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# COMPARATIVE ANTHROPOMETRY OF AIR STANDARDIZATION COORDINATING COMMITEE PERSONNEL FOR EQUIPMENT DESIGN: HELMETS

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FOR THE COMMANDER

CHARLES BATES, JR.
Chief
Human Engineering Division
Aerospace Medical Research Laboratory

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The objective of this report is to demonstrate that the comparability of body-size distributions of aircrew personnel of Air Standardization Coordinating Committee (ASCC) member nations is such that protective equipment sized and designed to fit personnel of one member nation will fit personnel of all member nations as well. The research reported on in this publication compares the available anthropometry of the head and face of member ASCC nations, demonstrates their similarities, and tests the theoretical suitability

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of a Royal Aircraft Establishment (RAE) sizing program for helmets to accommodate U. S. Air Force (USAF) personnel.

# PREFACE

This study was conducted under Project 7184, "Human Engineering in Advanced Systems," Work Unit 71840830, "Body Size and Mass of Air Force Personnel."

Dr. John T. McConville, Anthropology Research Project, Webb Associates, under contract AF33615-76-C-5007, and Mr. C. E. Clauser, Crew Station Integration Branch, Human Engineering Division, Aerospace Medical Research Laboratory, Wright-Patterson Air Force Base, Ohio, shared the responsibility for the research.

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## TABLE OF CONTENTS


| | Page |
|---|---|
| OBJECTIVE | 3 |
| THE DATA BASE | 3 |
| CONCLUSIONS | 12 |
| REFERENCES | 13 |


## LIST OF FIGURES


| Figure | | |
|---|---|---|
| 1 | Head circumference | 7 |
| 2 | Head length | 8 |
| 3 | Head breadth | 9 |


## LIST OF TABLES


| Table | | |
|---|---|---|
| 1 | Summary Statistics of Selected Head Dimensions of ASCC Military Populations | 4 |
| 2 | Deviations of Sample Mean Values from the USAF 1967 Mean Values | 5 |
| 3 | USAF 1965 Subsets--Mean Values of Selected Variables | 6 |
| 4 | Inter-Population Variation vs. Intra-Population Variation for Selected Head Variables | 10 |
| 5 | Deviations of Sizing Means Between USAF and RAF Anthropometry Compared in an RAF Six-Size Head Circumference Sizing System | 11 |

COMPARATIVE ANTHROPOMETRY OF AIR STANDARDIZATION COORDINATING COMMITTEE PERSONNEL FOR EQUIPMENT DESIGN: HELMETS

Objective. The purpose of this study is to demonstrate that the comparability of body-size distributions of aircrew personnel of Air Standardization Coordinating Committee (ASCC) member nations* is such that protective equipment sized and designed to fit personnel of one member nation will fit personnel of all member nations as well. This report compares the available anthropometry of the head and face of member nations, demonstrates their similarities, and tests the theoretical suitability of a Royal Aircraft Establishment (RAE) sizing program for helmets to accommodate U. S. Air Force (USAF) personnel.

The Data Base. The relevant data were assembled and tabulated to obtain an overview of what was available for comparative purposes (Table 1). Although it is apparent that information on a number of useful dimensions for some populations is missing, there are sufficient data to undertake the analysis.

It was found in compiling the results of these surveys that the data varied widely from survey to survey in terms of currency, number of head and face variables and completeness of measuring technique descriptions. The latter is of particular significance since the lack of detailed measurement descriptions or illustrations makes it difficult to determine whether measurements are comparable from one survey to another. In this analysis, measurements were considered to be comparable on the basis of the similarity in variable names although, as will become apparent in the following discussion, this may not be a wholly valid assumption.

Shown on Table 1 are means and standard deviations ( ) for the dimensions of the head and face as well as for each sample's age, height and weight. The single concession made to known differences in measurement techniques is the indication by the letter "p" in front of the numerical value that the measurement for the RAF Head Survey (column 9) was made from standardized photographs of the head, and by the letters "pd" that a value was derived from two such measurements, normally by subtraction.

In Table 2 the USAF 1967 variable means are used as a base for comparison and all other group means shown as deviations from them. (A minus sign indicates a sample mean is smaller than the USAF 1967 mean, and the absence of a sign indicates a positive value.) The delta ($\Delta$) values are in some instances not inconsiderable. Using the variable head circumference, for example, we find the $\Delta$ ranging from +0.78 (RAAF Aircrew) to -1.26 centimeters (1965 USAF). As a ratio of the base (USAF 1967) value, this is +1.4% to -2.2% or 3.6% range in $\Delta$'s.

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*ASCC member nations of Working Party 61 include Australia, Canada, England, New Zealand and United States.

