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Positional Differences in Muscle-to-bone Ratio in National Football League Players

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ABSTRACT

The purpose of the present study was to examine the muscle-to-bone ratio (MBR) in National Football League (NFL) players. Three hundred and forty-six NFL players had their total body lean, fat and bone masses determined using dual X-ray absorptiometry and were compared to 228 age-matched, healthy male controls. Compared to the control group, NFL players had a significantly lower percent total body fat (17.90 ± 6.92 vs. 22.93 ± 8.96 %, p = 0.053), but significantly greater total fat mass (19.76 ± 11.29 vs. 17.84 ± 12.11 kg, p < 0.0001), lean mass (84.55 ± 8.75 vs. 55.3 ± 11.79 kg, p < 0.0001), bone mineral content (4.58 ± 0.45 vs. 2.91 ± 0.67 kg, p < 0.0001), and bone mineral density (1.61 ± 0.11 vs. 1.26 ± 0.21 g/cm^2, p < 0.0001). NFL players had greater arm MBR (17.70 ± 1.47 vs. 16.48 ± 1.88, p < 0.0001) than controls; however, both trunk (26.62 ± 2.55 vs. 31.56 ± 4.19, p < 0.0001) and total (18.50 ± 1.31 vs. 19.12 ± 1.88, p < 0.001) MBR were lower in NFL players. Leg MBR was not significantly different between NFL players and controls (16.72 ± 1.53 vs. 16.85 ± 1.87, p = 0.34). When NFL players were categorized by their offensive or defensive position for comparison, no differences in total MBR were observed. However, leg MBR varied greatly among NFL players by position. It is possible that regional differences in MBR in the NFL players may be related to the demands of that position.

Introduction

American football, like a number of team sports, relies on the qualities of strength, speed, and power in order to maximize performance. Previously, we have demonstrated that specific body composition characteristics may help identify athletic success in both professional [1, 2] and collegiate [3, 4] football players. When classified by body mass index (BMI) the majority of National League Football (NFL) players would be classified as being overweight or obese [1]; however, this is due, mainly, to the large amount of muscle mass that these athletes have developed [1, 2]. The amount of muscle mass and percent body fat in NFL players varies greatly by position, with offensive and defensive linemen having a greater amount of muscle mass and a higher percent body fat than other positions [1, 4].

Not only do NFL players have greater amounts of total body and muscle masses, they also have higher bone mineral content (BMC) and bone mineral density (BMD) than nonathletic populations [1, 4]. Bosch et al. noted a range of BMC and BMD values among collegiate football players and individuals near the lower limits for total or regional BMD (e. g. 10th percentile) that may indicate heightened risk of bone injury in a collision sport [3].

One variable of recent interest is the ratio of lean muscle mass-to-bone mass (MBR). The MBR looks to understand the relationship between bone and the tissue that produces the largest physiological loads on a bone – muscle unit [5, 6]. The MBR can be affected not only by skeletal size, but also by the amount of muscle mass an individual carries on their skeletal frame. A larger MBR can mean either a high degree of muscular development or a small skeleton [7]. Although MBR has been previously reported in soccer [8, 9], rugby [7] and volleyball [10] athletes, these studies have utilized anthropometric measurements (i. e. skinfolds, circumferences, breaths, etc.) and a series of mathematical equations to divide the body into five different masses; skin mass, adipose mass, muscle mass, bone mass and residual mass [11] to calculate MBR. However, the validity of these anthropometric measures and the equations used to estimate muscle, bone, and fat masses have been questioned [12]. Recently, Gomez-Bruton et al. [13] used dual X-ray absorptiometry (DXA) to examine the MBR of adolescent swimmers and aged-matched controls. Gomez-Bruton et al. [13] reported that MBR was significantly lower in swimmers than in controls. DXA allows fat-free mass to be separated into bone mineral content and lean mass, thereby generating a three-component model [14, 15]. In addition, DXA allows for the segmental analysis of the DXA-based body composition data so that regional MBR values can be determined.

