Physiological Fitness of U.S. Army Aviators Compared to the U.S. General Population

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INTRODUCTION: U.S. Army aviators are required to maintain a level of physiological fitness as part of their qualifying process, which suggests that they are generally physically healthy. However, it has not been statistically proven that they are more "physiologically fit" than the general population.

METHODS: This retrospective study compares physiological measurements of U.S. Army aviators from the Aeromedical Electronic Resource Office database to the U.S. general population using the Center for Disease Control's National Health and Nutrition Examination Survey data. To enable an accurate comparison of physiological metrics between U.S. Army aviators and the U.S. general population, aviators were categorized into the same age groups and biological genders used for segmentation of the national population data.

RESULTS: On average, pulse rate was 4.85 bpm lower in male aviators and 6.84 bpm lower in female aviators. Fasting glucose levels were, on average, $10.6\,\mathrm{mg \cdot dL^{-1}}$ lower in aviators compared to the general population. Key metrics like pulse rate and fasting glucose were lower in aviators, indicating cardiovascular and metabolic advantages. However, parameters like cholesterol showed less consistent differences.

DISCUSSION: While aviation physical demands and administrative policies selecting for elite physiological metrics produce improvements on some dimensions, a nuanced view accounting for the multitude of factors influencing an aviator's physiological fitness is still warranted. Implementing targeted health monitoring and maintenance programs based on assessments conducted more frequently than the current annual flight physical may optimize aviator safety and performance over the course of a career.

KEYWORDS: aviator, physiological fitness, Aeromedical Policy Letters.

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While all U.S. soldiers must meet basic standards of physical fitness as outlined in U.S. Army Regulation 40-501, U.S. Army aviators are held to more stringent physical and mental requirements due to the unique demands of aviation duties. Specifically, Chapter 4 of the regulation and supporting Aeromedical Policy Letters outline elevated standards for visual acuity, color vision, depth perception, and other physiological metrics critical for in-flight performance and safety.[24] These metrics can also aid in identifying U.S. soldiers who are at risk for injuries and the development of health problems.[11,15] Though a wide range of individual variability exists between aviators, aviation standards and Aeromedical Policy Letters are precise given the immense risks inherent to flight.[6,20] Ultimately, the aviation branch depends on these standards to mitigate dangers and ensure only qualified U.S. soldiers operate Army aircraft. Although physical and mental fitness standards apply to all U.S. soldiers, the demands placed specifically on U.S. Army aviators within the aviation domain necessitate more specialized physical and cognitive capabilities that distinguish this population from the broader military community.

Monitoring physiological metrics makes it possible, in some cases, to identify U.S. soldiers at risk for developing health

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problems and enables healthcare providers to take steps to prevent these problems.[5] In addition to their high level of physical fitness, aviators experience environmental stressors that have a substantial effect on their physiology compared to other military professions. The flight environment exposes aviators to stressors associated with dynamic aircraft, such as gravitational forces, noise, vibration, alterations in barometric pressure, and temperature variation.[23] In addition to supplemental stressors aviators experience due to the dynamic environment, several genetic and gender-specific variables directly affect physiology.[18] As flight physiology is a critical aspect of aviation safety, it is essential to understand the physiological status of aviators to ensure safe and efficient operations.[3]

Although it has been assumed that aviators are more "physiologically fit" than the general population, to our knowledge, this assumption has not been statistically proven. It is important to quantify the difference in physiological fitness between U.S. Army aviators and the U.S. general population to inform aeromedical policy and standards. For this study, we differentiate physiological fitness (e.g., cardiovascular endurance, muscle strength, etc.) from physical fitness more broadly. We compared specific physiological measurements of U.S. Army aviators obtained from the Aeromedical Electronic Resource Office (AERO) database to values of individuals indexed in the U.S. Center for Disease Control and Prevention's National Health and Nutrition Examination Survey (CDC NHANES) database for the years 2012–2018. The CDC NHANES data represent the U.S. general population. We grouped aviators and the general population into biological gender and age-grouped categories to allow for statistical comparisons to assess if the U.S. aviation population is significantly "more physiologically fit" than the U.S. general population.

METHODS

Subjects

Prior to data acquisition and analysis, the study was reviewed and approved according to the U.S. Army Aeromedical Research Laboratory's Human Subjects Research Protection Plan. The USAARL Determination Official determined that the study met the criteria for exemption from Institutional Review Board review. The present study is retrospective in design, using de-identified data from the AERO medical record system (January 2013–December 2018) and publicly available data from the CDC NHANES database.

Procedure

AERO is a database system the U.S. Army, U.S. Navy, and U.S. Coast Guard use to record flight physical examinations for aviators, crewmembers, and aviation students. The anonymized dataset from AERO for this study contains information on all U.S. Army aviation personnel who received a Class II flight physical [rated aviator initial physical and rated aviator comprehensive (comprehensive every year (long) and interval (short)]. The dataset provided to the researchers contains the demographic variables of age and gender, but otherwise does not contain personally identifiable information. U.S Army aviators are required to complete a flight physical at least once every year. Aviators may also have multiple AERO entries within 1 yr due to follow-up assessments. To match the structure of the CDC NHANES 2-yr collection cycles, the AERO data were averaged into a single data entry for each unique aviator for each 2-yr window.

CDC NHANES is a program of surveys and studies conducted by the Centers for Disease Control and Prevention to assess the health and nutritional status of adults and children in the United States.[16] The CDC NHANES dataset is organized as a stratified, multistage probability sample. However, for this study, we treated the CDC NHANES data as a random sample of the U.S. population to allow for comparison with the AERO dataset. The final data used for statistical analysis contains 24,259 observations from AERO and 12,001 observations from CDC NHANES covering the years 2013–2018. Each observation from AERO represents one flight physical for a given 2-yr period. Each observation from CDC NHANES represents a unique individual for a given 2-yr period. The outcome variables of interest in both data sets are pulse, systolic and diastolic blood pressure, hematocrit, hemoglobin, fasting blood sugar, high-density lipoprotein (HDL), low-density lipoprotein (LDL), and triglycerides. Individuals with missing or extreme medical values were not included in the analysis.

