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Abstract

Movement variability has been considered important to execute an effective golf swing yet is comparatively unexplored regarding the golf putt. Movement variability could potentially be important considering the small margins of error between a successful and a missed putt. The aim of this study was to assess whether variability of body segment rotations influence putting performance (ball kinematic measures). Eight golfers (handicap range 0 – 10) performed a 3.2 metre level putt wearing retro-reflective markers which were tracked using a three-dimensional motion analysis system sampling at 120 Hz. Ball roll kinematics were recorded using Quintic Ball Roll launch monitor. Movement (segment) variability was calculated based on a scalene ellipsoid volume concept and correlated with the coefficient of variation of ball kinematics. Statistical analysis showed no significant relationships between segment variability and putting proficiency. One significant relationship was identified between left forearm variability and horizontal launch angle but this did not result in deficits in putting success. Results show that performance variability in the backswing and downswing is not related to putting proficiency or the majority of ball roll measures. Differing strategies may exist where certain golfers may have more fluid movement patterns thereby effectively utilising variability of movement. Therefore, golf instructors should consider movement variability when coaching the golf putt.

Introduction

The putting stroke accounted for 41% of all strokes during tournaments on the Professional Golf Association (PGA) Tour in 2014. [1,2] Additionally putting is a key determinate of earnings on the PGA Tour. [3,4] Recently movement variability has been identified as an important biomechanical principle to research. [5–7] Currently to date research of movement variability in the golf putt is scarce with more research needed in the area to establish its effect on performance. [8] Movement variability has been stated as important for successful performance and technique during the golf swing. [5,9] Considering similar performance goals for golf putting movement variability may also be important for this aspect of golf.

As outlined in dynamical systems theory, movement patterns arise, mature and develop from synergistic organisation of the neuromuscular system adapting to environmental factors exposed to, morphological factors and task constraints. [10] Different movement patterns will develop between individuals with a unique set of different constraints, allowing for different techniques to achieve the same performance outcome. [11,12] With the golf swing being a complex and high velocity technique the existence of an invariant movement pattern is unlikely. [5] Inter and intra-individual differences may also be apparent for the golf putt, due to the smaller margins of error between a successful or missed shot. [13,14] The consensus amongst the literature with the full golf swing in regard to movement variability is to reduce variability at key swing events for successful performance. [9,15,16]

The authors however consider using a time-continuous data set for the calculation of variability preferable to observing variability at specific points. [7] This is because the golf swing or putting stroke is a continuous skill and doesn't occur only at discrete points,

therefore it is more applicable to observe variability across the full movement. When variability across the golf swing from the start of the movement to impact was considered in the full golf swing, no relationship with an outcome measure (initial velocity of the golf ball) was identified. [5] A limitation of the aforementioned study was ball direction or accuracy was not considered a performance measure. Movement variability will likely affect the swing trajectories and club head angle at impact (affecting shot direction) as well as the speed of movement (affecting the ball flight velocity). Club head angle at impact has previously shown variability for the golf swing and golf putt. [13,14,17]

During putting it has been established that factors accounting for direction consistency/variability – putter face angle (80 – 83%), the trajectory of the putter path (17%) and horizontal impact point on the putter face (3%). [14,18] In principle if these task criterion factors remain consistent with a low variability the initial launch angle of the golf ball will remain consistent resulting in more putts that are successful. When considering technique it should matter little as to whether a consistent technique with low variability, or coordinated variability of body movement is utilised to achieve this. Therefore, emphasis always being placed on a low variability movement may be incorrect when considered from a dynamical systems approach and different strategies including variable body movement patterns may be integral to successful putting performance. [5,19]

Movement variability for some may be a key determining factor to the reduction in variance of the task criterion putter face angle at impact and therefore performance. Coaching and golf putting instruction manuals traditionally has focused on encouraging techniques aiming to achieve low variability, where a linear stroke is desired. [18] Scientific literature has however outlined this is biomechanically complicated and difficult with

88 reliance on compensatory muscle activity keeping the putter face square whilst the body

89 rotates. [14] This therefore may not be the best technique for golfers to adopt or coaches to

90 teach.

