USAARL Report No. 2018-20

Assessment of U.S. Army Anthropometric Standards and Methodology for Flight School Accession

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United States Army Aeromedical Research Laboratory

Injury Biomechanics & Protection Group

August 2018

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REPORT DOCUMENTATION PAGE	*Form Approved* *OMB No. 0704-0188*

1. REPORT DATE *(DD-MM-YYYY)*	**2. REPORT TYPE**	**3. DATES COVERED** *(From - To)*
24-08-2018	Final	May 2017 to April 2018

4. TITLE AND SUBTITLE
Assessment of U.S. Army Anthropometric Standards and Methodology for Flight School Accession

5a. CONTRACT NUMBER N/A
5b. GRANT NUMBER N/A
5c. PROGRAM ELEMENT NUMBER N/A

6. AUTHOR(S)
Moczynski, Allison N.; Weisenbach, Charles A.; McGhee, James S.

5d. PROJECT NUMBER N/A
5e. TASK NUMBER N/A
5f. WORK UNIT NUMBER N/A

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
U.S. Army Aeromedical Research Laboratory
P.O. Box 620577
Fort Rucker, AL 36362

8. PERFORMING ORGANIZATION REPORT NUMBER
USAARL 2018-20

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)
U.S. Army Aeromedical Activity
Fort Rucker, AL 36362

10. SPONSOR/MONITOR'S ACRONYM(S)
USAAMA

11. SPONSOR/MONITOR'S REPORT NUMBER(S)
N/A

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release; distribution unlimited.

13. SUPPLEMENTARY NOTES
Oak Ridge Institute for Science and Education; Laulima Government Solutions, LLC

14. ABSTRACT
Current Aviator anthropometry standards were reviewed to determine how well they ensure safety of flight while being cost effective in implementation. Anonymized data from Army flight school applicants over a 10-year period were analyzed. It was found that 41,512 (98.25%) applicants passed the anthropometry standards, while only 739 (1.75%) failed. A majority (98.47%) of the applicants who failed the standards and elected to apply for an anthropometry exception to policy (ETP) received one. This suggests that the current standards could be more efficient. Therefore, adjustments to anthropometry standards were modeled. These adjustments would pass 53.51-100% of applicants who received ETPs and 0-100% of applicants who were denied ETPs, potentially resulting in a cost avoidance of $552,500-$1,047,500 over the period studied. In addition, these adjustments would accept 55.63-97.19% of applicants who failed standards and elected not to apply for anthropometry ETPs.

15. SUBJECT TERMS
Anthropometry, screening method, rotary-wing, aeromedical policy, AERO database

16. SECURITY CLASSIFICATION OF: a. REPORT	b. ABSTRACT	c. THIS PAGE	**17. LIMITATION OF ABSTRACT**	**18. NUMBER OF PAGES**	**19a. NAME OF RESPONSIBLE PERSON** / **19b. TELEPHONE NUMBER** *(Include area code)*
UNCLAS	UNCLAS	UNCLAS	SAR	51	Loraine St. Onge, PhD / 334-255-6906

REPORT DOCUMENTATION PAGE (SF298)
(Continuation Sheet)

14. Abstract (continued)
The revised standards present an interim solution to widen the applicant pool and result in cost avoidance over time, but a comprehensive approach to developing better Aviator anthropometry standards should ultimately be taken.

Summary

Anthropometry is a key determinant of aviation safety and likely affects long-term pilot health. The U.S. Army Aeromedical Activity (USAAMA) is responsible for developing, promulgating, and adjudicating medical policies that support mission completion and aircrew health and safety. One way USAAMA meets this mission is by publishing Aeromedical Policy Letters (APLs), which provide the framework for U.S. Army aviation medicine practice. The U.S. Army Aeromedical Activity defined the acceptable ranges of aircrew anthropometry through its Anthropometry APL. The U.S. Army Aeromedical Activity requested the U.S. Army Aeromedical Research Laboratory to review the metrics used in the current Anthropometry APL and determine how well these metrics meet USAAMA's goal of ensuring safety of flight while being cost effective in implementation. The purpose of this paper is to report findings and model adjustments to the standards for USAAMA's consideration.

Anthropometry data from the Aeromedical Electronic Resource Office database for all Army flight school applicants over a 10-year period were analyzed to determine how many applicants passed the anthropometry standards listed in the Anthropometry APL. Anthropometry APL standards list that pilots must have a total arm reach (TAR) of at least 164 centimeters (cm), sitting height (SH) of no more than 102 cm, and a crotch height (CH) of at least 75 cm. The data showed that 41,512 (98.25%) applicants passed the current anthropometry standards, while only 739 (1.75%) failed. Applicants who fail the standards could elect to apply for an anthropometry exception to policy (ETP), though only about half (56.70%) of applicants who failed chose to do so. Applicants who apply for an ETP must undergo an in-cockpit evaluation with a senior instructor pilot who will manually deem them fit or unfit. A majority (98.47%) of the applicants who applied for an ETP received one; suggesting that the current standard may be inefficient. Therefore, adjustments to the current anthropometry standards were modeled that would pass more applicants who received ETPs while still rejecting those who were denied ETPs.

The modeled adjustments relaxed all three anthropometry standards by several centimeters. Total arm reach was relaxed from 164 cm to 149-160 cm. Sitting height was relaxed from 102 cm to 108 cm. Crotch height was relaxed from 75 cm to 62-72 cm. The result of the adjustments is a passing rate of 53.51-100% of applicants who received ETPs and 0-100% of applicants who were denied ETPs, which would result in a potential cost avoidance of $552,500-$1,047,500 over the period studied. Since it is unclear why some applicants who failed the current standards elected not to apply for an ETP, they were deemed part of an untapped applicant pool. Implementing the modeled adjustments would pass 55.63-97.19% of the applicants in this untapped pool. Regardless of which adjustment is chosen, the current standards can be relaxed several centimeters while still only allowing fewer than a 0.02% chance of accepting applicants who were denied ETPs previously, which is deemed acceptable by aeromedical safety standards.

Anthropometry is an important accession standard with many ramifications important to USAAMA's mission in the areas of aviation medicine, safety, and mission completion. A comprehensive approach should be taken to develop a better Anthropometry APL than is presently in use. Such an approach would ensure Aviator cockpit fit that would balance ergonomic issues with flight safety and long-term health implications. The current method outlined in the Anthropometry APL is limited. Current standards are one-tailed, though two-tailed standards should be considered to balance cockpit fit with safety and injury prevention.

The method is also univariate, though cockpit fit and aircraft manipulation are based on multivariate factors. There is a clear need for a new Anthropometry APL standard, but the current project is limited in creating an ideal dynamic, two-tailed, and multivariate approach. An interim solution would be to adjust the present three anthropometric standards listed in the Anthropometry APL using the guidelines suggested above, which would widen the applicant pool as well as result in cost avoidance over time.

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Acknowledgements

The authors would like to thank several people for their help in this project.

We would like to thank Mr. Martin Quattlebaum for providing and de-identifying the data from the Aeromedical Electronic Resource Office database as well as the funding for this project.

We would like to thank Ms. Jessica Cumbee for her editorial assistance in producing this document.

We would like to thank Dr. Morris Lattimore, Mrs. Catherine Davis, Mr. Joseph Licina, Mr. Patrick Estep, Mr. Tyler Rooks, Mrs. Kimberly Vasquez, and Mrs. Danielle Rhodes for their review of this document.

We would like to thank Ms. Jennifer Dudek for her analysis of mishaps related to human factors using the Risk Management Information System database.

We would like to thank Dr. Valeta Carol Chancey for her review of this document as Division Chief.

We would also like to thank COL Susan Fondy for her insightful review of the technical report.

Lastly, we would like to acknowledge that this research was supported in part by an appointment to the Postgraduate Research Participation Program at the U.S. Army Aeromedical Research Laboratory (USAARL) administered by the Oak Ridge Institute for Science and Education (ORISE) through an interagency agreement between the U.S. Department of Energy and the U.S. Army Medical Research and Materiel Command (USAMRMC).

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Table of Contents

List of Figures

List of Tables

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Introduction

Anthropometry is a key determinant of aviation safety and likely affects long-term pilot health. The U.S. Army Aeromedical Activity (USAAMA) is responsible for executing the medical aspects of the Army's Aviation Safety Program. It is responsible for developing, promulgating, and adjudicating medical policies that support mission completion and aircrew health and safety. One way USAAMA meets this mission is by publishing Aeromedical Policy Letters (APLs), which provide the framework for U.S. Army aviation medicine practice. USAAMA defines the acceptable ranges of aircrew anthropometry through its Anthropometry APL. Most APLs that USAAMA produces are practice guidelines prescribing how to handle medical conditions in the U.S. Army Aviation population. By contrast, the Anthropometry APL defines what the Army considers anthropometrically acceptable, which is a critical aspect of the man-machine interface.

The U.S. Army Aeromedical Activity requested that the U.S. Army Aeromedical Research Laboratory (USAARL) review the metrics used in the current Anthropometry APL and determine how well they meet USAAMA's goal of ensuring safety of flight while being cost effective in implementation. The purpose of this paper is to report findings and model recommendations for USAAMA's consideration. Formulating a comprehensive recommendation for improvements to the Anthropometry APL were beyond the scope of this project due to budget and time constraints. However, it is important to understand the components and ramifications of anthropometry in the man-machine interface should a more comprehensive effort be supported in the future.

Background

Anthropometry affects five principal areas of pilot safety and health:

1. Visual acquisition of information inside and outside the cockpit (design eye point)
2. Actuation of levers, switches, and circuit breakers with the hands (hand reach)
3. Control of anti-torque pedals and breaks with the feet (foot reach)
4. Risk of injury during mishaps (e.g., shin impingement on control panel)
5. Development of chronic musculoskeletal discomfort (e.g., chronic back pain)

Anthropometry and Design Eye Point

Situational awareness depends on being able to see what is around the helicopter. For example, a UH-60 pilot's area of regard is outside of the helicopter 85% of the time (Havir, Durbin, Frederick, & Hicks, 2006). Cockpit design criteria include a parameter known as the design eye point (DEP), which is important in determining external field of view (FOV) ("Military Standard: Aircrew Station Geometry for Military Aircraft," 1969). The DEP affects design of windscreen and chin bubble geometry, stanchion placement, instrument panel layout, door design, etc. Sitting with eyes below the DEP may result in an unacceptable downward viewing angle, while sitting with eyes above the DEP may result in a poor viewing angle for upper instrument panel viewing or a constrained upward viewing angle (Cote & Schopper, 1986). Aligning pilot eyes with the DEP is performed before each flight using the seat adjustment; however, seats are not infinitely adjustable and the anthropometry of sitting height in the pilot population is therefore important for optimizing this parameter.

Anthropometry and Hand Reach

Switches, levers, and circuit breakers must be within easy reach of the pilots. These can be located overhead, on the instrument panel, on the middle console between pilot and copilot stations, and on the cyclic and collective controls. Much of flight training is devoted to learning where these actuators are, and many emergency procedures depend on interacting with them quickly and effectively as well as simultaneously. This capability results principally from a combination of sitting height (SH) and total arm reach (TAR), and is limited in some flight conditions by the locking mechanisms of the restraint harness inertial reel. Ensuring that pilot reach is well accommodated has been a focal point for many anthropometry studies (Cote & Schopper, 1984; Gordon & Licina, 1999; Schopper & Cote, 1984; Schopper & Mastroianni, 1985; Schopper & Mastroianni, 1987).

Anthropometry and Foot Reach

Helicopter pedals control the tail rotor thrust, which counters the main rotor torque to adjust yaw (required for heading). Crotch height (CH), or leg length, is the limiting anthropometric measurement for this parameter. The aircraft design specifications for maximum yaw control input vary by maneuver and flight conditions, and are expressed in terms of fractions of the maximum input required under the worse possible conditions. Therefore, pilots must not only be able to reach the pedals, but must also be able to apply up to 125 pounds (556 N) of force through the range of pedal travel and during breaking ("Aeronautical Design Standard Performance Specification Handling Qualities Requirements for Military Rotorcraft," 2000).

Flight control requires simultaneous pedal, cyclic, and collective control inputs. From a practical standpoint, the static pressure a pilot must exert on the pedals in isolation does not reflect operational conditions. Schopper and Mastroianni studied the effect of small stature on forces required to move control surfaces individually (1985) and combined (1987). They found that in a test environment, all subjects could exert required forces individuall on the three control surfaces (pedals, collective, and cyclic). However, when combinations of inputs were required, a far more realistic condition, the ability to exert simultaneously the maximum design limits on all three controls resulted in substantial levels of force degradation. This was most evident in pedal forces, where 20-35% degradation was observed. Both studies were based on the 80 lbs (360 N) pedal input design limit associated with helicopter controls when in-flight hydraulic assist was off, as described in MIL-H-8501A ("Military Specification: Helicopter Flying and Ground Handling Qualities; General Requirements for," 1961). The basis for the currently required anthropometric measurement of CH is somewhat imprecise, as just being able to reach the pedals may not be a sufficient metric.