In the present study, we utilized DXA to determine regional as well as total fat, bone and lean muscle masses to calculate total MBR in NFL players. We compared total and regional MRB in NFL players to an age-matched healthy, male control group. In addition, we examined total as well as regional MBR by position in the NFL athlete population.

Materials and Methods

Subjects

This study used a retrospective analysis from previously collected data on NFL players from 2006 to 2011. NFL Players were either active on the roster, free-agents, or prospective draft choices. Four hundred and eleven NFL players were measured just prior to draft or prior to the start of the summer training camp. Due to the size limitations of the DXA scanner table, not all of the individuals were able to fit into the DXA scan field area. Therefore, scan data were only used for those individuals who fit 100 % in the DXA scanning field area. A total of 346 NFL players met this criteria and were compared to a group of 228 age-matched healthy, male controls. Individuals in the control group were randomly sampled from two population-based longitudinal studies investigating the development of obesity and insulin and their interaction with cardiovascular risk factors [16, 17]. All subjects' health status was determined via medical examination by a study physician or certified nurse practitioner. Subjects who smoked or were taking prescription medications, such as blood pressure, insulin, dyslipidemia or statin medication, were excluded from the study. This research project was approved by the Institutional Review Board for retrospective study data analyses. This study meets the ethical standards of the *International Journal of Sports Medicine* [18].

Experimental procedures

Height and weight were measured by a standard wall stadiometer and medical beam scale, respectively. Body mass index (BMI) was calculated as weight in kilograms divided by the height in meters squared. All subjects were scanned on a GE Healthcare Lunar iDXA (GE Healthcare Lunar, Madison, Wisconsin, USA) and standard DXA imaging and positioning protocols were followed. All scans were analyzed by the same technician using enCore software version 16.2 (GE Healthcare Lunar, Madison, Wisconsin, USA) to determine relative fat (percent body fat [%BF]), total LM, total FM, BMD, and BMC. Lean mass index (LMI) and fat mass index (FMI) were calculated by dividing LM and FM by height (m^2), respectively. Regional measures were also determined including LM, FM, BMC, and BMD for arm, leg, and trunk. MBR were calculated by dividing LM by BMC for total body as well as regional MBR of the arms, trunk, and legs.

Statistical analyses

Descriptive statistics were calculated as mean ± standard error of the mean (SEM) by position. Paired t-tests assessed total and regional differences calculated between NFL athletes and age-matched, healthy male controls. In addition to standard total and regional metrics of muscle, bone, and fat masses, the MBR was calculated for arm, leg, trunk, and total body.

NFL players were then categorized by position into one of nine categories: defensive backs (DB), defensive lineman (DL), linebackers (LB), offensive lineman (OL), quarterbacks (QB), running backs (RB), tight ends (TE) and wide receivers (WR). Punters and place kickers were combined into one category named punters/kickers (PK). Descriptive statistics were calculated using mean ± standard deviation (SD) by position. An analysis of variance (ANOVA) was used to test whether positional means were equal to each other. The Tukey HSD (honest significant different) method was used to compare each positional mean against the next to correct for type I error from performing multiple comparisons. Violin plots were used to visualize empirical distribution of the data. In addition, violin plots present the median (solid black line) as well as the quartiles (dashed black line) for arm, leg, trunk and total body MBR measurements by position. All analyses were performed using GraphPad Prism version 9.4.0 for Windows (GraphPad Software, San Diego, California USA).