Statistical Analysis

Descriptive statistics and plotting were performed using R (v4.2.1; R Core Team, Vienna, Austria; 2022), R Studio (2022.12.0 Build 353), and tidyverse (v2.0.0). Statistical analyses were performed using R (v4.2.1; R Core Team, 2022), tidyverse,[25] rstatix,[8] and WRS2 packages.[9] The purpose of the descriptive statistics performed in this study was simply to assess any potential statistical significance between groups. Therefore, inferential statistics were only used to support the observable data trends. The significance testing criterion was set at $P = 0.05$. To maintain appropriate statistical power and reduce the chance of a Type 1 error, the data was reduced to 150 observations per group before inferential testing (group is defined as each unique combination of age and flight status). Two-way analyses of variance (ANOVAs) were used to estimate the effect of age (four levels: 16–25, 26–35, 36–45, and 46–55), flight status (two levels: AERO and CDC NHANES), and the interaction effect for each outcome variable in the data. The assumptions of the two-way ANOVA were tested using the Shapiro-Wilk test (for normality of residuals) and Levene's test (for homogeneity of variance). When the assumptions for the two-way ANOVA were violated, a robust two-way ANOVA with 20% trimmed means was used (WRS2 package). When the interaction effect was significant, one-way ANOVAs were used to determine the effect of flight status for each age group. When the effect of age was significant, pairwise comparisons were made using *t*-tests (or the robust equivalent as described in the WRS2 documentation). *P*-values for one-way ANOVAs and pairwise comparisons were adjusted using the Bonferroni method. Importantly, *P*-values only pertain to the random samples used; however, the figures and summary statistics include all available data.

RESULTS

Our retrospective study compared the physiological metrics of U.S. Army aviators to those of the U.S. general population. We grouped the U.S. Army aviators and the U.S. general population by age and biological gender. The results of this study are represented in **Fig. 1, Fig. 2, Fig. 3, and Fig. 4** and **Table I**. A total of 24,259 U.S. Army aviators from the AERO database and 12,001 individuals from the CDC NHANES database were included in the analysis. Comparisons were made between U.S. Army aviators and the U.S. general population across age groups and biological sex for several physiological metrics.

U.S. Army male aviators demonstrated significantly lower pulse rates compared to the U.S. general population [$F(1, 1192) = 48.95$, $P < 0.001$]. U.S. Army female aviators showed a significant interaction effect between age and flight status [$F(3, 1150) = 12.18$, $P = 0.008$]. Pairwise comparisons showed that aviators had significantly lower pulse rates across all age groups ($P \leq 0.021$ for all). U.S. Army male aviators showed a significant interaction effect for diastolic blood pressure (BP) [$F(3, 1192) = 25.17$, $P < 0.001$] and systolic BP [$F(3, 1192) = 26.90$, $P < 0.001$]. Pairwise comparisons showed that U.S. Army male aviators had significantly higher diastolic and systolic BP compared to the U.S. general population in the youngest two age groups ($P < 0.01$ for all). U.S. Army female aviators also had a significant interaction effect for diastolic BP [$F(3, 1150) = 17.78$, $P < 0.001$] and systolic BP [$F(3, 1148) = 35.06$, $P < 0.001$]. Pairwise comparisons showed that U.S. Army female aviators had significantly higher diastolic and systolic BP compared to the U.S. general population in the youngest two age groups ($P < 0.01$ for all). Additionally, U.S Army female aviators in the 46–55 age group showed a significantly lower systolic BP than the U.S. general population ($P = 0.012$). Interestingly, the interaction plots show that aviator blood pressure for both men and women stay relatively consistent across age groups compared to the increase seen as age progresses in the general population.

U.S. Army male aviators showed a significant interaction effect for hematocrit levels [$F(3, 1191) = 9.88$, $P = 0.021$]. Pairwise comparisons showed that U.S Army male aviators ages 46–55 had significantly higher hematocrit levels compared to the U.S. general population ($P = 0.002$). U.S. Army male aviators showed significantly higher hemoglobin levels compared to the U.S. general population [$F(1, 1191) = 13.03$, $P < 0.001$]. U.S. Army female aviators had significantly higher hematocrit levels compared to the U.S. general population [$F(1, 1147) = 54.55$, $P < 0.001$]. U.S. Army female aviators showed a significant interaction effect for hemoglobin levels [$F(3, 1123) = 15.34$, $P = 0.002$]. Pairwise comparisons showed that U.S. Army female aviators had higher hemoglobin levels for age groups 16–25, 26–35, and 36–45 ($P < 0.001$ for all).

For total cholesterol, U.S. Army male aviators showed a significant interaction effect [$F(3, 1192) = 16.8$, $P < 0.001$]. Pairwise comparisons showed that male aviators ages 16–25 had higher cholesterol levels compared to the general population ($P = 0.013$), but male aviators ages 26–35 had lower cholesterol than the U.S. general population ($P = 0.024$). U.S. Army female aviators showed a significant interaction effect for total cholesterol [$F(3, 1150) = 9.71$, $P = 0.023$]; however, pairwise comparisons for each age group showed no significant differences between U.S. Army aviators and the U.S. general population ($P > 0.05$ for all).

Analysis of low-density lipoprotein revealed a significant interaction effect for men [$F(3, 1192) = 13.43$, $P = 0.005$]. Pairwise comparisons showed that LDL levels were significantly higher in U.S. Army male aviators compared to the U.S. general population for the 16–25 age group ($P < 0.001$). U.S. Army female aviators had significantly lower LDL levels compared to the general population [$F(1, 1149) = 5.33$, $P = 0.022$]. For HDL, U.S. Army male aviators had significantly higher levels compared to the U.S. general population [$F(1, 1192) = 30.34$, $P < 0.001$]. Comparatively, U.S. Army female aviators also showed significantly higher HDL levels [$F(1, 1145) = 231.33$, $P < 0.001$].

