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Body Composition Symmetry in Aircraft Pilots

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Abstract: The purpose of this study was to analyze the body composition symmetry in upper and lower body segments of aircrafts pilots. To reach the study aim, body composition in upper and lower body segments of 206 male aircraft pilots of the Spanish Army (23.1 ± 6.87 years) and 105 civilians (24.0 ± 6.29 years) were evaluated by a bioimpedance analyser (InBody 720, Biospace Co. Ltd., Seoul, Korea). Aircraft pilots presented a tendency to dysmetria in upper and lower body segments, showing fitter values in the protagonist side when performing flight functions. Dysmetria could be detrimental during flight manoeuvres and produce injuries in aircraft pilots. It would be recommended to design specific training protocols to improve this imbalance.

Keywords: pilots; body composition; body fat mass; lean mass; body water; symmetry

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Citation: Curiel-Regueros, A.; Ardigò, L.P.; Bustamante-Sánchez, Á.; Tornero-Aguilera, J.F.; Fuentes-García, J.P.; Clemente-Suárez, V.J. Body Composition Symmetry in Aircraft Pilots. *Symmetry* **2022**, *14*, 356. https://doi.org/10.3390/sym14020356

Academic Editor: John H. Graham

Received: 17 January 2022
Accepted: 9 February 2022
Published: 11 February 2022

1. Introduction

Military personnel are exposed to eliciting, stressful, and extreme contexts [1–4]. Psychophysiological stressors are easily found, such as sleep and resources [5] (water and food) deprivation while deployed in combat, which leads to psychological, cognitive, and physical impairment; adverse weather conditions that lead to hypothermia or acute dehydration [6], and heights of over 3500 m, which lead to hypoxic conditions [7]; and periods of high physical and psychological demands during either training or during operative missions [8,9]. To a large extent, all these highly stressful demands require an optimal psychological level, and ultimately a high level of physical performance, muscular strength, and optimal cardiovascular health through their active duty to tolerate the multiple stressors and successfully fulfil their mission [10,11].

However, given these varied psychophysiological demands, traditionally the performance of athletes has been tested by a large variety of test, such as running tests, push-ups, or swimming tests, among others [12]. The data from these tests are commonly assessed as a part of the military recruitment. The outcome of different types of physical performance indicators, either related to cardiovascular and strength factors, are commonly associated with body composition [13] characteristics, body size, body mass index (BMI), and its composition [14]. Yet, given the importance of weight, mass, and its distribution in military troops, it is worrying to see how the trend in weight and fat gain towards overweight and obesity, so present as a pandemic in Western culture [15], is spreading in the military environment [16]. While regular physical activity, good nutrition, and weight management promotes physical and mental performance and resistance to western diseases, excessive fat is associated with increased health risk and poor military appearance [17,18]. Likewise, it is important to bear in mind that regardless of the requirements and physical performance tests for access to military corps, once inside, there are different divisions and positions in which physical inactivity and sedentary lifestyle are present, such as administrative or management positions [19]. In general, body weight and body composition standard limits are assumed to reflect good health, and therefore those variables together with physical performance should be taken into consideration. Knowledge of the standard levels of body composition for the military is fundamental for the design of programs that adjust the requirements of each military body [20].

In this line, one of the most demanding military branches with the highest physical requirements and tougher tests for entry into the military is that related to the air forces, specifically fighter pilots [21]. Air force pilots are carefully selected and monitored to ensure that they are in excellent physical condition among their whole careers [22]. Pilots are involved in a highly demanding environment where they are exposed to large G-forces [23], which affect muscular activation and causes muscular hypertrophy [24]. Thus, optimal strength and lean mass values are necessary [25]. However, the authors suggest a selective hypertrophy of the side with the more used limbs, which can lead to muscle imbalances and dysmetria [26], causing disorders of muscle chains, increasing the prevalence of injuries, and leading to a loss of motor skills and performance [27], as the same case has been observed in other professions or groups of populations where dysmetria exists, such as in the higher requirement of one of the sides of handball players [28].