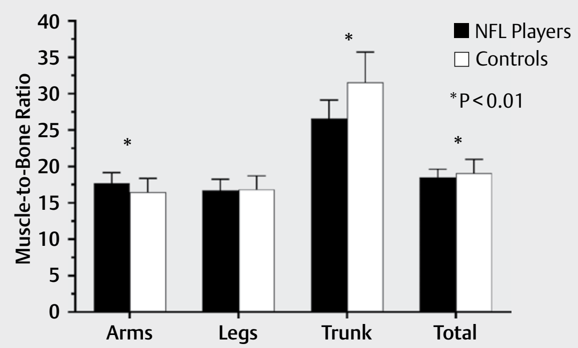
Results

Three hundred forty-six NFL players were matched to a population of healthy males (n = 228) by age. Therefore, by design, there were no significant differences in age (24.2 ± 2.6 vs. 24.0 ± 2.0 yrs., p = 0.33) between NFL players and controls. As expected, NFL players were significantly taller (187.2 ± 5.4 vs. 174.6 ± 11.1 cm, p < 0.001), heavier (109.0 ± 18.7 vs. 74.8 ± 20.7 kg, p < 0.001) and had a greater BMI (31.0 ± 4.5 vs. 25.2 ± 5.6 kg/m^2, p < 0.0001). Compared to the control group, NFL players had a lower %BF (17.90 ± 6.92 vs. 22.93 ± 8.96 %, p = 0.053), but significantly greater total FM (19.76 ± 11.29 vs. 17.84 ± 12.11 kg, p < 0.0001), LM (84.55 ± 8.75 vs. 55.3 ± 11.79 kg, p < 0.0001), BMC (4.58 ± 0.45 vs. 2.91 ± 0.67 kg, p < 0.0001), and BMD (1.61 ± 0.11 vs. 1.26 ± 0.21 g/cm^2, p < 0.0001). While the LMI (24.10 ± 11.14 vs. 19.92 ± 5.38 kg/m^2, p < 0.0001) was significantly greater in NFL players compared to controls, the FMI (5.5 ± 3.03 vs. 5.81 ± 3.83 kg/m^2, p = 0.39) was not significantly different. Regional body composition data of the NFL players to controls are presented in ▶ **Table 1**. Similar to total body composition measures, NFL players had significantly greater amounts of arm, leg, and trunk LM, and BMC. On the other hand, although FM was significantly greater for arms in NFL players, it was lower in the trunk region for NFL players and not significantly different in the legs between the two groups. The arm, leg, trunk, and total body MBR for NFL players and controls are presented in ▶ **Fig. 1**. NFL players had greater arm MBR (17.70 ± 1.47 vs. 16.48 ± 1.88, p < 0.0001) than controls; however, both trunk (26.62 ± 2.55 vs.

▶ **Table 1** Regional mean (±standard deviation) for body composition values of professional football players and aged-matched controls.

Position	Control (n = 228)	NFL Players (n = 346)	P-Value
Arm FM (kg)	1.85 ± 1.08	2.09 ± 1.17	0.01
Arm LM	6.74 ± 1.67	12.34 ± 1.52	< 0.0001
Arm BMC (kg)	0.41 ± 0.11	0.70 ± 0.09	< 0.0001
Leg FM (kg)	6.81 ± 4.19	6.79 ± 3.51	0.93
Leg LM (kg)	18.95 ± 4.47	30.40 ± 4.01	< 0.0001
Leg BMC (kg)	1.13 ± 0.27	1.82 ± 0.17	< 0.0001
Trunk FM (kg)	8.26 ± 7.04	6.78 ± 3.51	0.006
Trunk LM (kg)	26.27 ± 5.95	37.93 ± 4.01	< 0.0001
Trunk BMC (kg)	0.86 ± 0.28	1.46 ± 0.19	< 0.0001

FM = fat mass; LM = lean mass; BMC = bone mineral content; BMD = bone mineral density.



▶ **Fig. 1** Mean (±standard deviation) arm, leg, trunk, and total body muscle-to-bone ratio for NFL players (solid bar) and controls (open bars).

31.56 ± 4.19, p < 0.0001) and total (18.50 ± 1.31 vs. 19.12 ± 1.88, p < 0.001) MBRs were lower in NFL players than in the controls. Leg MBR was not significantly different between NFL players and controls (16.72 ± 1.53 vs. 16.85 ± 1.87, p = 0.34).

▶ **Table 2** compares the physical characteristics (age, height, weight, BMI) of the NFL participants by position. QBs were significantly older than LBs (25.9 ± 4.6 vs. 23.5 ± 2.1 yrs). There were no other differences in age between the other position groups. As expected, there were significant differences in height and weight between the different position groups, which led to significant differences in BMI.

