Body Composition Differences in Military Pilots and Aircrew

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BACKGROUND: This research aimed to analyze the body composition (BC) of different military units in the Spanish Armed Forces.

METHODS: We studied 179 male aircrew members (86 airplane pilots, 15 helicopter pilots and 78 transport aircrew) using bioimpedance.

RESULTS: Airplane pilots (AP) had higher means than transport aircrew (TA) in height (179.56 cm vs. 173.90 cm), total body water (46.72 L vs. 42.96 L), intracellular body water (29.45 L vs. 26.89 L), extracellular body water (17.27 L vs. 16.07 L), proteins (12.72 kg vs.11.63 kg), minerals (4.50 kg vs. 4.15 kg), soft lean mass (60.21 kg vs. 55.29 kg), fat free mass (63.95 kg vs. 58.74 kg), skeletal muscle mass (36.41 kg vs. 33.07 kg), and lower means in body mass index (24.01 kg vs. 25.49 kg), body fat mass (BFM) (13.53 kg vs. 18.81 kg) and percentage of body fat (PBF) (16.83 kg vs. 23.79 kg). Helicopter pilots also had significantly lower means in BFM (13.21 kg vs. 18.81 kg) and PBF (17.11 kg vs. 18.81 kg) than TA.

DISCUSSION: The different types of activity between AP (active coping with G forces) and TA (inactive) during operational flights negatively affects the body composition of TA. These results suggest differences in aircrews training and job tasks. Specific training is needed for each unit: it should be individualized, prevent injuries, and be directed by qualified personnel.

KEYWORDS: body composition, aircrew, body fat mass, pilots, body water.

Bustamante-Sánchez Á, Clemente-Suárez VJ. *Body composition differences in military pilots and aircrew*. Aerosp Med Hum Perform. 2020; 91(7):565–570.

Body composition (BC) has been traditionally studied in populations that need to perform well during physical activities, such as sportsmen.[2] The importance of having an optimal BC has been highlighted since it is one of the easiest anthropometric-performance variables to manipulate.[33] BC has also been of vital importance for military populations because it has been regarded as a performance indicator for fulfilling the physical demands required by armed forces, such as lifting, carrying, or fighting.[13,25] Lean mass (rather than speed) has been identified as a more important feature for metabolic and cardiovascular demands to load-carriage jobs.[24] Soldiers with similar fat-free mass but less body fat (14.0% vs. 25.2%) also perform better in aerobic (including $\dot{V}O_{2max}$, 52.1 $ml \cdot kg^{-1} \cdot min^{-1}$ vs. 44.1 $ml \cdot kg^{-1} \cdot min^{-1}$) and anaerobic tests, and develop better strength in upper and lower extremities.[12] Moreover, there is a need to study these BC indicators to prevent injuries among different military populations.[20]

A complete BC analysis should include different corporal regions, for which several methods have been reported to have enough accuracy and reliability.[38] These methods are the dual-energy X-ray absorptiometry (DXA), the dual-photon absorptiometry (DPA), and the electrical bioimpedance (BIA). BIA technology has a valid correlation with the DXA in the military[1] and healthy populations,[16,32] with lower limits of the intraclass correlation coefficient that are higher than 0.7 for fat mass and fat-free mass measurements.[35]

The relevance of BC in the military population is of growing importance, especially in aircrew, where it is crucial to ensure correct human-machine and human-equipment fit.[8,34] Some studies have used BC to ensure the health of aircrew during a medical examination, but there are still some questions that need to be studied, such as what is the optimum BC for each

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This manuscript was received for review in April 2019. It was accepted for publication in April 2020.

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DOI: https://doi.org/10.3357/AMHP.5401.2020

military group. Army BC standards have been traditionally registered and considered highly important,[15] but there is a need to state the differences in BC among different aircrew. This study aimed to analyze differences in BC in different military aircrew to better understand job-oriented operative demands and necessities. Airplane pilots are accustomed to resisting G forces while maintaining control of the aircraft, which usually implies muscular activations that develop hypertrophy[3,17,31] and favors the predominance of lean mass. We hypothesized that airplane pilots would have higher values of lean mass, higher body water, and lower values of body fat mass.

