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Which Specific Golf Skills Are Related to Performance in Skilled Junior Golfers?

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Golf performance relies on success at several different skills. However, no previous studies have investigated multiple skills with a single research sample to discriminate key performance determinants. Furthermore, such research is limited concerning junior performances, which is an important phase in the transfer to the professional level. The aims of the study were to evaluate performance in a golf skills test battery, to identify any significant determinants of junior golfers' handicaps and to analyse the strength of associations between these skills. Sixteen skilled junior golfers performed golf skills tests that assessed putting to driving skills. Significant determinants of handicap were found for short shots from the bunker, short and long approach shots, driving accuracy and Combine test. Data imply that junior players should focus on shot accuracy for the fastest performance achievement, especially in short approach shots. However, for long-term performance development, it is important that driving and putting skills are developed to enable successful transition to cope with professional tournament demands.

Introduction

Golf performance is determined by several discrete motor skills classified by shots such as putting, short shots around the green, short and long approach shots and drives from the tee. The goal is to achieve accurate (but sometimes *maximum*) distance and direction of the ball flight to hit as close as possible to the target and subsequently execute the fewest number of shots (Brožka et al., 2022). However, there are differences between skills regarding their relative importance for distance and direction due to the typical target sizes, surface conditions and surrounding hazards. Specifically, distance is more important when executing the drive shot, while approach shots rely more evenly on distance *and* direction to achieve success (Pelz, 1999). During player development, understanding the performance status and interrelationship between these skills is important to inform coach and player decision making regarding training behaviour (e.g., training balance and subsequent training structure). As such, the assessment and interpretation of skills test data require critical consideration within performance-focused settings (Grecic et al., 2017).

Whilst players' skills can be assessed during tournament play, recent evidence suggests that elite players are more independent from their coaches during these situations (Orr et al., 2021) and are often assessed during training conditions. Advances in ball-tracking technology also makes assessment more objective in these contexts and have become a common tool for coaches and players alike. Within the professional setting, however, broadcasters and the Tour organisation collate tournament statistics used to assess performance variables such as driving distance, driving accuracy, greens in regulation, putts per green, putts per green in regulation, sand saves and many others

(Alexander, 2005; Baugher et al., 2016; Brožka et al., 2022; Moy & Liaw, 1998; Quinn, 2006; Wiseman & Chatterjee, 2006). Indeed, these can be used to identify the key skills leading to success, failure, ranking and/or financial earnings at this most elite level. Nevertheless, some tournament statistics mentioned above do not describe a specific skill. Instead, they reflect the outcome of many combined skills of the player (e.g., greens in regulation, which is a measure of both the ability to hit drives and approach shots), including perceptual, cognitive and executional processes. Therefore, a more specific assessment of individual shot ability would be useful to inform the design of training behaviours in golfers.

In modern times, more nuanced game indicators have been developed which account for lie of the ball (rough, fairway, sand) and starting distance from the ball to the hole (Broadie, 2012; Fearing et al., 2010; James & Rees, 2008; Ketzscher & Ringrose, 2002; Stöckl et al., 2012). Broadie (2012) developed the 'Strokes Gained' indicator, which is now used by the Professional Golfers Association Tour (PGA Tour), because it compares a player's performance to the rest of the field and can isolate individual aspects of the game. Notably, this indicator shows the relative importance of putting and short game shots to have decreased in the professional game in the last 10 years. Driving distance replaced putting as the primary skill in determining earnings on the PGA Tour in 2011 (Baugher et al., 2016). However, in the years 2000–2010, there was still a statistically significant and moderate relationship between putting average and scoring average (Quinn, 2006: $r = 0.63$, $p < 0.05$; Wiseman & Chatterjee, 2006: $r = 0.68$, $p < 0.05$) and between putts per green in regulation and PGA Tour players season earnings (Alexander, 2005). Also, short approach shots (< 90 m) were an important determinant of performance (James & Rees, 2008; Pelz, 1999) and greens in regulation correlated with scoring average (Quinn, 2006: $r = -0.62$). Between the years 2010–2020, however, long approach shots and driving distance were *more* important than putting and short shots around the green (Baugher et al., 2016). Results suggest that long game accounts for 73% of the variation in total strokes gained compared to short shots (11%) and putting (17%; Broadie, 2012). As such, these statistics reveal how the professional game has evolved in terms of the demand on different skills.

