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*Original Research*

# Influence of Upper and Lower Body Anthropometric Measures on An Aggregate Physical Performance Score in Young Elite Male Soccer Players: A Case Study

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**Abstract**

**Background**: The present study aimed to determine the association of anthropometry-based characteristics with an aggregate score (AS) of physical performance in young elite soccer players. **Methods**: Sixteen under 15 elite players were enrolled. Among numerous anthropometrics variables, upper arm contracted (UACC) and relaxed circumference (UARC), corrected arm muscle area (AMAcorr), arm muscle circumference (AMC), thigh muscle circumference (TMC) and suprapatellar girths were also employed in this study. Players' physical performance was assessed by the change of direction (COD), 10 m and 20 m sprint, countermovement jump (CMJ) test, sprint with 90° turns (with ball), and yo-yo intermittent recovery test level 1 (Yo-Yo IRT1). The AS was computed by Principal Components Analysis technique with one component on normalized performance results. A stepwise regression analysis was conducted to assess potential association between anthropometry-based variables and AS. **Results**: Large negative correlations (r < –0.68) of AS with UACC, UARC, AMAcorr, and AMC were detected. UACC and TMC permits to accurately estimate AS explaining 60% of the total variance ($p < 0.001$). **Conclusions**: These findings demonstrated the importance of including anthropometry-based measures of both upper and lower body to the physical performance potential expressed by AS in elite youth soccer.

**Keywords:** soccer; youth; body composition; morphology; physical performance

## 1. Introduction

Anthropometry is of great importance in soccer performance [1] and health [2–4], especially when dealing with youngsters [5]. During growth, players undergo several morphological (e.g., upper and lower limb sizes) and body composition variations (e.g., balancing from low-to-high level of fat and lean mass) capable to characterize the way a young individual moves on and off the pitch [6,7]. Upper and lower limb fat areas are associated with repeated sprint ability (best and mean sprint time) [8], with the overall fat mass being apparently one of the affecting anthropometric predictors of change of direction (COD) ability [9] in young elite soccer players. While suboptimal total body composition (excessive fat mass) may contribute to also impair aerobic, sprint, and jump performance [10,11], the size of upper limbs appeared to be associated to a better sprint performance [9]. Accordingly, arm muscle and mid-upper arm circumferences were previously reported among the best predictors of 10 m and 20 m sprint performance in under 15 elite soccer players [9].

The nature of soccer performance is multidimensional having the young players being already required to cope with many demands underpinning certain muscle strength and power [12], agility and CODs [13], brief sprints [14], jumps [13], and aerobic [15] qualities. Altogether, these qualities identify the focus of field-based training along with technical and tactical stimuli to be addressed in order to keep each player fit, healthy, and competitive as much as possible. From a practical perspective, the idea to manage the training process by monitoring the multidimensional performance (holistically) can work to the advantage of practitioners [16], especially if information based on an individual's anthropometric measures (e.g., morphological data of upper and lower limbs) can be associated. To date, most of the studies established significantly relationships between morphology and body composition with aerobic fitness [8–10,17,18], repeated sprint ability [8], straight sprint [8,9,17] and vertical jump [8,9,17] performance as separate measures (single score) without formulating an holistic information (aggregate score) about the potential association between anthropometry and an overall players' physical performance status. Additional knowledge on such association might be useful to develop training programs aimed to improve the athleticism and health of young soccer players.

Therefore, the aim of this study was to determine the association of anthropometric-based characteristics with an aggregate score (AS) of physical performance in young elite soccer players.

## 2. Materials and Methods

### *2.1 Design*

A Cross-sectional design was employed in order to provide information on the potential association of anthropometry and physical performance at a given time [19].

