



Indonesian anthropometry update for special populations incorporating Drillis and Contini revisited

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ABSTRACT

Nowadays, research on anthropometry becomes more essential, and yet, it is critical due to its implication and contribution to product and system design. Since it deals with human capability and limitation on physical activities, its role becomes more important, especially, when it comes to the needs for special populations. This study provides a comparative study between elderly and children anthropometry using Drillis and Contini approach incorporating Chinese and non-Chinese ethnic groups. More than 1000 subjects involved in this study. After the data refinement process, there were 498 valid data for children (i.e., 98 Chinese male, 136 non-Chinese male, 134 Chinese female, and 130 non-Chinese female), and 556 valid data for elderly (i.e., 186 Chinese male, 148 non-Chinese male, 115 Chinese female, and 107 non-Chinese female).

In general, the finding shows that elderly (both male and female, both Chinese and non-Chinese) tends to have similar size and pattern with adult. Whilst, male and female children of 6–9 years sub-group (both Chinese and non-Chinese sub-group) tend to have higher weight ratio, compared to elderly and the children of 10–12 years sub-group. It was easily recognized that the children tend to have higher rate for limb segments compared to other body dimensions. At all sample groups, the eye height and shoulder height were found to be highly correlated with stature. Moreover, related to body weight, all samples show that thigh thickness and abdominal depth were deemed to be significant measures to be associated with.

The expected contribution of this study is that to update the Indonesian special population anthropometry and to identify which measures are significantly associated with stature and weight, respectively with regard to different special population and given limited anthropometric data. Practically, given the data of stature and body weight, product designer can predict the anthropometric characteristics for special population.

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1. Introduction

Ergonomics deals with more humanized product, services and work systems. Due to rapid changing environment and system, human needs become more dynamic. Nevertheless, the users insist upon more efficient, comfortable, safe, healthy and effective working systems. Lack of it will lead to work-related injuries, low productivity, and product failures in market (Helander, 1997).

In dealing with physical human needs, anthropometry has been extensively proposed. It is not only discussing about how to measure and collect body measures, but also how to fit proper measures

into product characteristics and designs. The proper design of facilities and equipment utilizing the anthropometric data will increase productivity and reduce work-related musculoskeletal disorders (Klamklay et al., 2008; Chuan et al., 2010; Hartono and Gunawan, 2015).

Related to the basic Ergonomics, according to Kroemer and Grandjean (1997), anthropometry deals with and fits to human characteristics. Some pertinent factors such as genders, nutrition, and ethnic may influence the various result of human body dimensions. In work system design, it is called as user-centered design which involves the product, the user and the task (Hartono and Gunawan, 2015). It is in line with the ergonomics basic concept of how to fit the task to the human. By considering the anthropometric aspects, inherently, it will produce more

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efficient and productive work, as well as reduce any musculoskeletal disorders.

The challenge of anthropometry research is that how to maintain good consistency of measurement. It may deal with consistent measurement tools and facilities, prior knowledge of experimenter and researcher, and other environmental factors. It does not mean that the findings of anthropometric data should be of the same all the times. However, it is rather to achieve good fit data with minimum amount of errors. The data inconsistency may occur due to the positive or negative trend of anthropometric data with a function of time or other factors such as improved exercise, nutrition or newly life style, ethnic group, and special population. Special population may refer to children, elderly, pregnant women, and the ones who have different ability.

More specifically, Chuan et al. (2010) have conducted anthropometry study considering Indonesian and Singaporean populations, and compared the current data with the older one. In general, Singaporeans have been found to be larger than Indonesians. Both current Singaporean and Indonesian samples were also significantly larger than past Singaporeans and Indonesians, respectively. It might be caused by the change of geographical origin, nutrition, social status, and ethnic group. Assumed that there is no significant bias on the anthropometric measurement, thus, a regular update on anthropometric data is required. There is a potential need to deal with human anthropometric variability in designing any product or work systems.

When it reaches different users of different region such as countries, the first challenge is that how to deal with users from different countries, then it continues to controllable factors (e.g., nutrition, exercise, and social status). More specifically, anthropometric differences are not only found among different countries, but also among different ethnic groups within countries. Ethnic differences become the important precursor of various anthropometric measures. According to Widyanti et al. (2015), the anthropometric measurement taking into account different nationalities and ethnic groups has been conducted, such as Norwegian (Bolstad et al., 2001), Algerian (Mokdad, 2002), Portuguese (Barroso et al., 2005), Polish (Jarosz, 1999), Mexican American (Pennathura and Dowling, 2003), Indian (Victor et al., 2002), Filipinos (Del Prado-Lu, 2007), Swedish (Hanson et al., 2009), Bangladeshi (Khadem and Islam, 2014), and Iranian (Ghaderi et al., 2014; Sadeghi et al., 2015). Moreover, anthropometry study has been conducted in clinical practice to quantify changes in the craniofacial framework considering more than 25 ethnic groups (Leslie et al., 2005). The findings have shown that different ethnic groups have their distinctive anthropometric measures.