METHODS

Subjects

We analyzed 179 male military aircrew (15 Helicopter Pilots, 86 Airplane Pilots, and 78 Transport Aircrew) of the Spanish Army and Spanish Air Force that belonged to Group I (pilots of any type of aircraft) and Group II (aircrew without direct responsibility on the aircraft) with a qualification of "fit" according to the periodic medical examination as recorded in the ministerial order 23/2011. During the research period they were carrying out the periodic aeromedical training included in the ministerial order 23/2011 and the STANAG 3114 "Aeromedical Training of Flight Personnel" (NATO regulations). Before starting the research, the experimental procedures were explained to all the participants, who gave their voluntary written informed consent under the Declaration of Helsinki. The procedures conducted in the present research were designed and approved by the Medical Service of the Aerospace Medicine Instruction Centre of the Spanish Air Forces.

Procedure

To perform the tests the participants stood upright on foot electrodes on the instrument platform, with arms not touching the torso. They were barefooted and without excess clothing. Four foot electrodes were used, two of which were oval-shaped and two heel-shaped, and prior to testing the skin was cleaned and dried. Participants were asked to grip the palm and thumb electrodes. The system was calibrated before the testing session and the contacting surface of the electrodes was cleaned with alcohol before each measurement. Participants abstained from alcohol consumption and vigorous exercise for 24 h before the measurement, and were measured in the morning after overnight fasting to control hydration status, as in previous research with bioelectrical impedance.[23]

Materials

A bioimpedance analyzer (InBody 720, Biospace Co. Ltd., Seoul, South Korea) was used for body mass measurement (to the nearest 0.1 kg). A portable stadiometer (SECA, Leicester, UK) was used for the measurement of body height (to the nearest 1 cm). BMI was calculated as the quotient of body mass (kg) to height squared (m^2). InBody 720 is a multifrequency impedance body composition analyzer, which uses an eight-point tactile electrode method to take readings from the body. It measures resistance at five specific frequencies (1 kHz, 50 kHz, 250 kHz, 500 kHz, and 1 MHz) and reactance at three specific frequencies (5 kHz, 50 kHz, and 250 kHz) on each of five segments (right arm, left arm, trunk, right leg, and left leg). Bioelectrical-impedance analysis (BIA) is one of the methods available for measuring body composition in healthy populations. Its simplicity, portability, cost, and subject acceptance make it a very desirable technique.[10] The reliability of BIA compared to the gold standard body composition measurement (DXA) has been successfully demonstrated for both normal and overweight populations.[28]

Data were electronically imported to Excel using Lookin'Body 3.0 software. The following parameters were analyzed:

i. Body mass (kg)
ii. Height (cm)
iii. Body Mass Index (BMI) ($kg \cdot m^{-2}$)
iv. Total Body Water (TBW) (kg) (including left and right arms, trunk, and left and right legs)
v. Intracellular Water (L) (including left and right arms, trunk, and left and right legs)
vi. Extracellular Water (L)
vii. Proteins (kg)
viii. Minerals (kg)
ix. Body Fat Mass (BFM) (kg) (including left and right arms, trunk, and left and right legs, in kg and %)
x. Percentage of Body Fat (PBF) (%)
xi. Soft Lean Mass (SLM) (kg)
xii. Fat Free Mass (FFM) (kg) (including left and right arms, trunk, and left and right legs, in kg and %)
xiii. Skeletal Muscle Mass (kg).

Statistical Analysis

The SPSS statistical package (version 21.0; SPSS, Inc., Chicago, IL) was used to analyze the data. Normality assumptions were checked with a Shapiro-Wilk test for the helicopter-pilots group and a Kolmogorov-Smirnov test for the other two groups. Homoscedasticity in parametric variables was tested with the Levene test. An ANOVA test was used to analyze homoscedastic parametric variables, together with a Tukey post hoc test to analyze pairwise comparisons. Welch test was used to analyze parametric variables that did not fulfill homoscedasticity assumptions, together with a Games-Howell post hoc test to analyze pairwise comparisons. Differences between groups were analyzed using a Kruskal-Wallis test for nonparametric variables with Bonferroni correction to analyze pairwise differences. The level of significance for all the comparisons was set at $P \leq 0.05$.

RESULTS

The results are reported as mean ± SD. **Table I** shows the results of body composition. Significant differences were

Table I. Results of Body Composition Variables.

