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Multivariate analyses of individual variation in soccer skill as a tool for talent identification and development: utilising evolutionary theory in sports science

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ABSTRACT

The development of a comprehensive protocol for quantifying soccer-specific skill could markedly improve both talent identification and development. Surprisingly, most protocols for talent identification in soccer still focus on the more generic athletic attributes of team sports, such as speed, strength, agility and endurance, rather than on a player's technical skills. We used a multivariate methodology borrowed from evolutionary analyses of adaptation to develop our quantitative assessment of individual soccer-specific skill. We tested the performance of 40 individual academy-level players in eight different soccer-specific tasks across an age range of 13–18 years old. We first quantified the repeatability of each skill performance then explored the effects of age on soccer-specific skill, correlations between each of the pairs of skill tasks independent of age, and finally developed an individual metric of overall skill performance that could be easily used by coaches. All of our measured traits were highly repeatable when assessed over a short period and we found that an individual's overall skill – as well as their performance in their best task – was strongly positively correlated with age. Most importantly, our study established a simple but comprehensive methodology for assessing skill performance in soccer players, thus allowing coaches to rapidly assess the relative abilities of their players, identify promising youths and work on eliminating skill deficits in players.

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KEYWORDS
Performance; soccer skill; soccer; evolutionary sports science

Introduction

Identifying future elite sports men and women is a lucrative industry that relies on knowing the underlying determinants of success in a given activity (Honer, Votteler, Schmid, Schultz, & Roth, 2015; Phillips, Davids, Renshaw, & Portus, 2010; Tucker & Collins, 2012; Vaeyens, Lenoir, Williams, & Philippaerts, 2008; Williams & Drust, 2012). Quantitative protocols for talent identification primarily aim to describe the physiological, morphological, sociological, psychological and technical traits that separate elite from sub-elite competitors in a specific sport (Pienaar & Spamer, 1998; Pienaar, Spamer, & Steyn Jr, 1998; Reilly, Williams, Nevill, & Franks, 2000; Vaeyens et al., 2008). For example, elite junior rugby players in South Africa were reliably discriminated from sub-elite players based on eight morphometric and performance traits, including sprint time, passing accuracy, arm strength, vertical jump height and body size (Pienaar et al., 1998). Such protocols can then be utilised to rapidly and reliably identify individuals that are likely to graduate to an elite level of competition from a larger pool of players. Despite the broad interest and potential financial gains for a rigorous scientific approach to early identification of talented junior soccer players, there is limited uptake of any specific quantitative protocols (Carling, Le Gall, Reilly, & Williams, 2009; Reilly et al., 2000; but see Honer et al., 2015). The most common approach to the recruitment of promising individuals into youth soccer academies is through the subjective opinions of coaches and talent scouts (Christensen, 2009; Williams & Reilly, 2000), even though it is well appreciated such selection processes can lead to repeated errors and misjudgements when used in isolation (Meylan, Cronin, Oliver, & Hughes, 2010; Williams & Reilly, 2000). One issue is that most quantitative protocols for talent identification in soccer focus more on the generic athletic attributes of team sports, such as speed, strength, agility and endurance, rather than skill (Gil, Gil, Ruiz, Irazusta, & Irazusta, 2007; Le Gall, Carling, Williams, & Reilly, 2010; Reilly et al., 2000; Vaeyens et al., 2008; but see Honer et al., 2015). This is surprising given that soccer is primarily a game that rewards high technical skill and the game's most skilful players attract the highest salaries and are the most revered and coveted. So why is there still no detailed and widely utilised quantitative metric for soccer-specific skill? Tests of soccer-specific skill are usually more time-intensive and can offer lower repeatabilities than measures of athletic performance (Ali et al., 2007), but there are also disagreements over which skills are the most relevant (Ali, 2011), and many coaches still feel that assessment of skill is their domain, not that of the scientists. But despite these potential barriers, the development of a comprehensive protocol for soccer-specific skill could markedly improve both talent identification and development (Honer et al., 2015).

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The science of talent identification has many similarities with the study of evolutionary biology: both seek to understand which of an individual's characteristics relate to its success – defined in terms of number and quality of offspring in evolution and notoriety and/or financial rewards in sport. In both cases, success is underwritten by genes, dependent on the environment and measured through relevant morphological, biochemical, physiological, cognitive and motor traits (Arnold, 1983). Although there is a range of analytical and statistical tools within the field of evolutionary biology to probe the underlying basis of success within populations (Arnold, 1983), few of these have been utilised within the sports sciences despite their clear utility to this field of biology. In evolutionary biology, methodologies focus on the level upon which natural selection predominantly acts on phenotypic traits – the level of the individual – and success (i.e., evolutionary fitness) is measured in a relative context – an individual's success is compared with variation in success across the population (Hamilton, 2009). However, most talent identification protocols focus more on comparisons among groups (elite versus non-elite) rather than among individuals using inter-individual correlations (Ali, Foskett, & Gant, 2008; Ali et al., 2007; Dardouri et al., 2014; Reilly et al., 2000; Rostgaard, Iaia, Simonsen, & Bangsbo, 2008; Unnithan, White, Georgiou, Iga, & Drust, 2012; Vaeyens et al., 2006; Waldron, 2010). While such analyses can provide a coarse understanding of the attributes required to reach elite status, they are limited in two key ways: success is an individual trait not a group trait and its calculation depends on knowing success relative to the group or population. Arnold (1983) developed a statistical framework to study how variation in lower-level structural traits (e.g., morphology, physiology) relates to an animal's evolutionary success through whole-animal performance (i.e., maximum running speed, endurance, motor skill etc.). Since then, Arnold's (1983) framework has guided phenotypic and evolutionary studies of performance and success. We now know that success in many complex functional activities – such as predator escape and fighting ability – is driven by differences in whole-animal performance, physiology and morphology among individuals (Bennett & Huey, 1990; Husak, 2006; Jayne & Bennett, 1990; Miles, 2004; Wilson et al., 2013; Wilson, Hammill, & Johnston, 2007). Based on evolutionary analyses of success, it is clear that it is variation in functional traits and performance *among individuals* – rather than between groups of individuals – that drives success. As applied to analyses of talent identification, the factors that determine whether or not an individual graduates to an elite level of a sport may be very different from the factors that determine success *within* the elite or sub-elite groups. Ultimately, talent identification protocols that compare elite and non-elite groups tell us little about what drives excellence by individuals within the elite population and, as an extension, which individual within an elite football academy is the most likely to be successful. To understand which traits underlie performance in the best of the best (e.g., what makes a Lionel Messi and Cristiano Ronaldo) – and the relative importance of each underlying trait – we have to develop protocols that explore variation among individuals, as per Arnold's framework (Arnold, 1983). This approach would allow us to ask which factors determine success among elite performers, rather than determining whether or not an individual could become elite. This forms the framework for our study as we seek to develop a quantitative assessment of skill performance.

