The purpose of this study was to investigate effects of different golf clubs on the ground reaction forces during the golf swing for females. Ten right-handed female varsity golfers voluntarily participated in this study. Using three different clubs, they hit the ball by their own swing in four conditions (full driver shot, controlled driver shot, 6-iron shot, and approach-wedge shot). Their motion was three-dimensionally captured which was performed with one foot on each force plate. There were no significant differences in the peak resultant forces between the golf clubs, but the peak resultant horizontal force differed between the golf clubs. The female golfers' resultant reaction force patterns were classified into three patterns, indicating that the golfers generated the reaction forces in their own ways, which would reflect the characteristics of their golf swing.

KEY WORDS: female golfer, golf swing, ground reaction force, golf club.

INTRODUCTION: Golf is one of sports that a wide range of population, from the young to the elderly, from male to female, has enjoyed playing competitively or recreationally, and in recent years, many Japanese females have become novice golfers. The ground reaction forces during the golf swing reflect the movements of the body segments and the center of mass, and also a weight shift of a golfer. Several studies have demonstrated that the rotation of the body-golf system has been associated with the horizontal reaction force in the target and rear leg (Williams & Cavanagh, 1983; McNitt-Gray et al., 2013; Peterson et al., 2016). Theoretically, in order to increase the shot distance, it is necessary to increase the club head speed at the ball impact. The kinematics during the golf swing was identical for driver and iron golf clubs (Bundey & Bellow, 1982), and center of pressure patterns were very similar within-golfer in the driver, 3-iron and 7-iron (Ball & Best, 2011). However, the ground reaction force pattern during the golf swing using different golf clubs has not been well investigated, which implies that there is little information on the ground reaction force patterns during the golf swing for females. Investigating the ground reaction forces and golf swing motions for females using different golf clubs is expected to increase own knowledge on the golf swing and skill acquisition for female golfers. Therefore, the purpose of this study was to investigate effects of different golf clubs on the ground reaction forces during the golf swing for females. McNitt-Gray et al. (2012) found significant smaller peak resultant horizontal reaction forces of the target leg in the controlled 6-iron shot. It is inferred that the heavier the club head swung by a golfer, the greater the centrifugal force, which implies that the horizontal ground reaction forces would increase in swinging a heavier head to control a golfer's posture during swing. Therefore, we have hypothesised that there is no differences in the peak resultant and vertical force between the golf clubs, but the peak resultant horizontal force differs between the golf clubs.

METHODS: Ten right-handed female varsity golfers (age, 20.1 ± 0.6 years; height, 1.59 ± 0.04 m; mass, 55.4 ± 5.9 kg) voluntarily participated in this study. Using three different clubs (driver, 6-iron, and approach wedge), they hit the ball by their own swing in four conditions (full driver shot, controlled driver shot, 6-iron shot and approach-wedge shot). The participants rated their own performance on a scale of 1 to 5 (5 = excellent). They were asked to repeat hitting the ball until at least three trials rated 4 or 5 had been captured successfully. Each shot was performed with one foot on each force plate (1000Hz, Kistler, 9287B). The resultant force, vertical force, resultant horizontal force and their peak forces from the beginning of backswing

to the ball impact were obtained for each foot using the ground reaction force data measured with each force plate. The instant of the ball displacement was defined as one frame prior to the beginning of ball movement due to the collision between the club head and the ball, which was detected with motion capture system (200Hz, VICON MX, Oxford Metrics, UK). Carefully observing the ground reaction forces from 0.4 second to impact, we found some differences in the resultant ground reaction force of the target leg such as time of peak appearance and the patterns: gradual decrease followed by acute increase, gradual increase to the small peak with a decrease toward impact, no remarkable increase and decrease. Therefore, we classified the ground reaction force patterns into three types from viewpoint of the force patterns of the target leg. The Friedman test was performed for the peak forces in the target and rear leg to see the differences between the golf clubs. When significant differences were found, the peak force in four club conditions were tested by using Wilcoxon rank-sum test. The level of statistical significance was set at 5%.