Regarding the concern on special population, a study on the effect of added weight on foot anthropometry in pregnant women by McCrory et al. (2016) has found that adding weight has brought significant changes in arch drop and arch rigidity index. Though, another factor such as the change of hormone concentrations should be taken into account. Another interesting study has been conducted by Harih and Dolšak (2013), which is about hand anthropometry for hand-operated tool. Its practical contribution is that the incorporation of the shape of hand during the optimal power-grasp posture. Significantly, it has improved the handle productivity. Related to children anthropometry, Jones et al. (2014) have conducted cross-country anthropometric study on height-for-age z-score (HAZ) and weight-for-height z-score (WHZ). The quality of child diets and population trends were deemed to be sensitive concerns. Moreover, Olafsdottir et al. (2014) have done a longitudinal study describing the relationship between dietary habits, TV time and anthropometric measures for children. It

showed that TV viewing activities have influenced the consumption of sugary drinks, and been followed by the increase in BMI and central obesity. Regarding the application of anthropometry for special population, a study on adult Special Olympics participants has been conducted by Temple et al. (2014). It was to explore the influence of gender and age on the body mass index (BMI). Interestingly, in general, it has been found that adult Special Olympics subjects have high level of BMI. In a wider coverage of application of anthropometric data, it might be applied into public facility. For instance, a recent study by Bombais et al. (2017) showed that the anthropometric data of adult were deemed critical to the bus layout and environment. Another interesting study on anthropometry for special population has been conducted by Widyanti et al. (2017). This study involved more than 600 Sundanese children anthropometric data (aged 6–9 years) in determining the clothing size. Moreover, study by Hartono (2016) which involved more than 400 subjects has found that limb segment and girth/width segment have a significant correlation with stature and body weight, respectively, through structural equation modeling (SEM).

With regard to Indonesia, a country with hundreds of ethnic groups, a research on the ethnic-based anthropometry for special population is relatively unexplored. A study by Chuan et al. (2010) has compared the Indonesian and Singaporean populations, and taken deeper analysis on the different ethnic groups (i.e., Chinese descendant and local citizen) within each country. A recent similar study by Widyanti et al. (2015) provides comparative anthropometric data among three major ethnic groups of Indonesian (i.e., Javanese, Sundanese and Minangkabau). This study, however, only discussed on Indonesian adult anthropometry. Practically, users are comprised of children, adult and elderly. Due to special need, influenced by growth period, elderly and children are called and adopted as the special population. Thus, it is of critical in the sense that how to satisfy their fitness and comfort when experiencing any product or working system. For example, due to aging, the diseases, disabilities and body function-decline will increase. More specifically, there are some challenges such as physical, social, and psychological functions that regard to performance-oriented assessment of mobility (Tinetti, 1986). Whilst, children have difficulty in fitting their capability to commonly used products and systems. For instance, Cadman et al. (1987) conducted a study of 3294 children of 4–16 years old with concern on chronic illness, physical disability and psychosocial problems. Both children and elderly have their specific and unique characteristics.

By considering different special populations (i.e., children and elderly) incorporating two different ethnic groups (i.e., Chinese and non-Chinese), this study is proposed to compare the differences in anthropometric measures. This current study can be considered a new study, but not necessarily the first one, made for special population in Indonesia. The previous study of anthropometry for special population in Indonesia has been conducted by Hartono (2016). The main difference is on the method used, number of samples and the depth of analyses. Following a study by Chuan et al. (2010), Chinese is regarded as the common ethnic group in the Southeast Asian region. Non-Chinese group will refer to the local citizen of a particular country. In Indonesia, the proportion of Chinese is around 5 percents, out of the country's total population.

By utilizing Drillis and Contini approach (Peacock et al., 2012), it is also to identify which measures are significantly associated with stature and weight, respectively with regard to different special population and ethnic groups. It is expected that the results of this study can be utilized as a general guide in predicting reliable and valid anthropometric measures considering different population and ethnic groups, with respect to the limited sample size.

2. Literature review

2.1. Special populations and ethnic groups in anthropometry

Special populations require special treatment. Since it is of uncommon population group, anthropometry should accommodate its unique characteristics and differences. They are facing potential problems, due to their limited abilities and needs. It may imply the challenge of how to design tools and tasks (Kroemer, 2006). The special populations differ from their peers in strength, posture and size, and sensing and predicting abilities. According to Kroemer (2006), more specifically, elderly as one of the special populations needs special attention in terms of body size and posture, physical abilities, and psychological traits change. Moreover, children may draw more attention as the younger the children are, the more different they are from the adult.