Research examining amateur golfers has analysed golf skills such as: putting (Carnahan, 2002; Gryc et al., 2017, 2021; Karlsen et al., 2008; Robertson et al., 2015), short shots around the green (e.g., chip and pitch shots; Brožka et al., 2021; Ma'mun & Abdullah, 2018; Pelz, 1999) and approach shots (Robertson et al., 2013). However, there is a need to extend this research by investigating a variety of golf skills in junior golfers. Such a study would be able to identify the performance determinants and key attributes that more skillful amateurs possess in relation to PGA Tour demands. In this way, coaches may be informed about potential strategies for faster improvements in their players (i.e., working to strengthen the most important skills), but also what may be required when considering transitions to the professional ranks (i.e., addressing any skill discrepancies). While we appreciate that performance analysis is not *the only* answer when it comes to informing a coach's decision making[1] (of course golf performance and development is complex and multifactorial, before even accounting for different perspectives within disciplines and theories), it is important at the very least to gain a better understanding about the nature of the game and skill demands for different categories of players.

Many studies have investigated golf performance based on tournament statistics, performance in skill tests, measurement of strength abilities and their relationships to performance in adult amateur and professional players (e.g., Broadie, 2012; James, 2007; Sell et al., 2007). By contrast, only a small number of studies have investigated those performance indicators in junior players aged between 14–18 years (Coughlan et al., 2018, 2020; Gryc et al., 2020; Majzub & Muhammad, 2011). In addition to understanding the most important skills at this junior level, investigating multiple skills within-participants has the potential to explain any transfer effects from one skill to another in order to optimise training gains. For example, in gymnastics, the forward roll skill positively transfers to the somersault skill so, practicing the former will help to improve or maintain the latter (Müssgens & Ullén, 2015). Consequently, the aims of the study were to evaluate performance in a golf skills test battery, to identify any significant determinants of handicap in junior golfers and to analyse the strength of associations between these skills.

Methods

Participants

A convenience sample of 16 skilled male junior golfers (M_{age} = 15.6 ± 1.2 years; M_{height} = 175.2 ± 10.6 cm; M_{mass} = 67.5 ± 13.6 kg; $M_{handicap}$ = 5.1 ± 5.5; $M_{playing\ experience}$ = 8.1 ± 2.4 years; $M_{training\ per\ week}$ = 15.8 ± 8.1 hrs) volunteered to take part in this study. Skill status was defined as playing at the highest level of competition for a given age category (i.e., National Championship for boys and cadets). The research was approved by the University's ethics committee and conducted in accordance with the ethical standards of the Helsinki Declaration and Research in the Field of Sports Sciences (Harriss & Atkinson, 2015). Research participants and their legal guardians provided signed informed consent before the start of the study.

Procedure

A field test battery was designed to evaluate the performance of several golf skills: putting (short putt success and long putt accuracy), short green-side shots (accuracy of shots from the fairway and bunker), approach shots (accuracy of short and long approach shots) and driving performance (driving accuracy and total distance). To achieve consistent conditions, testing took place across two consecutive days and following a self-directed warm-up: putts

1 Coaches should consider performer development from an interdisciplinary perspective (e.g., fitness, psychology, environment) to best understand the interaction between variables and shot execution (see Carson & Collins, 2017).