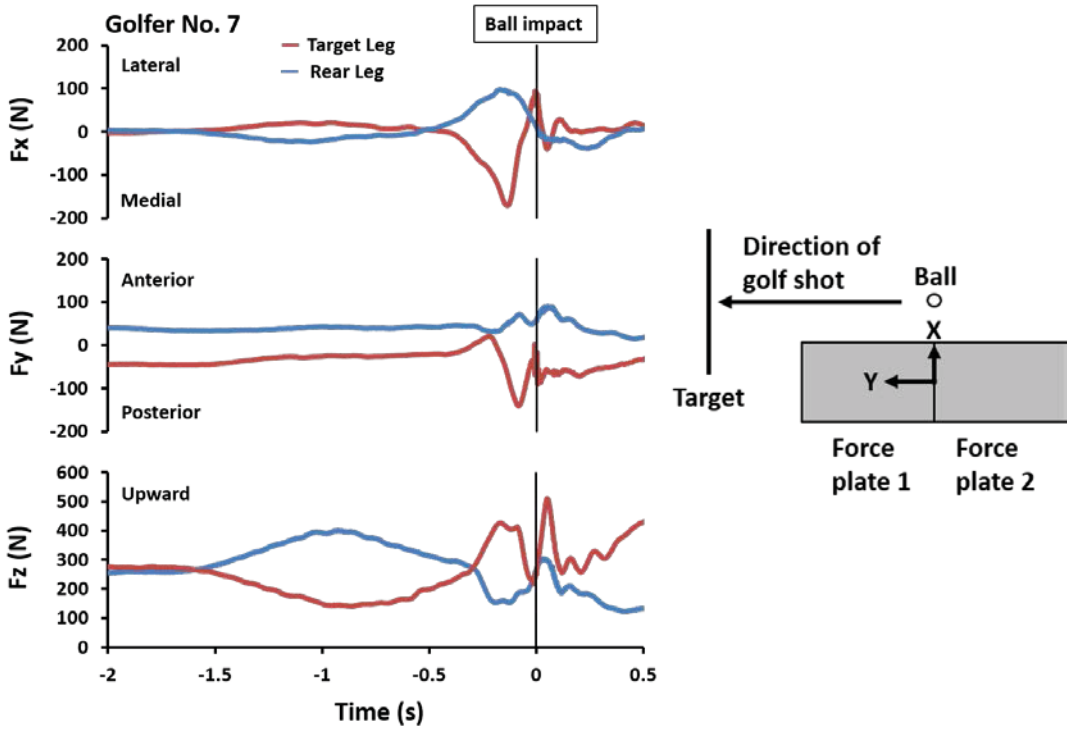

Figure 1: The force-time curves for the target and rear leg of golfer No. 7 during the full driver shot. The vertical lines indicate the instant of ball impact.

RESULTS: Figure 1 shows the force-time curves for the target and rear leg of golfer No. 7 during the full driver shot. Figure 2 shows the peak forces of the target and rear leg during the golf swing with different clubs. There were no significant differences in the peak resultant forces between the golf clubs, but the peak resultant horizontal force differed between the golf clubs during the golf swing. It would be worthy to note that the peak vertical force of the rear leg for the approach-wedge club was larger than that of the controlled driver. The peak resultant horizontal forces at both legs were larger in the full driver shot, and smaller in the approach-wedge shot than the others. Based on the observation, three patterns of the resultant force were discerned, as representatively shown in Figure 3. The first type exemplified by Golfer No. 2 was characterised by target-leg-weighted and the late peak force near the ball impact, the second one by Golfer No. 7 was by target-leg-weighted and the early peak force. The third one shown by Golfer No. 6 was rear-leg-weighted and no peak force.

