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Keywords: drive swing (드라이브스윙), multiple functional wear (다기능성웨어), swing plane (스윙평면).

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Abstract- The purpose of this study was to verify the effect of drive swing on multiple functional wear wearing in golf. The subjects were 6 men (22.67±0.82yrs, 175.42±3.42cm, 78.75±4.78kg), who had career each with at least 8 years golf experience with right-hander. For kinematical analysis, this study used equipments with 7 motion capture cameras (300Hz) and analysis program (Nexus 1.5). The total time of the club head, displacement magnitude of the COM and swing plane were compared of according to functional wear wearing and non-wearing during golf drive swing. The results of the study are as follows. The total time of the club on wearing (2.18±0.06sec) was faster than non-wearing (2.52±0.15sec). Displacement magnitude of the COM on wearing (4.06±0.67cm) was shorter than non-wearing (5.79±0.72cm). Also, swing plane was found to be significantly different of 3 phase excepted BST-DS (back swing top - down swing) phase. AD-BST (address - back swing top) phase on wearing (13.86±3.08cm) decrease more than non-wearing (20.82±3.99cm), DS-IP (down swing – impact) phase on wearing (6.25±1.35cm) decrease more than non-wearing (7.18±1.52cm) and IP – FT (impact – follow though) phase on wearing (7.93±2.09cm) decrease more than non-wearing (9.68±2.02cm). The multiple functional wear wearing was contribution to come close for one-plane, a long with consistency and accuracy on golf drive swing.

Keywords: drive swing (드라이브스윙), multiple functional wear (다기능성웨어), swing plane (스윙평면).

I. Introduction

Golf is a ball sport in which players use various clubs to hit balls into 18 hole cups on a course in as few strokes as possible. Golf can be divided into “tee shot” using driver in teeing ground, “iron shot” in fairway, rough and bunker, and “putt” in green. In particular, the result of the driver swing, the first strike, has an important effect on selecting the right clubs and building the seamless course strategies for second shot. For this reason, players need to swing the golf club in higher accuracy to move the ball a long distance to the most desirable position. For such higher accuracy of driver swing, the optimal combination of physical bodies' translational movement and club head's rotational movement generates maximum power and moves the ball into the target position The consistency of such physical movements, the direction and speed of club heads before and after the impact and the position and angle of clubs at the moment of the impact are all determined by the correlation between balls and heads. (Kwon, 2007) Therefore, having a systematic understanding of the right coordinated movements that allow to maintain the balance in bodies, swing trajectories and swing plane of club movements is very important for consistently accurate driver swings. (Hay, 1985; McLean, 1992; Heuler, 1996) Swing plane is referred to as the plane in the trajectory of club heads during the swing ranging from Address to Follow though. The swing planes are divided into One-Plane or Single Plane where arms and shoulders move up in parallel and Two-Plane where arms and shoulders are up on the different level. (Ben Hogan, 1966; Hardy, 2006; Lim, 2009) In his study in 2007, Kwon used 3D motion analysis technique to estimate the plane that is as close to the trajectory of the club head as possible. He compared the result with the actual swing trajectory and conducted the experiment to calculate swing flatness. As a result, he found that there was no perfect plane swing, but is the swing plane close to the trajectory of the club head. He also discovered that analyzing the swing using the swing flatness would be really helpful to confirm players' swing style or their swing consistency and accuracy. (Lim, 2009).

However, the previous kinematical studies on the driver swing have focused on increasing driving distance by analyzing X-factor that is an angle of relative rotation between pelvis and body segments at the top of back swing, body's rotation movement and good coordinated movements of wrist joints, the muscle power of major muscle contributing to swing, the swing speed of golf clubs and power generation through external force. (Lee, 1999; Kim, 1997; Horton, Lindsy & MacIntosh, 2001; Yi & So, 2004; Park, 2005; So, Lim, Kim & cho, 2005; Craig & Vince, 2010) However, unexpected ball control (hook, slice, draw or fade) caused by the increased driving distance might put professional and amateur golfers at risk of having bad results in the games. In other words, this does not fulfill the conclusive factors of “distance, consistency and accuracy” for good swing. (Koichiro, 1996) Even though the increase in the driving distance is important, the consistency and accuracy of swing are required to have a positive impact on final scores for golfers. Hence, in an effort to meet such conclusive factors for good swing, golfers have incrgly had a keen interest in golf lesson and related equipment. With this trend, golf equipment companies have thrived. (Lim, 2009; Kim, 2011).

