Anthropometric and fitness characteristics of international, professional and amateur male graduate soccer players from an elite youth academy

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Received 28 February 2008; received in revised form 7 July 2008; accepted 10 July 2008

Abstract

We compared anthropometric and fitness performance data from graduate male youth players from an elite soccer academy who on leaving the institution were either successful or not in progressing to higher standards of play. Altogether, 161 players were grouped according to whether they achieved international or professional status or remained amateur. Measures were taken across three age categories (under 14, 15 and 16 years of age). Players were assessed using standard measures of anthropometric and fitness characteristics. The skeletal age of players was also measured to determine maturity status. Multivariate analysis (MANCOVA) identified a significant ($p<0.001$) effect for playing status. Univariate analysis revealed a significant difference in maturity status in amateurs and professionals versus internationals ($p<0.05$), in body mass in professionals versus amateurs ($d=0.56$, $p<0.05$), in height ($d=0.85$, $p<0.01$) and maximal anaerobic power ($d=0.79$, $p<0.01$) in both professionals and internationals versus amateurs. There was also a significant difference in counter-movement jump ($d=0.53$, $p<0.05$) and 40-m sprint time ($d=0.50$, $p<0.05$) in internationals versus amateurs, as well as a significant main effect for age and playing position ($p<0.001$). Significant differences were reported for maturity status, body mass, height, peak concentric torque, maximal anaerobic power, and sprint and jump performance with results dependant on age category and playing position. These results suggest that anthropometric and fitness assessments of elite youth soccer players can play a part in determining their chances of proceeding to higher achievement levels.

Keywords: Football; Development; Talent; Maturity; Performance

1. Introduction

In elite soccer, coaches are constantly seeking the most effective formula for identifying and developing talented young players.\textsuperscript{1} In this respect, the role of the youth academy is vital in the long-term development of soccer players. Yet, different factors may predispose individuals towards a successful career in professional soccer and determining the traits that discriminate between performers may be difficult. When investigating youth soccer, researchers have typically undertaken comparisons between elite and sub-elite players or between already highly selected players exposed to systematic training. Researchers focusing on such groups have attempted to establish the distinguishing features of expertise and to identify the factors that determine a player’s potential to progress to higher levels of play.

Injury risk,\textsuperscript{2} training history and match experience,\textsuperscript{3,4} psychological,\textsuperscript{5} technical,\textsuperscript{6} motor,\textsuperscript{7} and perceptual-cognitive,\textsuperscript{8} skills have been investigated as predictors of expertise and successful performance in youth soccer. Additionally, anthropometric and physiological characteristics,\textsuperscript{9–11} maturity status\textsuperscript{12,13} and the influence of the period during the selection year in which players are born,\textsuperscript{14} have been shown to be predictors of success in young soccer players. As research is generally cross-sectional in nature, there is a need for a longitudinal approach to help talent prediction and development.\textsuperscript{15} Nevertheless, it is clear that the requirements for play are multifactorial and the distinguishing characteristics of elite players need to be investigated using multivariate analysis.\textsuperscript{5,16}
approach to compare the anthropometric and physical characteristics of male youth soccer players from an elite French development centre who upon graduation were either successful or unsuccessful in progressing to professional status.

2. Methods

A total of 161 elite youth soccer players attending the Clairefontaine Institut National du Football (National Institute of Football) participated. Participants were assessed over an 11-year period (1994–2005). The Institute is a pre-apprenticeship centre and has a 3-year residency policy which segregates players into three age categories: 1st year (under 14 years), 2nd year (under 15 years) and 3rd year (under 16 years). Some players were released or joined after the first year and therefore did not complete the 3-year residency. Those players who graduated either joined a professional club or continued to play soccer at amateur level. Some professionals were selected to play at international level. For the purposes of this study, players after graduating from the centre were divided into three cohorts for comparison: (1) ‘internationals’, players who succeeded in playing at least one match at full-international level and/or under 21 level (all were also full-time professionals); (2) ‘professionals’, players who succeeded in signing a contract with a professional club and who played at least one match as a full-time professional; and (3) ‘amateurs’, players who did not acquire a professional contract.