▶ **Table 3** compares total body composition data of the participants by position. We observed that DBs and WRs were not significantly different from each other in any metric. The OLs had significantly more FM and a greater FMI than DLs, but the two positions were similar for all measures of LM and LMI. Interestingly, we observed that LBs and RBs were not significantly different from each other for all measures except total LM, where LBs had significantly more LM than RBs (84.2 ± 4.9 vs. 87.7 ± 3.4 kg). However, the LMI for LBs and RBs was not significantly different. Finally, TEs were significantly different from OLs and DLs on all measures except total BMC and BMD.

▶ **Table 2** Mean (±standard deviation) for physical characteristics of professional football players by position.

Position	OL (n = 38)	DL (n = 47)	TE (n = 27)	LB (n = 48)	RB (n = 29)	PK (n = 17)	QB (n = 21)	DB (n = 64)	WR (n = 55)
Age (years)	24.2 ± 2.0[ab]	24.6 ± 3.1[ab]	23.9 ± 2.1[ab]	23.5 ± 2.1[a]	24.5 ± 2.9[ab]	25.0 ± 2.4[ab]	25.9 ± 4.6[b]	24.0 ± 2.4[ab]	23.9 ± 2.2[ab]
Height (cm)	192.8 ± 4.0[ab]	191.0 ± 3.1[b]	193.4 ± 3.5[ab]	186.7 ± 3.7[c]	181.4 ± 3.9[d]	187.4 ± 4.5[c]	188.7 ± 3.6[bce]	182.2 ± 3.0[d]	186.0 ± 3.9[ce]
Weight (kg)	139.8 ± 6.3[a]	132.1 ± 14.5[b]	113.0 ± 4.0[c]	109.6 ± 4.0[cd]	104.6 ± 7.3[de]	98.4 ± 6.5[e]	103.6 ± 14.2[ce]	91.1 ± 6.1[f]	94.0 ± 6.0[fe]
BMI (kg/m^2)	37.6 ± 1.8[a]	36.3 ± 4.5[a]	30.2 ± 1.3[b]	31.4 ± 1.4[b]	31.8 ± 2.1[b]	28.1 ± 2.8[bc]	29.1 ± 4.5b[cd]	27.5 ± 1.9[d]	27.2 ± 1.9

If positions share a letter within each row, they are not significantly different at p < 0.05; DB = defensive back; DL = defensive lineman; LB = linebacker; OL = offensive lineman; PK = punters/kickers; QB = quarterback; RB running back; TE = tight ends; WR = wide receivers.; BMI = body mass index (weight in kg/height in m^2).

Table 3 Total mean (± standard deviation) for body composition values of professional football players by position.

Position	OL (n = 38)	DL (n = 47)	TE (n = 27)	LB (n = 48)	RB (n = 29)	PK (n = 17)	QB (n = 21)	DB (n = 64)	WR (n = 55)
Total % Fat (%)	29.4 ± 2.0[a]	24.7 ± 6.8[b]	16.4 ± 3.5[c]	16.4 ± 3.0[cd]	15.7 ± 3.7[cde]	18.8 ± 4.6[ce]	19.6 ± 4.5[cde]	12.3 ± 3.4[e]	12.9 ± 3.1[e]
Total FM (kg)	39.7 ± 5.2[a]	32.2 ± 12.1[b]	17.8 ± 4.0[c]	17.2 ± 5.0[c]	15.9 ± 8.6[c]	17.9 ± 5.3[c]	19.5 ± 1.5[c]	10.8 ± 3.6[d]	11.6 ± 3.3[d]
FMI (kg/m^2)	10.7 ± 1.4[a]	8.9 ± 3.3.5[b]	4.8 ± 1.1[c]	5.0 ± 1.0[c]	4.8 ± 1.4[c]	5.1 ± 1.7[c]	5.5 ± 1.8[c]	3.1 ± 0.9[d]	3.3 ± 0.9[bd]
Total LM (kg)	95.0 ± 4.1[a]	94.9 ± 5.5[a]	90.3 ± 4.3[b]	87.7 ± 3.4[b]	84.2 ± 4.9[c]	76.3 ± 4.3[d]	78.9 ± 5.0[d]	75.8 ± 4.3[e]	78.0 ± 4.4[de]
LMI (kg/m^2)	25.6 ± 1.2[a]	26.0 ± 1.7[a]	24.2 ± 1.4[b]	25.2 ± 1.1[ab]	25.6 ± 1.4[a]	21.8 ± 1.7[c]	22.2 ± 1.5[c]	22.8 ± 1.3[c]	22.6 ± 1.3[c]
Total BMC (kg)	5.04 ± 0.31[a]	5.01 ± 0.36[a]	4.88 ± 0.32[ab]	4.68 ± 0.30[bc]	4.51 ± 0.29[c]	4.14 ± 0.29[d]	4.44 ± 0.32[cd]	4.19 ± 0.30[d]	4.34 ± 0.37[d]
Total BMD (g/cm^2)	1.69 ± 0.08[a]	1.71 ± 0.10[a]	1.64 ± 0.09[ab]	1.63 ± 0.09[ab]	1.63 ± 0.08[a]	1.49 ± 0.09[c]	1.53 ± 0.02[cd]	1.56 ± 0.10[e]	1.57 ± 0.11[bde]