# TABLE 1

## SUMMARY STATISTICS OF SELECTED HEAD DIMENSIONS OF ASCC MILITARY POPULATIONS

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Variable Name* | 1967 USAF n=2420 | 1965 USAF n=3869 | 1950 USAF n=4000 | 1964 USN n=1549 | 1973 RNZAF n=238 | 1971 RAAF Aircrew n=385 | 1971 RAAF Cadets n=97 | 1971 RAF n=2000 | 1972 RAF Heads n=500 | 1962 RCAF n=604 | 1974 CF n=565 |
| 1 Head Circ | 57.52 (1.43) | 56.26 (1.65) | 57.03 (1.53) | 57.54 (1.40) | 57.65 (1.37) | 58.30 (1.50) | 57.70 (1.50) | 57.67 (1.36) | 57.70 (1.37) | 57.28 (1.52) | 57.75 (1.52) |
| 2 Sagittal Arc | 34.64 (1.66) | 37.85 (1.53) | 38.11 (1.52) | 36.91 (2.18) | | | | | | | 36.44 (1.98) |
| 3 Min Frontal Arc | 13.60 (0.79) | 11.97 (0.88) | 13.67 (0.96) | | | | | | 13.21 (0.67) | | |
| 4 Bit-Coronal Arc | 35.76 (1.26) | 35.08 (1.39) | 35.05 (1.24) | 35.52 (1.32) | 36.68 (1.28) | | | 35.34 (1.26) | 36.13 (1.26) | | 35.41 (1.36) |
| 5 Bit-Min Front Arc | 30.81 (1.00) | 30.48 (1.11) | 30.48 (1.05) | 30.20 (1.08) | | | | | 31.31 (0.94) | | |
| 6 Bit-Subnasal Arc | 29.31 (1.02) | 28.70 (1.17) | 28.98 (1.07) | 28.68 (1.06) | | | | | 29.12 (1.00) | | |
| 7 Bit-Menton Arc | 32.65 (1.24) | 31.41 (1.44) | 32.33 (1.23) | 32.21 (1.27) | | | | | 32.40 (1.30) | | |
| 8 Bit-Submandibular Arc | 30.98 (1.58) | 29.29 (1.67) | 30.62 (1.54) | 31.22 (1.42) | | | | | 29.78 (1.45) | | |
| 9 Bit-Posterior Arc | 29.45 (1.49) | | 29.37 (1.34) | 31.44 (2.09) | | | | | 27.49 (1.13) | | |
| 10 Head Length | 19.87 (0.67) | 19.62 (0.72) | 19.70 (0.64) | 19.83 (0.66) | 19.71 (0.68) | | | 19.90 (0.64) | p**20.53 (0.60) | 19.36 (0.78) | |
| 11 Head Diag from Menton | 25.60 (0.76) | 25.15 (0.86) | | | 25.31 (0.93) | | | 26.21 (0.77) | 25.87 (0.78) | | |
| 12 Ear Breadth | 3.80 (0.30) | 3.52 (0.33) | 3.66 (0.27) | 3.57 (0.33) | | | | | | | |
| 13 Ear Length | 6.60 (0.43) | 6.34 (0.46) | 6.27 (0.41) | 6.53 (0.40) | | | | | | | |
| 14 Ear Lgth above Tragion | 2.94 (0.29) | 2.87 (0.30) | 2.97 (0.28) | | | | | | | | |
| 15 Head Breadth | 15.60 (0.54) | 15.31 (0.58) | 15.41 (0.51) | 15.57 (0.53) | 15.21 (0.52) | 15.70 (0.50) | 15.50 (0.50) | 15.78 (0.54) | p 16.34 (0.56) | 15.29 (0.59) | |
| 16 Max Frontal Br | 11.60 (0.46) | 11.46 (0.48) | 11.96 (0.50) | 12.26 (0.72) | | | | | 11.19 (0.38) | | |
| 17 Bitragion Br | 14.25 (0.56) | 13.83 (0.65) | 14.22 (0.53) | 13.99 (0.52) | 13.68 (0.62) | | | 13.91 (0.50) | 13.76 (0.61) | | |
| 18 Face Breadth | 14.23 (0.52) | 13.99 (0.56) | 14.09 (0.50) | 13.62 (0.71) | | | | | 14.20 (0.52) | 13.47 (0.81) | 14.12 (0.53) |
| 19 Bigonial Br | 11.73 (0.69) | 10.72 (0.54) | 10.86 (0.55) | 11.91 (0.85) | | | | | 11.94 (0.52) | | |
| 20 Ear to Ear Br | 18.83 (0.81) | 18.43 (0.93) | | | | | | | | | |
| 21 Biocular Br | 9.17 (0.49) | 9.42 (0.53) | 9.59 (0.44) | 9.43 (0.41) | | | | | p 8.91 (0.43) | | |
| 22 Interpupillary Br | 6.27 (0.36) | 6.23 (0.39) | 6.33 (0.36) | 6.51 (0.28) | | | | | p 6.48 (0.33) | | |
