International Journal of EXERCISE SCIENCE

Original Research

Fat-Free Mass Index in a Large Sample of Collegiate American Football Athletes

JENNIFER B. FIELDS‡[1,2], MARGARET T. JONES‡[2,3], NICHOLAS M. KUHLMAN†[1], MEGHAN K. MAGEE‡[5], ADAM FEIT‡[4], and ANDREW R. JAGIM‡[2,6]

[1]Department of Nutritional Sciences, University of Connecticut, Storrs, CT, USA; [2]Patriot Performance Laboratory, Frank Pettrone Center for Sports Performance, George Mason University, Fairfax, VA, USA; [3]Department of Sport, Recreation, and Tourism Management, George Mason University, Fairfax, VA, USA; [4]Department of Exercise Science and Athletic Training, Springfield College, Springfield, MA, USA; [5]Department of Exercise Science and Exercise Physiology, Kent State University, Kent, OH, USA; [6]Department of Sports Medicine, Mayo Clinic Health System, La Crosse, WI, USA

†Denotes graduate student author, ‡Denotes professional author

ABSTRACT

International Journal of Exercise Science 17(4): 129-139, 2024. High levels of fat-free mass (FFM) are favorable for athletes and are related to sport performance. However, fat-free mass index (FFMI), which includes adjustments for height, may offer a better way to characterize FFM beyond raw values. As FFMI is understudied relative to sport, the purpose of the current study was to assess position and age group differences in FFMI among collegiate American football players. National Collegiate Athletic Association DIII (n=111) football players underwent body composition assessment via bioelectrical impedance analysis. FFMI was calculated by dividing FFM by height squared. One-way analyses of variance with Bonferroni post-hoc tests were conducted to evaluate differences in FFMI by position and age groups ($\alpha<0.05$). The overall mean FFMI was 23.50 ± 2.04 $kg \cdot m^{-2}$, with values ranging from 18.1–27.7 $kg \cdot m^{-2}$. FFMI was highest in linemen (24.8 ± 1.5 $kg \cdot m^{-2}$) and lowest in specialty players (20.6 ± 1.4 $kg \cdot m^{-2}$) ($p<0.05$). No differences in FFMI were apparent across age groups ($p>0.05$). Current findings demonstrate that an athlete's upper limit for FFMI may exceed 25 $kg \cdot m^{-2}$, and differences exist across positions, likely due to position-specific demands. These measurements serve as a foundation for tailoring nutritional and exercise plans, forecasting athletic performance, and supplying coaches with standardized data about the potential for additional FFM accretion in collegiate American football players.

KEY WORDS: Body composition, lean mass, body fat percentage

INTRODUCTION

Optimal health is an essential component of top sport performance, and body composition plays a critical role in athlete health (32). Favorable body composition in athletes is generally characterized by greater amounts of fat-free mass (FFM) and less fat mass (FM), which tend to optimize strength to body mass ratio (6). High amounts of fat-free mass (FFM) have been related to vertical jump performance, sprint time, relative power, and maximal strength, while also reducing the risk of injury (33). Although body composition is considered an important parameter of sport performance, absolute measures of FFM do not account for height and body size differences, making direct comparisons across athletes challenging. Further, an absolute measure of FFM does not offer insights into an individual athlete's potential to gain more FFM or how changes in FFM may impact their athletic performance. Consequently, practitioners may not be able to determine what FFM values are 'optimal' vs. 'suboptimal'. Body size varies by sport and sport-position as do different training demands and performance goals (9, 10, 25); therefore, height-normalized metrics of body composition, such as fat-free mass index (FFMI) have been developed for a more accurate representation of performance capabilities and comparative purposes.

