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Anthropometric Profiling of Elite Junior and Senior Australian Football Players

James P. Veale, Alan J. Pearce, David Buttifant, and John S. Carlson

Purpose: Body structure and physical development must be addressed when preparing junior athletes for their first season in a senior competition. The aim of this preliminary study was to measure the extent of the assumption that final year junior Australian Football (AF) athletes are at a physical mismatch to their senior counterparts. ***Methods:*** Twenty-one male participants (17.71 ± 0.27 y) were recruited from one state based elite junior AF competition and forty-one male participants (22.80 ± 4.24 y) were recruited from one club competing in the senior elite Australian Football League (AFL), who were subsequently divided into two groups; professional rookies aged 18–20 y (19.44 ± 0.70 y; n = 18) and professional seniors aged 21+ y (25.43 ± 3.98 y; n = 23). Dual energy X-ray absorptiometry (DEXA) scans of all participants were completed. ***Results:*** Despite being an average 6.0% and 6.1% lighter in total weight and lean mass respectively, no significant difference was found between the elite junior athletes and their professional AFL rookie counterparts. However, significant differences were demonstrated in comparison with the professional AFL senior athletes ($P < .01$). Both professional AFL groups demonstrated greater than 0.3 kg total bone mineral content (BMC) than the elite junior athletes ($P < .01$) and significantly greater segmental BMC and bone mineral density (BMD) results ($P < .05$). ***Conclusion:*** While the results identify the differences in body composition of the elite junior athletes, development in a linear fashion is noted, providing useful information for the creation of age appropriate expectations and training programs.

Keywords: DEXA, bone mass, lean mass, bone mineral density, body composition

Profiling of elite sport athletes is a valuable means of talent identification and is critical for the development of individual strengths and weaknesses and in the design of appropriate strength and conditioning programs.[1] Commonly, athletes

James P. Veale is with the Centre for Ageing, Rehabilitation, Exercise and Sport (CARES), Victoria University, Melbourne, VIC, Australia, and the School of Sport and Exercise Science, Victoria University, Melbourne, VIC, Australia. Alan J. Pearce is with the Centre for Ageing, Rehabilitation, Exercise and Sport (CARES), Victoria University, Melbourne, VIC, Australia and the School of Sport and Exercise Science, Victoria University, Melbourne, VIC, Australia. David Buttifant is with the Collingwood Football Club, Melbourne, VIC, Australia. John S. Carlson is with the Centre for Ageing, Rehabilitation, Exercise and Sport (CARES), Victoria University, Melbourne, VIC, Australia.

across competition standards and age levels within team-sport research have all recorded greater total weight, lean mass and bone mass results, in conjunction with less total fat mass, compared with their age-matched control counterparts.[2–7] Greater whole body bone mineral content (BMC) and bone mineral density (BMD), with significantly higher levels recorded in the clinically relevant areas of the lumbar spine, femoral neck, pelvis and leg regions have also been reported within soccer players.[2,3] In a study measuring the association between physical activity and BMD development in soccer players, greater differences were generally shown between senior athletes (18–28 y) in comparison with age matched controls than was recorded by a group of junior athletes (13–17 y).[6] As the number of seasonal exercise sessions completed by the senior and junior athletes was approximately the same, the longer history of training within the older group was suggested the most likely explanation for the differences reported.[6] Nevertheless, while it remains contentious as to whether a particular body shape characterizes the likelihood of success at the professional team sport level,[8] few studies have been conducted to document the extent of any differences or map the stages of change from a junior (commonly ≤ 18 y of age) to professional rookie (commonly aged 18–21 y old during their first 2 or 3 y on a professional list) and finally professional senior athlete. As a consequence, in the absence of research identifying anthropometric profiles that characterize more successful Australian Football (AF) athletes, the current use of this factor within the talent identification (TID) process is based on face value appraisal of their assumed physical readiness or capacity for development.[1,8]

