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Body Composition and Readiness: Sex-Specific Changes in Military Students Assessed with MF-BIA/InBody970

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Abstract

This longitudinal study examined sex-specific changes in body composition across the first academic year in military university students using multi-frequency bioelectrical impedance analysis (InBody 970). A total of 497 cadets (408 men, 89 women) were assessed at baseline and follow-up. In both sexes, body mass increased primarily due to gains in fat-free mass and skeletal muscle mass, accompanied by higher total body water and basal metabolic rate, while changes in adiposity indicators were small. Men exhibited greater increases in lean-related parameters, whereas women showed a modest reduction in percent body fat. These findings support MF-BIA as a practical tool for large-scale monitoring of functional and medical readiness in military populations.

KEY WORDS: *body composition, military students, multi-frequency bioelectrical impedance analysis (MF-BIA), longitudinal study, skeletal muscle mass*

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1. Introduction

Body composition is among the key indicators of physical readiness and overall health status in military personnel. Recent studies emphasize the importance of maintaining adequate skeletal muscle and fat mass and their association with improved performance in military tasks, while also cautioning against unhealthy weight-control practices (e.g., disordered eating) that may arise in response to pressure to meet body-composition standards [1]. At the same time, the establishment of body-composition standards – particularly for accession – continues to be debated across armed forces. Population trends in obesity indicate that a substantial proportion of potential recruits do not meet current requirements, which has direct implications for recruitment capacity and overall operational readiness [2]. Basic combat training (BCT) induces changes in skeletal muscle mass (SMM) and body fat. However, the commonly used body mass index (BMI) cannot reliably distinguish the contribution of fat and muscle to total body mass. In practice, soldiers may present with lower percent body fat (%BF) and higher SMM at the same BMI after training; therefore, interpreting BMI as a proxy of individual adiposity can therefore be misleading [3], [4]. This aligns with a broader trend toward modernizing military approaches to body-composition assessment – moving away from purely circumference- and BMI-based metrics toward methods that more directly reflect actual body composition and thus reduce false classifications [5]. In this context, multi-frequency segmental bioelectrical impedance analysis (MF-BIA) is increasingly used as a rapid, non-invasive, and logistically feasible tool for monitoring key body-composition parameters. Recent military research demonstrates very high reliability and good agreement of MF-BIA devices (e.g., InBody 770) with dual-energy X-ray absorptiometry (DXA), while also highlighting biological variability and the importance of standardized testing conditions [6]. Validation studies in different populations also report high agreement for muscle mass and related components. Comparative studies of newer high-frequency BIA devices (including the InBody 970 generation) report high correlations with DXA for fat-free mass (FFM) and percent body fat (PBF) [7,8]. From a performance perspective, SMM is a key determinant of strength and military-specific tasks (e.g., load carriage, casualty evacuation, repeated strength-endurance activities). Among military cadets, field tests such as vertical jump and medicine-ball throw show moderate-to-strong correlations with SMM, whereas some traditional tests (e.g., sit-ups) correlate weakly. This supports prioritizing SMM and FFM as relevant predictors of strength capacity and developing more valid readiness tests. Moreover, although lower body mass may confer an advantage in calisthenics-based tasks, higher SMM – and sometimes even higher BMI – may improve performance in tasks such as ruck marching, load carrying, or deadlift-type lifts that better reflect real military duties [9,10]. Particular attention should be paid to visceral fat. In military men, higher visceral adiposity is clearly associated with increased cardiometabolic risk (e.g., metabolic syndrome, MetS), and thresholds for visceral adipose tissue (VFA/VAT) have been proposed to identify elevated MetS risk. These facts have direct implications for periodic medical screening and for targeting preventive and intervention programs during training. Hydration-related indices, especially total body water (TBW) and the extracellular-to-total body water ratio (ECW/TBW), can serve as practical indicators of fluid distribution and cellular integrity. Studies indicate that ECW/TBW reflects fluid distribution and may predict adverse physiological states, although its interpretation requires standardized measurement conditions [11-13]. Research further shows substantial sex differences not only in baseline body composition, but also in how body compartments respond to prolonged physical stress. Men typically exhibit higher absolute muscle mass and lower relative body fat, whereas women may display different metabolic strategies during physical stress, including a greater reliance on fat oxidation [14,15]. Understanding these sex-specific differences is essential for effective evaluation of military readiness, training individualization, and long-term optimization of fitness. Accordingly, longitudinal monitoring of body composition across the first academic year may improve understanding of sex differences and training adaptations (e.g., gains in SMM and FFM, changes in PBF and VFA) within a relatively standardized regimen. Therefore, the aim of this study was to analyze changes in selected body-composition parameters in men and women in a military setting using advanced MF-BIA technology (InBody 970) and to assess the magnitude of these changes between sexes.