Thus, these disorders can alter the performance of pilots to handle the joystick, dashboards, and flight pedals, including the peculiarity that all cabins have the controls on the same side, which could pose a life threat to the pilot itself. Then, the purpose of this study was to analyze the body composition symmetry in upper and lower body segments of aircraft pilots. We hypothesized that there would be differences in the symmetry in the upper and lower body segments of aircraft pilots due to the flight demands.

2. Materials and Methods

We analysed 206 male aircraft pilots (age: M = 23.1 years, SD = 6.87 years; height: M = 179.0 cm, SD = 6.12 cm; body mass: M = 73.58 kg, SD = 9.64 kg) of the Spanish Army with a qualification of "fit" according to the periodic medical examination, as recorded in the ministerial order 23/2011; and a control group of 105 subjects (62 males and 43 females) physically active and with no pathologies, with a military draft age and without any military experience and G-force continuous exposure or flight time (age: M = 24.0 years, SD = 6.29 years; height: M = 174.3 cm, SD = 8.78 cm; body mass: M = 71.21 kg, SD = 11.63 kg). During the research, 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 Spanish Air Forces and the University Ethic Committee (CIPI/18/093).

To implement the body composition assessment, we followed previous procedures [29–32] in which the participants stood upright on foot electrodes on the instrument platform, with their 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.

A bioimpedance analyser (InBody 720, Biospace Co. Ltd., Seoul, Korea) was used for body mass measurement (to the nearest 0.1 kg) and body height (to the nearest 0.1 cm). InBody 720 is a multifrequency impedance body composition analyser, 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 the 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. The reliability of BIA compared to the gold standard body composition measurement (DXA) has been successfully demonstrated for a wide range of normal and overweight populations [33–35] and military samples [36].

Data were electronically imported to Excel using Lookin'Body 3.0 software. The following parameters were analysed: i. Total Body Water (TBW) (kg) (including left and right arms, and left and right legs), ii. Intracellular Water (ICW) (l) (including left and right arms, and left and right legs), iii. Extracellular Water (ECW) (l) (including left and right arms, and left and right legs), iv. Body Fat Mass (BFM) (kg) (including left and right arms, and left and right legs, in kg and %), v. Fat Free Mass (FFM) (kg) (including left and right arms, and left and right legs), vi. Total Extremity Mass (TEM) (kg) (including left and right arms and left and right legs).

The SPSS statistical package (version 21.0; SPSS, Inc., Chicago, IL, USA) was used to analyse the data. Normality assumptions were checked with a Kolmogorov-Smirnov test for the whole group. Homoscedasticity was tested with the Levene test. A mixed ANOVA test—with two groups (pilots and control group), plus two factors (side of the extremity analysed)—was used to compare the effect of the group, the effect of the extremity side, and the interaction among the group and the extremity side. The level of significance for all the comparisons was set at $p < 0.05$.

3. Results

The results are reported with their mean and standard deviation. Table 1 shows the results of body composition symmetry for the arms. Significant differences were found between the pilots and the control group for all the comparisons (including both right and left arms), but for the total extremity mass. Pilots had higher means in fat free mass, total water, extracellular water, and intracellular water. Pilots had lower means than the control group for fat mass in both the left and the right arms. No statistically significant differences were found between sides for each group.

Table 1. Body composition results by arms.

	Pilots				Control Group				Group and Arm Effect		
	Right		Left		Right		Left				
	M	SD	M	SD	M	SD	M	SD	F	p	η^2
FFM (kg)	3.52 *	0.47	3.47 *	0.47	3.19 *	0.79	3.16 *	0.79	0.018	0.894	0.000
BFM (kg)	0.47 *	0.45	0.49 *	0.45	0.66 *	0.52	0.68 *	0.53	0.000	0.994	0.000
TEM (kg)	4.00	0.72	3.97	0.71	3.85	0.80	3.84	0.79	0.013	0.911	0.000
TBW (l)	2.73	0.37	2.70	0.36	2.47 *	0.62	2.45 *	0.61	0.021	0.886	0.000
ECW (l)	1.02	0.14	1.00	0.13	0.92	0.23	0.91	0.22	0.043	0.836	0.000
ICW (l)	1.71	0.23	1.69	0.22	1.55	0.38	1.53	0.38	0.011	0.916	0.000