| 23 Interocular Br | 3.33 (0.28) | 3.15 (0.28) | 3.17 (0.25) | 3.21 (0.29) | | | | | p 3.79 (0.33) | | |
| 24 Nose Breadth | 3.54 (0.29) | 3.42 (0.38) | 3.33 (0.26) | 3.54 (0.26) | | | | | p 3.73 (0.28) | | |
| 25 Lip Length | 5.23 (0.37) | 4.87 (0.44) | 5.16 (0.36) | 5.14 (0.43) | | | | | 4.79 (0.39) | | |
| 26 Ear Protrusion | 2.16 (0.34) | 2.11 (0.37) | 2.15 (0.36) | 2.19 (0.35) | | | | | | | |
| 27 Subnasale-Nasal Rt Lgth | 5.13 (0.37) | 5.10 (0.37) | 5.09 (0.34) | 5.34 (0.37) | | | | | pd†5.36 (0.39) | 5.00 (0.47) | |
| 28 Philtrum Lgth | 1.55 (0.28) | 1.47 (0.26) | 1.94 (0.34) | | | | | | | | |
| 29 Lip to Lip Length | 1.73 (0.38) | 1.86 (0.40) | 1.62 (0.31) | 1.66 (0.36) | | | | | | | |
| 30 Menton-Subnasale Lgth | 6.90 (0.53) | 7.01 (0.61) | 6.67 (0.69) | 7.02 (0.59) | | | | | pd 7.18 (0.50) | 7.15 (0.53) | |
| 31 Face Length | 12.03 (0.61) | 11.92 (0.68) | | | | | | | p 12.54 (0.62) | | 12.31 (0.64) |
| 32 Glabella-Vertex | 9.27 (0.97) | 9.21 (0.81) | | | | | | | p 9.79 (0.71) | | |
| 33 Nasal Root-Vertex | 10.75 (0.94) | 10.84 (0.78) | | | 10.25 (0.86) | | | 10.63 (0.96) | p 11.33 (0.77) | | |
| 34 X-Canthus-Vertex | 11.95 (0.77) | | | | 10.54 (0.89) | | | | p 12.04 (0.62) | | |
| 35 Pronasale-Vertex | 14.74 (1.10) | 14.83 (0.87) | | | | | | | | | |
| 36 Subnasale-Vertex | 16.09 (1.02) | | | | | | | | p 16.70 (0.76) | | |
| 37 Stomion-Vertex | 18.37 (1.00) | 18.23 (0.84) | | | | | | | p 18.92 (0.76) | | |
| 38 Menton-Vertex | 22.77 (1.02) | 22.67 (0.97) | | 22.18 (1.02) | 22.34 (1.09) | | | 22.95 (1.01) | p 23.87 (0.85) | | |
| 39 Tragion-Vertex | 13.45 (0.61) | | 12.97 (0.75) | 13.11 (0.64) | 13.25 (0.74) | | | 13.03 (0.64) | p 13.87 (0.53) | 13.07 (0.89) | |
| 40 Glabella to Wall | 20.35 (0.67) | 19.83 (0.71) | | | | | | | | | |
| 41 Nasal Root to Wall | 20.17 (0.66) | 19.60 (0.70) | 19.69 (0.86) | 20.04 (0.69) | | | | | p 20.25 (0.60) | | |
| 42 X-Canthus to Wall | 17.79 (0.66) | 17.21 (0.74) | 17.21 (0.79) | 17.78 (0.70) | | | | | p 17.86 (0.57) | | |
| 43 Pronasale to Wall | 22.68 (0.75) | 21.98 (0.82) | | 22.85 (0.76) | | | | | p 22.58 (0.70) | | |
| 44 Subnasale to Wall | 20.99 (0.79) | 20.55 (0.91) | | | | | | | p 20.79 (0.71) | | |
| 45 Lip Prom to Wall | 21.16 (0.86) | | | | | | | | | | |
| 46 Chin Prom to Wall | 20.47 (1.05) | | | | 20.92 (1.13) | | | 19.98 (1.07) | p 19.79 (0.88) | | |
| 47 Tragion to Wall | 10.33 (0.65) | 9.63 (0.68) | 10.23 (0.75) | 10.81 (0.76) | 10.23 (0.84) | | | 10.14 (0.69) | p 9.94 (0.57) | | |
| 48 Age | 30.03 (6.31) | 22.69 (6.49) | 27.39 (4.22) | | 27.84 (7.23) | | | 30.76 (6.49) | | | 31.53 (8.17) |
| 49 Height | 177.34 (6.19) | 175.28 (6.56) | 175.56 (6.16) | 177.64 (5.91) | 176.95 (6.48) | 176.80 (8.60) | 176.60 (6.20) | 177.00 (6.20) | | 175.99 (6.14) | 175.05 (6.32) |
| 50 Weight | 173.60(21.44) | 156.49(23.92) | 163.44(20.82) | 171.40(19.09) | 165.99(19.40) | 169.12(22.71) | 158.32(17.42) | 165.43(19.42) | | 167.56(20.43) | 169.69(25.86) |