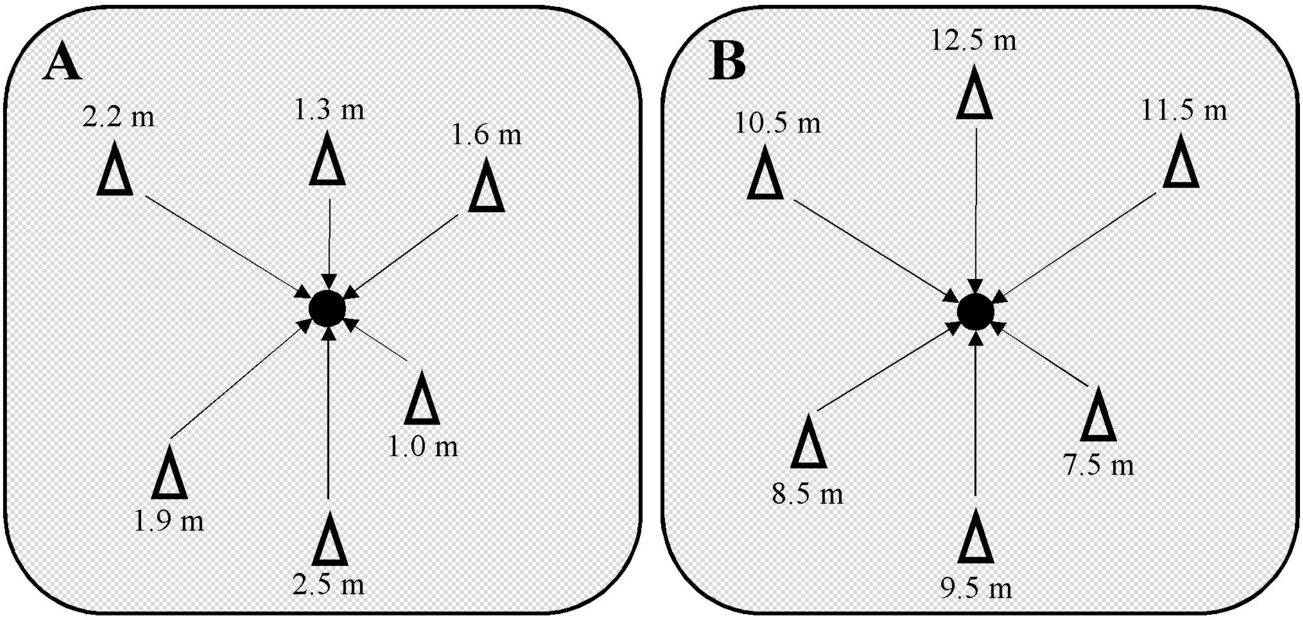

Figure 1. Schematic showing the layout of the short putts test (A) and long putts test (B).

and short shots on Day 1, with approach shots and drives on Day 2. A putting green speed of 10 ft. was measured on the Stimp metre, which is considered Championship standard (Moffat et al., 2018).

Putts were made to two separate holes, one hole consisted of six distances for short putts (1.0 m, 1.3 m, 1.6 m, 1.9 m, 2.2 m and 2.5 m) and the other consisted of six distances for long putts (7.5 m, 8.5 m, 9.5 m, 10.5 m, 11.5 m and 12.5 m) as shown in the Figure 1. Each putt was performed from a different position around each of the holes, which was consistent across all participants. For both putting tests, players performed three cycles of one putt from each distance in order from shortest to longest putt (i.e., 18 short and 18 long putts). Short putt success was evaluated by the percentage of putts made, whilst long putt accuracy was evaluated manually by radial error (i.e., the distance between the middle of the ball and the middle of the hole; Couceiro et al., 2012).

For short fairway shots around the green, the hole was located 7 m from the edge of the green and performed from five distances (7.5 m, 12.5 m, 17.5 m, 22.5 m and 27.5 m). For bunker shots, the hole was 6–8 m from the edge of the green depending on the hitting angle and performed from three positions 15 m, 20 m and 25 m as shown in the Figure 2A. Stroke order from different distances was randomised and then repeated, resulting in a total of 10 fairway shots and six bunker shots (i.e., two shots from each distance). As per the long putting test, radial error for each shot was recorded manually (Couceiro et al., 2012).