It is now recognized that the game-day physical demands of AF have increased across all field positions, with players running faster, more often and for longer distances than previously recorded.[9,10] With the increased speed of the modern game, soft-tissue and over-use injuries are reportedly on the rise in AF,[11,12] coupled with a slowly progressing increase in shoulder injuries related to the greater number or risk involved in tackling activities.[12] However, in conjunction with these game developments, anecdotal evidence suggests that younger players are being exposed to elite level senior AF quicker and earlier than ever before, despite only a four-month chronological and training age difference from their day of selection (also known as drafting) to the first round of the following senior professional season. However, although it has generally been agreed that a high percentage of athletes recruited each year are ready for senior AF based on skill level alone, it is difficult to ascertain how many are physically ready to cope with the demands of elite senior football.[13,14] Only one study within AF has compared the two population groups, reporting the lower whole body mass of selected players into one elite junior AF team in comparison with their senior counterparts.[15] Therefore, while players within junior AF competitions are still developing physically, it has been suggested that an increase in body mass accompanied with an increase in strength is the greatest challenge in physically preparing these athletes to compete at an elite senior level.[15]

Therefore, a common under-researched area within AF is the physical preparation of elite junior athletes when making the transition from junior to senior competitions. Presently, there is an absence of evidence-based research to refute or support the observation that a young athlete is ready for the physical demands of senior AF based on their current physique. While physiological measures of speed, power, endurance and agility have been broadly researched,[13,15–18] the aim of our preliminary study was to a) quantify the differences in body composition (lean mass, fat mass, BMC and BMD) between elite junior and professional AF rookie and senior athletes, and b) explore trends that exist between age-matched elite and subelite junior AF athletes.

Methods

Subjects

Fifty-seven male elite junior athletes from one state based elite junior AF competition were invited by random selection to participate in this study, of which 21 responded (17.71 ± 0.27 y); 41 male elite senior participants (22.80 ± 4.24 y) were recruited from one club competing in the Australian Football League (AFL) elite senior competition and were divided into two similar sized groups based on chronological age and training experience: 18–20 (19.44 ± 0.70 y; $n = 18$) and 21+ (25.43 ± 3.98 y; $n = 23$). For this study, athletes within their first 2 y as a professional AF athlete (18–20 y) were classified as rookies, whereas those with a greater training experience (21+ y) were classified as seniors. Furthermore, an exploratory study was conducted within the junior participants comparing elite (17.70 ± 0.23 y; $n = 11$) and subelite (17.71 ± 0.33 y; $n = 10$) groups, whereby elite athletes were classified as those who had represented their state at the Australian under 18 nationals on at least one occasion, while the subelite athletes had not. Dual energy X-ray absorptiometry (DEXA) scans of all participants were completed over a 2-wk period during the early rounds of the competitive season. All participants involved in the study were provided with verbal and written communications of the study's requirements and gave informed consent before their participation. Ethical approval was granted by the University Human Research Ethics Committee and in accordance with the Declaration of Helsinki, each volunteer and parent provided written informed consent.

Test Procedures

Using a Hologic QDR 4000/W fan beam DEXA scanner (software version APEX 2.3, Waltham, MA), whole-body scans were used to calculate lean body mass (kg), body fat (kg), total bone area (cm^2), BMC (kg) and BMD ($g \cdot cm^{-2}$).[3] Fat-free lean mass in the limbs only was assumed to be a surrogate measure of muscle mass.[19] The total body scans were divided into subregions, following the methodology of Calbet et al.[3] Previous research has reported laboratory precision errors for regional analysis of the complete body scan, defined by the coefficient of variation (CV) for repeated measures estimated in young volunteers with repositioning: BMC < 3.5%, BMD < 4%, bone area < 4.8%, and fat-free lean mass < 3.3%.[3,19]

Statistical Analysis

Each scan was recorded and a comparison between means was calculated by a one-way ANOVA to measure the variance between the elite junior, professional AF rookie and senior athletes involved in this study. Where the ANOVA detected significant differences, Scheffe's post hoc tests and Cohen's effect size (ES) conventions were used to determine statistical and practical significant differences between groups. Furthermore, regional differences within the groups (right vs. left side) were estimated using paired *t* tests. Within the exploratory study, an independent samples *t* test was used to measure the difference between the elite and subelite junior athletes. An alpha level of $p \leq 0.05$ was accepted as significant. We used similar criteria to Hopkins[20] to interpret the magnitude of the effect sizes (ES) being: < 0.2 trivial, 0.2–0.6; small, 0.6–1.2 moderate, 1.2–2.0 large and > 2.0 very large. Data are presented as means (± SD).