Consent forms were completed for each participant by a parent or guardian. Ethics approval was obtained from the Fédération Française de Football. Playing position was recorded for each participant as goalkeeper, defender, midfielder or forward. A total of 23 goalkeepers, 32 defenders, 61 midfielders and 45 forwards participated. All players performed a battery of fitness tests at the beginning of the competitive season, before the pre-season training period, as part of their respective training programmes. The assessment of biological maturity status via skeletal age was carried out as part of the Institute’s pre-participation screening programme. To ensure standardisation of test administration across the entire study period, all tests were scheduled at the same time of day and carried out in the same order and using the same apparatus. All procedures over the entire study period were undertaken by the same physician who specialised in sports medicine. Each test was preceded by a standardised warm-up and familiarisation session. Participants were instructed to refrain from strenuous exercise for at least 48 h prior to the fitness test session and consume their normal pre-training diet prior to the session.

Measurements for each participant in each age category were undertaken according to two main categories: anthropometric and fitness performance. The biological maturity status of each player was also recorded. The procedures in each element of assessment are described in turn.

Participants’ height was measured with a fixed stadiometer (Holtain Ltd., Crymych, Dyfed) and mass with a Seca beam balance (Seca, Hamburg, Germany). As an estimate of adiposity, skinfold thickness was measured at four sites on the left-side of the body using a Harpenden skinfold caliper (British Indicators Ltd., Luton). Measures taken at four sites (triceps, biceps, subscapular and suprailiac) were used for the calculation of percent body fat according to the equations previously described by Durnin and Wormersley.17

The sprint performance of players was evaluated from a standing start over distances of 10, 20 and 40 m, respectively, using single-beam electronic timing gates (Tag Heuer, Switzerland). Two efforts with a 10-min interval were undertaken with data from the fastest 40-m effort being recorded (along with the corresponding times over 10 and 20 m). The recorded time over the last 10 m of the fastest 40-m sprint was used to derive each individual’s maximal anaerobic power output.18 Players also performed a vertical jump (counter-movement jump with arm swing) to determine lower body explosive strength. Three jumps were undertaken on a jump mat (Ergojump, Magica, Italy), with data from the best effort being recorded. The strength of the knee flexors and extensors of both the dominant and non-dominant legs was measured on a Cybex 340 isokinetic dynamometer (Cybex, New York, USA). Strength was assessed by determining the peak concentric torque at 1.05 and 4.19 rad s⁻¹. Three maximal voluntary repetitions were undertaken, with test order proceeding from the slower to the faster speed. Peak torque data were normalised with respect to lean body mass. The estimated $V_{O2max}$ values were calculated using a continuous progressive track run test.19

A standard radiological examination of the left hand and wrist of each player was carried out at the beginning of the season to determine skeletal age using the matching atlas of Greulich and Pyle.20 The Greulich–Pyle method is used internationally as a standard method for determining skeletal age. It has been shown to be both appropriate and reliable.21 and provides a simple and quick means of obtaining skeletal age.22 Skeletal age is an indicator of biological maturity status and players were classed according to the individuals’ skeletal age compared with their chronological age.16 A positive score indicates that skeletal age is in advance of chronological age, whereas a negative score indicates that skeletal age lags behind chronological age.12

The data are expressed as means and standard deviations (mean ± S.D.) for the groups of international, professional and amateur players on the 17 dependant variables (height, mass, percentage body fat, 10, 20, 40-m sprint, maximal anaerobic power, counter-movement jump, peak concentric torque at 1.05 and 4.19 rad s⁻¹ for hamstrings and quadriceps of both the dominant and non-dominant legs and estimated aerobic power).