	AIRPLANE PILOTS	HELICOPTER PILOTS	TRANSPORT AIRCREW
Body Mass (kg)	77.49 ± 11.83	76.09 ± 9.94	77.55 ± 14.76
Height (cm)	179.56 ± 6.85 (0.000)†††	177.25 ± 5.54	173.90 ± 8.56
BMI (kg · m^{-2})	24.01 ± 3.21 (0.003)††	24.17 ± 2.70	25.49 ± 3.65
TBW (L)	46.72 ± 5.54 (0.002)††	45.87 ± 5.15	42.96 ± 7.74
ICW (L)	29.45 ± 3.46 (0.001)†††	28.85 ± 3.28	26.89 ± 4.95
ECW (L)	17.27 ± 2.10 (0.006)††	17.01 ± 1.90	16.07 ± 2.81
Proteins (kg)	12.72 ± 1.50 (0.001)†††	12.48 ± 1.40	11.63 ± 2.15
Minerals (kg)	4.50 ± 0.57 (0.001)†††	4.53 ± 0.58	4.15 ± 0.71
BFM (kg)	13.53 ± 7.98 (0.000)†††	13.21 ± 4.33(0.007)‡‡	18.81 ± 8.46
PBF (%)	16.83 ± 7.52 (0.000)†††	17.11 ± 4.14 (0.001)‡‡‡	23.79 ± 7.86
SLM (kg)	60.21 ± 7.11 (0.002)††	59.08 ± 6.66	55.29 ± 10.01
FFM (kg)	63.95 ± 7.58 (0.002)††	62.87 ± 7.12	58.74 ± 10.59
SMM (kg)	36.41 ± 4.51 (0.001)†††	35.63 ± 4.28	33.07 ± 6.46

BMI: Body Mass Index. TBW: Total Body Water. ICW: Intracellular Water. ECW: Extracellular Water. BFM: Body Fat Mass. PBF: Percentage of Body Fat. SLM: Soft Lean Mass. FFM: Fat Free Mass. SMM: Skeletal Muscle Mass. Significant differences between airplane pilots and transport aircrew (in parenthesis, *P*-value): ††$P \leq 0.01$; †††$P \leq 0.001$. Significant differences between helicopter pilots and transport aircrew (in parenthesis, *P*-value): ‡‡$P \leq 0.01$; ‡‡‡$P \leq 0.001$.

found between Airplane Pilots and Transport Aircrew in all variables except in Body Mass. Airplane Pilots had higher means in Height, TBW, ICW, ECW, proteins, minerals, SLM, FFM, and SMM; and lower means in BMI, BFM, PBF. Helicopter pilots also had significant lower means in BFM and PBF than Transport Aircrew. No differences were found between airplane and helicopter groups.

Table II shows the results of FFM and BFM by body segments. With regard to FFM variables, Airplane Pilots had significantly higher means than Transport Aircrew in all variables studied. No differences were found between Airplane Pilots and Helicopter Pilots, or between Helicopter Pilots and Transport Aircrew. With respect to BFM variables, Airplane Pilots had significantly lower means than Transport Aircrew in all variables studied. Helicopter Pilots also had significantly lower means than Transport Aircrew in all variables related to BFM. No differences were found between Airplane Pilots and Helicopter Pilots.

Table III shows the results of water by body segments. Airplane Pilots had significantly higher means than Transport Aircrew in all variables studied. No differences were found between Airplane Pilots and Helicopter Pilots, or between Helicopter Pilots and Transport Aircrew.

DISCUSSION

The aim of this study was to analyze differences in body composition among different military aircrew to better understand job-oriented operative demands and necessities for them. All hypotheses were partially compiled since airplane pilots had higher values of lean mass (1), higher body water (2), and lower values of body fat mass (3), than transport aircrew. However, there were no differences between the airplane and helicopter pilots in any variable studied. Moreover, helicopter pilots had lower body fat than transport aircrew, although they had similar results in body water and lean mass.

Body mass, height, and BMI represent a first overview of a morphological group's characteristics. The sample of pilots studied had lower height, weight, and BMI than helicopter pilots[34] and the general military population.[22] Airplane pilots presented significantly lower body fat (BFM, TBF, FFM) and higher lean mass (SLM, SSM) than helicopter pilots and aircrews. Compared with other such highly physically demanding professionals as elite athletes, participants of the present research had lower SMM, proteins, minerals, ICW, and ECW, and higher PBF, although Airplane Pilots were the group closest to these results of BC in indoor sportsmen,[9] probably because their need to develop peaks of maximum strength when

Table II. Results of Fat Free Mass and Body Fat Mass by Body Segments.

