

Influence of hand acceleration on putter face angle at impact event: An experimental study in amateur Golfers

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Abstract:

Putting contributes substantially to overall scoring performance in golf, with the putter face angle at impact event widely recognized as the primary factor determining the initial direction of the ball. Previous biomechanical research has indicated that hand acceleration can influence clubhead direction during the putting stroke. However, empirical evidence directly linking hand acceleration to putter face alignment among developing or amateur golfers remains limited. **Purpose:** The purpose of this study was to examine the effect of forward hand acceleration toward the target on putter face angle at impact event and to evaluate the effectiveness of specific training drills designed to reduce excessive hand acceleration during the putting stroke. **Methods:** Twenty healthy undergraduate students (mean age: 20.3 ± 1.13 years) who had successfully completed a Basic Putting Technique course participated in this study. All participants were classified as amateur golfers and were assigned to either a control group ($n = 10$), which followed the standard putting curriculum, and an experimental group ($n = 10$), which performed the same curriculum supplemented with two targeted drills aimed at reducing forward hand acceleration. Hand acceleration and putter face angle at impact were recorded using the CAPTO putting analysis system at three time points: baseline, week 2, and week 4. Descriptive statistics and paired-sample t-tests were conducted using SPSS 20.0 to analyze within and between-group changes. **Results:** The results revealed a significant association between hand acceleration patterns and putter face angle at impact. After 4 weeks of training, the experimental group demonstrated a significant reduction in forward hand acceleration accompanied by improved putter face alignment toward a neutral position ($p < 0.05$), whereas the control group showed minimal changes. **Conclusion:** These findings indicate that targeted interventions aimed at controlling hand acceleration can effectively improve putter face alignment at impact, thereby enhancing putting accuracy. The results provide practical implications for golf coaching and contribute to the development of evidence-based training strategies for amateur golfers.

Keywords: putter kinematics, hand acceleration, putting accuracy, putter face angle.

Introduction

Putting skill is a critical determinant of amateur golf performance, accounting for approximately 43% of total strokes in a typical round and playing a decisive role in a golfer's ability to convert putts into successful scores (Gryc & Brožka, 2021; Richardson et al., 2012). Although the movement appears simple, the biomechanics underlying an effective putting stroke are highly sensitive. Land and Tenenbaum (2012) reported that elite golfers exhibited significantly more accurate putter face angles at impact ($0.50^\circ \pm 0.42^\circ$) compared with amateurs ($0.76^\circ \pm 0.88^\circ$), resulting in a higher number of holed putts. Elite golfers' face angles were closer to 0° , representing a flush impact with the ball and a straighter starting line toward the hole. Additionally, the lower standard deviation observed in elite players indicated greater consistency and reduced variability at impact. Similar findings were reported by Wu et al. (2020), who showed that elite golfers demonstrated lower and more consistent putter face angles at impact ($0.75^\circ \pm 1.30^\circ$) than amateur golfers ($0.79^\circ \pm 1.37^\circ$) during a 3 m putt. Together, these studies suggest that superior putting performance is strongly associated with both the accuracy and precision of face angle control at impact. Previous research consistently indicates that putting accuracy and precision improve as the putter face angle at impact approaches 0° , reflecting a more square and stable contact with the ball (Mackenzie et al., 2011; Pataky & Lamb, 2018; Richardson et al., 2018; Tanaka & Sekiya, 2011; Toner & Moran, 2011).