91 The aim of this study was to assess whether the variability of body segment rotations and

92 putter rotations influence the variance of performance measures (ball roll kinematics:

93 velocity, side spin, initial ball roll, forward rotation, vertical launch angle and horizontal

94 launch angle). It was hypothesised that significant relationships would exist between the

95 variability of body segments and performance measures.

96 **Methods**

97 **Participants**

98 A total of 8 right-handed golfers participated in the study (age 34 ± 11 years; handicap

99 6.0 ± 3.4 (handicap range 0 – 10); height 1.80 ± 0.06 metres; mass 83.4 ± 12.2 kg). All

100 golfers were free of musculoskeletal injury for a minimum period of 3 months and played

101 a minimum of once a week. During testing participants wore their own personal golfing

102 attire and suitable dark, tight fitting non-reflective shorts and short sleeved top. All

103 participants provided written informed consent and the study was approved by the

104 institutional ethics committee of University of Hertfordshire.

105

106 **Experimental set-up**

107 Testing was completed on a Huxley Golf (Huxley Golf., Hampshire, UK) artificial putting

108 green (3.66 x 4.27 metres) registering 11 on the stimpmeter (The United States Golf

Association., Far Hills, NJ, USA). A level, straight 3.2 metre putt was setup thus minimising the effect of green reading and aim with a regulation 108 mm hole. [14,20] Participants used their own personal putter for the protocol. The rationale for this was the participant would be using a putter they were already habituated to. This ensured the body movement kinematics were a true reflection of their technique, whereas a standardised putter not fitted to each of the participants could negatively influence this. The golf ball for the protocol were Srixon Z-STAR (Srixon Sports Europe LTD., Hampshire, UK) and each trial completed used the same ball. Body movement kinematics were recorded using a ten camera motion analysis system (Motion Analysis Corporation., Santa Rosa, CA, USA) sampling at 120 Hz.

Retro-reflective markers were attached to participants in accordance with a modified whole body Helen Hayes marker set (total 31 markers; 14 mm) at the following anatomical locations: top of head, front of head, rear head, acromion process (left and right), lateral epicondyle of humerus (left and right), styloid process of the radius (left and right), on the forearm intersecting the humeral epicondyle and styloid process of the radius (left and right), anterior superior iliac spine (left and right), the sacrum, the thigh (intersecting the plane between the hip and knee markers (left and right)), lateral aspect of the joint centre of the knee (left and right), the shank (intersecting the plane between the knee and ankle markers (left and right)), the lateral malleolus (left and right), the posterior aspect of the calcaneus (left and right) and the third metatarsal (left and right). Markers were placed directly on the skin using double sided tape, except the acromion process (pair of), anterior superior iliac spine (pair of), sacrum, calcaneus (pair of) and third metatarsal (pair of) which were placed on skin tight 'under-armour' clothing or shoes ensuring minimal

132 movement of markers relative to underlying body landmarks. Additionally, a marker was

133 placed on the left scapula for asymmetry and medial aspects of the knee (left and right)

134 and medial malleolus (left and right) so the joint centres of the knee and ankle could be

135 calculated.

136 Two retro-reflective markers were placed on the superior aspect of the putter face to

137 calculate putter face angle at impact and throughout the putting stroke. A retro-reflective

138 marker was also placed on the putting line. The capture volume was calibrated according

139 to manufacturer's guidelines, resulting in an average residual for all cameras of < 0.2 mm.

140 The motion analysis system was calibrated where the positive movement along the X-

141 axis was defined as movement towards the target (golf hole); positive movement along

142 the Y-axis was defined as movement anteriorly perpendicular to the target; and the Z-axis

143 perpendicular to the X, Y plane.