2. Methods

Participants. This study used a prospective longitudinal design with two repeated measurements collected at the beginning and end of the first academic year. A total of 497 military university students were included (408 men, 89 women). The men were 20.1 ± 1.40 years old, with a body height of 181.6 ± 6.72 cm and body mass of 78.9 ± 10.01 kg. The women were 19.9 ± 1.02 years old, with a body height of 167.9 ± 6.69 cm and body mass of 63.2 ± 7.90 kg. All first-year cadets enrolled in the academic year were eligible for participation. Exclusion criteria included acute injury, chronic disease, or inability to complete both measurement sessions. Participation was mandatory as part of the regular physical fitness assessment program. All participants provided informed consent prior to enrollment. Measurements were conducted in the morning hours under standardized conditions, with participants wearing light sports clothing and instructed to refrain from strenuous exercise and heavy meals prior to the assessment. The study was approved by the Ethics Committee of the University of Defence Brno (Physical Training and Sports Centre), and all procedures conformed to the principles of the Declaration of Helsinki.

Procedures. All measurements were performed in the morning under fasted, pre-breakfast conditions and in a controlled laboratory environment. Body composition was assessed at two time points (baseline and end of year 1) using multi-frequency bioelectrical impedance analysis (MF-BIA; InBody 970, InBody Co., Seoul, Korea). All assessments adhered to institutional standard operating procedures, including device-specific posture and contact requirements, the use of light clothing, and the removal of metallic objects. When applicable, manufacturer-recommended pre-assessment controls (e.g., hydration standardization, avoidance of recent physical activity, and abstinence from food or caffeine within the specified time window) were applied as part of routine laboratory practice. The body composition assessment included a comprehensive set of anthropometric and physiological indicators derived from multi-frequency bioelectrical impedance analysis (MF-BIA; InBody 970). Basic anthropometric variables comprised body height, weight and body mass index (BMI). Lean and muscular compartments were evaluated using fat-free mass (FFM) and skeletal muscle mass (SMM). Adiposity was quantified through body fat mass (BFM) and percent body fat (PBF). Indicators of fat distribution and cardiometabolic risk included waist-to-hip ratio (WHR) and visceral fat area (VFA). Hydration and fluid-balance status was assessed using total body water (TBW) and the extracellular to total body water ratio (ECW/TBW). Basal metabolic rate (BMR) was also obtained as a general metabolic indicator. The selection of MF-BIA (InBody 970) was supported by recent validation and reliability evidence demonstrating strong agreement with dual-energy X-ray absorptiometry (DXA) and by its practical suitability for large-scale longitudinal monitoring in military populations [6–8].

Statistical analyses. Statistical analyses were performed using standard procedures for continuous data evaluation. Descriptive statistics (mean and standard deviation) were calculated for all variables. Prior to inferential testing, the distribution of each variable was assessed using the Shapiro-Wilk test to determine adherence to normality assumptions. Depending on distributional characteristics and the analytical objective, either parametric or non-parametric tests were applied. Paired t-tests were used to evaluate within-subject changes over time for normally distributed variables, whereas the Wilcoxon signed-rank test served as the non-parametric alternative. Between-sex comparisons were conducted using independent-samples t-tests for normally distributed data or the Mann-Whitney U test when normality assumptions were violated. Effect sizes for pre-post comparisons were calculated using Cohen's dz [16], which accounts for the within-subject dependence structure inherent to repeated-measures designs. Between-group effect sizes were quantified using Hedges' g [17], which provides a small-sample bias-corrected estimate of standardized mean differences. Effect magnitudes were interpreted using conventional benchmarks (small ≈ 0.20, medium ≈ 0.50, large ≈ 0.80); where appropriate, 95% confidence intervals for effect sizes were reported to aid precision and practical interpretation. Statistical significance was set at $p < 0.05$. All analyses were conducted following established methodological standards to ensure robustness and reproducibility.

