Body Composition Comparison of Upper- and Underclass Reserve Officers' Training Corps Cadets

Quincy R. Johnson; Cameron S. Mackey; Tyler D. Muddle; Douglas B. Smith; Jason M. DeFreitas

INTRODUCTION: Body composition (BC) measurements are used to determine qualification for enlistment and to ensure active members are meeting standards. Although there is extensive research on BC in active-duty military, very few have examined ROTC cadets. The purpose of this study was to identify and quantify differences in BC between freshman/sophomore [underclass (UND)] and junior/senior [upperclass (UPP)] ROTC cadets by using bioelectrical impedance spectroscopy (BIS).

METHODS: UND ($N = 21$) and UPP ($N = 15$) Air Force ROTC cadets volunteered for this study. BIS was used to measure fat mass percentage (FM%), fat free mass percentage (FFM%), total body water percentage (TBW%), extracellular fluid percentage (ECF%), and intracellular fluid percentage (ICF%). Separate one-way ANOVAs were run between UND and UPP for all dependent variables with a Bonferroni correction factor. Additionally, a Pearson correlation between abdominal circumference (AC) and FM% was conducted.

RESULTS: No significant differences were observed between the UND and UPP groups' BMI. However, significant differences were observed for ECF%, ICF%, TBW%, FFM%, and FM% in which the UPP had a higher TBW%, ICF%, FFM%, and a lower ECF% and FM% compared to the UND.

CONCLUSIONS: This study observed significant differences in BC across class ranks in ROTC cadets. Findings from this study suggest that due to an increased exposure to ROTC training, UPP cadets have a more ideal body composition (FFM% and FM%) when compared to UND cadets.

KEYWORDS: Air Force, bioelectrical impedance spectroscopy, body fat percentage, Reserve Officers Training Corps, physical fitness.

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Officers in the U.S. military are commissioned through four main sources: the U.S. Military Academy, the Reserve Officers' Training Corps (ROTC), Officer Candidate School, and Direct Appointment. ROTC programs were established to supplement the service academies in producing leaders for the military and their origins date back to the Land Grant Act of 1862. This Act required all colleges to offer military training as a payback for the land grants they received from the federal government.[8] Currently, there are more than 600 colleges and universities throughout the United States that offer ROTC programs. Specifically, the Air Force ROTC's program is located on 145 college and university campuses along with more than 1100 additional institutions across the United States.[2] In addition to leadership courses that prepare cadets for military service, physical fitness assessment (PFA) performance has become a determining factor for success within most ROTC programs.

The Air Force uses AFI 36-2905 to conduct its PFA, which is characterized by three components: body composition, aerobic capacity, and muscular endurance.[4] Altogether, these assessments are meant to provide commanders with a means to determine overall fitness of their personnel and set the standard for evaluating fitness levels within military personnel. Circumference measurements of the abdomen are the primary method for assessing body composition and recent studies have suggested that optimal body composition is related to higher

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fitness levels and reduced injury risks.[9,10,14] While abdominal circumference may be a quick method to provide information regarding body composition, bioelectrical impedance analysis (BIS) may be an alternative that can provide a more in-depth look at the body composition of our military personnel. These findings may provide information which may be used for improving physical fitness training (PT) programs.

BIS has been proven to be a valid, reliable, and efficient alternative for evaluating body composition which can provide information that current measures do not.[2,3] BIS uses low voltage currents to evaluate body composition based on the principle that electric current flows at different rates through the body depending on its composition.[3] Thus, the impedance measures (resistance and reactance) are used to predict fat mass, fat mass percentage (FM%), fat free mass, fat free mass percentage (FFM%), and total body water using various equations. Although current evidence suggests body composition may provide an accurate prediction of fitness levels in military personnel, very few studies have investigated changes in body composition over time spent in the military. In addition, no published studies have examined differences in body composition (BC) between underclassmen (UND) and upperclassmen (UPP) Air Force ROTC cadets. Therefore, the purpose of this investigation was to determine if a difference existed in BC between UND and UPP ROTC cadets. We hypothesized that prolonged exposure to PT will result in improved BC when comparing UPP to UND ROTC cadets, and that abdominal circumference (AC) will be correlated to FM%. Specifically, we believe that BC values for UPP cadets will indicate increased fat free mass and decreased fat mass as an adaptation to PT.

