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Determination of Surface Area of Head for Biomedical and other Applications

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ABSTRACT

A simple, rapid and reproducible method has been devised for measuring the surface area of the head relevant for armour design. In this method, the following stages are involved : (i) securing a kraft paper over the head with the help of elastic band, (ii) tightly folding the paper wherever necessary to make a snug contour-matched paper dome, (iii) marking the folded areas with lines, (iv) spreading the paper and cutting out areas within the folds and the area falling outside the marked periphery of interest, (v) weighing the cut-out pieces and a few pieces of known area from the same sheet, and finally (vi) calculating the head-surface area. Preliminary data on 12 volunteers indicated that head-surface area has no significant correlation with their age, total body-surface area calculated from height and weight or with the circumference of their heads. A significant and positive correlation was found with cephalic length. The new method can find application in biomedical studies and head gear designs (e.g. helmets).

INTRODUCTION

Measurements of skin-fold thickness, height and weight, thoracic and cephalic dimensions[1] are generally done for anthropometric characterisation and classification of individuals. An important parameter in physiological studies, such as basal metabolic rate, is the estimation of total body or skin-surface area. Loss of body heat or moisture depends on body-surface area. Exposure to chemicals or radiation depends on the body surface area. So, there is the probability of being hit by enemy fire in a battlefield. For designing helmets, the estimates of the surface area of heads of individuals are required. Extensive research has been conducted on the problem of body-surface area measurements and in fact, a simple formula is available for the calculation of skin-surface area from the measurement of a subject's height and weight[2]. But, no suitable simple method could be found in published literature for measuring head-surface area. Also, no published correlation could be found with other cephalic parameters. In this communication, a simple, rapid and reproducible method devised specifically for measuring the surface area of the head relevant for armour design, has been reported. The method has potential use in biomedical research as well.

2. MATERIALS AND METHODS

2 Method of Surface Area Determination

The volunteer's head was wrapped with kraft paper (72 × 56 cm) of uniform thickness. The sheet was so placed that the approximate centre of the sheet touched the mid-point of the scalp. The ends of the sheet were drawn downwards and an elastic circular band was fixed on the paper spread over the head ensuring that the periphery of the band touched the glabella on the forehead, upper ear margins on either side, and a point lying 2 cm below the farthest occipital point on the rear of the head.

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Wherever necessary, tight inward folds of the paper were made to make a smooth, snug, contour-matched shape of the head as shown in Fig. 1(a). The elastic band helped to hold the folds in place. The paper dome fitting on the head presented a continuous appearance due to the juxtaposition of edges of the invaginated sectors of the sheet. Such folded areas were marked with fine lines for subsequently distinguishing them from the continuous areas on the paper. The periphery of the area of interest was marked. The elastic band and the paper dome were then removed from the head.