3. Results

Table 1 presents baseline and end-of-year values for body-composition parameters in men (n = 408) and forms the basis for interpretation of within-year changes. Descriptively, men exhibited a modest increase in body mass from baseline to follow-up, with the pattern of change suggesting that gains were driven primarily by the lean compartment. More pronounced increases were observed in skeletal muscle mass (SMM), fat-free mass (FFM), and total body water (TBW), consistent with the parallel increase in basal metabolic rate (BMR), which is closely linked to metabolically active tissue. In contrast, body fat mass (BFM) increased only minimally, while percent body fat (PBF) remained essentially unchanged. Thus, the increase in total body mass appears to reflect growth in the fat-free compartment rather than increased adiposity. The ECW/TBW ratio remained stable, suggesting unchanged fluid distribution without evidence of increased extracellular fluid retention. Visceral fat area (VFA) increased in men; however, in the context of overall body-composition changes, this increase was small relative to the magnitude of gains observed in FFM and SMM.

Table 1. Descriptive statistics (start vs. end) and paired changes (Δ = end − start) – men (n = 408)

Variable	Mean (Start)	SD (Start)	Mean (End)	SD (End)	Mean Change (Δ)	95% CI – Lower	95% CI – Upper	p-value	Cohen dz
Age	20.09	1.40	20.80	1.42	0.71	0.66	0.75	0.0000	1.43
Height	181.58	6.72	181.59	6.72	0.01	-0.11	0.12	1.0000	0.01
Weight	78.85	10.05	81.19	9.97	2.34	2.01	2.67	0.0000	0.69
BMI	23.89	2.49	24.60	2.45	0.71	0.61	0.81	0.0000	0.71
SMM	38.94	4.78	40.16	4.80	1.22	1.07	1.36	0.0000	0.82
FFM	68.26	7.98	70.16	8.01	1.90	1.67	2.14	0.0000	0.77
BFM	10.59	4.42	11.03	4.65	0.44	0.22	0.65	0.0001	0.20
PBF	13.21	4.40	13.38	4.55	0.17	-0.05	0.39	0.1833	0.07
WHR	0.83	0.04	0.83	0.05	0.00	0.00	0.01	0.0000	0.25
TBW	50.03	5.80	51.37	5.83	1.34	1.17	1.52	0.0000	0.75
ECW/TBW	0.37	0.01	0.37	0.01	0.00	0.00	0.00	0.0000	-0.52
BMR	1844.39	172.38	1885.48	173.08	41.09	35.92	46.25	0.0000	0.77
VFA	42.21	21.77	44.27	22.79	2.06	1.06	3.06	0.0002	0.20

Notes: BMI = body mass index; SMM = skeletal muscle mass (kg); FFM = fat-free mass (kg); BFM = body fat mass (kg); PBF = percent body fat (%); WHR = waist-to-hip ratio (index); TBW = total body water (L); ECW/TBW = extracellular water (index); BMR = basal metabolic rate (kcal/day); VFA = visceral fat area (cm^2); values are reported as mean (SD); mean change (Δ) was calculated as End – Start; 95% CI denotes the 95% confidence interval for the mean change; p-values are two-sided; effect size is reported as Cohen's dz for paired samples.

Table 2 summarizes baseline and end-of-year values for body-composition parameters in women (n = 89). Women showed a modest increase in body mass across the observation period, again characterized mainly by increases in the lean compartment.

