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Morphological Status of Cadets and Pilots of the Croatian Air Force

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A B S T R A C T

Results of the analysis of morphological status of cadets and pilots of the Croatian Air Force are presented, in relation to the morphological status of a sample of conscripts of the Croatian Army. The results of the morphological status of body built of the flier potential of the Croatian Air Force, i.e., the potential (cadets) and active fliers (pilots), suggest a process of spontaneous (or possibly systematic) selection of flier candidates based on anthropometric criteria. Based on the obtained anthropometric data, it may be concluded that persons who choose to candidate for and are selected to join the Croatian Air Force as pilots, are of specific personal appearance and body built.

Key words: *morphological status, cadets, pilots, conscripts, discriminant analysis*

Introduction

Being a pilot is an extremely demanding form of human activity in terms of physical, mental and emotional strains. It requires constant adaptation to unnatural conditions, which are caused by the fact that flying implies being separated from the ground and extremely rapid passing of various orientation points, etc. In addition, working as a pilot requires high reliability in performing complex activities in a limited workspace overloaded with a multitude of signaling and steering instruments and in which any error may be fatal. In war conditions, flying military aircrafts is even more complex due to simultaneous fighting engagement in which a pilot is required to perform breakneck acrobatic piloting in order to evade enemy's attacks together with being involved in fighting.

In such conditions that are additionally often accompanied by time deficit, even a minor disproportion (of a few centimeters only) between the dimensions of human executive organs and the steering instruments may be the cause of clumsy or imprecise performance of steering moves or absence of fateful reactions needed for avoiding danger, engine trouble, damaging and threat to other people.

Because of all this, getting to know the man's structural specificities, body measures and dynamic characteristics of functioning of different body parts engaged in operative moves in piloting by means of anthropometric studies is of key importance primarily for defining ergonomic parameters of cockpit construction, rationally organized work space for pilots and various signaling and steering instruments in it, as well as fighting instruments in military airplanes.

In studies that deal with the idea of constructing rationally organized working space in cockpit, particular attention is dedicated to the following issues:

- The arrangement of steering instruments in relation to the possibilities of limbs' access to instruments, i.e. legs and arms reach;
- The elimination of obstacles (side panels and fences) that impede free access to signaling and steering instruments;
- Defining the criteria for optimal conformity in a limited work space;
- The need of support for body parts that are excessively engaged or forced to maintain long and uncomfortable position (e.g. head and limbs);

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- The elimination of the sources of pressure on certain body parts, particularly on wrists, etc.

The need for anthropometric treatment of pilots is, however, not limited only to questions of defining construction parameters and determining selection criteria for choosing the right school candidates or assigning pilots to aircrafts, but also to resolving numerous essential issues related to situational problems of piloting or long-term maintenance of pilots' capacity for work. The results of morphological studies provide the basis for treating the following questions:

- Insuring a comfortable position of a pilot in the cockpit;
- Design of equipment: clothes, shoes (especially helmets), work supplies and fighting equipment in military aircrafts;
- The impact of equipment to preciseness and dynamics of operative moves in steering an aircraft as well as in fighting actions;
- Determining risk factors in using rescuing devices;
- Intra-individual variability of anthropometric traits as a consequence of destructive factors and processes of deterioration, etc.

In view of this, the study of anthropometric variables as related to risk factors in rescuing crewmembers by means of throwing out seats as reported by Edwards[1] is very informative. He concludes that 199 pilots (out of the total of 810 airplanes that had an accident) who suffered more serious injuries were heavier (average weight was 88 kg as opposed to 79 kg) and taller (185 cm as opposed to 180 cm) and, therefore, more prone to any kind of spinal fracture. Robinette and Whitestone[2] point out to the importance of a more modern approach in treating the issue of relation between the human body and the equipment, stressing how crucial it is by surfaces scanning to estimate precisely to what extent the equipment fits as far as the size is concerned to the position of the body in equipment. The need of permanent research of anthropometric features of pilots is further supported by the study conducted by Ree[3], which shows that the average height of KLM pilots (KLM Royal Dutch Airlines) has increased by 18 mm every ten years for the last two decades. About 6% of their pilots are taller than 1905 mm, which is the top height limit for pilots in a pilot cabin. The need for permanent observation is also stressed by Grant[4], who tackles the problem of specific factors in the work environment, as well as the sources of an increased muscular and bone pain in HH-60G flight engineers and shooters. His results indicate that the present seat configuration forces the majority of HH-60G flight engineers and shooters to acquire various awkward neck, back and leg positions during flight. The back support design of the crew members' seats and insufficient room for legs and feet between seats and the aircraft are two essential flaws that must be dealt with in order to improve body position and reduce the stress of muscular and bone system in flight engineers and shooters of this type of helicopter.