Short approach shots, long approach shots and driving accuracy were obtained by administering the 'Combine test' developed by Trackman Golf (TrackMan, Denmark) and its validity was verified by Robertson et al. (2013). Specifically, players perform three strokes to each target (55 m, 65 m, 75 m, 85 m, 95 m, 105 m, 125 m, 145 m, 165 m and driver stroke) and this was repeated twice (total of 60 strokes) as shown in Figure 2B. Distances from 55–95 m were

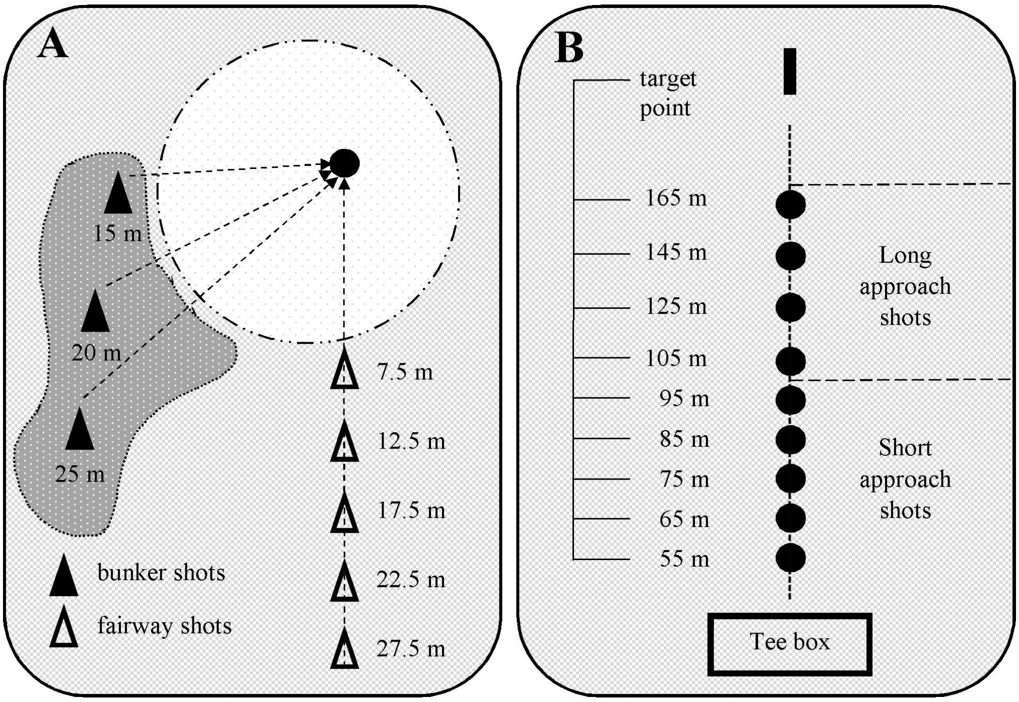

Figure 2. Schematic showing short shots test from fairway and bunker (A) and the Combine test (B).

considered as short approach shots because players used less than full swings. Distances 105–165 m were considered as long approach shots because players used full swings with irons (James & Rees, 2008). Shot accuracy was evaluated using radial error. Drive performance was evaluated by both accuracy (resting ball lateral error from target line) and distance (i.e., total distance). Combine test overall accuracy was evaluated by mean radial error for each stroke for all distances and by side deviation from the target line for drives. The 3D Doppler Radar Trackman 4 (Trackman, Denmark) was used to record all performance data. The device (the reliability was verified in a study by Leach et al., 2017) was setup and calibrated to a single flag on the driving range (over 165 m) which served as the target line for all shots (i.e., participants did not hit onto a green for each shot).

The players' performance level was evaluated by handicap; a lower handicap means higher performance level (Bradshaw et al., 2009). For our purposes, the best players with a plus-handicap (i.e. over zero) were classified as having a negative handicap. The chronological age of participants was used as a mediation effect variable to assess the influence of age on performance.