Anthropometry and Risk of Mishap Injury

Anthropometry can affect the risk of experiencing an acute injury during a mishap. Extremities are the single most frequently injured body region in survivable crashes (43%) (Shanahan & Shanahan, 1989). Long limbs may present an impediment to egress, a safety issue, and may increase the risk of incurring an acute injury in the limbs. During helicopter crashes, shin fractures can occur when legs flail forward and strike fixed structures or become trapped within the airframe (Cullen, 2004). Defining a CH standard provides one example where injury mitigation during mishap is possible by carefully limiting the anthropometric standard. Long legs ensure adequate pedal authority, but may increase the chances of shin impingement on the lower edge of the control panel or present an impediment to egress. The ideal CH standard will include measurements that are long enough to manipulate the pedals while excluding measurements that are too long to reasonably fit within the aircraft.

Anthropometry and Chronic Back Pain

Apart from the ergonomic aspects of anthropometry, there is evidence that anthropometry has implications for the development of orthopedic problems. The incidence of back pain in rotary-wing Aviators is higher than that of the general public (Bridger, Groom, Jones, Pethybridge, & Pullinger, 2002). Though the precise etiology of back pain is still a subject of research, a strong association with prolonged exposure to poor posture in helicopter seats and increased back symptoms has been identified (Bridger et al., 2002; Orsello, Phillips, & Rice, 2013; Walters, Cox, Clayborne, & Hathaway, 2012). Height is associated with poor sitting posture, as is the seat geometry of helicopters (Orsello et al., 2013). Orsello et al., in a large case-control analysis of U.S. Navy helicopter pilots, determined that height was a significant predictor for in-flight lumbar pain among pilots with no history of prior back pain (2013). In the cohort studied, pilots equal to or taller than the median (180 cm) had twice the odds of developing back pain than shorter pilots. The mechanism of action proposed is that the taller pilots must "hunch over" during flight (Orsello et al., 2013). Similarly, Harrison, Neary, Albert, and Croll showed that neck pain could be predicted by the Aviator's height and the duration of his or her longest night vision goggle mission (2012).

Army Aeromedical Policy Letters and Anthropometry

The importance of anthropometry standards has been recognized for many decades. The best description of these studies up until 1989 is reported by Schrimsher and Burke and will not be fully recounted here (1989). Prior to 1987, there were 20 measurements recorded during entry flight physicals (Schrimsher & Burke, 1989). In 1984, Schopper and Cote worked to find which anthropometric metrics most efficiently predicted cockpit reach of hand- and foot-operated controls (1984). They evaluated eight tall and eight small male subjects (chosen for their size) in the operational platforms existing in the 1984 Army inventory to see how well each subject could reach instructor-pilot-designated switches and control surfaces with the shoulder harness unlocked. Schopper and Cote determined that TAR and leg length (measured as CH) were the most efficient discriminators between those who could and could not perform operationally critical reaches. Sitting height was best at ensuring proper helmeted cockpit head clearance (DEP was not considered). Total body weight was noted to be an excellent predictor of thigh mass, which can restrict lateral, aft, and posterior cyclic travel, though this did not become an anthropometric standard. This study provided the impetus for the Aeromedical Consultants Advisory Panel to adopt the present three-measurement system codified in the 1987 APL 11-87 ("Anthropometry," 2015). The three measurements include TAR, which must be at least 164 cm, SH, which must be no more than 102 cm, and CH, which must be at least 75 cm. The standards and methods expressed in this APL have not substantially changed despite documented changes in Aviator anthropometry and introduction of new platforms (Churchill, McConville, & Laubach, 1971; Gordon et al., 2012; Gordon & Licina, 1999; Schrimsher & Burke, 1989; White, 1961).

Aeromedical Policy Letter 11-87, renamed the Anthropometry APL, was last updated in May 2015 and is the version evaluated in this study. The qualification procedure can be described as a tiered system ("Anthropometry," 2015). It integrates anthropometric standards with aviation expertise. First, three anthropometric measurements of applicants are taken during the initial flight physical. The first measurement, TAR, is defined as the horizontal distance between fingertips when standing erect with arms outstretched at 90 degree angles (Figure 1) ("Anthropometry," 2015). The second measurement, SH, is defined as the distance between the sitting surface and the top of the head when the applicant is sitting on a hard, flat surface with feet flat on the floor (Figure 2) ("Anthropometry," 2015). The third measurement, CH, is defined as the distance between the floor and the perineum in the midline when standing erect with feet bare, heels together, and knees locked (Figure 3) ("Anthropometry," 2015). If an applicant meets the standards published in the Anthropometry APL (Table 1), he or she is considered anthropometrically cleared. If he or she does not meet the standards, the applicant then has the choice to pursue an exception to policy (ETP). If the applicant chooses to apply for an ETP, he or she must sit in each of the operational Army platforms to demonstrate cockpit fit to a senior instructor pilot (SIP) during a process called an in-cockpit evaluation (ICE). After the ICE, an advisory memorandum is sent to USAAMA and an ETP is issued or denied. The ETP process depends on the expertise of the SIP to overcome the limitation of the univariate standards used in the APL. Senior instructor pilot judgement has been assumed to be correct; however, SIP judgement has not yet been validated in this paradigm.

Figure 1. Total arm reach measurement. Total arm reach is defined as the horizontal distance between fingertips. Applicants must stand erect against a wall, stretch both arms out parallel to the wall to form 90 degree angles. Elbows must be locked. The horizontal distance between the fingertips is then recorded in centimeters ("Anthropometry," 2015). Figure taken from Gordon et al., 2012.

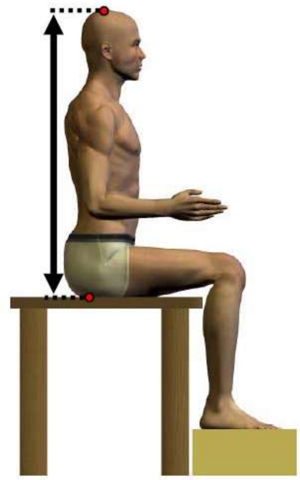

Figure 2. Sitting height measurement. Sitting height is defined as the distance between the sitting surface and the top of the head. Applicants must sit on a hard, flat surface. Feet must be flat on the floor and buttocks, shoulders, and the back of the head must be against a wall. A straight angle ruler is placed along the back and on the head, and the distance between the sitting surface and top of the head is recorded in centimeters ("Anthropometry," 2015). Figure taken from Gordon et al., 2012.

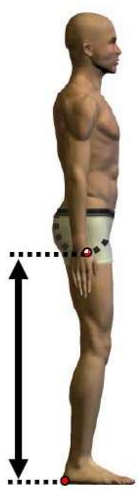

Figure 3. Crotch height measurement. Crotch height is defined as the distance between the floor and the perineum in the midline. Applicants must stand erect against a wall with bare feet. Heels must be together, weight must be evenly distributed, and the knees must be locked. The distance between the floor and the perineum is then recorded in centimeters ("Anthropometry," 2015). Figure taken from Gordon et al., 2012.

Table 1. Current Anthropometry Standards

Metric	Qualified If:
Total Arm Reach	≥ 164 cm
Sitting Height	≤ 102 cm
Crotch Height	≥ 75 cm

Note. U.S. Army rotary-wing Aviators must meet these three anthropometry standards published in the Anthropometry Aeromedical Policy Letter in May 2015 (“Anthropometry,” 2015).

The ETP process is cumbersome, especially for applicants who are remote from the operational aircraft, such as Reserve Officers’ Training Corps cadets. In addition, it is expensive. Travel costs and SIP compensation for ICEs are estimated to be $2500 per applicant. It was noted by waiver authorities that a majority of applicants who apply for ETPs receive one, spurring the question of whether or not valuable resources were being spent on ICEs when it was known that applicants would inevitably pass. The standards outlined in the current Anthropometry APL have not been changed since they were first published in 1987, despite documented changes in Aviator anthropometry and operational platforms (Churchill et al., 1971; Cote & Schopper, 1984; Gordon & Licina, 1999; Gordon et al., 2012; Schopper & Cote, 1984; Schrimsher & Burke, 1989; White, 1961). Therefore, the effectiveness of the Anthropometry APL in assessing anthropometric cockpit compatibility in the current Aviator population and with the current operational aircraft needed to be assessed.

Methods

A retrospective analysis utilizing the Aeromedical Electronic Resource Office (AERO) and Risk Management Information System (RMIS) databases was performed. The AERO database was used to characterize anthropometry of flight school applicants over the time period studied, and the RMIS database was used to assess the role anthropometry has had in rotary-wing aircraft mishaps.

The AERO database contains medical data from all U.S. Army rotary-wing flight school applicants and rated pilots, to include anthropometry measurements and ETP statuses (did/did not apply; did/did not receive). The U.S. Army Aeromedical Activity provided de-identified data from the AERO database on all U.S. Army flight school applicants from 1 January 2005 to 31 December 2014. The provided data included measurements for TAR, CH, SH, height, and weight, as well as whether or not applicants applied for an ETP and whether or not they received an ETP.

Incomplete data sets or data sets from a non-U.S. Army flight school applicant were excluded from analysis. Data from the most recent entries were used for analysis when multiple entries were available. Applicants with extremely high (TAR > 200 cm; SH > 106 cm; CH > 106 cm) or extremely low measurements (TAR < 120 cm; SH < 60 cm; CH < 60 cm) were flagged. In addition, applicants that had a difference of more than 25 cm between height and TAR or height and the combination of SH and CH were flagged. Lastly, applicants with differences of 15

The remaining data were then sorted into seven cohorts based on anthropometric statuses following the paradigm in Figure 4, which follows the ETP process described in the Anthropometry APL. The applicants meeting inclusion criteria were placed in a group that contained all applicants (*All*). This group was further broken down. Applicants who passed all three Anthropometry APL standards, described in Table 1, were placed into the *Pass* group. Applicants who failed one or more of the standards were placed into the *Fail* group. The *Fail* group was further broken down into two groups: those who did (*Yes App*) and did not (*No App*) apply for anthropometry ETPs. Lastly, the *Yes App* group was further broken down into groups of applicants who did (*Yes ETP*) and did not (*No ETP*) receive anthropometry ETPs after an ICE by an SIP. Descriptive statistics were then used to characterize the identified cohorts. The Wilcoxon Ranked Sum test was used to determine statistically significant differences ($p < 0.05$) between groups. In addition, further analysis was performed on small applicants (those who failed TAR and/or CH standard) and tall applicants (failed SH standard) in the applicable cohorts.

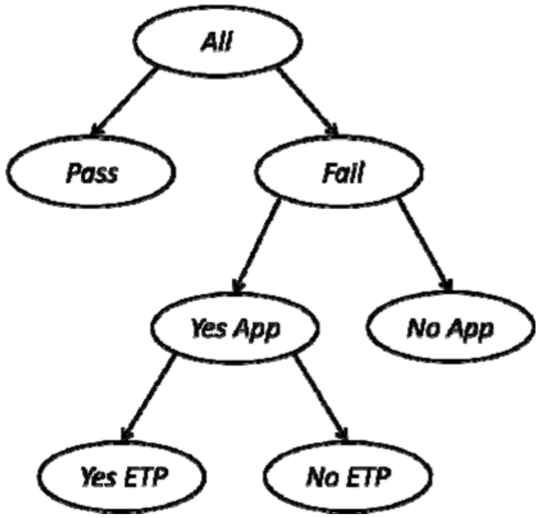

Figure 4. Flowchart for sorting data obtained from AERO database into data cohorts. Data from Army rotary-wing flight school applicants over a 10-year period taken from the AERO database was pooled into seven cohorts based on anthropometric status. The *All* cohort includes all applicants. The *Pass* cohort includes all applicants who passed the current anthropometry standards outlined in the Anthropometry APL. The *Fail* cohort includes all applicants who failed one or more of the anthropometry standards. The *Yes App* cohort includes all applicants who failed the anthropometry standards and elected to apply for an anthropometry ETP. The *No App* cohort includes all applicants who failed the anthropometry standards and elected not to apply for an anthropometry ETP. The *Yes ETP* cohort includes all applicants who failed the anthropometry standards, elected to apply for an anthropometry ETP, and received an anthropometry ETP. The *No ETP* cohort includes all applicants who failed the anthropometry standards, elected to apply for an anthropometry ETP, and were denied an anthropometry ETP.

The entire applicant pool (*All*) was used to create a better understanding of modern Aviator anthropometry. The *No App* group was analyzed to determine whether it represents a lost pool of potentially acceptable applicants. The *Yes App* group was analyzed to determine whether current anthropometry standards are inefficient and, if so, used to create models of adjustments to the current standards. Adjustments to the standards were to have values that passed more of the *Yes ETP* applicants while passing no more than 2% of the *No ETP* applicants, which would be deemed an acceptable risk by aviation safety standards (Mitchell & Evans, 2004).

The U.S. Army Combat Readiness Center maintains the RMIS database, which includes information on all Army rotary-wing mishaps. To validate the assumption that SIP judgement can reliably compensate for the shortfalls caused by the current univariate system, the U.S. Army Combat Readiness Center was asked to evaluate their database, looking for indicators of anthropometric-related incidents. The findings served as an indication of the validity of SIP judgment because anyone having had a mishap with anthropometric implications and an anthropometry ETP might represent a lapse in SIP judgment.