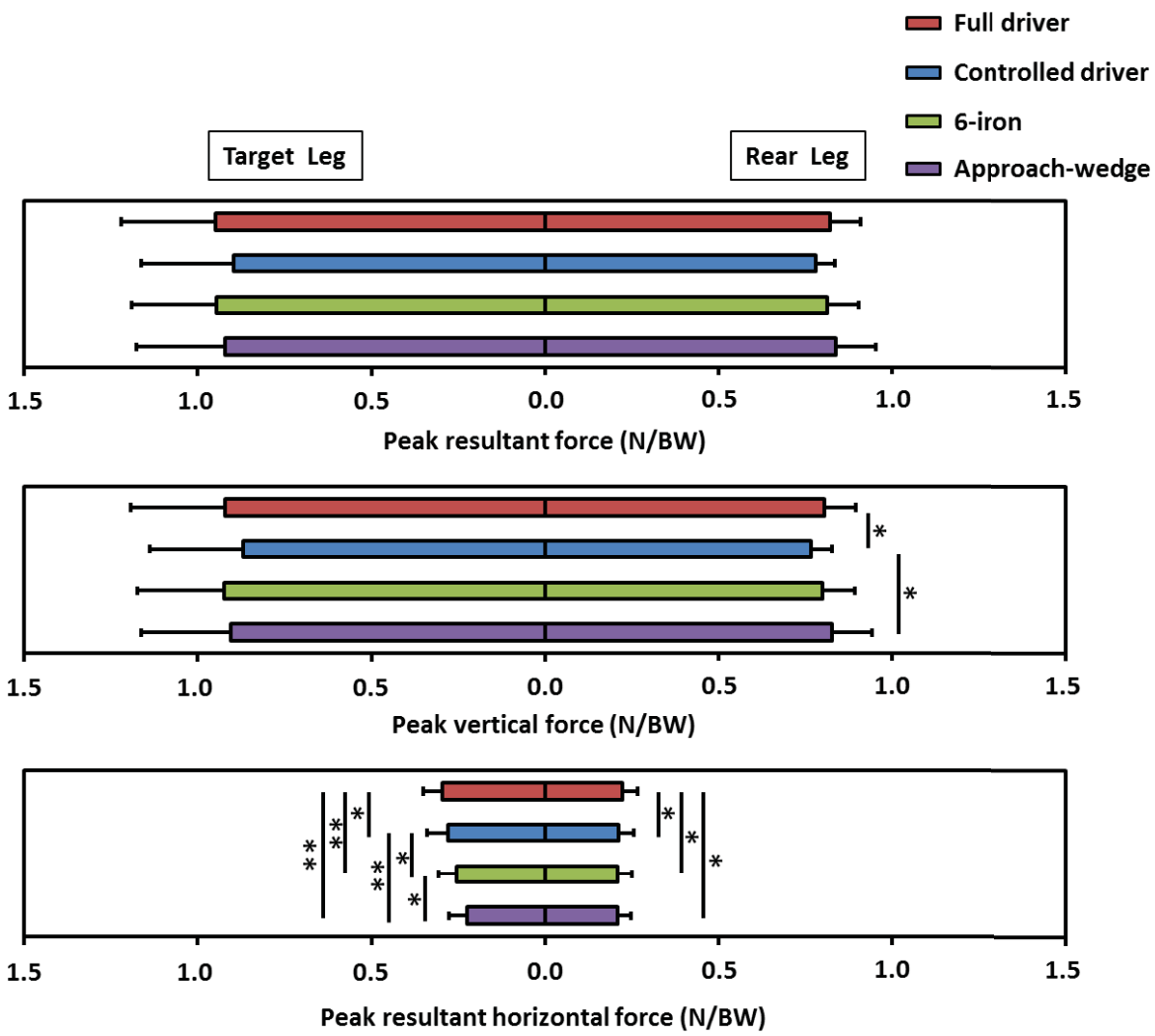

Figure 2: The peak forces of the target and rear leg during the golf swing with different clubs in mean ± 1SD (n = 10). The asterisks (* and **) indicate significant differences at $p < 0.05$ and $p < 0.01$, respectively.

DISCUSSION: No differences in the peak resultant forces between the golf clubs partially supported with our hypothesis. Several studies (Williams & Cavanagh, 1983; McNitt-Gray et al., 2013; Peterson et al., 2016) revealed that the rotation of the body-golf club system was associated with the horizontal reaction forces in the target and rear leg. The results of this study were similar to that of the previous studies that the increase of the shot distance due to the use of a different club might be determined by the horizontal reaction forces which contributed to the rotation of the body-golf club system about the vertical axis through the center of mass of the body. We recognized three patterns of the resultant reaction force at the target and rear leg (Figure 3). The past study demonstrated that the ground reaction forces during the golf swings quite varied between the male golfers (McNitt-Gray et al., 2013). The female golfer's resultant reaction force patterns were classified into three patterns, indicating that the golfers generated the reaction forces between in their own ways, which would reflect at the characteristics of their golf swing. The reaction force patterns of the both legs indicated a clear weight shift from the rear to the target leg as demonstrated by Golfers No. 2 and 7, and a less weight shift in Golfer No. 6. It is inferred that the golf swing with different golf clubs and the shot distance as a result would be controlled by the horizontal reaction force in the target and rear leg regardless of the individual patterns. In future study, we will investigate the relationship between the reaction force patterns and the movement of body-club system, increasing the number of female golfers.