Compared to adults as a common group, special population which consists of children and elderly groups may have different anthropometric dimensions, in terms of the size and ratio between measures. In order to fit the facilities and equipment to specific population group, thus, selection process and utilization of anthropometric database is crucial and critical (Wickens et al., 2004). It implies that the detailed characteristics of anthropometric data should be of critical part in any anthropometry studies. A study by Widyanti et al. (2015) has confirmed the significant difference among different ethnic groups. Some demographic factors such as ethnic origin, social status, sufficient nutrition and geographical origin were shown significantly in influencing the differences on anthropometric measures. It was then followed by the different measures between male and female subjects. Male was found to be bigger and taller than female anthropometric data (Widyanti et al., 2015; Chuan et al., 2010). It implies that diversified ethnic groups within a particular population may bring significant differences in anthropometric data. More specifically, ethnic differences should be considered in any system design process.

2.2. Drillis and Contini revisited

According to Peacock et al. (2012) and Drillis and Contini (1966), several body segments are inter-correlated. Through a single measure of stature (body height), the other body dimensions have been hypothesized that they can be predicted sufficiently and accurately (Drillis and Contini, 1966; Pheasant and Haslegrave, 2006). Their findings have been published and applied (Peacock et al., 2012). In order to improve the reliability of Drillis and Contini's prediction model, a study done by Peacock et al. (2012) showed that width and girth measures were inter-correlated and more associated with body weight, than body height. Thus, apart from stature, the addition of body weight serves greater accuracy.

Body height and weight are commonly used as the reference points. It means that they can be used as predictors to other measures. Width and girth measures had more significant correlation with body weight, whereas, stature has been set to be a predictor for limb length.

In short, according to Peacock et al. (2012), limb segments are significantly related to the whole-body density. Recent research on Indonesian adult anthropometry shows that several body measures are significantly inter-correlated (see Hartono and Gunawan, 2015). Stature and body weight are deemed to be the most basic body segments for predicting other measures. Related to the previous study in 2010 (Chuan et al., 2010), the current Indonesian anthropometric measures were relatively higher and bigger than the old ones due to better income, education, nutrition and medical services. In short, the body dimensions which are significantly associated either with stature or weight can be identified (Hartono and

Gunawan, 2015). Subsequently, it helps product designers to fit the body measures to particular physical product or any human-work system interactions more effectively and efficiently.

3. Research methodology

This study and data collection has been carried out over a period of 24 months (in a range of 2015–2016). It applied convenience sampling to select and arrange the subjects. Anthropometry research is one of the very sensitive research forms dealing with human. Hence, it is quite challenging, subjects may refuse or disregard our invitation to join the experiment. Due to this consideration on the ease of subject accessibility and approach, the convenience sampling has been chosen. The intended subjects were selected based on their availability and willingness to respond. To avoid any potential biases, the experimenter has filtered the subjects by asking their willingness to join the survey and confirming the criteria required. Gravetter and Forzano (2012) pointed out that there is a strategy to reduce bias by ensuring that the subjects are reasonably representative and not strongly biased. It means that the subjects should be the representative of the population of interest. This strategy has been used in this current study as well. All samples have been carefully selected according to the intended main criteria (i.e., Indonesian children aged 6–12 years, and Indonesian elderly aged 55 years and above).

According to Chuan et al. (2010), the data collection on body dimensions is a very sensitive, thus, some respondents may refuse. The potential subjects were approached and asked whether they were willing to participate in the proposed anthropometric study. Some potential questions and doubts asked by the subjects have been directly responded. It has been continued until everything has been settled, and agreed by the subjects. If the subjects refused, the experimenters left and the measurement was cancelled.

3.1. Subjects

As for children subjects, the experimenter asked permission from their parents or teachers, whereas, for elderly, the experimenter asked directly to the subjects and or the owner of elderly house where they were staying. In total, more than 1000 subjects involved in the study. There were 498 children aged 6–12 years (i.e., 98 Chinese male, 136 non-Chinese male, 134 Chinese female, and 130 non-Chinese female), and 556 elderly aged 55 years and above (i.e., 186 Chinese male, 148 non-Chinese male, 115 Chinese female, and 107 non-Chinese female). Due to a relatively wide range of ages, more specifically, the children group was divided into two age groups (i.e., 6–9 years and 10–12 years) at each of the ethnic groups (i.e., Chinese and non-Chinese). Moreover, in order to increase data validity by excluding any uncontrollable measurements, the x-bar control chart was utilized. According to BPS (2015), the numbers of Indonesian children aged 6–12 years and elderly aged 55 years and above were 32,433,444 and 26,474,282 people, respectively. According to Altares et al. (2003), by using Sloven's formula [$n = N / (1 + N \cdot e^2)$], where: n = minimum number of samples, N = total population, and e = error tolerance] with an error tolerance of 5%, the expected minimum number of children and elderly samples were 399 and 400, respectively. Hence, the samples of both children and elderly taken in this study were deemed sufficient. In addition to the elderly subjects, there was no one had serious health problems during the experiment.