Considering the importance of coordinating construction solutions of cockpit and steering instruments in aircrafts and psychical and psychological characteristics of a pilot, Croatian Air Force has initiated the study of anthropometric features of their pilots and cadets. Material collected so far represents the starting point in searching for the answer to two key questions: 1) Which parameters should be paid particular attention to in the construction of aircrafts (or choosing from the ones offered on the market) so that all ergonomic requirements of optimal adaptation of aircrafts to anthropometric features of the Croatian Air Force population be satisfied? and 2) What anthropometric criteria are obligatory in the selection of candidates for pilot education or for assignment of pilots to the existing types of aircrafts in case adaptations to individual anthropometric features or adequate ergonomic reconstruction cannot be insured or performed?

Air force pilots represent a specific, carefully selected and unique sample of the population in each country. It is characterized by numerous specific psychological, health and physical traits, the favorable combination of which is observable in its extremely low probability of appearance. This is one of the reasons why in selecting pilots the selection criteria cannot be based on the data collected for the needs of school medicine, sport, work medicine, population genetics and ergonomics[5,6], and not even on the first detailed measuring of anthropometric status of the Croatian Army carried out from 1993 through 1995 on the sample of 4268 conscripts at the then Center for Strategic Research of Defense in the Ministry of Defense of the Republic of Croatia[7].

The comparative analysis of the profile of professional, morphological, health and psychological characteristics of potential pilots (cadets) and Croatian Air Force fliers' characteristics is aimed at determining the present status of fliers' potential as well as the degree of compatibility of those profiles as defined on the basis of the selection norms that have been applied in Croatian Air Force since 1992 for the selection of school candidates (potential pilots) at the Faculty of Transport and Traffic Engineering as related to the accessible profiles of pilots and the selection criteria of military and air force systems in other countries. Such an analysis may provide an insight into our own reality and serve as the basis for considering means of conducting rational and economic moves in compensation of possible deficits of human resources.

Considering that the active life of military pilots, and especially pilots of supersonic planes, is significantly shorter than the active life in many other vocations, the low probability of finding the candidates who possess the required characteristics, and the cost of military pilots' education, it becomes understandable how valuable, among other things, are the studies that provide an insight into the frequency of the required profile of morphological characteristics in a population.

Materials and Methods

The field measurement of body features of pilots of the Croatian Air Force as well as junior and senior students at the Faculty of Transport and Traffic Engineering (cadets) was carried out in different Air Force bases and in the Center for Strategic Research. 127 pilots and flight engineers together with 154 cadets participated in the study.

Cadets were aged between 19 and 28, and the average age at the time of measuring was 21.5 years. The youngest among pilot was 21 and the oldest 56, while the average age was 34.7 years. For the needs of analysis of morphological traits, the pilots are divided into three age groups as specified in Table 1. In this way the youngest group of pilots is comparable to the cadets, and both these groups can be compared to the sample of the Croatian Army conscripts as the control group[7]. The two remaining groups of older pilots enable the research of the aging phenomenon. The data on conscripts were randomly taken from the Database of Anthropometric Features of Croatian Soldiers[8] until the size of the sample reached 200 conscripts thus being comparable to the analyzed sample of cadets and pilots.

Measuring of 59 anthropometric variables was planned for determining morphological status of cadets and pilots of the Croatian Air Force, and 57 were actually measured. Because of a lack of a pilot seat model it was impossible to measure the length of the upper leg in sitting position and the »leg's reach« in the functional position for various aircraft models.