In our study, we used a multivariate methodology based on evolutionary analyses of individual success (i.e., adaptation) to develop a conceptual framework for talent identification based on a range of soccer-specific skill traits. We focused on an overall assessment of skill rather than athletic or psychological traits because of the widely acknowledged importance of skill to the success of professional soccer players by coaches and talent scouts (Christensen, 2009; Rampinini, Impellizzeri, Castagna, Coutts, & Wisloff, 2009), the oft-cited difficulties associated with its measurement (Ali, 2011), and its common exclusion or lower importance given to its assessment for talent identification protocols (Gil et al., 2007; Le Gall et al., 2010; Reilly et al., 2000; Unnithan et al., 2012; Vaeyens et al., 2006; Williams & Ford, 2009). When developing our protocol, we also wanted to acknowledge that the ability for an individual to perform effectively in a match will be dependent on a wide range of underlying skill-based traits and it is unlikely that measuring a few dimensions of sport-specific skill (performance across only a few tasks) will capture an accurate assessment of an individual's capabilities. To circumvent this issue, we measured multiple axes of soccer-specific skill and we assessed those skill tasks we expect to be most relevant to success in competitive soccer at a professional level (Bloomfield, Polman, & O'Donoghue, 2007). In addition, to make our protocol useful for those wishing to obtain a detailed assessment of an individual player's skill in a short period of time – especially given the time constraints facing many coaches – we designed a protocol that could be administered within a single training session. Based on these objectives, we tested the performance of 40 individual academy-level players across an age range of 13–18 years old in eight different soccer-specific tasks. We explored four different issues related to skill assessment of soccer players. First, we quantified the repeatability of each of our eight measures of skill performance and also our combined metric of overall skill. Second, we explored how age was associated with each of the eight soccer tasks and our composite metric of overall skill. Third, by controlling for any effects of age on skill performance, we then examined correlations among performances that were independent of age. Finally, we used an exploration of individual variation in overall skill performance across all of the eight skill tasks to provide a relative metric of overall skill that could be used by coaches to rank each individual player's ability and potential for future success.

Materials and methods

We recorded the performance of 40 individual's from the Coventry City Football Academy, Coventry, UK in eight soccer-specific skill tests. All players and guardians gave consent to be involved in the investigation that was granted ethical approval by the Coventry University Faculty of Health and Life Sciences ethics committee. The average age of participants was 16.0 (SD = 1.7; range 13.6–18.5 years old). We designed our skill assessment protocol to test approximately 10–16 players during a 2-h session as a part of their regular training schedule. Each player was rotated through each test station in pairs, whereby each pair visited eight stations throughout the session. A total of 12 min was assigned to each drill so that players could complete a drill and be ready for the next within the allotted time. Players were randomly assigned to a starting station, such that the order of testing was different for each pair of players. Each of the skill tests was designed to quantify an individual player's ability to execute a specific skill considered important and relevant to match performance (Bloomfield et al., 2007) and those skills routinely required during games at each age level from junior to senior competitions. For each player, we measured performance in the following soccer-specific motor-skill tasks: (i) passing accuracy over 20 m, (ii) lofted passing accuracy over 35 m, (iii) shooting accuracy over 20 m, (iv) performance during a wall-pass accuracy test, (v) maximum dribbling speed, (vi) average juggling (i.e., keep-up) ability, (vii) dynamic passing test using two rebound boards set at right angles, (viii) dynamic passing test using two rebound boards set at 135°. Our unique testing design relies on correct technique to execute each skill – thereby making it a useful training as well as testing protocol – and is referred to as University of Queensland Football Skill Assessment Protocol. At the beginning of each new skill test, as each pair of players moved among the tasks each participant was given 60 s to familiarise themselves with each technique and the rules.

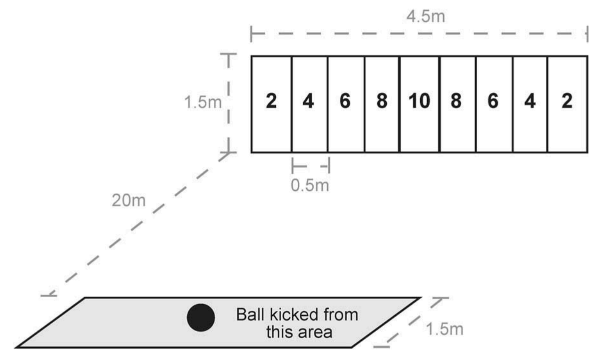

Figure 1. The dimensions and set-up for the 20 m passing and shooting tests showing the kicking zone and the size of the target and scoring zones. The black circle indicates the starting position of the ball. See methods text for more details.

University of Queensland Football Skill Assessment Protocol

Passing accuracy over 20 m

Passing the ball accurately is a critical skill used in open play and is important for players in every position. This particular drill tests a player's ability to pass a ball accurately, also allowing coaches to observe and critique a player's technique with both left and right feet. We assessed passing accuracy by giving each player 28 attempts to pass a ball using the inside part of the foot towards a target 20 m away: seven attempts with the left foot and seven attempts with the right foot, repeated after a 4 min rest. At the start of each attempt, the ball was placed 1.5 m behind the 20 m line; players were required to push the ball forward with a single touch and then pass the ball at the target before they reached the 20 m line (Figure 1). If the ball proceeded over the 20 m passing line before being passed then a score of zero was applied for that pass.

The target was a tarpaulin (1.5 m high × 4.5 m wide) comprising a series of scoring zones (each of 1.5 m high × 0.5 m wide) clearly marked across its width (Figure 1). A ball striking the tarpaulin received the points associated with the scoring zone it hit: 10 points for hitting the central scoring zone, 8 points for hitting the next 50 cm zone on either side, and so on (Figure 1). If the width of the ball hit two scoring zones then the points were allotted according to which zone the majority of the ball hit. If the ball hit two scoring zones equally then it was scored as an intermediate score; for example, if the ball hit directly between the 8- and 6-point scoring zones, then the kick was scored as the average of the two scores (i.e., 7 points). Points were awarded when any part of the ball was below the 1.5 m cut-off height regardless of what proportion of the ball hit the upper edge of the scoring zone. A player's individual performance for this task was calculated by adding up accumulated points and dividing it by 28, which corresponded to the average points per kick. For the purposes of calculating measures of repeatability, the first set of 14 kicks were used as test 1 and the second set of 14 kicks after the 4 min break were taken as test 2.

Lofted passing accuracy over 35 m

Long passes are commonly used in open play to rapidly move attacking play, change the direction of movement whilst in possession, or play a ball to a team-mate that is in free space when the player in possession is under pressure. This drill tests a player's ability to play a lofted-pass (35 m) using correct technique and accuracy, thus also allowing coaches to analyse and critique a player's technique with both left and right feet. Lofted-pass accuracy was assessed by giving each player 28 attempts to make a lofted pass off their boot laces (this part of the foot must be used) at a large target placed on the ground 35 m away with a dummy player placed in the middle of it (Figure 2A). Players were given seven attempts with their left foot and seven attempts with the right foot, repeated after a 4 min rest. To start each attempt, players pushed the ball forward with a single touch and then kicked the ball at the target. The ball was not allowed to proceed across the designated 35 m passing line, otherwise a score of zero was applied for that pass. Players alternated between passes with their left and right feet.

