A comparative study on the cardiac morphology and vertical jump height of adolescent black South African male and female amateur competitive footballers

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Abstract

Objective: The aim of this comparative study was to determine the gender differences in cardiac morphology and performance in adolescent black South African footballers.

Methods: Anthropometry, electrocardiography and echocardiography data were measured in 167 (85 males and 82 females) adolescent black South African footballers (mean age: 14.8 ± 1.3 years). Vertical jump height was used as a performance measure of explosive lower-limb power.

Results: The males had less body fat compared with the females (12.1 ± 3.6 vs 16.8 ± 4.1%, p < 0.05), while females had higher left ventricular end-diastolic diameters compared with males (48.7 ± 3.7 vs 40.7 ± 8.1, p < 0.05). Vertical jump height was higher in males (37.2 ± 10.3) compared with females (31.2 ± 8) and was inversely associated with body fat (β = −0.2, p < 0.05) and positively associated with lean mass (β = 0.5, p < 0.05).

Conclusion: The findings showed that adolescent black South African male footballers had a performance advantage over females for explosive lower-limb power, which was explained by differences in body composition and not cardiac morphology.

Keywords: adolescent, black South African, footballers, cardiac morphology, vertical jump height

Methods

Data for this comparative study of adolescent black South African footballers were collected from seven of the nine provinces (the Eastern Cape, Free State, Gauteng, KwaZulu-Natal, Limpopo, Mpumalanga and Western Cape). Participants included were within the age range of 12 to 18 years, without injury and actively involved in competitive amateur-level football. Ethical clearance for the study was granted by the University of the Witwatersrand (M140513).

Participants dressed with minimal clothing on the testing day. No shoes were worn for the anthropometric measurements. Height (m) was measured using a stadiometer (Seca 217, UK) and weight (kg) was measured using a digital scale (Seca 844, UK). Body mass index (BMI) was calculated as weight (kg)/height (m²) and presented using BMI for age guidelines.

The Omron sphygmomanometer (Canada) and accompanying stethoscope were used to measure systolic and diastolic blood pressure (BP) with the participant in a seated position after five minutes’ rest period. Three measurements were taken and the average of the second and third BP measurements was recorded. Skinfold measurements were used to determine proxy measures of body fat and muscle mass using standardised methods.

Echocardiography was performed and measures of cardiac morphology included interventricular septal (IVS) thickness, ejection fraction percentage and left ventricular end-diastolic...
Table 1. Characteristics of adolescent South African footballers by gender

| Variables | Total sample (n = 167) | Males (n = 85) | Females (n = 82) | Percentage difference* |
|-----------|------------------------|----------------|----------------|------------------------|
| Proportion (%) | 100 | 50.9 | 49.1 | 1.8 |
| Age (years) | 14.8 ± 1.3 | 15.5 ± 1.1 | 14.1 ± 1.1 | 9.5 |
| Height (m) | 1.61 ± 0.1 | 1.66 ± 0.1 | 1.56 ± 0.1 | 6.2 |
| Weight (kg) | 54 ± 8.5 | 58.3 ± 7.2 | 49.5 ± 7.3 | 16.3 |
| BMI (kg/m²) by age range | | | | |
| 12-13 years (n=27) | 19.9 ± 2.3 (26) | 20.1 ± 1 (4) | 19.8 ± 2.5 (22) | 1.5 |
| 14-15 years (n=35) | 20.7 ± 2.1 (92) | 20.9 ± 1.4 (35) | 20.5 ± 2.3 (57) | 1.9 |
| 16-17 years (n=46) | 21.1 ± 2.2 (49) | 21.3 ± 1.9 (46) | 20.7 ± 2.0 (3) | 1.9 |
| Body fat (%) | 14.4 ± 4.5 | 12.1 ± 3.6 | 16.8 ± 4.1 | 32.5 |
| Lean mass (%) | 51.4 ± 4.9 | 53.5 ± 3.9 | 48.7 ± 4.7 | 9.4 |
| Ejection fraction (%) | 64.7 ± 7.2 | 64.8 ± 7 | 63.1 ± 7.3 | 2.7 |
| IVS thickness (mm) | 9.2 ± 1.7 | 9.9 ± 1.5 | 8.4 ± 1.6 | 16.4 |
| LVED | 44.8 ± 7.5 | 48.7 ± 3.8 | 40.7 ± 8.1 | 17.9 |
| Resting heart rate (bpm) | 68.9 ± 9.8 | 65.8 ± 10.6 | 72.2 ± 7.6 | 9.3 |
| Peak heart rate (bpm) | 174.8 ± 9 | 176.2 ± 8.1 | 172.8 ± 4.8 | 2.2 |
| Systolic BP (mmHg) | 113.8 ± 10 | 117.2 ± 10.9 | 110.3 ± 7.5 | 6.1 |
| Diastolic BP (mmHg) | 71.2 ± 8.2 | 72.3 ± 8.1 | 69.3 ± 8.4 | 4.2 |
| VJH (cm) | 37.2 ± 10.3 | 43.1 ± 8.9 | 31.2 ± 8.9 | 32 |
| Trunk flexibility (cm) | 40.3 ± 4.9 | 40.3 ± 3.7 | 40.4 ± 5.9 | 0.3 |

