An Anthropometric Study of Head for Designing Ergonomic Helmet for Acehnese Adults

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Abstract. One of the fundamental applications of ergonomics is the use of an anthropometric approach for product design and evaluation. Redesigning ergonomic helmets using anthropometric methods is the aim of the study. In this study, participants consisted of 102 women and 102 men who were involved voluntarily. Based on the preliminary study, we found the following head dimensions considered important for helmet design, including: Head breadth, Menton to top of the head, Diametric menton to back of the head, Nose to top of head, Pronasale to back of head, Face breadth, and Eye to back of head. Anthropometric data are presented in this paper, and proposed helmet size design data is discussed.

1. Introduction
Motorcycles are among common modes of transportations by people with low-moderate incomes in developing countries including Indonesia [1]. Although traveling on a motorcycle is associated with a higher risk of death or injury [2], motorcycles are still among the most preferred transportation mode by people [3]. This condition is supported by the fact that the prices of motorcycles are affordable, coupled with the advantage in dealing with traffic jam conditions.

Unfortunately, the high use of the motorcycle is accompanied by high rates of motorcycle accidents [4]. The World Health Organization reports that nearly 60% of deaths caused by road accidents involve motorcyclists, especially in low and middle-income countries [5]. Most motorcycle accidents occur at young ages. Young ages range from fifteen and nineteen years [6]. The severity of motorcycle accident varies from minor, moderate to severe injuries. The death of motorcycle riders from the results of previous studies due to head injury [7]. In this case, efforts have been made to minimize deaths from motorcycle accidents, including, one of which is to ride a motorcycle must use a helmet.

Safety helmets, although not the best protective equipment but protect motorcycle users from injury and can prevent about 32% of head injuries during a motorcycle accident [8]. Although regulations have been implemented in several countries, there seems a reluctance to use helmets while driving for several reasons, including discomfort in wearing a helmet [9].

Indonesia is developing countries that face the problem of high motorcycle use and high motorcycle accidents [10]. The high number of fatality accidents seems due to the lack of use of helmets. This problem is often associated with helmet size. There is no standard helmet size for Indonesian yet. The current helmet size is determined by helmet manufacturers with lack support of
the anthropometric study, resulting in varying size helmet size is simply determined based on head circumference. Considering that head anthropometry is not only related to head circumference, but it also is not surprising that helmet size, in general, is not suitable for users.

Anthropometry is defined as the application of ergonomics to measurements people's body [11]. Measurement of the people's body [12] is key in determining the product size. For helmet design, the anthropometric head is used as a basis for determining size. Given Indonesia's anthropometric data there are ethnic differences. [13], in this study, we focused on Acehnese adults, because Aceh was a province that suffered from high motorcycle accidents and head injuries, the purpose of the study is to measure Acehnese anthropometry and to use the data for redesigning helmet sizes. The more fit the helmet to the motorcycle riders, the more will they use the helmet, and the risk of fatality injury will be minimized.

2. Methods
A. Participant
Participants are Acehnese adults (ranging from 18 to 22 years) consisted of 102 women and 102 men who were involved voluntarily in this study and the participants were randomly selected.

B. Tools
Head anthropometry measurement was conducted using Martin anthropometer, due to its flexibility.

C. Procedure
The measurements were conducted by a research assistant who had been trained in using body martin instruments and was also proficient in anthropometric measurements. Following [14], seven dimensions of head anthropometry were measured, including Head breadth. Menton to top of the head, Diametric menton to back of the head, Nose to top of the head, Pronasale to back of the head, Face breadth, and Eye to back of the head as can be seen in Table 1.

| No | Dimension | Picture | Associated helm dimensions |
|----|-----------|---------|----------------------------|
| 1  | Head breadth | ![Head breadth](image) | Helmet width |
| 2  | Menton to top of the head | ![Menton to top of the head](image) | Helmet height |
| 3  | Diametric menton to back of the head | ![Diametric menton to back of the head](image) | Helmet diameter |
| 4  | Nose to top of the head | ![Nose to top of the head](image) | Glass helmet height |
3. Result
The anthropometric head dimensions for Acehnese adult’s samples are shown in table 2 and Table 3, consecutively for men and women.

**Table 2. Head Antropometry For Men**

| No | Dimensions                                      | Mean (cm) | σ (cm) | Percentiles 5 (cm) | Percentiles 50 (cm) | Percentiles 195 (cm) |
|----|-------------------------------------------------|-----------|--------|---------------------|---------------------|----------------------|
| 1  | Head breadth                                    | 17.52     | 2.99   | 12.61               | 17.52               | 22.43                |
| 2  | Menton to top of the head                       | 22.55     | 3.47   | 16.86               | 22.55               | 28.24                |
| 3  | Diametric menton to back of the head            | 25.66     | 2.16   | 22.11               | 25.66               | 29.21                |
| 4  | Nose to top of the head                         | 15.77     | 1.84   | 12.76               | 15.77               | 18.78                |
| 5  | Pronasale to eye                                | 19.66     | 2.46   | 15.62               | 19.66               | 23.70                |
| 6  | Face breadth                                    | 16.34     | 2.14   | 12.84               | 16.34               | 19.85                |
| 7  | Eye to back of the head                         | 16.91     | 2.61   | 12.63               | 16.91               | 21.18                |

**Table 3. Head Antropometry For Women**

| No | Dimensions                                      | Mean (cm) | σ (cm) | Percentiles 5 (cm) | Percentiles 50 (cm) | Percentiles 195 (cm) |
|----|-------------------------------------------------|-----------|--------|---------------------|---------------------|----------------------|
| 1  | Head breadth                                    | 17.30     | 2.94   | 12.48               | 17.30               | 22.13                |
As expected, there were statistical differences in dimensions between men and women, in which four of the seven dimensions of male dimensions are larger than women.

4. Discussion
The aim of the study was to redesign helmets in accordance with the anthropometric dimensions of Acehnese adults. Our preliminary study showed the inconvenience of using helmets because of their unfit size to users.

There are several methods for determining the standard size of a product, the method often used is based on percentiles [15]. In this case, the 5th percentile is used as a reference for size S, 50th percentile for size M, 95th percentile for size L.

This study has some boundary that needs to be considered. First, the number of samples is quite low considering the Acehnese adult population (i.e. 5.19 million, BPS, 2019). Further research including more samples is needed to strengthen the results. Second, the measurement conducted manually may have an issue related to lack of reliability, so that a more sophisticated and reliable measurement method is needed.

Despite its limitations, this research can be seen as the first step in the measurement of head anthropometry in Indonesia, focused on Aceh. The ergonomic helmet size design based on the anthropometry measures is shown in Figure 1.
5. Conclusion

There are seven head dimensions considered to be important for helmet design, namely: Head breadth, Menton to top of the head, Diametric menton to back of the head, Nose to top of the head, Pronasale to back of the head, Face breadth, and Eye to back of the head. Data of each dimension is presented, and the size of the helmet is proposed.

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