FFMI is a height-normalized measure of FFM, and is calculated by dividing fat-free mass (in kg) by height (m^2) (19). FFMI was originally developed as a clinical metric to screen for individuals who may be at risk for protein malnutrition (35), and later used as a screening tool to detect possible steroid abuse in resistance-trained men (19). Recently, FFMI has found new applications in sports, helping evaluate athletic potential, tailor training and nutrition, support athlete recruitment, and gauge an individual's capacity for further FFM development. Low FFMI values can signal athletes at risk of low energy availability (33, 31) prompting adjustments in nutrition and training to target FFM gain. Meanwhile, higher FFMI values can indicate an athlete's proximity to their genetic FFM potential. It was originally suggested that 25.0 $kg \cdot m^{-2}$ was the naturally attainable upper threshold of FFMI in resistance-trained men (19); however, one recent study reported upper limits of 28.1 – 31.7 $kg \cdot m^{-2}$ in National Collegiate Athletic Association (NCAA) Division I and II American football athletes (33), indicating the proposed upper threshold may not be applicable to all athletes. FFMI may help provide a valuable metric to characterize FFM values across the sport, thus allowing for normative profiles across levels of competition, position groups, and age groups. Further, FFMI normative data and the subsequent establishment of player profiles can assist American football coaches in recruiting and designing training programs to optimize player potential, performance, and overall health.

In recent years, bioelectrical impedance (BIA) technology has gained popularity as a body composition assessment tool in athletes due to its cost, ease of use, time to administer, and portability. BIA is an indirect technique for estimating body composition, as it sends electrical currents through the body's tissues to calculate impedance, otherwise known as the resistivity and reactance of the current (26, 21). These values are then incorporated into customized equations to estimate FFM, fat mass, and total body water. Many studies have compared BIA with other 2-compartment assessments of body composition devices in a wide variety of athletes and results have produced similar and valid results ($r > 0.667$; SEE < 4.3% body fat; TE: < 4.6% body fat; < 2.4 kg FFM) (26). Despite being sensitive to hydration status and menses, if the BIA guidelines are followed and athletes are tested under the ideal conditions, BIA can provide valid body composition estimations similar to underwater weighing and air-displacement plethysmography (26).

More research is needed to assess the utility of FFMI in American football athletes. Specifically, NCAA DIII athletes are underrepresented in research, despite making up 243 (46%) collegiate programs within the United States (28). The current study aimed to extend the existing FFMI literature in collegiate American football players by assessing potential variations in FFMI among different positions and age groups. We hypothesized that FFMI will differ significantly among position groups and age categories. Additionally, we expected that the previously suggested limit of 25 kg · m^{-2} may underestimate the FFMI upper limit for collegiate football players.

METHODS

Participants

A convenience sample of NCAA DIII (n=111) collegiate men football players participated in this study (Table 1). Inclusion criteria were athletes between the ages of 18-22; athletes who did not meet this criteria were excluded. Athletes were categorized by position group as follows: linemen (LINE: offensive and defensive line (n=39)), interior skill (I-SKILL: running back, linebacker, quarterback, full back (n=38)), perimeter skill (P-SKILL: wide receiver, defensive back (n=29)) or special teams (SPECIALTY: kickers (n=5)). All athletes were participating in a strength and conditioning program that had them lifting 2x/week, which included structured programming under the direction of a Certified Strength and Conditioning Specialist®. All athletes included in the study completed a health history form and were medically cleared for intercollegiate athletic participation. Risks and benefits were explained to athletes, and an institutionally approved written informed consent form was signed before participation. All procedures involving human subjects were conducted in accordance with the requirements of the Declaration of Helsinki and approved by the Institutional Review Boards for Human Subjects (IRB # 3182021). This research was carried out fully in accordance with the ethical standards of the International Journal of Exercise Science (27).

Table 1. Athlete (n=111) characteristics.

Age (yrs.)	19.5 ± 1.2
Weight (kg)	93.2 ± 14.4
Height (cm)	181.0 ± 5.9
BF (%)	16.8 ± 6.8
FM (kg)	16.5 ± 8.8
FFM (kg)	77.3 ± 6.6

Values are mean ± SD.
BF: body fat; FM: fat mass; FFM: fat-free mass.

