LEVERAGING SPORTING EQUIPMENT BALANCE AND WEIGHT DISTRUBUTION INFLUENCE ON PUTTING KINEMATICS –A STUDY ON COUNTER-BALANCED PUTTER DESIGN

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Golf club putter designs have been consistenly introducing new design to enhance performance and enjoyment of the game. The purpose of this paper was to look into the effects of counter-balanced design on putting kinematics. Twelve (n=12) male, right-handed, expert-skilled golfers (height 178.1±3.8cm, age 36.8 ±6.2yrs, and handicap 3.9 ±2.8) were recruited for the study. Research results suggest that Counter-Balanced have altered the putting kinematics, with longer follow-through, decease rise angle, increased rotation during the downswing and timing of follow-through. Future study focuses on the cross-sectional skill levels, cordinate change of body joints in relation to phase and relative club position, and synchronize with EMG data between various skill level.

KEY WORDS: Golf, putting kinematics, putter design

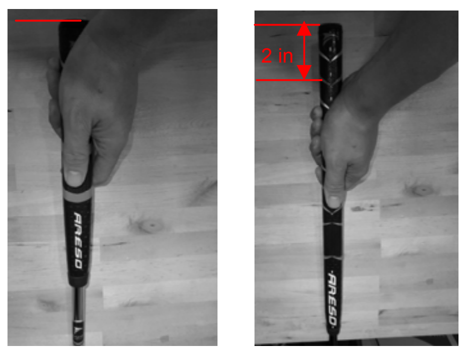
INTRODUCTION: In golf, putting is considered one of the most important factors for scoring of professional Tour players (Alexander & Kern, 2005), and accounts for 43% ± 2% per round (Pelz & Frank, 2000). Unlike the long game, short game like putting, is focused on its accuracy and consistency (Hume, Keogh & Reid, 2005). Putting stroke requires accurate and repeatable stroke especially during impact stage, and one of the most recent putter design is to grip down or to have extra weights on the grip end of the club, also known as the counter-balanced putter.

The putting stroke is divided into three phases, phase one (P1), the backswing (BS) is deifined from address position (ADR) to the top of backswing (TOB); phase two (P2) is from top of backswing to impact (IMP), and phase three (P3) is from impact to finish (FT), and down-swing (DS) is the combination of P2 and P3 (Delay et al., 1997). Coordination and temoporal parameters of putting stroke are defined as rhythm (RHYTHM, relation of BS / FS time) and impact timing (TIMING, the relation of Impact time / FS time), are both important factors for consistency and feel (Marquardt, 2007). Past researches mainly focused on putting stroke have showed significant difference in putting stroke between skill levels, with the better-skilled golfers having shorter BS, longer amplitude for DS, and longer stroke duration (Marquardt, 2007; Lee et al., 2008; Wu et al., 2010). Also another study suggested a slower velocity at impact was observed for better-skilled players (Marquardt, 2007).

There has been several attempts to improve the perfromance of glof club by introducing new designs including a long/ belly putter (Pelz, 1990). However, past golf-related researches mainly focused on full-swing (Schmidt, Roberts, & Rothberg, 2006; Komi, Roberts, & Rothberg, 2007) or putting pressure (Chen et al., 2008); other studies focused on interactionbetween human and equipment (Wu et al., 2012; 2013),Counter-balanced putter were introduced towards last months of 2013 by numerous Golf Makers and have yet been investigated. The purpose of this study was to examine the influence of the counter-balance putter on the characteristics of the putting stroke.

METHODS: Subjects: Subjects were twleve (n=12), male, right-handed, highly-skilled golfers (height 178.1±3.8cm, age 36.8 ±6.2yrs, and handicap 3.9 ±2.8), and randomly divided evenly into two groups, standard (STD) and counter-balanced putter (CBP). All subjects were informed of the experimental procedures and all agreed before participating in the research.

Procedure: Subjects first asked to stretch, followed by warm-up practice with own equipment for five minutes before experiment. Ten putts from two meters (2m) were recorded per session. Subjects were asked to perform each putt with pre-shot routine to ensure consistency (MacPherson, Collins, & Morris, 2008). Experiment setting took place in an indoor studio on an artificial turf surface (Tourlink LLC., USA) with Stimp 9.
Equipment: Both groups used the same model, with exception that the controlled group uses standard head weight (355g) with length of 34 inches while the expriment group used heavier head (395g) with 36 inches putter, which participant were to grip down two inches.
Data processing: Putter strokes were measured with ultrasonic systems (PuttLab 5, Science & Motion Sports GmbH), with three sensors attached perpendicular to the putter face, on balance point on the putter shaft, and distanced 25cm from the putter sitting point. The sampling rate of the positional data was 70 Hz per sensor. The analysis was done with SAM Puttlab 5 software which includes specific data analysis and filtering techniques for processing human movement data (Marquardt & Mai, 1994).
Statistics: Data were processed with SPSS 19.0 software. Mean values of the trials for each grip were computed and analysis with repeated measurement. Significant level set at $\alpha=0.05$.



