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U.S. Army Aviation Life Support Equipment Retrieval Program: Prediction of Sitting Height Based on Stature for Mishap Injury Analysis

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During an analysis of injury patterns in OH-58 and UH-1 mishaps, the U.S. Army Aeromedical Research Laboratory (USAARL) found sitting height data was available only for aviators trained after 1986. Since many aviators flying during the study period were trained before 1986, a model was developed to predict sitting height based on some other measure. Stature was selected since it is measured annually, is consistent from year to year, and is available for all aviators in the study.

The linear regression models were developed for each gender to predict sitting height from stature. Two cohorts of aircrew members were studied and compared; a 1988 anthropometry survey of Army aviators (487 males and 334 females), and an anthropometry dataset of 1988 aviator training applicants (6,071 males and 239 females) stored in the Aviation Epidemiology Data Register (AEDR).

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19. Abstract (Continued):

There was an excellent correlation between sitting height and stature in the 1988 anthropometry survey cohort ($r=0.804$ for males and $r=0.816$ for females) and moderate correlation between variables in the 1988 aviator training applicant cohort ($r=0.580$ for males and $r=0.619$ for females). Using a confidence interval of four standard deviations from the parameter estimate, analysis showed the gender-specific linear regression models for the two study cohorts were statistically different ($p<0.0001$).

The model selected was based on the 1988 Army anthropometry survey for male aviators. This model had a strong linear correlation between sitting height and stature, and male aviators were involved in mishaps more often than females (98.7 percent of cases reviewed). USAARL judged the reliability of the 1988 Army anthropometry survey better than that of the 1988 AEDR data based on Army aviator training applicants. The findings of the OH-58 mishap injury analysis based on the selected model are published separately.

Table of contents

List of tables 1

List of figures 1

Military relevance 3

Methods 3

Results 4

Discussion 6

Conclusions 7

References 8

List of tables

Table

1. Comparison of the correlations for sitting heights and stature for the two study cohorts by gender 5

2. Bivariate linear regression models for the two study cohorts by gender 6

List of figures

Figure

1. Plot comparing sitting height and stature among a sample of 487 male Army aviators in 1988 4

2. Plot comparing sitting height and stature among a sample of 334 female soldiers meeting anthropometric entry standards for Army aviator training in 1988 5

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Military relevance

The Aviation Training Brigade (ATB) and the U.S. Army Aeromedical Center (USAAMC), Fort Rucker, Alabama, are considering revising the current 102 centimeter sitting height entry standard (U.S. Army Aeromedical Center, 1990; U.S. Army Aeromedical Center, 1996) for aviator training applicants to an undetermined standard below 102 centimeters. ATB and USAAMC tasked the U.S. Army Aeromedical Research Laboratory (USAARL) to conduct an analysis of the sitting height distribution among male and female applicants for entry into the Army Aviation Branch, which was provided in a related report (Mason and Shannon, 1996). This analysis showed that adoption of a sitting height qualification standard of less than or equal to 97 centimeters could reduce the aviator training applicant pool up to 9.57%. There was no operationally significant difference in the risk of sitting height aeromedical disqualification for warrant officer versus commissioned officer applicants (Relative $risk_{(Katz)}$=1.13, $CI_{0.95}$=1.06,1.23). Male applicants carried the entire burden of the increased risk for aeromedical disqualification if the sitting height standard were changed (Relative $risk_{(Katz)}$=19.6, $CI_{0.95}$=9.83,39.3).

ATB and USAAMC requested an analysis of the risk for injury in OH-58 mishaps stratified by the sitting height of cockpit crewmembers. This analysis was handicapped by missing sitting height records among Army aviators involved in OH-58 mishaps, and the comparison population, aviators involved in UH-1 mishaps. As an option, researchers could limit the analysis of OH-58 mishaps to only aircrew members with sitting height data available in the U.S. Army Aviation Epidemiology Data Register (AEDR). Alternatively, researchers could construct a model to predict sitting height based on a measurement that is available on most aircrew members, such as stature. To provide additional information to aircrew member anthropometry policy makers, this paper discusses the development of models to predict sitting height when the stature is known.

The AEDR is a family of databases storing information on the health of Army aviators, flight surgeons, aeroscout observers, air traffic controllers, and applicants to these occupations. One element of the AEDR stores flight physical information, which includes anthropometric measures for aviator training applicants.