Protocol

This cross-sectional study aimed to establish normative FFMI values for collegiate American football players. Body composition assessments using BIA were conducted at the start of the football season, and FFMI values were adjusted for height (33). This study compared FFMI values across positions and age groups and identified the reasonably attainable upper limit by calculating the 97.5th percentile values.

Athletes were instructed to report to the laboratory in a euhydrated state and to refrain from eating and exercising for at least 3 hours before the single study visit, during which body composition assessments were collected (17, 14). However, all testing was completed between the hours of 6:00-8:00am and thus, was likely following an overnight fast. To ensure participants arrived euhydrated, they were asked to consume water the day before testing and upon waking in the morning (18, 22). A portable stadiometer was used to collect height, while body composition was assessed using bioelectrical impedance analysis devices (InBody270, Biospace, California, USA). The InBody 270 devices has been previously validated against dual energy X-ray absorptiometry and may be an acceptable alternative assessment, despite underestimating FFMI (29). Athletes were instructed to stand on the platform, align the soles of their feet with the metal electrodes, and remain still while their weight was measured. Next, they were instructed to grab the handles, place their thumb on the oval electrodes, and keep their arms straight and away from their body.

FFMI was calculated using the following equation (35): FFMI (kg)/Height^2 (m^2)

Previous research has indicated that there may be bias in FFMI values toward taller individuals (19). To account for this, raw FFMI was regressed against height, using only cases in which FFMI values were above the median (33). The slope of the regression line was used to calculate height-adjusted FFMI ($FFMI_{adj}$) values based on the average heights in the sample (1.81 m), following previously used methods to reflect more accurately those closer to upper threshold of FFM accretion (33, 7):

$FFMI_{adj}$ = FFMI + ([-3.7] x [1.81 – subject height])

Statistical Analysis

Data were analyzed using IBM SPSS Statistics Version 25 (IBM, Armonk, NY, USA) and are presented as mean ± SD. Non-normally distributed variables (body weight and height) were log-transformed using a natural log transformation. Differences between $FFMI_{raw}$ and $FFMI_{adj}$ were assessed using a paired-samples t-test. One-way analyses of variance with Bonferroni post hoc comparisons were used to determine differences in FFMI across playing position and age group ($p < 0.05$). Partial eta^2 (η^2) effect sizes were calculated and interpreted as follows: small: 0.01-0.06; moderate: 0.06-0.14; and large: >0.14 (23). Percentile classifications were calculated for the 10th, 25th, 50th, 75th, 90th, and 97.5th percentile to determine the natural upper limit for FFMI.

RESULTS

The mean $FFMI_{raw}$ for the entire sample was 23.6 ± 2.0 kg · m^{-2} and the median was 24.0 kg · m^{-2}. The mean $FFMI_{adj}$ was also 23.9 ± 2.2 kg · m^{-2}. A paired sample t-test revealed no differences between raw and adjusted FFMI values for the entire sample ($p = 0.404$); thus, $FFMI_{raw}$ was used for all analyses.

Twenty-three athletes (21%) had $FFMI_{raw}$ values above 25.0 kg · m⁻² with a range of 18.1 – 27.7 kg · m⁻² and an interquartile range of 22.1 – 24.7 kg · m⁻². Ninety-five percent of values fell between 19.5 and 27.5 kg · m⁻².

Table 2. FFMIraw values and percentiles.