The target area was a series of five concentric rings, each with a diameter 1 m greater than the circle within it and diminishing in points, depending on where the ball lands: the middle circle (0.5 m diameter) was 20 points, the next was 18 points, and so on (Figure 2B). If the ball landed outside the rings but on the tarpaulin (6 × 8 m total size), the player was awarded 10 points. If the ball landed within 1 m of the side of the tarpaulin or within 2 m of the rear of the tarpaulin, then 6 points was awarded. If the ball reached a distance

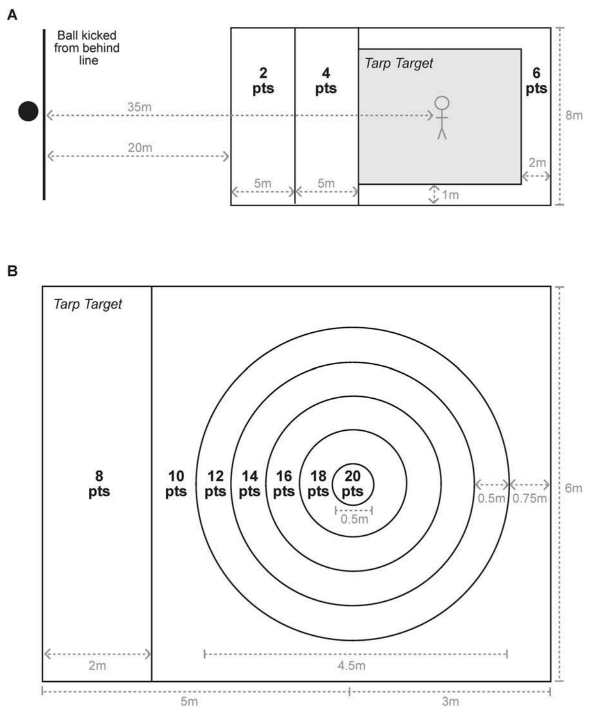

Figure 2. The dimensions and set-up for the 35 m lofted-pass test showing the larger full set-up with the lower scoring zones (A) and the size and scoring zones for the tarpaulin (B). The black circle indicates the starting position of the ball. See methods for more details.

between 25–30 m on the full (and within the 8 m target width), then 4 points was awarded. If the ball reached a distance between 20–25 m (and within the 8 m target width), then 2 points was awarded. Points for these shorter distances were primarily provided for those younger players that struggled to reach a distance of 35 m before the ball landed. As with the targets used in other tests, a ball that hit the tarpaulin would receive the points associated with the scoring zone it mostly fell within. If the ball struck two scoring zones equally, then it was given an intermediate score. A player's individual performance for this task was calculated by adding up all of their accumulated points and dividing it by 28, which corresponded to their average points per kick. Repeatability was calculated by comparing the first set of 14 kicks with the second set of 14 kicks (after the 4 min break) for each player.

Shooting accuracy over 20 m

Shooting from outside the penalty box is a common method of scoring. The ability to execute a shot using the in-step (top of the foot) with both power and accuracy is one of the most important attributes that a player can possess for attacking play. This specific drill quantifies a player's accuracy when using this in-step shooting technique from 20 m. The set-up for measuring shooting accuracy at 20 m was identical to that outlined above for the passing accuracy from 20 m (Figure 1), except each player had to use their in-step and received a score of zero if they did not use the correct technique. A player's performance for this task was calculated by adding up their accumulated points and dividing it by 28, which corresponded to average points per kick. Repeatability was calculated by comparing the first set of 14 kicks with the second set of 14 kicks (after the 4 min break) for each player.

Wall-passing test

Wall passes (or one-two passes) are commonly used to open up defences using rapid and accurate passing. This specific drill tests a player's ability to make two successive accurate passes with the second a first-time pass occurring when the ball is moving at speed towards the player. As with each of the skill tasks, players only score points when they use the specified technique with the correct foot, otherwise a score of zero applies for that attempt. The aim of this task was to accumulate as many points in 45 s as possible. To begin, players stood behind the first line and the time started when the ball was first touched (Figure 3). Players first used technique #1 by dribbling the ball beyond the first line and then kicked the ball towards the rebound board with their right foot at a distance >5 m away from the central rebound board (Figure 3B). As the ball returned to the player, which they received at a distance <5 m from the rebound board, they then played a first-time pass towards target *a* with their left foot. At this stage the player sprinted back to the first cone where they could get another ball and then dribble it back beyond the first cone again. However, on this occasion they had to switch to technique #2, in which they passed the ball towards the central rebound board with their left foot and then used a first time pass towards target *b* with their right foot (Figure 3C). The players continued this process switching back and forth between technique #1 and #2 until 45 s elapsed. Only when players used the correct technique could they score points. This protocol was completed three times by each player with a break of 2.5 min between each trial. The average score across all three trials was taken as an indicator of an individual player's ability to perform an accurate and consistent wall-pass.

The scoring targets were tarpaulins (1.5 m high × 2.5 m long) comprised of a series of scoring zones (1.5 m high × 50 cm) clearly marked along its length (Figure 3A). The central scoring zone was worth 6 points, the 50 cm areas on either side of the central zone worth 4 points, and the outer zones worth 2 points. Points were awarded when any part of the ball was below this 1.5 m cut-off height. As with the targets used in other tests, a ball striking the tarpaulin received the points associated with the scoring zone it fell mostly within. If the ball struck two scoring zones equally, then it was given an intermediate score. Repeatability was calculated by comparing the first and second trials for each player.

Dribbling speed

Dribbling with the ball is a skill required by all players but is especially effective for those attacking players looking to break open a defence by running at opponents through tight spaces. This drill tests a player's ability to dribble the ball rapidly through a marked circuit, where good performance relies on close ball control and the ability to maintain control during rapid changes of direction. Dribbling speed was

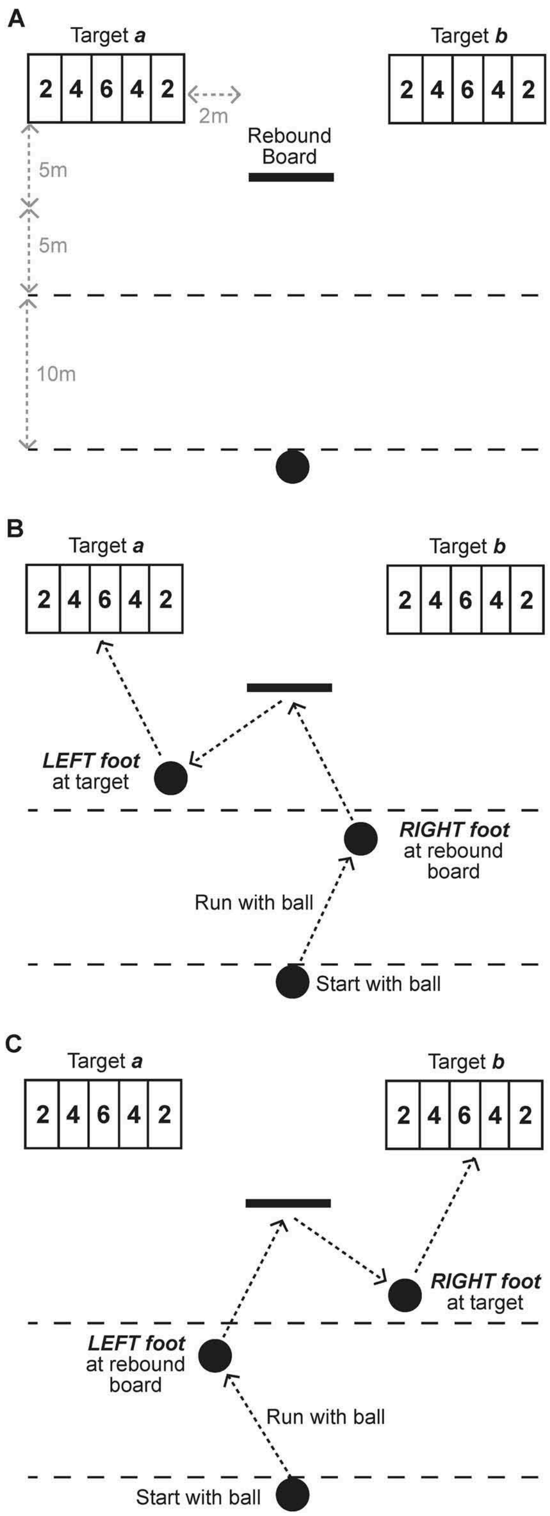

Figure 3. The dimensions and set-up for the wall-pass test (A). Players stand behind the first marker and time starts when the first ball is touched. (B) Players must first use technique #1 by dribbling the ball beyond the first cone and then kicking the ball towards the rebound board with their right foot. As the ball returns to the player, which they must receive at a distance <5 m from the rebound board, they must then play a first-time pass towards target *a* with their left foot. (C) After sprinting back to their start position, then the players must use technique *b*, in which they pass the ball towards the rebound board with their left foot and then use a first time pass towards target *b* with their right foot. The players continue this process switching back and forth between technique #1 and #2 until 45 s elapses.