144 To record the ball roll kinematics, a Quintic (Quintic Consultancy Ltd., Coventry, UK) high

145 speed camera (UI-5220RE) sampling at 220 Hz was positioned perpendicular to the

146 putting line. The Quintic v2.4 launch monitor software was used to analyse the recorded

147 ball roll. Kinematic variables analysed were initial velocity (m·s^{-1}, calculated across the

148 first 6 recorded frames), side spin (the amount of side spin (rpm) placed on the ball during

149 impact), vertical (whether the ball was launched in the air) and horizontal (the degree to

150 which the ball deviates from the original putting line) launch angle (^{0}), initial ball roll

151 (whether the ball has positive rotation (topspin) or negative rotation (backspin) at the point

152 of impact (rpm)) and forward roll (the distance at which the ball starts positive rotation

153 (cm)). For a trial to be considered valid, the initial ball velocity had to be between 2.10 –

154 2.28 m·s^{-1}. This was to eliminate participants' preference of either putting to hole the ball

155 successfully at very low or high velocities which could alter movement variability

156 observed. Putts that did not meet the initial ball velocity requirements were eliminated

157 from analysis. Despite this only one putt was eliminated from analysis.

158

159 **Procedure**

160 Participants were allowed up to ten minutes to habituate themselves to the golf putt, to

161 ensure that the markers did not inhibit or alter their technique. Within the ten minute

162 habituation period, the investigator instructed the participant as to the velocity required

163 for a putt to be categorised successful. Once the participant was comfortable and ready

164 to proceed, they lined up the golf putt and approached the putt. The 3D motion analysis

165 system recorded the trial and the outcome of the putt was recorded (successful or

166 missed). This process was completed until 10 successful putts had been completed with

167 time between each trial for the participant to reline up the putt. All putts (successful and

168 unsuccessful) were included for analysis.

169

170 **Data Processing**

171 Three-dimensional coordinate data were processed using Cortex (Motion Analysis

172 Corportation; Santa Rosa, CA, USA) software with an Euler sequence of X, Y, Z. The 3D

173 coordinate data were filtered using a fourth-order low pass Butterworth filter, consistent

174 with previously published literature. [16,21,22] Cut off frequency was determined using

175 residual analysis with an r^2 threshold of 0.85. [23] Cut off frequencies used for the markers

176 ranged from 6 – 8 Hz. Due to intra and inter subject differences in the duration of trials,

177 3D segmental coordinates and putter rotations were time-normalised to 101 data points

178 using a cubic spline algorithm. The section of the golf putt that was normalised was from

179 the first movement during the putt backswing until the point of impact with the golf ball,

180 the follow-through was not used for analysis. This allowed for accurate means and

181 variation to be calculated. Following this, kinematic data were processed into segments.

182 Performance variability was calculated for all body segments as outlined previously within

183 golf literature. [5] Rotations were normalised to the position at address one frame before

184 the trial started.   Following this normalisation process, the standard deviation was

185 calculated for the 101 data points for all the trials of each participant's X, Y and Z

186 coordinates. These were then combined via multiplication to have a single number

187 represent the 3D rotational variability. [5,24] The equation below was used to calculate a

188 scalene ellipsoid for each participant representing the 3D variability of the rotations for

189 the 101 data points. [5] This was then averaged to give a mean variability volume

190 (degrees^3):

191
$$VV = \frac{\sum_{n=1}^{101} \frac{4}{3}\pi(sd_{xi} \cdot sd_{yi} \cdot sd_{zi})}{101}$$

192 where VV is the mean variability for each segments rotation, [sd_{xi}, sd_{yi}, sd_{zi}] are the

193 standard deviations for all planes of movement at point *i*. When interpreting the mean

194 variability score (VV), it was important to consider the range of rotation for each of the

195 segments. Therefore, the mean variability score was standardised to the 3D rotations.

196 The calculation used to calculate the average 3D distance over the trials (degrees) were:

197
$$PD = (\sum_{i=1}^{101} \sqrt{(x_{i+1} - x_i)^2 + (y_{i+1} - y_i)^2 + (z_{i+1} - z_i)^2})$$

198   where PD is the performance distance of each segment, $[x_i, y_i, z_i]$ and $[x_{i+1}, y_{i+1}, z_{i+1}]$ are

199   the positions at a point *i* during the trial and point *i*+1. This was adapted from previous

200   literature that has calculated movement variability. [5] Performance variability was defined

201   as the mean variability volume divided by the performance distance:

$$PV = \frac{VV}{PD}$$

202

203   where PV is termed the performance variability. [5] This provided a volume per distance

204   measure (degrees^3/degrees). The only segment that was analysed in a different fashion

205   was the putter segment where only Z rotations were recorded, therefore the standard

206   deviations were totalled and normalised by the Z rotations displacement.

