Retrospective Assessment of U.S. Army Aviator Anthropometric Screening Process

Allison N. Moczynski; Charles A. Weisenbach; James S. McGhee

INTRODUCTION: The current U.S. Army aviator anthropometric screening process for rotary-wing cockpit compatibility was codified over 30 yr ago. Critical to the process are the anthropometric standards that define what is acceptable for U.S. Army flight school applicants. The purpose of this study was to assess and optimize the efficiency of the standards in screening for anthropometric cockpit compatibility while maintaining safety.

METHODS: A retrospective analysis was performed. Anthropometry and disposition data of flight school applicants from 2005 to 2014 were taken from the Aeromedical Electronic Resource Office database to determine efficiency of the process. Data on mishaps from 1972 to 2017 were retrieved from the Risk Management Information System database to determine the safety benchmark of the existing process, to which adjusted standards would be held. Adjustments to standards were modeled that would more efficiently pass applicants over the period studied without exceeding the established acceptable safety level.

RESULTS: There were 40,136 (98.28%) applicants who passed the standards, while 702 (1.72%) failed. Most (98.52%) applicants who failed the standards and applied for an anthropometry exception to policy (ETP) received one. The models would pass up to 396 (99.25%) applicants who received ETPs without exceeding the established number of mishaps attributable to the anthropometry standards, which was found to be zero.

DISCUSSION: The screening process is efficient and effective, but could be improved. Adjusting the standards could increase process efficiency by passing more applicants during their flight physical and widening the applicant pool, while maintaining the current level of safety.

KEYWORDS: cockpit fit, aeromedical policy, accession policy, human factors.

Moczynski AN, Weisenbach CA, McGhee JS. *Retrospective assessment of U.S. Army aviator anthropometric screening process.* Aerosp Med Hum Perform. 2020; 91(9):725–731.

Anthropometry has long been known to impact aviation safety as well as long-term aviator health.[3,7,21] Many surveys and studies have been conducted to better understand the role of aviator anthropometry during flight.[10,16,17] Operationally, anthropometry affects visual acquisition inside and outside the cockpit as well as actuation of controls with the hands and feet.[6,16,17] Ensuring appropriate aviator fit within the cockpit is critical for proper aircraft control. The purpose of the current study was to assess and optimize the efficiency of the Anthropometry Aeromedical Policy Letter (APL) in screening for anthropometric cockpit compatibility between today's U.S. Army aviators and aircraft cockpits while maintaining its effectiveness.

Anthropometry requirements for U.S. Army aviators are defined in the APL published by the U.S. Army Aeromedical Activity.[2] The APL describes a two-tiered screening process for determining anthropometric cockpit compatibility. The first part of the APL defines three anthropometric measurement standards applicants must meet: total arm reach (TAR), crotch height (CH), and sitting height (SH) (**Fig. 1**). TAR and CH screen for applicants who are too small to perform operationally critical reaches, and SH screens for applicants who are too tall to have sufficient helmeted head clearance with the top of more restrictive cockpits.[5,15] Presently, the APL states that TAR

From the U.S. Army Aeromedical Research Laboratory, Injury Biomechanics & Protection Group, Fort Rucker, AL.

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

Address correspondence to: Dr. James S. McGhee, 110 6th St, Fort Rucker, AL 36362; james.s.mcghee.civ@mail.mil.