Results

Characterization of Overall Applicant Pool

The data collected from the AERO database provided 63,715 data sets. After removing entries as previously described, 42,251 data sets remained for analysis (Figure 5, Table 2). These 42,251 applicants were placed in the *All* group. Of this group, 41,512 (98.25%) applicants passed all three anthropometry standards and were placed in the *Pass* group, while the remaining 739 (1.75%) applicants were placed in the *Fail* group. The *No App* group contained 320 applicants (43.30% of the *Fail* cohort) and the *Yes App* group contained the remaining 419 applicants (56.70% of *Fail* cohort). Only six (1.43%) applicants of the *Yes App* group were denied ETPs and placed in the *No ETP* group while 413 (98.57%) applicants were placed in the *Yes ETP* group. Of all the applicants from this 10-year period, 1.75% failed the anthropometry standards and 0.01% were denied anthropometry ETPs.

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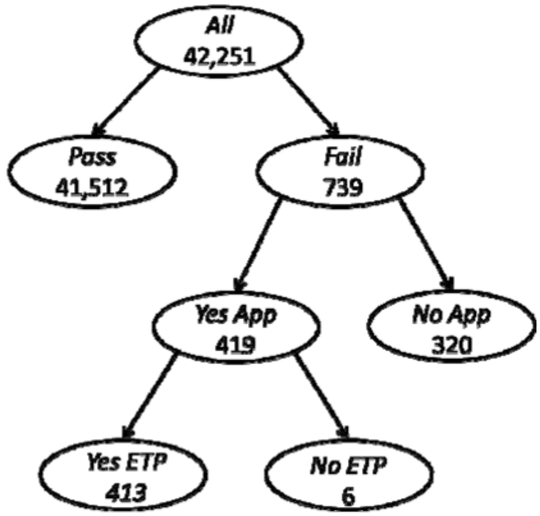

Figure 5. Number of applicants in cohorts according to Anthropometry APL criteria.

Table 2. Summary of Applicant Cohort Distribution

	# of Applicants	**% of *All***	**% of *Fail***	**% of *Yes App***
All	42,251	100		
Pass	41,512	98.25		
Fail	739	1.75	100	
No App	320	0.76	43.30	
Yes App	419	0.99	56.70	100
Yes ETP	413	0.98	55.89	98.57
No ETP	6	0.01	0.81	1.43

Note. Applicants were distributed into seven cohorts based on their anthropometric status as outlined in Figure 4. A majority of applicants passed the anthropometry standards. Of those who failed, a little more than half elected to apply for anthropometry ETPs. A majority of ETP applicants received ETPs and were deemed anthropometrically acceptable.

There were statistically significant differences ($p < 0.001$) between the *Pass* and *Fail* cohorts for all three measurements (Tables 3-5). Applicants who failed the Anthropometry APL standards had, on average, statistically significantly lower measurements for TAR, SH, and CH than applicants who passed the standards. There were no statistically significant differences between the *Yes App* and *No App* cohorts for TAR ($p = 0.0934$), SH ($p = 0.9354$), or CH ($p = 0.2164$). There were also no statistically significant differences between the *Yes ETP* and *No ETP* cohorts for the TAR ($p = 0.1393$) and CH ($p = 0.1289$) measurements, though both measurements were on average lower for the *No ETP* cohort. There was a statistically significant difference between the *Yes ETP* and *No ETP* cohorts for the SH (p = 0.0172) measurement, which was also on average lower for the *No ETP* cohort.

Table 3. Descriptive Statistics of TAR Measurement for All Cohorts

	Total Arm Reach (cm)					
	N	**Mean (STD)**	**Median**	**Minimum**	**Maximum**	**Range**
All	42,251	180.56 (8.79)	181	132	221	89
Pass	41,512	180.89 (8.42)	181	164	221	57
Fail	739	162.35 (9.91)	160	132	220	88
No App	320	163.32 (11.45)	161	132	211.50	79.50
Yes App	419	161.61 (8.50)	160	149	220	71
Yes ETP	413	161.66 (8.55)	160	149	220	71
Passed TAR	*68*	*175.71 (12.59)*	*172*	*164*	*220*	*56*
Failed TAR	*345*	*158.89 (3.15)*	*160*	*149*	*163.80*	*14.80*
No ETP	6	158.42 (1.36)	158.75	156	160	4
Passed TAR	*0*	*N/A*	*N/A*	*N/A*	*N/A*	*N/A*
Failed TAR	*6*	*158.42 (1.36)*	*158.75*	*156*	*160*	*4*

Note. TAR measurement values were similar in the *All* and *Pass* cohorts. The TAR measurement values in the *Fail* cohort were significantly ($p < 0.001$) lower than in the *Pass* cohort. The TAR values were lower in the *Yes App* than in the *No App* cohort, but this difference was not statistically significant (p = 0.0934). Similarly, the TAR values were lower in the *No ETP* than in the *Yes ETP* cohort, but the difference was not statistically significant (p = 0.1393).

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Table 4. Descriptive Statistics of SH Measurement for All Cohorts

	Sitting Height (cm)					
	N	**Mean (STD)**	**Median**	**Minimum**	**Maximum**	**Range**
All	42,251	91.62 (4.51)	92	61	108	47
Pass	41,512	91.70 (4.43)	92	61	102	41
Fail	739	86.91 (5.97)	86	66	108	42
No App	320	87.23 (6.91)	86	66	108	42
Yes App	419	86.66 (5.13)	86	69	108	39
Yes ETP	413	86.72 (5.12)	86	69	108	39
Passed SH	*397*	*86.02 (3.78)*	*86*	*69*	*99*	*30*
Failed SH	*16*	*104.21 (1.81)*	*103.50*	*102.30*	*108*	*5.70*
No ETP	6	82.17 (3.87)	81.50	77	88	11
Passed SH	*6*	*82.17 (3.87)*	*81.50*	*77*	*88*	*11*
Failed SH	*0*	*N/A*	*N/A*	*N/A*	*N/A*	*N/A*

Note. SH measurement values were similar in the *All* and *Pass* cohorts. The SH measurement values in the *Fail* cohort were significantly ($p < 0.001$) lower than in the *Pass* cohort. The SH values were lower in the *Yes App* than in the *No App* cohort, but this difference was not statistically significant ($p = 0.9354$). The SH values were significantly ($p = 0.0172$) lower in the *No ETP* cohort than in the *Yes ETP* cohort.

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Table 5. Descriptive Statistics of CH Measurement for All Cohorts

	Crotch Height (cm)					
	N	**Mean (STD)**	**Median**	**Minimum**	**Maximum**	**Range**
All	42,251	84.95 (5.80)	85	62	124	62
Pass	41,512	85.10 (5.70)	85	75	124	49
Fail	739	76.88 (5.77)	76	62	106.50	44.50
No App	320	76.95 (6.42)	75	65	106.50	41.50
Yes App	419	76.82 (5.22)	76	62	104	42
Yes ETP	413	76.86 (5.23)	76	62	104	42
Passed CH	*290*	*78.87 (4.88)*	*77*	*75*	*104*	*29*
Failed CH	*123*	*72.13 (1.96)*	*73*	*62*	*74.90*	*12.90*
No ETP	6	74 (3.16)	72.50	71	78	7
Passed CH	*2*	*78 (0)*	*78*	*78*	*78*	*0*
Failed CH	*4*	*72 (0.82)*	*72*	*71*	*73*	*2*

Note. CH measurement values were similar in the *All* and *Pass* cohorts. The CH measurement values in the *Fail* cohort were statistically significantly ($p < 0.001$) lower than in the *Pass* cohort. The CH values were lower in the *Yes App* than in the *No App* cohort, but this difference was not statistically significant ($p = 0.2164$). Similarly, the CH values were lower in the *No ETP* than in the *Yes ETP* cohort, but the difference was not statistically significant ($p = 0.1289$).

The *Yes ETP* cohort contained more extreme measurements than the *No ETP* cohort (Figure 6). The lowest TAR measurement in the *Yes ETP* cohort (149 cm) was 15 cm lower than the APL standard, while the lowest TAR measurement in the *No ETP* cohort (156 cm) was only 8 cm lower. The highest TAR measurement in the *Yes ETP* cohort (220 cm) was 56 cm greater than the APL standard, while the highest TAR measurement in the *No ETP* cohort (160 cm) was 4 cm lower than the APL standard. The minimum SH in the *Yes ETP* cohort (69 cm) was 33 cm lower than the APL standard, while the minimum SH in the *No ETP* cohort (77 cm) was 25 cm lower than the APL standard. The maximum SH in the *Yes ETP* cohort (108 cm) was 6 cm greater than the APL standard, while the maximum SH in the *No ETP* cohort (88 cm) was 14 cm lower than the APL standard. Lastly, the minimum CH measurement in the *Yes ETP* cohort (62 cm) was 13 cm lower than the APL standard, while the CH measurement in the *No ETP* cohort (71 cm) was only 4 cm lower. The maximum CH in the *Yes ETP* cohort (104 cm) was 29 cm higher than the APL standard, while the maximum CH in the *No ETP* cohort (78 cm) was only 3 cm higher.

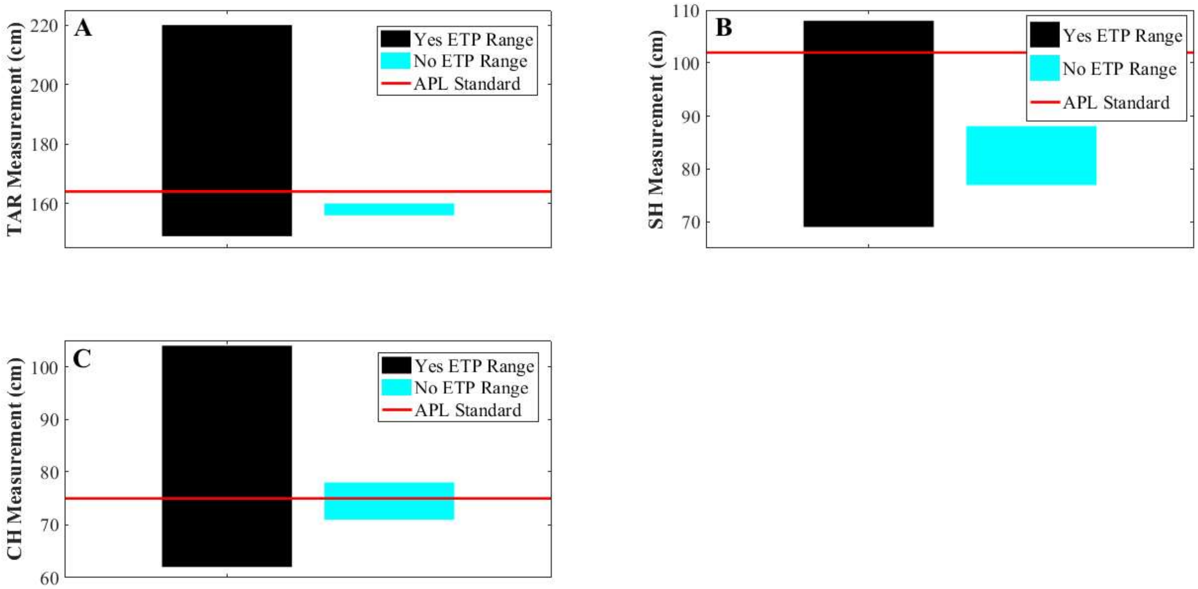

Figure 6. Anthropometry measurement ranges for *Yes ETP* and *No ETP* cohorts. The *Yes ETP* cohort had a much greater range of measurements for (A) TAR, (B) SH, and (C) CH. However, this difference is not surprising considering the population sizes of the two cohorts (*Yes ETP*: 413; *No ETP*: 6)

The *All* and *Pass* cohorts had almost identical measurements and probability densities for all three measurements (Figures 7-9). Similarly, the *Fail, No App, Yes App,* and *Yes ETP* cohorts had almost identical measurements and probability densities for all three measurements. These values were, on average, lower than those from the *All* and *Pass* cohorts. The *No ETP* cohort had measurement values and probability densities that were different and lower than all other cohorts.