METHODS

Subjects

Male ($N = 30$) and female ($N = 6$) Air Force ROTC cadets (mean ± SD; age 20.14 ± 2.07; height 174.67 ± 8.52 cm; weight 76.33 ± 9.70 kg; body mass index 25.01 ± 2.65) volunteered for body composition measurements that used BIS. Additionally, cadets were split into two groups depending on if they were UND [$N = 21$ (men = 16, women = 5)] or UPP [$N = 15$ (men = 14, women = 1)] to determine if there was a difference in body composition between grade classifications. All subjects signed a written informed consent document. The University Institutional Review Board for human subjects research approved this study.

Body Composition

After consent, height to the nearest 0.1 cm and weight to the nearest 0.1 kg were measured. Weight was taken with the participant wearing loose fitting gym clothes (i.e., t-shirts, athletic shorts, etc.) with shoes removed. BMI was calculated as kg/m^2. After height and weight assessments, participants were placed in a supine position for ~10 min with their arms abducted and legs separated. Height, weight, and gender were programmed into the BIS device. Two single-tab electrodes were placed on the right side of the body 5 cm apart on the wrist and the ankle (**Fig. 1**). Impedance was measured using 256 frequencies between 4 kHz and 1000 kHz to estimate total body water (TBW%), extracellular fluid (ECF%), and intracellular fluid (ICF%) based on Cole modeling with Hanai mixture theory, which the BIS device used to estimate FFM%, FM%, TBW%, ECF%, ICF%, and BMI.

Statistical Analysis

All data were analyzed using PASW software version 24.0 (SPSS Inc., Chicago, IL, USA). Separate one-way ANOVAs [Group (UND vs. UPP)] were run for all dependent variables (FFM%, FM%, TBW%, ECF%, ICF%, and BMI) using a Bonferroni correction factor. Additionally, a Pearson correlation between AC and FM% was conducted. An alpha level of $P \leq 0.05$ was considered significant for all comparisons.

RESULTS

Means and standard deviations for descriptives and each variable measured are presented in Fig. 1, **Fig. 2**, and **Fig. 3**. Significant differences were observed for ECF% ($F_{1,35} = 5.50$; $P = 0.025$), ICF% ($F_{1,35} = 5.50$; $P = 0.025$), TBW% ($F_{1,35} = 14.13$; $P \leq 0.001$), FFM% ($F_{1,35} = 13.90$; $P \leq 0.001$), and FM% ($F_{1,35} = 13.90$; $P \leq 0.001$) in which the UPP had more TBW%, ICF%, FFM%, and less ECF%, fat mass, and FM% compared to the UND. A significant, weak, positive correlation ($r = 0.289$; $r^2 = 0.083$; $P = 0.044$) was observed between AC (M ± SD = 32.99 ± 2.60) and FM% (M ± SD = 16.67 ± 8.07) (**Fig. 4**).

DISCUSSION

The primary purpose of the present study was to identify and quantify differences in BC between UND and UPP ROTC cadets by using BIS. Secondary objectives of this study included identifying the effects of exposure to ROTC physical training on BC, and examining the relationship between AC and FM%. Results from the present study indicated significant differences between the UND and UPP groups for TBW%, ICF%, FFM%, but none were detected for BMI. Additionally, participants in the UND group had significantly more ECF% and a higher FM% compared to the UPP group, and the UPP group had significantly more TBW%, ICF%, and FFM% when compared to the UND group. Also, of interest is the result of the correlation. While a significant relationship between AC and FM% was expected, it is surprising that FM% only accounted for ~8% of the variance in AC ($R^2 = 0.0832$). Although most would have expected there to be a strong relationship between abdominal circumference and fat mass, we believe that our findings shed light on two important factors. First, when compared to traditional approaches, using in-depth BC measuring methods like BIS can provide additional relevant information regarding each cadet's health status. Implementing BIS techniques into BC assessments within ROTC commissioning programs could