$FFMI_{raw}$ Mean ± SD	$FFMI_{raw}$ Range	$FFMI_{raw}$ 10th	$FFMI_{raw}$ 25th	$FFMI_{raw}$ 50th	$FFMI_{raw}$ 75th	$FFMI_{raw}$ 90th	$FFMI_{raw}$ 97.5th
23.6 ± 2.0	18.1–27.7	20.9	22.1	23.5	24.7	26.7	27.4

Positional differences were apparent ($p < 0.001$, Table 3), with highest values observed in LINE (24.8 ± 1.5 kg · m⁻²) and I-SKILL (23.9 ± 2.0 kg · m⁻²) and lowest values in P-SKILL (21.8 ± 1.0 kg · m⁻²) and SPECIALTY (20.6 ± 1.4 kg · m⁻²) (Figure 1).

Table 3. $FFMI_{raw}$ values across position groups.

	$FFMI_{raw}$ (kg · m⁻²)	Range (95% CI)
LINE (n=39)	24.8 ± 1.5	21.4 – 27.5 (24.3 – 25.2)
I-SKILL (n=38)	23.9 ± 2.0	18.1 – 27.7 (23.2 – 24.5)
P-SKILL (n=29)	21.8 ± 1.0*^	19.7 – 22.9 (21.4 – 22.2)
SPECIALTY (n=5)	20.6 ± 1.4*^	19.2 – 22.9 (18.0 – 23.1)
p-value	<0.001	
η^2	0.426	

Values are mean ± SD.
LINE: linemen; I-SKILL: interior skill; P-SKILL (perimeter skill); SPECIALTY: special teams.
*Significantly different than LINE; ^Significantly different than I-SKILL.

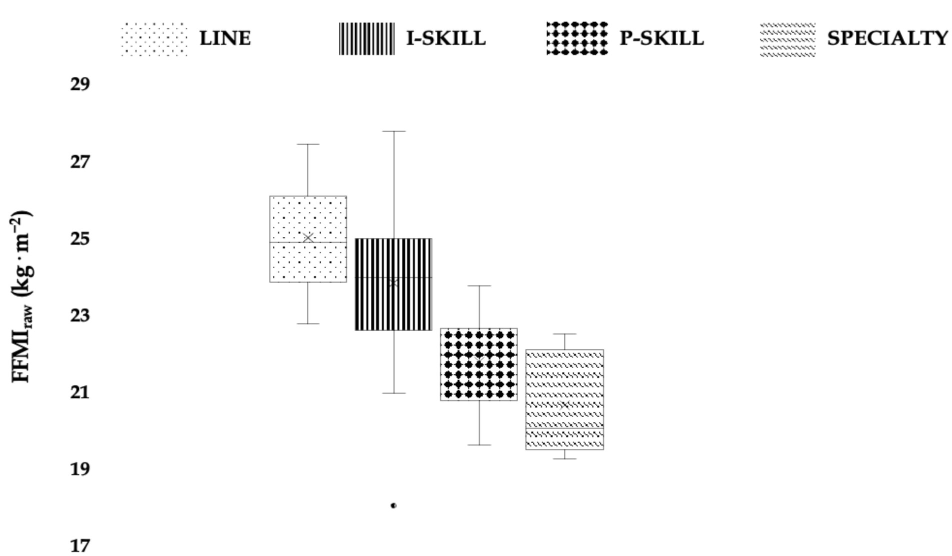

Figure 1. Boxplots of $FFMI_{raw}$ (kg · m⁻²) by position in DIII football players (n=111). LINE: linemen; I-SKILL: interior skill; P-SKILL: perimeter skill; SPECIALTY: special teams.

No differences were observed across age groups (p=0.283). After covarying for position makeup, $FFMI_{raw}$ was lowest in 18 year olds (p=0.020) (Table 4).

Table 4. $FFMI_{raw}$ values across age groups.