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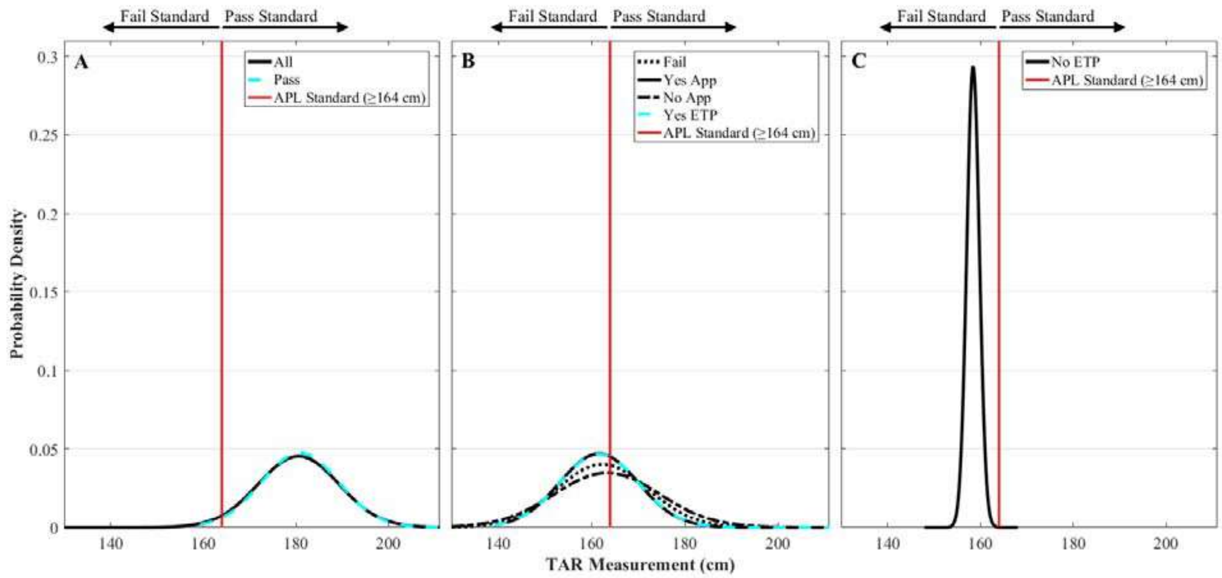

Figure 7. Normalized probability densities of TAR measurements. (A) The probability densities for the *All* and *Pass* cohorts were very similar. As can be seen in the probability density curve for the *All* cohort, only a small portion (1.37%) of all applicants failed the TAR standard. (B) The probability densities for the *Fail*, *Yes App*, *No App*, and *Yes ETP* cohorts were similar and, on average, lower than the probability densities for the *All* and *Pass* cohorts. A majority (71.25-83.77%) of the applicants in these four cohorts failed the TAR standard. Relaxing the TAR standard by a small amount could pass a substantial number of applicants in these cohorts. (C) The probability density for the *No ETP* cohort was lower than and different from all other cohorts. Current APL standards failed all applicants in the *No ETP* cohort for insufficient TAR. While adjusting the TAR standards could allow more applicants in the *Yes ETP* cohort to pass, it could also result in the passing of applicants in the *No ETP* cohort.

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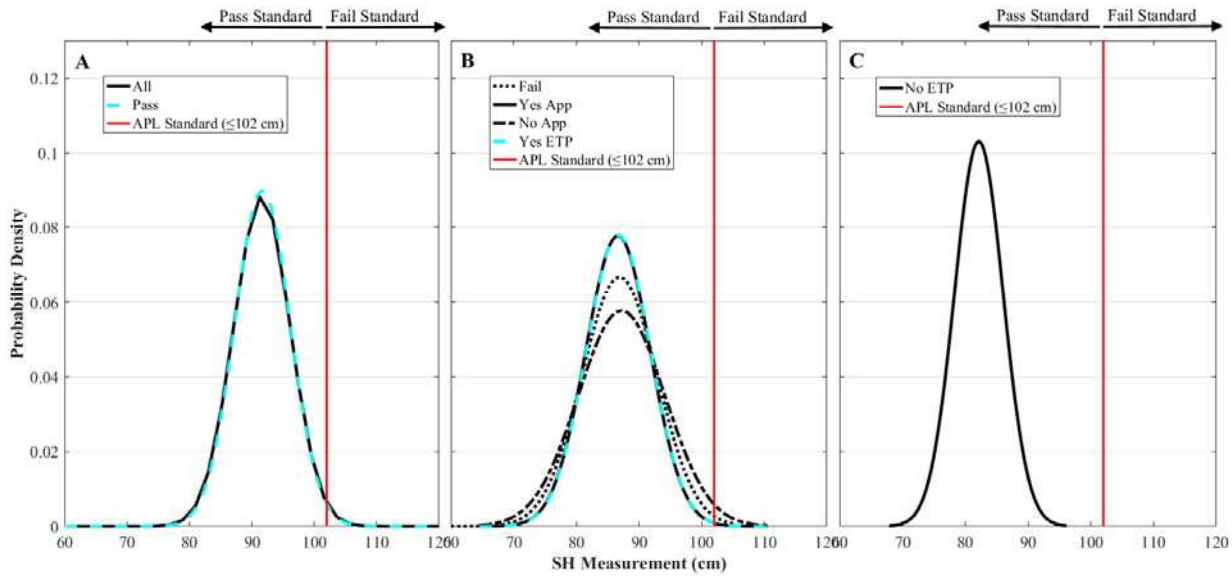

Figure 8. Normalized probability densities of SH measurements. (A) The probability densities for the *All* and *Pass* cohorts were very similar. As can be seen in the probability density curve for the *All* cohort, only a small portion (0.11%) of all applicants failed the SH standard. (B) The probability densities for the *Fail*, *Yes App*, *No App*, and *Yes ETP* cohorts were similar and, on average, lower than the probability densities for the *All* and *Pass* cohorts. Very few (3.82-9.06%) applicants in these four cohorts failed the SH standard. Relaxing the SH standard could pass some of these tall applicants. (C) The probability density for the *No ETP* cohort was lower than all other cohorts. No applicants in the *No ETP* cohort failed the SH standard, so adjusting the SH standard will not affect the passing rate in this cohort.

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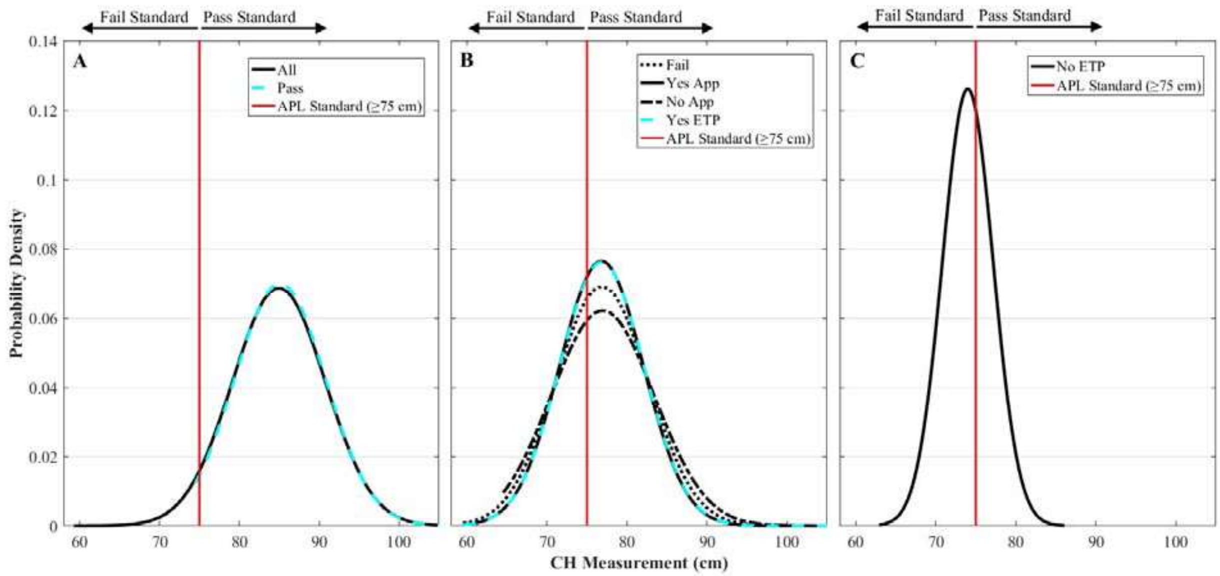

Figure 9. Normalized probability densities of CH measurements. (A) The probability densities for the *All* and *Pass* cohorts were very similar. As can be seen in the probability density curve for the *All* cohort, only a small portion (0.62%) of all applicants failed the CH standard. (B) The probability densities for the *Fail*, *Yes App*, *No App*, and *Yes ETP* cohorts were similar and, on average, lower than the probability densities of the *All* and *Pass* cohorts. Slightly fewer than half (29.78-42.50%) of the applicants in these four cohorts failed the CH standard. Relaxing the CH standard by a small amount could pass a substantial number of applicants in these cohorts. (C) The probability density of the *No ETP* cohort was lower than and different from all other cohorts. Current standards failed over half (66.67%) of these applicants for insufficient CH. While adjusting the CH standards could allow more applicants in the *Yes ETP* cohort to pass, it could also result in the passing of applicants in the *No ETP* cohort.

The cohorts that contained applicants who failed the Anthropometry APL standards were further analyzed to determine which standards were causing the greatest number of failures. As can be seen in Table 6, TAR was the predominant cause of failure (71.25-100%), followed by CH (29.78-66.67%) and then SH (0-9.06%). With the exception of the *No ETP* cohort, a majority (77.19-82.81%) of applicants in all cohorts who failed the anthropometry standards only failed one standard. In the *No ETP* group, more applicants failed two standards (66.67%) than only one standard (33.33%). Again, for the applicants who failed only one standard, TAR was the greatest cause of failure, followed by CH and then SH. All applicants who failed two standards failed both TAR and CH. No applicants failed all three anthropometry standards.

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Table 6. Analysis of the Cause for Anthropometric Failure

	Fail	***No App***	***Yes App***	***Yes ETP***	***No ETP***
Total in Cohort	739	320	419	413	6
Fail TAR, N (%)	579 (78.35)	228 (71.25)	351 (83.77)	345 (83.54)	6 (100)
Fail SH, N (%)	45 (6.09)	29 (9.06)	16 (3.82)	16 (3.87)	0 (0)
Fail CH, N (%)	263 (35.59)	136 (42.50)	127 (30.31)	123 (29.78)	4 (66.67)
Fail 1 standard, N (%)	591 (79.97)	247 (77.19)	344 (82.10)	342 (82.81)	2 (33.33)
Fail only TAR, N (%)	*431 (58.32)*	*155 (48.44)*	*276 (65.87)*	*274 (66.34)*	*2 (33.33)*
Fail only SH, N (%)	*45 (6.09)*	*29 (9.06)*	*16 (3.82)*	*16 (3.87)*	*0 (0)*
Fail only CH, N (%)	*115 (15.56)*	*63 (19.69)*	*52 (12.41)*	*52 (12.59)*	*0 (0)*
Fail 2 standards, N (%)	148 (20.03)	73 (22.81)	75 (17.90)	71 (17.19)	4 (66.67)
Fail TAR + SH, N (%)	*0 (0)*	*0 (0)*	*0 (0)*	*0 (0)*	*0 (0)*
Fail TAR + CH, N (%)	*148 (20.03)*	*73 (22.81)*	*75 (17.90)*	*71 (17.19)*	*4 (66.67)*
Fail SH + CH, N (%)	*0 (0)*	*0 (0)*	*0 (0)*	*0 (0)*	*0 (0)*
Fail 3 standards, N (%)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)

Note. The five cohorts that contained applicants who failed the anthropometry standards were analyzed to determine which standards caused failure. The majority of applicants failed TAR. Crotch height was the second greatest cause of failure, while only a small number of applicants failed SH. With the exception of the *No ETP* cohort, a majority of applicants failed only one standard, where again TAR was the leading cause of failure followed by CH and then SH. When two standards were failed, TAR and CH were the cause. There were no applicants who failed both TAR and SH or both SH and CH. There were no applicants who failed all three standards.

Anthropometry of Small Applicants

Analyzing overall, average anthropometry of cohorts could cause valuable results to be washed out. Therefore, the anthropometry of applicants who failed the anthropometry standards for being too small was analyzed separately from the entire cohort. Small applicants were defined as those with insufficient reach (failed TAR and/or CH standard). As can be seen in Table 7, most (90.94-100%) applicants who failed the anthropometry standards failed for insufficient reach.

The mean, median, and maximum TAR measurements for small applicants in the *Fail*, *No App*, *Yes App*, and *Yes ETP* cohorts were similar (Table 8). Small applicants in the *No App* cohort had a lower minimum TAR measurement than those in the *Yes App* cohort, but had the same maximum TAR measurement; therefore, small applicants in the *No App* cohort fell within a wider range of TAR measurements than in the *Yes App* cohort. Despite these differences, there was no statistically significant (p = 0.5920) difference between the distribution of TAR measurements of small applicants in the *No App* and *Yes App* cohorts (Figure 10). Small applicants in the *Yes ETP* cohort had larger TAR measurements than those in the *No ETP* cohort; however, this difference was not statistically significant (p = 0.1713) (Figure 11).

Sitting height measurements for small applicants in the *Fail*, *No App*, *Yes App*, and *Yes ETP* cohorts were similar (Table 9). Small applicants in the *Yes App* cohort had slightly larger SHs than those in the *No App* cohort, but this difference was not statistically significant (p = 0.1975). Small applicants in the *No ETP* cohort had statistically significantly (p = 0.0209) smaller SH measurements than those in the *Yes ETP* cohort. Small applicants in the *No ETP* cohort also had a smaller range of SH measurements that fell within roughly the middle of the SH measurement range of the small applicants in the *Yes ETP* cohort.

Crotch height measurements for small applicants in the *Fail*, *No App*, *Yes App*, and *Yes ETP* cohorts were similar (Table 10). The CH measurements for small applicants in the *Yes App* cohort were statistically significantly larger (p = 0.0105) than those for small applicants in the *No App* cohort. Small applicants in the *No ETP* cohort had, on average, smaller CH measurements than those in the *Yes ETP* cohort, but this difference was not statistically significant (p = 0.1586). The small applicants in the *No ETP* cohort had a smaller range of CH measurements that fell roughly within the middle of the CH measurement range of the small applicants in the *Yes ETP* cohort.