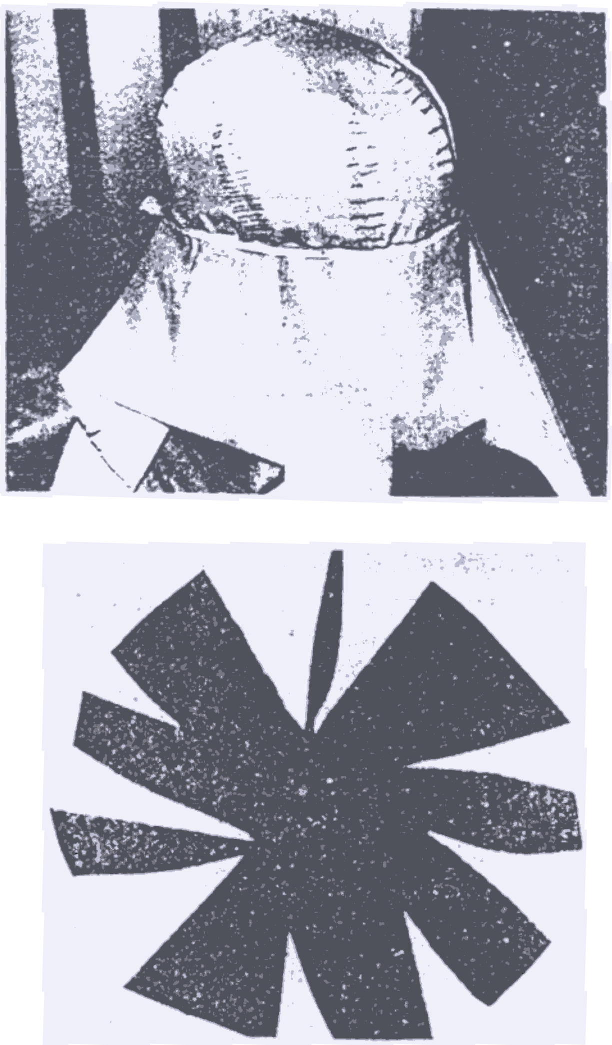

Figure 1 Method for head-surface area measurement : (a) Head covered with paper and folds marked with lines, and (b) cut-out corresponding to area of interest.

With the help of fine scissors, portions of the paper that went into the folds—indicated as areas that broke continuity of the markings—as well as those which were outside the marked peripheral line, were cut-out. The cut-out corresponding to the head-area of interest is seen in Fig. 1(b).

From the discarded major part of the sheet four rectangular pieces of known dimensions (e.g. 11 × 15 cm) were also removed. The paper cut-out was weighed in a sensitive analytical balance (Essae-Digi Counting Scale DC-80; M/s Essae Teraoka, Bangalore) and the weight, W_1, was accurately recorded. The four rectangular pieces of paper were together weighed and their weight, W_2, was also recorded.

From the gravimetric data the head-surface area A_h was calculated by applying the formula,

$$A_h = (W_1/W_2)\,A$$

where W_1 is weight in grams of the paper representing the actual area of the head, A is the total area in cm^2 of the four rectangular paper pieces (4 × length × breadth in cm) and W_2 is the total weight in grams of the four pieces of paper.

Reproducibility of the method was determined by carrying out the measurement on a single individual in quintuplicate and calculating the coefficient of variation, CV. Subsequently, determinations of head-area were carried out on 12 different individuals in separate experiments.

2.2 Precautions for Accurate A_h Determination

For exact determination of surface areas of interest, care has to be taken regarding cleanliness of both the paper and the head. Uniformity in the thickness of the paper is also important. Crimps in the paper and overlaps will bring in errors and hence should be avoided. Similarly, no extraneous matter (e.g. hair oil) should be allowed to be absorbed into or be stuck over the paper while folding it on the head since that can give false and high values of the surface area. Clean surfaces ensure accurate results. Sensitivity of the balance used for weighing papers is also important. Certainly, tonsured heads are ideal for more accurate results since at least in certain cases there can be variation in the thickness of hair. Also a larger number of samples can give more reliable information; and paired data on non-tonsured and tonsured heads can help in the calculation of correction factors.

2.3 Other Measurements

Length of the curve connecting the glabella, upper ear margins, and a point 2 cm below the farthest occipital point was measured as circumference. Maximal cephalic length was measured from glabella in front to the furthest occipital point in the rear. Height and weight of individual volunteers were accurately recorded. From these values total body-surface area was calculated using the formula of Meeh as modified by Du Bois and Du Bois[2] :

$$A = W^{0.425} \times H^{0.725} \times 71.84$$

where, A is surface area in cm^2, W is weight in kg, and H is height in cm.

2.4 Statistical Analysis

Coefficient of variation (CV) and correlation coefficient (r) of calculated head-area of interest, with height, weight, total body-surface area, head-circumference, cephalic length, etc., were calculated from the conventional formulae[3] and their significance evaluated.