Results

Results for the whole body composition analysis are presented in Table 1. Despite there being no significant difference between the elite junior athletes and their AFL rookie counterparts for mean age, height, total weight, total lean mass and total fat mass, the junior athletes were on average 5.01 kg and 4.36 kg lighter in total weight (ES = 0.72) and lean mass (ES = 0.78) respectively (Table 1). On average, the elite junior athletes were 7.65 kg and 5.78 kg lighter in total weight and total lean mass than their AFL senior counterparts respectively, with significant differences calculated between total body weight ($F = 6.312$ (3, 23), $P = .004$), total lean mass ($F = 5.584$ (3, 23), $P = .008$; Figure 1) and total fat mass ($F = 3.490$ (3, 23), $P = .050$; Table 1). Furthermore, the elite junior athletes had 0.34 kg and 0.42 kg less total bone mineral content (Table 1) than both elite AFL population groups (rookie; $F = 8.518$ (3, 18), $P = .017$ and senior; $F = 8.518$ (3, 23), $P = .001$) and a significantly lower BMD compared with the AFL senior group ($F = 7.307$ (3, 23),

Table 1 Mean (± SD) results of the three groups (elite junior; elite professional AFL rookies 18–20 y; elite professional AFL seniors 21 y) for whole body composition analysis

	Elite Junior (*n* = 21)	AFL Rookies (*n* = 18)	AFL Seniors (*n* = 23)
Age (y)	17.71 ± 0.27#	19.44 ± 0.70‡	25.43 ± 3.98
Height (cm)	187.02 ± 8.05	188.11 ± 5.60	187.4 ± 6.73
Weight (kg)	78.40 ± 7.12#	83.41 ± 6.74	86.06 ± 7.63
Lean Mass (kg)	67.10 ± 5.97#	71.47 ± 5.25	72.89 ± 6.32
% BW	85.62 ± 1.92	85.62 ± 1.66	84.72 ± 1.92
Fat Mass (kg)	8.13 ± 1.88#	8.44 ± 1.81	9.58 ± 2.03
%BW	10.32 ± 1.92	10.06 ± 1.58	11.10 ± 1.95
Bone Mass (kg)	3.17 ± 0.29*#	3.51 ± 0.36	3.59 ± 0.39
%BW	4.05 ± 0.23	4.19 ± 0.21	4.17 ± 0.28
BMD	1.27 ± 0.06#	1.33 ± 0.08	1.36 ± 0.08

*Values significantly different from those of elite profession AFL rookie footballers ($P < .05$).

#Values significantly different from those of elite profession senior footballers ($P < .05$).

‡Values significantly different between the elite professional AFL rookie (18–20 y) and elite professional AFL senior (21+ y) footballers ($P < .05$).