Table 2. Descriptive statistics (start vs. end) and paired changes (Δ = end − start) − women (n = 89)

Variable	**Mean (Start)**	**SD (Start)**	**Mean (End)**	**SD (End)**	**Mean Change (Δ)**	**95% CI – Lower**	**95% CI – Upper**	**p-value**	**Cohen dz**
Age	19.93	1.02	20.51	1.15	0.58	0.47	0.68	0.0000	1.15
Height	167.90	6.69	167.98	6.84	0.08	-0.30	0.45	0.6829	0.04
Weight	63.16	7.90	64.09	7.85	0.93	0.42	1.44	0.0006	0.38
BMI	22.43	2.73	22.76	2.78	0.33	0.15	0.51	0.0006	0.38
SMM	26.48	3.14	27.14	3.04	0.66	0.43	0.90	0.0000	0.59
FFM	47.84	5.23	48.93	5.08	1.09	0.69	1.48	0.0000	0.57
BFM	15.32	4.53	15.16	4.62	-0.16	-0.58	0.27	0.4654	-0.08
PBF	23.95	4.91	23.34	4.94	-0.61	-1.17	-0.06	0.0327	-0.23
WHR	0.84	0.04	0.84	0.04	0.00	0.00	0.01	0.5573	0.04
TBW	35.02	3.81	35.80	3.69	0.78	0.48	1.06	0.0000	0.55
ECW/TBW	0.38	0.00	0.38	0.01	0.00	0.00	0.00	0.0203	-0.25
BMR	1403.33	112.87	1426.94	109.55	23.61	15.07	32.17	0.0000	0.57
VFA	62.53	20.96	61.89	21.30	-0.64	-1.87	0.59	0.3274	-0.11

Notes:see Table 1.

The most pronounced changes were observed in SMM, FFM, and TBW, consistent with their physiological interdependence, and were accompanied by an increase in BMR. In contrast, BFM changed minimally and PBF showed a small decrease, indicating that the overall body-mass increase was not driven by increased adiposity. The ECW/TBW ratio remained stable, suggesting preserved fluid distribution and no meaningful extracellular fluid retention. VFA showed a small decrease in women over the observation period.

Table 3. Between-sex differences in mean paired changes (Δ = men − women) in body composition parameters.

Variable	Mean Change (Δ)	95% CI – Lower	95% CI – Upper	p-value	Hedges g
Age	0.13	0.02	0.24	0.0260	0.26
Height	-0.07	-0.46	0.32	0.8637	-0.05
Weight	1.41	0.80	2.02	0.0000	0.43
BMI	0.38	0.18	0.59	0.0006	0.39
SMM	0.56	0.28	0.83	0.0000	0.39
FFM	0.81	0.35	1.28	0.0001	0.34
BFM	0.60	0.12	1.07	0.0156	0.27
PBF	0.78	0.19	1.38	0.0054	0.33
WHR	0.00	0.00	0.01	0.1356	0.21
TBW	0.56	0.23	0.92	0.0003	0.33
ECW/TBW	0.00	0.00	0.00	0.0249	-0.27
BMR	17.48	7.47	27.46	0.0002	0.34
VFA	2.70	0.32	5.07	0.0400	0.25

Table 3 presents between-sex differences in mean paired changes. Positive values indicate a greater increase (or smaller decrease) in men. The largest between-sex differences were observed for variables related to the fat-free compartment, with men showing greater gains in body mass, BMI, SMM, FFM, TBW, and BMR, whereas between-sex differences in adiposity-related variables were smaller.

4. Discussion

Key findings and relevance to military readiness. The primary finding is that across the first academic year, both men and women increased body mass primarily through gains in the fat-free compartment (FFM) and skeletal muscle mass (SMM), accompanied by increases in total body water (TBW) and basal metabolic rate (BMR), whereas changes in adiposity-related indicators were small. This profile is favorable from a military-readiness perspective, as higher SMM/FFM underpins force production and performance in physically demanding, task-relevant duties. At the same time, the body-composition literature highlights that pressure to meet standards may promote unhealthy weight-control behaviors, underscoring the importance of interpreting body-composition change in a combined performance – health framework [1].