DOI: https://doi.org/10.3357/AMHP.5462.2020

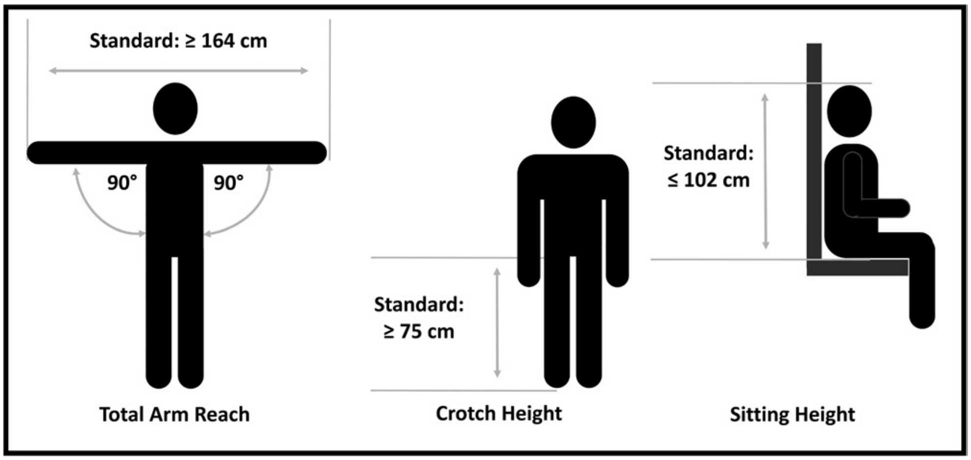

Fig. 1. Anthropometric measurement standards listed in the Anthropometry Aeromedical Policy Letter. Total arm reach is defined as the horizontal distance between fingertips when the aviator candidate is standing erect against a wall with arms outstretched at a 90 degree angle and parallel with the wall and with the elbows locked. Crotch height is defined as the distance between the floor and the point where light contact is made with the perineum in the midline when the aviator candidate is standing erect against a wall in bare feet with heels together, weight evenly distributed, and knees locked. Sitting height is defined as the distance between the sitting surface and the top of the head when the aviator candidate is sitting on a hard, flat surface with feet flat on the floor and with the buttocks, shoulders, and back of head against a wall.[2] Figure recreated from "Anthropometry," 2015.[2]

must be at least 164 cm, CH must be at least 75 cm, and SH can be no greater than 102 cm.[2]

The second part of the APL outlines the process of obtaining an anthropometry Exception to Policy (ETP).[2] If an applicant fails one or more of the listed anthropometric standards, he or she must pass an in-cockpit evaluation (ICE) in all operational U.S. Army rotary-wing platforms.

A standardization instructor pilot (SIP) personally observes the applicant to determine whether anthropometric cockpit fit is acceptable. If the applicant passes the ICE in all of the operational rotary-wing aircraft, an advisory memorandum is sent to the U.S. Army Aeromedical Activity and an ETP is recommended to the appropriate waiver authority. The process of obtaining an ETP can be expensive and cumbersome for both the U.S. Army and the applicant. Additionally, it can represent a significant barrier for those who are remote from operational aircraft, such as Reserve Officers' Training Corps cadets. Therefore, it is necessary that the APL correctly passes as many acceptable applicants as possible, to reduce the number of applicants who must undergo the ETP process.

Currently it is unknown how effective the APL is at passing qualified applicants. Since it was first published in 1987, there have been no changes to the anthropometry standards despite notable changes in aviator anthropometry.[4,9,18] Additionally, only three of the rotary-wing aircraft used to define the anthropometry standards are still in operational use by the U.S. Army today, and their cockpits have been modified from their initial versions. It is possible that the standards outlined in the APL are an outdated and an inefficient way to assess cockpit compatibility. The standards could be failing anthropometrically acceptable applicants, causing them to unnecessarily undergo the ETP process. Worse, it is possible that the standards are passing applicants with unacceptable anthropometry, who may not be able to complete flight school or who then become a flight safety issue.

METHODS

The study was conducted under a protocol reviewed and approved according to the U.S. Army Aeromedical Research Laboratory's Human Research Protection Program. It was deemed exempt from voluntary consent from subjects.

We defined the efficiency of the APL as its ability to pass as many anthropometrically acceptable applicants as possible without the need for an ICE. Efficiency was assessed using the Aeromedical Electronic Resource Office (AERO) database. The AERO database is maintained by the U.S. Army Aeromedical Activity and contains medical records for all rated U.S. Army aviators and flight school applicants. Flight school applicant anthropometric (TAR, CH, and SH), aeromedical summary (ICD codes of failed anthropometry standards) and disposition (ETP status) data was surveyed over a 10-yr period between 2005 and 2014. Additionally, the physical classes (Class 1 or Class 2) of all flight physicals performed on applicants from the data were surveyed from the AERO database.

The AERO data were reviewed for quality before analysis. Applicant files with incomplete data were rejected. Additionally, all data sets that contained measurement errors (e.g., TAR of 17 cm) were also rejected. In the event that applicants had multiple entries (duplicate entries or multiple medical encounters in which anthropometry was measured), the most recent entry was used while the previous entries were removed from the data set. In doing so, only one complete data set for each applicant was included in the analysis.