Two different sets of analysis were undertaken. First, the dataset was analysed using a two-way multivariate analyses of co-variance (MANCOVA) in which playing status (international, professional and amateur) and age (U14, U15 and...
Table 1
Biological maturity, anthropometric and fitness characteristics of elite youth soccer players across three age categories

<table>
<thead>
<tr>
<th></th>
<th>Under 14</th>
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<th>Under 15</th>
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<th>Under 16</th>
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<tbody>
<tr>
<td></td>
<td>Internals</td>
<td>Professionals</td>
<td>Amateurs</td>
<td>Internals</td>
<td>Professionals</td>
<td>Amateurs</td>
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<td></td>
<td>n = 16</td>
<td>n = 56</td>
<td>n = 89</td>
<td>n = 16</td>
<td>n = 54</td>
<td>n = 76</td>
</tr>
<tr>
<td>Chronological age (years)</td>
<td>13.4 ± 0.4</td>
<td>13.6 ± 0.4</td>
<td>13.5 ± 0.5</td>
<td>14.4 ± 0.4</td>
<td>14.5 ± 0.4</td>
<td>14.4 ± 0.4</td>
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<tr>
<td>Skeletal age (years)</td>
<td>13.2 ± 1.1</td>
<td>13.7 ± 1.1</td>
<td>13.9 ± 1.5</td>
<td>14.3 ± 1.5</td>
<td>14.9 ± 1.4</td>
<td>15.3 ± 1.7</td>
</tr>
<tr>
<td>Skeletal age–chronological age (years)</td>
<td>6.0 ± 1.1</td>
<td>0.1 ± 1.2</td>
<td>0.4 ± 1.4</td>
<td>0.1 ± 1.5</td>
<td>0.4 ± 1.4</td>
<td>0.9 ± 1.6</td>
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<tr>
<td>Anthropometry</td>
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<tr>
<td>Mass (kg)</td>
<td>52.5 ± 9.9</td>
<td>53.8 ± 9.5</td>
<td>50.8 ± 9.2</td>
<td>59.3 ± 10.3</td>
<td>60.3 ± 9.2</td>
<td>58.4 ± 9.2</td>
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<tr>
<td>Height (cm)</td>
<td>165.2 ± 10.5</td>
<td>165.0 ± 8.8</td>
<td>162.1 ± 9.0</td>
<td>171.5 ± 9.4</td>
<td>170.8 ± 8.0</td>
<td>169.1 ± 8.2</td>
</tr>
<tr>
<td>Body fat (%)</td>
<td>11.9 ± 1.42</td>
<td>12.5 ± 2.6</td>
<td>12.4 ± 2.3</td>
<td>11.6 ± 1.8</td>
<td>13.0 ± 5.0</td>
<td>12.6 ± 2.52</td>
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<tr>
<td>Physiological</td>
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<tr>
<td>Vertical jump (cm)</td>
<td>43.7 ± 7.25</td>
<td>42.6 ± 5.8</td>
<td>42.8 ± 5.5</td>
<td>47.9 ± 6.1</td>
<td>46.3 ± 5.5</td>
<td>45.1 ± 5.3</td>
</tr>
<tr>
<td>10-m Sprint (s)</td>
<td>1.96 ± 0.10</td>
<td>1.95 ± 0.09</td>
<td>1.96 ± 0.08</td>
<td>1.87 ± 0.08</td>
<td>1.89 ± 0.08</td>
<td>1.89 ± 0.07</td>
</tr>
<tr>