Table 7. Distribution of Small and Tall Applicants in Applicable Cohorts

	Total in Cohort	**Small in Cohort, N (%)**	**Tall in Cohort, n (%)**
Fail	739	694 (93.91)	45 (6.09)
No App	320	291 (90.94)	29 (9.06)
Yes App	419	403 (96.18)	16 (3.82)
Yes ETP	413	397 (96.13)	16 (3.87)
No ETP	6	6 (100)	0 (0)

Table 8. Descriptive Statistics of TAR Measurements in Small Applicants

	Total Arm Reach (cm) in Small Applicants					
	N (%)	**Mean (STD)**	**Median**	**Minimum**	**Maximum**	**Range**
Fail	694 (93.91)	160.41 (5.98)	160	132	186	54
No App	291 (90.94)	160.56 (7.03)	160	132	186	54
Yes App	403 (96.18)	160.31 (5.09)	160	149	186	37
Yes ETP	397 (96.13)	160.34 (5.13)	160	149	186	37
No ETP	6 (100)	158.42 (1.36)	158.75	156	160	4

Note. Mean and median TAR measurement values in small applicants (failed TAR and/or CH APL standard) in the *Fail*, *No App*, *Yes App*, and *Yes ETP* cohorts were similar. There was no significant difference between the TAR values for small subjects in the *No App* and *Yes App* cohorts ($p = 0.5920$). As can be seen, the mean and median TAR measurement in small applicants in the *No ETP* cohort was lower than in the other cohorts. However, small applicants in the *No ETP* cohort did not have significantly lower TAR measurements than small applicants in the *Yes ETP* cohort ($p = 0.1713$).

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Table 9. Descriptive Statistics of SH Measurements in Small Applicants

	Sitting Height (cm) in Small Applicants					
	N (%)	**Mean (STD)**	**Median**	**Minimum**	**Maximum**	**Range**
Fail	694 (93.91)	85.76 (4.03)	86	66	99	33
No App	291 (90.94)	85.48 (4.30)	86	66	95	29
Yes App	403 (96.18)	85.96 (3.81)	86	69	99	30
Yes ETP	397 (96.13)	86.02 (3.78)	86	69	99	30
No ETP	6 (100)	82.17 (3.87)	81.50	77	88	11

Note. Mean and median SH measurement values in small applicants (failed TAR and/or CH APL standard) in the *Fail*, *No App*, *Yes App*, and *Yes ETP* cohorts were similar. There was no significant difference between the SH values for small subjects in the *No App* and *Yes App* cohorts (p = 0.1975). As can be seen, the mean and median SH measurement in small applicants in the *No ETP* cohort was lower than in the other cohorts. These SH measurements of small applicants in the *No ETP* cohort were significantly (p = 0.0209) lower than in small applicants in the *Yes ETP* cohort.

Table 10. Descriptive Statistics of CH Measurements in Small Applicants

	Crotch Height (cm) in Small Applicants					
	N (%)	**Mean (STD)**	**Median**	**Minimum**	**Maximum**	**Range**
Fail	694 (93.91)	75.93 (4.21)	76	62	94	32
No App	291 (90.94)	75.59 (4.43)	75	65	94	29
Yes App	403 (96.18)	76.18 (4.03)	76	62	92.70	30.70
Yes ETP	397 (96.13)	76.21 (4.03)	76	62	92.70	30.70
No ETP	6 (100)	74 (3.16)	72.50	71	78	7

Note. Mean and median CH measurement values in small applicants (failed TAR and/or CH APL standard) in the *Fail*, *No App*, *Yes App*, and *Yes ETP* cohorts were similar. There was a significant difference between the CH values for small subjects in the *No App* and *Yes App* cohorts (p = 0.0105). As can be seen, the mean and median CH measurement in small applicants in the *No ETP* cohort was lower than in the other cohorts. These CH measurements of small applicants in the *No ETP* cohort were not significantly (p = 0.1586) different from those in small applicants in the *Yes ETP* cohort.

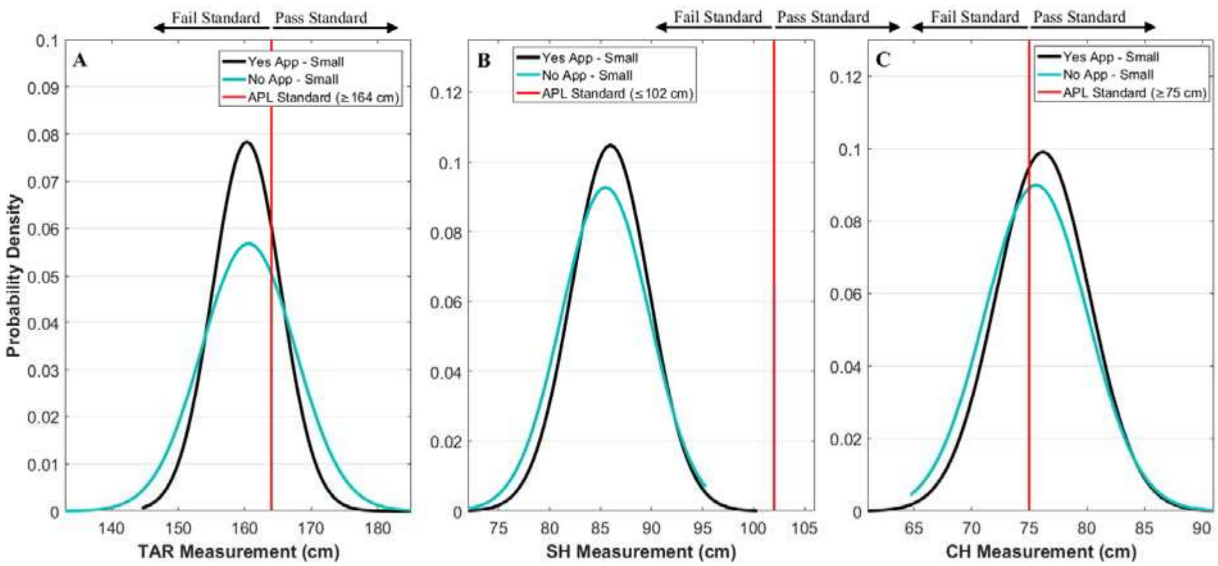

Figure 10. Normalized probability densities of anthropometry measurements in small applicants in the *Yes App* and *No App* cohorts. (A) Small applicants (failed TAR and/or CH APL standard) in the *No App* cohort have similar TAR measurements to those in the *Yes App* cohort. There was no significant ($p = 0.5920$) difference between the distributions of TAR measurements of small applicants in these two cohorts. (B) Small applicants in the *No App* cohort have similar SH measurements to those in the *Yes App* cohort. There was no significant ($p = 0.1975$) difference between the SH measurements of small applicants in these two cohorts. (C) The CH measurements of small applicants in the *No App* cohort were significantly ($p = 0.0105$) smaller than those of small applicants in the *Yes App* cohort.

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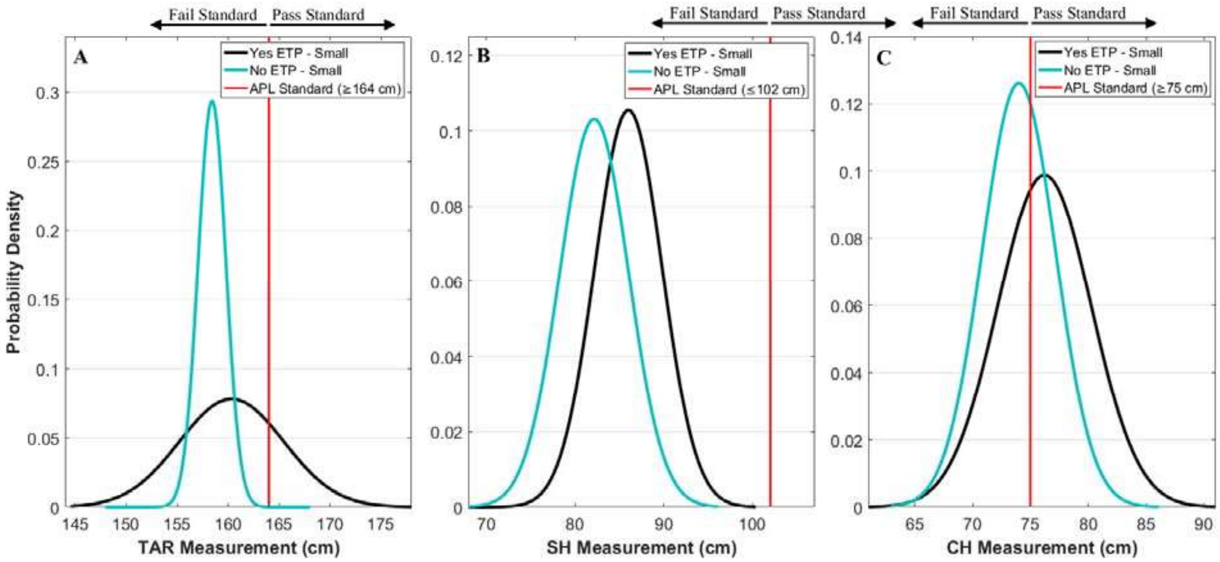

Figure 11. Normalized probability densities of anthropometry measurements in small applicants in the *Yes ETP* and *No ETP* cohorts. (A) Small applicants (failed TAR and/or CH APL standard) in the *No ETP* cohort had lower TAR measurements to those in the *Yes ETP* cohort. There was no significant difference (*p* = 01713) in TAR measurements in these two groups. (B) Small applicants in the *No ETP* cohort had significantly lower (*p* = 0.0209) SH measurements than those in the *Yes ETP* cohort. (C) Small applicants in the *No ETP* cohort had lower CH measurements than those in the *Yes ETP* cohort; however, the difference was not significant (*p* = 0.1586).

Anthropometry of Tall Applicants

Analyzing overall, average anthropometry of cohorts could cause valuable results to be washed out. Therefore, the anthropometry of applicants who failed the anthropometry standards for being too tall was further analyzed. Tall applicants were defined as those with excessive SH (failed SH standard). As can be seen in Table 7, very few (3.82-9.06%) applicants who failed the anthropometry standards failed for excessive SH. The *No App* cohort had the largest percentage of tall applicants in the cohorts compared. In fact, the *No App* cohort had almost 2.5 times as many applicants as the *Yes App* cohort. There were no applicants in the *No ETP* cohort with excessive height.

Total arm reach measurements for tall applicants in the *Fail*, *No App*, *Yes App*, and *Yes ETP* cohorts were similar (Table 11). Tall applicants in the *No App* cohort had lower TAR measurements than those in the *Yes App* cohort, but the difference was not statistically significantly different (*p* = 0.3126) (Figure 12).

Sitting height measurements for tall applicants in the *Fail*, *No App*, *Yes App*, and *Yes ETP* cohorts were similar (Table 12). Tall applicants in the *No App* cohort had slightly higher SH measurements than those in the *Yes App* cohort, but the difference was not statistically significantly different (*p* = 0.1136).

Crotch height measurements for tall applicants in the *Fail*, *No App*, *Yes App*, and *Yes ETP* cohorts were similar (Table 13). Tall applicants in the *No App* cohort had slightly lower CH measurements than those in the *Yes App* cohort, but the difference was not statistically significantly different ($p = 0.2747$). The tall applicants in the *No App* cohort had a broader range of CH measurements than those in the *Yes App* cohort, which had both lower and higher CH measurements than the *Yes App* Cohort.

Table 11. Descriptive Statistics of TAR Measurements in Tall Applicants

	Total Arm Reach (cm) in Tall Applicants					
	N (%)	**Mean (STD)**	**Median**	**Minimum**	**Maximum**	**Range**
Fail	45 (6.09)	192.28 (10.49)	193	164	220	56
No App	29 (9.06)	191.10 (10.25)	191.50	164	211.50	47.50
Yes App	16 (3.82)	194.47 (10.90)	196	169	220	51
Yes ETP	16 (3.87)	194.47 (10.90)	196	169	220	51
No ETP	0 (0)	N/A	N/A	N/A	N/A	N/A

Note. Total arm reach measurement values in tall applicants (failed SH APL standard) in the *Fail*, *No App*, *Yes App*, and *Yes ETP* cohorts were similar. There were no applicants who failed the SH standard in the *No ETP* cohort. Therefore, TAR measurements for tall applicants in the *Yes App* and *Yes ETP* cohorts are the same, since the tall applicants in the *Yes ETP* cohort make up all the tall applicants in the *Yes App* cohort. Tall applicants in the *Yes App* cohort had higher TAR measurements than tall applicants in the *No App* cohort. However, this difference was not significant ($p = 0.3126$).

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Table 12. Descriptive Statistics of SH Measurements in Tall Applicants

	Sitting Height (cm) in Tall Applicants					
	N (%)	**Mean (STD)**	**Median**	**Minimum**	**Maximum**	**Range**
Fail	45 (6.09)	104.57 (1.63)	104	102.30	108	5.70
No App	29 (9.06)	104.78 (1.52)	105	103	108	5
Yes App	16 (3.82)	104.21 (1.81)	103.50	102.30	108	5.70
Yes ETP	16 (3.87)	104.21 (1.81)	103.50	102.30	108	5.70
No ETP	0 (0)	N/A	N/A	N/A	N/A	N/A

Note. Sitting height measurement values in tall applicants (failed SH APL standard) in the *Fail*, *No App*, *Yes App*, and *Yes ETP* cohorts were similar. There were no applicants who failed the SH standard in the *No ETP* cohort. Therefore, SH measurements for tall applicants in the *Yes App* and *Yes ETP* cohorts are the same, since the tall applicants in the *Yes ETP* cohort make up all the tall applicants in the *Yes App* cohort. There was no significant difference (p = 0.1136) in SH measurement of tall applicants in the *No App* and *Yes App* cohorts.

