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Letter to the Editor

Biomechanical Analysis of Slope Perception and Body Alignment in Healthy Subjects

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Dear Editor-in-Chief

In putting performance, the player's putting technique and environmental conditions of the green, including grass condition, humidity, spike marks, and slope, should be considered (1). Moreover, the ability to perceive information such as the distance and direction of the ball's motion to the hole cup considering the green's conditions is essential in putting (2). The green's slope, in particular, is a key factor that directly affects the determination of the ball's trajectory (1). Thus, it is essential for a player to successfully predict the trajectory of the ball's motion by reading the slope towards the hole cup, in addition to the stroke's technicality (3).

For these reasons, golfers determine the best putting line through the maximum use of diverse sensory functions. A proficient golfer can read the slope of the green based on their rich experience of putting and their personal stroke style and determines the green's slope primarily using their vision (1). However, a player with a high dependency on their vision is likely to overlook the data of the slope being contaminated by the data of various environmental factors in the area surrounding the green. Therefore, for complementation, the player's somatosensory organs may be applied to perceive directly the green's slope, thereby minimizing errors in visual perception (4).

While the individual roles of visual perception and other senses may vary, they are known to converge rather than act independently for goal-oriented motion (5). As golfers cannot quantitatively determine the slope of the green during a game, this is determined by integrating the visual information from the environmental factors of the green and somatosensory information from the direct touch on the green (2). Such efforts to identify the slope of the green based on visual and somatosensory data to increase the success rate of putting have been made over a long period. However, few studies have quantitatively measured the somatosensory abilities of golfers to verify their body alignment during putting. The purpose of this study aimed to examine the slope perception ability of healthy subjects using a tilting platform and verified the body alignment at address position.

The participants in this study were 21 males and 5 females (22.54±2.15 years, 174.65±6.07 cm, 71.35±9.27 kg) healthy college golf players with no history of musculoskeletal injury in the past 12 months. This study was approved by the relevant Konkuk University Institutional Review Board, an ethics institution founded to protect

the bioethics and safety of the study participants (Ethical Number-7001355-201705-HR-177).

To analyze kinematic variation on the five slopes, a repeated-measures analysis of variance was performed with Bonferroni's post hoc test. For all statistical analyses in this study, SPSS 24.0 (Armonk, New York, USA) was used, and the level of significance was set to α=.05.

In the slope perception test, the slope of the tilting platform was set to a maximum of 2°, considering the participants' safety with controlled visual and auditory senses, and the slope around the hole cup, as recommended by the United States Golf Association (USGA), was approximately 3° or less. In addition, a safety fence was installed on the tilting platform to prevent falls during the experiment.

In random order, the tilting platform was set to a slope of 0.5, 1, 1.5, and 2° in the toe-down, toe-up, left, and right directions, respectively, in triplicate. The platform's slope direction was defined as follows: toe down when the body was inclined forward, toe-up when the body was inclined backward, left when the body inclined leftward, and right when the body inclined rightward.

As a results, the mean perceived slopes were 1.98, 2.72, 2.18, and 2.24° in the toe-down, toe-up, left, and right directions, respectively, and the estimated test-retest ICC was 0.729 (95% confidence interval [CI]:0.394–0.878) for the toe-down direction, 0.592 (95% CI: -0.228–0.856) for the toe-up direction, 0.537 (95% CI: -0.019–0.791) for the left direction, and 0.702 (95% CI:0.341–0.866) for the right direction (Table 1).

Table 1: Slope perception test and ICC results

Variable	*Toe-down*	*Toe-up*	*Left*	*Right*
Angle(°)	1.98±0.72	2.72±1.03	2.18±0.66	2.24±0.71
ICC	0.729	0.592	0.537	0.702

Table 2 showed that the participants' body alignment in address according to slope showed no significant variation regarding the pelvis-based shoulder angle, foot-based pelvis angle, and foot-based shoulder angle (Table 2).

Table 2: Body alignment in address according to slope

Variable	*FT*	*SL 1*	*SL 2*	*HK 1*	*HK 2*	*F-value*	*p-value*
S/P	1.69	1.77	2.57	1.95	2.03	1.352	.267
	(1.99)	(2.87)	(2.78)	(2.02)	(3.21)		
P/F	-2.14	-2.31	-3.05	-2.30	-2.00	1.394	.252
	(2.61)	(3.42)	(3.68)	(2.69)	(3.00)		
S/F	-.45	-.53	-.48	-.35	-.03	.730	.574
	(3.01)	(3.65)	(3.04)	(3.12)	(3.43)		

*significant difference at p<.05
(+) indicates open and (-) indicates closed.
S/P, shoulder/pelvis; P/F, pelvis/foot; S/F, shoulder/foot

In summary, it is thus important to improve slope perception in the toe-down, toe-up, and right directions through proprioceptive training, as participants exhibited relatively low levels of perception here compared to the left direction.

Conflict of Interest

The authors declare that there is no conflict of interest.

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