Penner (2003) and Marquardt (2007) illustrated how the hands and wrists influence the distal segment of the putting system, noting that excessive or abrupt hand acceleration can introduce unintended torque on the putter head. These works lay important theoretical groundwork. Besides, a notable gap remains in understanding how hand acceleration affects putter face angle among developing golfers, particularly amateurs or novice. Existing studies rarely evaluate the direct association between hand acceleration toward the target direction and the resulting face alignment at impact event. The scientific literature on hand acceleration during the putting stroke is notably sparse. Moreover, there is limited empirical evidence on whether targeted training interventions

can help reduce excess hand acceleration to improve face-angle control in this population. This gap is especially relevant in contexts like Vietnam, where structured golf education is emerging and scientific literature on putting mechanics is still limited. From a practical perspective, difficulties in controlling forward hand acceleration are commonly observed among amateur golfers and represent a key limitation in putting consistency. Previous studies have consistently reported that amateur players exhibit greater kinematic variability and reduced precision in low-velocity control during the putting stroke compared with elite golfers, indicating less stable acceleration and timing control (Hasegawa et al., 2017; Wu et al., 2020). Such variability has been associated with less consistent putter face alignment at impact, which directly compromises putting accuracy (Richardson et al., 2018). These findings suggest that excessive or poorly regulated hand acceleration can introduce unintended torque on the putter, thereby increasing face angle error at ball contact.

Accordingly, the purpose of this research was to evaluate the influence of hand acceleration toward the target on putter face angle at impact event among amateurs. Specifically, the study examined whether reducing forward hand acceleration through specialized training drills could promote a more square and consistent putter face at ball contact. To achieve this aim, the research pursued two main tasks: (1) measuring and comparing hand acceleration and putter face angle across participants to clarify their relationship, and (2) proposing and experimentally testing targeted training interventions designed to reduce excessive hand acceleration and improve face alignment at impact. By identifying hand acceleration as a modifiable biomechanical factor, the present study provides coaches and educators with a concrete performance variable that can be directly targeted in training. Integrated biomechanical analysis with applied training strategies and recording using the CAPTO Putting Analysis System, this study seeks to extend current knowledge on putting performance and provide practical, evidence-based guidance for coaches, players, and academic golf programs, particularly within the developing golf community in Vietnam.

Material & methods

Participants

Twenty undergraduate students (age 20.3 ± 1.13 years) majoring in Golf at Faculty of Sport Science, Ton Duc Thang University, Vietnam volunteered to participate in the study. All participants had completed the Basic Putting Technique course which included 30 hours of practical training, and were classified as amateur golfers with a handicap index ≥ 36 . Based on convenience sampling, participants were assigned into two equal groups: an experimental group (7 males, 3 females) and a control group (7 males, 3 females). All participants were right-handed and reported no musculoskeletal injuries within the previous six months. Prior to data collection, participants were informed of the study's procedures and provided verbal consent.

Procedure and Instruments



Figure 1 CAPTO DEVICE

All putting trials were performed indoors on a standardized synthetic putting surface to minimize environmental variation. Each participant used the same putter model-PING PLD Milled Anser (Matte Black), 34-inch shaft, 350 g head weight with standard lie and loft angles, as well as identical balls (Titleist Tour Soft, 45.2 g, 346 dimples) to ensure measurement consistency.

Hand acceleration and putter face angle were recorded using the CAPTO Putting Analysis System (Precision, 2016), an inertial measurement unit (IMU)-based device attached to the putter shaft. CAPTO provides real-time kinematic data with high sampling precision and has been validated in previous putting biomechanics studies (Marquardt, 2007). The variables measured included hand target acceleration (m/s^2) across the forward stroke and face angle at impact (degrees) relative to the target line.

The testing protocol consisted of three assessment sessions: Baseline, after 2 weeks, and after 4 weeks of training. Each participant performed 10 putts per session from a fixed distance of 1.8 meters.



Figure 1: Indoor Putting System Setup: the CAPTO device mounted on the putter to collect data

The control group trained using the standard basic putting curriculum, whereas the experimental group followed the same program supplemented with two drills specifically designed to reduce forward hand acceleration: the Pincers Drill and the Lag Putting Drill. The experimental group practiced at a frequency of five sessions per week, performing 15-30 minutes of drill work prior to each putting practice session over the four-week intervention period.