Table 13. Descriptive Statistics of CH Measurements in Tall Applicants

	Crotch Height (cm) in Tall Applicants					
	N (%)	**Mean (STD)**	**Median**	**Minimum**	**Maximum**	**Range**
Fail	45 (6.09)	91.49 (6.80)	92	76	106.50	30.50
No App	29 (9.06)	90.71 (7.15)	91	76	106.50	30.50
Yes App	16 (3.82)	92.91 (6.07)	92.50	80	104	24
Yes ETP	16 (3.87)	92.91 (6.07)	92.50	80	104	24
No ETP	0 (0)	N/A	N/A	N/A	N/A	N/A

Note. Crotch height measurement values in tall applicants (failed SH APL standard) in the *Fail*, *No App*, *Yes App*, and *Yes ETP* cohorts were similar. There were no applicants who failed the SH standard in the *No ETP* cohort. Therefore, CH measurements for tall applicants in the *Yes App* and *Yes ETP* cohorts are the same, since the tall applicants in the *Yes ETP* cohort make up all the tall applicants in the *Yes App* cohort. Tall applicants in the *Yes App* cohort had higher CH measurements than tall applicants in the *No App* cohort. However, this difference was not significant (p = 0.2747).

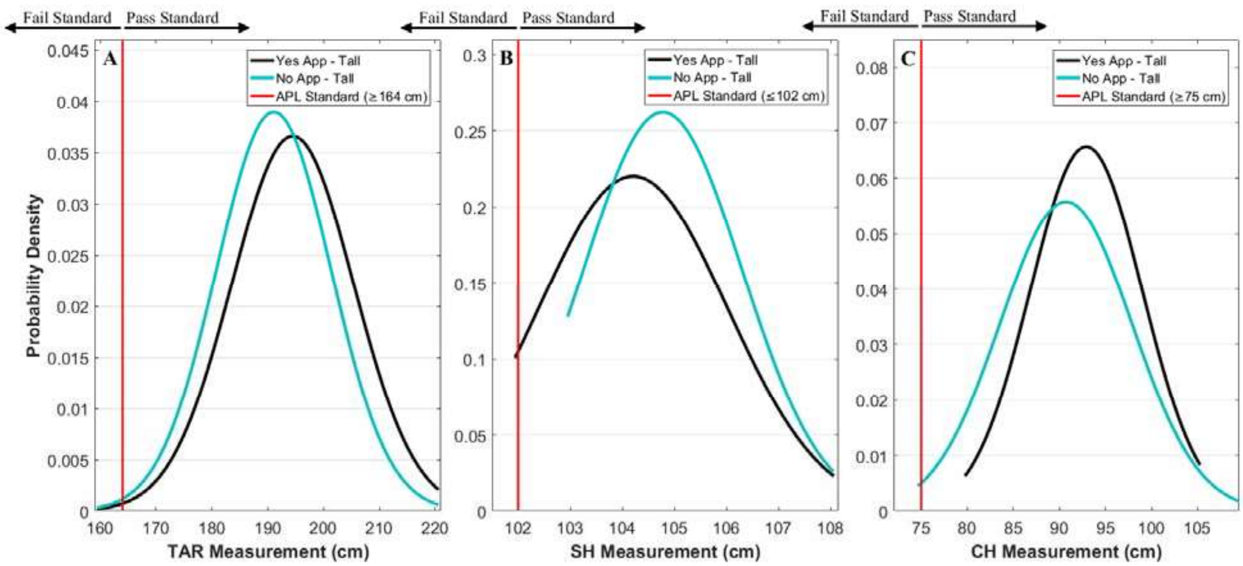

Figure 12. Normalized probability densities of anthropometry measurements in tall applicants in the *Yes App* and *No App* cohorts. (A) Tall applicants (failed SH APL standard) in the *No App* cohort have lower TAR measurements to those in the *Yes App* cohort, but this difference was not statistically significant (p = 0.3126). (B) Tall applicants in the *No App* cohort have higher SH measurements than those in the *Yes App* cohort, but this difference was not statistically significant (p = 0.1136). (C) The CH measurements of tall applicants in the *No App* cohort smaller than those in the *Yes App* cohort, but this difference was not statistically significant (p = 0.2747).

Potential Adjustments to Anthropometry Standards

As was shown in Figure 5 and Table 2, only six applicants who failed the anthropometry standards and underwent an ICE were denied anthropometry ETPs. In contrast, 413 (98.57% of applicants who applied for ETPs) were granted anthropometry ETPs. Various adjustments to the current standards were modeled to see the effects on the passing rates in the *Yes ETP* and *No ETP* cohorts and cost-savings due to the decrease in ETP applications. The goal was to increase the passing rate of the *Yes ETP* cohort while still minimizing the passing rate of the *No ETP* cohort. The anthropometry of the six applicants in the *No ETP* cohort, whose detailed measurements can be seen in Table A1 in Appendix A, and the applicants in the *Yes ETP* cohort were heavily considered when modeling the adjustments.

The first set of modeled adjustments (Model I) was designed to include the maximum number of applicants in the *Yes ETP* cohort while excluding all applicants in the *No ETP* cohort. This set of adjustments suggests that TAR should be at least 160 cm, SH should be less than 108 cm, and CH should be at least 72 cm (Table 14). These values would pass 221 (53.51%) applicants in the *Yes ETP* cohort as well as 178 (55.63%) applicants in the *No App* cohort and would result in an estimated cost savings of $552,500 over the 10-year period studied (Table 15). Model I was deemed the most efficient adjustment to the anthropometry standards that was conservative enough to fail all applicants deemed anthropometrically unacceptable.

Next, a less conservative set of adjustments was modeled. Model II was designed to pass all the applicants in the *Yes ETP* cohort without regard for the passing rate of the *No ETP* cohort. This second adjustment suggests that TAR and CH be at least 149 cm and 62 cm, respectively, while SH should be no greater than 108 cm (Table 14). The result is that all 413 (100%) applicants in the *Yes ETP* cohort, 311 (97.19%) of applicants in the *No App* cohort, and all six (100%) applicants in the *No ETP* cohort would pass (Table 15). While Model II would pass all six applicants deemed anthropometrically unacceptable, it is within the 2% margin of error allowed for aviation safety standards. In fact, Model II would have a less than 0.02% chance of passing these six unacceptable applicants. Model II was deemed the most efficient adjustment to anthropometry standards that still fell within the aviation safety standard margin of error.

Several other adjustments with various levels of conservancy between those of Model I and Model II were modeled. However, these models were not as efficient as Models I and II and are therefore not further described in this report. For example, other models that excluded all *No ETP* applicants passed fewer *Yes ETP* applicants than Model I and resulted in a lower estimated cost saving. Alternatively, other models that passed some *No ETP* applicants (and remained within the 2% margin of error for aviation safety standards) passed fewer *Yes ETP* applicants than Model II.

Table 14. Potential Adjustments to Aviator Anthropometry Standards

	Current Standard	**Model I**	**Model II**
TAR	≥ 164 cm	≥ 160 cm	≥ 149 cm
SH	≤ 102 cm	≤ 108 cm	≤ 108 cm
CH	≥ 75 cm	≥ 72 cm	≥ 62 cm

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Table 15. Effects of Potential Adjustments to the Anthropometric Standards on Passing Rate in Applicants Who Failed Current Anthropometry Standards

	Model I	**Model II**
***Yes ETP* Passed, N (%)**	221 (53.51)	413 (100)
***No ETP* Passed, N (%)**	0 (0)	6 (100)
***No App* Passed, N (%)**	178 (55.63)	311 (97.19%)
Estimated Cost Savings	$552,500	$1,047,500

Note. Model I is the most conservative adjustment to current Anthropometry APL standards. It passes only a little more than half of the applicants in the *Yes ETP* cohort, but fails all of the applicants in the *No ETP* cohort. Model I was deemed the most efficient adjustment to the standards that was conservative enough to fail all applicants deemed anthropometrically unacceptable. Model II is the least conservative adjustment modeled. It includes all applicants who applied for ETPs, to include both those who were and were not deemed anthropometrically acceptable. Though Model II passes all six applicants in the *No ETP* cohort, it still falls within the 2% margin of error allowed for aviation safety standards. Model II was deemed the most efficient adjustment to anthropometry standards that still fell within the aviation safety standard margin of error. The number of applicants who would pass the adjusted standards during the initial flight physical was multiplied by the estimated cost of an ICE ($2500/applicant) to obtain the cost saving estimates over the 10-year period.

Aviation Mishaps Related to Anthropometry

The U.S. Army Combat Readiness Center surveyed their database for the years 1972 to 2017. There were 602 mishaps that were attributed to human factors, the category to which anthropometry is classified. There was one event in which thigh mass caused an inability to access full cyclic travel in a weight lifter, which resulted in a mishap. Further details on this mishap are provided in “Size Matters!” and will not be recounted here (2006). There were no mishaps for which unacceptable TAR, SH, or CH were listed as factors.

Discussion

Data Characterization

Characterization of the applicant pool revealed that there were similarities in all three anthropometry measurements for the *All* and *Pass* cohorts, which is reasonable considering the *Pass* cohort comprises 98.25% of the *All* cohort. These similarities are evident in the means, medians, standard deviations, and probability densities of the two cohorts. There were also similarities in all three measurements for the *Fail, No App, Yes App, and Yes ETP* cohorts. Since there were no statistically significant differences between the *No App* and *Yes App* cohorts and these two cohorts comprise the *Fail* cohort, anthropometry measurements for all three are expected to be similar. In addition, the *Yes ETP* cohort comprises 98.57% of the *Yes App* cohort, so it was expected that the *Yes ETP* cohort will have similar anthropometry measurements as the

Yes App and therefore also the *No App* and *Fail* cohorts.

Overall, applicants who failed the anthropometry standards were significantly smaller than applicants who passed the standards. Though they were too small to pass the standards, they were still deemed anthropometrically acceptable through SIP evaluation. Only the smallest applicants were denied anthropometry ETPs and deemed anthropometrically unfit. These applicants had, on average, the smallest TARs, SHs, and CHs than any other cohort. Though their average anthropometry measurements were smaller, their minimum and maximum measurements provided interesting results. The *No ETP* cohort had higher minimum TAR and CH measurements than the *Yes ETP* cohort, suggesting that smaller applicants in the *Yes ETP* cohort with a smaller reach passed their ICEs while applicants in the *No ETP* cohort with a larger reach failed their ICEs. A similar comparison could not be made with the maximum SH measurements in these two cohorts, since all applicants in the *No ETP* cohort failed for being too small and therefore did not have large SH measurements. Lastly, there is a difference in ranges between these two cohorts. Applicants in the *Yes ETP* cohort represent a much larger range and variety of anthropometry measurements than applicants in the *No ETP* cohort. This is, however, not that surprising since there were 413 applicants in the *Yes ETP* cohort and only six applicants in the *No ETP* cohort. In addition, the *Yes ETP* cohort contained both small and tall applicants while the *No ETP* cohort contained only small applicants.

A more in-depth analysis of small (failed TAR and/or CH standard) and tall (failed SH standard) applicants was performed. It was found that most applicants who failed the anthropometry standards failed for insufficient reach and that only a few failed for excessive SH. The only statistically significant difference between the anthropometry of small applicants in the *No App* and *Yes App* cohorts was found in the CH measurements. There was no statistically significant difference between the anthropometry of tall applicants in these two cohorts. In comparing the small applicants in the *Yes ETP* and *No ETP* cohorts, it was found that there was no statistically significant difference in the TAR and CH measurements. In fact, the only statistically significant difference between the anthropometry of small applicants in these two cohorts was found in the SH measurements. This was an interesting finding, suggesting that applicants who were denied ETPs for being too small may have failed due to insufficient SH, or the combination of insufficient SH and reach, rather than insufficient reach alone. In addition, it further demonstrates that anthropometric cockpit compatibility is multifactorial. The combined anthropometry of applicants in the *No ETP* cohort, who theoretically had similar TARs and CHs as the applicants in the *No ETP* cohort, deemed them unfit for the aircraft while the applicants in the *Yes ETP* cohort were able to compensate for their small stature and still operate the aircraft.

Overall, results suggest that small applicants may need manual ICEs to assess anthropometric cockpit fit while it can be assumed that large applicants (with SH of ≤ 108cm) will be anthropometrically cleared. Though large anthropometry may not be ideal, tall applicants were still able to operate the aircraft and pass ICEs. Small applicants may be able to compensate for their small stature, but will need to be manually assessed since cockpit fit is multifactorial and anthropometric standards may not be able to perfectly decide if small applicants will or will not fit into an aircraft.