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In particular, Korean golf market has grown by 5 to 10 percent over the last 10 years. The golf course market is worth 3 trillion won, the golf-ware market is worth 1.2 trillion won, the golf club market is 700 billion won and the golf equipment market is 300 billion won. Given such statistics, the golf industry including the golf equipment market is worth nearly 6 trillion won. (Park, Woo & Lim, 2012).

Recently, many golfers are wearing functional clothing that helps minimize the possible injuries by swing and maximize sports performance. (Chae & Kang, 2011) The major function of multiple functional wears is to keep pleasant physical state for players by facilitating perspiration during the game and eventually improve players' performance in the games by optimizing the mechanical characteristics determined by molecule orientation and crystallization such as tensile strength, friction and flexibility. (Kwon & Kouh, 2002; Doan et al., 2003; Chae & Kang, 2011) It is reported that among various mechanical characteristics of multiple functional wears, compression bandaging that was inspired by a technique of taping heavily used muscles during the game actually improved muscle strength and endurance, relieved muscle pain and fatigue by reducing muscle vibration and eventually enhance play performance with better bending of each joint and better rotating during the extension. (Doan et al., 2003; Song, 2007; Chae & Kang, 2011) Likewise, the previous studies demonstrate that multiple functional wears that is similar to the taping method would upgrade golf driver swing movement and in the end improve the conclusive factors of consistency and accuracy for good swing by reducing the dispersion of the scope of which muscles and joints move. In conclusion, the main purpose of this study is to investigate and verify the effect of multiple functional wears on golf driving swing through the analysis of kinematical variables.

II. Methods

a) Subjects

For this study, we chose multiple functional wear brand Z that is on sale in Korea. This brand's multiple functional clothing is characterized by elastic fabrics in the left and right and top and bottom, stitching along the body lines and mesh fabric for the inner side of arms. This clothing is made of 80% of nylon and 20% of polyurethane. (Figure 1) 6 male, right-handed amateur golfers who have played golf for 8 years or higher were specially selected as the subject of this study. Their average age was 22.67±0.82 years, their average height was 175.42±3.42 cm and their average weight was 78.75±4.78 kg.



Fig. 1 : Multiplefuctional wear product

b) Experimental Equipments

In the study, we installed 7 infrared cameras for motion analysis to analyze the kinematical variables displayed in golf drive swing movements in three dimensions with and without wearing multiple functional clothing. We also attached reflection markers (14 mm in diameter) on the surface of multiple functional wears and clubs to correctly analyze the body movement and club swing, calculate combined movement displacement and analyze the total travel distance of clubs and swing plane. In total, 35 markers were attached to R/L, Anterior and Posterior Head, R/L Shoulder, R/L ASIS, R/L PSIS, CLAV, STRN, C7, T 10, RBAK, R/L Elbow, R/L, Medial and Lateral Wrist, R/L Finger, R/L Lateral Thigh, R/L Knee, R/L Tibia, R/L Ankle and R/L Toe. In addition, 38 reflection markers were attached to shaft, shaft neck and head of the club by each. Table 1 shows in detail the experimental equipment used in this study. Figure 2 shows where the reflection markers were attached.

Table 1 : Experimental equipments

Classification	Model	Manufacture
Motion capture	MX13 1.3 Motion Capture Camera 7unit	Vicon (UK)
Data acquisition	MX Control	Vicon (UK)
	MX Net	Vicon (UK)
Human measurement	Martin calipers	Takei (Japan)
Analysis software	NEXUS 1.5	Vicon (UK)
	Polygon version 3.1 build 201	Vicon (UK)

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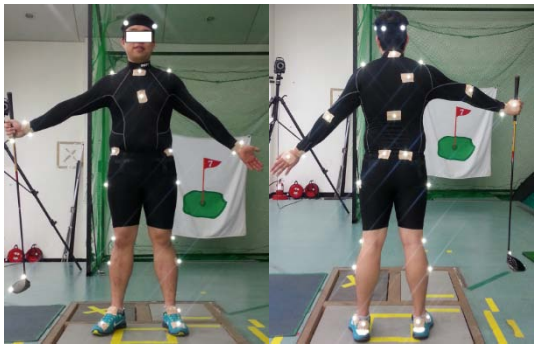