The Pincers drill, developed by Maria Palozola (2023) requires the player to separate both hands slightly and hold the putter primarily with the palms, thumbs, and index fingers. This grip removes the influence of the other fingers, preventing excessive grip pressure and limiting the ability to apply sudden force to the putter head. By performing comfortable-distance putts with this modified grip, the golfer experiences a more natural pendulum motion, promoting relaxation and encouraging the putter head to swing freely. This drill aims to minimize unnecessary hand action and reduce abrupt acceleration during the stroke, thereby improving face stability at impact. The Lag Putting drill, introduced by Jude Hobbs, emphasizes moderate grip pressure and smooth tempo to promote controlled hand movement throughout the stroke. The player applies a grip pressure of approximately 50%, performs relaxed backswings to sense pendulum freedom, and allows the hands to initiate the downswing slightly before the putter head. This sequence helps create natural lag while maintaining a soft and fluid motion. The drill is designed to enhance stroke rhythm, reduce excessive forward hand acceleration, and support more stable putter-face alignment during impact.



Figure 2. Illustration of (1) the Pincers Drill and (2) the Lag Putting Drill

Data Collection and Statistical Analysis

All data were collected using the CAPTO Putting Analysis System, which recorded hand-target acceleration and putter face angle at impact across all putting trials. Raw kinematic values from each participant were exported directly from CAPTO software for subsequent analysis. Data processing and statistical analyses were conducted using SPSS 20.0. The statistical analyses included descriptive statistics (Mean, Standard deviation, Minimum, Maximum) for hand acceleration and face-angle metrics across baseline, 2 weeks, and 4 weeks measurements. Paired-samples t-tests to compare pre-test and post-test values within each group, assessing changes in hand acceleration and face-angle alignment following the intervention period. Independent-samples t-tests to examine between-group differences in hand acceleration and face angle at each measurement time point. All statistical significance levels were set at $p < 0.05$, consistent with recommendations for biomechanical and motor-performance research.

Results

A total of 20 amateur golfers participated in the study, consisting of 14 males (70%) and 6 females (30%). The control group included 10 participants (7 males and 3 females) with a mean age of 20.7 ± 1.06 years, while the experimental group also comprised 10 participants (7 males and 3 females) with a mean age of 19.9 ± 1.10 years. Across both groups, the overall mean age was 20.3 ± 1.13 years, indicating a relatively homogeneous young adult sample. All participants were classified as amateur golfers with a handicap index of Callaway ≥ 36 , confirming a comparable skill level at baseline. The balanced distribution in gender, age, and handicap between the two groups supports the internal validity of subsequent comparisons made in the intervention.

Table 1: Sample characteristics

Group	Gender	Age (Mean $\pm$ SD)	Handicap Index
Control	Male: n = 7 (70%)	20.7 ± 1.06	Callaway (≥ 36)
	Female: n = 3 (30%)		
Experimental	Male: n = 7 (70%)	19.9 ± 1.10	Callaway (≥ 36)
	Female: n = 3 (30%)		
n=20	Male: n = 14 (70%) Female: n = 6 (30%)	20.3 ± 1.13	Callaway (≥ 36)

Baseline results indicated that both the control and experimental groups started at a similar performance level (Table 1). Before the intervention, average hand acceleration was $1.39 \pm 0.63 \text{ m/s}^2$ for the control group and $1.42 \pm 1.16 \text{ m/s}^2$ for the experimental group. The mean putter face angle was likewise comparable at $1.20^\circ \pm 1.07^\circ$ and $1.43^\circ \pm 1.95^\circ$, respectively, confirming equivalent initial conditions.

Table 2. Mean $\pm$ SD of Hand Acceleration results after 4 weeks training (m/s^2)

Group	Baseline (Mean $\pm$ SD)	After 2 weeks (Mean $\pm$ SD)	After 4 weeks (Mean $\pm$ SD)	<i>p-value</i>
Control	1.39 ± 0.63	1.40 ± 0.77	1.48 ± 1.04	0.18
Experimental	1.42 ± 1.16	0.49 ± 1.06	0.21 ± 0.71	0.01*

Note: *Statistical significance at $p < 0.05$

After two weeks of training, slight improvements appeared in both groups. The control group showed only small fluctuations, whereas the experimental group demonstrated a notable decrease in hand acceleration, suggesting early responsiveness to the intervention drills.