3.2. Procedure

Subjects were barefooted, wearing t-shirts and pants, and measured using 36 body dimensions as modified and used by

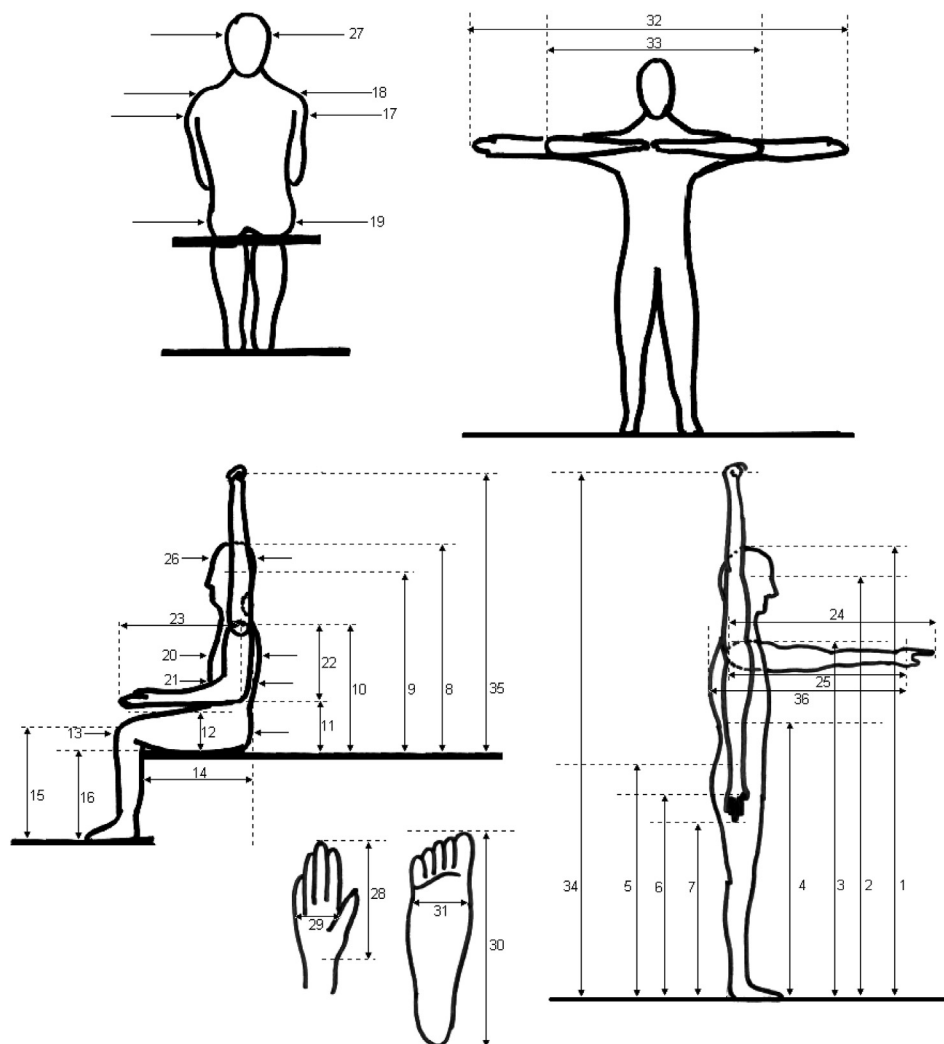


Fig. 1. Thirty six body landmarks (modified from Chuan et al., 2010).

[Note: Numbers shown in Fig. 1 show the names of body dimension as available in Table 1].

Chuan et al. (2010). Ideally, each section of data collection, there were at least two experimenters involved. However, in a special case, there was only one experimenter getting involved due to either the time or appointment constraint with the prospective subject. As a consequence, the experiment took longer. In addition, it is when the subject deals with the experimenter regardless the gender issue, thus, the experiment will be carried on. Hence, the

male experimenter may have an opportunity to do measurement to female subject, and vice versa. In the case of two experimenters, one took the measurement and the other one recorded the data. All those activities are shown in Figs. 2 and 3. In order to minimize any potential human errors during data collection process, all experimenters have been selected through the evaluation process conducted by the representative of ergonomics laboratory in the



Fig. 2. Measurement of elderly by 1 experimenter.



Fig. 3. Measurement of elderly by 2 experimenters.

university and equipped with the knowledge on how to use the equipment, body landmarks, and recognize the bony tips that influence the validity of measured figures. The experimenters have conducted several practices and pilot tests to get engaged with the experiment and data collection process.

In addition, once the anthropometric data have been collected,

the identification of outlier data was conducted through the use of x-bar control chart. It is to identify the causes of variation to investigate, and to decide whether we need to exclude the uncontrollable data (Montgomery et al., 2010). Thus, the final data set is hoped to be stable and valid.

Table 1

Anthropometric data for 6–9 years old children with subgroups of Chinese and non-Chinese (all dimensions in cm).