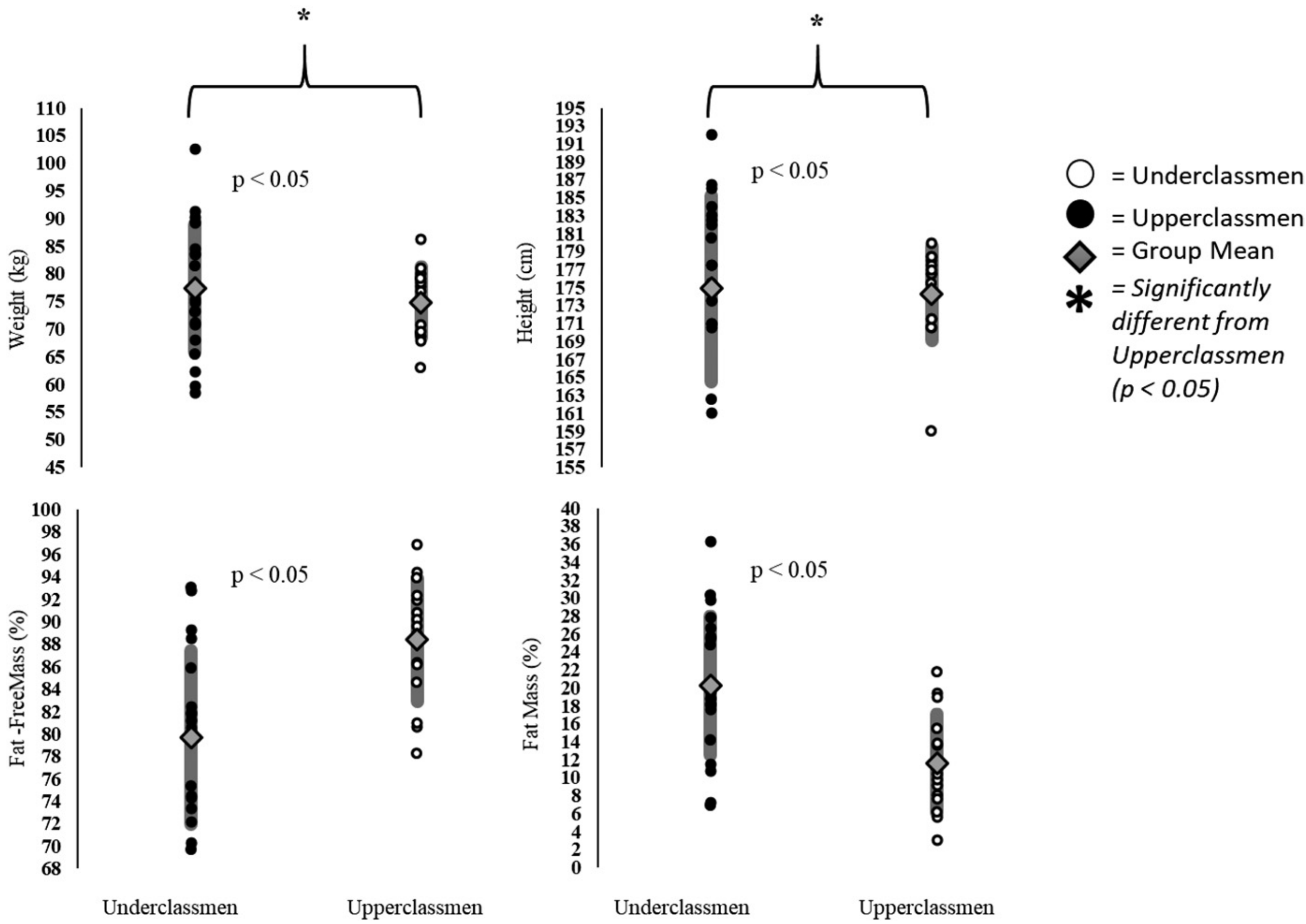

Fig. 1. Mean ± SD for weight (kg), height (cm), FFM percentage (%), and FM percentage (%) for ROTC cadets.

potentially improve current recommendations and approaches for exercise, nutrition, and recovery. Second, potential differences in the specific locations of body fat likely explains the relationship between FM% and AC.

We believe that there are two forms of fat that may have influenced the relationship between FM% and AC; subcutaneous and visceral fat. To our knowledge, subcutaneous fat accumulates under the skin and can often be seen, palpated, or touched, whereas visceral fat surrounds the organs and usually cannot be palpated or measured without the use of BIS or far more invasive and expensive procedures like computed tomography scans. Thus AC measurements may not always be the most precise way to evaluate BC, especially for the purposes of categorizing individuals as healthy vs. nonhealthy. Although we often assume that individuals with less subcutaneous or visible fat are healthier than those with more subcutaneous fat, the opposite may very well be true. In a simple modification to a visceral fat assessment method presented by Shiga et al.,[13] in which BIS electrodes work in the same way as they normally would by providing feedback on FM% and FFM%, electrodes are placed 5 cm above the belly button and in the same position on the lower back instead of on the wrist and ankle to provide subcutaneous and visceral body fat percentage measurements. Advancements in BC assessments like these could improve upon traditional BC assessment methods and recommendations for diet, exercise, and BC in the ROTC and active-duty military populations.

Based on our findings, BC differences between UND and UPP ROTC cadets appeared to be attributed to an increased exposure to PT. The results of the present study are supported by research performed by Aandstad et al.[1] in which significant percent body fat improvements in Air Force ROTC cadets were observed after performing PT 2–3 times per week for 1 yr. Furthermore, research conducted by Hydren et al.[6] and Pihlainen et al.[11] used various measurements (i.e., skinfold, waist circumference, etc.) to measure BC in military personnel after participating in PT. Their findings also support our initial assumptions that prolonged exposure to PT results in increased lean body mass, skeletal muscle mass, and decreased fat percentages, which have been proven to be strong overall predictors for successful military task performance.[11] From the findings of previous research, it is realistic to assume that ROTC cadets participating in commissioning programs with PFAs that are similar to their respective military branch can expect to not only improve their BC as they transition from UND to UPP grade classifications, but additional physical measures (e.g., aerobic capacity, muscular endurance, etc.) that may improve their likelihood of successfully completing military specific tasks. Essentially, these are all incentives for participating in