After four weeks, hand acceleration in the experimental group decreased markedly from 1.42 m/s^2 to 0.21 m/s^2 , while the control group showed a minimal increase to 1.48 m/s^2 . The between-group difference was statistically significant ($p = 0.01$), indicating that the proposed drills effectively reduced forward hand acceleration.

Table 3. Mean $\pm$ SD of Face Angle results after 4-weeks training ($^\circ$)

Group	Before Training (Mean $\pm$ SD)	After 2 weeks (Mean $\pm$ SD)	After 4 weeks (Mean $\pm$ SD)	<i>p-value</i>
Control	1.20 ± 1.07	0.83 ± 1.43	0.91 ± 0.96	0.70
Experimental	1.43 ± 1.95	0.42 ± 1.05	0 ± 0.41	0.04*

Note: *Statistical significance at $p < 0.05$.

Across the four-week period, the experimental group continuously improved in putter-face alignment, reducing the value from 1.43° to 0° , while the control group showed only minimal change ($1.20^\circ \rightarrow 0.91^\circ$). The between-group comparison revealed a borderline significant difference ($p = 0.04$) favoring the experimental group. Overall, the results demonstrate that the intervention drills produced meaningful and consistent improvements in both hand acceleration and putter face angle, with significantly greater progress observed in the experimental group compared to the control group.

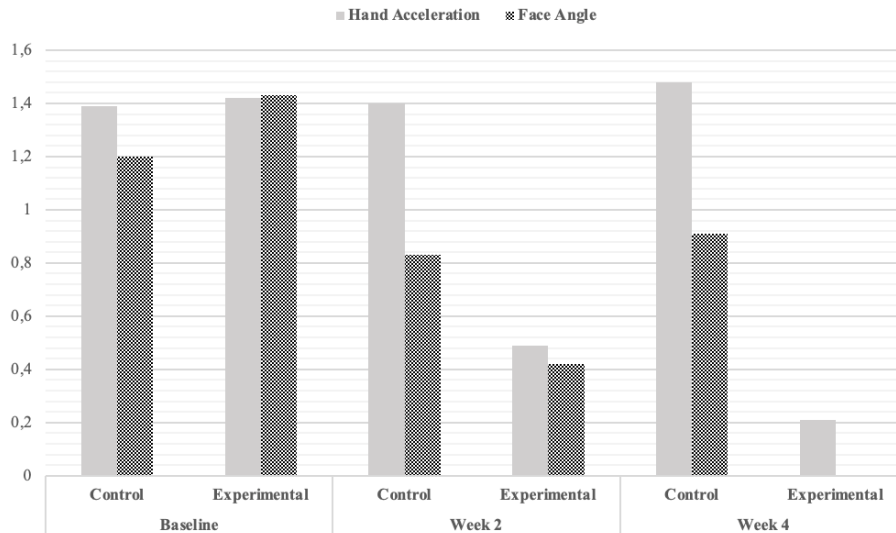


Figure 4: Changes in Hand Acceleration and Putter Face Angle across 4-weeks for Control and Experimental groups

Dicussion

The results of this study demonstrate that reducing forward hand acceleration during the putting stroke leads to a more stable putter-face angle at impact event. The current study expands on this principle by showing that modifying hand acceleration through targeted drills can meaningfully influence face alignment. Similarly, the reduction in hand acceleration observed in the experimental group supports Grober's (2009) resonance model, which suggests that an efficient putting stroke approaches zero acceleration near impact to maintain a

square face. Therefore, the present findings reinforce existing biomechanical evidence while offering new empirical data for amateur and developing golfers.