Dimension	Male								Female							
	Chinese				non-Chinese				Chinese				non-Chinese			
	5th	50th	95th	SD	5th	50th	95th	SD	5th	50th	95th	SD	5th	50th	95th	SD
1. Stature	100.7	117.8	134.9	10.4	104.6	121.7	138.9	10.4	108.1	121.9	135.6	8.4	89.5	122.8	156.2	20.3
2. Eye height	80.7	101.2	121.8	12.5	93.0	111.3	129.5	11.1	96.7	110.0	123.3	8.1	89.3	116.4	143.5	16.5
3. Shoulder height	72.4	90.2	107.9	10.8	79.3	99.3	119.3	12.2	83.0	97.6	112.1	8.8	75.3	101.1	126.9	15.7
4. Elbow height	54.6	68.1	81.6	8.2	62.2	76.6	90.9	8.7	65.6	74.7	83.8	5.5	60.3	84.6	109.0	14.8
5. Hip height	43.5	59.2	74.9	9.5	51.0	67.8	84.6	10.2	56.7	67.0	77.3	6.3	49.2	74.1	99.0	15.1
6. Knuckle height	35.4	46.1	56.9	6.5	40.5	51.0	61.6	6.4	43.1	50.8	58.6	4.7	42.9	57.6	72.3	8.9
7. Fingertip height	29.5	39.3	49.1	5.9	34.8	44.4	54.0	5.8	38.9	43.8	48.7	3.0	36.9	51.7	66.5	9.0
8. Sitting height	52.4	61.0	69.7	5.2	54.4	64.9	75.4	6.4	55.2	63.0	70.8	4.7	52.8	67.0	81.2	8.6
9. Sitting eye height	40.3	52.1	64.0	7.2	41.7	53.4	65.0	7.1	47.3	54.0	60.7	4.1	43.6	59.0	74.4	9.4
10. Sitting shoulder height	26.4	37.2	48.0	6.6	29.9	41.9	53.9	7.3	34.5	41.1	47.7	4.0	29.4	43.5	57.5	8.6
11. Sitting elbow height	9.7	14.9	20.2	3.2	7.9	15.5	23.1	4.6	10.6	16.8	22.9	3.7	7.9	17.8	27.8	6.1
12. Thigh thickness	5.7	10.3	14.9	2.8	5.2	9.9	14.6	2.8	5.7	8.8	11.9	1.9	5.2	9.9	14.6	2.8
13. Buttock-knee length	25.3	35.2	45.1	6.0	30.0	40.2	50.5	6.2	34.8	40.0	45.1	3.2	30.4	43.7	57.0	8.1
14. Buttock-popliteal length	20.5	29.5	38.5	5.5	25.5	34.5	43.6	5.5	29.0	34.2	39.4	3.2	27.0	38.3	49.6	6.9
15. Knee height	28.4	37.7	47.0	5.7	27.8	40.2	52.5	7.5	31.9	42.2	52.6	6.3	29.1	44.4	59.7	9.3
16. Popliteal height	24.4	31.4	38.4	4.2	25.4	33.1	40.8	4.7	25.7	32.7	39.7	4.3	25.3	36.7	48.0	6.9
17. Shoulder breadth (bideltoid)	24.4	29.9	35.4	3.4	24.5	32.1	39.8	4.6	25.4	31.2	37.0	3.5	20.5	35.9	51.4	9.4
18. Shoulder breadth (biacromial)	14.9	22.7	30.5	4.8	14.3	25.7	37.2	7.0	16.1	24.3	32.5	5.0	13.6	28.4	43.1	9.0
19. Hip breadth	17.7	24.1	30.6	3.9	16.7	26.5	36.3	5.9	19.7	26.0	32.4	3.9	14.5	29.3	44.1	9.0
20. Chest (bust) depth	10.3	14.6	18.9	2.6	8.2	14.6	21.1	3.9	10.7	15.1	19.4	2.6	6.4	15.8	25.3	5.7
21. Abdominal depth	10.8	16.0	21.3	3.2	9.5	17.4	25.2	4.8	12.5	16.7	20.8	2.5	7.0	17.5	27.9	6.3
22. Shoulder-elbow length	16.2	22.5	28.8	3.8	14.4	25.2	36.1	6.6	18.2	24.6	30.9	3.9	10.7	25.0	39.3	8.7
23. Elbow-fingertip length	23.2	30.0	36.9	4.2	25.2	33.6	42.0	5.1	27.3	31.8	36.4	2.8	17.2	35.9	54.7	11.4
24. Upper limb length	35.3	48.3	61.3	7.9	40.5	52.1	63.6	7.0	42.3	50.7	59.0	5.1	34.6	52.8	71.0	11.1
25. Shoulder-grip length	26.3	37.7	49.1	6.9	32.1	43.3	54.6	6.8	35.0	42.3	49.6	4.5	31.8	48.7	65.7	10.3
26. Head length	11.8	16.3	20.7	2.7	12.7	17.8	23.0	3.1	14.0	16.7	19.4	1.7	14.0	18.6	23.2	2.8
27. Head breadth	9.6	15.8	22.0	3.8	9.8	16.8	23.9	4.3	11.9	17.2	22.5	3.2	8.1	19.2	30.3	6.8
28. Hand length	9.6	12.4	15.2	1.7	10.6	13.9	17.2	2.0	11.4	14.2	17.1	1.7	10.3	15.8	21.2	3.3
29. Hand breadth	4.8	6.1	7.4	0.8	4.8	6.6	8.4	1.1	5.3	6.6	8.0	0.8	3.3	6.2	9.1	1.8
30. Foot length	13.0	17.1	21.2	2.5	14.7	19.3	23.8	2.8	15.6	19.3	22.9	2.2	14.2	19.3	24.4	3.1
31. Foot breadth	4.3	6.8	9.2	1.5	5.3	7.7	10.0	1.4	5.7	7.7	9.7	1.2	4.6	8.5	12.4	2.4
32. Span	85.2	108.2	131.3	14.0	99.7	122.2	144.6	13.7	99.9	118.0	136.1	11.0	95.5	130.3	165.2	21.2
33. Elbow span	42.4	61.8	81.1	11.8	47.7	63.4	79.1	9.5	52.4	61.7	71.1	5.7	47.0	67.7	88.4	12.6
34. Vertical grip reach (standing)	107.1	132.1	157.1	15.2	118.3	146.1	173.8	16.9	123.9	143.4	162.8	11.8	119.3	160.0	200.8	24.8
35. Vertical grip reach (sitting)	63.4	83.9	104.4	12.5	69.1	86.6	104.1	10.6	70.1	81.8	93.4	7.1	60.0	86.9	113.9	16.4
36. Forward grip reach	31.2	45.3	59.4	8.6	36.7	51.6	66.4	9.0	38.3	49.9	61.5	7.1	38.1	59.8	81.5	13.2