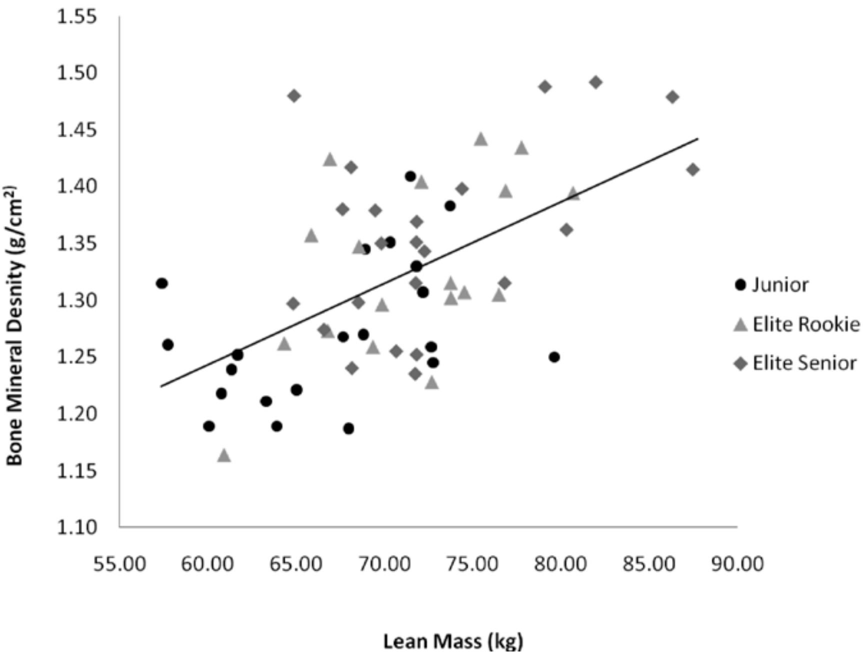

Figure 1 — Lean mass (kg) and bone mineral density (g/cm^2) of the three population groups (elite junior, elite professional AFL rookie and senior athletes; R = .57, R^2 = 0.32).

P = .002; Figure 1). No difference was demonstrated between the three groups for the percentage of body mass comprised of lean mass, fat mass, or bone mineral content (Table 1).

Segmental analysis of total body and lean mass weight demonstrated significantly greater mass in all body areas, excluding total lean mass in the right leg, between the elite junior and professional AFL senior athletes (ranging from F = 4.062 (3, 23) to 12.758 (3, 23), P = .001 to P = .003; Table 2). While only total mass and lean mass in the left arm were significantly less in the elite junior athletes compared with AFL rookies (F = 11.732 (3, 18), P = .001 and F = 12.758 (3, 18), P = .002 respectively), small to moderate ES differences were recorded throughout the body regions measured (ranging from ES 0.47 to 0.80). Bone mineral content and BMD analysis demonstrated significantly less results in all body segments, excluding BMC of the lumbar spine and BMD of the legs, in the elite junior athletes compared with their professional AFL senior counterparts (ranging from F = 4.087 (3, 23) to F = 26.408 (3, 23), P = .001 to P = .003; Table 3). Nonsignificant differences were demonstrated between the elite junior and AFL rookie groups for BMC in the spine, pelvis and left leg and BMD in the pelvis and legs, with small to moderate ES differences (ranging from ES 0.31 to 0.84). Paired t test analysis demonstrated significant differences between arms and legs for total weight (ranging from P = .001 to P = .005), total lean mass (ranging from P = .001 to P = .007;

Table 2 Mean (± SD) results of the three groups (elite junior; elite professional AFL rookies 18–20 y; elite professional AFL seniors 21+ y) for segmental body total and lean mass analysis

	Elite Junior (*n* = 21)	AFL Rookies (*n* = 18)	AFL Seniors (*n* = 23)
Total Mass (kg)			
Left Arm	4.59 ± 0.44*#	5.01 ± 0.41	5.26 ± 0.47
Right Arm	4.85 ± 0.54#	5.27 ± 0.59	5.58 ± 0.65
Trunk	36.23± 3.34#	38.34 ± 3.04	40.08 ± 3.46
Left Leg	13.24 ± 1.43#	14.24 ± 1.52	14.47 ± 1.55
Right Leg	14.05 ± 1.63#	14.79 ± 1.49	15.05 ± 1.77
Subtotal	72.97 ± 6.99#	77.71 ± 6.64	80.46 ± 7.55
Head	5.43 ± 0.38	5.81 ± 0.64	5.60 ± 0.67
Mass (kg, % total mass)			
Left Arm	3.97 ± 0.42 (86.49%)*#	4.36 ± 0.36 (87.03%)	4.56 ± 0.42 (86.69%)
Right Arm	4.23 ± 0.49 (87.22%)#	4.60 ± 0.50 (87.29%)	4.86 ± 0.54 (87.10%)
Trunk	31.99 ± 2.97 (88.30%)#	33.78 ± 2.57 (88.11%)	34.71 ± 304 (86.60%)
Left Leg	11.17 ± 1.10 (84.37%)#	12.03 ± 1.04 (84.48%)	12.12 ± 1.28 (83.76%)
Right Leg	11.81 ± 1.24 (84.06%)	12.48 ± 1.03 (83.38%)	12.57 ± 1.37 (83.52%)
Subtotal	63.18 ± 5.90 (86.58%)#	67.32 ± 5.15 (86.63%)	68.82 ± 6.27 (85.53%)
Head	3.93 ± 0.29 (72.38%)	4.26 ± 0.57 (73.32%)	4.06 ± 0.47 (72.50%)