M: Mean. SD: Standard Deviation. F: Fisher-Snedecor test. η^2: Partial eta squared. N/A: FFM: Fat Free Mass. BFM: Body Fat Mass. TEM: Total Extremity Mass. TBW: Total Body Water. ICW: Intracellular Water. ECW: Extracellular Water. * Differences between pilots/control groups ($p < 0.05$). Differences between left/right arms ($p < 0.05$). Normality and homoscedasticity ($p > 0.05$) in all samples.

Table 2 shows the results of body composition symmetry for the legs. Significant differences were found between the pilots and the control group for all the comparisons (including both right and left legs). Pilots had higher means in fat free mass, total extremity mass, total water, extracellular water, and intracellular water. Pilots had lower means than the control group for fat mass in both the left and the right legs No statistically significant differences were found between sides for each group.

Table 2. Body composition results by legs.

	Pilots				Control Group				Group and Side Effect		
	Right		Left		Right		Left				
	M	**SD**	**M**	**SD**	**M**	**SD**	**M**	**SD**	**F**	***p***	**η^2**
FFM (kg)	9.92 *	1.05	9.84 *	1.04	8.99 *	1.69	8.95 *	1.65	0.025	0.874	0.000
BFM (kg)	1.62 *	0.65	1.60 *	0.63	1.91 *	0.90	1.90 *	0.90	0.000	0.993	0.000
TEM (kg)	11.5 *	1.33	11.4 *	1.31	10.9 *	1.67	10.8 *	1.62	0.019	0.890	0.000
TBW (l)	7.69 *	0.81	7.64 *	0.81	6.97 *	1.30	6.95 *	1.28	0.023	0.880	0.000
ECW (l)	2.83 *	0.31	2.83 *	0.31	2.57 *	0.47	2.58 *	0.47	0.013	0.908	0.000
ICW (l)	4.86	0.51	4.81	0.50	4.40	0.83	4.36	0.81	0.029	0.865	0.000

M: Mean. SD: Standard Deviation. F: Fisher-Snedecor test. η^2: Partial eta squared. N/A: FFM: Fat Free Mass. BFM: Body Fat Mass. TEM: Total Extremity Mass. TBW: Total Body Water. ICW: Intracellular Water. ECW: Extracellular Water. * Differences between pilots/control groups ($p < 0.05$). Differences between left/right arms ($p < 0.05$). Normality and homoscedasticity ($p > 0.05$) in all samples.

4. Discussion

The purpose of this study was to analyse the body composition of aircraft pilots and the symmetry between the left and right sides of both the upper and lower body. A tendency to dysmetria is observable due to the physical requirements of pilots. However, there are no significant differences between both sides, so the study hypothesis is not supported.

The lack of research in this line has limited the understanding of the effects on body composition and symmetry in body composition in military population group. Specifically, the analysis of body composition of military personnel allows us to understand the requirements of these extreme activities from land forces to aircraft aircrews. The body composition values analysed differ from other military corps due to different operational needs and physiological adaptations [37,38]. Previous research found that the body fat of land forces were between 7.6 ± 3.2 kg and 9.7 ± 0.4 kg [38,39], and in aircraft personnel between 13.21 ± 4.33 kg and 18.81 ± 8.46 kg [32]. Regarding muscular mass in land forces, previous research found values between 63.3 ± 8.0 kg and 72.8 ± 2.9 kg [37–39], and in aircraft personnel between 58.74 ± 10.59 kg and 63.95 ± 7.58 kg [32]. To the best of our knowledge, no previous studies analysed symmetry in this population despite its importance for correct health and performance, as well as the implications for their operativity in these special populations, specially pilots that are exposed to an eliciting and extreme context [40,41].