Table 2. Pearson’s correlations for VJH, ejection fraction, IVS thickness and LVED presented by gender

| Variables | VJH | Ejection fraction | IVS thickness | LVED |
|-----------|-----|-------------------|---------------|------|
| Males Females | Males Females | Males Females | Males Females |
| Age | 0.4* 0.1 | 0.2 0.01 | -0.2 -0.1 | -0.2 -0.1 |
| BMI | 0.2 -0.1 | 0.1 0.2 | -0.2 0.1 | -0.2 0.1 |
| Body fat | -0.3* -0.4* | -0.5* 0.1 | 0.4* -0.2 | -0.1 -0.2 |
| Lean mass | 0.7* 0.7* | 0.1 -0.1 | -0.1 -0.3* | 0.1 -0.3* |
| Ejection fraction | 0.2 -0.1 | -0.4 0.5* | -0.02 0.5* |
| IVS thickness | -0.1 -0.2 | -0.4 0.5* | 0.1 0.9* |
| LVED | 0.1 -0.2 | -0.02 0.5 | 0.1 0.9* |
| Resting heart rate | -0.2 -0.3* | 0.3* -0.1 | -0.4* -0.3* | -0.1 -0.3* |
| Systolic BP | -0.1 0.2 | 0.1 -0.004 | 0.1 -0.02 | 0.03 -0.04 |
| Diastolic BP | -0.3* 0.2 | -0.1 -0.1 | 0.04 -0.5* | -0.1 -0.6* |
| VJH | 0.2 -0.1 | -0.1 -0.2 | 0.1 -0.2 |
| Trunk flexibility | -0.3* 0.2 | -0.04 0.2 | 0.1 0.2 |

Results

The participants were from Gauteng (n = 35), Kwa-Zulu Natal (n = 27), Mpumalanga (n = 36), Western Cape (n = 15), Eastern Cape (n = 19), Free State (n = 19) and Limpopo (n = 16). The mean age of the study population was 14.8 ± 1.3 years, with a mean BMI of 20.6 ± 2.4 kg/m². The female (n = 82) footballers were younger compared with the males (n = 85), and presented with significantly higher body fat measures and lower lean mass (Table 1).

Resting BP, IVS thickness and LVED were significantly higher in males compared with females; however end-diastolic volumes were similar. Flexibility did not differ between the males and females, however VJH was significantly higher in males compared with females (Table 2).

For those who had cardiac auscultation conducted (79 males and 20 females), none of the females presented with abnormal auscultation, while five of the males had functional systolic ejection murmurs (6.3%) and one had a tricuspid regurgitation murmur (3/6) (1.3%). No resting or stress ECGs showed any pathological abnormalities.