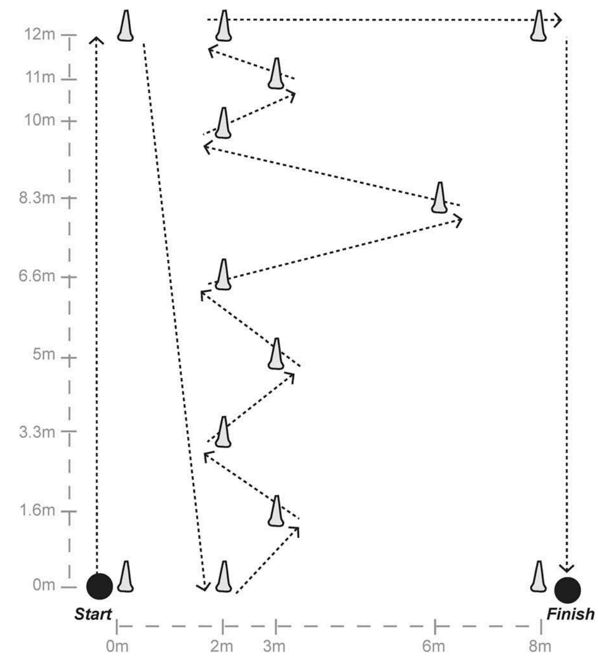

Figure 4. The dimensions for the dribbling speed performance task with the dotted line and arrows indicating the path taken by the players. See methods for more details about set-up.

quantified by recording the total time taken for an individual to dribble (i.e., kick) the football through a 61.2 m agility course (Figure 4). Each individual was given three attempts at the task with 2.5 min rest between each and the quickest was taken as their peak performance (for all skill tests, an individual's peak performance was their single best performance in that task). Each player started with the ball behind the first cone and proceeded through the circuit as fast as possible. Time was stopped when both the player and ball crossed the finish line. The time taken to complete the circuit was recorded with a stopwatch and then converted to average speed over the 61.2 m. Time penalties were allotted to a player's total time to account for errors using the following system: (i) +1 s for each missed cone, (ii) +2 s if two cones in succession were missed (note: although this penalty was applied it was never part of an individual's quickest time, which was taken as their peak performance), and (iii) +0.5 s for each cone knocked over. Repeatability was calculated by comparing a player's first and second tests of dribbling speed.

Juggling ability

Although juggling is a skill rarely executed during a game, the ability to kick the ball with precision and delicate touch is frequently used during a match. This drill quantifies a player's ability to maintain delicate control over a ball by juggling – or keeping the ball in the air using left and right feet alternately. In this test, a player juggled the ball for 60 s within a square (1.5 × 1.5 m) measured out with small cones. A juggle was defined as a single kick, and a mistake occurred when: (i) a player touched the ball with the same foot in successive kicks, (ii) a player stepped outside the marked square area, or (iii) the ball touched the ground. After each mistake, the player had to stop the ball and begin again. Total score was calculated by adding up the number of juggles using the correct technique during the 60 s. For example, if a player juggled correctly for 20 successive kicks, then stepped out of the area, then restarted and made 24 successive kicks, then the ball touched the ground, then restarted and made 24 successive kicks before the time ended, then their total score was 68 (20 + 24 + 24). Each player completed the test three times, with 2.5 min rest between, and the average score across the three trials was used as their measure of juggling performance. Repeatability was calculated by comparing a player's first and second juggling scores.

Short-passing performance with rebound boards at 90°

The most commonly used technique in open play is the short pass between team members. In this task, we assessed a player's ability to receive a pass by bringing the ball under rapid control and then execute a subsequent pass with accuracy and speed. We emphasise both the correct positioning of the player's body during this drill and kicking with the appropriate foot, ensuring that the ball is always protected from opponents when passing the ball at 90° to the angle of ball reception. Two techniques were employed and tested in this task, both simulating the situation when a player received a ball and plays a subsequent pass while under pressure from an opponent. Technique #1 simulates when the pressure from an opponent is from behind and technique #2 simulates when the pressure is from the direction in which the ball is received, thus requiring the player to turn with the ball to protect it. Two rebound boards (1.2 m long × 0.46 m high; Rebound Box, Birmingham, UK) were set at right angles to each other (Figure 5A) with the centre focal point (where the player being assessed stands) 5 m from each of the rebound boards.

Technique #1

Step 1: The player passed the ball towards rebound board *a* with their right foot. Time started when the ball hit rebound board *a* (Figure 6A). Step 2: The player received the rebounded ball with their right foot in order to set-up a pass with their left foot (Figure 6B). Step 3: The player passed the ball towards rebound board *b* with their left foot (Figure 6C). Step 4: The player received the rebounded ball with their left foot in order to set-up a pass with their right foot (Figure 6D). The player then repeated Step 1 by passing the ball towards rebound board *a* with their right foot. One cycle was completed when the ball hit rebound board *a* again. The time needed to complete 10 cycles was recorded as the player's score.

Technique #2

Step 1: The player passed the ball towards rebound board *a* with their left foot. Time started when the ball hit rebound board *a* (Figure 6E). Step 2: The player received the rebounded ball with their right foot and turned with the ball in order to set-up a pass again with their right foot (Figure 6F). Step 3: The player passed the ball towards rebound board *b* with their right foot (Figure 6G). Step 4: The player received the rebounded ball with their left foot and turned with the ball to set-up a pass with their left foot (Figure 6H). The player then repeated Step 1 by passing the ball towards rebound board *a* with their left foot. One cycle was completed when the ball hit rebound board *a* again. The time needed to complete 10 cycles was recorded as the player's score.

In both technique #1 and #2, penalties were awarded as extra time added to the final score: (i) +1 s for each extra touch on the ball while setting up a pass, (ii) +1 s for every touch on the ball with the wrong foot and (iii) +1 s for each time the ball misses the rebound board. If the ball missed the rebound board, then time was immediately stopped and only restarted when the player kicked a replacement ball towards the rebound board.

Each technique was performed twice for each player, with a 2 min rest between each test. For each attempt, we divide 60 by the total time taken (in seconds) to complete the 10 cycles to convert this number into a measure of number of circuits per minute. For example, if a player takes 30 s to complete the 10 cycles, then the rate is two circuits per minute. We then calculated the average circuits per minute across all four tests as the overall performance in this short-passing drill. Repeatabilities were calculated by comparing the combined results of the first circuit of techniques #1 and #2 with the second circuit.

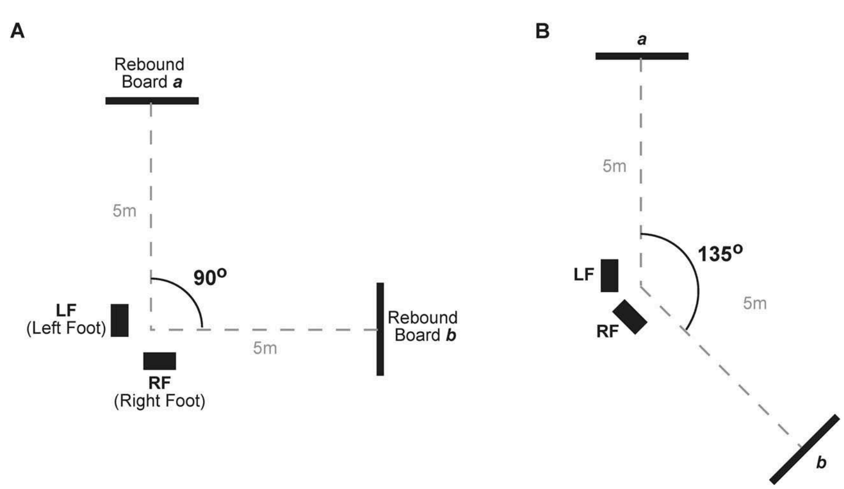

Figure 5. Dimensions and set-up for the (A) 90° rebound-board passing test and (B) 135° rebound-board passing test. See methods text for more details about set-up.