*Age in years, weight in pounds, all others in cm.
**Measured from photographs.
†Derived from measurements made from photographs.



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## TABLE 2

## DEVIATIONS OF SAMPLE MEAN VALUES FROM THE USAF 1967 MEAN VALUES

| Variable Name* | 1<br>1967<br>USAF<br>n=2420 | 2<br>1965<br>USAF<br>n=3869 | 3<br>1950<br>USAF<br>n=4000 | 4<br>1964<br>U.S.Navy<br>n=1549 | 5<br>1973<br>RNZAF<br>n=238 | 6<br>1971 RAAF<br>Aircrew<br>n=385 | 7<br>1971 RAAF<br>Cadets<br>n=97 | 8<br>1971<br>RAF<br>n=2000 | 9<br>1972 RAF<br>Heads<br>n=500 | 10<br>1962<br>RCAF<br>n=604 | 11<br>1974<br>CF<br>n=565 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 Head Circ | 57.52 | -1.26 | -0.49 | 0.02 | 0.13 | 0.78 | 0.18 | 0.15 | 0.18 | -0.24 | 0.23 |
| 2 Sagittal Arc | 34.64 | 3.21 | 3.47 | 2.27 | | | | | | | 1.80 |
| 3 Min Frontal Arc | 13.60 | -1.63 | 0.07 | | | | | | -0.39 | | |
| 4 Bit-Coronal Arc | 35.76 | -0.68 | -0.71 | -0.24 | 0.92 | | | -0.42 | 0.37 | | -0.35 |
| 5 Bit-Min Front Arc | 30.81 | -0.33 | -0.33 | -0.61 | | | | | 0.50 | | |
| 6 Bit-Subnasal Arc | 29.31 | -0.61 | -0.33 | -0.63 | | | | | -0.19 | | |
| 7 Bit-Menton Arc | 32.65 | -1.24 | -0.32 | -0.44 | | | | | -0.25 | | |
| 8 Bit-Submandibular Arc | 30.98 | -1.69 | -0.36 | 0.24 | | | | | -1.20 | | |
| 9 Bit-Posterior Arc | 29.45 | | -0.08 | 1.99 | | | | | -1.96 | | |
| 10 Head Length | 19.87 | -0.25 | -0.17 | -0.04 | -0.16 | | | 0.03 | p** 0.66 | -0.51 | |
| 11 Head Diag from Menton | 25.60 | -0.45 | | | -0.29 | | | 0.61 | 0.27 | | |
| 12 Ear Breadth | 3.80 | -0.28 | -0.14 | -0.23 | | | | | | | |
| 13 Ear Length | 6.60 | -0.26 | -0.33 | -0.07 | | | | | | | |
| 14 Ear Lgth above Tragion | 2.94 | -0.07 | 0.03 | | | | | | | | |
| 15 Head Breadth | 15.60 | -0.29 | -0.19 | -0.03 | -0.39 | 0.10 | -0.10 | 0.18 | p 0.74 | -0.31 | |
| 16 Max Frontal Br | 11.60 | -0.14 | 0.36 | 0.66 | | | | | -0.41 | | |
| 17 Bitragion Br | 14.25 | -0.42 | -0.03 | -0.26 | -0.57 | | | -0.34 | -0.49 | | |
| 18 Face Breadth | 14.23 | -0.24 | -0.14 | -0.61 | | | | | -0.03 | -0.76 | -0.13 |
| 19 Bigonial Br | 11.73 | -0.01 | -0.87 | 0.18 | | | | | 0.21 | | |
| 20 Ear to Ear Br | 18.83 | -0.40 | | | | | | | | | |
| 21 Biocular Br | 9.17 | 0.25 | 0.42 | 0.26 | | | | | -0.26 | | |
| 22 Interpupillary Br | 6.27 | -0.04 | 0.06 | 0.24 | | | | | p 0.21 | | |
| 23 Interocular Br | 3.33 | -0.18 | -0.16 | -0.12 | | | | | p 0.46 | | |
| 24 Nose Breadth | 3.54 | -0.12 | -0.21 | 0.0 | | | | | p 0.19 | | |
| 25 Lip Length | 5.23 | -0.36 | -0.07 | -0.09 | | | | | -0.44 | | |
| 26 Ear Protrusion | 2.16 | -0.05 | -0.01 | 0.03 | | | | | | | |
| 27 Subnasale-Nasal Rt Lgth | 5.13 | -0.03 | -0.04 | 0.21 | | | | | 0.23 | -0.13 | |
| 28 Philtrum Length | 1.55 | -0.08 | 0.39 | | | | | | | | |
| 29 Lip to Lip Length | 1.73 | 0.13 | -0.11 | -0.07 | | | | | | | |
| 30 Menton-Subnasale Lgth | 6.90 | 0.11 | -0.23 | 0.12 | | | | | pd† 0.28 | | |
| 31 Face Length | 12.03 | -0.11 | | | | | | | p 0.51 | | 0.28 |
| 32 Glabella-Vertex | 9.27 | -0.06 | | | | | | | p 0.52 | | |
| 33 Nasal Rt-Vertex | 10.75 | 0.09 | | | -0.50 | | | -0.12 | p 0.58 | | |
| 34 X-Canthus-Vertex | 11.95 | | | | -1.41 | | | | p 0.09 | | |
| 35 Pronasale-Vertex | 14.74 | 0.09 | | | | | | | | | |
| 36 Subnasale-Vertex | 16.09 | | | | | | | | p 0.61 | | |
| 37 Stomion-Vertex | 18.37 | -0.14 | | | | | | | p 0.55 | | |
| 38 Menton-Vertex | 22.77 | -0.10 | | -0.59 | -0.43 | | | 0.18 | p 1.10 | | |
| 39 Tragion-Vertex | 13.45 | | -0.48 | -0.34 | -0.20 | | | -0.42 | p 0.42 | -0.38 | |
| 40 Glabella to Wall | 20.35 | -0.52 | | | | | | | | | |
| 41 Nasal Rt to Wall | 20.17 | -0.57 | -0.48 | -0.13 | | | | | p 0.08 | | |
| 42 X-Canthus to Wall | 17.79 | -0.58 | -0.58 | -0.01 | | | | | p 0.07 | | |
| 43 Pronasale to Wall | 22.68 | -0.70 | | 0.17 | | | | | p -0.10 | | |
| 44 Subnasale to Wall | 20.99 | -0.44 | | | | | | | p -0.20 | | |
| 45 Lip Prom to Wall | 21.16 | | | | | | | | | | |
| 46 Chin Prom to Wall | 20.47 | | | | 0.45 | | | -0.49 | p -0.68 | | |
| 47 Tragion to Wall | 10.33 | -0.70 | -0.10 | 0.48 | -0.10 | | | -0.19 | p -0.39 | | |
| 48 Age | 30.03 | -7.34 | -2.64 | | -2.19 | | | 0.73 | | | 1.50 |
| 49 Height | 177.34 | -2.06 | -1.78 | 0.30 | -0.39 | -0.54 | -0.74 | -0.34 | | -0.97 | -2.29 |
| 50 Weight | 173.60 | -17.11 | -10.16 | -2.20 | -7.61 | -4.48 | -15.28 | -8.17 | | -6.04 | -3.91 |

*Age in years, weight in pounds, and all others in cm.
**Measured from photographs.
†Derived from measurements made from photographs.