BMI versus true body composition. Our data illustrate a common issue in training populations: BMI may increase even when adiposity does not. In men, BMI increased while PBF remained essentially unchanged, indicating that BMI was driven largely by gains in FFM/SMM. This aligns with evidence from military training showing that the BMI–%BF relationship shifts over the course of training, such that BMI becomes a poor proxy for individual adiposity [3]. Accordingly, these findings support ongoing modernization of body-composition policies toward methods that more directly quantify true body composition and reduce false classifications [5].

Comparison with basic combat training (BCT): why effect magnitudes differ. In short-duration military training (~8 weeks), DXA-based studies report reductions in %BF on the order of several percentage points (approximately −3.3% in men and −4.0% in women), while circumference-based approaches underestimate these changes [4]. In contrast, our year-long observations showed stable PBF in men and a small decrease in women, with dominant increases in SMM/FFM. Differences in training duration and structure, energy balance conditions, and methodology (DXA vs. MF-BIA) likely contribute to these contrasting trajectories. Although MF-BIA shows good agreement for FFM and PBF, some outputs – particularly segmental measures – may be more sensitive to measurement conditions [6-8].

MF-BIA (InBody 970) for large-scale military monitoring. MF-BIA provides a rapid, non-invasive, and operationally feasible approach for repeated measurements in large cohorts [6]–[8]. Military validation work also emphasizes high reliability and good agreement with DXA, alongside biological variability and the importance of strict standardization (e.g., fasting, avoiding recent exercise, consistent time-of-day) [6]. These considerations support the use of MF-BIA for longitudinal monitoring when standardized procedures are implemented.

Functional relevance and sex-specific interpretation. Increased SMM and FFM are central to military readiness, as muscle mass underpins strength and performance in task-relevant duties such as lifting, load carriage, and movement under external load [9], [10]. Field tests such as vertical jump power and medicine-ball throw show stronger associations with SMM than traditional calisthenics tests (e.g., sit-ups), supporting a focus on SMM/FFM and the development of more valid readiness measures [9]. Moreover, task-based readiness assessments may relatively favor higher SMM (and in some cases higher BMI), whereas calisthenics-only tasks often favor lower body mass – an important consideration when interpreting body-composition standards in relation to real military requirements [10]. In this context, between-sex comparisons indicated larger gains in the fat-free compartment in men, while differences in adiposity-related indicators were smaller. These findings are consistent with documented sex differences in energy balance and metabolic responses during military training, including a greater reliance on fat oxidation in women [14], [15]. Importantly, some long-duration, arduous training studies report different body-composition trajectories (e.g., relative stability of lean mass with concurrent increases in fat mass during specific training phases), highlighting the sensitivity of adaptations to training structure, content, and energy availability [14]. Therefore, body-composition changes should be interpreted in a sex-specific manner and within the context of the specific training program and its energetic demands [14,15].

Health-related indicators: visceral fat and hydration status. Changes in visceral fat area (VFA) were small, with men exhibiting a modest increase and women showing stable to slightly lower values. Although the observed effect sizes were small, visceral adiposity remains clinically relevant because it is strongly associated with cardiometabolic risk and established thresholds linked to metabolic syndrome [11]. From a medical-readiness perspective, even small longitudinal changes in VFA may therefore warrant attention. However, methodological caution is required when interpreting these findings. Thresholds reported in the literature are typically derived from DXA-based estimates of visceral adipose tissue expressed as volume or mass, whereas MF-BIA devices such as the InBody report VFA as an area estimate (cm^2). These metrics are not directly interchangeable and cannot be converted without a validated cross-method relationship [11]. Accordingly, VFA assessed by MF-BIA should be interpreted primarily as a trend-based risk indicator rather than an absolute diagnostic measure. Hydration-related indicators remained largely stable across the observation period. Total body water (TBW) increased in both sexes in parallel with gains in FFM and SMM, reflecting the close physiological linkage between lean tissue and body water. In contrast, the ECW/TBW ratio showed only negligible changes. This finding is methodologically important, as ECW/TBW is sensitive to measurement conditions and, in some contexts, may reflect altered fluid distribution or adverse physiological states [12], [13]. The stability of ECW/TBW in the present study supports consistent measurement conditions and suggests that the observed changes in body composition were not confounded by shifts in fluid distribution. Together, these findings reinforce the importance of standardized assessment protocols when MF-BIA is used for longitudinal monitoring of health-related indicators in military populations.