	AIRPLANE PILOTS	HELICOPTER PILOTS	TRANSPORT AIRCREW
FFM Right Arm (kg)	3.60 ± 0.55 (0.009)††	3.50 ± 0.55	3.27 ± 0.80
FFM Left Arm (kg)	3.55 ± 0.55 (0.007)††	3.46 ± 0.52	3.22 ± 0.79
FFM Trunk (kg)	27.95 ± 3.24 (0.005)††	27.25 ± 3.06	25.88 ± 4.75
FFM Right Leg (kg)	9.95 ± 1.30 (0.000)†††	9.50 ± 1.04	9.02 ± 1.70
FFM Left Leg (kg)	9.87 ± 1.28 (0.000)†††	9.42 ± 1.02	8.97 ± 1.69
BFM Right Arm (kg)	0.73 ± 0.71 (0.000)†††	0.65 ± 0.31 (0.004)‡‡	1.19 ± 0.88
BFM Left Arm (kg)	0.74 ± 0.72 (0.000)†††	0.67 ± 0.34 (0.003)‡‡	1.22 ± 0.88
BFM Trunk (kg)	6.99 ± 4.52 (0.000)†††	6.92 ± 2.67 (0.014)‡	9.81 ± 4.53
BFM Right Leg (kg)	1.98 ± 0.96 (0.000)†††	1.93 ± 0.51 (0.003)‡‡	2.71 ± 1.08
BFM Left Leg (kg)	1.97 ± 0.96 (0.000)†††	1.90 ± 0.49 (0.002)‡‡	2.68 ± 1.06

FFM: Fat Free Mass. BFM: Body Fat Mass. Significant differences between airplane pilots and aircrew (in parenthesis, *P*-value): ††$P \leq 0.01$; †††$P \leq 0.001$. Significant differences between helicopter pilots and aircrew (in parenthesis, *P*-value): ‡$P \leq 0.05$; ‡‡$P \leq 0.01$.

Table III. Results of Body Water by Body Segments.

	AIRPLANE PILOTS	HELICOPTER PILOTS	TRANSPORT AIRCREW
TBW Right Arm (L)	2.80 ± 0.43 (0.010)†	2.72 ± 0.43	2.54 ± 0.62
TBW Left Arm (L)	2.76 ± 0.44 (0.007)††	2.69 ± 0.41	2.50 ± 0.61
TBW Trunk (L)	21.68 ± 2.51 (0.006)††	21.15 ± 2.37	20.1 ± 3.67
TBW Right Leg (L)	7.71 ± 1.01 (0.000)†††	7.37 ± 0.81	7.00 ± 1.31
TBW Left Leg (L)	7.66 ± 1.00 (0.001)†††	7.31 ± 0.79	6.97 ± 1.31
ICW Right Arm (L)	1.75 ± 0.27 (0.007)††	1.70 ± 0.26	1.59 ± 0.39
ICW Left Arm (L)	1.73 ± 0.27 (0.005)††	1.68 ± 0.24	1.56 ± 0.38
ICW Trunk (L)	13.67 ± 1.57 (0.002)††	13.28 ± 1.50	12.57 ± 2.35
ICW Right Leg (L)	4.89 ± 0.63 (0.000)†††	4.66 ± 0.51	4.40 ± 0.84
ICW Left Leg (L)	4.83 ± 0.62 (0.000)†††	4.61 ± 0.49	4.36 ± 0.83
ECW Right Arm (L)	1.05 ± 0.16 (0.016)†	1.01 ± 0.16	0.96 ± 0.23
ECW Left Arm (L)	1.03 ± 0.17 (0.013)†	1.00 ± 0.16	0.94 ± 0.23
ECW Trunk (L)	8.01 ± 0.96 (0.027)†	7.87 ± 0.88	7.53 ± 1.33
ECW Right Leg (L)	2.82 ± 0.39 (0.012)††	2.71 ± 0.31	2.60 ± 0.48
ECW Left Leg (L)	2.82 ± 0.39 (0.000)†††	2.71 ± 0.31	2.61 ± 0.49

TBW: Total Body Water. ICW: Intracellular Water. ECW: Extracellular Water. Significant differences between airplane pilots and aircrew (in parenthesis, *P*-value): †$P \leq 0.05$; ††$P \leq 0.01$; †††$P \leq 0.001$.

piloting. But compared with ultra-endurance athletes, the muscle mass of pilots and aircrews are higher as well as body fat.[6] This fact proves the different physiological adaptations that each group obtains from previous training and occupation.