Anthropometric measures were chosen and their measuring was carried out in accordance with the methodology presented in the International Biological Program (IBP)[9]. Table 3 contains the list of all the anthropometric measures applied in this study as well as the corresponding codes, which will be consistently used in the text further on. The list of variables is completely the same for all the observed groups of cadets, pilots and conscripts, with the exception of »smiling« mouth width, which was not taken among conscripts.

TABLE 1
NUMBER OF CADETS, PILOTS AND CONSCRIPTS BY AGE GROUPS

Age (years)	Cadets	Pilots	Conscripts	Total
–30	154	41	200	170
31–40	–	55	–	55
40+	–	31	–	31
Total	154	127	200	481

Results

In this study of morphological status of the Croatian Air Force cadets and pilots, the difference between cadets, three age cohorts of pilots and Croatian Army conscripts was tested by means of discriminant analysis with the aim of in-depth analysis of the position of cadets and pilots in the population fit for military service which they are normally chosen from. The difference between conscripts on the one hand, and cadets and pilots on the other, is obvious: according to the results of discriminant analysis, only one discriminant function that explains for 93.42% of variance, divides the two groups. According to correlations of that function with the original variables, it resulted that upper leg length, face breadth, forearm length, upper arm length, pelvis breath, and the eyes level in the sitting position are responsible for such sample division. In order to illustrate these differences it suffices to present the position of the groups in a coordination system made up of two discriminant functions (responsible for 98.72% variability of the total system of measures) in Figure 1. Discrimination of the group of conscripts is clearly discernable from the group of cadets and pilots by the first discriminant function, while the second discriminant function pro-

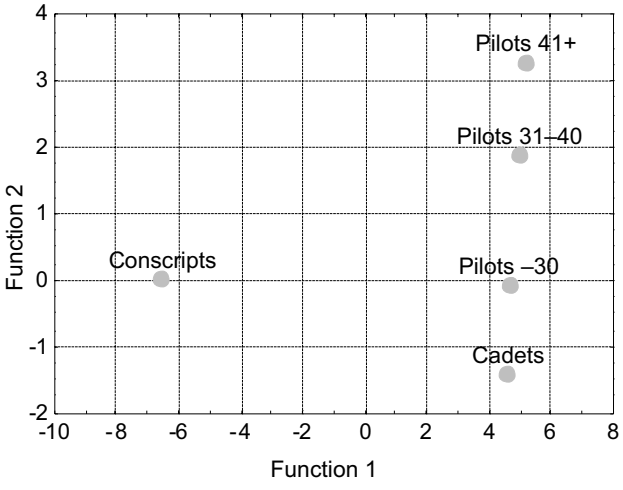

Fig. 1. Position of cadets, pilots of different age groups and conscripts with regard to the first two discriminant functions.

TABLE 2
CANONICAL DISCRIMINANT FUNCTIONS FOR THE FOUR GROUPS UNDER STUDY

Dis. fun.	Eigen–value	% of variance	Cum. %	Can. correl.	Test of functions	Wilks' Λ	χ^2	df	p
					0	0.106627	559.605	168	<0.001
1	3.7086	81.41	81.41	0.8875	1	0.502061	172.259	110	<0.001
2	0.6089	13.37	94.78	0.6152	2	0.807785	53.365	54	0.500
3	0.2380	5.22	100.00	0.4384					

vides information on the differences between different age groups of cadets and pilots.

As regards the already confirmed statistically significant differences in morphological traits between the defined groups of cadets up to 30 years of age, pilots up to 30 years of age, pilots from 31 through 40 years of age, and pilots of over 40 years of age, we wanted to find out the specificities of differences between these groups by performing discriminant analysis. By means of canonical discriminant analysis two discriminant functions that explain the differences between the four analyzed groups of examinees were defined. The first discriminant function explains for 81.41% of variance between the groups of pilots and cadets, and the second for only 13.37% of differences (Table 2).