Methods

In 1988, the Army completed an anthropometry survey of U.S. Army personnel (Gordon et al., 1989). Anthropometrists measured the subjects with calibrated designed equipment, ensuring the greatest possible degree of accuracy and reproducibility. Army aviators were included in the survey. The survey team found a representative sample of male Army aviators. Since only 2.5% of Army aviators were female (Mason and Shannon, 1994), the survey team was unable to find a sufficient number of female aviators. To represent a potential population of Army female aviators, the survey team selected female Army soldiers who met the anthropometry entry requirements for Army aviator training (Donaldson and Gordon, 1991). The sitting height and stature for 487 males and 334 females were extracted from the 1988 aviator anthropometry database.

For a comparison population, the AEDR was queried for all flying duty medical examinations (FDME) completed on applicants to Army aviator training for the period 1 January 1988 to 31 December 1988. The last FDME was retained for analysis when an individual had multiple FDMEs during the study period. Records for 32 individuals were discarded because of missing gender and/or anthropometry data. The final data set contained the sitting height and stature for 6,071 male and 239 female aviator training applicants.

SAS® CORR and SAS® REG were used in the correlation analysis and linear regression model derivation (SAS Institute, 1996). Confidence intervals for the slope of the regression model were based on four standard deviations from the parameter estimate.

Results

Figure 1 shows the relationship between sitting height and stature among male aviators in the 1988 Anthropometric Survey of U.S. Army Personnel, Pilots (Donelson and Gordon, 1991). Figure 2 shows the same relationship among the female potential aviators in the 1988 survey. Both figures show a linear relationship between increasing sitting heights and increasing stature. The figures show sitting height in centimeters and stature in inches because these are the units of measure used for FDMEs.

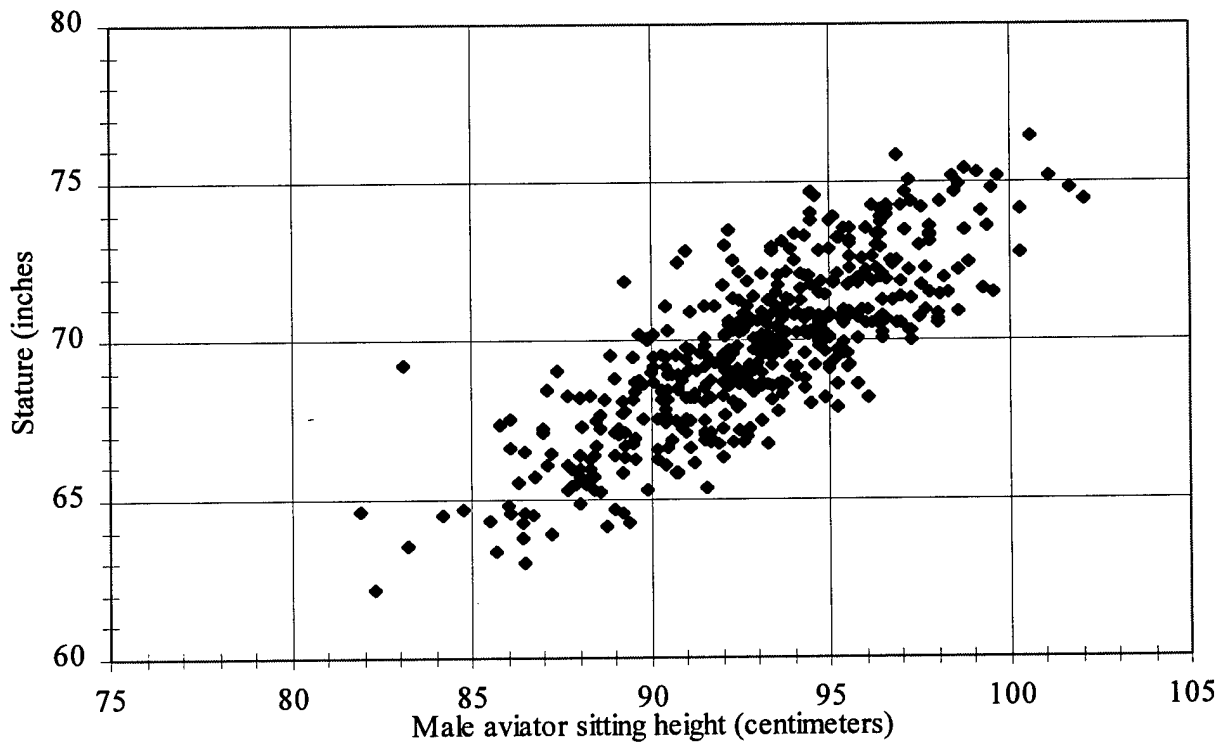

Figure 1. Plot comparing sitting height and stature among a sample of 487 male U.S. Army aviators in 1988 (Donelson and Gordon, 1991).