### *2.2 Participants*

Sixteen males under 15 elite soccer players (ages 14.0 ± 1.3 years, body weight 63.4 ± 6.4 kg, height 175.8 ± 5.8 cm, fat mass = 10.56 ± 1.44%, fat-free mass = 89.44 ± 1.44%) voluntarily participated in the study. All players were part of the same soccer academy of an Italian professional club (Serie A division). Soccer training experience (~6.0 ± 1.0 year) and weekly training routine (4 sessions and a week-end match) were similar among the players. All the participants were informed about the experimental risks and procedures. They verbally agreed and provided a written consent along with their parents. The study procedures were approved by the Ethics Committee of the local University.

### *2.3 Procedures*

The experimental setting and procedures took place in June. All participants were tested twice with at least 48 h in between. In the first occasion, among several anthropometric measurements, body mass and height were also included in the assessment. In the second occasion, all the participants underwent a testing battery encompassing, sprint, vertical jump, COD ability, dribbling, and aerobic performance assessment. They were instructed to avoid any moderate-to-high-intensity physical efforts in the 2 days before as well as abstaining from consuming caffeinated drinks in the 24 h prior testing.

### *2.4 Morphological Data Assessment*

The morphological data assessment included the: (1) the direct measurement of upper arm relaxed (UARC) and contracted (UACC) circumference, waist (WC) and hip (HC) circumferences, suprapatellar girths (SPG) derived from both right and left legs, sum of 8 skinfolds (Σ8 SKF) (retrieved from adding triceps, subscapular, biceps, iliac crest, supraspinal, abdominal, anterior thigh, and medial calf thickness), sum of 4 skinfold (Σ4 SKF) (retrieved from adding anterior thigh, abdominal, triceps, and medial calf thickness), and the sum of 2 skinfold (Σ2 SKF) (retrieved from adding triceps and subscapular thickness) for each participant. Then, fat mass was obtained by SKF measures and subtracted from body mass to derive fat-free mass (FFM) following a recent approach [20]; (2) the indirect measurement of upper arm muscle (AMA) and thigh muscle (TMA) areas, upper arm fat (AFA) and thigh fat (TFA) areas, arm muscle (AMC) and thigh muscle (TMC) circumferences [21] for each participant. Additionally, a corrected value of AMA (AMAcorr) was also computed by the Heymsfield's equation. Circumference, girths, and skinfolds were measured to the nearest of 0.1 cm (by a tape, Lufkin executive thinline, W606ME) and 0.1 mm (by a skinfold caliper, Holtain Ltd, Crymych, UK), respectively. A certified professional performed all the measurements as previously reported [9].

### *2.5 Physical Performance Assessment*

Physical performance assessment included the following tests: 10 m and 20 m sprint, countermovement jump (CMJ) test, change of direction (COD) ability, sprint with 90° turns (with ball), and yo-yo intermittent recovery test level 1 (Yo-Yo IRT1). This testing order was chosen to avoid potential fatigue-related effects while also planning an adequate recovery period of 10 min between each test [13]. Except to Yo-Yo IRT1, running/sprinting-based tests were conducted using an electronic timing gates system (Microgate, Bolzano, Italy) to detect time performance. All tests were conducted outdoor on an artificial turf at the same time of day for each participant.

Sprint performance. Sprinting time over 10 m (split time, from 0 m to 10 m) and 20 m sprint were recorded at the same time. At their volition, the participants started accelerating maximally up to 20 m. There were allowed three trials with a 2 min recovery in between. The best time recorded at 10 m and 20 m were integrated to the analysis.

Vertical jump. The participants performed a countermovement jump (CMJ) test to indirectly record vertical jump height by the Optojump next system (Optojump Next System, Microgate, Bolzano, Italy). During the trial, they were asked to jump keeping their hands on the hips without bending the legs from take-off and landing phase. There were planned three CMJ trials interspersed by 2 min of recovery, and the highest jump trial was used for the analysis

COD ability. COD ability was tested over a 5 m + 5 m course with a turning point (90°) represented by a cone. For a better description of the test please refer to the work of Trecroci *et al*. [22]. The distance between the starting line to the cone and between the cone to the finish line was 5 m each. The participants changed direction around the cone using the same side-step technique in each bout. There were planned 3 bouts in each direction and the average best performance (between right and left directions) time was considered. A 2 min recovery period was given between each bout. Then, together with the 10 m sprint time were used to calculate the COD deficit. Specifically, it was possible by subtracting the 10 m sprint time from the average best performance time. As previously suggested, COD deficit has the potential to assess an actual COD ability unbiased toward linear sprint capacity [23,24].