Age Groups	$FFMI_{raw}$ ($kg \cdot m^{-2}$) (95% CI)	$FFMI_{raw}$ ($kg \cdot m^{-2}$), corrected for position makeup (95% CI)
18 (n=32)	22.9 ± 1.9 (22.3 – 23.6)	22.8 ± 1.8 (22.2 – 23.4)
19 (n=24)	23.8 ± 1.3 (23.2 – 24.3)	24.0 ± 2.5* (23.3 – 24.7)
20 (n=24)	24.0 ± 2.4 (23.0 – 25.0)	24.0 ± 2.5* (23.3 – 24.7)
21 (n=31)	23.4 ± 2.3 (22.6 – 24.4)	23.9 ± 2.2* (23.2 – 24.7)
p-value	0.283	0.020
η^2	0.041	0.088

Values are mean ± SD.
95% CI: 95% Confidence Intervals.
*Significantly different than 18-year-olds.

DISCUSSION

This study aimed to extend the FFMI literature in collegiate American football players and assess FFMI variations across positions and age groups. Our findings suggest that the upper limits for FFM accretion in male athletes may be higher than previously assumed, as the FFMI limit of 25 $kg \cdot m^{-2}$ underestimates that observed in American collegiate football players. Further, FFMI values varied significantly among playing positions.

There is limited data available regarding FFMI in collegiate American football players. Of the available research, only one prior study reported FFMI values in DIII players (4), of which appear to be slightly higher (24.28 ± 2.04 $kg \cdot m^{-2}$) than those observed in the current study (23.6 ± 2.0 $kg \cdot m^{-2}$). Further, when comparing the limited FFMI research, values appear to be lower in DIII compared to DI and DII players. For example, Trexler et al. reported average FFMI values of 24.3 ± 1.8 $kg \cdot m^{-2}$ in DI athletes and 23.4 ± 1.8 $kg \cdot m^{-2}$ in DII athletes (33). Differences in FFMI may be attributable to different methodologies used for assessing body composition and differences in the level of players. For example, in the current study, body composition was assessed via bioelectrical impedance, whereas previous studies used air displacement plethysmography (Bod Pod) (7, 4) and dual-energy-x-ray absorptiometry (DXA) (33). The InBody270 (12) has shown to underestimate body fat and overestimate FFM in comparison to the DXA, suggesting bioelectrical impedance may produce higher FFMI values compared to the DXA. Therefore, caution should be exercised when comparing FFMI values across assessment methodologies. Secondly, differences in FFMI values among the literature most likely reflect differences in the level of competition (DI vs. DII vs. DIII) and subsequently the body stature, physiques, and physical capabilities of players recruited to compete at that level. For example, when compared to the DII and DIII level of competition, DI athletes have exhibited greater body mass (~103-131 kg) (1, 5, 13, 37) height (~192 cm) (5, 13, 37), lean mass (~70-90 kg) (37, 3), strength

(11), speed (2), and power (11, 24). These football programs likely recruit athletes who are more fully developed and physically skilled, thus unsurprisingly showing higher FFMI values as the level of competition increases. It should be noted that DIII athletes are non-scholarship players and often have limited access to resources that DI and DII athletes have (i.e., strength staff, nutrition, and dietetic support), along with differences in off-season training requirements, all of which likely contributes to the observed differences across divisions.

An important finding of the current study was that 23 athletes (21%) had a FFMI above 25 $kg \cdot m^{-2}$ (range: 18.1 – 27.7 $kg \cdot m^{-2}$). Similarly, Trexler et al (33). reported that 26.4% of their sample of DI and DII football athletes had FFMI values above 25 $kg \cdot m^{-2}$, with a maximal observed value of 31.7 $kg \cdot m^{-2}$. Other research has reported lower maximal FFMI values of 25.9 $kg \cdot m^{-2}$ and 24.8 $kg \cdot m^{-2}$ in smaller samples of DII and DIII football athletes, respectively (7, 4). The current findings highlight that collegiate American football players have the potential to achieve FFMI values significantly exceeding 25 $kg \cdot m^{-2}$. Further, the percentile ranges presented in the current study may serve as a way to characterize FFMI values within collegiate American football. Interestingly, prior research in collegiate American football have showed taller athletes had higher FFMI values; however, the current study's regression model showed a negative slope, indicating an inverse association between height and FFMI. While an unexpected finding, perhaps this association may be attributed to a lower level of competition where body stature and physique is less emphasized.