The mechanisms underlying these improvements can be explained through the kinematic interaction between the hands and putter head. According to Penner (2003), the putting stroke acts as a simplified double-pendulum system in which excessive proximal-segment acceleration (hands and wrists) introduces unwanted torque that disrupts distal-segment control (putter head). The Pincers drill limits finger-driven manipulation by shifting control to the palms, inherently reducing abrupt accelerations. The Lag Putting drill, meanwhile, promotes a smoother tempo and preserves lag between the hands and putter head, preventing premature hand dominance in the downswing. These mechanisms likely contributed to the substantial decrease in hand acceleration (-1.21 m/s^2) and the improved face alignment (reduced to 0°) found in the experimental group. Together, these findings indicate that stroke efficiency is improved when the hands act as stabilizers rather than drivers of the putter head. The study's results are consistent with patterns reported in previous analyses of skilled golfers. Marquardt (2007, 2016) found that elite players typically exhibit low hand acceleration and minimal wrist torque at impact, allowing them to return the putter face to a neutral position with greater consistency. The improvements observed in the experimental group suggest that such advanced biomechanical characteristics can be trained, even among novice or developing players, when drills specifically target hand acceleration control. Notably, eight out of ten participants in the experimental group improved their face angle toward neutral alignment, which supports the idea that structured practice focusing on motor-control parameters can yield measurable performance benefits.

From a practical perspective, these findings offer several implications for golf coaching and skill development. First, integrating drills that directly manage hand acceleration may help instructors address common errors such as overactive hands, excessive grip tension, or late forcing of the stroke - issues frequently observed in amateur players. Second, the drills used in this study require no specialized equipment other than a putter and practice surface, making them accessible and easy to incorporate into regular training. Third, the clear and measurable improvements over a 4-weeks period suggest that instructors can adopt short-term intervention cycles to monitor progress and adjust training loads accordingly. As golf continues to expand in Vietnam, these evidence-based training methods may support the development of more structured and objective instructional programs. Finally, this study adds to the limited body of research on putting biomechanics among amateur golfers in Vietnam. While previous studies have focused on professional or elite players, the present research demonstrates that meaningful biomechanical improvements can be achieved with targeted drills in early-stage learners.

Conclusions

This study examined the influence of hand acceleration on putter face alignment at the moment of ball impact and evaluated the effectiveness of two targeted training drills: the Pincers Drill and the Lag Putting Drill among undergraduate golf major students. The results demonstrated that hand acceleration is a biomechanically meaningful factor influencing putter face angle at impact. After a 4-weeks intervention, the experimental group exhibited a significant reduction in forward hand acceleration accompanied by improved face-angle alignment toward 0° , whereas the control group showed only minimal changes. These findings confirm that excessive forward hand acceleration contributes to unstable face alignment and that targeted training can effectively enhance stroke stability and putting performance in developing golfers.

The theoretical contribution of this work lies in extending existing golf biomechanics literature by empirically establishing the relationship between hand acceleration and putter face angle in developing amateur golfers. While previous studies have predominantly focused on elite or professional populations, this study provides new evidence that hand acceleration is a modifiable biomechanical factor influencing putting performance among amateur players, thereby enhancing current understanding of proximal segment control in the putting stroke. The implications of these results are directly relevant to golf coaching and skill development, as they support the integration of hand acceleration focused drills into putting instruction. The findings suggest that simple, targeted interventions can effectively enhance stroke stability and face angle consistency, offering a practical and accessible approach for improving putting performance in educational and training environments, particularly within emerging golf programs.

To translate this foundational insight into practical application, future research should build upon these findings by incorporating larger sample sizes, longer intervention durations, and additional biomechanical variables such as wrist kinematics, grip pressure, and putter head acceleration. Further investigations across different skill levels and putting distances would also help refine evidence based training frameworks and strengthen the generalizability of hand acceleration focused putting interventions.

Conflicts of interest: The authors declare no conflicts of interest regarding the publication of this study.

Declaration of generative AI and AI-assisted technologies in the writing process

During the preparation of this work the authors used ChatGPT 5.1 (OpenAI) in order to support the refinement of English academic writing, including language polishing, structural editing, and alignment with international journal stylistic conventions. After using this tool/service, the authors reviewed and edited the content as needed and takes full responsibility for the content of the publication.

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