Fig. 2 : Marker placements

c) Experimental Procedure

The experiment was conducted in the lab setting that ensured the safety by having sufficient space for the subjects to exert drive swing movement and installing nets at the place to which ball will reach. Infrared camera for motion was used to conduct 3D calibration with the Non-linear transformation (NLT) method and create the global coordinate system of anterior-posterior axis (x-axis), medial-lateral axis (y-axis), and vertical axis (z-axis). All subjects were asked to sign the experiment consent and change their pants into tights before sufficient warming-up and swing practice. The subjects who got ready for the experiment were selected by random to wear multiple functional wears and ordinary tights. Under the two conditions of wearing and non-wearing multiple functional wears, the subjects did swings 10 times. Given the expected fatigue by repetitive drive swing, the subjects were encouraged to take 10-minuate break at the interval of the two conditions. After the end of the swings, they were asked to choose 3 swing movements that they thought to be excellent. Each 3 swing movements selected by every subject was analyzed by researchers.

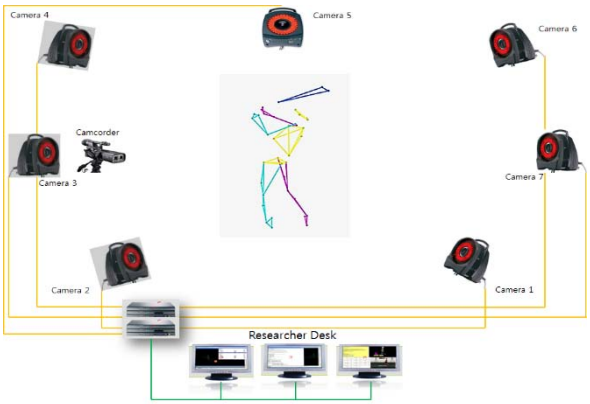

Fig. 3 : Experimental equipments set-up

d) Data Analysis

Figure 4 shows major events and phases required to analyze drive swing movements with wearing multiple functional wears.

Event 1 is the moment of “Address”. Event 2 is the moment of “Back Swing” when the markers on the right hand are at the highest position. Event 3 is the moment of “Down Swing” when the vertical position of the markers on the club head is down to the ground. Event 4 is the moment of “Impact” when the ball and club face are met. Event 5 is the moment of “Follow Through” when the shaft and the ground are horizontal after the ball is hit forward. Event 6 is the moment of “Finish” when the markers on right elbow are at the highest position to the left, the direction to which the ball moves. Furthermore, the six events were broken down into four phases –backswing, downswing, impact and follow –that affect the consistency and accuracy of golf swing the most. The six events and the four phases were analyzed in this study. The ratio of camera sampling was set at 300 Hz per second. The collected data was processed with NEXUS 1.5 program. For 3-dimensional motion analysis, we selected as kinematical variables a) the total travel time of the club head to see how consistent the drive swing movement is, with and without multiple functional wears, b) the body-oriented combined (x, y, z) movement displacement to see how dispersed the body movement is, and c) the swing flatness to analyze the swing plane and check the accuracy of actual drive swing.

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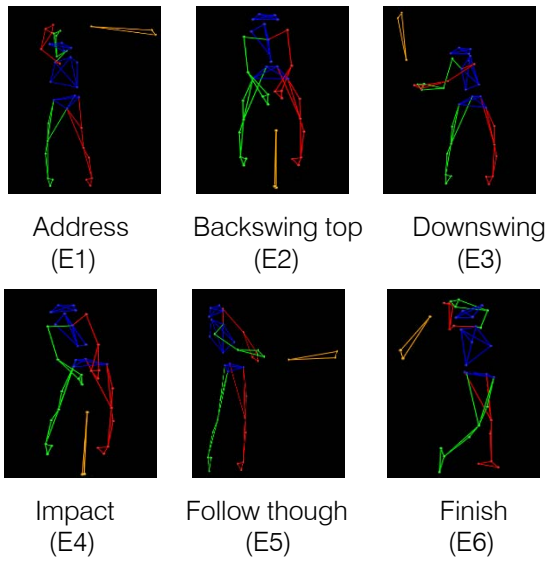

Fig. 4 : Event & phase

e) Statistical Analysis

The subjects of this study were asked to do the swings 10 times with wearing and non-wearing multiple functional wears by each in order to find the effect of multiple functional wears on golf drive swing. During this experiment collected was the data on the three swing movements considered appropriate to analyze the swing movements of six subjects with wearing and non-wearing multiple functional wears. (6 people* 2 conditions * 3 movements * 3 variables) Microsoft office excel 2007 was used to estimate the average and the standard deviation of all variables. A statistics analysis program, SPSS 18.0 was also used to conduct paired t-test and thus to verify the statistical significance of the consistency and accuracy of drive swing movements depending on whether to wear and non-wear multiple functional wears. The significance level was set at $p<.05$.