*Values significantly different from those of elite profession AFL rookie footballers ($P < .05$).
#Values significantly different from those of elite profession senior footballers ($P < .05$).

excluding elite junior legs) and BMC (ranging from $P = .001$ to $P = .037$) for all three groups, while significant differences in BMD were also demonstrated between the arms only (rookies; $P = .008$, seniors; $P = .002$).

Results for the within-groups analysis of the junior population are presented in Table 4. The elite level junior athletes had a significantly greater lean mass as a percentage of their body weight (t[11 df]= 16.07, $P = .034$), less total fat mass (t[11 df]= 14.241, $P = .037$) and less fat mass as a percentage of body weight (t[11 df]= 16.729, $P = .024$). No significant difference was recorded for segmental analysis of total body weight, lean mass, BMC or BMD.

Table 3 Mean (± SD) results of the three groups (elite junior; elite professional AFL rookies 18–20 y; elite professional AFL seniors 21+ y) for segmental body BMC and BMD analysis

	Elite Junior (n = 21)	AFL Rookies (n = 18)	AFL Seniors (n = 23)
BMC (kg)			
Left Arm	0.21 ± 0.02*#	0.24 ± 0.03	0.25 ± 0.02
Right Arm	0.23 ± 0.02*#	0.26 ± 0.04	0.27 ± 0.04
Left Rib	0.13 ± 0.01*#	0.15 ± 0.02	0.16 ± 0.02
Right Rib	0.13 ± 0.01*#	0.16 ± 0.02	0.16. ± 0.02
T Spine	0.13 ± 0.02#	0.15 ± 0.02	0.15 ± 0.02
L Spine	0.08 ± 0.01	0.09 ± 0.02	0.09 ± 0.02
Pelvis	0.46 ± 0.06#	0.51 ± 0.08	0.52 ± 0.08
Left Leg	0.63 ± 0.08#	0.70 ± 0.09	0.72 ± 0.10
Right Leg	0.65 ± 0.09*#	0.74 ± 0.11	0.74 ± 0.11
Subtotal	2.65 ± 0.28*#	2.98 ± 0.35	3.06 ± 0.38
Head	0.52 ± 0.06	0.52 ± 0.07	0.52 ± 0.11
BMD (g/cm^2)			
Left Arm	0.86 ± 0.03*#	0.96 ± 0.04	0.91 ± 0.06
Right Arm	0.89 ± 0.04*#	0.94 ± 0.06‡	0.99 ± 0.05
Left Rib	0.84 ± 0.05*#	0.91 ± 0.08	0.93 ± 0.08
Right Rib	0.82 ± 0.05*#	0.88 ± 0.05	0.88 ± 0.07
T Spine	0.95 ± 0.08*#	1.06 ± 0.09	1.07 ± 0.10
L Spine	1.24 ± 0.13*#	1.40 ± 0.17	1.46 ± 0.17
Pelvis	1.39 ± 0.13#	1.47 ± 0.11	1.51 ± 0.14
Left Leg	1.46 ± 0.12	1.52 ± 0.11	1.55 ± 0.15
Right Leg	1.44 ± 0.12	1.51 ± 0.13	1.53 ± 0.12
Subtotal	1.19 ± 0.07*#	1.26 ± 0.08	1.28 ± 0.08
Head	1.96 ± 0.19	1.97 ± 0.20	2.02 ± 0.26

*Values significantly different from those of elite profession AFL rookie footballers ($P < .05$).