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Delta values must be approached with caution since they do not always reflect actual deviations between comparable samples; rather, they can often be the result of anomalies inherent in the data-gathering process. Among the common problems of anthropometric comparison are (1) variability in measuring techniques and/or landmarks used by different anthropometrists and (2) the variability in the composition (age, stature, weight, ethnic background, etc.) of the different populations surveyed.

It is obvious from some of the delta values in Table 2 that despite the similarity of variable names, different techniques/landmarks may have been employed. We see, for example, that Minimum Frontal Arc (Variable 3) for the USAF 1965 sample is 12% less than the USAF 1967 value, raising the strong possibility that different forehead landmarks were used for the measurement. Deviations of this magnitude strongly suggest differences in landmark interpretation, especially when viewed in conjunction with the fact that for the same two samples the differences in Bitragion-Minimum Frontal Arc (Variable 5) are only 1%.

Further evidence that some variations in data are caused by differences in measuring techniques can be seen by studying Figures 1-3 in which the means, plus/or/minus two standard deviations, are plotted for three variables: head circumference (Figure 1), head length (Figure 2), and head breadth (Figure 3). The area between the dotted lines represents the plus/or/minus two standard deviations (95%) variance for the 1967 USAF sample. It will be noted that the head circumference for the RAF 1971 Survey and the RAF Head Survey are essentially identical (Figure 1), whereas the head length (Figure 2) and head breadth means (Figure 3) of the RAF head study are approximately a standard deviation larger than the comparable dimensions of the RAF 1971 study. As noted above, in the RAF head study head circumference was measured in the traditional manner while the latter two variables were measured from photographs.

A second course of artifactual variability in comparing anthropometric head data from different surveys is the possible difference in age and general body size of the subject populations. One means of demonstrating this kind of difference is to examine a survey in which one can assume that the measurement techniques are comparable throughout and compare the head data for specific subsets within that survey population. The USAF 1965 survey, for example, contained a number of subsets and selected head measurements from three such groups and are shown in the following table.

TABLE 3

USAF 1965 SUBSETS--MEAN VALUE OF SELECTED VARIABLES *

| n | Subset | Age | Stature | Weight | Head Circ | Head Length | Head Breadth |
|---|---|---|---|---|---|---|---|
| 2527 | Basic Trainees | 18.82 | 175.07 | 68.73 | 55.88 | 19.53 | 15.21 |
| 792 | Enlisted | 26.01 | 174.72 | 73.46 | 56.64 | 19.69 | 15.40 |
| 549 | Officers | 32.09 | 177.10 | 77.77 | 57.47 | 19.95 | 15.66 |

* Age in years, weight in kilograms, all other values in centimeters.