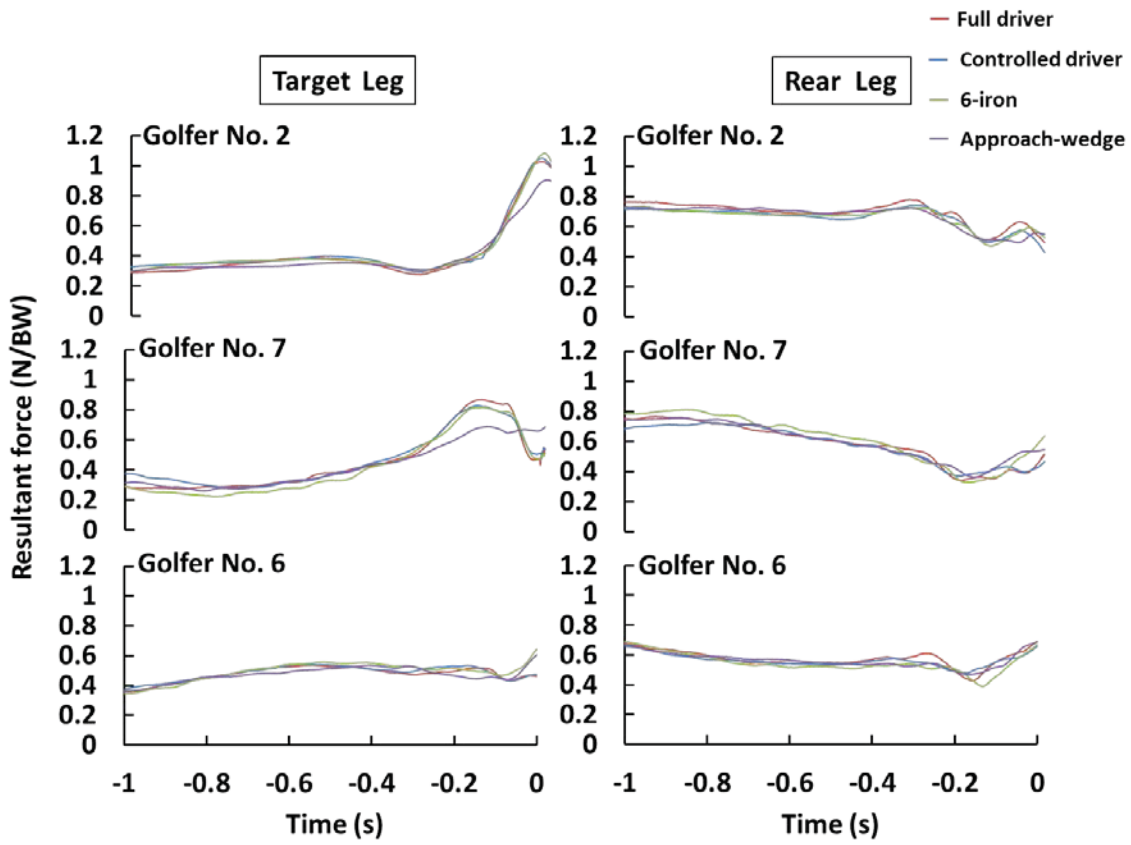

Figure 3: Three representative resultant force patterns for the target and rear leg during the swing with four clubs (full driver, controlled driver, 6-iron and approach-wedge). Time 0 indicates ball impact.

CONCLUSION: No significant differences in the peak resultant forces between the golf clubs, but the peak resultant horizontal force differed between the golf clubs during the golf swing. The female golfers' resultant reaction force patterns were classified into three patterns, indicating that the golfers generated the reaction forces in their own ways, which would reflect the characteristics of their golf swing.

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