By analysing the upper body symmetry of the aircraft pilots tested, we found similar values in the fat free mass than previous literature in airplane and helicopter pilots. In this investigation, the pilots analysed presented a 3.52 ± 0.47 kg of FFM in the right arm and 3.47 ± 0.47 kg in the left arm similar as in previous studies in helicopter pilots who showed a 3.50 ± 0.55 kg FFM in the right arm and 3.46 ± 0.52 kg in the left arm [32]. In the same case, it showed similarities in airplane pilots, who presented 3.60 ± 0.55 kg of FFM in the right arm and 3.46 ± 0.52 kg in the left arm [32]. There were significant differences in FFM values between soldiers 3.52 ± 0.47 kg versus civilians 3.19 ± 0.79 Kg. Higher values were shown in the military group, as the functions and physical requirements similarity in these military corps most likely produces the same response as in previous research, which showed the same discrepancy in the skeletal muscle in the right arm (3.60 ± 0.55 kg vs. 3.27 ± 0.80 kg) and (3.55 ± 0.55 kg vs. 3.22 ± 0.79 kg) in the skeletal muscle in the left arm between pilots and transport aircrew [32].

Regarding body fat mass, we found values lower than those of airplane pilots 0.73 ± 0.71 kg BFM in the right arm and 0.74 ± 0.72 kg in the left arm, and helicopter pilots who presented 0.65 ± 0.31 kg of BFM in the right arm and 0.67 ± 0.34 kg of BFM in the left arm [32] versus 0.47 ± 0.45 kg BFM in the right arm and 0.49 ± 0.45 kg in the left arm, as was shown in this investigation. However, in all cases we can see a trend of slight dysmetria between both sides, where the body fat values are higher on the left side, but with better values than the control group, which showed 0.66 ± 0.52 kg BFM in the right arm and 0.68 ± 0.53 kg in the left arm. In addition, a slight dysmetria is presented by the control group, who had higher levels of body fat due to their daily physical requirements.

The similarities in the fat-free mass and fat mass behaviour in the military groups and the difference in parameters analysed in civilian personnel would be due to the contextual demands in both groups being totally contrary. In addition, we found a trend dysmetria between sides in pilots, most likely due to the right arm using the main flight joystick, which is used constantly, while the left arm only uses the throttle lever and control panel. The flight controls for pilots are the same whether you are left- or right-handed. For this reason, less BFM is observed in the right arm, the most frequently used, as higher muscle activation produces a greater consumption of metabolic resources. The effects of the G forces, and the constant stimulation in the same muscular area, can produce this dysmetria, which, if not controlled, could produce a decompensation that could result in injuries.

We also found in the aircraft pilots analysed in the present research a tight dysmetria in lower body segments. This result was in line with previous research in airplane pilots, who showed 9.95 ± 1.30 kg FFM in the right leg and 9.87 ± 1.28 kg FFM in the left leg, or helicopter pilots who presented 9.50 ± 1.04 kg FFM in the right leg and 9.42 ± 1.02 kg FFM in the left leg [32] versus 9.92 ± 1.05 kg FFM in the right leg and FFM in the left leg 9.84 ± 1.04 kg, as presented in this investigation. In the three cases, to a greater or lesser extent we can observe an imbalance with higher values in the right side. The control group presented in this research 8.99 ± 1.69 kg FFM in the right leg and FFM in the left leg 8.95 ± 1.65 kg, lower values compared to the military personal observed in this investigation. In addition, lower values than male and female athletes were observed, such as in female tennis players, who presented 11.35 ± 0.41 kg FFM in the right leg and 11.05 ± 0.20 kg and FFM in the left leg; basketball players, who showed 11.88 ± 0.68 kg FFM in the right leg versus 11.62 ± 0.93 kg FFM in the left leg; or gymnastics athletes, who showed 14.01 ± 0.46 kg FFM in the right leg and 13.50 ± 0.20 kg in the left leg [42].

This fact shows how the flight time, performed in a sitting position, the lack of racing situations, the lack of load of heavy elements, or the specific work of strength in the lower body produces physiological adaptations such as muscle atrophy, increased body fat, and dysfunction of the metabolic system, which can lead to some types of imbalances, producing physiological adaptations in the body composition due to the stimuli received [43–45].