207

Data Analysis

208

209   Segmental rotations (°) (X, Y and Z) were formulated for the pelvis, torso, left and right

210   upper arm and left and right lower arm. These segments were selected as they have

211   previously been analysed and are thought to contribute to the impulse being imparted on

212   the ball during the putt. [18,25,26] Ball kinematic variables measured were: velocity (velocity

213   (m/s) of the ball during the first 6 frames captured), side spin (cut or hook (the amount of

214   side spin (rpm) placed on the ball during impact)), initial ball roll (whether the golf ball had

215   positive rotation (topspin) or negative rotation (backspin) at the point of impact), forward

216   roll (the distance at which the ball is rolling in a positive direction), vertical launch angle

217   (the launch angle at the point of impact on the vertical axis) and the horizontal launch

218   angle (the launch angle at the point of impact on the horizontal axis). Associations

219   between performance variability for body segment rotation and outcome variability (ball

220   kinematic variables) were calculated and outcome variability was tested as a coefficient

221   of variation (%). [5]

222

223   Data were exported to the statistical software package SPSS v23 (SPSS Inc, Chicago,

224   USA) for analysis. The data were analysed for normality using a Shapiro-Wilk test of

225   normality and assessment of kurtosis and skewness values. The data were found to be

226   non-parametric and therefore a Spearman's rank correlation coefficient test was carried

227   out. The boundaries set for the coefficient statistics were; $r = 0.8 - 1.0$, very strong, $r =$

228    $0.6 - 0.8$, strong, $r = 0.4 - 0.6$, moderate, $r = 0.2 - 0.4$, weak, $r = 0.0 - 0.2$, no relationship.

229   Level of significance was set at $\alpha < 0.05$.

230   **Results**

231   Individual performance variability for the segment rotations are presented in Figure 1. A

232   range of variability was observed, the largest being 0.74 degrees^3/degrees for participant

233   one. Participant eight demonstrated virtually no segment variability suggesting a very

234   consistent movement pattern.

235

236   FIGURE ONE ABOUT HERE

237

238   Putter variation, variation of putter face angle at address and putting proficiency are

239   presented in Table 1. Participant eight displayed the best putting proficiency (83%) this

240   was coupled with one of the lower performance variability scores for the putter (0.17

241 degrees^3/degrees). A range of correlations were observed between segment variability,

242 putter face angle at address and putting proficiency (putter and putting proficiency; no

243 association, left forearm and putting proficiency; moderate association, right upper arm

244 and putting proficiency; strong association). However, all correlations were identified all

245 to be non-significant (Table 2).

246

247 TABLE 1 & 2 ABOUT HERE

248

249 Mean ball roll kinematic results are presented in Table 3 and correlation coefficients

250 between performance measurement variability (ball roll kinematics) and segment rotation

251 variability in Table 4. One significant correlation was identified between segment

252 variability of the left forearm and variability of the horizontal launch angle of the golf ball

253 (r = .92 (very strong association), p < .01). Additionally, near significant positive

254 relationship was identified for the variability of the pelvis and horizontal launch angle (r =

255 .65 (strong association), p = .08).

256

257 TABLE 3 & 4 ABOUT HERE

258

259 **Discussion**

260 This is one of the first studies to have considered body segment variability during the golf

261 putting stroke. It was hypothesised that significant relationships would exist between the

262 variability of body segments and variability of performance measures. This hypothesis

263 can predominantly be rejected with no significant relationships identified between

264 segment variability and putting proficiency and only one significant correlation identified

265 between the variability of the horizontal launch angle and variability of the left forearm

266 segment.

267 Within golf to date variability has only been considered for the full golf swing. [5,9,15,16]

268 Despite this, the desired outcome for the putt is very similar to the full swing; a shot that

269 is accurate with the correct amount of power applied. Therefore, to obtain this sought

270 after outcome, theoretically, a movement system must be a balance of stable (persistent)

271 and flexible motor outputs, allowing the golfer to adapt to the requirements of the shot.