III. Results and Discussion

The subjects in this study were randomly selected to wear or non-wear multiple functional wears and do the golf drive swings. The result of analyzing kinematical variables is as follows.

a) Total time of the club head

Table 2 shows the difference in the total travel time of the club head from the moment of being ready for the drive swing to that of follow through under the two conditions of wearing and non-wearing multiple functional wears.

Table 2 : Total time of the club head

(Unit: sec)

Group	N	M	SD	t
Wearing	6	2.18	0.06	-7.18***
Non-Wearing		2.52	0.15	

****p< .001*

The result is that the average travel time with wearing multiple functional wears was 0.34±0.09 sec shorter than without multiple functional wears. This difference was found to be statistically significant ($p=.001$). In reality, the shorter the travel time of the club head is, the faster the club head moves. The travel time is also closely related to the travel distance of the ball. (Choi, 1996) This result is not different from the result of the previous studies on multiple functional wears and the improvement of driving distance. However, the average travel time of the club head under the two conditions presented in this study was 2.35 seconds, higher than the previous studies of 0.72 to 0.91 seconds. (Park, Lee & Song, 2000; Lim, 2009) This gap is believed to drive from the different swing styles of the subjects, their skill levels (professional vs. amateur golfers) and the different definition of phases with the previous studies. With the emphasis on the consistency and accuracy of the swing, the standard deviation values of the total travel time of the club head showed the slight different between wearing and non-wearing multiple functional wears. The standard deviation of wearing multiple functional wears was 0.06, slightly lower than that of non-wearing multiple functional wears at 0.15. This result demonstrates that wearing multiple functional wears have a positive impact on the consistency of body movement during the drive swing.

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b) Displacement magnitude of the COM

Table 3 shows the difference in the combined movement displacement of COM (center of mass), from the moment of being ready for the drive swing to that of follow through under the two conditions of wearing and non-wearing multiple functional wears. The result is that the average combined movement displacement of body center with wearing multiple functional wears was 1.73±0.05 cm lower than without multiple functional wears. This difference was found to be statistically significant (p=.002). How the COM moves at the time of the golf drive swing can vary among players. However, most players move their COM into the right feet at the moment of backswing and back to the left feet at the time of between downswing and follow through, following the direction that the ball travels.

Table 3 : Displacement magnitude of the COM

(Unit: cm)

Group	N	M	SD	t
Wearing	6	4.06	0.67	-3.18***
Non-Wearing		5.79	0.72	

***p< .01*

Note: COM - Center of mass.

However, golfing requires the continuous movement of body parts based on anatomical positions into the direction of front-back (x-axis), left-right (y-axis) and verticality (z-axis). Under such circumstance, maintaining body balance and doing the swing is the key. If the center of body is tilted to the front or back, it affects the flying trajectory of the ball and cause Slice or Hook. (Lee, Yang & Kim, 1998) The study in 1993 by Leadbetter and Huggan claimed that the center of gravity must be moved naturally into the target direction to the degree where the center of swing is not swayed. In this way, players can exert the golf swing along with natural rhythm and maintain the accuracy of the ball strike natural rhythm. For this reason, the lower combined movement displacement of body center is can ensure that the central axis of the swing is more stabilized and the consistency and accuracy of the swing is enhanced.

c) Swing plane

Table 4 shows the difference in the swing plane, from the moment of being ready for the drive swing to that of follow through under the two conditions of wearing and non-wearing multiple functional wears.