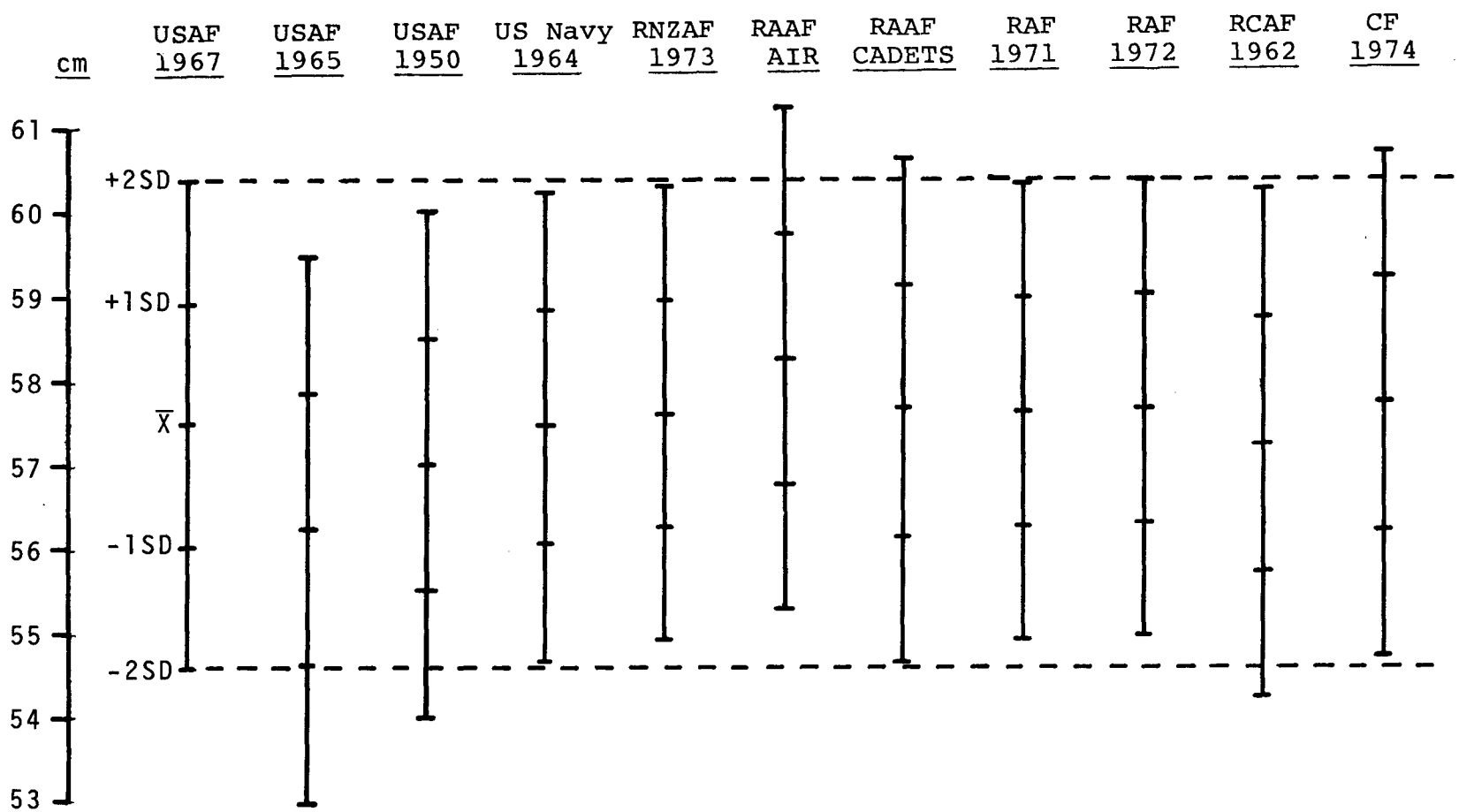


Figure 1. Head circumference.

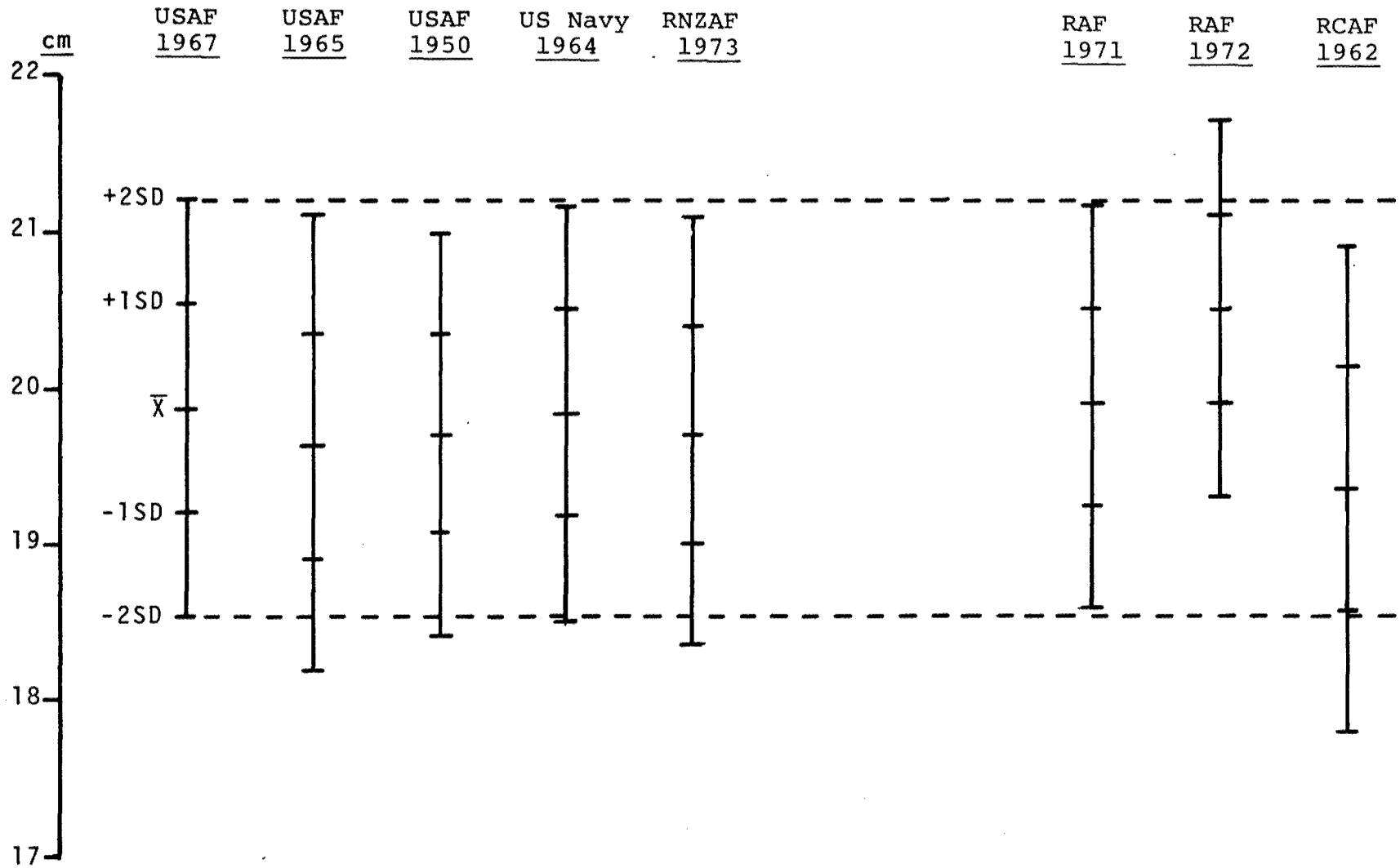


Figure 2. Head length.