Furthermore, we incorporated analysis of the total cholesterol to HDL cholesterol ratio, a widely used cardiovascular risk stratification tool that compares relative levels of atherogenic lipoproteins to circulating concentrations of high-density lipoprotein particles.[19] The total cholesterol to HDL cholesterol ratio has been shown in multiple large cohort studies to predict incidence of coronary artery disease events and mortality independent of LDL cholesterol levels.[2,4,17] For U.S. Army male aviators, the total cholesterol to HDL ratio was significantly lower than the U.S. general population [$F(1, 1185) = 22.71$, $P < 0.001$]. For U.S. Army female aviators, a significant interaction effect was observed [$F(3, 1145) = 10.28$, $P = 0.018$]. Pairwise comparisons showed significantly lower ratio values across all four age groups ($P < 0.001$ for all). For triglycerides, no significant differences occurred in the male comparison groups. However, U.S. Army female aviators showed a significant interaction effect [$F(3, 1150) = 22.76$, $P < 0.001$]. Pairwise comparisons showed that U.S Army aviators ages 36–45 and 46–55 both had significantly lower triglyceride levels compared to the U.S. general population ($P < 0.02$ for all). Analysis of fasting blood glucose showed a significant interaction effect for both men [$F(3, 1183) = 8.13$, $P = 0.046$] and women [$F(3, 1131) = 17.88$, $P < 0.001$]. Pairwise comparisons showed that U.S. Army aviators had significantly lower glucose levels than the U.S. general population across all age groups and both sexes ($P < 0.001$ for all).

DISCUSSION

To be qualified for flight duty, U.S. Army aviators must meet strict physical fitness standards, pass a rigorous physical fitness test, and meet other U.S. Army standards defined in Chapter 4

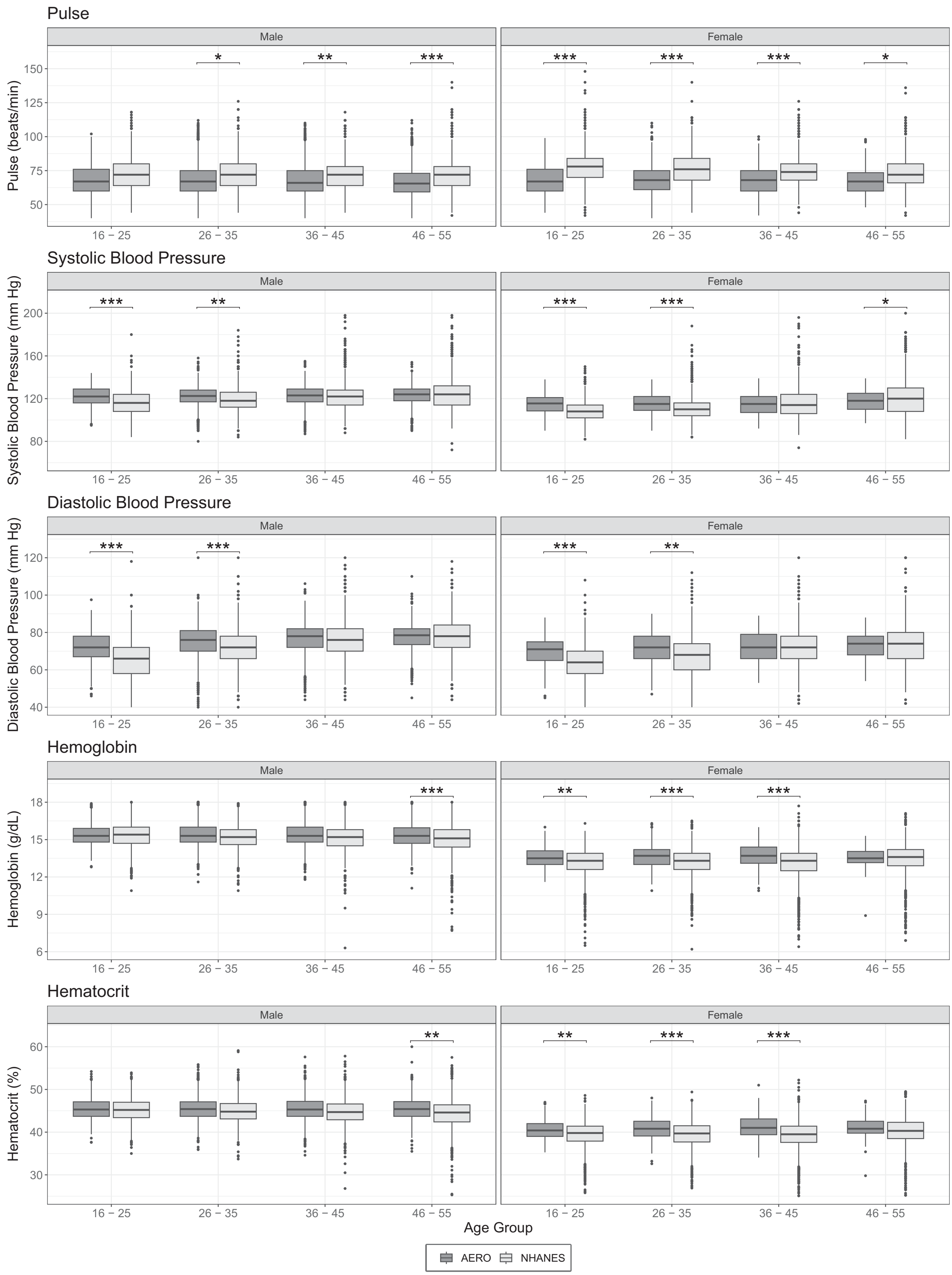

Fig. 1. Pulse, systolic and diastolic blood pressure, hemoglobin, and hematocrit box plots. This figure represents a standardized way of visualizing key statistical information about the distribution of quantitative data. The box encloses the interquartile range between the first and third quartiles, and the median is marked by a line inside the box. The whiskers extend to the minimum and maximum values in the dataset unless there are outliers. Outliers are data points (depicted by dots) that fall a specified distance above quartile 3 or below quartile 1 (1.5 times the interquartile range). The asterisks indicate the level of significance at the *P*-value levels of < 0.05, < 0.01, and < 0.001.