Dribbling skill. To assess players' dribbling skill was employed the sprint test with 90° turns whit ball (S90 with ball). All participants were asked to perform six 90° turns as fast as possible around six markers, within a 15 m course. For a better description of the test layout refer to the original work by Sporis *et al*. [25]. There were planned 3 trials while dribbling the ball with 2 min recovery period in between. The best performance time was integrated in the analysis.

Aerobic performance. Yo-yo intermittent recovery test level 1 (Yo-Yo IRT1) test was performed to assess player's aerobic performance. The test consists of 2 × 20 m shuttle runs at increasing speeds, interspersed with 10 s of active recovery, controlled by audio signals according to the guidelines by Bangsbo *et al*. [26]. Once a participant was no longer able to maintain the required speed the test ended. At this stage, the distance achieved was recorded and integrated in the analysis.

### *2.6 Statistical Analysis*

Data distribution was verified by the Shapiro Wilk's test for each variable. Intra-class Correlation Coefficient (ICC – 3,1) was computed for reliability purposes. The aggregate physical performance score (AS) was computed by Principal Components Analysis (PCA) technique on normalized (min-max scaler approach) performance results. A stepwise regression with forward propagation analysis was conducted to assess potential association between anthropometry-based variables and AS. Statistical analysis was performed using Python 3.8 language programming, and the IBM SPSS Statistics software (v. 21, New York, NY, USA). The statistical significance was set at 0.05 (5%).

## 3. Results

ICC values showed good-to-high reliability within the physical performance test ranging from 0.89 to 0.94. The AS score created by three components PCA explained 94% of the total variance of the performance test. Strong negative correlation was detected between AS score and sprint 10 m (r = –0.98, $p < 0.001$), sprint 20 m (r = –0.95, $p < 0.001$), CMJ (r = –0.89, $p < 0.001$), and COD (r = –0.80, $p < 0.001$), respectively. Moreover, low correlation coefficient was detected between AS score and Yo-Yo IRT1 test (r = –0.05, $p > 0.1$), and S90 with ball (r = –0.40, $p > 0.05$). Correlation analysis between AS score and morphological data was reported in Fig. 1. In particular, AS score was negatively correlated with morphological data such as UACC (r = –0.75, $p < 0.001$), UARC (r = –0.68, $p < 0.05$), AMA (r = –0.68, $p < 0.05$), and AMC (r = –0.68, $p < 0.05$). Table 1 and Eqn. 1 shows the stepwise linear regression outcome. Specifically, only UACC and TMC were included in the final model as the best predictors of the AS. Both variables explained 60% of the AS variance ($p < 0.001$).

**Table 1. Stepwise linear regression analysis.**

| Predictor | Coefficient | t-score | *p*-value |
|---|---|---|---|
| Constant | 3.572 ± 1.605 | 2.226 | 0.044 |
| UACC | –0.278 ± 0.061 | –4.549 | 0.001 |
| TMC | 0.089 ± 0.046 | 2.925 | 0.036 |

Note: UACC, upper arm contracted circumference; TMC, thigh muscle circumference.

$$AS = 3.572 - 0.278 \times UACC \times -0.278 + 0.089 \times TMC \quad (1)$$

## 4. Discussion

The main findings of this study revealed that UACC and TMC predicted the AS in young elite soccer players. In other words, measures of upper and lower limbs were informative enough to explain most of the variance of a holistic performance underpinning short sprints, vertical jump, COD, dribbling, and aerobic performance qualities. To the extent of the authors' knowledge, this is the first study taking into account the potential association between anthropometric measures and an overall physical performance status in youth elite soccer.