Limitations. Key limitations include the use of MF-BIA, which – despite good validity and reliability for FFM and PBF – remains an indirect method sensitive to hydration, feeding status (fasted vs. post-meal), and recent physical activity. These factors may increase variability in certain outputs and warrant cautious interpretation of small changes, particularly in segmental and visceral parameters. Second, detailed information on training load, dietary intake, and energy availability across the year was not available, which may influence especially adiposity-related outcomes (including VFA) and contribute to differences across protocols. Third, the unequal group sizes (men vs. women) may reduce precision for some between-sex comparisons. Fourth, only two time points were available, limiting the ability to capture within-year dynamics of body-composition changes across different training phases. Finally, the sample comprised first-year military university students, which may limit generalizability to professional personnel, other age groups, or highly specialized training courses.

5. Conclusions

Across the first academic year, both men and women exhibited predominantly favorable body-composition changes, characterized by increases in skeletal muscle mass (SMM), fat-free mass (FFM), and total body water (TBW), while changes in adiposity-related indicators were small; women additionally showed a modest decrease in percent body fat (PBF). Effect-size estimates indicate a practically meaningful adaptation toward higher functional capacity relevant to military readiness. The findings further demonstrate that body mass index (BMI) may not reliably reflect changes in adiposity in training populations, as increases in BMI can primarily result from gains in FFM and SMM. From a monitoring perspective, routine assessment of SMM and FFM appears particularly relevant for evaluating functional readiness, whereas visceral fat area (VFA) should be interpreted longitudinally as a complementary indicator of medical readiness. Overall, the results support MF-BIA as a practical and operationally feasible tool for routine, large-scale body-composition monitoring in military settings, provided that measurement conditions are standardized and adaptations are interpreted in a sex-specific manner.