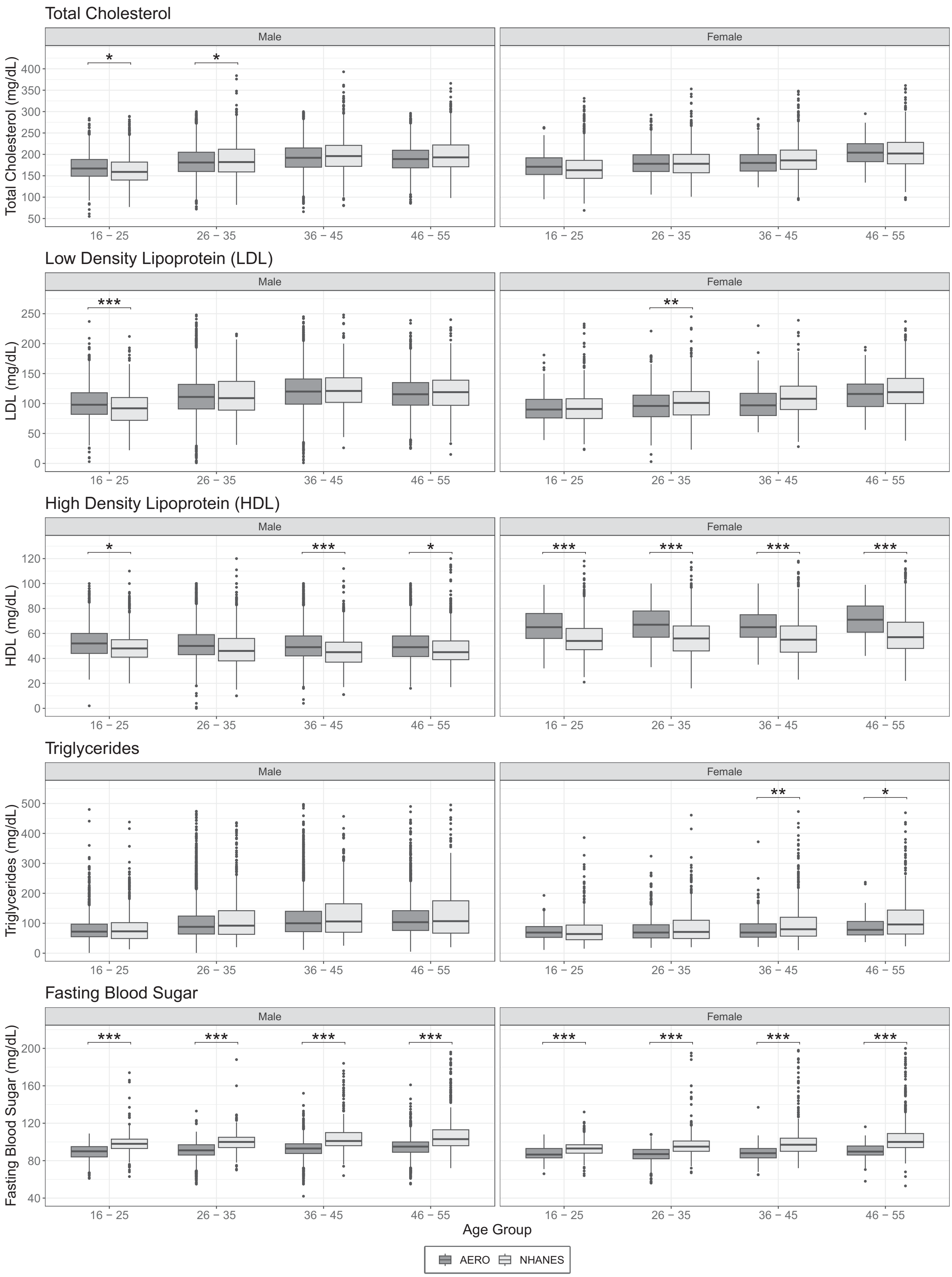

Fig. 2. Fasting blood sugar, total cholesterol, low density lipoprotein, high density lipoprotein, and triglyceride box plots. The box encloses the interquartile range between the first and third quartiles, and the median is marked by a line inside the box. The whiskers extend to the minimum and maximum values in the dataset. Outliers are data points (depicted by dots that fall a specified distance above quartile 3 or below quartile 1 (1.5 times the interquartile range). The asterisks indicate the level of significance at the *P*-value levels of < 0.05, < 0.01, and < 0.001.