Effectiveness of the Anthropometry APL

A majority of applicants (98.25%) passed the anthropometry standards during their initial entry flight physicals and were considered anthropometrically cleared. A small number (1.75%) of applicants failed the current Anthropometry APL standards. The 1.75% comprises 739 applicants who needed further review to determine their anthropometric eligibility. Of these 739 applicants, again a majority (98.57%) passed their ICEs, received ETPs, and were deemed anthropometrically cleared. The results suggest that the current anthropometry standards are reasonably efficient in passing applicants during their initial flight physical; however, the Anthropometry APL could be made more efficient by updating the standards to pass more of the applicants in the *Yes ETP* cohort.

Only one mishap in the RMIS database lists anthropometry as a factor. In this mishap, thigh mass was indicated as a factor. However, this is not an anthropometry metric listed in the Anthropometry APL. In addition, thigh mass is a metric that can change size throughout a pilot's career. It is possible for a pilot to be anthropometrically cleared and to later develop unacceptable thigh mass, weight, girth, or a similar metric. Therefore, the data validates SIP judgement in identifying applicants who are anthropometrically acceptable to operate the aircraft. In addition, data shows that the Anthropometry APL is effective at passing only acceptable applicants in regards to TAR, SH, and CH, since no mishaps listed any of these anthropometry metrics as a factor.

Proposed Adjustments to Anthropometric Standards

It was determined that the Anthropometry APL could be made more efficient by passing more applicants in the *Yes App*. Although only 0.98% of total applicants in the 10-year period studied failed the anthropometry standards and still received anthropometry ETPs, this group constitutes 413 individuals. At an estimated cost of $2,500 per applicant for an ICE, the group of applicants currently analyzed represents a cost of over $1 million. New standards that would accept even a portion of these applicants would result in notable savings for the U.S. Army. Adjustments to the standards with various levels of conservancy were modeled, which, over the period studied, resulted in the passing of 53.51-100% of applicants in the *Yes ETP* cohort, the passing of 0-100% of applicants in the *No ETP* cohort, and a cost-savings of $552,500-$1,047,500 due to the reduction of required ICEs.

The majority of anthropometry failures were caused by the TAR standard. In fact, this metric was the only cause of failure for more than half of the applicants who failed the APL standards. Therefore, focus was placed on the TAR measurement when adjusting the anthropometry standards. Most applicants who failed anthropometry only failed one standard, so interactions between two standards were not considered in choosing the values of these adjustments. Relaxing the standards proved to be a difficult process, as there were no clear values for TAR, SH, and CH that would include all of the *Yes ETP* applicants while excluding all of the *No ETP* applicants.

Model I (details found in Table 14) would include 221 (53.51%) applicants in the *Yes ETP* cohort and none of the applicants in the *No ETP* cohort. Model I is the most conservative, and therefore represents the smallest potential cost avoidance of $552,500 over the 10-year period of this study. This model was deemed to be the most efficient model that still excluded all of the applicants who failed their ICEs.

Model II (details found in Table 14) is the least conservative model. It passes the greatest number of applicants in the *Yes ETP* and *No ETP* cohorts and leads to the greatest potential cost avoidance of $1,047,500 over the 10-year period studied. These adjustments would include all 413 (100%) applicants in the *Yes ETP* cohort and all six (100%) applicants in the *No ETP* cohort. However, the chance that these standards accept applicants deemed anthropometrically unacceptable is roughly 0.01% and well within the aviation safety standard.

The modeled adjustments to the Anthropometry APL standards outlined above are similar to critical measurements found in previous studies. Schopper and Cote evaluated critical minimum measurement limits for TAR and CH when wearing warm weather flight uniforms (1984), and their results are in line with the models described in this report. Schopper and Cote determined that the minimum TAR for the UH-60 and CH-47 were 153 cm and 165 cm, respectively (1984). The modeled adjusted TAR standards in this study range from 149-160 cm. The lowest recorded CHs for both the UH-60 and CH-47 were 69 cm (Schopper & Cote, 1984). There was no observed critical measurement for these two aircraft (Schopper & Cote, 1984). The adjusted CH standards modeled in this report range from 62-72 cm. Schopper and Cote also evaluated the critical maximum measurement for SH (1984). No critical maximum measurement was observed for either the UH-60 or CH-47, though the maximum measured SH was 102 cm (Schopper & Cote, 1984). While Schopper and Cote were not able to find a critical maximum SH, SIP judgement in the current study has deemed a SH of 108 to be acceptable (1984). The adjusted SH standards modeled in this report range from 102-108 cm.

Potential Untapped Applicant Pool

There were 320 (43.30% of the *Fail* cohort) applicants who failed the APL standards and elected not to apply for an ETP. Some in this cohort may have had anthropometrics so far out of standard that application for an ETP would have been pointless. However, since there was no overall statistically significant difference between the *Yes App* and *No App* cohort, this is unlikely. Others may have had a change of heart regarding aviation training. For some, the process itself may have represented an insurmountable barrier. Though determining the reason why the applicants in the *No App* cohort chose not to apply for an ETP is beyond the scope of this investigation, the *No App* cohort represents a sizeable potential applicant pool. Since there was no statistically significant difference between the anthropometry of the *Yes App* and *No App* cohorts, it can be assumed that roughly the same percent (98.57%) of applicants in the *No App* cohort could have received an ETP had they gone through an ICE. Easing the artificial burden of the ETP application process by adopting the adjustments to anthropometry standards outlined in this report would make 178-311 (55.63-97.19% of *No App*) more applicants eligible to be anthropometrically qualified to attend flight school. In addition, it is unknown how many Service Members did not even attempt to apply for flight school because they believed their anthropometry to be unacceptable. Relaxing the anthropometric standards may encourage more applicants to apply for flight school, thereby widening the applicant pool even further.

Shortcomings of the Present Three-Metric Approach

The ability of the accession method and standards described in the 2015 Anthropometry APL to meet USAAMA anthropometry objectives is limited. It is based on a study that focused primarily on ensuring sufficient reach. Consequently, it does not adequately address several other important issues, such as DEP, pedal authority in an operational setting, injury during mishap, and long-term medical complications. The current project analyzed the three one-tailed, univariate metrics in current use and so is restricted by design in its ability to comment on a more comprehensive set of limits. If the current Anthropometry APL is updated, these considerations should be taken into account for maximum improvement to the current screening method.

One-Tailed Standards

Proper cockpit fit is a balance between safety and reach; however, the current one-tailed system only addresses part of this balance. For example, defining a minimum limit for CH ensures that pilots are able to reach the pedals. It does not exclude pilots with long legs who might be at a higher risk for impediment to egress (e.g., legs become tangled within airframe) during a mishap. Likewise, the limit for SH is designed to prevent the head from being too close to the cockpit ceiling in an attempt to prevent acute injury during a mishap. It does not take into account long-term medical complications that can be caused by hunching over, which may be required for tall pilots. In addition, the DEP, a vision parameter, is not the defining factor as perhaps it should be. As was discussed previously, pilots with eyes considerably above and below the DEP may not have an adequate FOV.

Univariate Surrogate

Hand reach, the ability to actuate switches and other systems of the aircraft, within the cockpit was found to be the overwhelmingly greatest reason for anthropometric failure in this study. Hand reach is determined not only by arm reach (TAR), but also SH, the ability to lean forward within the restriction of the shoulder harness, and, to a lesser degree, body rotation around the spinal axis. Thus, it is a multivariate function that is not easily accommodated by using a univariate surrogate. For this reason, using univariate measurements will never be perfect and a secondary mechanism, such as reliance on an SIP's judgment, will always be required. The effect the interaction between the three anthropometry measurements has on cockpit fit can be easily seen in the data. As was shown in Tables 3-5 and Figure 6, the *Yes ETP* cohort had a more extreme range of measurements for TAR, SH, and CH, than the *No ETP* cohort. For example, the minimum TAR measurement of the *Yes ETP* cohort (149 cm) was 15 cm lower than the APL standard, while the minimum TAR measurement for the *No ETP* cohort (156 cm) was only 8 cm lower. Table A2 in the Appendix shows that the *Yes ETP* applicants with shorter TARs and CHs ultimately received ETPs despite having more extreme measurements. This is due to the multivariate interaction of the other anthropometry components that may compensate for the more extreme measurements.

Perhaps a solution to the univariate problem could be to consider other anthropometry metrics in addition to or instead of the three presently used metrics. Though no mishaps were noted to result from the three anthropometric factors listed in the Anthropometry APL, there is a record of one mishap resulting from increased thigh mass that restricted cyclic input. Body mass index was previously rejected from the list of anthropometric measurements, though it is noted to be a good indicator of thigh mass (Cote & Schopper, 1984). Slope landings to the maximum standard of 15 degrees often require considerable lateral cyclic input, which can be limited by thigh mass. Perhaps the decision to reject body mass index from the list of anthropometric measurements should be reevaluated. In addition, it would be valuable to reference specifications for physical accommodation in aircraft, as outlined in MIL-STD-1472G, when ("Department of Defense Design Criteria Standard: Human Engineering," 2012). This report contains design criteria standard based on anthropometrics of U.S. Army personnel, and considers numerous anthropometric measurements in addition to or instead of TAR, SH, and CH.

Other measurements that could be beneficial to determining cockpit fit include sitting eye height, thumb reach, upper body reach, and leg clearance, which have been investigated previously by Tucker and Crawford (2000) and Schopper and Cote (1984). Sitting eye height affects pilots' external visibility and determines if pilots can align their eyes with the DEP (Tucker & Crawford, 2000). Setting limits to this metric may exclude pilots who are too short or too tall to have a proper FOV or properly align their eyes with the DEP. Thumb reach is measured from the back of the shoulder to the thumb. The metric may be better than TAR at determining if pilots can reach and manipulate controls, since it does not include the width of the torso. Applicants with wide torsos may pass the TAR standard even though their hand reach may be too short. It is possible that eliminating the torso width from a reach measurement may be more effective. Better yet, upper body reach measures the length from the buttocks, up the back to the shoulder, and down the arm to the fingertips (Schopper & Cote, 1984). The metric is a multivariate way to measure reach that combines SH with TAR. Using a measurement like this may be more effective in determining if small applicants will have sufficient hand reach. Lastly, leg clearance, or buttock-knee length, can be used to determine if pilots can clear the main instrument panel (Tucker & Crawford, 2000). The measurement could be used to reject applicants whose legs are too long and therefore are at a higher risk for lower limb injury or impediment to egress.

Additional Considerations

Cockpit fit is affected by the maximum travel in the seat and pedal adjustment mechanisms and limiations as well as the baseline anthropometry the pilot brings to the cockpit. However, a third factor, often overlooked but increasing in importance, is the effect of the required flying kit on cockpit fit. This includes Aviator personal protective equipment such as helmets, armor, survival vests and attendant equipment, special thermal uniforms (hot and cold), and over water equipment. These can easily put a pilot, who otherwise would marginally meet the anthropometric requirements, past the limit for safe flight. Cote and Schopper reported on an extensive anthropometric look at all U.S. Army operational aircraft existing in 1984 using cold and warm weather kits (1984). They found that four aircraft could not accommodate the tallest individual in their sample (sitting height of 102 cm) and that, while wearing the cold weather kit, problems with cyclic travel restrictions were observed ("Aeronautical Design Standard Performance Specification Handling Qualities Requirements for Military Rotorcraft," 2000; Cote & Schopper, 1984; Schopper & Cote, 1984). In addition, they determined that when wearing a cold weather kit, the critical minimum TAR for the UH-60 and CH-47 increased to 164 and 169 cm, respectively. With a current TAR standard of 164 cm, it is possible that some pilots who passed the Anthropometry APL standards may not have adequate reach when wearing bulkier kits and gear. As the Aviator's kit has become increasing bulky, consideration of this factor becomes increasingly important.

In addition, the present Anthropometry APL is static. It does not have a way to respond to new aviation platforms as they come into the fleet or new Aviator kits, uniforms, and gear. In fact, many of the studies upon which the present standards are based used aircraft no longer in the Army inventory. An improved APL would include a regulatory method responsive to new aircraft cockpits. This may be in the form of cockpit three-dimensional modeling that would take anthropometric extremes into account. While this is an advisable feature, it is beyond the scope of this effort. Though there is clearly a need for a new Anthropometry APL standard, the current project is limited in creating an ideal dynamic, two-tailed, and multivariate approach. An interim solution to revise the three anthropometry measurement standards and widen the acceptable anthropometry range has been provided in this report.

Limitations of Study

Human error was a limitation in this study. The AERO database includes anthropometry data measured and entered by humans, and there are multiple ways error can occur during this process. For example, though there are standards for how to measure TAR, SH, and CH, applicants were not measured by the same person, and there is no guarantee that they were all measured the same. In fact, it was not uncommon for applicants with multiple entries to have measurements that spanned the range of a few centimeters. Error can also occur when data is entered into the database. Many applicants had to be rejected from the data set because anthropometry measurement values were entered incorrectly or incompletely. It is also possible that measurements were entered incorrectly but remained in the data set. Some applicants with questionable entries were flagged but not discarded because their anthropometry was deemed physically possible; however, there is no way to distinguish between applicants whose anthropometry was entered incorrectly and those who had anthropometry measurements that were just outside of the norm.

Senior instructor pilot evaluation of anthropometric fit is a crucial component of the current system, yet the ICE is a subjective procedure. Applicants who apply for anthropometry ETPs are not evaluated by the same SIP. In addition, some SIPs may be more strict than others when it comes to anthropometry evaluation. The three proposed adjustments to current anthropometry standards are based on the anthropometry of applicants in the *Yes ETP* and *No ETP* cohorts. Applicants were placed in these cohorts based on the subjective evaluation of the SIPs rather than pure and objective anthropometrics.

