TECHNICAL BRIEF

Relationship Between Head Mass and Circumference in Human Adults

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INTRODUCTION

Although a number of studies have been performed to characterize the mass and inertial properties of the human head in both cadaver and living subjects [1-8], a correlation between head anthropometry and head mass has not been previously reported. This technical brief presents data that was collected at the University of Washington as part of a Cooperative Research And Development Agreement (CRADA No. 98-138-HE-01) between the US Air Force Research Laboratory (Biodynamics and Acceleration Branch) and the University of Washington's Applied Biomechanics Laboratory (formerly the Orthopaedic Biomechanics Laboratory). These data were collected in 1999 as part of an investigation on the potential for using computed tomography (CT) to calculate the inertial properties of the human head using cadaver specimens. While the mass and inertial properties of these test subjects were reported in several published documents [9-10], a direct correlation between head mass and anthropometry from this data set had not been previously examined or reported until now. This relationship may be of value in estimating human head mass from head anthropometry.

METHODS

A brief description of the methods used to acquire the head mass and anthropometry is included below. A more detailed presentation of the methods, which includes all other measurements made to meet the goals of the original study, can be found in the referenced paper [9].

Specimens

A total of 15 human cadaver specimens (i.e., head/neck complexes) were obtained for this study from the International Institute for the Advancement of Medicine (Scranton, PA). The subject demographics were eight males ranging in age from 16 - 80 years (mean 56±22 years), and seven females ages 23-97 years (mean 62±24 years). The overall mean age was 59±22 years.

The specimens were harvested immediately following autopsy and stored fresh frozen (unembalmed) at -20°C until used in the study. Each specimen was pre-screened by the biospecimen provider for blood-borne pathogens (Hep-B and HIV) and for any previous history of head or neck trauma. Upon receipt of the specimens, radiographic assessment was made to rule out any gross pathology or abnormalities. The head anatomy that was included in the measurement protocols was the entire head disarticulated from the cervical spine at the occipital condyles, similar to the studies by Walker et al. [4] and Beier et al. [6]. The hair from each head was shorn using barbers shears to reduce any measurement artifact due to the hair. The handling of all biological tissues was in accordance with Centers for Disease Control (CDC) guidelines and procedures.

Mass Measurements

To obtain the mass and inertial properties of the cadaver heads, a digital mass and moment table (Model XR-50 Mass Properties Instrument, Space Electronics LLC, Berlin, CT) was used (see Figure 1). Each specimen's mass, center of gravity (CG), and moments of inertia (MOIs) were measured, however only the head mass will be presented in this report. The mass of each specimen was measured twice, and the mean was calculated and used in this analysis.

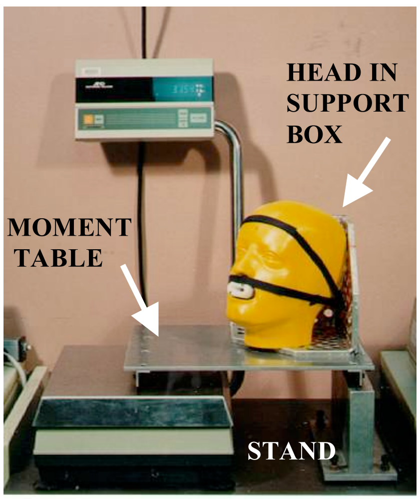

Figure 1. *Manikin head in XR-50 Mass Properties Instrument being measured for CGx.*

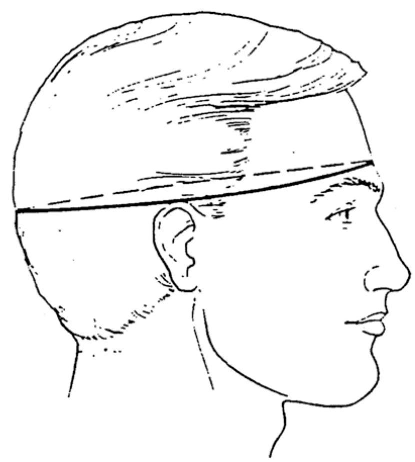

Figure 2. *Diagram of head circumference measurement made using a cloth ribbon tape.*

Anthropometry Measurements

Basic head anthropometry was also measured in the original study, but was not reported in any of the resulting publications. These metrics included head circumference, head length, and head breadth. The head circumference measurements were made using ribbon tape and the length and breadth measurements using calipers. The maximum head circumference of the head was recorded above the supraorbital ridges (above the eyebrows) and ears as shown in Figure 2.