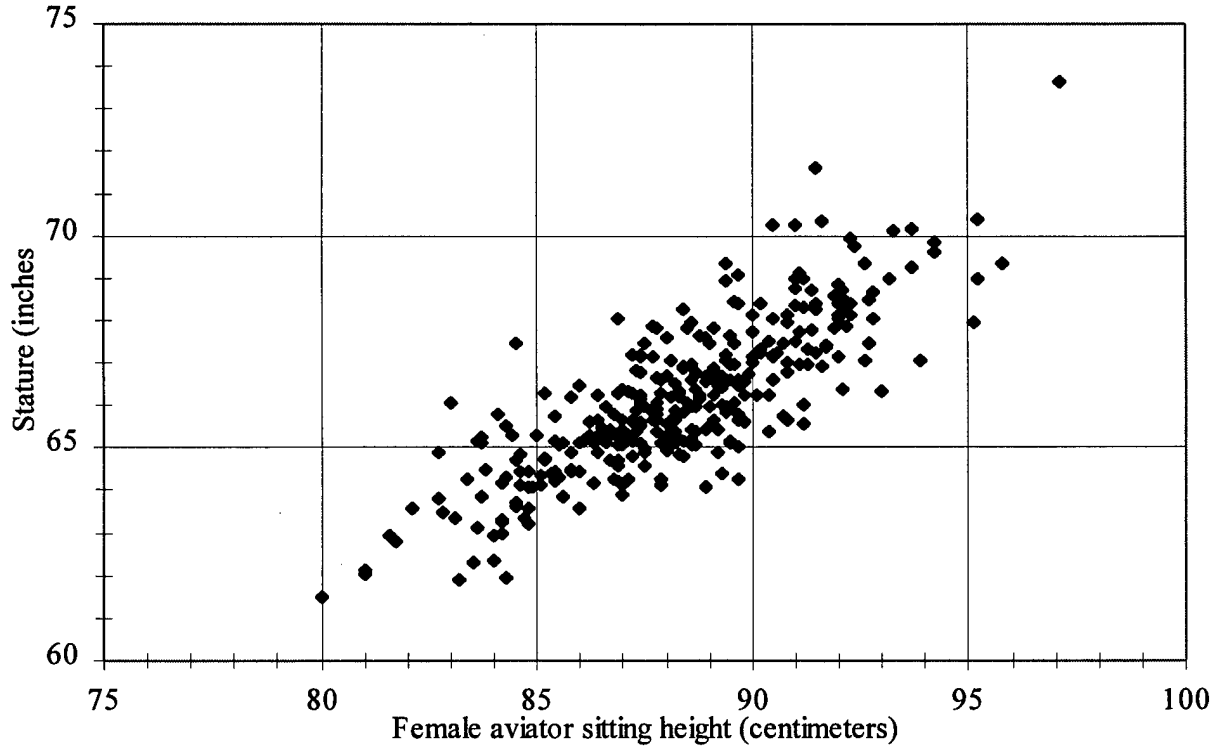

Figure 2. Plot comparing sitting height and stature among a sample of 334 female soldiers meeting anthropometric entry standards for Army aviator training in 1988 (Donelson and Gordon, 1991).

Table 1 compares the bivariate correlations for the two study cohorts by gender. Each cell contains the Pearson product-moment correlation (r) for the two study cohorts by gender. An r of 1.0 indicates a perfect one-to-one relationship between the two variables, and an r of 0.0 indicates no relationship between variables. There is an excellent correlation between sitting height and stature in the 1988 anthropometry survey cohort and moderate correlation between variables in the 1988 aviator training applicant cohort.

Table 1.
Comparison of the correlations for sitting height and stature for the two study cohorts by gender.