The result is that at the AD-BST phase, the average flatness value with wearing multiple functional wears was 6.96±0.91cm lower than with non-wearing multiple functional wears. The difference was statistically significant.(p=.03) At the BST-DS phase, the average flatness value with wearing multiple functional wears was 3.72±0.49cm lower than with non-wearing multiple functional wears. The difference was not statistically significant. (p=.14)

Table 4 : Flatness of the Swing

(Unit: cm)

Phase	Group	N	Mean	SD	t
AD – BST (Max)	Wearing	6	13.86	3.08	-3.30*
	Non- Wearing		20.82	3.99	
BST - DS (Max)	Wearing	6	14.00	3.35	-1.73
	Non-Wearing		17.72	2.86	
DS - IP (Max)	Wearing	6	6.25	1.35	-4.55**
	Non-Wearing		7.18	1.52	
IP - FT (Max)	Wearing	6	7.93	2.09	-3.86**
	Non-Wearing		9.68	2.02	

**p< .05, **p< .01*

Note: AD-Address, BST-Backswingtop, DS-Downswing, IP-Impact, FT-Follow though

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At the DS-IP phase, the average flatness value with wearing multiple functional wears was 0.93±0.17cm lower than with non-wearing multiple functional wears. The difference was statistically significant. (p=.01) At the IP-FT phase, the average flatness value with wearing multiple functional wears was 1.75±0.07cm lower than with non-wearing multiple functional wears. The difference was statistically significant. (p=.01) As a result, the difference of the average flatness values between the two conditions of wearing and non-wearing multiple functional wears was all statistically significant at the three phases except for the BST-DS phase. Here, the flatness value is required to analyze swing plane.

Lim reported in his study in 2009 that the good swing in golf is to make the accurate impact on the ball with fast speed. To that end, swinging the club within the consistent trajectory of swing is the key. As such, sing plane swing is better than double or multiple plane swing to maintain the more consistent and accurate swing trajectory. If the swing is kept into the right direction consistently, the one plane swing is likely to make the positive impact in repeat and eventually on the ball trajectory. (Hardy, 2006) All in all, it can be concluded that considering the experimental result in this study that the difference of swing plane between wearing and non-wearing multiple functional wears was statistically significant, wearing multiple functional wears contributes to making the swing close to the one plane.

IV. Conclusion

The study was designed to verify the effect of wearing multi functional wears on golf drive swing. In this study, we compared and analyzed how the kinematical variables are transformed to assess the consistency and accuracy of the swing with wearing and non-wearing multi functional wears for amateur golfers.

The conclusion of this study is the following. First, there was the statistically significant difference in the total travel time of the drive swing between wearing and non-wearing multi functional wears. The travel time with wearing multi functional wears was shorter than that of non-wearing multi functional wears. This result can be interpreted as wearing multi functional wears increasing the speed of the club head. In addition, the smaller value of the standard deviation with wearing multi functional wears can also be considered as the positive effect of multi functional wears on the consistency of body movement. Second, the result of combined movement displacement of body center analysis showed the statistically significant difference between wearing and non-wearing multi functional wears. The average value of the body center movement with wearing multi functional wears was smaller than that of the opposite case. This means that the axis of body center is not swayed and more stabilized with wearing multi functional wears, which will improve the consistency and accuracy of the swing. Third, the analysis the variables of the swing plane generated the result that the swing plane with wearing multiple functional wears was lower than with non-wearing multiple functional wears at every phase. The difference between the two conditions was all statistically significant at the AD-BST, DS-IP and IP-FT phases except for BST-DS. This result proves that wearing multiple functional wears can contribute to making the swing close to the swing plane in order to maintain the consistent swing trajectory for the club.

The value of this study lies in quantifying the effect of wearing multiple functional wears inspired by the taping method on golf drive swing with kinematical variables and generating the results. However, the subjects of the study might have felt the different intensity of pressure from multiple functional wears in different body parts. There were also the limits in analyzing kinematical variables to test the consistency and accuracy of the swing and conducting the field test to measure the direction that the ball flies as well as the equipment used in this study, such as the instrument of measuring the ball flying direction. Therefore, what we need to make sure in the follow-up study will be to consider accurately the different physical characteristics of each subject, realize the swing analysis that ensures the accurately measurement of the pressurized body parts and the intensity of multiple functional wears, and fulfill the condition that allows for measuring the ball flying direction. Furthermore, this study is expected to fuel the development of the golf equipment that helps improving the consistency and accuracy of an iron shot and putter shot, not just the drive swing and, going further, lead to the study on the fitting of multiple functional wears for design proposals based on individual's physical characteristics.

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