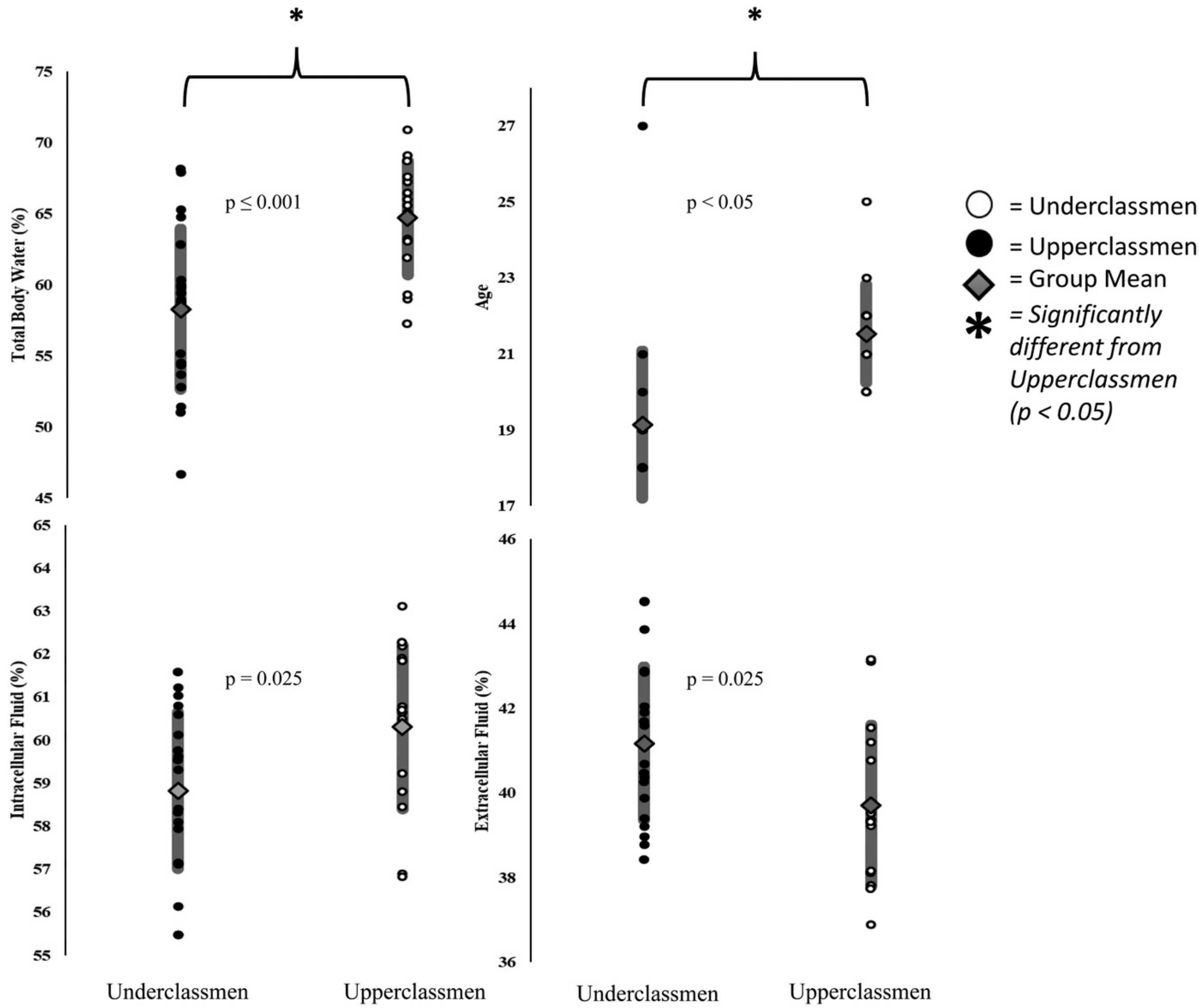

Fig. 2. Mean ± SD for total body water percentage (TBW %), age, intracellular fluid percentage (ICF, %), and extracellular fluid percentage (ECF, %).

ROTC programs for those wishing to commission into the military.

In general, the quantity of exercise between UND and UPP groups was kept relatively constant during our investigation. Regardless of grade classification, all ROTC cadets were required to attend PT three times per week and each PT session was approximately 1 h in duration. Additionally, all cadets performed similar exercise regimens which typically consisted of upper and lower body local muscular endurance exercises (i.e., push-ups and sit-ups for time) twice a week and cardiovascular endurance exercises (i.e., 2–3 mile runs) at least once a week. Therefore, we believe that the significantly different BC observed between the UPP and UND groups can be attributed to an increased PT exposure, significant differences in age, and possible differences in physiological or body maturation. We noticed through indirect observation that ROTC cadets in our program participated in approximately 90 PT sessions over the course of 1 academic year (30 wk). For this study, the UND group consisted of freshmen (0–1 yr in the ROTC Program) and sophomores (1–2 yr), whereas the UPP group consisted of juniors (2–3 yr), seniors (3–4 yr), and super-seniors (4–5 yr) at the time of their BC assessment. Therefore, we can assume that the UPP group had participated in at least 90 more PT sessions when compared to the UND group at the time of their assessment. Ultimately, we believe that even though the quantity of exercise for cadets remained constant throughout 1 academic year, the UPP group's increased PT exposure over the course of their academic career may have influenced the BC differences observed between groups.