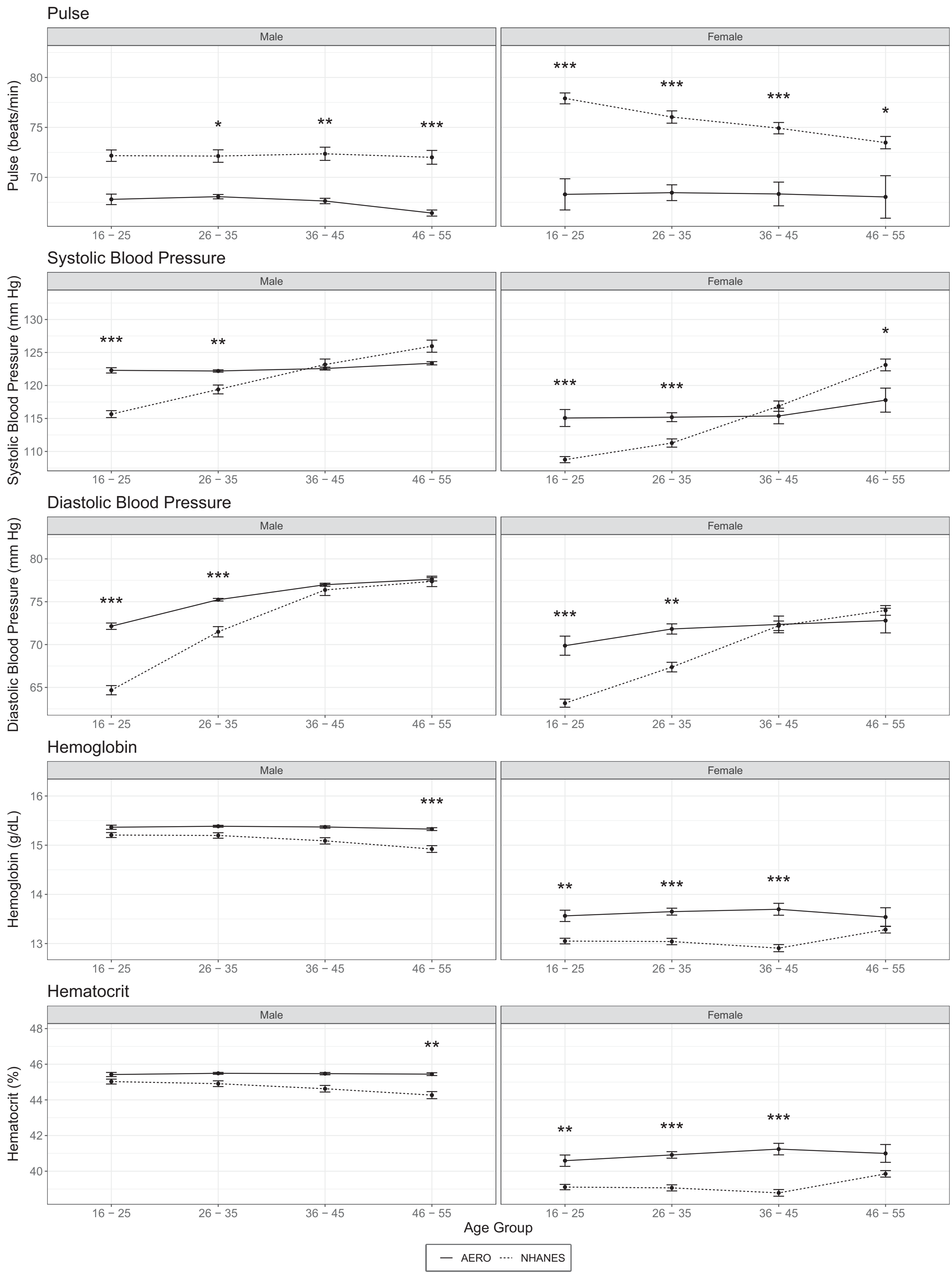

Fig. 3. Interaction plots of physiological metrics for pulse, systolic blood pressure, diastolic blood pressure, hemoglobin, and hematocrit. The data that is displayed is the mean response for two factors and their interaction. It allows for visual assessment to determine if the relationship between levels of one factor differs depending on the level of the other factor. The plots display the mean values for each factor level combination with error bars representing 95% confidence intervals. The asterisks indicate the level of significance at the *P*-value levels of < 0.05, < 0.01, and < 0.001.