Differences among position groups likely result from the distinct physical demands of each position (9), and the subsequent body type often recruited to play that position. LINE (24.8 ± 1.5 $kg \cdot m^{-2}$) and I-SKILL (23.9 ± 2.0 $kg \cdot m^{-2}$) positions displayed higher FFMI values than P-SKILL (21.8 ± 1.0 $kg \cdot m^{-2}$) and special teams (20.6 ± 1.4 $kg \cdot m^{-2}$). These differences were expected as LINE and I-SKILL players require greater body size, lean mass, and strength to meet their positional requirements of blocking and tackling, while P-SKILL positions emphasize greater speed and maneuverability to propel their bodies quickly and explosively down the field (8, 36). Similar positional differences were reported in DI and DII football athletes, with LINE having the greatest FFMI (~25 $kg \cdot m^{-2}$), followed by I-SKILL players (~24 $kg \cdot m^{-2}$) (33). While there are the only two studies reporting FFMI values across positions in collegiate American football athletes, other research reports that LINE players exhibit greater body weight, body fat %, fat mass, and FFM (20, 34), which may be associated with success in their position.

When adjusted for position, differences in FFMI were apparent across age groups, with 18-year olds displaying the lowest FFMI. This was in agreement with the study's hypothesis, as younger athletes entering college may have less experience with a consistent strength and conditioning program, while older athletes have been exposed to a more consistent and specialized training schedule, thus enabling them to more closely achieve their genetical potential for size and FFM accretion. While limited research has explored FFMI differences across age groups (33), previous studies in collegiate American football athletes have reported longitudinal improvements in FFM, with an approximate 4 kg increase from freshmen to senior year (13, 34, 15). However, Trexler et al. (33) reported no statistical difference in FFMI across age groups in their sample of

DI and DII football players. Authors concluded that the lack of statistical difference across groups was likely due to the specificity of the recruiting class. Each class at varying levels of competition may differ in body composition, prior experience with strength and conditioning, and injury acquisition, which may confound the expected increase in FFMI across their collegiate career (33). This emphasizes the importance of tracking longitudinal changes in body composition to evaluate athlete physical development and exercise program effectiveness.

Despite this study's strengths, it's important to acknowledge its limitations. First, BIA tends to overestimate FFM, is sensitive to hydration status and recent exercise, and uses many assumptions to calculate BF%. While athletes were instructed to arrive at the laboratory in a hydrated, fasted state, and having abstained from exercise, quantitative measurements were not collected to confirm compliance with these criteria. Additionally, while collegiate athletes are subject to random, year-round drug testing, anabolic-androgenic steroid use was not screened in the current investigation.

In conclusion, FFMI values displayed small differences to those previously reported in collegiate American football athletes. This study demonstrates that an athlete's upper limit for FFMI may extend well beyond 25 $kg \cdot m^{-2}$, and differences exist across positions for collegiate American football. A lower FFMI may indicate an athlete has potential for further muscle accretion and subsequent training and nutritional strategies may be implemented accordingly. Conversely, a higher FFMI that approaches the upper limit may shift training away from hypertrophy-focused goals and may prioritize speed, power, and sport-specific skills (33). Additionally, determining normative values and percentile rankings of FFMI in collegiate athletes may provide important insight into athlete recruitment and development, potential success in a specific position, exercise programming, injury and health status, and setting realistic body composition goals.

REFERENCES

1. Abbey EL, Wright CJ, Kirkpatrick CM. Nutrition practices and knowledge among NCAA Division III football players. J Int Soc Sports Nutr 14: 13, 2017.