RESULTS

The results of the head mass and anthropometry measurements are shown in Table 1. Linear regression and correlation analysis for mixed-gender head mass as a function of head circumference yielded strong correlation with an r-squared value of 0.9014 (see Figure 3). Similar analyses for head length and breadth (versus head mass) produced weak correlations (Figure 4).

Table 1. *Measured head mass and anthropometry data for 15 human cadaver specimens.*

	Subject #	Age (Years)	Head Mass (Kg)	Circumference (cm)	Length (cm)	Breadth (cm)
Females	F-02	68	2.98	53.7	18.4	14.3
	F-05	70	2.78	53.3	18.1	14.3
	F-06	49	3.00	54.3	15.0	11.2
	F-07	97	2.75	54.0	18.0	15.0
	F-13	23	2.78	52.0	18.3	13.8
	F-15	51	3.09	54.0	18.5	14.0
	F-17	77	2.87	52.7	17.4	14.3
	Mean	**62**	**2.89**	**53.4**	**17.7**	**13.8**
	Std. Dev.	**24**	**0.13**	**0.8**	**1.2**	**1.2**
Males	M-09	44	3.04	53.0	18.0	14.2
	M-10	46	4.38	60.3	25.0	15.5
	M-11	55	3.53	56.4	18.7	15.1
	M-12	16	3.96	58.5	20.0	15.7
	M-14	68	3.75	55.7	18.9	15.9
	M-18	83	3.21	55.3	18.6	14.6
	M-19	80	2.92	55.2	18.7	15.3
	M-20	59	4.45	60.8	19.7	16.4
	Mean	**56**	**3.65**	**56.9**	**19.7**	**15.3**
	Std. Dev.	**22**	**0.58**	**2.7**	**2.2**	**0.7**

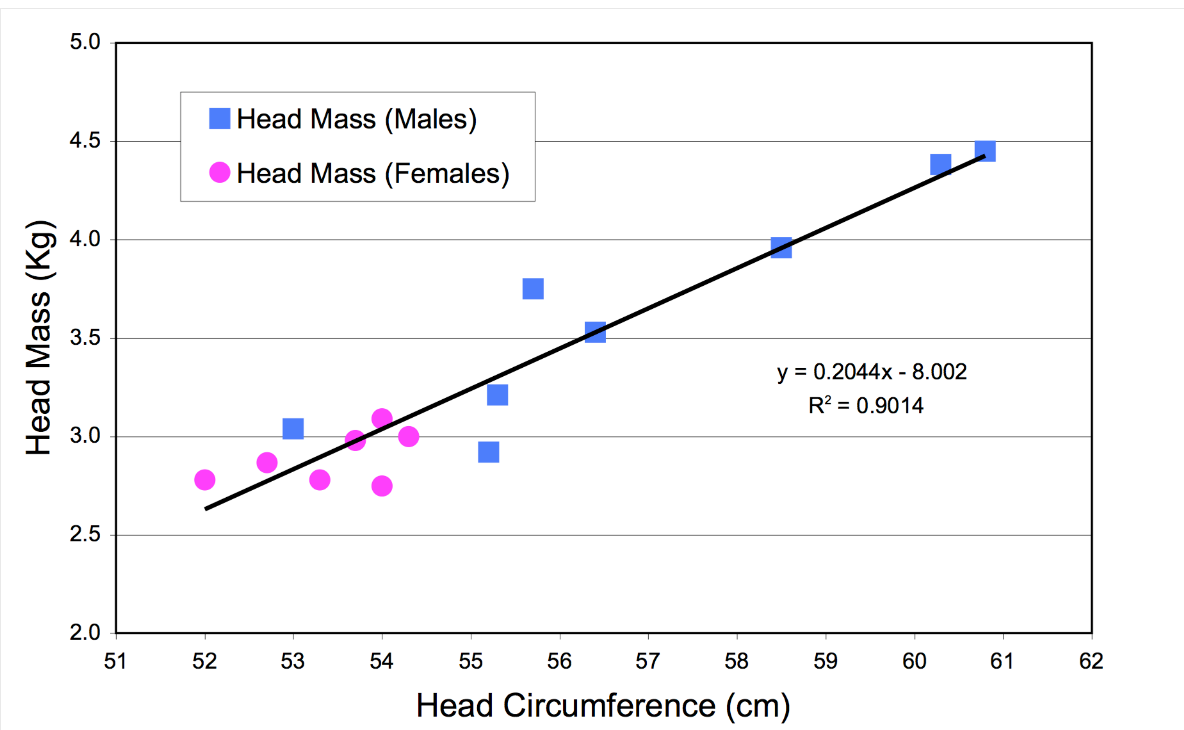

Figure 3. *Plot of human head mass as a function of head circumference. The linear regression was made for both males and females combined.*