Statistical Analysis

Descriptive statistics were calculated for all golf skills tests, age and handicap. Normal distribution of each parameter was verified by Shapiro-Wilk tests. Most of the data were normally distributed and therefore parametric variants of the tests were used. Relationships between the golf skills was examined using Pearson product-moment correlation coefficient (r) and interpreted as: negligible (0.00–0.10), weak (0.10–0.39), moderate (0.40–0.69), strong (0.70–0.89) and very strong (0.90–1.0; see Schober et al., 2018). Simple linear regression analysis was used to identify potential determinants of players' handicap. Multivariate regression analysis was used to control for the age of participants. The p-value was set at $\alpha = 0.05$ in all the statistical analyses. Microsoft Excel (Redmond, WA, USA) and the statistical software R v3.5.2 (Vienna, Austria) were used for statistical analyses.

Results

Descriptive statistics and correlations between each golf skill are shown in Table 1. A significant and very strong positive relationship ($r = 0.91$; $p < 0.001$) was found between short shots from the bunker and short approach shots. Short shots from the bunker and long approach shots were found to have a significant and strong positive relationship ($r = 0.73$; $p = 0.001$). Short approach shots and long approach shots also had a significant and strong positive relationship ($r = 0.73$; $p = 0.001$). Long approach shots and driving distance were significantly correlated but this was only moderate and negative in direction ($r = -0.56$; $p = 0.023$); in other words, players that were longer from the tee were also more accurate when executing the long approach shots.

A significant strong positive relationship was found between the Combine test and short shots from the bunker ($r = 0.84$; $p < 0.001$). Also, a significant moderate negative relationship was found between the Combine test and driving distance ($r = -0.53$; $p = 0.035$). Furthermore, the Combine test significantly correlated to long approach shots (very strong positive relationship; $r = 0.98$; $p < 0.001$), to short approach shots (strong positive relationship; $r = 0.81$; $p < 0.001$) and to driving accuracy (moderate positive relationship; $r = 0.51$; $p = 0.045$). However, the Combine test is composed of different skills so these significant relationships are assumed.

A strong significant negative relationship was found between age and handicap (i.e., handicap; B = −2.99; Stand. B = −0.64; $p = 0.008$; $R^2 = 0.41$). Regression analyses predicting players' performance based on tests results and age are shown in Table 2 and pictorially in Figure 3. Significant predictors of handicap (both unadjusted and adjusted for age) were only found for individual tests for short shots from bunker, short approach shots, long approach shots, driving accuracy and Combine test. From the multiple linear regression analysis, short shots from the bunker explained 53% of the variance, which increased to 66% when also including age into the model. Short approach shots explained 51% of the variance, which increased to 61% when age was accounted for. Fifty percent of the variance was explained by long approach shots, increasing to 58% when age was included. Driving accuracy explained 34% of the variance, which increased to 58% when age was accounted for. Sixty-three percent of the variance was explained by Combine test, which increased to 67% when adjusted for age.

Discussion

The aims of this study were to evaluate performance in a golf skills test battery, to identify significant determinants of skilled junior golf performance and to analyse the strength of associations between these skills. In summary, data suggest that putting, short shots from the fairway and driving distance are

Table 1. Performance of junior golf players in golf skill tests and correlations between each golf skill

	Golf skill	(Mean ± SD)	1	2	3	4	5	6	7	8
1	Short putts success (%)	61.11 ± 13.18	1							
2	Long putts accuracy (m)	0.79 ± 0.21	−0.39	1						
3	Short shots from fairway accuracy (m)	2.51 ± 0.98	−0.40	−0.01	1					
4	Short shots from bunker accuracy (m)	4.44 ± 2.41	−0.01	0.08	−0.29	1				
5	Short approach shots accuracy (m)	5.58 ± 1.34	0.04	−0.05	−0.31	**0.91***	1			
6	Long approach shots accuracy (m)	12.04 ± 5.30	0.18	0.04	−0.43	**0.73***	**0.73***	1		
7	Driving accuracy (m)	16.43 ± 5.06	0.19	0.46	−0.03	0.46	0.23	0.38	1	
8	Driving distance (m)	225.69 ± 22.20	−0.26	0.22	0.30	−0.46	−0.45	**−0.56***	−0.05	1
9	Combine test accuracy (m)	9.25 ± 2.87	0.18	0.10	−0.40	**0.84***	**0.81***	**0.98***	**0.51***	**−0.53***