Applicants were sorted into seven cohorts based on disposition status and results of the aeromedical summary (**Fig. 2**). The data (All) were subdivided into cohorts that contained applicants who passed the anthropometry standards (Pass) and those who failed the standards (Fail). The Fail cohort was further subdivided into applicants who elected to apply for an ETP (Yes App) and those who did not (No App). The Yes App cohort was further subdivided into applicants who did (Yes ETP) and did not (No ETP) receive an ETP. Additionally, it was determined which applicants in the Yes ETP cohorts became rated aviators (defined by receiving a Class 2 physical in subsequent years) rather than remained applicants (defined by the presence of only a Class 1 physical).

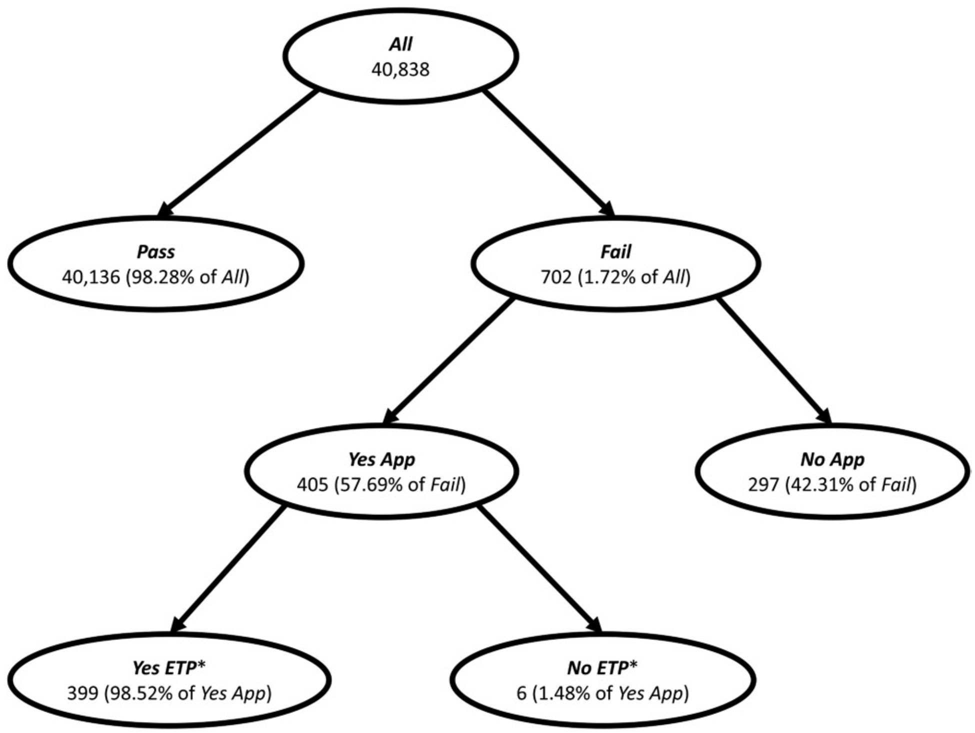

Fig. 2. Number of applicants in the seven cohorts according to the process outlined in the Anthropometry Aeromedical Policy Letter. Figure recreated from Moczynski, 2018.[13] *ETP: Exception to policy.

The adjustments were created using both the AERO and RMIS data. Using the AERO data, the anthropometry of all applicants in each cohort was characterized and causes of anthropometric failures in applicable cohorts were analyzed. Then, the anthropometry standards were adjusted based on the anthropometry of applicants in the Yes ETP cohort who became rated aviators, as their anthropometry was proven to be successful in the completion of training. The results of any anthropometry-related mishaps found in RMIS would be factored into the adjustments as a parameter. The effects of passing rates for all applicants in the Yes ETP, No ETP, and No App cohorts were then assessed to determine changes in efficiency and effectiveness.

The efficiency of the APL in passing anthropometrically acceptable applicants was analyzed by comparing the percentage of all applicants (All cohort) who passed the anthropometry standards (Pass cohort) and the percentage of applicants who applied for and received ETPs (Yes ETP cohort).