Table 2
Anthropometric data for 10–12 years old children with subgroups of Chinese and non-Chinese (all dimensions in cm).

Dimension	Male								Female							
	Chinese				non-Chinese				Chinese				non-Chinese			
	5th	50th	95th	SD	5th	50th	95th	SD	5th	50th	95th	SD	5th	50th	95th	SD
1. Stature	124.1	139.1	154.2	9.2	123.9	140.3	156.7	10.0	124.2	141.0	157.7	10.2	111.4	137.0	162.6	15.5
2. Eye height	113.2	126.9	140.6	8.3	109.6	126.7	143.8	10.4	112.8	130.7	148.6	10.9	90.1	121.1	152.1	18.8
3. Shoulder height	98.5	112.3	126.2	8.4	92.0	112.3	132.6	12.3	98.3	113.6	129.0	9.3	76.6	104.0	131.4	16.7
4. Elbow height	75.6	87.0	98.5	7.0	66.6	84.7	102.8	11.0	75.3	87.2	99.1	7.2	61.4	85.0	108.5	14.3
5. Hip height	65.0	76.7	88.4	7.1	60.4	75.8	91.2	9.3	66.4	79.9	93.3	8.2	49.9	75.6	101.2	15.6
6. Knuckle height	48.9	59.5	70.2	6.5	44.6	58.4	72.2	8.4	50.3	60.1	70.0	6.0	41.2	56.2	71.2	9.1
7. Fingertip height	42.1	50.7	59.4	5.3	38.1	48.5	58.9	6.3	42.6	51.3	60.0	5.3	37.2	50.3	63.5	8.0
8. Sitting height	62.2	70.6	78.9	5.1	57.2	68.0	78.8	6.6	61.4	70.9	80.5	5.8	52.6	67.5	82.5	9.1
9. Sitting eye height	51.5	60.1	68.8	5.3	46.1	58.6	71.2	7.6	50.0	60.6	71.1	6.4	46.3	62.3	78.2	9.7
10. Sitting shoulder height	37.9	46.9	55.9	5.5	34.0	45.5	57.1	7.0	36.2	45.7	55.2	5.8	26.9	42.6	58.4	9.6
11. Sitting elbow height	12.0	18.4	24.8	3.9	9.9	17.5	25.0	4.6	11.0	18.1	25.2	4.3	7.9	18.0	28.0	6.1
12. Thigh thickness	6.4	10.7	15.0	2.6	5.3	11.8	18.2	3.9	7.1	10.9	14.7	2.3	5.9	10.7	15.5	2.9
13. Buttock-knee length	38.8	46.0	53.1	4.3	33.7	44.4	55.1	6.5	37.9	46.6	55.4	5.3	28.4	42.9	57.3	8.8
14. Buttock-popliteal length	31.0	39.3	47.6	5.1	27.8	37.5	47.2	5.9	32.8	39.6	46.4	4.1	27.4	37.7	47.9	6.2
15. Knee height	37.5	44.8	52.1	4.4	34.0	42.2	50.5	5.0	36.5	44.4	52.3	4.8	30.4	45.1	59.9	9.0
16. Popliteal height	32.3	37.5	42.8	3.2	28.5	36.8	45.0	5.0	29.9	37.5	45.0	4.6	25.3	36.1	46.9	6.5
17. Shoulder breadth (bideloid)	26.3	34.4	42.4	4.9	23.5	33.8	44.0	6.2	25.4	35.5	45.6	6.1	21.6	35.4	49.3	8.4
18. Shoulder breadth (biacromial)	20.4	28.5	36.6	4.9	16.6	27.8	38.9	6.8	18.0	29.2	40.5	6.8	13.2	26.6	40.1	8.2
19. Hip breadth	21.9	31.1	40.2	5.5	19.3	27.8	36.4	5.2	20.0	29.8	39.6	5.9	16.5	30.5	44.4	8.5
20. Chest (bust) depth	12.0	17.0	22.0	3.1	10.8	16.5	22.2	3.5	10.2	16.1	21.9	3.5	9.0	17.1	25.2	4.9
21. Abdominal depth	10.5	17.8	25.1	4.5	11.9	19.2	26.5	4.5	9.4	16.9	24.5	4.6	6.4	16.9	27.5	6.4
22. Shoulder-elbow length	22.4	29.0	35.6	4.0	18.4	28.6	38.8	6.2	22.4	29.0	35.6	4.0	13.1	26.3	39.5	8.0