<td>20-m Sprint (s)</td>
<td>3.34 ± 0.14</td>
<td>3.32 ± 0.14</td>
<td>3.33 ± 0.14</td>
<td>3.17 ± 0.13</td>
<td>3.20 ± 0.14</td>
<td>3.22 ± 0.11</td>
</tr>
<tr>
<td>40-m Sprint (s)</td>
<td>5.88 ± 0.29</td>
<td>5.91 ± 0.29</td>
<td>5.91 ± 0.28</td>
<td>5.52 ± 0.40</td>
<td>5.63 ± 0.26</td>
<td>5.69 ± 0.23</td>
</tr>
<tr>
<td>Maximal anaerobic power (W)</td>
<td>1718 ± 529</td>
<td>1698 ± 489</td>
<td>1606 ± 490</td>
<td>2308 ± 684</td>
<td>2248 ± 601</td>
<td>2091 ± 557</td>
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<tr>
<td>Peak torque (Nm kg\textsuperscript{-1})</td>
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<tr>
<td>Hamstring</td>
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<tr>
<td>1.05 rad s\textsuperscript{-1} Dominant leg</td>
<td>2.5 ± 0.4</td>
<td>2.48 ± 0.36</td>
<td>2.52 ± 0.36</td>
<td>2.76 ± 0.29</td>
<td>2.61 ± 0.48</td>
<td>2.67 ± 0.38</td>
</tr>
<tr>
<td>4.19 rad s\textsuperscript{-1} Dominant leg</td>
<td>1.9 ± 0.3</td>
<td>1.80 ± 0.36</td>
<td>1.83 ± 0.25</td>
<td>2.02 ± 0.25</td>
<td>1.91 ± 0.38</td>
<td>1.94 ± 0.29</td>
</tr>
<tr>
<td>1.05 rad s\textsuperscript{-1} Non-dominant leg</td>
<td>2.5 ± 0.3</td>
<td>2.42 ± 0.44</td>
<td>2.47 ± 0.30</td>
<td>2.59 ± 0.37</td>
<td>2.57 ± 0.46</td>
<td>2.54 ± 0.34</td>
</tr>
<tr>
<td>4.19 rad s\textsuperscript{-1} Non-dominant leg</td>
<td>1.8 ± 0.3</td>
<td>1.71 ± 0.35</td>
<td>1.77 ± 0.24</td>
<td>1.91 ± 0.33</td>
<td>1.81 ± 0.33</td>
<td>1.86 ± 0.27</td>
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<tr>
<td>Quadriceps</td>
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<tr>
<td>1.05 rad s\textsuperscript{-1} Dominant leg</td>
<td>3.5 ± 0.6</td>
<td>3.5 ± 0.6</td>
<td>3.5 ± 0.6</td>
<td>3.5 ± 0.6</td>
<td>3.6 ± 0.7</td>
<td>3.6 ± 0.4</td>
</tr>
<tr>
<td>4.19 rad s\textsuperscript{-1} Dominant leg</td>
<td>2.0 ± 0.4</td>
<td>2.1 ± 0.3</td>
<td>2.0 ± 0.3</td>
<td>2.1 ± 0.4</td>
<td>2.1 ± 0.4</td>
<td>2.2 ± 0.3</td>
</tr>
<tr>
<td>1.05 rad s\textsuperscript{-1} Non-dominant leg</td>
<td>3.3 ± 0.5</td>
<td>3.5 ± 0.7</td>
<td>3.6 ± 0.4</td>
<td>3.5 ± 0.7</td>
<td>3.6 ± 0.7</td>
<td>3.5 ± 0.5</td>
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<tr>
<td>4.19 rad s\textsuperscript{-1} Non-dominant leg</td>
<td>2.0 ± 0.3</td>
<td>2.1 ± 0.4</td>
<td>2.1 ± 0.3</td>
<td>2.1 ± 0.4</td>
<td>2.2 ± 0.3</td>
<td>2.2 ± 0.3</td>
</tr>
<tr>
<td>VO\textsubscript{2max} (ml/(kg·min))</td>
<td>59.2 ± 3.2</td>
<td>58.2 ± 2.69</td>
<td>57.8 ± 2.8</td>
<td>61.5 ± 3.87</td>
<td>59.9 ± 2.7</td>
<td>60.1 ± 3.6</td>
</tr>
</tbody>
</table>