If positions share a letter within each row, they are not significantly different at $p < 0.05$; DB = defensive back; DL = defensive lineman; LB = linebacker; OL = offensive lineman; PK = punters/kickers; QB = quarterback; RB running back; TE = tight ends; WR = wide receivers.; FM = fat mass; FMI = fat mass index; LM = lean mass; LMI = lean mass index; BMC = bone mineral content; BMD = bone mineral density.

Regional body composition data of the participants by position are presented in ▶ **Table 4**. Similar to total body composition, the OLs had significantly more FM than DLs, but the two positions were similar for all measures of LM. TEs, RBs and LBs mirrored each other for measures of regional body composition, while DBs and WRs mirrored each other regarding regional body composition. Similarly, QBs and PKs tended to mirror each other in regional body composition.

Mean (± SD) MBR for arms, legs, trunk and total body by position are presented in ▶ **Table 5**. The empirical distribution for the MBR as well median and quartiles for arm, leg, trunk, and total body are presented as violin plots in ▶ **Fig. 2**. There were no significant differences in the total MBR across positions. The arm MBR in QBs was significantly lower than DLs. There were a number of differences in leg MBR between positions. Positions that mirrored each other such as WRs and DBs or OLs and DLs had similar leg MBR. The only difference in trunk MBR was PKs having a significantly greater trunk MBR than OLs.

Discussion

To our knowledge, this is the first study to report total MBR in NFL players. In the present study, NFL players had lower total MBR as well as trunk MBR compared to aged-matched healthy male controls. Although the NFL players have a significantly greater amounts of both BMC and LM than controls, they had a lower total MBR. This is due to the fact that the NFL players were taller, resulting in a larger total skeleton and ultimately a greater amount of BMC for a proportional amount of LM resulting in lower total MBR. Although we found differences between professional football players and a control population, no positional differences in total MBR in the NFL athletes were observed.

Brocherie et al. [9] reported a total MBR of 4.3 ± 0.5 in male Qatari national soccer athletes. Bernal-Orozco et al. [8] reported a similar total MBR value of 4.2 ± 0.4 in group of young professional soccer athletes and observed no positional differences in total MBR. A total MBR of 4.58 ± 0.49 was reported in a group of amateur rugby players with no difference in the total MBR across positions [7]. Carvajal et al. [10] reported a total MBR value of 5.2 ± 0.7 in a group of Cuban female Olympic volleyball athletes and reported no positional differences in total MBR in these athletes. These total MBR values are considerably lower than the total MBR of 18.50 ± 1.31 we observed in the NFL players or the 19.12 ± 1.88 we observed in our age-matched, healthy control group. The reason for this difference in total MBR values from the present study compared to these other studies [7–10] is in the methods used to determine muscle and bone masses. All of these studies [7, 9, 10] utilized anthropometric measurements (i. e. skinfolds, circumferences, breaths, etc.) and a series of equations to estimate bone and muscle masses [11]. From these estimated values of bone and muscle masses, the MBR was then calculated. The validity of these anthropometric measures and equations to estimate muscle and bone masses has been questioned [12].