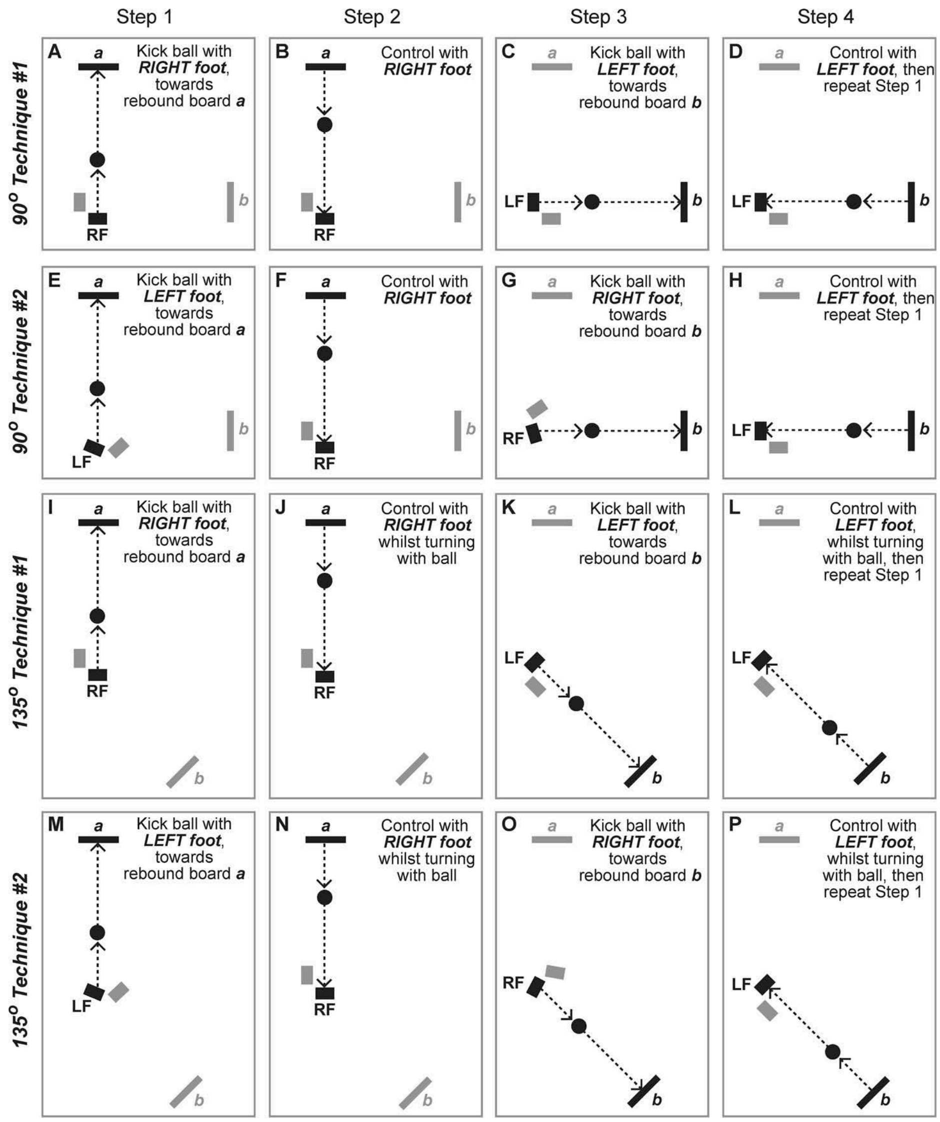

Figure 6. Technique used for 90° rebound board test and 135° rebound board test. Steps 1–4 for technique #1 in the 90° rebound-board passing test are shown in panels (A) to (D), while panels (E) to (H) represent steps 1–4 for technique #2 in the 90° rebound-board passing test. Steps 1–4 for technique #1 in the 135° rebound-board passing test are shown in panels (I) to (L), while panels (M) to (P) represent steps 1–4 for technique #2 in the 135° rebound-board passing test. In each panel *a* represents rebound board *a* and *b* represents rebound board *b*. RF is the right foot and LF is left foot. In each panel, the active foot and rebound board in each step is black, while the inactive foot and rebound board in each step is in grey.

Short-passing performance with rebound boards at an angle of 135 degrees

A commonly used skill in open play is the ability to receive a ball from a teammate, turn with the ball through a wide angle and play a subsequent pass to another teammate. This technique is crucial for rapid ball distribution through the midfield area of the pitch and high performance in this skill allows players to open up the game rapidly using technique and vision. Therefore, this particular drill tests a player's ability to receive a pass by bringing it under control rapidly whilst turning with the ball and then executing a subsequent pass with accuracy. We emphasised the correct body shape during this drill and the use of the appropriate foot to ensure the ball was protected from opponents before being passed on to a teammate that was at an angle of 135° to the line of ball reception (Figure 5B). In this test, two rebound boards were set at an angle of 135° to each other (Figure 5B). The player was positioned 5 m from each rebound board in the centre. As described in the short-passing drill above, where rebound boards were set at 90°, each individual was assessed twice using both techniques #1 and #2 (Figures 6I–P). For each attempt, we divide 60 by the total time taken (in seconds) to complete the 10 cycles to convert this number into a measure of number of circuits per minute.

Statistical analyses

We first standardised the raw performance values from each of the eight measures so that they all possessed the same mean (mean = 0) and standard deviation (SD = 1). To do this, we subtracted the mean value for each particular task from each individual's score for that same task and then divided it by the overall standard deviation for the task. This ensured that each

Table 1. Principal components analysis matrix of the eight soccer-specific skill performance traits (N = 40) showing the factor loadings of each measured variable and the direction in which they contribute towards the components. See the text for a description of each trait. The first component of the PCA (PCA1) explained 46.9% of the variation in the data and the second component (PCA2) explained 14.4% of the variation.

	Factor loadings	
Skill performance traits	PCA1	PCA2
20 m pass	0.38	−0.12
35 m pass	0.42	−0.03
20 m shot	0.33	−0.42
Wall-pass	0.32	−0.51
Juggle	0.13	0.43
Dribble	0.32	0.53
Rebound 90	0.39	0.29
Rebound 135	0.44	0.06

Table 2. Repeatabilities of the eight individual soccer-specific skill performances and the overall metric of skill for the 40 youth players. The intra-class correlation coefficients (ICC), and the Pearson's product moment correlation and its confidence interval range are provided for each metric of performance.