All data are expressed as mean ± S.D.

\textsuperscript{a} Significantly different (p < 0.05) from internationals.

\textsuperscript{b} Significantly different (p < 0.05) from amateurs.
U16) were the between-participant variables. As described by Vaeyens et al., maturation (the difference between skeletal and chronological age) was used as the covariate. All 17 dependent measures were included in the analysis. Second, professionals (including internationals due to the small sample size) and amateurs were compared for differences across positional groups (goalkeeper, defender, midfielder and forwards). All age categories were combined. A two-way MANCOVA was employed in which playing status (professional, amateur) and position (goalkeeper, defender, midfielder and forwards) were the between-participant factors and maturation the covariate. All 17 dependent measures were included in the analysis. The level of significance was set at \( p < 0.05 \). Follow-up univariate analyses using Bonferroni-corrected pair wise comparisons were used where appropriate. Cohen’s effect size \((d)\) conventions were used for small \((0.25)\), medium \((0.5)\) and large \((0.8)\) comparative effects. All calculations were performed using Microsoft Excel (Version 2003, Microsoft, Seattle, WA) and Statistica Version 8 (Statsoft, Tulsa, OK).

3. Results

Over the 10-year study period, 56 players succeeded in turning professional, 16 played international soccer, whereas 89 players did not progress to higher levels of play. Altogether, full datasets for the 3-year residency were available for a total of 115 players, whereas the other players completed either one or two full years at the Institute. The descriptive characteristics of the participants are presented in Table 1.

The first analysis revealed significant main effects for playing status, \( F(34, 644) = 3.28 \), Wilks’ lambda = .85, \( p < 0.001 \), and age, \( F(34, 644) = 7.44 \), Wilks’ lambda = .51, \( p < 0.001 \). There was no interaction between age and playing status, \( F(68, 1265) = .77 \), Wilks’ lambda = .85, \( p > 0.05 \). Follow-up analyses revealed a significant difference in maturity status in the amateurs versus internationals and professionals versus internationals \((d = 0.87, p < 0.01)\), in body mass in the professional versus amateur groups \((d = 0.56, p < 0.05)\), in height \((d = 0.85, p < 0.01)\) and maximal anaerobic power \((d = 0.79, p < 0.01)\) in both professionals and internationals versus amateurs, and counter-movement jump \((d = 0.53, p < 0.05)\) and 40-m sprint time \((d = 0.50, p < 0.05)\) in internationals versus the amateurs. Similarly, there was a significant difference in maturity status in the U15 \((d = 0.49, p < 0.05)\) and U16 age category \((d = 0.56, p < 0.05)\) in amateurs compared to internationals. In the U16 category, there was a significant difference in both height \((d = 0.59, p < 0.05)\) and maximal anaerobic power \((d = 0.49, p < 0.05)\) in the internationals versus the amateurs.

The second analysis showed significant main effects for playing status, \( F(17, 323) = 3.94 \), Wilks’ lambda = .82, \( p < 0.001 \), and playing position, \( F(51, 962) = 4.81 \), Wilks’ lambda = .50, \( p < 0.001 \). Also, there was a significant interaction between playing status and position, \( F(51, 962) = 1.37 \), Wilks’ lambda = .81, \( p < 0.01 \). Significantly greater differences for body mass \((d = 0.72, p < 0.01)\), maximal anaerobic power \((d = 0.45, p < 0.05)\) preferred \((d = 0.60, p < 0.05)\) and non-preferred \((d = 0.84, p < 0.01)\) leg peak hamstring torque at 4.19 rad s\(^{-1}\) and sprint time over distances of 10 \((d = 0.50, p < 0.05)\) and 20 m \((d = 0.47, p < 0.05)\) were observed in professional versus amateur goalkeepers. Defenders in the professional group demonstrated significantly higher values for body mass \((d = 0.51, p < 0.05)\), height \((d = 0.66, p < 0.05)\) and maximal anaerobic power \((d = 0.64, p < 0.05)\) versus amateurs. In the professional group, significant differences were reported for maximal anaerobic power values in midfielders \((d = 0.62, p < 0.05)\) and for counter-movement jump in the forwards \((d = 0.50, p < 0.05)\) compared to amateurs.

4. Discussion

In the present study, anthropometric and fitness characteristics profiles were compared across three age categories in academy-based elite youth soccer players. Superior performance was demonstrated on several of the anthropometric and fitness measures across the three combined age categories in players who were successful in attaining international or professional level compared to players who remained amateur. While results were dependant on age category and playing position, they did not distinguish consistently between professionals and internationals (although internationals demonstrated a trend towards superior performance in nine out of 14 fitness tests).