In conjunction with increased exposure to physical activity, exercise physiology text has long suggested a relationship between age and the physiological maturation of our body's respiratory, muscular, and endocrine systems.[5,12] It has been reported that the respiratory system matures by age 20–25 yr for both males and females,[12] peak muscle mass develops between 16–20 yr for females and 18–25 yr in males, and the

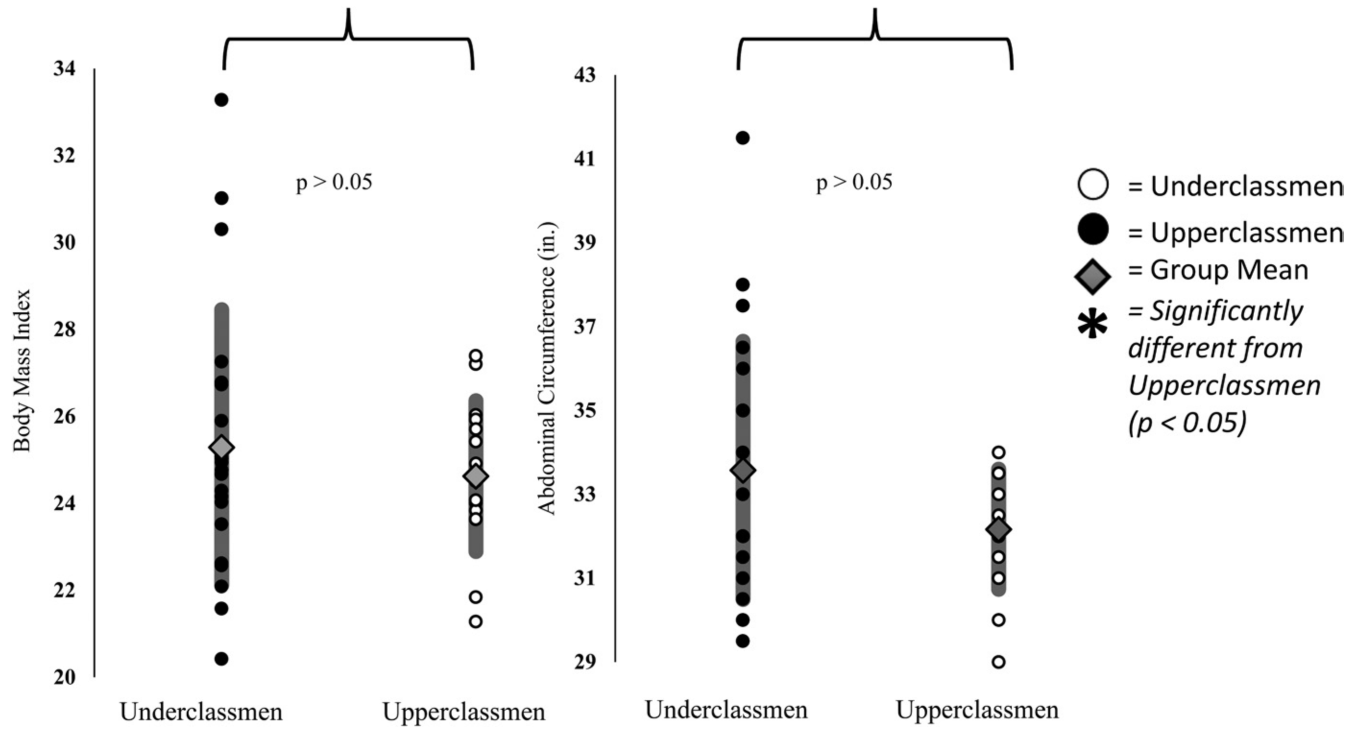

Fig. 3. Mean ± SD for body mass index (BMI) and abdominal circumference (AC) for ROTC cadets.