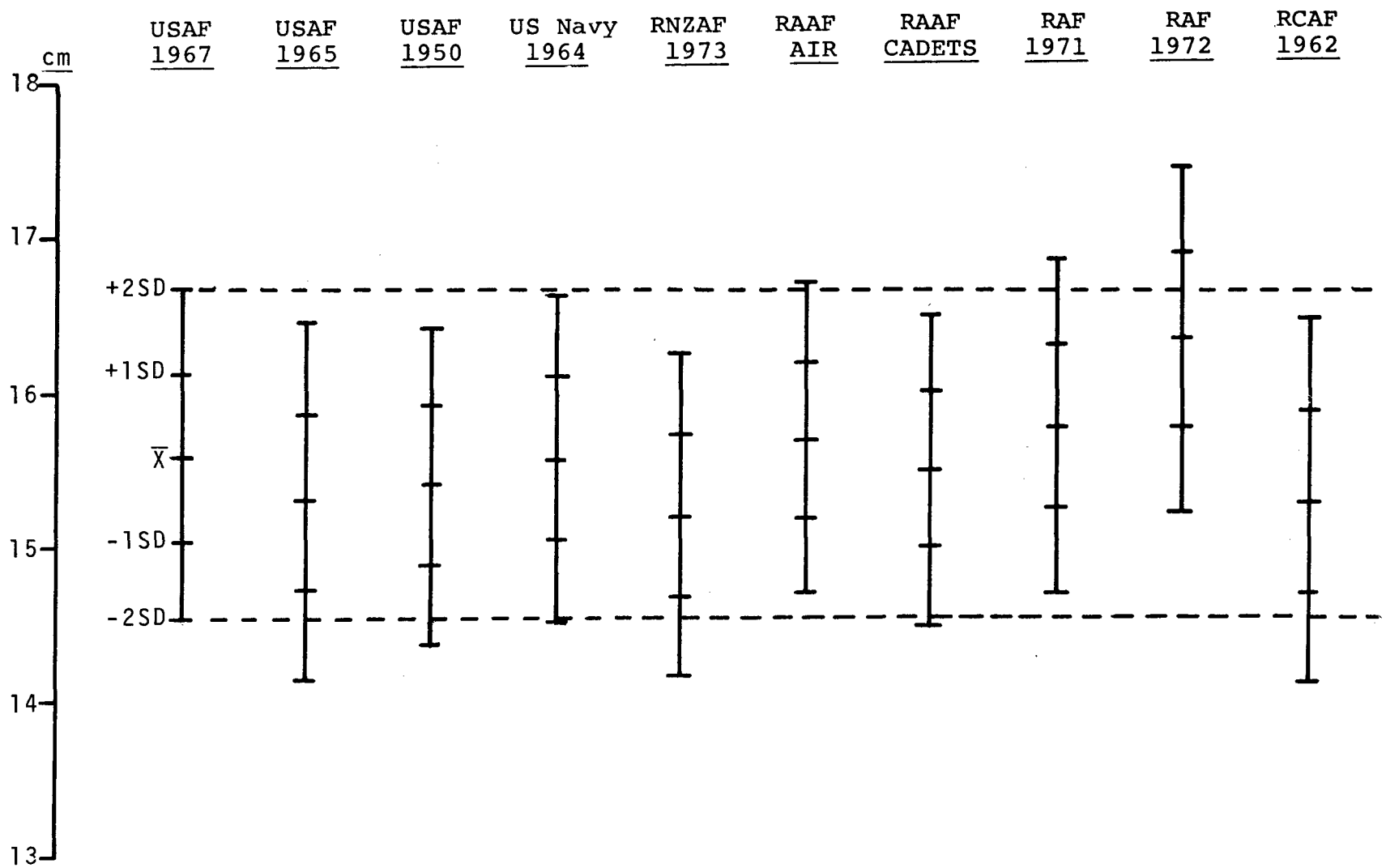


Figure 3. Head breadth.

As can be observed, the range of age, stature and weight is considerable. Correspondingly, the range of the head measurements is also of noticeable magnitude. The range of subgroups means from smallest to largest delta for head circumference is 1.59 cm; for head length, 0.42 cm; and for head breadth, 0.45 cm. This level of variance approaches that for the samples tabulated in Table 1, as can be seen in the following comparison.

TABLE 4

INTER-POPULATION VARIATION VS. INTRA-POPULATION VARIATION FOR SELECTED HEAD VARIABLES

| | Head Circ Δ Means | Head Length Δ Means | Head Breadth Δ Means |
|---|---|---|---|
| Selected subsets, 1965 Survey | 1.59 cm | 0.42 cm | 0.45 cm |
| Eleven surveys cited in Table 1* | 2.04 cm | 0.54 cm | 0.57 cm |

What is apparent from these comparisons is that the differences in head dimensions between the various ASCC groups are relatively small when viewed against the range of variability within any single sample. With this factor in mind, it is of some interest to determine how well design criteria developed by one ASCC nation might accommodate service personnel from other ASCC nations.