Anthropometric equations estimate the wet bone mass while DXA determines the dry bone ash (i. e. dry bone mass). The average wet skeletal bone mass in males is approximately 10.5 kg, while the mean dry skeletal bone mass in males is approximately 4.0 kg [19].

▶ **Table 4** Regional mean (±standard deviation) for body composition values of professional football players by position.

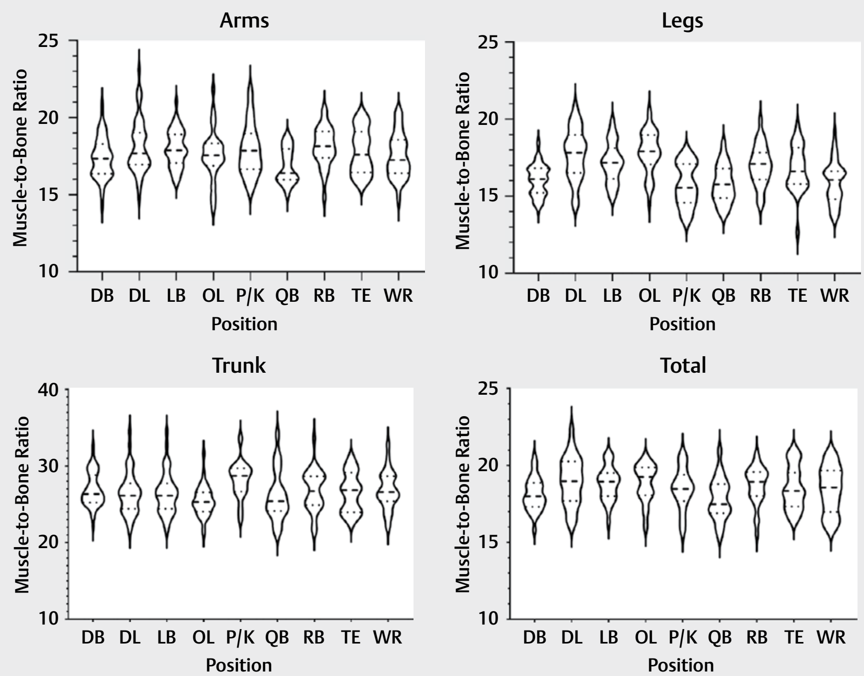
Position	OL (n=38)	DL (n=47)	TE (n=27)	LB (n=48)	RB (n=29)	PK (n=17)	QB (n=21)	DB (n=64)	WR (n=55)
Arm FM (kg)	4.3±7.3[a]	3.2±1.1[b]	1.9±4.5[c]	1.8±3.4[c]	1.7±4.4[c]	1.9±4.9[c]	2.11±6.1[c]	1.1±0.3[d]	1.2±3.3[d]
Arm LM (kg)	13.6±1.2[ab]	13.8±1.4[a]	13.3±1.0[a]	13.0±0.8[bc]	12.4±1.1[c]	10.7±1.1[d]	11.3±0.9[d]	11.1±0.9[d]	11.4±1.0[d]
Arm BMC (kg)	0.78±0.08[a]	0.77±0.09[ab]	0.75±0.07[ab]	0.73±0.06[bc]	0.69±0.06[cd]	0.60+0.05[e]	0.67±0.05[cf]	0.64±0.06[def]	0.66+0.07[def]
Leg FM (kg)	11.9±2.4[a]	11.1±4.0[a]	6.2±1.4[b]	6.5±1.4[b]	5.8±1.8[bc]	6.0±1.7[bc]	6.5±1.8[b]	3.9±1.2[d]	4.3±1.2[cd]
Leg LM(kg)	34.9±2.2[a]	34.9±3.4[a]	31.8±2.2[b]	31.6+1.9[b]	30.4±2.2[b]	26.2±2.0[c]	17.4±0.1[c]	26.9+2.0[c]	28.0±2.2[c]
Leg BMC (kg)	1.96±0.12[a]	1.97±0.16[a]	1.90±0.16[ab]	1.85±0.15[bc]	1.80±0.11[bd]	1.68±0.14[de]	1.74±0.13[cde]	1.68±0.11[e]	1.77±0.14[cd]
Trunk FM (kg)	22.3±3.2[a]	16.8±7.3[b]	8.7±2.6[c]	7.9±2.1[c]	7.4±2.6[cd]	9.0±3.2[c]	9.9±3.8[c]	4.8±2.1[e]	5.13±1.9[de]
Trunk LM (kg)	42.4±2.5[a]	42.0±3.0[a]	41.2+2.3[a]	39.1±1.9[b]	37.4±2.6[bc]	35.7±2.5[cd]	36.2±2.8[ce]	34.0±1.9[d]	34.8±2.0[de]
Trunk BMC (kg)	1.68±0.15[a]	1.60±0.16[ab]	1.56±0.12[bc]	1.47±0.12[cd]	1.40±0.13[de]	1.27±0.11[e]	1.40±0.15[df]	1.27±0.11[e]	1.31±0.13[ef]