Skill task	ICC	r_P	r_P (CI range)
20 m pass	0.90	0.59	0.33–0.76
35 m pass	0.93	0.65	0.42–0.80
20 m shot	0.88	0.54	0.28–0.73
Wall-pass	0.91	0.60	0.38–0.77
Juggle	0.95	0.72	0.53–0.84
Dribble	0.83	0.47	0.18–0.68
Rebound 90	0.88	0.54	0.27–0.73
Rebound 135	0.94	0.67	0.44–0.81
Overall	0.98	0.87	0.76–0.93

of the tasks was comparable in mean and standard deviation and we refer to these as the standardised raw values of performance (Wilson, Niehaus, David, Hunter, & Smith, 2014). Following this, we conducted a principal components analysis (PCA) on all eight measures of performance using the standardised raw values. The first component of the PCA explained 47% of the variation observed in skill performance (Table 1). All vectors of PCA-1 loaded in the same direction, thereby representing overall skill. The second component of the PCA-2 explained 14% of the variation and was indicative of a negative correlation between static passing tests and the more dynamic movement-based skill tasks (Table 1). Positive values of PCA-2 indicated high performance in movement based skill tasks (e.g., dribbling speed and performance in rebound board tests), while negative values indicated high performance in the static passing tests (e.g., 20 m passing and 35 m passing tests).

To calculate an individual's performance in each skill task relative to their age (i.e., correcting for the role of an individual's age on their performance), we calculated the residuals for each performance trait when regressed upon an individual's age (this was only performed for those performance traits that were significantly affected by age). Thus, values above the line of best fit were then indicative of a high level of performance for that task relative to an individual's age. These residual values were then referred to as an individual's age-corrected performance in each skill task.

Estimates of repeatability were performed on each of the eight skill performance traits and the composite measure of overall skill by calculating intra-class correlation coefficients and Pearson's product moment correlations. All correlations among pairs of skill performance were conducted using Pearson's product moment correlations. These analyses were conducted on both the standardised raw data and age-corrected data. To correct for multiple statistical comparisons, we used a Bonferroni correction factor that divided the significance value of 0.05 by the number of comparisons being conducted. All statistical analyses were performed using the software package R or JMP.

Results

All eight soccer-specific skill performance tasks were highly repeatable and intra-class correlation coefficients (ICC) ranged from a low of 0.83 for dribbling speed to a high of 0.95 for juggling performance (Table 2). Based on the composite measure of performance across all tests of soccer-specific performance the ICC was 0.98 (Table 2), demonstrating that the overall measure of performance was highly repeatable.

Based on analyses of standardised raw data, we found 18 positive associations among the 28 pairs of skill-based traits, but did not identify any significant negative correlations (Table 3). For example, accuracy in the 20 m passing test was significantly positively correlated with accuracy in both the 35 m lofted-pass (r_p = 0.53; P = 0.0004), the 20 m shooting test (r_p = 0.52; P = 0.0006), performance in the wall-pass test (r_p = 0.42; P = 0.006), maximum dribbling speed (r_p = 0.35; P = 0.03) and rebound board passing ability through 90° (r_p = 0.42; P = 0.007) and 135° (r_p = 0.48; P = 0.002). Maximum dribbling speed was also positively correlated with accuracy in the 35 m lofted passing test (r_p = 0.43; P = 0.006), and passing performance in the 90° (r_p = 0.59; P < 0.0001) and 135° (r_p = 0.47; P = 0.002) rebound-board test.

The relationship between an individual's age (years and days since birth) was significantly positively correlated with some, but not all, of the eight soccer-specific skill tests (Figure 7). An individual's age was significantly positively correlated with accuracy in the 35 m lofted-pass test (r_p = 0.38; P = 0.015; Figure 7B), performance in the wall-pass test (r_p = 0.36; P = 0.025; Figure 7D) and performance in the 135° rebound board test (r_p = 0.40; P = 0.01; Figure 7H). However, an individual's age was not significantly associated with accuracy in the 20 m passing test (r_p = 0.12; P > 0.05; Figure 7A), accuracy in the 20 m shooting test (r_p = 0.21; P > 0.05; Figure 7C), juggling ability (r_p = 0.00001; P > 0.5; Figure 7E), maximum dribbling speed (r_p = 0.08; P > 0.05; Figure 7F) and

Table 3. Correlation matrix of the eight soccer-specific skill traits using the raw standardised data for the 40 youth players. Significant correlations between pairs of performance traits are indicated by bold text.

	20 m pass	35 m pass	20 m shot	Wall-pass	Juggle	Dribble	Rebound 90
35 m pass	**0.53**						
20 m shot	**0.52**	**0.39**					
Wall-pass	**0.43**	**0.51**	**0.46**				
Juggle	0.23	0.17	0.11	−0.03			
Dribble	**0.35**	**0.43**	0.20	0.10	0.17		
Rebound 90	**0.42**	**0.50**	0.20	**0.40**	0.11	**0.59**	
Rebound 135	**0.48**	**0.67**	**0.53**	**0.40**	0.14	**0.47**	**0.70**