272 [11,15] It was also found no relation between performance variability and ball velocity

273 variability, concluding that individual players use their own strategies to control

274 performance variability so it did not affect outcome variability. [5] The results of the current

275 study suggest this is also evident for the golf putt. With no significant correlations identified

276 between variability of segments and putting proficiency suggest some golfers within the

277 current study utilised or controlled performance variability to minimise output variability.

278 Therefore, less variability isn't necessarily desirable for all golfers, with some golfers able

279 to still putt successfully despite demonstrating more variability than others. For example

280 participant one showed the second largest variability of the left forearm and largest

281 variability of the pelvis (Figure 1) and had a 73% success rate. Whereas, in comparison

282 participant seven demonstrated less segment variability and had a 67% rate, less than

283 that of participant one and participant three who demonstrated low performance variability

284 and was the worst performing golfer (52%). The most successful golfer (83%) participant

285 eight demonstrated virtually no movement variability, emphasising the individual
286 approaches observed in the current study.

287 It has been reported that a reduction in the variability of the hand trajectory from mid-
288 downswing to impact improved performance for the full golf swing. [16] This however
289 contrasting evidence exists with increased variability observed during the downswing
290 phase. [5] Results from the current study (analysed to impact) shows that segment
291 variability of the left forearm increased the variability of the horizontal launch angle with a
292 very strong relationship observed (Table 4). This suggests that players that demonstrate
293 less variability will see better performances, as in the ball starts travel in the intended
294 direction. However, this did not translate to a positive relationship in variability of the left
295 forearm and putting proficiency with a non-significant moderate association observed. A
296 potential explanation for this may be the additional variability observed at address (0.48
297 – 1.77 degrees, Table 1). Previously, the putter face angle has been deemed to be
298 essential regarding the initial direction of the golf putt. [13,14,18] Across the studies a range
299 of 80-95% of the starting direction (horizontal launch angle) of a putt was accredited to
300 putter face angle. [13,14,18] It may be the case variability of the putter face angle may
301 accommodate some variability of the angle at address. Demonstrating that performance
302 variability may not be detrimental to performance, whereby a different combination of
303 rotations result in a square putter face at impact is equally as desirable as minimal
304 variability. Another factor that could have influenced results were the range of initial ball
305 velocity range the participants were instructed to follow. However, no participants
306 mentioned this as an issue or factor they considered when completing the protocol.

307   Previously it has been observed greater movement variability of the pelvis and trunk in

308   less proficient golfers (< 79% success rate) in comparison to more proficient golfers (>

309   79% success rate). [25] The current study's results are in contrast to this. Golfers in the

310   current study demonstrated a consistent variability of the pelvis (0.01 – 0.74

311   degrees^3/degrees) and trunk (0.00 – 0.09 degrees^3/degrees). This includes participant

312   one who demonstrated increased variability of the pelvis in comparison to the other

313   participants and was not the worst performing golfer (Figure 1). Additionally, no significant

314   correlations were observed for performance variability of the pelvis (r = -.44; moderate

315   association) and trunk (r = -.38; weak association) with putting success rate (Table 2).

316   Differences between the two studies may be due to the analysis techniques, whereby

317   individual putting events during the stroke were assessed whereas the current study

318   totalled variation for all three planes and normalised the data by the rotational

319   displacement of each segment. It also may be due to the large intra and inter-subject

320   variability observed in both this study and the previous article that differences actually

321   existed between each study. [25]

322   It is proposed by the authors of the current study that different styles of putting may be

323   employed by golfers. Whereby some utilise more stable motor outputs (participant eight)

324   whereas others utilise more flexible motor outputs (participant one). More research into

325   movement variability and putting is needed to confirm this however. This study

326   additionally provides support for previous biomechanical literature that it is beneficial for

327   individual based analysis within biomechanical golf analysis. [5,27] Future research needs

328   to test a larger number of highly skilled participants to determine whether different styles

329   of putting exist when considering movement variability. Based on the results of the current

330 study the practical implications of the study are golf coaches should aim to ascertain

331 whether the golfer utilises movement variability or has a consistent movement pattern and

332 refine their current technique. It may not be beneficial to teach a new consistent putting

333 style.