not related to this stage and level of performance. In light of these findings, we put forward several possible explanations that should be considered within the coaching context and to advance our understanding of what could be quite surprising data. Firstly, it is possible that the demands from golf course conditions at the junior level do not put pressure on these skills to make them meaningfully important beyond a certain level of performance. In other words, it is not until the golf course, or test battery, demands greater precision that skill differences are revealed. For example, driving the golf ball a long distance on a course that is not demanding on length off the tee might actually cause a player greater difficulty due to a higher demand for accuracy at long driving distances; therefore, players might not train with their driver so often or they might focus on their accuracy rather than distance, which could explain why driving distance was not a significant determinant of handicap, but accuracy was. Equally, for the long putt distances tested in this study, finishing 80 cm or 30 cm to the hole makes no handicap difference since both lead to a 2-putt performance. Putting on greens with extreme slopes and/or from further distances might again reveal such differences. An alternative, and potentially additional, explanation is that junior coaches tend to emphasise these skills during training and they are practiced equally across these golfers. Indeed, except for short shots from the fairway (39%), results of non-significant skills showed the lowest coefficient of variation scores (short putting: 22%; long putting: 27%; driving distance: 10%; cf. bunker shots: 54%; long approach shots: 44%), which suggests that players are most consistent in these skills and hence, a relationship with performance was not found. This greater consistency may even result from 'standardised' training protocols such as hitting to distances identified at the driving range (e.g., 50 m and 75 m targets). On the other hand, short shots from the fairway had a higher coefficient of variation (39%) which, could suggest that the differential across these skills within the sample acts to cancel out any effect of handicap (e.g., someone good at putting might be bad at short fairway shots and vice versa). Finally, the non-significant determinant of handicap found for driving distance also shows the lowest coefficient of variation scores (10%), perhaps because it is underpinned more by physical capacity than the other skills, which seem like they are more determined by technical factors. Therefore, they might be more variable than a metric which is more influenced by physical capacity. For the moment at least, these speculations need further investigation into training history and golfer characteristics for an enhanced understanding.

For aspiring junior golfers, an important consideration is whether their current skill-set balance is adequate to transition into the professional ranks, or if a change in emphasis may be required to better prepare them for competition at the highest level. In 2013, the importance of golf skills (related to earnings) for professional PGA Tour players was as follows: driving distance, driving accuracy, putting performance, iron approach shots, short shots from fairway and short shots from bunker (Baugher et al., 2016). Notably within our study, driving distance and putting performance were not significant determinants.

Table 2. Regression analysis predicting players' performance (handicap) based on golf skills tests

Golf skill	Unadjusted				Adjusted for Age			
	B	*Stand. B*	*p*	*Multiple R^2*	B	*Stand. B*	*p*	*Multiple R^2*
Short putts success (%)	0.11	0.26	0.322	0.07	0.02	0.05	0.823	0.41
Long putts accuracy (m)	1.25	0.05	0.862	<0.01	0.29	0.01	0.960	0.41
Short shots from fairway accuracy (m)	−1.13	−0.2	0.46	0.04	−0.04	−0.01	0.974	0.41
Short shots from bunker accuracy (m)	1.68	0.73	0.001	0.53	1.28	0.56	0.009*	0.66
Short approach shots accuracy (m)	2.95	0.71	0.002	0.51	2.17	0.53	0.021*	0.61
Long approach shots accuracy (m)	0.74	0.71	0.002	0.50	0.53	0.51	0.038*	0.58
Driving accuracy (m)	0.64	0.58	0.018	0.34	0.48	0.43	0.039*	0.58
Driving distance (m)	−0.06	−0.23	0.394	0.05	0.03	0.14	0.576	0.42
Combine test accuracy (m)	1.53	0.79	<0.001	0.63	1.23	0.64	0.007*	0.67