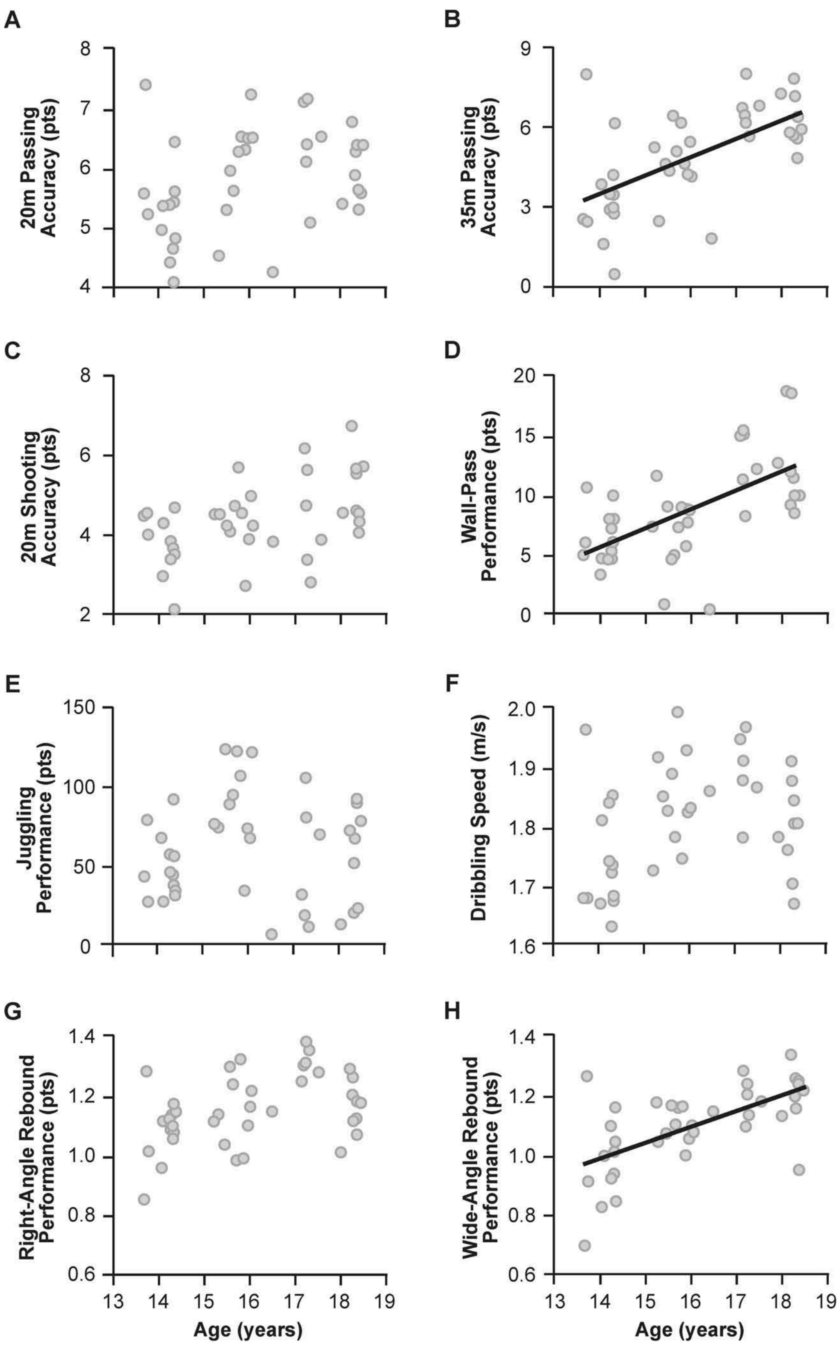

Figure 7. The relationship between an individual's age (years and days since birth) and their (A) accuracy in the 20 m passing test ($r_p = 0.12$; $P > 0.05$), (B) accuracy in the 35 m passing test ($r_p = 0.38$; $P = 0.015$), (C) accuracy in the 20 m shooting test ($r_p = 0.21$; $P > 0.05$), (D) performance in the wall-pass test ($r_p = 0.36$; $P = 0.025$), (E) juggling 'keep-up' ability ($r_p = 0.00001$; $P > 0.5$), (F) maximum dribbling speed averaged across through the entire test circuit ($r_p = 0.08$; $P > 0.05$), (G) performance in the 90° rebound board test ($r_p = 0.16$; $P > 0.1$), (H) performance in the 135° rebound board test ($r_p = 0.40$; $P = 0.01$). Significant correlations were taken at the level of $P < 0.05$ and also shown by a correlation line on the figure. N = 40.

performance in the 90° rebound board test ($r_p = 0.16$; $P > 0.1$; Figure 7G).

The relationship between an individual's age was significantly positively correlated with their overall performance averaged across all eight soccer-specific skill traits based on the sum of all raw-standardised data ($r_p = 0.40$; $P = 0.01$; Figure 8A) and overall performance when based upon PCA-1 ($r_p = 0.43$; $P < 0.01$; Figure 8B). In addition, an individual's age was positively correlated with their highest peak performance across any of the skill traits based on the raw-standardised data ($r_p = 0.36$; $P = 0.02$). Each of the performance tasks differed among the age-groups except for the 20 m passing accuracy test ($F_{2,37} = 2.5$; $P = 0.09$; Table 4). The overall skill performance averaged across all standardised tasks significantly varied among the age-groups ($F_{2,37} = 14.5$; $P < 0.0001$; Table 4).

When we corrected for player age (for those traits significantly affected by age), we also found positive associations among several pairs of skill-based traits but no significant negative correlations (Table 5). Accuracy in the 20 m passing test was positively correlated with accuracy in both the 35 m

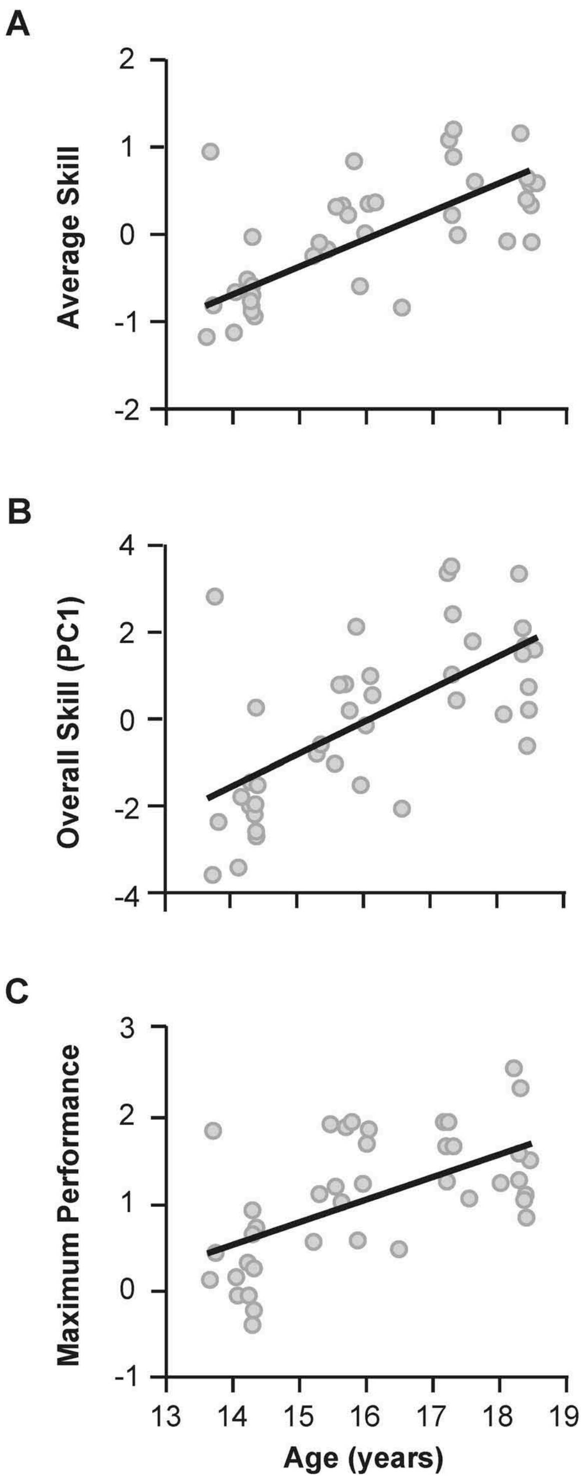

Figure 8. The relationship between an individual's age (years and days since birth) and their (A) overall performance across all eight soccer-specific skill traits based on the sum of all raw-standardised data (r_p = 0.40; P = 0.01), (B) overall performance based on the first dimension of a principal component conducted on all eight soccer-specific performance traits (r_p = 0.43; P < 0.01), and (C) highest peak performance for any of the skill traits based on the raw-standardised data (r_p = 0.36; P = 0.02). N = 40.

lofted pass (r_p = 0.43; P = 0.005) and 20 m shooting test (r_p = 0.44; P = 0.005) and short-passing performance in the dynamic 90° (r_p = 0.33; P = 0.04) and 135° (r_p = 0.36; P = 0.02) rebound-board test. In addition, maximum dribbling speed was positively correlated with accuracy in the 35 m lofted

Table 4. Performance of the U14 s (N = 13), U16 s (N = 11) and U18 s (N = 16) academy players in each of the eight soccer-specific skill tasks, the composite measure of skill based on raw-standardised values, maximum performance, and the first dimension of the principal component analysis conducted on all the traits (PCA-1). Significance among the age groups was taken at the level of P < 0.05.

Performance trait	U14 s	U16 s	U18 s	$F_{2,37}$ statistic	P-value
20 m pass (pts/kick)	5.31 ± 0.24	5.86 ± 0.30	6.00 ± 0.20	2.5	0.09
35 m pass (pts/kick)	3.41 ± 0.53	4.75 ± 0.33	6.01 ± 0.37	11.7	0.0002
20 m shot (pts/kick)	3.72 ± 0.20	4.36 ± 0.30	4.75 ± 0.28	4.9	0.01
Wall-pass (pts/kick)	6.49 ± 0.62	6.97 ± 0.92	11.8 ± 1.17	10.4	0.0003
Juggles (No./min)	50.6 ± 5.6	90.4 ± 8.8	53.0 ± 8.7	3.9	0.03
Dribble (m/s)	2.39 ± 0.04	2.53 ± 0.04	2.51 ± 0.03	5.3	0.01
Rebound 90 (cycles/min)	1.08 ± 0.03	1.14 ± 0.04	1.21 ± 0.03	5.2	0.01
Rebound 135 (cycles/min)	0.98 ± 0.04	1.10 ± 0.02	1.18 ± 0.02	13.8	<0.0001
Overall performance	−0.60 ± 0.15	0.09 ± 0.12	0.42 ± 0.13	14.5	<0.001
Maximum performance	0.42 ± 0.16	1.31 ± 0.16	1.47 ± 0.14	15.1	<0.001
PCA-1	−1.74 ± 0.32	0.13 ± 0.32	1.32 ± 0.38	15.8	<0.001

Table 5. Correlation matrix of the eight soccer-specific skill traits using the data corrected for an individual's age (years and days since birth) for the 40 youth players. Significant correlations between pairs of performance traits are indicated by bold text.