334 **Conclusion**

335 This is the one of the first studies to have considered movement variability effect on

336 performance measures in the golf putt. It was established that there was no relationship

337 between putting proficiency and performance (segment) variability. One significant

338 relationship was observed between left forearm variability and the horizontal launch angle

339 of the ball but this was not a detriment to performance, this may have been because of

340 the variability of the putter face angle at initial setup. Considering the statistically non-

341 significant results it is postulated that different styles of golf putting may exist; one

342 whereby more stable motor outputs are utilised and secondly where more flexible motor

343 outputs are adopted. We emphasise the need to include individual based analysis in

344 future biomechanical golf studies. Golf coaches should aim to determine whether

345 movement variability is being utilised where output variability is not affected resulting in

346 equally effective performance as a golfer who demonstrates a highly consistent

347 movement pattern.

348

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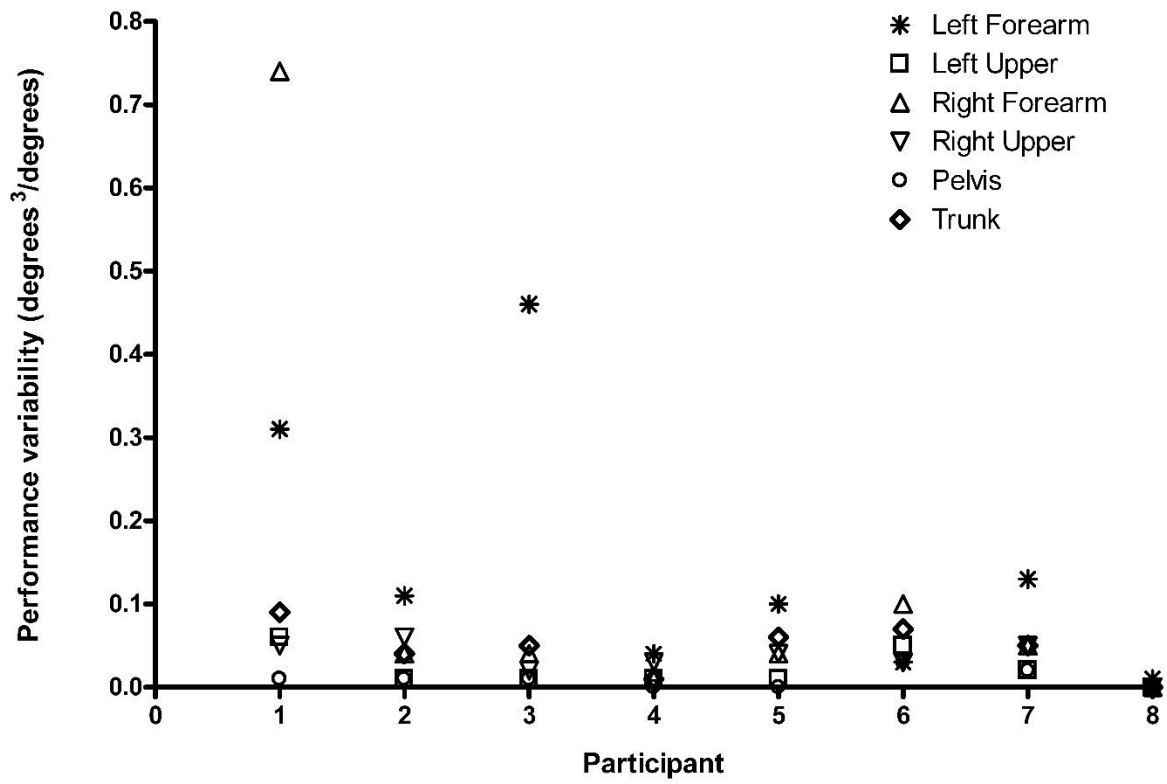
Figure 1. Scatterplot of performance variability scores for the segment rotations during

the putting stroke

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Table 1. Performance variability scores for the putter Z rotations during the putting stroke and the putter face angle at address.