The effectiveness of the APL was defined as its ability to fail anthropometrically unacceptable applicants. Effectiveness was assessed using data from the Risk Management Information System (RMIS) database. The RMIS database is maintained by the U.S. Army Combat Readiness Center and contains information on all noncombat U.S. Army aviation mishaps. Mishap reports related to human factors, under which anthropometry is subcategorized, were surveyed for a 46-yr period between 1972 and 2017. Reports were reviewed to determine whether unacceptable anthropometry was the cause of any mishap.

Results from the database reviews were further analyzed to determine if the measurement standards could be adjusted to make the APL more efficient. The goal was to adjust the anthropometry standards to minimize the number of applicants who needed to undergo the ETP process without compromising safety. Two adjustments to the standards were evaluated. The first adjustment (Adjustment I) was designed to be the most conservative and pass the maximum number of applicants in the Yes ETP cohort while excluding all of the applicants in the No ETP cohort. The second adjustment (Adjustment II) was designed to be less conservative and to pass as many applicants in the Yes ETP cohort as possible while maintaining the safety level of the present screening process.

RESULTS

Review of the AERO database revealed 63,714 flight school applicant records between 2005 and 2014. A total of 22,876 (35.90%) entries in the raw data were removed. Of the entries removed, 822 (3.59%) were incomplete, 1900 (8.31%) contained measurement error, and 20,154 (88.10%) were a multiple entry. The remaining 40,838 data sets were placed in the All cohort (Fig. 2). Of all the applicants in the 10-yr period studied, 1.72% failed the anthropometry standards and 0.01% were denied anthropometry ETPs.

Review of the RMIS database revealed 602 mishaps in which human factors were found to either be causative or present between 1972 and 2017. Of these reports, only one cited anthropometry as a factor. This mishap was caused by limited cyclic travel due to an extreme forward positioning in the seat of the front aviator, who was not wearing a the lap belt restraint. This aviator was a large individual (more than 6 ft in height and more than 270 lbs in weight) and did not fasten the lap belt restraint because it caused discomfort. It resulted in the fatality of an aviator and the loss of an aircraft.[19] There were no mishaps for which unacceptable TAR, CH, or SH were listed as factors.

The characterized anthropometry for all applicants in each cohort is shown in **Table I**. Analyzing the causes of anthropometric failures revealed that most applicants failed for having insufficient reach (failed TAR and/or CH standard) rather than excessive height (failed SH standard). Overall, TAR was the predominant cause of failures (**Table II**). CH was the second highest cause of failures. SH was the least common cause of failures.

Table I. Mean Anthropometry Standard Measurements for all Cohorts; Mean (SD).

COHORT	*N*	TOTAL ARM REACH (cm)	CROTCH HEIGHT (cm)	SITTING HEIGHT (cm)
All	40,838	180.37 (8.53)	84.87 (5.56)	91.72 (4.33)
Pass	40,136	180.68 (8.17)	85.02 (5.45)	91.80 (4.26)
Fail	702	162.46 (9.52)	76.73 (5.44)	87.07 (5.77)
Remained Applicant		162.04 (8.36)	76.29 (4.97)	86.86 (5.32)
Rated Aviator		160.99 (7.84)	77.10 (4.84)	86.65 (4.99)
No App	297	163.72 (11.01)	76.70 (6.09)	87.42 (6.53)
Yes App	405	161.54 (8.15)	76.76 (4.92)	86.82 (5.13)
Remained Applicant	*189*	162.15 (8.47)	76.36 (5.00)	87.01 (5.30)
Rated Aviator	216	160.99 (7.84)	77.10 (4.84)	86.65 (4.99)
Yes ETP*	399	161.58 (8.20)	76.80 (4.94)	86.89 (5.12)
Remained Applicant	183	162.28 (8.57)	76.44 (5.04)	87.17 (5.27)
Rated Aviator	216	160.99 (7.84)	77.10 (4.84)	86.65 (4.99)
No ETP*	6	158.42 (1.36)	74.00 (3.16)	82.17 (3.87)

* ETP: Exception to Policy.