	20 m pass	35 m pass	20 m shot	Wall-pass	Juggle	Dribble	Rebound 90
35 m pass	**0.43**						
20 m shot	**0.44**	0.15					
Wall-pass	0.30	0.22	0.26				
Juggle	0.24	0.22	0.12	−0.04			
Dribble	0.28	**0.33**	0.08	−0.09	0.18		
Rebound 90	**0.33**	**0.35**	0.02	0.21	0.12	**0.54**	
Rebound 135	**0.36**	**0.46**	**0.34**	0.04	0.17	**0.39**	**0.63**

pass (r_p = 0.33; P = 0.04) and the 90° (r_p = 0.54; P = 0.0003) and 135° (r_p = 0.39; P = 0.01) rebound-board passing test. The 90° rebound-board passing test was also highly positively correlated with the 135° rebound-board passing test (r_p = 0.63; P < 0.0001).

Peak performance across all the eight soccer-specific skill tasks was positively associated with performance averaged across all other skill tasks when conducted on the raw-standardised data (r_p = 0.79; P < 0.01). Thus, individuals performing well in one task seemed to also perform well in other tasks.

Discussion

Our study establishes a simple scientific protocol to measure skill performance in soccer players that coaches can use to assess the relative abilities of their players, identify promising youths, and highlight skill deficits that can be targeted in training. We adapt multivariate statistical techniques commonly used in evolutionary biology to show correlations between several key skills as well as their importance to overall skill in individual players. We show that an individual's overall skill – as well as their performance in their best task – is strongly positively correlated with age. However, among individual skill tasks only the wall-pass, lofted-pass (35 m) and 135° rebound-board tests were positively associated with age. Previous work has also shown that many soccer skills are positively associated with age while others are not (Figueiredo, Coelho e Silva, & Malina, 2011; Huijgen, Elferink-Gemser, Post, & Visscher, 2010; Malina et al., 2005). Although quantifying the effect of age on skill is interesting, it is the variation away from the mean effect of age on skill that is most likely to reveal an individual's potential to succeed in the sport. In other words, those individuals that are more than one standard deviation above the mean performance for their age group are those that talent scouts most wish to identify, but they are also the individuals that tend to decrease the probability of detecting any effects of age on metrics of skill. Interestingly, chronological age and biological maturity seem to be weaker predictors of soccer-specific skill than athletic traits such as speed, strength and agility (Figueiredo et al., 2011; Malina et al., 2005). For those football development programmes that wish to minimise age-biases currently dominating many talent identification and development structures, then longitudinal studies focusing more on skill assessment models that predict future success may offer improved outcomes.

Repeatability of measurements – whether they are performance abilities or any other aspect of the phenotype – is a concept taken from quantitative genetics theory and describes the degree to which within-individual variation contributes to the total variation within a population (Boake, 1989; Lessells & Boag, 1987). We know that natural selection can only act upon those traits that show (i) significant levels of variation *among* individuals and (ii) lower levels of variation *within* individuals (Boake, 1989). Low trait repeatabilities can occur when individuals are similar in trait values – because of environmental (training, diet, etc.) or genetic effects – or when the measurement of a trait is insufficiently controlled because of random environmental factors (Bell, Hankison, & Laskowski, 2009; Boake, 1989). Soccer skills like passing, dribbling and shooting typically show higher within-individual variation relative to measures of athleticism such as speed, agility and endurance (Ali, 2011). Motor skills are complex traits controlled by numerous anatomical, physiological and psychological pathways (Kleim et al., 2002; Nudo, Milliken, Jenkins, & Merzenich, 1996; Remple, Bruneau, VandenBerg, Goertzen, & Kleim, 2001) and may differ more, with time or environment, than athletic traits (Ali, 2011; Ali et al., 2007). For example, an average sprinter could never run as fast as Usain Bolt, but an average footballer could kick as accurately as Lionel Messi in a one-off kick – in other words, the variance in soccer-specific skills is often much greater than many athletic traits. Thus, it is crucial when measuring performance in soccer-specific skill traits that sample sizes are sufficiently high and testing conditions sufficiently controlled (Ali, 2011). In our study, all our measured traits were highly repeatable when assessed over a very short period – values were strongly correlated for individual traits (0.83–0.95) as well as for the overall skill metric (0.98). Our protocol is therefore highly repeatable and detects important individual differences in soccer-specific skill performance.

Athletic traits are commonly used to assess soccer players because they are easy to integrate into training programmes. To encourage coaches to adopt skill assessments, they must be accurate, simple to conduct and beneficial for player development. We designed our protocol to meet these needs. First, the entire skill testing can be conducted within one training session, ensuring it does not interfere with the coach's normal training regimen. Second, we emphasise the use of proper technique – that used by the best players in the sport – which means that repeated practise for any of the skill tests is likely to improve player performance. Third, the tasks used in our assessment protocol are fundamental skills used frequently during a standard game of soccer, making our protocol highly relevant to overall proficiency in competitive games. Fourth, all of our skill tasks are measured in players independently from others, to ensure that other participants do not confound assessment. Finally, as much as possible, each task isolates a specific skill so we can obtain clear performance metrics for each action rather than just a single test that combines all actions in a multi-faceted test (e.g., passing, dribbling, shooting) (Wilson et al., 2014). On their own, combination tests such as those used previously (Zelenka, Seliger, & Ondrej, 1967) can make it difficult to isolate and identify problem areas for individual player, even though they may be highly repeatable and reliably distinguish between elite and non-elite players.

Although our skill protocol offers a comprehensive assessment of individual performance, we believe it could be further enhanced to form the basis of a flexible and adaptable quantitative assessment programme for any football academy or international youth development system. Basing a long-term assessment programme on just these eight skill tasks could result in a number of potential pitfalls, with the most obvious being an over-emphasis on these particular skills. In other words, players could just 'study for exam success' by only practising those specific tasks that will be regularly assessed. To circumvent this potential issue and provide a more rounded assessment model, we suggest a larger number of possible skill tasks could be designed (25–50 different tasks) and then drawn from at random on a specific testing day. For example, the pool of potential tasks could include 5–10 tasks in each of the following categories: dribbling, short-passing, long-passing, juggling and rebound-board tasks. On a particular testing day, one task from each category could be assessed. A larger diversity of tasks that could be potentially measured will more closely mimic the extensive skill sets that a player requires in game situations.

This paper identifies a reliable scientific protocol that can be used to measure individual and composite skill performance in soccer players. It is easily implemented in a single training session with minimal equipment required; and therefore, provides feasible means for coaches to identify promising players and assess individual player ability. This protocol could also be used to determine the success of training programmes that target specific skills (individual skill assessment) or overall skill improvement (composite metric). Further research should assess the sensitivity of this protocol for detecting changes in performance following training. Further studies should also compare individual metrics of skill with variation in match performance, particularly in elite competitions. In this way, sport could further borrow tools from evolutionary biology to identify the specific trait combinations that best predict success in elite competitions, providing the means to improve strategies for emerging talented youth.

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Disclosure statement

No potential conflict of interest was reported by the authors.

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