If positions share a letter within each row, they are not significantly different at $p < 0.05$; DB = defensive back; DL = defensive lineman; LB = linebacker; OL = offensive lineman; PK = punters/kickers; QB = quarterback; RB running back; TE = tight ends; WR = wide receivers.; FM = fat mass; LM = lean mass; BMC = bone mineral content; BMD = bone mineral density.

▶ **Table 5** Muscle-to-bone ratio (±standard deviation) of professional football players by position.

Position	OL (n=38)	DL (n=47)	TE (n=27)	LB (n=48)	RB (n=29)	PK (n=17)	QB (n=21)	DB (n=64)	WR (n=55)
Arm MBR	17.5±1.4[ab]	18.2±1.7[b]	17.8±1.4[ab]	18.0±1.2[ab]	18.1±1.3[ab]	17.9±1.7[ab]	16.9±1.1[a]	17.4±1.3[ab]	17.5±1.4[ab]
Leg MBR	17.9±1.4[a]	17.7±1.6[ab]	16.8±1.5[bce]	17.2±1.3[a]	17.0±1.3[ad]	15.7±1.4[de]	15.8±1.2[e]	16.1±1.0[f]	15.9±1.4[ef]
Trunk MBR	25.4±2.0[a]	26.4±2.7[ab]	26.5±2.5[ab]	26.4±2.7[ab]	26.8±2.7[ab]	28.2±2.4[b]	26.2±3.3[ab]	26.9±2.2[ab]	26.8±2.5[ab]
Total MBR	18.8±1.2[a]	19.0±1.6[a]	18.6±1.4[a]	18.8±1.1[a]	18.7±1.2[a]	18.5±1.4[a]	17.8±1.4[a]	18.1±1.1[a]	18.4±1.5[a]

If positions share a letter within each row, they are not significantly different at $p < 0.05$; DB = defensive back; DL = defensive lineman; LB = linebacker; OL = offensive lineman; PK = punters/kickers; QB = quarterback; RB running back; TE = tight ends; WR = wide receivers.; MBR = muscle-to-bone ratio.



▶ **Fig. 2** Violin plots of arms, legs, trunk and total muscle-to-bone ratio by position (DB = defensive back; DL = defensive lineman; LB = linebacker; OL = offensive lineman; PK = punters/kickers; QB = quarterback; RB running back; TE = tight ends; WR = wide receivers).

The differences in wet and dry bone masses explain the differences in MBR values. It is also important to note that while DXA determines each individual's bone mass, the anthropometric method assumes a given value for bone mass that is the same for everyone. Data in a number of studies have demonstrated that age, sex and race affect both wet and dry bone masses [19]. No studies that used anthropometrics to determine the total MBR utilized an age-matched control group, so a comparison to a normal population is not possible [7–10]. To date, one study [13] has used DXA to determine muscle and bones masses to determine total MBR in athletes. Although Gomez-Bruton et al. [13] used DXA to determine total MBR, they did not report the values in adolescent swimmers, but only reported Z-score values.