effects of postpubertal hormone influence contributes to hypertrophy, increased muscle size, and variations in BC during early adulthood.[5] Specifically, optimal respiratory function, muscle size, muscular strength, hormonal influence, and BC are often associated with the transition from puberty to early adulthood.[5,12] Compelling enough, the significant differences in age and BC between grade classifications that we identified drove us to consider the potential influence physiological maturation has on BC in military populations. We imagine that these significant differences can be linked to the respiratory, muscular, and endocrine systems being more developed in the UPP group, which probably contribute to an increased metabolism, optimal hormonal responses, muscle mass, or ultimately an improved FFM% and BC overall as observed in this study.

While the ECF%, ICF%, and FFM% measurements were significantly different between UND and UPP grade classifications, no significant differences were observed in TBW, ECF, ICF, and FFM. These findings can best be explained by research conducted by Kakade et al.[7] in which the relationships between FFM% and ICF%, and FM% and ECF% were established. Findings from the aforementioned study suggested that ECF% and ICF% can be estimated based on the predicted TBW volume, FFM%, and FM%. The authors of the previous study also suggested that FFM is a good conductor because it generally contains a large amount of water, amino acids, proteins, and electrolytes (which are primary constituents of ICF), compared to FM%, which is more of an insulator due to the resistive properties of fat and is composed of several constituents found in ECF%. Thus, higher FFM% and TBW% values can be associated with higher ICF% values, and higher FM values can be associated with higher ECF% values. Altogether, these four values (TBW%, FFM%, ECF%, and ICF%) may provide imperative information about the hydration level and nutrition status of our military personnel. Furthermore, emphasis should be placed on the importance of evaluating these values in military personnel and investigating how they may be used to improve cognitive and physiological military task performance.

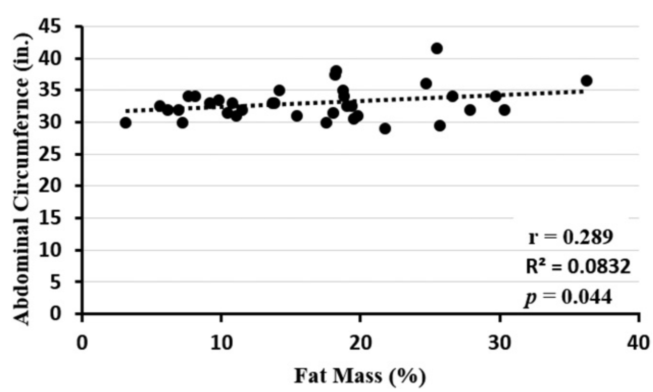

Fig. 4. Correlation for abdominal circumference (in inches) to fat mass (%).

There are a few potential limitations to this study that should be addressed. While the sample sizes for each grade classification sufficiently represented the ROTC population, it may be more beneficial to monitor BC changes in each ROTC cadet as they transition from UND to UPP. Additionally, assessing BC changes at the beginning and end of each semester could provide investigators with novel insight on the characteristics of BC adaptations to PT in commissioning programs. Lastly, it may be more ideal to assess BC in this demographic prior to exposure to PT. Implementing a similar research and assessment model as cadets arrive back to their respective college campuses, but before mandatory PT begins, may provide a more accurate report of their baseline BC.