#Values significantly different from those of elite profession senior footballers ($P < .05$).

‡Values significantly different between the elite professional AFL rookie (18–20 y) and elite professional AFL senior (21+ y) footballers ($P < .05$).

Table 4 Mean (± SD) results of the two groups (subelite and elite junior athletes) for whole body composition analysis

	Subelite (n = 10)	Elite (n = 11)
Age (y)	17.71 ± 0.33	17.70 ± 0.23
Height (cm)	184.75 ± 8.59	189.09 ± 7.30
Weight (kg)	79.43 ± 6.96	77.47 ± 7.47
Lean Mass (kg)	67.20 ± 5.18	67.01 ± 6.86
% BW	84.69 ± 1.97^	86.47 ± 1.49
Fat Mass (kg)	9.05 ± 2.10^	7.29 ± 1.23
%BW	11.31 ± 1.93^	9.43 ± 1.46
Bone Mass (kg)	3.18 ± 0.36	3.17 ± 0.24
%BW	4.00 ± 0.21	4.10 ± 0.25
BMD (g/cm^2)	1.28 ± 0.06	1.27 ± 0.07

^Values significantly different between subelite and elite junior footballers ($P < .05$).

Discussion

The aim of this preliminary study was to measure the body composition differences between elite junior AF athletes and their professional adult AFL counterparts. Supporting previous research within a different football code,[2] no significant difference was recorded between the two elite professional AFL groups for total body composition measurements (Table 1) or most segmental analyses (Table 2 and 3). Furthermore, supporting the general assumption of a greater physical development within the professional AFL senior athletic population, a significant elevation in total body weight ($P < .05$), comprising a significantly greater lean mass ($P < .05$) was demonstrated in the professional AFL senior players when compared with their elite junior counterparts. In addition, a significantly greater BMC and BMD was commonly found throughout the body in the professional AFL senior athletes ($P < .05$). Therefore, the results of this study support the common perception of the body compositional differences between elite junior athletes and their senior counterparts, despite the chronological age of the junior athletes suggesting they are on the verge of participating in an elite senior competition.

Anecdotal evidence demonstrates a large discrepancy in total weekly training hours between part-time elite junior AF athletes (roughly 8 h) to their full-time rookie and senior counterparts (roughly 40 h). While no statistically significant difference in total body weight or lean mass was recorded between the elite junior and professional AFL rookie athletes, the finding of moderate ES differences suggests that 1 or 2 y of training and participation (on top of further growth and maturational changes) may have an effect on the body size of the professional AFL rookie athletes (Table 1). Furthermore, despite the 6–9 kg difference in total mass, the junior and both senior populations recorded a similar proportion of lean mass, fat mass and bone mass as a percentage of total body weight (Table 1), suggesting a linear progression in body composition development occurs in AF athletes from elite junior through to the professional rookie and finally senior level (Figure 1). While future research would benefit from investigating the impact of biological maturity within the junior population via the use of a maturity offset score,[21] the differences demonstrated within this study are important for the adjustment of age appropriate physical expectations placed on these athletes.[22] Such data is also useful in the design of age specific training programs targeting an increase in lean muscle mass (and therefore total body weight) of elite junior AF athletes.[15]