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References

1. L. Cialdella-Kam, T. K. Bloedon, and M. S. Stone, "Body composition as a marker of performance and health in military personnel," *Frontiers in Sports and Active Living*, vol. 5, 2023. https://doi.org/10.3389/fspor.2023.1223254.
2. W. Potter and K. E. Friedl, "US Army Accession and Retention Standards: Impact on obesity and medical readiness," *Military Medicine*, vol. 190, no. 7–8, pp. 1587–1594, 2025. https://doi.org/10.1093/milmed/usae554.
3. S. A. Foulis, J. M. Hughes, B. A. Spiering, L. A. Walker, K. I. Guerriere, K. M. Taylor, S. P. Proctor, and K. E. Friedl, "US Army basic combat training alters the relationship between body mass index and percent body fat," *Military Health*, vol. 169, no. 4, pp. 340–345, 2023. https://doi.org/10.1136/bmjmilitary-2021-001936.
4. S. A. Foulis, K. E. Friedl, B. A. Spiering, L. A. Walker, K. I. Guerriere, V. P. Pecorelli, D. J. Zeppetelli, M. C. Reynoso, K. M. Taylor, and J. M. Hughes, "Body composition changes during 8 weeks of military training are not accurately captured by circumference-based assessments," *Frontiers in Physiology*, vol. 14, 2023. https://doi.org/10.3389/fphys.2023.1183836.
5. P. M. Bartlett, H. L. McClung, K. M. Taylor, and W. J. Tharion, "Modernizing the U.S. Army's body composition policy," *Military Review*, Online Exclusive, 2026. Available: https://www.armyupress.army.mil/journals/military-review/online-exclusive/2026-ole/body-composition-policy.
6. D. P. Looney, E. A. Schafer, C. L. Chapman, R. R. Pryor, A. W. Potter, B. M. Roberts, and K. E. Friedl, "Reliability, biological variability, and accuracy of multi-frequency bioelectrical impedance analysis for measuring body composition components," *Frontiers in Nutrition*, vol. 11, 2024. https://doi.org/10.3389/fnut.2024.1491931.
7. A. Buch, M. T. V. Joseph, M. R. Roy, and A. Y. Xu, "Validation of a multi-frequency BIA (InBody-770) vs DXA in older adults with T2DM," *Nutrition & Diabetes*, vol. 12, no. 45, 2022. https://doi.org/10.1038/s41387-022-00223-1.
8. Yi, J. Y. Baek, E. Lee, H.-W. Jung, and I.-Y. Jang, "A Comparative study of high-frequency bioelectrical impedance analysis and dual-energy X-ray absorptiometry for estimating body composition," *Life*, vol. 12, no. 7, p. 994, 2022. https://doi.org/10.3390/life12070994.
9. A. Aandstad, "Association between performance in muscle fitness field tests and skeletal muscle mass in soldiers," *Military Medicine*, vol. 185, no. 5–6, pp. 839–846, 2020. https://doi.org/10.1093/milmed/usz437.
10. K. A. Feeney, B. F. Melton, G. A. Ryan, H. W. Bland, and C. R. Butler, "The association between body composition and performance on military fitness tests," *Journal of Strength and Conditioning Research*, vol. 39, no. 1, pp. 94–98, 2024. https://doi.org/10.1519/JSC.0000000000004952.
11. S. E. da Rosa, A. C. Costa, M. S. R. Fortes, R. A. Marson, E. B. Neves, L. C. Rodrigues, P. F. Ferreira, and J. F. Filho, "Cut-off points of visceral adipose tissue associated with metabolic syndrome in military men," *Healthcare*, vol. 9, no. 7, p. 886, 2021. https://doi.org/10.3390/healthcare9070886.
12. R. Francisco, F. Jesus, C. L. Nunes, A. Carvalho, M. Alvim, F. Campa, L. B. Sardinha, G. V. Mendonça, H. Lukaski, and A. M. Silva, "Prediction of body water compartments by raw bioelectrical impedance parameters in athletes: Comparison between series and parallel measurements," *Scandinavian Journal of Medicine & Science in Sports*, vol. 33, no. 10, pp. 1998–2008, 2023. https://doi.org/10.1111/sms.14443.
13. L. Chen, J. Zhang, Z. Xu, M. Huang, F. Hua, and Y. Fu, "ECW/TBW ratio as a potential predictor of diabetic peripheral neuropathy," *Frontiers in Endocrinology*, vol. 16, 2025. https://doi.org/10.3389/fendo.2025.1560902.
14. T. J. O'Leary, R. M. Gifford, R. L. Knight, J. Wright, S. Handford, M. C. Venables, R. M. Reynolds, D. Woods, S. L. Wardle, and J. P. Greeves, "Sex differences in energy balance, body composition, and metabolic and endocrine markers during prolonged arduous military training," *Journal of Applied Physiology*, vol. 136, no. 4, 2024. https://doi.org/10.1152/japplphysiol.00864.2023.
15. M. E. Beckner, L. Thompson, P. N. Radcliffe, R. Cherian, M. Wilson, N. Barringer, L. M. Margolis, and J. P. Karl, "Sex differences in body composition and serum metabolome responses to sustained, physical training suggest enhanced fat oxidation in women compared with men," *Physiological Genomics*, vol. 55, pp. 235–247, 2023. https://doi.org/10.1152/physiolgenomics.00180.2022.
16. J. Cohen, *Statistical Power Analysis for the Behavioral Sciences (2nd ed.).* Hillsdale, NJ: Lawrence Erlbaum Associates, 1988.
17. L. V. Hedges, "Distribution theory for Glass's estimator of effect size and related estimators," *Journal of Educational Statistics*, vol. 6, no. 2, pp. 107–128, 1981.