2. Abrantes C, Maçãs V, Sampaio J. Variation in football players' sprint test performance across different ages and levels of competition. J Sports Sci Med 3: 44-49, 2004.

3. Bosch TA, Carbuhn AF, Stanforth PR, Oliver JM, Keller KA, Dengel DR. Body composition and bone mineral density of Division 1 collegiate football players: A consortium of college athlete research study. J Strength Cond Res 33(5): 1339-1346, 2019.

4. Brandner CF, Harty PS, Luedke JA, Erickson JL, Jagim AR. Sport differences in fat-free mass index among a diverse sample of NCAA Division III collegiate athletes. J Strength Cond Res 36(8): 2212-2217, 2022.

5. Buell JL, Calland D, Hanks F, Johnston B, Pester B, Sweeney R, et al. Presence of metabolic syndrome in football linemen. J Athl Train 43(6): 608-616. 2008.

6. Carling C, Orhant E. Variation in body composition in professional soccer players: Interseasonal and intraseasonal changes and the effects of exposure time and player position. J Strength Cond Res 24(5): 1332-1339, 2010.

7. Currier BS, Harty PS, Zabriskie HA, Stecker RA, Moon JM, Jagim AR, et al. Fat-free mass index in a diverse sample of male collegiate athletes. J Strength Cond Res 33(6): 1474-1479, 2019.

8. Edwards T, Spiteri T, Piggott B, Haff GG, Joyce C. A narrative review of the physical demands and injury incidence in American football: Application of current knowledge and practices in workload management. Sports Med 48(1): 45-55, 2018.

9. Fields JB, Merrigan JJ, White JB, Jones MT. Body composition variables by sport and sport-position in elite collegiate athletes. J Strength Cond Res 32(11): 3153-3159, 2018.

10. Fields JB, Metoyer CJ, Casey JC, Esco MR, Jagim AR, Jones MT. Comparison of body composition variables across a large sample of National Collegiate Athletic Association women athletes from 6 competitive sports. J Strength Cond Res 32(9): 2452-2457, 2018.

11. Fry AC, Kraemer WJ. Physical performance characteristics of American collegiate football players. J Strength Cond Res 5(3): 126-138, 1991.

12. Garcia JR, Manimaleth R, Czartoryski P, Napolitano P, Watters H, Weber C, et al. A comparative study of body composition assessment techniques: DXA and InBody 270. J Exerc Nutr 3(3): 10, 2020.

13. Hoffman JR, Ratamess NA, Kang J. Performance changes during a college playing career in NCAA division III football athletes. J Strength Cond Res 25(9): 2351-2357, 2011.

14. InBody USA. The InBody Test and InBody Test Procedures. Available at: https://inbodyusa.com/general/inbody-test/; n.d.

15. Jacobson BH, Conchola EG, Glass RG, Thompson BJ. Longitudinal morphological and performance profiles for American NCAA division I football players. J Strength Cond Res 27(9): 2347-2354, 2013.

16. Johnson SL, Stone WJ, Bunn JA, Lyons TS, Navalta JW. New author guidelines in statistical reporting: Embracing an era beyond p < .05. Int J Exerc Sci 13(1): 1–5, 2020.

17. Kaminsky LA, Whaley MH. Differences in estimates of percent body fat using bioelectrical impedance. J Sports Med Phys Fitness 33(2): 172–177, 1993.

18. Kim J-H, Cheung B-Y, Lee Y-J, Choi W-S. Evaluation of appropriacy of taking water 2 hours before bioelectrical impedance analysis: Single-frequency bioelectrical impedance analysis versus multi-frequency bioelectrical impedance analysis. Korean J Fam Pract 9(1): 114–117, 2019.

19. Kouri EM, Pope HG, Katz DL, Oliva P. Fat-free mass index in users and nonusers of anabolic-androgenic steroids. Clin J Sport Med 5(4): 223-228, 1995.