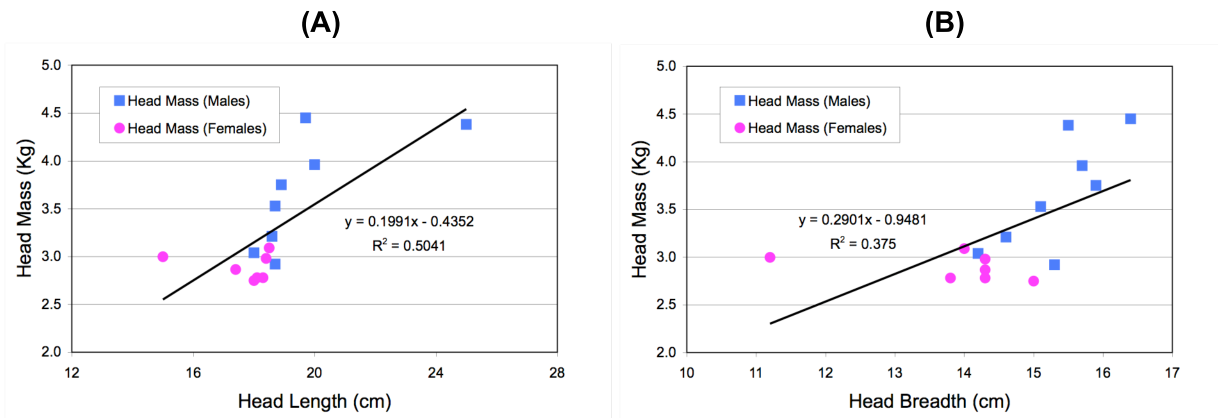

***Figure 4.** Plots of head mass as a function of **(A)** head length, and **(B)** head breadth.*

DISCUSSION

A number of papers and reports have presented mass and inertial properties of the human head [1-10]; however, I am unaware of any that have performed a correlation analysis with head anthropometry to determine whether head mass can reasonably predicted from head geometry. This technical brief presents an analysis performed using head mass and anthropometry data collected at the University of Washington as part of a previous investigation [9], but which had not been correlated or published.

The findings of the current analysis suggest that of the three anthropomorphic metrics compared (head circumference, length and breadth), head circumference was a reliable predictor of head mass. An r-squared correlation coefficient of 0.9014 demonstrated a strong relationship between these two parameters. Much weaker correlations were observed between head mass and head length and breadth.

A closer examination of the head length and breadth data (Table 1) revealed that one female subject (#F-06) with the smallest head length and breadth measurements (15.0 and 11.2 cm respectively) appeared to be an outlier, however her head circumference (54.3 cm) was actually above the female mean. Hence, while the correlations between head mass and length/breadth would have been improved (r^2 = 0.5562 for length an r^2 = 0.6529 for breadth) by removing this subject, there was insufficient justification to do so. One thought is that length or breadth alone does not take into account the shape of the human head. So, for example, a "pear-shaped" transverse cross-section could have short length and breadth measurements, but might have a normal circumference. Nevertheless, even if we had removed subject #F-06 from the analysis, head circumference would have remained the best predictor of head mass by more than 24%.

Limitations of this study include the use of fresh frozen cadaver tissues. It is certain that fluid loss from the brain (e.g., cerebral spinal fluid) and soft tissues structures occurred during the dissection and storage process. This would explain the lower average mass values of our male subjects (under 4 Kg) as compared to the results of previous studies which ranged from 4 to 5 Kg. However, all of the specimens in this study underwent the same protocols and were stored under the same conditions, hence this consistency would have provided for similar losses in fluid mass among specimens. Ideally, these measurements would have been best made immediately following autopsy; unfortunately this would not have been possible. Another limitation is the small sample size contained in this study. An "n" of 15 is considered small especially given a mixed-gender sample. More specimens would obviously strengthen the findings of this study, however the number of samples was limited by the availability of funds.

CONCLUSIONS

The findings of this technical brief demonstrate a strong relationship between head mass and head circumference based on a study of 15 human cadaver heads. Head length and breadth were not well correlated with mass. Although additional specimen data would help to increase confidence in this observed relationship, this is the first study to report a direct correlation between human head mass and circumference.

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