When recruiting for commissioning programs like the ROTC, recruiters should consider presenting the benefits participation has on BC as cadets' transition from UND to UPP class ranks and into active duty military service. In the future, this study can be replicated in other commissioning programs to determine if similar effects occur. Additionally, by using the methodology presented in this manuscript, BC differences can also be compared between first and fourth-year active duty military personnel or between reservists and active duty military personnel. Notably so, findings from these studies may differ for these populations when comparing years of service. To conclude, tracking BC as cadets transition through grade classifications within military commissioning programs may benefit both the program and the cadets by providing insight on the effectiveness of the program's PT, changes in BC from year to year, and cadet's preparedness for the PFA as they begin active duty military service.

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REFERENCES

1. Aandstad A, Hageberg R, Sæther Ø, Nilsen RO. Change in anthropometrics and aerobic fitness in air force cadets during 3 years of academy studies. Aviat Space Environ Med. 2012; 83(1):35–41.
2. Aandstad A, Holtberget K, Hageberg R, Holme I, Anderssen SA. Validity and reliability of bioelectrical impedance analysis and skinfold thickness in predicting body fat in military personnel. Mil Med. 2014; 179(2):208–217.
3. Dehghan M, Merchant AT. Is bioelectrical impedance accurate for use in large epidemiological studies? Nutr J. 2008; 7:26.
4. Department of the Air Force. Fitness Program: AFI 36-2905. Washington (DC): HQ USAF/SGO; 2013. [Accessed October 20, 2018]. Available from: http://www.au.af.mil/au/awc/awcgate/af/afi36-2905.pdf.
5. Haff GG, Triplett NT. Essentials of strength training and conditioning, 4th ed. Champaign (IL): Human Kinetics; 2015.
6. Hydren JR, Borges AS, Sharp MA. systematic review and meta-analysis of predictors of military task performance. J Strength Cond Res. 2017; 31(4):1142–1164.
7. Kakade SS, Jagadale AB. Development of system for estimation of total body water (tbw), fat mass (fm), fat free mass (ffm) using bioimpedance analysis technique. International Conference on Communication and Signal Processing (ICCSP); 6–8 April 2016; APEC, Madras, India. Piscataway (NJ): IEEE; 2016. https://doi.org/10.1109/ICCSP.2016.7754127
8. Kizilkaya Z, Buttrey SE, Dolk DR, Kocher K. An analysis of the effect of commissioning sources on retention and promotion of U.S. Army officers. Monterey (CA): Naval Postgraduate School; 2004. [Accessed July 2019]. Available from: http://www.dtic.mil/dtic/tr/fulltext/u2/a424559.pdf.
9. Madureira TBS, Farah BQ, dos Santos MAM, de Freitas Berenguer M, de Lima PFM, et al. [Changes induced by military physical training on the body composition of military young adults.] ConScientiae Saúde. 2013;12(1):55–61 [in Portuguese].
10. Nogueira EC, Porto LG, Nogueira RM, Martins WR, Fonseca RM, et al. Body composition is strongly associated with cardiorespiratory fitness in a large Brazilian military firefighter cohort. J Strength Cond Res. 2016; 30(1):33–38.
11. Pihlainen K, Santtila M, Häkkinen K, Kyröläinen H. Associations of physical fitness and body composition characteristics with simulated military task performance. J Strength Cond Res. 2018; 32(4):1089–1098.
12. Sharma G, Goodwin J. Effect of aging on respiratory system physiology and immunology. Clin Interv Aging. 2006; 1(3):253–260.
13. Shiga T, Oshima Y, Kanai H, Hirata M, Hosoda K, Nakao K. A simple measurement method of visceral fat accumulation by bioelectrical impedance analysis. IFMBE Proceedings of the 13th International Conference on Electrical Bioimpedance and the 8th Conference on Electrical Impedance Tomography. Berlin: Springer-Verlag; 2005.
14. Thomas DQ, Lumpp SA, Schreiber JA, Keith JA. Physical fitness profile of army ROTC cadets. J Strength Cond Res. 2004; 18(4):904–907.