Most of the studies investigated the informative role of anthropometric assessment on several aspects of performance on an individual level [8–10,17,18]. However, the present finding appears in line with that previously observed by the mentioned studies. For instance, Bongiovanni and colleagues demonstrated that the upper and lower body anthropometric features were strictly related to sprint and aerobic fitness performance in U15 elite male soccer players [9]. Moreover, they reported that morphological features linked to specific body regions (upper and lower limb) may be preferred over whole body measures to interpret male players' physical potential in vertical jump and sprint performance [27,28]. In keeping with this, it has been demonstrated that regional (lower limb), rather than total body composition (i.e., bioimpedance-related parameters), was more susceptible to changes in response to a training period along with physical performance improvement (i.e., vertical jump and aerobic fitness) [29]. All together these findings lead to assume that controlling for regional anthropometric parameters (morphological or body composition parameters) could improve the understanding of the association between "body recomposition" [30] and performance linked to the efficacy of specific targeted training programs.

How the overall physical performance status is associated with upper and lower limb variables (i.e., UACC and TMC, respectively) opens an interesting methodological assessment front. For instance, obtaining UACC and TMC may be an affordable and non-invasively mean to collect information on several physical determinants of soccer performance at once. This applies well in soccer where the time available for testing is limited and field-based tests such as CMJ and Yo-Yo IRT1 may represent a practical challenge to implement, being an additional load for play-