23. Elbow-fingertip length	31.2	37.7	44.2	3.9	30.2	37.4	44.6	4.4	31.1	38.8	46.4	4.6	18.2	34.0	49.7	9.6
24. Upper limb length	53.4	60.8	68.2	4.5	47.8	59.9	72.1	7.4	50.9	61.3	71.7	6.4	35.0	51.7	68.3	10.1
25. Shoulder-grip length	39.7	48.6	57.5	5.4	38.2	50.7	63.1	7.6	41.9	51.6	61.4	5.9	29.6	47.1	64.6	10.6
26. Head length	14.1	18.3	22.5	2.6	13.0	18.3	23.7	3.3	13.7	17.7	21.7	2.4	12.9	18.2	23.5	3.2
27. Head breadth	13.4	17.4	21.5	2.5	9.8	17.2	24.6	4.5	11.3	18.5	25.7	4.4	9.0	18.8	28.6	5.9
28. Hand length	13.0	15.7	18.5	1.7	11.2	15.2	19.2	2.4	12.6	16.1	19.7	2.2	9.4	14.7	19.9	3.2
29. Hand breadth	5.8	7.2	8.6	0.9	5.1	7.0	8.9	1.2	5.1	7.2	9.3	1.3	3.8	7.1	10.3	2.0
30. Foot length	18.5	21.7	24.9	1.9	15.7	21.9	28.0	3.8	18.3	21.2	24.2	1.8	14.4	20.3	26.2	3.6
31. Foot breadth	6.7	8.9	11.1	1.3	6.3	8.4	10.6	1.3	6.3	8.6	10.8	1.4	4.8	8.5	12.1	2.2
32. Span	123.0	137.5	151.9	8.8	113.5	136.3	159.1	13.9	123.2	141.4	159.7	11.1	93.0	129.3	165.5	22.0
33. Elbow span	59.9	70.0	80.1	6.2	54.5	70.4	86.3	9.7	61.2	72.8	84.3	7.0	49.1	68.0	86.9	11.5
34. Vertical grip reach (standing)	148.4	164.0	179.5	9.4	138.0	166.7	195.4	17.4	143.8	167.5	191.2	14.4	118.9	156.0	193.1	22.6
35. Vertical grip reach (sitting)	82.4	94.1	105.7	7.1	76.0	93.4	110.7	10.6	80.1	96.1	112.1	9.7	59.8	85.7	111.6	15.7
36. Forward grip reach	45.5	56.4	67.2	6.6	43.4	57.3	71.2	8.5	47.5	59.9	72.3	7.5	37.2	59.0	80.9	13.3

3.3. Body landmarks and measurement equipment

There were 36 body dimensions, body weight, and the classification of Chinese or non-Chinese, utilized. All those body dimensions were specified by [Pheasant and Haslegrave \(2006\)](#) and used by [Chuan et al. \(2010\)](#).

By adapting what has been utilized by [Chuan et al. \(2010\)](#) and [Al-Ansari and Mokdad \(2009\)](#), a convenient anthropometric tape, small stool, weighing scale have been used. It is due to simple, portable and inexpensive consideration, and yet, it is effective and efficient. To ensure more effective, efficient and less bias result, the experimenters and helpers were well trained. The subjects must have been asked to maintain proper posture, yet natural, during the period of measurement. It took about 20–30 min to complete one subject. Ideally, to promote privacy and code of conduct, since it is so sensitive, male experimenter has been responsible for male respondents, whereas female experimenter has taken care of female respondents, unless the subjects agree with any experimenters regardless their gender type.