Gender	1988 Army aviator anthropometry survey	1988 Aviator training applicants in AEDR
Male	r=0.804	r=0.580
Female	r=0.816	r=0.619

Table 2 shows the linear regression models for both study cohorts by gender. Analysis shows the gender-specific models for the two study cohorts are statistically different ($p<0.0001$). The model is expressed as:

Predicted sitting height in millimeters = intercept + (slope x stature in millimeters)

$$\hat{p}_{SH} = \beta_0 + (\beta_1 \text{ x } HT)$$

Table 2.
Bivariate linear regression models for the two study cohorts by gender.

Gender	Model	$CI_{model\ slope}$	r^2
	1988 Army aviator anthropometry survey		
Male	$\hat{p}_{SH} = 198.49 + (0.4127 * HT)$	0.3573,0.4682	0.6462
Female	$\hat{p}_{SH} = 32.61 + (0.5060 * HT)$	0.4272,0.5848	0.6641
	1988 Aviator training applicants in AEDR		
Male	$\hat{p}_{SH} = 303.65 + (0.3480 * HT)$	0.3229,0.3731	0.3364
Female	$\hat{p}_{SH} = 328.53 + (0.3303 * HT)$	0.2213,0.4393	0.3826

Discussion

Several sources of measurement error are possible. First, the natural phenomenon of regression to the mean. When is a measurement retaken before it is recorded? In the AEDR population, a person who is actually 2 centimeters above an anthropometry standard, but measured at or below the standard, is observed and recorded as qualified. This individual will not be remeasured to determine the actual measurement. Conversely, an individual who is actually 2 centimeters below the standard, but measured at or above the standard, is observed to be borderline disqualified. The flight surgeon's office will likely remeasure the second individual and record the more favorable of the two measurements. Remeasurement in this manner shifts the estimate of the mean towards the null value, that is, regression to the mean.

Measurements on Army personnel recorded in the AEDR are conducted in over 700 flight surgeon offices across the Department of Defense and host Allied nations, instead of a centralized examination station staffed with anthropometrists. The quality assurance of equipment and measurement personnel across these examination sites is known to be variable. For example, the first author visited a facility where a torn paper measuring tape was retaped to the wall many times. Calibration showed the sitting heights were in error by 3 centimeters. Another clinic measured

applicants fully clothed with shoes or boots rather than in the prescribed measurement ensemble of socks and physical training uniform. Another clinic had a fixed sitting block with a permanently mounted and calibrated metal tape for measuring sitting height and the measurement policy on display. Which clinic provided accurate and reproducible sitting height measurements? So, we are not surprised to discover in this study that the reliability and model fit of the 1988 Army anthropometry survey is much better than the 1988 AEDR data for Army aviator training applicants.

There are reports of systematic error where the incorrect measurement is recorded in the AEDR. For example, the first author witnessed flight surgeon office staff coaching tall examinees to compress themselves downward in order to improve their chances of passing the sitting height standard. The compression reduces the actual sitting height by several centimeters. USAAMC encountered circumstances where sympathetic staff members admitted to recording qualifying measurements when they measured the applicant as disqualified.

Selection bias leads to missing data points in the AEDR data. How many applicants are discouraged from applying for aviator training by aviation mentors or flight surgeon office staff because they are obviously too tall or too short? These applicants at the extremes of anthropometry miss having their findings recorded in the AEDR and bias our report.

Finally, sampling creates a possible source of error. Due to the unavailability of trained female aviators for measurement in the 1988 Army anthropometry survey, a representative sample was derived using female subjects who met the anthropometry entry standards for Army aviator training. Since then, USAARL measured 78 trained female Army aviators in 1995. Comparing the model derived from 1988 data (Table 2) with the data from the 1995 sample, it was found that the Table 2 model may not accurately represent the female aviator population (Carson et al., 1996).

Conclusions

During an analysis of injury patterns in OH-58 and UH-1 mishaps, USAARL found sitting height data were available only for aviators trained after 1986. Since many aviators flying during the study period were trained before 1986, a model was developed to predict sitting height based on some other measure. Stature was selected since it is measured annually, is consistent from year to year, and is available for all aviators in the study.

The model based on the 1988 Army anthropometry survey for male aviators was selected. This model had a strong linear correlation between sitting height and stature, and male aviators were more often involved in mishaps than females (98.7% of cases reviewed). USAARL judged the reliability of the 1988 Army anthropometry survey as better than that of the 1988 AEDR data based on Army aviator training applicants.

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