Instead, and in contrast to the skills ranking order above, these initial data suggest that players should focus on improving the accuracy of short approach shots that, even when as little as by 1 m, could lead to an improvement of handicap by 2.95 points. A possible explanation for this discrepancy with the PGA Tour is that players compete on much longer courses compared to junior players, so driving distance has greater potential to differentiate the good from the best. In addition, the putting conditions on the PGA Tour are without doubt far more challenging due to the combination of green speeds and severe slopes which change from week-to-week for different courses. Indeed, linked to this is the change in grass type and variables such as growth direction, or 'grain', to contend with. Consequently, proficiency in this fine motor skill is also a key differentiator at the PGA Tour level. Furthermore, we highlight the difference in skill execution conditions between these two groups of golfers. While players may have been motivated to do well in the skills test battery administered in this study, the conditions are incomparable to the competition pressures present during PGA Tour play when livelihoods, titles and world rankings are on the line. Therefore, in addition to aspiring professional players training to adjust their skill-set balance, it is crucial that these skills are capable of remaining consistent and robust under conditions of high competitive stress (Carson & Collins, 2016).

An interesting and perhaps unexpected finding was the strong positive correlation between bunker shots and long approach shots. Given some reasonable similarity in technique between short approach shots and short bunker shots, this seems logical, but for long approach shots this same reasoning is somewhat less obvious. Therefore, we suggest that the strong transfer effect might not be due to technical similarities alone. Indeed, this could also be due to shared cognitive demands/processes facing the player in both situations. Using the meshed control framework (Christensen et al., 2016), these two skills could require a more 'adaptive' or 'problem solving' control style, requiring the golfer to focus more deeply on key skill execution parameters. In fact, mental preparation and concentration factors have been found to account for skill differences between low and high handicapped golfers (Thomas & Over, 1994). In short, skilled golfers must be proficient/flexible in their use of attentional strategies to cope with the varying demands imposed by different types of shots within the game (see Orr et al., 2021). Accordingly, future research into skills tests might also consider probing measures of psychomotor control to better understand the interrelationship between skills *and* their performance under stressful conditions.

Despite the novel insights gained from this study, it was not without limitation. Chronological age was used for analyses which could produce differences up to 4 years compared to the biological age (Malina et al., 2004). Physical abilities relating more to biological than chronological age could therefore affect tested skills such as driving distance or long approach shots (i.e., a shorter iron would be used for longer hitters). However, in the context of competitive junior golf, biological age is not accounted for and so there remains a benefit to understanding the system demands regardless of such differences. Secondly, golfers in this study were not screened for areas of their game that were being worked on, or if they were currently experiencing a transition period. Examples could include biological growth spurt, a change in coach, playing style, practice regime or technique. Indeed, such challenges are known to perturb performance along the talent development pathway and have been identified as crucial moments by coaches due to their potential for significant impact (both positive and negative; e.g., MacNamara et al., 2010; Taylor & Collins, 2018). Future studies should therefore seek to obtain this information to determine not only the skill, but also playing status of players when taking the tests. From a study design perspective, we note the cross-sectional design limitation. Repeated tests over the course of a season might reveal that the consistency, or establishment, of these skills might have greater predictive ability than the average score as opposed to handicap.

Summary of the implications and applications of the research

The present study suggests that the most important determinants of performance in skilled junior level golfers are short and long approach shot accuracy and driving accuracy. More specifically, these data imply that junior players should focus on accuracy of short approach shots to generate the fastest performance achievement at this level. However, for long-term performance development, it is important that other skills are developed to enable successful transition to cope with professional tournament demands; namely, longer hitting distances and more accurate putting. Furthermore, this study has suggested that future golf skills tests should seek an interdisciplinary approach with psychomotor factors to better understand how certain skills might be able to transfer for maximal gains.

Declaration of interest statement

The authors report there are no competing interests to declare.

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