Lastly, it is difficult to determine if aviation mishaps are due to anthropometry. A review of the U.S. Army Combat Readiness Center database only revealed one mishap where anthropometry was cited as a cause. It was not until later in the investigation that it was determined that thigh mass was a factor ("Size Matters!," 2006). Determining the role anthropometry plays in a mishap is difficult to quantify. Therefore, it is possible that applicants with unfit anthropometry were passed or given ETPs, though the results do not reveal any mishaps related to TAR, SH, or CH.

Recommendations

Anthropometry is an important accession standard with many ramifications important to USAAMA's mission in the areas of aviation medicine, safety, and mission completion. The current Anthropometry APL standards are based on ensuring adequate reach and head clearance within the aircraft. These standards are not necessarily optimal for pilot performance or ensuring that pilots can operate the aircraft well by manipulating controls and pedals, which may need to occur concurrently. A comprehensive approach to developing a better Anthropometry APL than is presently in use should be undertaken. Such an approach would ensure an Aviator cockpit fit that would balance ergonomic issues with flight safety and long-term health implications. An interim solution would be to adjust the present three anthropometric measurements, which would widen the applicant pool as well as result in considerable cost avoidance over time.

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Appendix A. Additional Anthropometry Data Analysis

Table A1. Anthropometry Measurements of All Applicants in No ETP Cohort

Applicant #	TAR (cm)	SH (cm)	CH (cm)	Weight (lbs)	Height (in)	Gender
1	*159*	85	*72*	119	62	F
2	*159*	81	78	98	59	F
3	*158*	82	78	115	60	F
4	*158.50*	77	*72*	120	60	F
5	*160*	80	*71*	120	61	F
6	*156*	88	*73*	119	60	F

Note. Italicized, red measurements constitute failed measurements. All of the six applicants in the *No ETP* cohort failed TAR. Most (4/6) failed CH in addition to TAR. Weight and height measurements have been included for more information; however, these two measurements are not considered when assessing anthropometric clearance.

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Table A2. Examples of *Yes ETP* and *No ETP* Cohort Applicant Anthropometry

Applicant #	Cohort	Identifying Measurement	TAR (cm)	SH (cm)	CH (cm)
1	*Yes ETP*	Min. TAR	149	85	75
2	*No ETP*	Min. TAR	156	88	73
3	*Yes ETP*	Max. TAR	220	103	99
4	*No ETP*	Max. TAR	160	80	71
5	*Yes ETP*	Min. SH	155	69	80
6	*No ETP*	Min. SH	158.50	77	72
7	*Yes ETP*	Max. SH	202	108	104
4	*No ETP*	Max. SH	156	88	73
9	*Yes ETP*	Min. CH	174	90	62
4	*No ETP*	Min. CH	160	80	71
7	*Yes ETP*	Max. CH	202	108	104
9	*No ETP*	Max. CH	159	81	78

Note. Cockpit fit is determined by the multivariate interaction of Aviator anthropometry. Univariate measurements are not the best way to determine cockpit fit. Applicants in the *Yes ETP* cohort had more extreme values for all three measurements than the applicants in the *No ETP* cohort (see Tables 3-5 and Figure 6 for more details on the range of measurements). Though the minimum TAR and CH in the *Yes ETP* cohort was lower than in the *No ETP* cohort, a multivariate comparison of the data shows than these individuals in the *Yes ETP* cohort compensate by having greater measurements in other areas. For example, compare Applicant #1 to Applicant #4. Applicant #1 has a much lower TAR measurement, but has higher SH and CH measurements than Applicant #4. The multivariate interaction of TAR, SH, and CH allowed Applicant #1 to receive an anthropometry ETP, while Applicant #4 was denied an ETP. In some cases, similar anthropometry measurements yield different results. For example, compare Applicants #5 and #6. Applicant #5 has a lower TAR and SH than Applicant #6; however, both applicants have the same combined SH and CH (149 cm) and very similar TARs. Despite this, Applicant #6 is denied a ETP while Applicant #5 receives a ETP. This suggests that multivariate interaction of anthropometry in Applicant #5 allows him/her to fit in aircraft cockpit while the interaction in Applicant #6 combined with a short CH causes him/her to fail the ICE. Applicant #9 has a CH well below the APL standard, while Applicant #4 only falls short by a few centimeters. However, Applicant #9 has a much higher TAR and SH and ultimately receives an ETP while Applicant #4 does not.

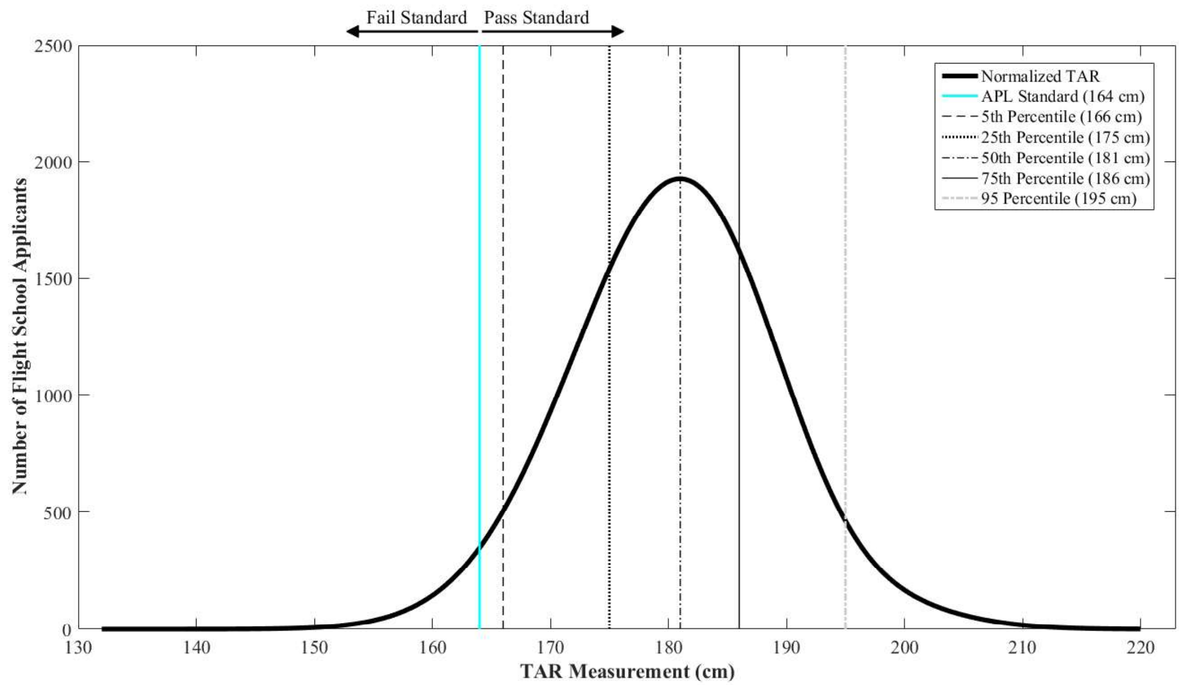

Figure A1. Normalized distribution of TAR measurements for all applicants.

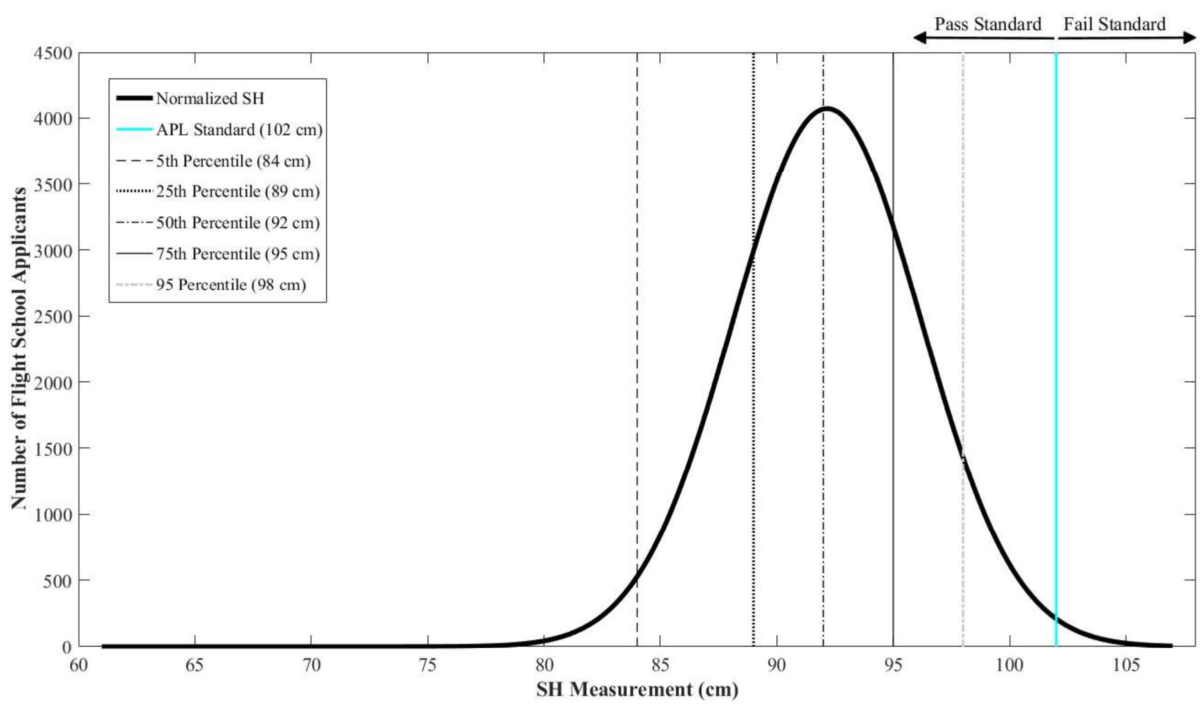

Figure A2. Normalized distribution of SH measurements for all applicants.

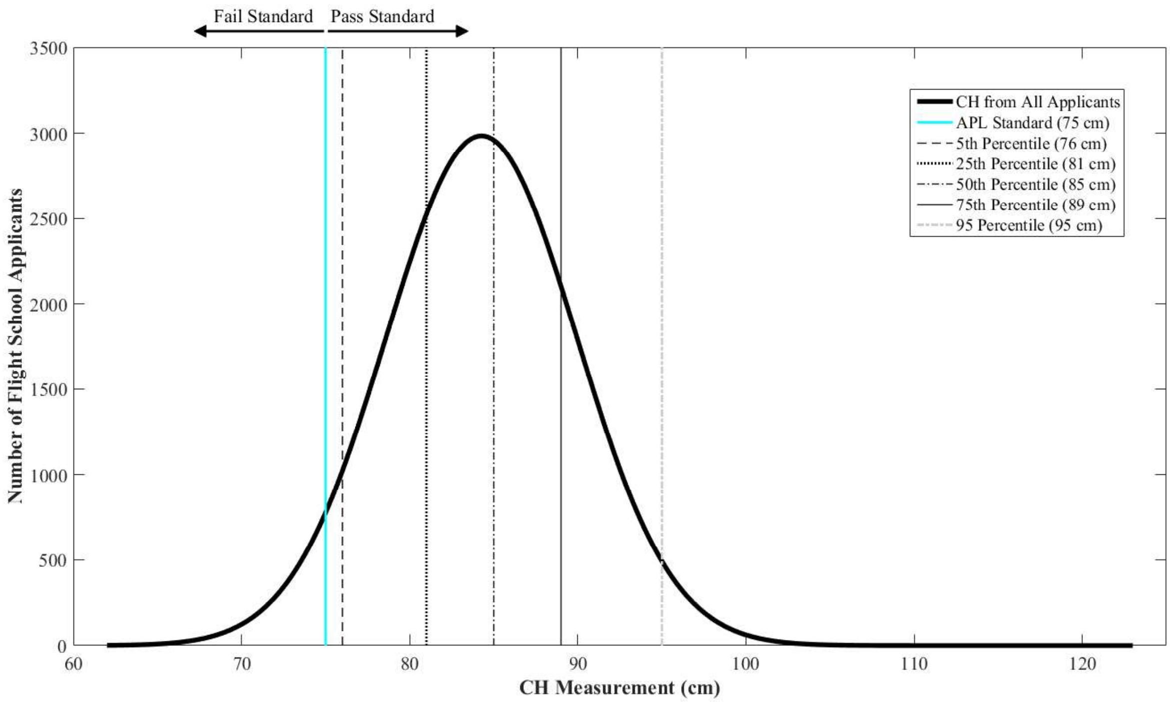

Figure A3. Normalized distribution of CH measurements for all applicants.

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Appendix B. Acronyms

AERO – Aeromedical Electronic Resource Office

APL – Aeromedical Policy Letter

CH – crotch height

cm = centimeters

DEP – design eye point

ETP – exception to policy

FOV – field of view

ICE – in-cockpit evaluation

RMIS – Risk Management Information System

SH – sitting height

SIP – senior instructor pilot

TAR – total arm reach

USAAMA – U.S. Army Aeromedical Activity

USAARL – U.S. Army Aeromedical Research Laboratory

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