These results could be explained by considering that transport aircrew usually spend most of their job time sitting in the aircraft and less time running, or carrying loads, than other units, which may result in less calorie consumption. This fact in contrast to the high-calorie demands of infantry units made differences in BC between them, showing airborne, parachute, and elite infantry units having lower body fat and higher muscle mass.[27] Fine motor skills, rather than large group muscle's demands, are more important for some of the aircrew unit's performance (like mechanics or doctors). This could also lead to less protein intake and explain a lower mean for aircrew. Moreover, protein intake has been recommended to protect fat-free mass during weight loss periods.[26] Dehydration has been traditionally linked to poorer performance in both motor skills and vigilance-related attention[4] in sportsmen and infantry guards.[11] This fact, together with the higher water composition of muscles, could explain the differences in TBW and minerals between Airplane Pilots and Transport Aircrew.[39]

A body fat mass excess is associated with a poorer performance in all activities related to moving. Speed, endurance, jump, and agility are negatively affected by a high level of adiposity.[19] BFM, together with FFM, has been better considered than BMI alone in BC interpretation.[2,21] The difference in FFM for all body segments except left-arm between Airplane Pilots and Transport Aircrew highlights the use of joysticks or yokes where the right hand is predominantly active during the flight, although this subtle difference does not exist in BFM analysis. So, this is a subject for future exploration.

The relationship between body water and performance in athletes has been studied in terms of motor skills[5,29,30] and the ability to maintain cognitive function and attention.[4] The capacity of attention is crucial for airplane pilots while performing their jobs.[7] In terms of power, the loss of TBW and ICW produces worse grip strength in athletes,[30] and a loss of ICW affects forearm power.[29] All these factors could be related to the higher ICW values in Airplane Pilots, who have to deal with G forces while controlling their aircraft.[18,37]

The main limitation of this study was the small sample size for helicopter pilots, due to resource availability compared to the other two groups. In addition, we did not have the permission to gather age data, and we could not study stress hormones (such as cortisol, adrenaline, etc.), and type of job as aircrew, to better categorize BC demands by subunits. We did not gather background variables (like nutrition, economic, education and physical activity levels in leisure time) that could have helped us to better understand the differences between groups. These background variables could be studied to design longitudinal research to understand the underlying mechanisms of BC changes. It is important to take into account that some research has stated that it is possible that BIA underestimates fat mass in normal weight,[36] and overestimates percent body fat mass, particularly in obese populations,[14,28] possibly because age is not included as a variable in their assessment algorithm.[36] This fact should be taken into account in future research. The dominant arm in the use of joysticks, and the predominant type of aircraft controller (yokes, joysticks) should be taken into account in the future too, to better understand upper body segment analysis.

These results could help to find specific training for better aircrew preparation processes. The data collected in the present work are of vital importance to define specific training systems as well as operational protocols for flight personnel in the development of their different tasks in their job, both in military and civil aviation. Training should be specific, individualized, and directed by qualified personnel, and prevent injuries. While many of the studies agree on the need for flight crews to be trained to withstand the stresses of flight, many of the recommendations still lack adequate specificity as there is a need to take into account the actual needs of the aircrew population.

CONCLUSION

Body Composition depends on the aircrew's job. Airplane pilots had higher means than Transport Aircrew in Height, TBW, ICW, ECW, proteins, minerals, SLM, FFM, and SMM; and lower means in BMI, BFM, and PBF. Helicopter pilots also had significantly lower means in BFM and PBF. The different types of activities related to airplane pilots (actively coping with G forces) and aircrew (inactive) during operational flight periods negatively affects Body Composition of Transport Aircrew. These facts have to be taken into account in order to better prepare each unit.

ACKNOWLEDGMENTS

We would like to acknowledge the contribution of the Aerospace Medicine Instruction Centre of the Spanish Air Forces (Centro de Instrucción de Medicina Aeroespacial, CIMA), including the colonel, the military instructors, and the medical service personnel for their excellent work and collaborative spirit towards the present research.

Financial Disclosure Statement: The authors certify that they have no involvement in any organization or entity with any financial interest, or non-financial interest. This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

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