Discussion

The structural matrix in Table 3 indicates that *the first discriminant function* is defined primarily by the circumference variables (body circumferences, transverse measures and body weight), head variables, subscapular and biceps skinfolds, and by lower leg length among longitudinal variables. It is interesting to point out that all the variables that define the first discriminant function were significantly higher in pilots than in cadets: circumferences (abdomen, chest, neck, and forearm circumferences), transverse measures (thoracic cavity depth, transverse chest and bicondylar humerus), body mass and subscapular and biceps skinfolds. The only longitudinal measures that influence more the forming of the first than of the second variable is lower leg length, which is significantly longer in cadets than in pilots. Among head variables, ear length and breadth, lip thickness and head breadth significantly more to the structure of the first than to the structure of the second discriminant function. With regard to its structure, *the first discriminant function* could be defined as the *general factor of body trunk circumference* that comprises some other specificities of the morphological head features (greater ear dimensions – both length and breadth, extremely thin lips and a pronounced head breadth). *The second discriminant function* is defined primarily by the quantities of subcutaneous fat tissue of the body trunk (suprailiac, abdominal and midaxillar skinfolds) and of the upper arm (triceps skinfold) as well as limbs circumferences (upper leg, relaxed and flexed upper arm). Among head variables, nose height from its root to the lower rim of the upper lip, interorbital width and head length need to be mentioned. From all of the above it can be observed that the mentioned measures, i.e. the ones that define the first and the second discriminant function, mainly represent morphological traits that are mostly conditioned by age.

The structure of the two discriminant functions and the accompanying mean values for every analyzed group (group centroid values) (Figure 2) indicate that two most similar groups are pilots up to 30 and pilots between 31 and 40 years of age. They differ from others by lower values of the measures that refer to the second discriminant function (subcutaneous fat tissue and limbs circumferences). It is interesting to mention that, regarding the values of the second discriminant function, the cadets are more similar to the pilots of over 40 than to the pilots of their age (up to 30) and that between the cadets and the pilots over 40 the similarity regarding the second discriminant function is more pronounced than that between groups 2 and 3 (pilots between 31 and 40, and pilots over 40). As far as the first discriminant function marked by pronounced body trunk circumference, ear length, thin lips and head breadth is concerned, the cadets obtained the lowest values, and the pilots up to 30 somewhat higher. These two groups are then followed by the pilots between 31 and 40, while the pilots over 40 years of age scored highest values for the mentioned measures.

The prediction analysis regarding membership in one of the four groups (cadets up to 30 years of age, pilots up to 30 years of age, pilots from 31 through 40 years of age, and pilots of over 40 years of age) indicated that in 86.48% of cases an examinee fitted the morphological traits of the group he was assigned to. It is worth noticing that among cadets a very high percentage of examinees fitted the group they belong to (89.6%) (Table 4). Only 10.3% of cadets were morphologically more similar to pilots than to other cadets, which means that in 8.4% of cases (13 examinees) were more similar to their pilot peers up to 30 years of age, and in 1.9% (3 examinees) to the group of pilots between 31 and 40 years of age. At the same time, the pilots of up to 30 years of age, seem to be morphologically a quite heterogeneous group and in »only« 85.4% of cases were morphologically well assigned to their age group, while in 2.4% of cases they are more similar to the cadets, and in 12.2% of cases to the older group of pilots (31 through 40 years of age), but none of them fits mostly the oldest group of pilots.

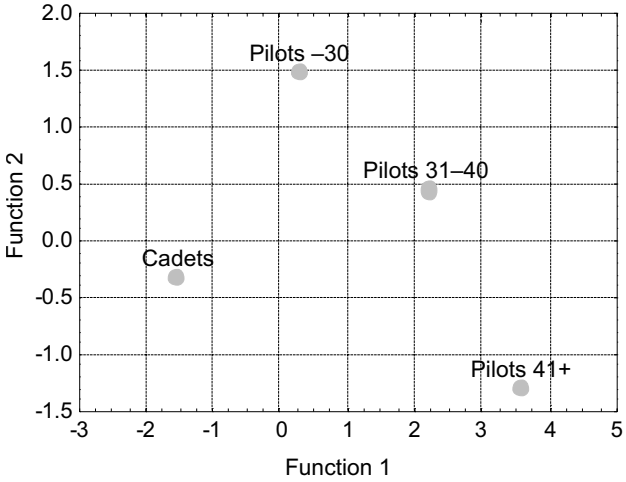

Fig. 2. Position of cadets and pilots of different age groups with regard to the first two discriminant functions.