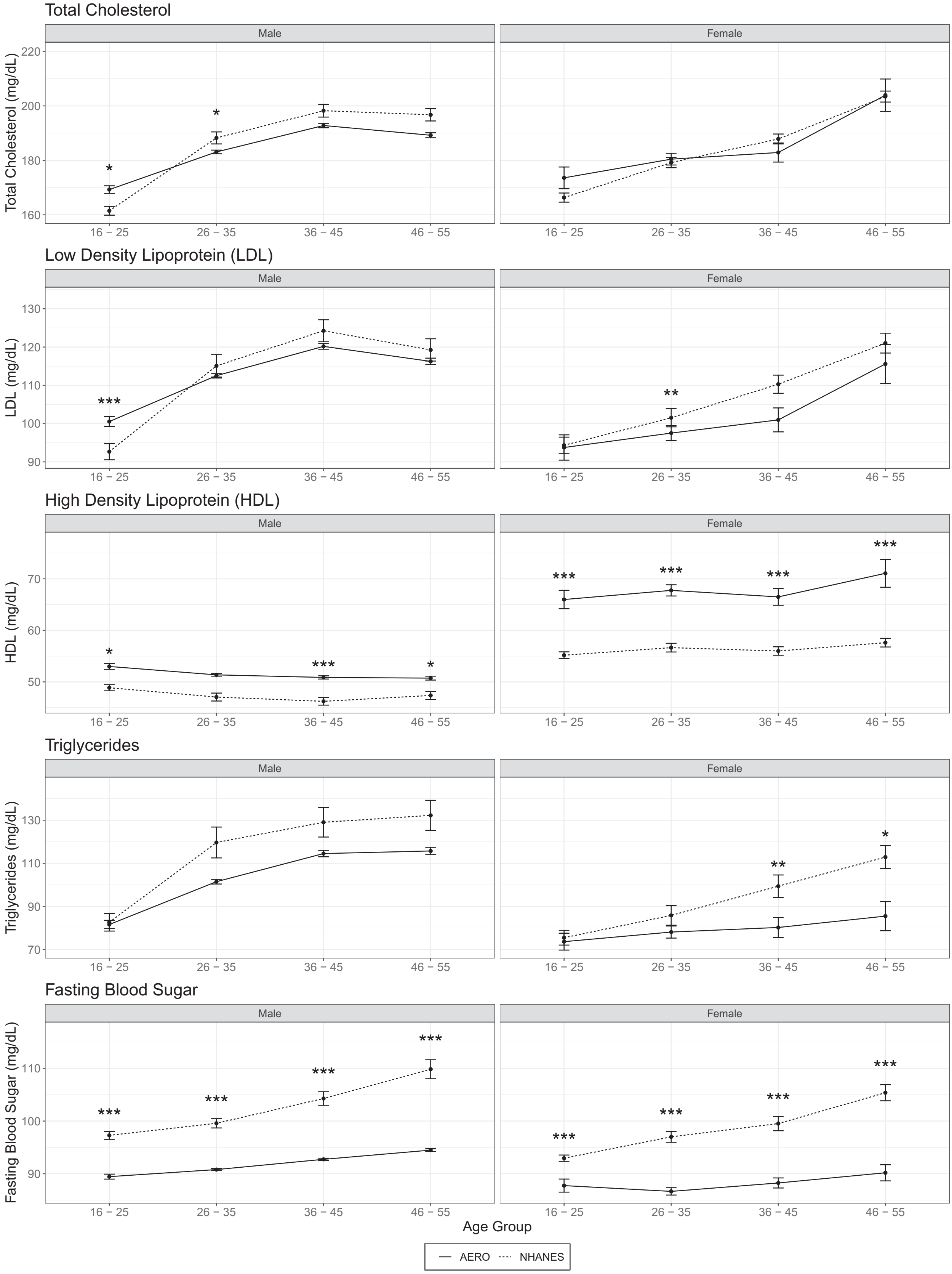

Fig. 4. Interaction plots of physiological metrics for total cholesterol, low density lipoprotein, high density lipoprotein, triglycerides, and fasting blood sugar. The plots display the mean values for each factor level combination with error bars representing 95% confidence intervals. The asterisks indicate the level of significance at the *P*-value levels of < 0.05, < 0.01, and < 0.001.

Table I. Tabular Representation of Physiological Metrics.

METRIC	GENDER	AGE GROUP	SAMPLE SIZE AERO	SAMPLE SIZE NHANES	MEAN AERO	MEAN NHANES	STANDARD DEVIATION AERO	STANDARD DEVIATION NHANES	*P*-VALUE
Pulse (bpm)	Male	16–25	1874	1606	67.80	72.17	11.60	11.70	0.068
		26–35	10,120	1259	68.06	72.13	11.19	11.31	0.024
		36–45	6588	1180	67.63	72.36	11.24	11.56	0.001
		46–55	4285	1235	66.42	72.00	10.16	12.40	0.000
	Female	16–25	212	1660	68.29	77.90	11.60	11.36	0.000
		26–35	742	1344	68.46	76.04	10.95	11.51	0.000
		36–45	287	1428	68.34	74.92	10.25	10.97	0.000
		46–55	108	1377	68.04	73.48	11.28	11.67	0.021
Systolic blood pressure (mmHg)	Male	16–25	1875	1547	122.29	115.66	8.91	10.53	0.000
		26–35	10,122	1221	122.20	119.40	8.76	12.00	0.007
		36–45	6590	1129	122.57	123.18	8.75	14.25	1.000
		46–55	4284	1178	123.37	125.96	8.21	16.05	1.000
	Female	16–25	212	1594	115.07	108.76	9.54	9.46	0.000
		26–35	743	1294	115.20	111.28	9.35	11.45	0.000
		36–45	287	1346	115.38	116.87	10.23	14.69	1.000
		46–55	108	1296	117.78	123.11	9.66	16.40	0.012
Diastolic blood pressure (mmHg)	Male	16–25	1875	1506	72.14	64.68	8.24	10.64	0.000
		26–35	10,121	1217	75.24	71.50	7.81	10.68	0.000
		36–45	6590	1130	76.98	76.38	7.38	11.18	1.000
		46–55	4284	1177	77.62	77.37	6.63	10.61	0.501
	Female	16–25	212	1577	69.87	63.16	8.29	9.52	0.000
		26–35	743	1288	71.82	67.37	8.27	10.26	0.007
		36–45	287	1344	72.35	72.19	8.42	10.41	1.000
		46–55	108	1294	72.80	73.98	7.63	10.39	1.000
Hemoglobin ($g \cdot dL^{-1}$)	Male	16–25	1578	1538	15.37	15.21	0.85	1.00	0.428
		26–35	8098	1234	15.39	15.20	0.88	1.00	1.000
		36–45	5386	1134	15.37	15.09	0.89	1.10	0.331
		46–55	3479	1222	15.33	14.92	0.86	1.23	0.000
	Female	16–25	172	1610	13.56	13.05	0.77	1.17	0.001
		26–35	602	1337	13.65	13.04	0.88	1.21	0.000
		36–45	234	1431	13.70	12.91	0.94	1.40	0.000
		46–55	86	1380	13.54	13.28	0.90	1.31	0.805
Hematocrit (%)	Male	16–25	1771	1542	45.42	45.03	2.51	2.75	1.000
		26–35	9334	1238	45.49	44.91	2.60	2.89	1.000
		36–45	6187	1139	45.47	44.63	2.63	3.17	0.358
		46–55	4058	1233	45.44	44.27	2.58	3.53	0.002
	Female	16–25	202	1610	40.59	39.11	2.30	3.07	0.007
		26–35	680	1337	40.91	39.06	2.44	3.19	0.000
		36–45	268	1431	41.24	38.78	2.70	3.61	0.000
		46–55	107	1380	41.00	39.85	2.64	3.46	0.070
Total Cholesterol ($mg \cdot dL^{-1}$)	Male	16–25	1843	1520	169.26	161.47	30.59	32.08	0.013
		26–35	9857	1231	183.08	188.24	33.78	39.53	0.024
		36–45	6508	1135	192.79	198.23	33.27	40.17	1.000
		46–55	4270	1216	189.22	196.73	30.67	40.38	1.000
	Female	16–25	209	1588	173.57	166.32	29.37	34.08	0.074
		26–35	734	1328	180.44	179.17	29.73	34.75	1.000
		36–45	287	1420	182.87	187.85	30.30	34.93	0.306
		46–55	108	1358	203.94	203.43	31.50	37.94	1.000
Low Density Lipoprotein ($mg \cdot dL^{-1}$)	Male	16–25	1839	696	100.54	92.66	28.18	28.46	0.000
		26–35	9865	504	112.52	115.08	31.29	33.51	1.000
		36–45	6502	533	120.17	124.26	30.50	33.87	1.000
		46–55	4268	557	116.26	119.25	28.08	35.05	1.000
	Female	16–25	209	706	93.75	94.35	24.37	28.66	1.000
		26–35	734	608	97.52	101.53	26.86	29.89	0.004
		36–45	288	623	100.97	110.29	27.09	30.22	0.750
		46–55	108	634	115.58	121.03	27.14	33.33	1.000

(*Continued*)

Table I. (*Continued*).