While the present findings agree with those of Vaeyens et al. in that performance characteristics vary according to age group, they contradict to some extent those observed in the only other study based on elite academy soccer players by Franks et al. These authors compared those from the Football Association’s National Centre of Excellence who succeeded in signing a contract as a full-time professional and those who did not acquire a professional contract on graduation. Players could not be discriminated on the basis of anthropometry or sprint performance, although these players were clearly distinguished from a non-elite, age-matched group. It was concluded that it can be difficult to separate players already highly selected and exposed to systematic training and other more complex factors may determine the players’ employability as professionals. The lack of agreement between the present findings and those of Franks et al. could be explained by cultural differences in talent identification and development. However, while differences across measures were identified in the present study between professionals and amateurs, the lack of significant differences between professionals and internationals would support to a certain extent the findings of Franks et al. in that these factors may not be the most discriminating at the very highest level.

In accordance with previous reports on elite youth soccer players, the difference between skeletal age and chronological age across all groups indicates that players
were generally classed as average maturers. Amateur players were generally more advanced compared to the other groups in terms of maturity status although professionals were also ahead compared to international peers. This observation in amateur players is of particular interest: although these players were generally more advanced in terms of maturity, and theoretically in physical precocity, inferior performances were observed in this group across most of the evaluated characteristics, which contrasts with a previous report on youth soccer players. It is difficult to suggest reasons for this finding and further research on the current dataset is required to estimate the contribution of maturity status to variation in functional performances. However, it has been reported that elite, 14-year-old soccer players who demonstrate advanced maturity have much less potential for growth and development of strength and therefore have a reduced margin for progression compared to players who are behind in maturity. This fact may partly explain the reasons for non-selection of the amateur players.

Previous reports on youth soccer players have disclosed significant differences in anthropometric and fitness measures between both standards of play and across playing positions. In the present study, players attaining higher levels of play and especially those in defensive roles (goalkeepers and defenders) were differentiated in terms of anthropometric measures and particularly in height and/or body mass from their amateur peers. This result supports the findings of Gil et al. who indicated that body size is an important criterion in talent selection. High anaerobic capacities are also desirable for success in top-class soccer and are decisive in critical match events. The present data suggest that maximal sprint speed, maximal anaerobic power, peak torque and jumping capacity can discriminate across various age categories and/or playing positions between youth players who are successful or not in achieving the highest standards of play. These results also suggest that performance assessment can play an important role in player selection and confirm the conclusions of Jankovic et al. in that measures of physical performance are useful in predicting later success in soccer. However, in the present players, significant differences in the anthropometric and fitness measures between playing standards were only observed at U16 level. This finding strengthens the conclusions of Vaeyens et al. which suggested that discriminating characteristics of fitness change with competitive age levels. It also suggests a need for further investigation into the relevance of specific fitness training protocols and tests at different ages during adolescence.

We acknowledge two limitations of this study. First, the Institute is a ‘feeder’ academy for professional clubs and players graduate at 16 years of age. It would therefore be relevant to follow and compare measures through the participants’ later years of development. Many of the physical qualities that distinguish between players may not be apparent until late adolescence, although any further improvements in professional players may be confounded due to prolonged training. Second, the number of tests conducted was limited because the test session was completed in the pre-season phase when there were high demands on training time. Agility, repeated-sprint ability, dribbling and anticipation skill are other discriminating factors between youth players of different standards and positions. Finally, it would also be desirable to measure physiological capacities directly rather than rely on performance-based estimates.

5. Conclusion

While talent selection is based on many aspects of performance, the present results suggest that certain fitness assessment data are important in determining whether already highly selected elite youth soccer players are successful or not in ascending to higher standards of play. Such measures may not be sensitive enough to be used reliably on their own for talent identification and selection purposes. Future analyses could therefore embrace areas such as players’ mental and technical skills or practice history profiles to provide an even more comprehensive model for defining the prerequisites for professional and international soccer.

Practical implications

- Practitioners should consider fitness characteristics in the development of elite youth soccer players and that performance on tests of these characteristics can vary according to age category and playing position.
- Measures of fitness characteristics can help to discriminate players already selected and exposed to systematic training and may provide a basis for employing objective criteria in respect to player selection and development.
- Age-specific reference values from this sample of youth soccer players may be useful for trainers and coaches in both the talent evaluation and development processes.

Acknowledgements

The authors would like to thank the physiotherapists at the INF for their help in the collection of data. No financial assistance was obtained for this project.

References