Using bivariate analysis, there was a significant positive correlation between VJH and age, and lean mass, while body fat, diastolic BP and trunk flexibility were negatively correlated in males. In females, body fat and resting heart rate were negatively correlated with VJH, while lean mass was positively correlated.
The higher lower-limb dynamic explosive power values observed in male compared with female footballers supports the well-known notion of gender functional strength differences. In this study population, however, the sociopolitical landscape of South Africa cannot be excluded as an additional source of this discrepancy.13

Despite encouraging participation in sport, policy makers fail to account for the limited resources and lack of accessibility experienced by female athletes in South Africa. There are still barriers even when there are opportunities. For example, most premier league football teams have the capability to allow for the development of adolescent footballers, but the training is often performed in the late afternoons to night-time. With personal safety being a concern, these facilities may not easily be accessible for adolescent female footballers, even if located within walking distance. Therefore female subjects may not fully engage in football training as a consequence.

The daily demands of schoolwork and other life stresses can further de-emphasise the central focus on football. In addition, incentives to participate in professional football are currently more favourable for male subjects compared with females; however, gender equality in various sports is being addressed.

Although studies have shown that the untrained female can improve cardiovascular function by participating in recreational competitive football,14 males still have a more pronounced physiological advantage over age-matched females. The diameters of the male participants’ left ventricles are similar to those of footballers of African descent living in Europe,15 suggesting some degree of genetic heritability.

On the other hand, the female participants seem to be more aligned with the adaptations experienced by volleyball athletes.16 This is evident by the finding that females have smaller heart sizes and lower left ventricular mass compared with males.17 Therefore, even though the cardiovascular adaptations to aerobic sport are similar, the absolute difference in cardiac structure is higher in male subjects. Moreover, the variation in cardiac morphology can also be explained by the fact that height is highly associated with heart size and function,18 and male subjects in our study were taller compared with females.

The vertical jump test is not only an indicator of explosive strength, but also of neuromuscular adaptation. Our study findings show that age, gender and body composition have an influence on the difference in results for this variable. Therefore, the lower VJH values in females can be explained by lower muscle mass, younger age and increased body fat.

It is worth considering the specificity of training to explain the advantage noted in males. Current knowledge shows that for optimal neuromuscular adaptation, athletes need to engage in a progressive strength-training programme, and actively challenge the neuromuscular system.16 Tendons assist with functional movement by acting as shock absorbers and energy capacitors within the muscle-tendon complex.19 Further research is needed to determine whether female footballers have lower jump height as a result of lower tendon compliance for explosive activities.

The findings of this study highlight the interconnected characteristic of the various cardiac muscle components. This points to the complexity involved in trying to comprehend cardiac development in footballers. For example, our study findings show that lean muscle mass was associated with LVED volume in the regression analyses, but football training is
seasonal, with the pre-season representing a period of strength development, while the competitive phase of the sport is typical of peak performance during match play. This suggests that the training adaptation is non-linear, but rather fluctuates depending on external exercise demand.

The level of primary sex hormones also alters during the football seasons and depends on internal (e.g. menstrual cycle in females) and external stresses (e.g. more resistance training in males, often to enhance body image). Serum testosterone levels can influence muscle architecture and function, and it is during times of peak training stress when the advantages of this anabolic hormone are most notable. In football, this usually occurs during the aerobic component of play, when the slow-twitch muscle fibres are most active. The body adapts by improving cardiac output, essentially by increasing left ventricular mass, which is more pronounced in male athletes.

The main limitation of this study is that causality could not be inferred in this comparative study, indicating the need for longitudinal studies of adolescent African footballers to confirm our findings.

**Conclusion**

This comparative study demonstrated the gender differences in performance as a result of physiological and cardiovascular advantages in male subjects. In addition, football training can remodel body composition, resulting in enhanced jumping ability, which is essential during competitive match play.

Ms Kendra Dykman and Mr Dane Schaefer captured the collected data.

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