METRIC	GENDER	AGE GROUP	SAMPLE SIZE AERO	SAMPLE SIZE NHANES	MEAN AERO	MEAN NHANES	STANDARD DEVIATION AERO	STANDARD DEVIATION NHANES	*P*-VALUE
High Density Lipoprotein ($mg \cdot dL^{-1}$)	Male	16–25	1834	1520	52.99	48.87	12.18	11.84	0.021
		26–35	9820	1231	51.36	47.06	12.58	13.76	0.059
		36–45	6471	1132	50.87	46.23	12.85	12.66	0.000
		46–55	4253	1215	50.73	47.37	12.59	13.74	0.017
	Female	16–25	204	1587	65.98	55.18	12.99	13.24	0.000
		26–35	706	1324	67.76	56.64	14.74	15.65	0.000
		36–45	280	1418	66.49	55.99	13.90	15.81	0.000
		46–55	103	1352	71.06	57.61	14.01	15.70	0.000
Triglycerides ($mg \cdot dL^{-1}$)	Male	16–25	1844	653	81.64	82.68	42.11	53.25	1.000
		26–35	9875	496	101.50	119.68	54.71	81.33	1.000
		36–45	6512	515	114.54	129.04	61.14	79.21	0.235
		46–55	4273	537	115.74	132.25	56.55	82.37	1.000
	Female	16–25	209	682	73.69	75.52	28.88	45.59	0.120
		26–35	734	584	78.14	85.86	38.74	56.28	1.000
		36–45	288	603	80.26	99.40	40.03	65.27	0.002
		46–55	108	621	85.52	112.90	35.75	67.95	0.016
Fasting Blood Sugar ($mg \cdot dL^{-1}$)	Male	16–25	1223	661	89.45	97.29	8.39	9.83	0.000
		26–35	7009	502	90.79	99.58	8.32	10.10	0.000
		36–45	6305	512	92.74	104.28	8.47	14.86	0.000
		46–55	4269	520	94.49	109.84	8.80	20.96	0.000
	Female	16–25	143	689	87.75	92.95	7.57	8.02	0.000
		26–35	552	585	86.65	97.01	8.38	12.76	0.000
		36–45	280	591	88.25	99.52	8.15	16.77	0.000
		46–55	108	610	90.19	105.38	8.15	19.33	0.000

Tabular representation of physiological metrics between groups for pulse, systolic blood pressure, diastolic blood pressure, hemoglobin, and hematocrit and lipid profiles. Summary statistics are representative of all available data and *P*-values are derived from the reduced data set.

of Army Regulation 40-501.[22] These requirements likely contribute to their physical fitness and well-being. However, aviators encounter many environmental stressors that can have a negative impact on health, such as high altitude, noise, and vibration.[7] Nonetheless, some research suggests that the stressors also promote physiological adaptations that improve overall health, such as increased red blood cell production, which improves tissue oxygen delivery, as a result of the stressor.[26] In addition to these factors, genetic factors and individual differences must be taken into consideration. Some people have a genetic predisposition to be more physiologically fit than others,[12] and it is plausible that people who seek aviation careers may have a genetic makeup that renders them healthier than the general population. Furthermore, the healthy worker effect, a type of selection bias that occurs in occupational cohort studies, can lead to an underestimation of the risks associated with certain occupations and is especially applicable to the comparisons made in this study.[21] Any U.S. Army aviator who does not meet standards is likely to be identified and removed from the workforce, which can skew the results of studies that compare the health of aviators to the general population.

Our study compared the physiological measurements of U.S. Army aviators to those of the U.S. general population to assess if the aviation population is truly "more physiologically fit" than the U.S. general population. U.S. Army aviator flight physical data from the AERO database were compared to age, time, and biological gender-grouped data from the CDC NHANES database. The results of this study showed that there were statistically significant differences between U.S. Army aviators and the U.S. general population in many physiological metrics. Key metrics like pulse rate and fasting glucose were consistently lower in U.S. Army aviators across age and gender. This implies U.S. Army aviators have physiological advantages that may reduce their risk of chronic cardiovascular and metabolic diseases. Maintaining ideal physical fitness and body weight promotes cardiovascular endurance and resilience.[14] Hence, U.S. Army aviators may perform duties safely for longer durations under high stress compared to the general population. However, a nuanced perspective is warranted, as some parameters like cholesterol and blood pressure showed less consistent differences.

Though aviation demands can initially induce adaptive responses like lowered heart rate, occupational stresses over time negatively impact other physiological measures. In particular, chronic noise exposure is a well-documented hazard faced by aviators that distinguishes them from the general population. Persistent loud noise from aircraft engines has been shown to contribute to hearing loss and tinnitus among pilots. This is likely the primary domain where aviators physiologically diverge from the public due to direct occupational environmental exposure.[13] Additional effects of vibration and altitude changes include increased blood pressure and hematocrit production over time, which may plateau at subclinical levels or become pathological after years of service without intervention.[1] Some research also indicates aviators experience more spinal issues like low back and neck pain later in their careers, partially due to vibration exposure.[10] While aviation may confer initial cardiovascular benefits, certain exposures produce measurable declines not faced by the nonflying population, especially in hearing, but also potentially in blood composition, spine health, and other areas. This highlights the need for monitoring tailored to aviation hazards over the career span.

Overall, while this study shows some selective advantages for aviators, it does not fully support the assumption that they are "generally healthier" across all cardiovascular and metabolic markers. For example, U.S. Army male aviators showed minimal differences compared to the U.S. general population with respect to LDL, cholesterol, triglyceride, hemoglobin, and hematocrit measurements across the various age groups. Hence, targeted initiatives to optimize physiological fitness may be beneficial, but close monitoring of aviators over their career is still warranted to detect negative impacts of flight on specific health parameters. Rather than making broad generalizations, it would be prudent for U.S. military health policy makers to take a more measured approach based on regular health assessments of U.S. Army aviators. Areas like pulse rate, where aviators show clear advantages, can be maintained with physical fitness training. Parameters like blood pressure, where U.S. Army aviators appear comparable to (and in some groups higher than) the U.S. general population, may require routine monitoring and management. A balanced, evidence-based approach accounting for the impacts of flight will optimize aviator safety, health, and performance.