Standard (STD) Counter-Balance (CBP)

Figure 1: Illustration of the two grip designs

RESULTS: Mean and standard deviation values and average of putting kinematics parameters using controlled group (standard, STD) and experiment group (counter-balanced putters, CBP) are shown in Table 1. There were no significant difference in holing percentage between STD (87.5%) and CBP (88.2%). Results suggest that there were no significant difference in temproal and amplitude with BSTIME (p=.842) while CBP's FSTIME (p=.017) was significant longer. Both showed no significantly difference in putter head displacement in BSPATH (p=.079) and but CBP were significant longer on FSFATH (p=.020). CBP has slower time to impact (TIMP) than STD, but both were within range of good players (Marquardt, 2007). Impact velocity (VIMP) for CBP was slightly slower (p=.171) but were not significant. Rise angle was significant lower with CBP (p=.007). Rotation on the DS were all significant from the top of backswing to impact (ROTIMP) (p=.000), during impact (ROTRATE) (p=.021) and total rotatoin (ROTTOT) (p=.000). Significant difference were seen with CBP having shorter TIMING (p=.007) but not with RHYTHM (p=.056).

Table 1: Summary of Statistically Analysis of Putting Kinematics between Golf Club Types (mean±SD)

	Unit	STANDARD (STD)	COUNTER-BALANCE (CBP)
Back-Swing Duration(BSTIME)	**(Sec)**	0.678 ±0.096	0.684±0.141
Forward Swing Duration (FSTIME)	**(Sec)**	0.831±0.132	0.915±0.191*
Back-swing Length (BSPATH)	**(m)**	0.186. ±0.010	0.200±0.047
Forward-swing Length(DSPATH)	**(m)**	0.540±0.100	0.589±0.102*
Time-to-Impact (TIMP)	**(sec)**	0.327±0.064	0.319±0.059
Impact Velocity (VIMP)	**(m/s)**	1.305±0.149	1.273±0.057
RISE	**(°)**	2.05 1.402	1.37 1.002*
Rotation-to-Impact(ROTIMP)	**(°)**	4.51±1.491	6.22±1.476*
Rotation TOTAL (ROTTOT)	**(°)**	11.30±6.957	17.61±4.12*
Rotation during Impact (ROTRATE)	**(°)**	-22.95±12.767	-35.51±14.276*
RHYTHM		2.11±0.301	2.14±0.216
TIMING		0.40±0.077	0.36±0.07*

*Significantly level (p<.05)

DISCUSSION: STD and CBP were within range for temporal, BSTIME 0.670s±.09; FSTIME0.820s±0.1, of Tour player (Marquardt, 2007). During DS, CBP has longer amplitude and temporal but TIMING fall within range of Tour players 0.39±0.04 (Marquardt, 2007). Only temporal parameters that were significant was TIMP which were signs of the proficency but within range of Tour level (Marquardt, 2007; Lee et al., 2008). Angular accelaration of rotation from top to impact (ROTIMP), through impact (ROTRATE) and total (ROTTOT) were all significantly with due to the larger mass. The finding was similarly discussed with equipment effects on kinematics (Wu et al., 2013). Subjects all revealed feeling ease to accelerate the club head during DS, and less feel of club head. Overall, CBP showed matches all characteristics of proficiency but have significantly longer DS, which is opposite of larger grip (Wu et al., 2013) and different in rhythm, timing, and total rotation of the downswing.

CONCLUSIONS: Overall, counter-balanced putter design will altered the stroke to the lesser skilled, and alternated the putting kinematics, notably longer DS, increase in total rotation during downswing and increased ratio in TIMING. This could be due to the larger momentum due to the heavier mass and leverage, even with counter-balancing the weight in the end of the club increase both the temporal and displacement of the FS but didn't contribute to faster velocity or temporal to impact. Increase rotation through the putting stroke in the DS and decrease in RISE angle. Both styles match the trait of good players from past researches but lacks support that CBP will be beneficial for good players.

Research limitation is that the due to the increase in total weight, swing weight was significantly heavier for CBP and limitation to the number of participants. Future study focuses on adding full body segment information, also considering different weighting and position of the weights with large sectional subjects from age, gender and skill levels.

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