Adjustments to the standards were based on the analysis of the cause of anthropometric failures and mishap findings. Insufficient reach (failed TAR and/or CH) was found to be the greatest cause of failure. Of those two measurements TAR was the greatest cause of failure, so this standard was adjusted first. Adjusting the TAR standard could pass many more applicants in the Yes ETP, No ETP, and No App cohorts than adjusting CH or SH by the same amount. Once the TAR standard had been adjusted, focus was placed on the CH standard, which was the second greatest cause of failure. Once the CH had been adjusted, focus was placed on adjusting the SH standard. Since there were no mishaps attributed to TAR, CH, or SH, the RMIS data did not provide additional constrains to the adjustments to the anthropometry standards. The result was two models that expanded all three anthropometry measurements standards by several centimeters (**Table III**).

DISCUSSION

One purpose of the Anthropometry APL is to provide an efficient screening process for anthropometric cockpit compatibility. Analysis of applicant disposition data from the AERO database revealed that a majority of applicants were anthropometrically cleared, including both applicants who passed the anthropometry standards and those who were cleared after an ICE. In fact, only six applicants (0.01%) in the 10-yr period studied were deemed anthropometrically unacceptable and denied ETPs. Since 98.25% of applicants passed the anthropometry standards without the need for an ICE, it can be assumed that the anthropometric standards defined in the APL are close to being the most efficient way to screen modern applicants for compatibility in today's operational cockpits.

A second purpose of the APL is to ensure that there are no mishaps caused by aviators not fitting adequately into operational cockpits. Review of the RMIS database suggests that that the current APL is effective in meeting this requirement in regards to having adequate reach and helmeted head clearance with the top of the cockpit, as seen by the lack of any of mishaps attributed to TAR, CH, or SH. Additionally, it also suggests that aviators who fail the anthropometry standards but receive ETPs are no more likely to cause an anthropometry-related mishap than aviators who pass the standards. However, the RMIS review shows that the current screening process may not be ideal in assessing cockpit fit. The anthropometry-related mishap, which resulted in both a fatality and loss of an aircraft, found in the RMIS database search was due to the lack of a fastened lap belt and an unacceptable anterior abdominal point in the aviator. Weight, thigh circumference, and abdominal circumference are not screened for in the APL and are measurements that can change over time. This begs the question of whether additional metrics (e.g., thigh circumference, waist circumference, anterior abdominal point, and eye height) should be included in the APL and whether anthropometry screening for measurements that can change over time (e.g., thigh circumference and waist circumference) should be a requirement in the yearly flight physical rather than a one-time evaluation. In fact, the request to update and

Table II. Causes of Anthropometry Standard Failure.

	FAIL	NO APP	YES APP	YES ETP*	NO ETP*
Total in Cohort, *N*	702	297	405	399	6
Fail Reach, *N* (%)	659 (93.87)	271 (91.25)	388 (95.80)	382 (95.74)	6 (100)
Fail TAR†, *N* (%)	550 (83.46)	210 (77.49)	340 (87.63)	334 (87.43)	6 (100)
Fail CH‡, *N* (%)	249 (37.78)	130 (47.97)	119 (30.67)	115 (30.10)	4 (66.67)
Fail Height (SH§), *N* (%)	43 (6.13)	26 (8.75)	17 (4.20)	17 (4.26)	0 (0)
Fail 1 standard, *N* (%)	562 (80.06)	228 (76.77)	334 (82.47)	332 (83.21)	2 (33.33)
Fail 2 standards, *N* (%)	140 (19.94)	69 (23.23)	71 (17.53)	67 (16.79)	4 (66.67)
Fail 3 standards, *N* (%)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)

* ETP: exception to policy; †TAR: total arm reach; ‡CH: crotch height; §SH: sitting height.

Table III. Adjusted Anthropometry Standards and Their Effects on Cohort Passing Rates.