This study has several limitations. First, it is a retrospective study, which introduces a risk of bias. The study only looked at U.S. Army aviators, so it is unclear if the findings apply to other military aviators or Army soldiers in general. The study is cross-sectional in design and, although it did include age-banding, the study did not follow individuals over time to see how their overall physiological profiles changed. The retrospective data points were drawn from the AERO database, which has inherent constraints limiting the breadth and depth of analysis. Specifically, the dataset's narrow focus on aviation-specific metrics and its limited number of physiological parameters restricts the ability to derive significant insights about broader health or performance outcomes. The study did not control for other factors influencing health, such as diet, smoking, or exercise. The reasons for the differences obtained are not fully understood. However, they may be due to a combination of factors, including the rigorous physical fitness standards that aviators must meet, the environmental stressors they are exposed to, and their lifestyle choices.

Importantly, as briefly mentioned previously, a significant limitation of our study is the lack of data on smoking rates and behaviors within both the U.S. aviation and U.S. general population samples. Smoking has well-established effects on cardiovascular parameters like blood pressure and hematologic markers that could influence the differences observed between groups. Without controlling for smoking, we cannot definitively conclude that higher blood pressure and hematocrit levels among aviators relate to superior fitness or occupational stresses rather than simply reflecting higher smoking prevalence. The omission of smoking data hampers the ability to characterize overall health advantages and weakens arguments regarding adaptive or maladaptive responses to aviation hazards. The lack of correlation with smoking behavior is a major shortcoming that restricts the interpretability of our findings. Future studies should capture smoking rates and incorporate this data into analysis to permit appropriate conclusions regarding cardiovascular health, hematologic impacts, and overall fitness. Controlling smoking would greatly strengthen the evidence available to military health policymakers in optimizing aviator standards and safety initiatives relating to flight physiology.

Moreover, the CDC NHANES database uses a stratified, multistage, probability-cluster sampling design. This approach intentionally oversamples certain demographic groups, including older adults, African Americans, and Hispanics. The oversampling ensures sufficient data is collected from these groups to yield representative sample sizes reflecting their proportion in the overall U.S. population based on census data. It accounts for anticipated noncompliance and nonparticipation rates within each stratum. In this way, oversampling typically underrepresented groups enhances the probability of obtaining an adequately sized sample to reflect the true national demographic distribution. The resulting dataset provides a representative portrait of the population, not an overrepresentation of the oversampled groups.

Our retrospective analysis provides a statistical comparison between U.S. Army aviators and the U.S. general population, assessing many physiological variables that aid in assessing cardiovascular health, metabolic, and lipid profiles. Our study suggests that the current regulations and Aeromedical Policy Letters are effective at promoting physiological advantages for U.S. Army aviators to help lower their risk for developing cardiovascular disease, diabetes, and other chronic diseases compared to the U.S. general population. Importantly these findings draw attention to the need to evaluate all physiological metrics in a systematic fashion. Interestingly, the data did not reveal comprehensive health advantages across all metrics examined. Taken together, these findings indicate a nuanced relationship between aviation and physiological fitness. The requirements of U.S. Army aviation appear to promote cardiovascular endurance and metabolic health but may not lead to global improvements across all health parameters. Targeted monitoring and maintenance initiatives may be warranted to optimize aviator physiological fitness over a career span, particularly to detect potential negative impacts of occupational stresses over time.

Although we cannot definitively attribute these findings to any individual or group of specific variables, our results are likely due to numerous factors, including but certainly not limited to the strict physical fitness standards that U.S. Army aviators must meet, the environmental stressors they encounter, and the regulatory environment of accession and retention standards that apply throughout their career. The findings of this study also have several implications for U.S. military health policy. For example, the findings support ongoing review and evidence-based modification of medical standards to optimize health outcomes (adding emerging metrics like heart rate variability that better predict overall physiological status). The results highlight the need for more targeted monitoring and maintenance programs to mitigate potential negative effects of aviation stresses over time. This could include more frequent or in-depth hearing tests, spinal health checks, blood pressure monitoring, etc., based on an analysis of aviation-specific risks.

Furthermore, the results suggest the possibility of adjusting fitness standards to be more specialized to the physical and mental demands of flying rather than general fitness benchmarks. This could help attract and retain aviators with capabilities optimized for the aviation environment. Moreover, this study provides impetus for further research into other potential health impacts of aviation service and additional metrics that may offer early warning signs of subtle declines, for example, detailed studies on effects of vibration, noise, fatigue cycles, etc. However, it is essential to note that this study only examined a limited number of physiological metrics currently monitored according to medical standards. In addition to the physiological metrics in this study, future research should consider other factors to gain a full picture of overall health. Furthermore, researchers could consider other factors when assessing the overall health of aviators, such as heart rate variability, respiratory function, and real-time operator state. Finally, this study reinforces the importance of ongoing qualification standards in ensuring the aviation population is shaped toward health and supports periodic review of disqualifying conditions based on current evidence.

Other factors to evaluate when assessing overall health include individual physiological trends, mental health, sleep quality, smoking, and nutrition. Future studies should examine these factors to get a more comprehensive understanding of the health of aviators. Aviators, over their lifetime, may maintain "normal" physiological metrics and year-to-year trends should be considered when evaluating an individual's health status. Mental health is essential to consider as aviators experience stressful situations that can negatively impact their mental health.[13] Sleep quality is also important, as sleep deprivation can impair cognitive function and increase the risk of mishaps.[1] Nutrition is another critical factor, as aviators must maintain a healthy diet to optimize their performance.[10] By considering these factors, we can better understand an aviator's health status and develop more effective strategies for improving or maintaining their health and well-being.

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