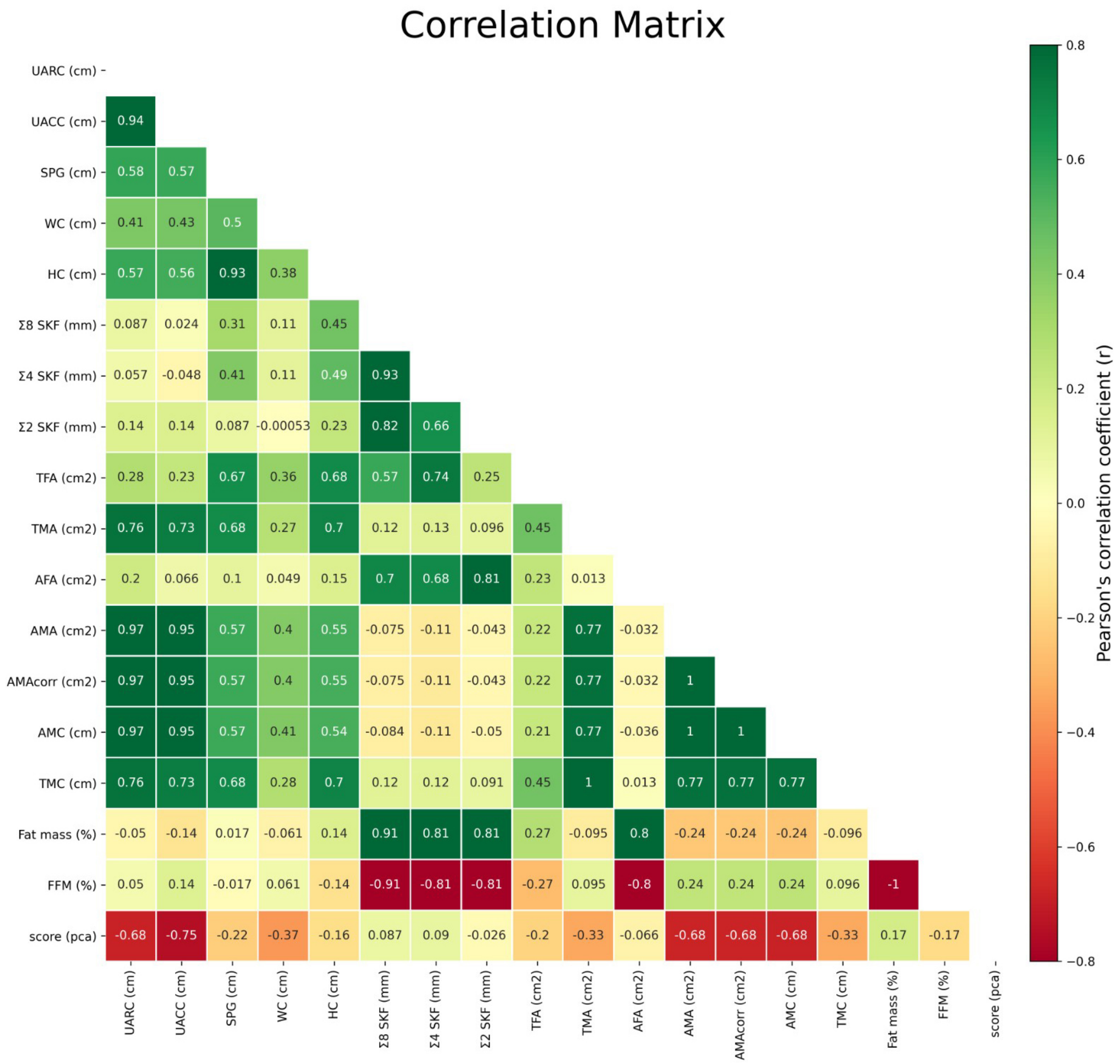


**Fig. 1. Correlation matrix on a heat map.** Note: UARC, upper arm relaxed circumference; UACC, upper arm contracted circumference; SPG, suprapatellar girth; WC, waist circumference; HC, hip circumference; Σ8 SKF, sum of 8 skinfolds; Σ4 SKF, sum of 4 skinfolds; Σ2 SKF, sum of 2 skinfolds; TFA, thigh fat area; TMA, thigh muscle area; AFA, arm fat area; AMA, arm muscle area; AMAcorr, corrected arm muscle area; AMC, arm muscle circumference; TMC, thigh, muscle circumference; FFM, fat-free mass.

ers. Conversely, no other information exist in literature to be compared, thus additional studies will have to establish the potential relationship between morphological data and different types of AS, perhaps not only derived from product-oriented scores (based on a quantitative performance score as jump height or distance covered in CMJ and Yo-Yo- IRT1, respectively) but also on more process-oriented scores embracing movement quality assessment (based on a qualitative performance scores) as athletic ability assessment [31], soccer injury movement screen [32], and functional movement screen [33,34]. Such information would contribute to monitor the components related to injury prevention and health spheres [35,36].

## 5. Study Limitations

Of note, the present study does not provide any information on potential gender difference, and it may represent a limitation. Indeed, males have greater relative lean muscles mass than females counterpart, especially in specific body regions (i.e., upper body) [37]. Accounting for such difference would provide additional and extended knowledge on the role of anthropometric (i.e., morphology and body composition) variable of upper and lower body regions on physical performance in female soccer players. This could work to the advantage of practitioners who would better support their female athletes by managing strength and lean body mass development in the attempt to improve their health and athleticism [38].

## 6. Conclusions

The current study reported that upper and lower morphological measures in terms of UACC and TMC are important predictors for the overall physical performance status in youth elite soccer. The assessment of a few anthropometric data may be very insightful to derive a holistic information of young players' physical potential. This would also allow practitioners to save time and effort while avoiding discomfort to their players of undergoing a physical testing battery within the competitive period.

## Author Contributions

AR, TB, and AT designed the research study. AR, TB, GM, LC, and AT performed the research. FMI provided help and advice on experimental procedures. AR analyzed the data. AR and AT wrote the manuscript. All authors contributed to editorial changes in the manuscript. All authors read and approved the final manuscript.

## Ethics Approval and Consent to Participate

The study procedures were approved by the Ethics Committee of the University of Milan (Approval number: 32/16).

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## Conflict of Interest

The authors declare no conflict of interest. AT is serving as one of the Guest editors of this journal. We declare that AT had no involvement in the peer review of this article and has no access to information regarding its peer review. Full responsibility for the editorial process for this article was delegated to DM.

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