	ANTHROPOMETRY APL†	ADJUSTMENT I	ADJUSTMENT II
Total Arm Reach Standard	≥ 164 cm^3	≥ 160 cm	≥ 141 cm
Crotch Height Standard	≥ 75 cm^3	≥ 72 cm	≥ 68 cm
Sitting Height Standard	≤ 102 cm^3	≤ 108 cm	≤ 108 cm
Yes ETP* Passing Rate, *N* (%)	0/399 (0.00%)	220/399 (55.14%)	396/399 (99.25%)
No ETP* Passing Rate, *N* (%)	0/6 (0.00%)	0/6 (0.00%)	6/6 (100.00%)
No App* Passing Rate, *N* (%)	0/297 (0.00%)	170/297 (57.24%)	293/297 (98.65%)
Overall Risk of Passing No ETP* Applicants, *N* (%)	0/40,838 (0.00%)	0/40,838 (0.00%)	6/40,838 (0.01%)

* ETP: Exception to policy; †APL: Aeromedical Policy Letter.

change the anthropometry standards has already been made in the literature, in which incorporating anterior abdominal point was mentioned.[1]

Though the screening process was found to be efficient, adjusting the anthropometric measurement standards could potentially increase the efficiency without compromising aviation safety. A majority (98.57%) of applicants who applied for ETPs ultimately received them. Even though these applicants failed the standards defined in the APL, they were manually deemed anthropometrically acceptable by SIPs. Proposed adjustments to the anthropometry standards were developed that would allow more of these applicants, who would pass an ICE, to pass the anthropometry standard outright, thus avoiding the ETP process altogether. Adjustment I allowed 220 (55.15%) applicants in the Yes ETP cohort and 170 (57.24%) applicants in the No App cohort to avoid the ETP process and move directly into the Pass cohort. Adjustment II allowed 396 (99.25%) applicants in the Yes ETP and 293 (98.65%) applicants in the No App cohort to move directly into the Pass cohort. Adjustment I effectively failed all six applicants in the No ETP cohort, maintaining the same level of effectiveness provided by the current anthropometry standards. Adjustment II passed all applicants in the No ETP cohort, resulting in a 0.01% risk of passing applicants with unacceptable anthropometry during the 10-yr time period. While this risk rate falls well under the 2% aviation safety standard, relaxing the APL in such a fashion would incur more risk than the current methods and Adjustment I.[12] While Adjustment II could increase the burden of screening out unacceptable individuals during flight school to the school house, this burden is inherent and will exist under the current screening process, regardless of what the anthropometry standards are.

While analyzing the anthropometry data of recently rated aviators makes a positive case for adjusting the anthropometric screening process, adjusting the standards should be performed with caution. Expanding the anthropometric standards too aggressively may allow applicants who are too small to control the aircraft to pass. Additionally, just because one small applicant passed an ICE does not mean that another applicant with similar anthropometry will be able to. Therefore, adjusting the standards to allow even the smallest applicants to pass, such as in Adjustment II, may not be ideal. Unfortunately, excluding the smallest applicants may more negatively impact the accession of female aviators than men, since they tend to have smaller statures.

Conversely, adjusting the standards to allow the tallest applicants to pass also possesses issues. The current SH standard (SH ≤ 102 cm) already passes the greater than 99th percentile male U.S. Army soldier.[8] Relaxing the SH standard to what was proposed in Adjustments I (SH ≤ 108 cm) and II (SH ≤ 108 cm) would allow even taller applicants to pass. Previous research showed that aviators with a SH of 102 cm, though above even the 99th percentile male U.S. Army soldier, could fit in U.S. Army rotary-wing cockpits. However, just because SIPs deemed that applicants with taller SHs (e.g., 108 cm) could fit in current cockpits, it does not mean that these tall applicants should be sitting in these cockpits. Tall aviators may need to slouch or hunch forward to ensure they have helmeted head clearance with the top of the cockpits. Such a position would not be ideal or ergonomic, which may increase the risk of developing chronic neck and back pain in these tall aviators.[11,14,21]

Additionally, both small and tall applicants may not have statures ideal for the design eye point of the aircraft, which the current APL does not take into consideration when determining anthropometric cockpit compatibility. From a safety perspective, it may be better to adjust the standards moderately, as in Adjustment I, and still have SIPs assess the smallest and tallest applicants through an ICE. Regardless, any adjustments to the standards should be further evaluated before implementation, and the practical effects of changing the standards should be considered.

Moving forward, several improvements to the current screening process should be considered. Ideally, the screening process should be dynamic and multivariate as well as two-tailed for the SH metric. For example, it could involve a form of cockpit three-dimensional modeling that would take anthropometric extremes into account, as is being done by other sister services.[20] Three-dimensional modeling may be able to take into account the human-machine interface better than mathematical models can and may be able to provide cockpit compatibility assessments similarly to those performed by the SIPs. This would be particularly valuable as future vertical lift platforms are designed and implemented.