The use of DXA to determine muscle and bone masses also allows for the calculation of regional as well as total MBRs, which is not possible when using anthropometrics Similar to total MBR, trunk MBR was significantly lower in the NFL players compared to controls. This is not surprising given the amount of core exercises that NFL players do compared to the normal population. In the present study, arm MBR was significantly greater in the NFL players while there was no difference in leg MBR between NFL players and controls. Although one would expect arm and leg MBR to be similar, these differences may be due to the fact that the legs support a larger total mass in the NFL group, and NFL players do large volumes of training that load the lower body (e. g. squat lift, deadlift, etc.). This loading of both bone and muscle results in proportional changes in muscle as well as bone. Although the arms also undergo target strength training (e. g. arm curls, bench press), they are not involved in supporting the body mass as are the legs. This results in less loading of the bone and ultimately leads to development of more LM than BMC in the NFL player's arms.

Although there were no positional differences in total MBR between the NFL athletes, there were positional differences within regional MBR measures. Arm MBR in QBs was significantly lower than in DLs, indicating a greater amount of muscle mass per unit of bone in DLs. There were no other differences in arm MBR between any of the other positions. Trunk MBR showed PKs having a significantly greater trunk MBR than OLs. This would suggest that the PKs have a greater amount of LM for the same amount of BMC. There were a number of differences in leg MBR between the different positions. QBs and PKs had the lowest leg MBR values, while OLs and DLs had the highest leg MBR values. This was evident in positions that mirror each other such as WRs and DBs, as well as OLs and DLs. The fact that leg MBR values were similar in offensive and defensive positions that mirror each other is not too surprising. It has been reported [1, 3] that offensive and defensive positions that mirror each other have similar total as well as regional measures of FM, LM and BMC. In the present study, we also observed similar overall patterns of body compositions in individuals who played offensive or defensive that mirrored each other. Although OLs had a higher % BF and total FM than DLs, the two positions were similar in overall BMC and LM.

To date, no other studies have compared the body composition of NFL players to an age-matched, healthy male control group. As expected, the NFL players in this analysis were significantly taller and had more total, fat, and lean masses than their age-matched counterparts. Total BMC and BMD were also significantly greater in the NFL players than controls. The greater amount of BMC and higher BMD in NFL players compared to aged-match controls is not surprising. It has been reported that athletes in high impact sports (e. g. gymnastics, judo, karate, volleyball, and other jumping sports) or odd-impact loading (e. g. soccer, basketball, racquet games, step-aerobic and speed skating) have higher bone mass compared to athletes from low impact sports (e. g. swimming, water polo, cycling) [20]. In addition, high impact sports have been reported to improve bone mass [21–23]. Therefore, given the impact and training that football players are exposed to, a greater BMD would be expected.

Limitations and further studies

To our knowledge, this is the first paper to present both total and regional MBR data as determined using DXA in professional football players. The addition of an age-matched control group adds context to a general population. Our data creates templates for total as well as regional MBR values for NFL players at different positions as well as increases the understanding of how NFL players differ from the general population.

Strengths of the current study include the use of DXA for measures of body composition. In addition, unlike other studies, an age-matched, healthy male control group was utilized for comparison. Limitations of the current study include potential technician testing variation, cross sectional analysis, and lack of performance data. Future studies should investigate the relationship between MBR and performance metrics (e. g. power, strength, and game performance), create a competitive ranking of players, and observe changes in MBR in relation to physiological and mechanical loading.

Conclusions

DXA allows coaches and athletic trainers the opportunity to determine MBR that does not require specialized anthropometric devices. Unlike anthropometric methods that utilize skinfolds, circumferences, length and breaths to estimate muscle, fat and bone masses, DXA provides a valid, accurate and high-resolution measure of a three-component model of body composition. In addition, the DXA can provide both total as well as regional measures of MBR and is much faster than anthropometric methods to calculate MBR. In the present study, we observed that total MBR was lower in NFL players than aged-matched healthy controls. This lower total MBR suggests that NFL players have a higher amount of bone for a given amount of lean mass.

Conflict of Interest

The authors declare that they have no conflict of interest.

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