Test of Anthropometric Comparability: There is not, unfortunately, a great deal of published material on recommended anthropometric design criteria for helmet sizing. The recent publication by Simpson, Specimen Size Rolls for Aircrew Headgear Based on an Analysis of the Head Measurements of 2000 RAF Air Crew, contains a six-size head circumference sizing program similar to the one recommended by Zeigen for the USAF in 1960. The American program has been widely used and the head forms developed as a part of this program are accepted as a standard by many military and industrial designers in the United States. The key or sizing variable, head circumference, was not broken out into comparable head-size categories in the two sizing programs so, in order to make a comparison possible, the USAF 1967 data were reanalyzed to correspond to the six sizing categories recommended in the RAF program. The results of this comparison are shown in Table 5. The table lists in columns the difference (Δ) in centimeters (USAF size category mean minus RAF size category mean), the average difference for the six size categories, disregarding sign $(|\bar{\Delta}|)$, and this difference as a percent of the RAF mean value $\left(\frac{|\bar{\Delta}|}{\bar{x}}\right)$. The first

*The 1972 RAF head data, measured from photographs, were excluded from the computation because the variance in the results would have unnecessarily skewed the results.

TABLE 5

DEVIATIONS OF SIZING MEANS BETWEEN USAF AND RAF ANTHROPOMETRY COMPARED IN AN RAF SIX-SIZE HEAD CIRCUMFERENCE SIZING SYSTEM

| HEAD CIRC RANGE (cm) | Size 1 53.6-54.9 | Size 2 55.0-56.3 | Size 3 56.4-57.7 | Size 4 57.8-59.1 | Size 5 59.2-60.5 | Size 6 60.6-62.0 | $\lvert\bar{\Delta}\rvert$ | $\frac{\lvert\bar{\Delta}\rvert}{\bar{x}}$ |
|---|---|---|---|---|---|---|---|---|
| TARIFF Δ% | +1.08 | +3.65 | -0.38 | -3.30 | -0.95 | -0.11 | 1.58 | - |
| Head Breadth Δ cm* | 0.06 | -0.09 | -0.16 | -0.17 | -0.17 | -0.24 | 0.15 | 0.95% |
| Head Length | 0.03 | 0.03 | 0.03 | 0.01 | 0.04 | 0.24 | 0.06 | 0.30 |
| Head Circ | -0.05 | 0.01 | 0.02 | -0.01 | 0.01 | 0.11 | 0.04 | 0.07 |
| Bitrag-Coronal Arc | 0.71 | 0.43 | 0.49 | 0.48 | 0.59 | 0.67 | 0.56 | 1.58 |
| Bitragion Breadth | 0.33 | 0.40 | 0.36 | 0.37 | 0.34 | 0.25 | 0.34 | 2.44 |
| Max Diag from Menton | -0.46 | -0.55 | -0.51 | -0.61 | -0.59 | -0.55 | 0.55 | 2.10 |
| Menton to Wall | 0.52 | 0.64 | 0.53 | 0.52 | 0.49 | 0.84 | 0.59 | 2.95 |
| Menton to Vertex | -0.06 | -0.24 | -0.29 | -0.15 | -0.08 | -0.33 | 0.16 | 0.70 |
| Tragion to Wall | 0.38 | 0.29 | 0.18 | 0.23 | 0.16 | 0.34 | 0.26 | 2.56 |
| Tragion to Vertex | 0.55 | 0.41 | 0.41 | 0.45 | 0.58 | 0.33 | 0.46 | 3.53 |
| Nasion to Vertex | 0.12 | 0.03 | 0.12 | 0.12 | 0.35 | 0.23 | 0.16 | 1.51 |
| Nasion to Menton | -0.25 | -0.28 | -0.22 | -0.27 | -0.34 | -0.52 | 0.31 | 2.52 |

* USAF 1967 size subgroup mean value minus RAF size subgroup mean value.

row of the table shows the difference in tariffs for the two samples. The tariffs (ratio of number of subjects in the sizing category subgroup to total sample size) range in absolute difference from a minimum of 0.11 (Size 6) to a maximum of 3.65 (Size 2) with an average absolute deviation of 1.56% and includes 100% of the RAF sample and 99.75% of the USAF 1967 sample. This suggests that the head circumference distributions of the two samples were very similar, a conclusion reinforced by comparison of the mean head circumferences of the six subgroups. Scanning across the table, it can be seen that the differences in head circumference range from 0.01 to 0.11 cm with the average absolute difference of the six being 0.04 cm. The variables of head length and head breadth also show a very low order of difference as would be expected due to their rather strong relationship with head circumference. The remaining variables show a greater level of difference due, in part, to possible differences in measuring techniques but also partly due to the generally low level of relationship between most of the dimensions of the head and face. What this means, of course, is that by control of a key or sizing dimension, such as head circumference, we effectively control its variance and that of the dimensions most highly correlated with it but exert modest control of the variance of the other head and face dimensions. The standard deviations of the dimensions listed in Table 5 for each of the six sizing category subgroups were found to be virtually identical in most instances. This would mean that helmet design dimensions based on category means and standard deviations would be essentially the same for the two populations.

Conclusions. It appears, therefore, that helmets or other headgear which are successfully fitted for a member nation's flying personnel could be fitted with equal success to the flying personnel of other ASCC nations.

One final note: if anthropometric surveys are to be used for comparative purposes, it is of singular importance that anthropometric techniques be standardized or, if that is not possible, that measuring techniques be fully reported so as to facilitate assessment of their comparability.

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