Limitations and Assumptions

Human error and subjectivity may be limitations in the current study. Data entered into the AERO database may have been recorded incorrectly or inconsistently. Measurements were taken by clinical personnel, most of whom had no formal training in taking anthropometric measurements, at various U.S. Army installations instead of a single location. These measurements may have been entered into the database incorrectly by clerks, especially since there was no uniform data entry quality control program in place. Every effort was made to remove all unrealistic applicant entries in the AERO dataset.

Applicants may have passed or failed the ICE due to the subjective decisions made by SIPs. SIP judgment is considered the gold standard for assessing cockpit compatibility, and the APL recognizes that their experienced eye represents a superior standard to the three measurements taken during a flight physical. These static measurements cannot take into account things such as waist flexion or torso rotation that affect an applicant's ability to fit in and operate an aircraft like a SIP observing an applicant in a cockpit seat would. As such, SIPs will doubtless continue to have a place in the anthropometric screening process. However, the various SIPs who performed these ICEs may have evaluated compatibility differently.

Additionally, it is unknown why applicants washed out of flight school after taking their initial entry flight physical. There is a possibility that some inappropriately passed the screening process, including the SIP evaluations during the ICEs, but failed to complete training due to anthropometric reasons. This should be explored further and might provide valuable information for future studies. To avoid passing applicants who would be deemed anthropometrically unacceptable once they began flight school, the adjustments to the standards made in the current study were based on applicants who were known to have become rated aviators.

Finally, it is difficult to quantify the effect anthropometry has during mishaps. Only one mishap in the RMIS database was identified that cited anthropometry as a cause, but that does not rule out the possibility that anthropometry may have been an unrecognized factor in other mishaps. Additionally, the RMIS data surveyed include only information on noncombat-related mishaps. Anthropometry may have played a role in combat-related mishaps, which were not reviewed in this study. Therefore, it is possible that applicants with inadequate anthropometry were anthropometrically cleared based on the process and standards defined in the APL. A larger review of rotary-wing mishaps and anthropometry requirements (including the U.S. Navy, U.S. Air Force, and FAA) might provide additional insights.

Conclusion

Assessment of the Anthropometry APL determined that the present screening process is efficient and effective in screening for anthropometric cockpit compatibility, but could be improved. If the anthropometry standards could be updated to reflect anthropometric compatibility between today's aviator population and aircraft cockpits, more applicants could pass the anthropometry standards during their initial flight physical, thus avoiding the costly and time-consuming ETP process. The result would be a more efficient screening process. In addition, it might widen the qualified applicant pool by passing applicants who were deterred by the ETP process or did not even bother to apply to flight school because they believed their anthropometry was unacceptable. A comprehensive approach to developing a better APL than is presently in use should be undertaken, in which alternative or additional anthropometric measurements, design eye point, crash dynamics, and future vertical lift platforms are incorporated. Such an approach would ensure an aviator-cockpit fit that would balance ergonomic issues with flight safety and long-term health implications.

ACKNOWLEDGMENTS

The authors thank Martin Quattlebaum and Jennifer Dudek for their technical assistance in conducting the AERO and RMIS reviews, respectively. The authors would also like to thank MAJ Grace Lidl and Danielle Rhodes for their review of this document.

This research was supported in part by an appointment to the Postgraduate Research Participation Program at the U.S. Army Aeromedical Research Laboratory administered by the Oak Ridge Institute for Science and Education through an interagency agreement between the U.S. Department of Energy and the U.S. Army Medical Research and Materiel Command.

Financial Disclosure Statement: The authors have no competing interests to disclose.

Authors and affiliations: Allison N. Moczynski, B.S., and U.S. Army Aeromedical Activity, Fort Rucker, AL; Oak Ridge Institute for Science and Education, Oak Ridge, TN; Charles A. Weisenbach, M.S., Naval Medical Research Unit Dayton, Wright-Patterson AFB, OH; Oak Ridge Institute for Science and Education, Oak Ridge, TN; and James S. McGhee, M.D., M.P.H., U.S. Army Aeromedical Activity, Fort Rucker, AL.

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