TABLE 3
CORRELATION OF VARIABLES AND CANONICAL DISCRIMINANT FUNCTIONS FOR THE FOUR GROUPS UNDER STUDY

Code	Variable	Fun. 1	Fun. 2	Fun. 3
AN24	Abdomen circumference (cm)	0.38002	0.14658	0.11682
AN15	Thoracic cavity depth (cm)	0.32657	–0.03736	0.06831
AN51	Ear length (cm)	0.27659	–0.22652	–0.14150
AN23	Chest circumference (cm)	0.25006	0.11815	0.14430
AN50	Lip thickness (cm)	–0.23633	0.07346	–0.01029
AN32	Triceps skinfold (mm)	0.23164	0.11847	–0.01123
AN14	Chest transverse (cm)	0.21748	0.02333	0.20955
AN37	Body mass (kg)	0.21285	0.14920	0.04176
AN22	Neck circumference (cm)	0.20730	0.03492	0.13799
AN52	Ear breadth (cm)	0.20045	0.14379	–0.05649
AN27	Forearm circumference (cm)	0.19316	0.13034	0.01122
AN30	Biceps skinfold (mm)	0.17024	0.05724	–0.08717
AN07	Lower leg length (cm)	–0.16051	0.00412	0.00386
AN29	Lower leg circumference (cm)	0.13698	0.11805	–0.03861
AN40	Head breadth (cm)	0.12923	0.02897	0.02615
AN17	Bicondylar humerus (cm)	0.12717	0.10122	–0.12429
AN21	Ankle breadth (cm)	0.10887	–0.09509	–0.00963
AN01	Body height (cm)	–0.09988	0.05431	–0.02838
AN05	Leg length (cm)	–0.09816	0.09056	–0.01119
AN20	Bicondylar femur (cm)	0.08380	–0.01486	–0.00849
AN34	Suprailiac skinfold (mm)	0.19886	0.35502	0.12049
AN36	Abdomen skinfold (mm)	0.28286	0.32651	0.16332
AN33	Suprailiac skinfold (midaxillar) (mm)	0.26234	0.28971	0.09349
AN28	Upper leg circumference (cm)	0.11202	0.28963	0.12684
AN31	Triceps skinfold (mm)	0.19366	0.23774	–0.10085
AN45	Nose height (cm)	0.02815	–0.23205	0.09950
AN53	Interorbital width (cm)	–0.11662	–0.19649	0.09482
AN26	Flexed upper arm circumference (cm)	0.15527	0.19352	0.14052
AN25	Relaxed upper arm circumference (cm)	0.16547	0.17072	0.13038
AN06	Upper leg length (cm)	–0.02750	0.15112	–0.04342
AN38	Head length (cm)	–0.08200	–0.15040	0.04887
AN08	Tibial length (cm)	–0.06217	0.14655	–0.09455
AN48	Mouth width (cm)	0.09478	–0.11915	0.02162
AN04	Knee level in sitting position (cm)	–0.06555	0.11314	–0.00670
AN12	Forearm length (cm)	–0.07887	0.10889	0.05992
AN16	Pelvis breadth (cm)	0.06166	–0.09934	0.04269
AN55	Head circumference (cm)	0.04393	–0.09631	0.03638
AN54	Bizygomatic diameter (cm)	–0.05337	–0.09562	–0.01112
AN46	Nose height (cm)	0.00755	–0.09069	0.02851
AN02	Suprasternal height (cm)	–0.04276	0.08406	–0.06544
AN47	Nose breadth (cm)	0.13139	–0.06492	–0.23312
AN44	Face height (cm)	0.01646	–0.06192	0.23111
AN18	Wrist breadth (cm)	0.02948	–0.08757	–0.19227
AN35	Subscapular skinfold (mm)	0.01912	0.11897	0.15804
AN41	Forehead width (cm)	0.03267	0.02203	–0.14849
AN43	Lower jaw width (cm)	0.10568	–0.01805	0.13653
AN19	Hand width (cm)	0.06025	–0.04541	–0.12911
AN42	Face breadth (cm)	0.09165	–0.01557	0.12310
AN49	»Smiling« mouth width (cm)	–0.03892	–0.10806	0.11277
AN11	Upper arm length (cm)	–0.00669	0.01150	–0.10001
AN03	Sitting height (cm)	–0.03035	–0.04842	0.06683
AN39	Head height (cm)	–0.02584	0.01679	–0.06534
AN58	Eye level in sitting position (cm)	0.01706	0.04269	0.05922
AN10	Arm length (with an extended hand) (cm)	–0.04233	0.04176	–0.05196
AN09	Foot length (cm)	–0.02506	0.00254	0.03082
AN13	Biacromial diameter (cm)	–0.01352	0.00157	0.01458