Participant	Playing Handicap	Performance variability (degrees)	Variability of face angle at address (degrees)	Putting Proficiency (Success Rate %)
1	8	0.35	0.75	73
2	10	0.29	0.73	75
3	5	0.18	0.67	52
4	10	0.15	0.48	71
5	6	0.20	1.77	76
6	0	0.26	0.54	59
7	6	0.24	0.70	67
8	3	0.17	0.66	83

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435 Table 2. Correlation coefficients (r (p)) between putting proficiency and segment rotation

436 variability.

	Segment Variability							
	Left Forearm	Right Forearm	Left Upper Arm	Right Upper Arm	Pelvis	Trunk	Putter	Putter Face Angle
Putting Proficiency	-.56 (.15)	.02 (.97)	-.27 (.52)	-.61 (.11)	-.44 (.28)	-.38 (.35)	.03 (.94)	.30 (.46)

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438   Table 3. Ball roll kinematic variables for all participants (mean ± SD).

Participant	Velocity (m·s^{-1})	Spin (Cut (+), Hook (-), rpm)	Initial Ball Roll (rpm)	Forward Rotation (cm)	Vertical Launch Angle (°)	Horizontal Launch Angle (°)
Average	2.22 ± 0.09	1 ± 18	18 ± 39	3.0 ± 3.3	4.0 ± 2.1	1.0 ± 1.4
1	2.28 ± 0.09	19 ± 17	65 ± 14	0.0 ± 0.1	2.0 ± 1.1	1.9 ± 1.7
2	2.11 ± 0.09	-20 ± 11	10 ± 17	1.9 ± 2.3	4.3 ± 0.6	0.2 ± 0.7
3	2.08 ± 0.11	34 ± 10	38 ± 12	0.1 ± 0.2	3.1 ± 0.6	-1.3 ± 0.9
4	2.20 ± 0.15	-5 ± 11	-17 ± 14	5.2 ± 2.5	7.1 ± 3.0	2.9 ± 1.0
5	2.33 ± 0.13	4 ± 18	75 ± 17	0.0 ± 0.1	0.8 ± 0.5	0.6 ± 1.1
6	2.22 ± 0.08	-13 ± 8	-31 ± 10	9.0 ± 1.8	5.6 ± 0.8	1.4 ± 1.2
7	2.27 ± 0.16	-6 ± 17	16 ± 11	2.2 ± 2.8	3.5 ± 0.7	0.1 ± 1.1
8	2.26 ± 0.07	-4 ± 11	-16 ± 11	5.4 ± 4.5	5.5 ± 0.9	2.3 ± 1.2

439   Key: Cut Spin refers to clockwise rotation and Hook Spin anti-clockwise rotation; a positive Vertical Launch Angle refers the

440   the trajectory of the ball in the Z axis; a negative Horizontal Launch Angle refers to the trajectory of the ball moving left of

441 the intended target line and a positive Horizontal Launch Angle refers to the trajectory of the ball moving right of the intended

442 target line.

443 Table 4. Correlation coefficients *(r (p))* between performance measures variability and segment rotation variability.

	Left Forearm	Right Forearm	Left Upper Arm	Right Upper Arm	Pelvis	Trunk	Putter (Z rotations)
Velocity	.03 (.95)	.29 (.48)	-.31 (.45)	-.13 (.77)	-.02 (.95)	-.16 (.71)	-.38 (.35)
Side Spin	-.45 (.26)	.69 (.06)	-.17 (.70)	-.01 (.98)	.10 (.82)	.01 (.98)	.33 (.42)
Initial Ball Roll	-.45 (.27)	-.04 (.93)	-.51 (.20)	.01 (.99)	-.42 (.31)	-.65 (.08)	-.16 (.70)
Forward Roll	-.54 (.17)	.00 (1.0)	-.48 (.23)	-.05 (.91)	-.32 (.44)	-.68 (.06)	-.20 (.63)
Vertical Launch Angle	.111 (.79)	.23 (.58)	.23 (.59)	-.48 (.22)	.07 (.86)	.34 (.41)	.10 (.82)
Horizontal Launch Angle	.92 (<.01)*	-.09 (.83)	.11 (.79)	.16 (.70)	.65 (.08)	.42 (.30)	-.10 (.98)

444 (Significant relationship *, $p < .05$).

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