Regarding fat mass in the lower body, we observed lower values than in previous research. Pilots presented 1.62 ± 0.65 kg BFM in the right leg and 1.60 ± 0.63 kg in the left leg in comparison with airplane pilots, who showed 1.98 ± 0.96 kg BFM in the right leg and 1.97 ± 0.96 kg BFM in the left leg, and helicopter pilots, who showed 1.93 ± 0.51 kg BFM in the right leg and 1.90 ± 0.49 kg BFM in the left leg [32]. In addition, values are lower than in the civil group, who showed 1.91 ± 0.90 kg BFM in the right leg and 1.90 ± 0.90 kg BFM in the left leg.

Similar to the upper body, it was observed how body fat values were higher on the left side in both groups. The imbalance in aircraft pilots between sides could most likely be due to the physical and metabolic requirements. This limb dominance makes it more active, which produces an imbalance and differences in the body composition, creating a risk for lower-limb injuries, as in other population groups that produce similar imbalances such as in downhill skiers [46].

Regarding the trend in dysmetria observed in pilots, we found that it was a common factor in other demanding professions, such as in professional athletes or ultraendurance runners [29,47]. We could compare our results to what is observed in sports where the predominance of the dominant side produces imbalance and body asymmetry. In obvious cases, such as in tennis, there is a dysmetria between the arms due to the demand of the dominant arm when picking up the racket [48]; in basketball, where the use of the dominant arm is continuous [49]; or in football players, who show an imbalance from an early age also due to using the dominant side to kick the ball [50].

4.1. Practical Application

The present results, alongside other physiological variables analysed in this specific population [51], could help to design specific training for military and civil aircrew. Specific training based on muscular and a standardized evaluation of dysmetria could become essential tools to avoid any type of injury or imbalance and thus improve physiological responses to extreme stimulations.

4.2. Limitation of the Study and Future Research Lines

The main limitation of this study is the lack of collection of skinfolds or DXA scan values, which can give us more specific values for the behaviour of body composition in this group. Another limitation is that the control group was not equal in numbers and it was not composed solely of men, as in the experimental group, which could have influenced the control group parameters.

Creating a database regarding the type of training of pilots, their diets, and the difference in physiological response between genders and military forces could be useful in future studies to track the real response longitudinally and design more specific protocols.

5. Conclusions

Aircraft pilots presented a tendency to dysmetria in upper and lower body segments, showing fitter values in the protagonist side when performing flight functions. Dysmetria could be detrimental during flight manoeuvres and produce injuries in aircraft pilots, and it would be recommended to design specific training protocols to improve this imbalance.

Author Contributions: Conceptualization, V.J.C.-S., Á.B.-S.; methodology and formal analysis A.C.-R., Á.B.-S., J.F.T.-A. and V.J.C.-S. investigation, A.C.-R., Á.B.-S., J.F.T.-A., J.P.F.-G. and V.J.C.-S.; data curation, V.J.C.-S.; writing—original draft preparation, A.C.-R., L.P.A., Á.B.-S., J.F.T.-A., J.P.F.-G. and V.J.C.-S.; writing—review and editing, A.C.-R., L.P.A., Á.B.-S., J.F.T.-A., J.P.F.-G. and V.J.C.-S.; visualization, A.C.-R., Á.B.-S. and V.J.C.-S.; supervision and funding acquisition, V.J.C.-S. All authors have read and agreed to the published version of the manuscript.

Funding: The authors certify that they are not involved in any organization or entity with any financial interest, or non-financial interest, in the subject discussed in this manuscript. This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

Institutional Review Board Statement: The study was conducted in accordance with the Declaration of Helsinki, and approved on 4 April 2018 by the Institutional Review Board (CIPI/18/093).

Informed Consent Statement: Informed consent was obtained from all subjects involved in the study.

Data Availability Statement: All the data are presented in the study.

Acknowledgments: We would like to acknowledge the contribution of the Aerospace Medicine Instruction Centre of 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.

Conflicts of Interest: The authors declare no conflict of interest.

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