20. Kraemer WJ, Ratamess NA, Spiering BA, Hatfield DL, Vingren JL, Volek JS. Body size and composition of National Football League players. J Strength Cond Res 19(3): 485-489, 2005.

21. Kushner RF. Bioelectrical impedance analysis: A review of principles and applications. J Am Coll Nutr 11(2): 199-209, 1992.

22. Kyle UG, Bosaeus I, De Lorenzo AD, Deurenberg P, Elia M, Gómez JM, et al. Bioelectrical impedance analysis-part II: Utilization in clinical practice. Clin Nutr 23(6): 1430–1453, 2004.

23. Lakens D. Calculating and reporting effect sizes to facilitate cumulative science: A practical primer for t-tests and ANOVAs. Front Psychol 4: 863, 2013.

24. Lockie RG, Dawes JJ, Jones MT. Relationships between linear speed and lower-body power with change-of-direction speed in National Collegiate Athletic Association Divisions I and II women soccer athletes. Sports 6(2): 30, 2018.

25. Mala L, Maly T, Zahalka F, Bunc V, Kaplan A, Jebavy R, et al. Body composition of elite female players in five different sports games. J Hum Kinet 45(1): 207-215, 2015.

26. Moon JR. Body composition in athletes and sports nutrition: An examination of the bioimpedance analysis technique. Eur J Clin Nutr 67 (1): S54-59, 2013.

27. Navalta JW, Stone WJ, Lyons TS. Ethical issues relating to scientific discovery in exercise science. Int J Exerc Sci 12(1): 1–8, 2019.

28. NCSA College Recruiting. Full list of Division 3 football teams. Available at: https://www.ncsasports.org/football/division-3-colleges; 2022.

29. Schoenfeld BJ, Nickerson BS, Wilborn CD, Urbina SL, Hayward SB, Krieger J, et al. Comparison of multifrequency bioelectrical impedance vs. dual-energy x-ray absorptiometry for assessing body composition changes after participation in a 10-week resistance training program. J Strength Cond Res 34(3): 678-688, 2020.

30. Stuempfle KJ, Katch FI, Petrie DF. Body composition relates poorly to performance tests in NCAA Division III football players. J Strength Cond Res 17(2): 238-244, 2003.

31. Takai Y, Kai T, Horio K, Nakatani M, Haramura M, Aoki T, et al. Lean body mass index is an indicator of body composition for screening prospective young adult soccer players. Football Sci 14: 8-14, 2017.

32. Thomas DT, Erdman KA, Burke LM. Position of the Academy of Nutrition and Dietetics, Dietitians of Canada, and the American College of Sports Medicine: Nutrition and athletic performance. J Acad Nutr Diet 116(3): 501-528, 2016.

33. Trexler ET, Smith-Ryan AE, Blue MNM, Schumacher RM, Mayhew JL, Mann JB, et al. Fat-free mass index in NCAA Division I and II collegiate American football players. J Strength Cond Res 31(10): 2719-2727, 2017.

34. Trexler ET, Smith-Ryan AE, Mann JB, Ivey PA, Hirsch KR, Mock MG. Longitudinal body composition changes in NCAA Division I college football players. J Strength Cond Res 31(1): 1-8, 2017.

35. VanItallie TB, Yang MU, Heymsfield SB, Funk RC, Boileau RA. Height-normalized indices of the body's fat-free mass and fat mass: Potentially useful indicators of nutritional status. Am J Clin Nutr 52(6): 953-959, 1990.

36. Wellman AD, Coad SC, Goulet GC, McLellan CP. Quantification of competitive game demands of NCAA Division I college football players using global positioning systems. J Strength Cond Res 30(1): 11-19, 2016.

37. Wichmann TK, Wolfson J, Roelofs EJ, Bosch TA, Bach CW, Oliver JM, et al. Longitudinal assessment of NCAA Division I football body composition by season and player age. J Strength Cond Res 33(5): 1339-1346, 2019.