3. RESULTS

Different morphometric values of the individuals studied are given in Table 1. It can be seen that measured head-surface area varied between 507 and 740 cm^2. The area of our interest formed 3.63 per cent of total body-surface area (Table 1) calculated from height and weight of the individuals[2]. In the present study, total body-surface area of the people varied between 15676 and 18830 cm^2.

An attempt has been made to analyse if there is any correlation between different parameters, such as age, body-surface area, height, length, etc. with the estimated approximate head-surface area. It is seen that the head-surface area surprisingly has very little correlation with total body-surface area (Table 1). Between height and weight which went into total body-surface area calculation[2], the former has better (though not significant) correlation than the latter, with head-surface area. The correlation coefficient of 0.2069 with head-circumference is also not statistically significant.

Significant positive correlation ($r = 0.57$; $P < 0.05$) was obtained between maximal cephalic length and

Table 1. Anthropometric details and statistical data

Parameter	Value	Mean±SD	Correlation coefficient* (r)	
Head-surface area (cm^2)	507-740	624.5±57.0		
Age (yr)	31-56	43.3±6.9	0.1591	>0.05
Height (cm)	157-177	166.3±8.0	0.1705	>0.05
Weight (kg)	51-83	65.0±9.6	0.0604	>0.05
Total body-surface area (cm^2)	15676-18830	17203±1184	0.0053	>0.05
Head circumference (cm)	53-5'	55.5±1.2	0.2069	>0.05
Maximal cephalic length (cm)	31-36	33.2±1.2	0.5706	
Upper ear marginal distance (breadth) (cm)	28-32	30.0±1.6	0.4909	<0.05
Rectangular area (calculated) (cm^2)	868-1116	996±77	0.5913	<0.05

* In relation to head area of interest (see text for more details; n = 12)

measured head-surface area. Rectangular area obtained by multiplication of maximal cephalic length with distance between upper margins of ears (breadth) also gave a good correlation ($r = 0.59$; $P < 0.05$).

4. DISCUSSION

The method devised by us for head-surface area measurement proved not only very simple but also rapid and reproducible. Total time needed for folding the paper over head and further steps of marking folded areas, cutting and weighing was about 15 min. Reproducibility of the method was also good since the coefficient of variation by the method was found to be only 4.3.

The paper-fold method devised by us for head-surface area measurement is fairly simple and can be adopted for other applications as well. It may be possible to extend this method for the measurement of surface area of other parts of the body, such as chest and for anthropological, neonatological as well as zoomorphometric and toxicological studies. It could also be used to find the surface area of inanimate objects. Material requirement, say, for coating, or for providing covers, head gears, or helmets of specified weight per unit area can be approximated.

Determination of surface area of head will be more useful in biomedical studies as also in the design of helmets. For biomedical applications the method might prove to be one of the best if measurements are done with larger sample sizes on tonsured heads though in relation to headgears hair thickness can be of no significance since they are worn over heads with hair. The covered kraft paper can be used to make casts for manufacturing headgears. If headgears are thus moulded to perfectly fit the heads, then by using these casts their weights would indeed be the minimum and be related to the head-surface area as measured by this technique. Often, helmets are being made using head circumference as the indicator for size, while head height, head length, head width are also critical measurements for standardisation of headgears. From the results given in Table 1, it is seen that head-surface area is related to cephalic length and breadth.

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REFERENCES

Williams, P.L.; Warwick, R.; Dysan, M. & Bannister, L.H. Gray's anatomy, Ed. 37. Churchill Livingstone Publishers, Edinburgh, 1989. p. 396.

2 Best, C.H. & Taylor, N.B. The physiological basis of medical practice, Ed. 8. Scientific Book Agency, Calcutta, 1967. p. 1286.

3 Raghuramulu, N.; Nair, K.M. & Kalyanasundaram, S. A manual of laboratory techniques. National Institute of Nutrition, Hyderabad, 1983. p. 281.