Bone adaptation occurs under the imposition of mechanical stresses, with areas of the skeleton that receive a direct physical load (such as the femoral neck) reporting a greater exercise increment of BMD.[2,3,23,24] Furthermore, athletes have reported a significant elevation in total skeletal BMC as a result of combined increases in both bone size and density.[2] Elite junior athletes within this study were not compared with an age-matched control group as it has previously been concluded that intensive exercise started during or before adolescence promotes bone hypertrophy and increases the BMD and BMC of the loaded skeletal areas.[2,3,25] Subsequently, this same trend can confidently be expected within the junior athletes of this current study.[2–4,6] However, believed to be of greater importance was the comparison between elite junior athletes and recent graduates to the senior AF competition level (AFL rookies), with further analysis made against those of a more mature training age (AFL seniors). Interestingly, while previous research has reported greater differences between athletes and their age-matched control counterparts in athletes of superior training age,[2,3,6] this study demonstrated a number of common body areas that were physically developed within the elite junior AF athletes to the same extent as their professional AFL counterparts. No BMD differences were demonstrated within the important areas of the legs or BMC differences in the lumbar spine, with only the pelvis region reporting significantly greater BMD and BMC development within the professional senior AFL athletes (Table 3). While not ignoring the natural process and rates of bone development, this finding suggests the positive effects of impact loading on bone development as a result of early participation within the team sport environment,[2,3] with nonimpact loaded body segments significantly weaker within the elite junior athletes.[2]

Despite AF requiring the use of both sides of the body to complete key game skills such as kicking and handballing,[10] this study demonstrated significant differences in the body composition of both arms and legs within each population group analyzed (Table 2 and 3). Total body mass, lean mass, BMC and BMD all demonstrated significant differences in one or both sets of limbs within each group, suggesting athletes involved at the elite level of AF are one side dominant in their physical make-up. In contrast, soccer research has reported whole-body symmetry.[3] The bilateral nature of soccer involving kicking with both legs and the external forces exerted on the nondominant leg to maintain balance and support during the kicking phase was suggested to contribute to the symmetrical leg bone development.[3] It can therefore be postulated that, despite the advantage of being equally skilled on both sides of the body, AF athletes tend toward using a preferred leg for kicking that exposes them to the potential for developing a muscular imbalance. Furthermore, the differences in game-day physical load experienced and kicking techniques used by the two football codes may suggest further research is required to identify possible reasons for limb and body asymmetry in AF athletes.

Consequently, the use of DEXA technology can provide significant insight and assist in monitoring the physical development of young athletes within elite senior competitions, identifying asymmetry that may reduce a potential injury risk and further enhance their physical development.

Within our study, the junior population was also divided into two groups to measure the trends in physical development between elite and subelite athletes based on their level of competition. While no significant difference in total body weight or lean mass was recorded between the two groups, the elite junior athletes recorded a significantly greater percentage body weight of lean mass, in accordance with the significantly less absolute fat mass and proportion of total body mass comprised of fat. With bone development showing no difference between the two groups,[2,26] a trend toward the selection of leaner athletes can be suggested at higher levels of competition, with these athletes holding a greater advantage toward using their lean mass, in the absence of excess detrimental fat weight, for superior physical performance.[8,27–29] Therefore, future research documenting the longitudinal analyses of junior athletes will provide a more complete physical model of the more successful junior athlete.[28] Nevertheless, training programs at the junior level of AF should be aimed toward decreasing total body fat mass in conjunction with improvements in both strength and lean muscle mass.

Conclusion

While the aim of this preliminary study was to report the differences in body composition between athletes at different competition levels, a potential limitation was the inability to control for the effects of individual maturation. Furthermore, the authors note that this study used a population sample of elite junior athletes from one state competition and elite senior athletes from one national level AF team, potentially limiting the findings by the training practices exposed to the small number of participants involved. Therefore, a national study at the elite junior level, controlling for the effects of maturation,[21] would provide a more in-depth representation of the body compositional status of athletes preparing to make the step into the elite senior AF competition. While this study has provided a preliminary comparison of the differences in body composition between elite junior and senior AF athletes, as well as trends within both the elite junior and senior populations, longitudinal analysis mapping the physical development and progression of athletes over an extended time period would provide valuable evidence in assessing their physical preparation and readiness to compete at the senior AF level.

Practical Applications

- Weight training should be implemented at the junior level to build whole body mass and to counter the asymmetrical loads placed on the body through the nature of the game.
- Although DEXA technology is not an easily accessible technology, fitness staff at football clubs should conduct regular basic anthropometric measurements of junior athletes focusing on limb girths and skinfolds.
- Individual physical development must be considered when selecting junior athletes to participate in senior AF competitions.

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