TABLE 4
RESULTS OF CLASSIFICATION OF THE FOUR EXAMINED GROUPS

Active belonging	N	Estimation of group belonging			
		Cadets	Pilots (≤ 30 years)	Pilots (31–40 years)	Pilots (41+ years)
Cadets	154	138	13	3	0
		89.6%	8.4%	1.9%	0.0%
Pilots (≤ 30 years)	41	1	35	5	0
		2.4%	85.4%	12.2%	0.0%
Pilots (31–40 years)	55	1	6	42	6
		1.8%	10.9%	76.4%	10.9%
Pilots (41+ years)	31	0	0	3	28
		0.0%	0.0%	9.7%	90.3%

Because the average age of this group of pilots was 26.02, which means that a relatively low number of them »passed« into an older age group (12.2%) and that 88% of pilots from this group are classified well as regards their age. The greatest age dispersion is found in the group of pilots between 31 and 40, in which 76.4% of pilots fit their age group morphologically. Compared to the cadets and the lowest age group of pilots, this group resembles the group of pilots over 40 in 10.9% of cases. In 10.9% of cases they mostly resemble pilots up to 30 years of age, and in the remaining 1.8% of the cadets. The pilots over 30 were well grouped according to their morphological traits in 90.3% of cases, whereas in 9.7% they are characterized by morphological features that are typical of the pilots between 31 and 40 years of age.

Conclusions

The preliminary study of the morphological status of body built of the Croatian Air Force fliers' potential, potential (cadets) and active fliers (pilots), suggest a process of spontaneous (or possibly systematic) selection of flier candidates based on anthropometric criteria. Based on the obtained anthropometric data, it may be concluded that persons who choose to candidate for and are selected to join the Croatian Air Force as pilots, are of specific personal appearance and body built. Similarly, this preliminary study points out to systematic deterioration, i.e. to unfavorable changes of morphological body built features of pilots as the result of aging. Body height and all measures that participate in its formation are greater and more homogeneous in cadets and active pilots as compared to the measures found in Croatian Army conscripts. At the same time they are significantly higher in cadets than in active pilots. Transversal measures, width and depth of certain body parts, are greater in pilots than in cadets, and are significantly greater and more homogeneous among fliers than among conscripts. All measures of body volumes are greater in pilots than in cadets, but are greater and more homogeneous in these two groups than among army conscripts. Greater mass of fat tissue was found in pilots than in cadets and conscripts, while cadets have greater muscular mass than conscripts. Compared to pilots, cadets are characterized by more pronounced morphological face features and head length measures, while at the same time all the head measures are greater in pilots, as well, compared to Croatian Army conscripts.

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MORFOLOŠKI STATUS KADETA I PILOTA HRVATSKOG RATNOG ZRAKOPLOVSTVA

S A Ž E T A K

Prikazani su rezultati analize morfološkog statusa kadeta i pilota Hrvatskog ratnog zrakoplovstva, u odnosu na morfološki status uzorka ročnika Hrvatske vojske. Prema tim rezultatima snimka morfološkog statusa građe tijela letačkog potencijala HRZ-a, potencijalnog (kadeta) i aktualnog djelatnog letačkog sastava (pilota), ukazuje na spontano djelovanje (ili možda sustavno provođenje) selekcije kandidata za letačko zanimanje po antropometrijskim kriterijima. Prema dobivenim antropometrijskim podacima, za zanimanje vojnih pilota odlučuju se, a i biraju, osobe specifičnog tjelesnog izgleda i građe.