4. Result

4.1. Anthropometry for children and elderly

This section shows a summary of the anthropometric data of Indonesian children and elderly, both male and female taking into

account Chinese and non-Chinese classification (see [Tables 1–3](#)). In general, it shows that the male children tend to have the same dimensions as the female children do at both age sub-groups (i.e., 6–9 years and 10–12 years), except for Chinese sub-group at the age 6–9 years. At the 6–9 years sub-group, the Chinese female children tend to have larger dimensions than the Chinese male children. It may be related to the fact that the physical growth of boys, in general, is about 2 years later than that of girls ([Gavin, 2015](#)).

Compared to children sample, the anthropometric dimensions of male elderly were larger than those of the female elderly at both Chinese and non-Chinese sub-groups.

4.2. Comparison of values of stature, weight and BMI for elderly and children samples

A summary of the basic descriptive statistics of stature and weight (mean, standard deviation, maximum and minimum values) and BMI is shown in [Table 4](#). It includes both Chinese and non-Chinese sub-groups for male and female samples. Body Mass Index (BMI) is proposed to be a health indicator for a particular group, which is defined as the weight (in kg) divided by the square of stature (in m²). Referring to [WHO \(2016\)](#), all values of BMI are within the normal range of 18.5–24.99, except for the sub-groups of Chinese children of 6–9 years (see [Table 4](#)).

Table 3

Anthropometric data for elderly with subgroups of Chinese and non-Chinese (all dimensions in cm).

Dimension	Male								Female							
	Chinese				non-Chinese				Chinese				non-Chinese			
	5th	50th	95th	SD	5th	50th	95th	SD	5th	50th	95th	SD	5th	50th	95th	SD
1. Stature	140.4	159.9	179.5	11.9	138.0	158.9	179.8	12.7	128.7	153.5	178.2	15.0	124.2	149.7	175.1	15.5
2. Eye height	128.1	148.6	169.1	12.5	126.7	148.0	169.4	13.0	114.0	139.8	165.7	15.7	113.0	137.9	162.8	15.1
3. Shoulder height	112.6	130.8	149.1	11.1	111.7	130.3	148.9	11.3	91.5	114.4	137.3	13.9	91.5	113.7	135.8	13.5
4. Elbow height	85.8	97.1	108.4	6.9	87.8	98.5	109.3	6.5	73.8	91.2	108.6	10.6	75.3	93.0	110.7	10.7
5. Hip height	77.5	89.7	101.9	7.4	78.4	90.4	102.4	7.3	66.6	84.4	102.2	10.8	64.5	82.9	101.3	11.2
6. Knuckle height	57.3	67.8	78.2	6.3	58.1	68.2	78.3	6.1	49.1	63.7	78.3	8.9	50.7	63.3	75.9	7.7
7. Fingertip height	49.3	59.0	68.8	5.9	49.1	58.7	68.3	5.8	41.3	55.7	70.1	8.7	42.1	55.7	69.3	8.3
8. Sitting height	68.4	79.5	90.5	6.7	68.3	78.9	89.6	6.5	47.3	66.5	85.7	11.7	46.4	66.7	86.9	12.3
9. Sitting eye height	54.6	65.7	76.8	6.8	55.3	65.9	76.6	6.5	43.6	59.8	76.0	9.8	42.3	59.0	75.7	10.1
10. Sitting shoulder height	43.1	54.4	65.6	6.8	42.7	53.1	63.4	6.3	35.6	48.3	61.1	7.7	35.6	48.3	61.0	7.7
11. Sitting elbow height	14.9	23.4	31.9	5.2	14.1	22.8	31.5	5.3	9.0	18.1	27.3	5.6	8.6	18.6	28.6	6.1
12. Thigh thickness	10.3	15.1	19.9	2.9	9.6	14.9	20.2	3.2	6.5	12.6	18.8	3.7	6.1	12.5	19.0	3.9
13. Buttock-knee length	50.8	57.7	64.5	4.2	50.8	57.5	64.1	4.0	41.9	54.3	66.7	7.6	42.1	54.5	66.8	7.5
14. Buttock-popliteal length	41.2	48.6	55.9	4.5	41.0	48.3	55.6	4.4	36.1	45.8	55.5	5.9	36.4	45.8	55.1	5.7
15. Knee height	47.3	54.8	62.3	4.6	46.9	54.5	62.1	4.6	42.8	52.9	63.0	6.1	41.8	51.9	62.0	6.1
16. Popliteal height	34.3	42.2	50.1	4.8	34.0	41.6	49.1	4.6	32.4	41.9	51.3	5.7	33.5	42.1	50.7	5.2
17. Shoulder breadth (bideltoid)	38.2	46.9	55.6	5.3	38.0	46.4	54.8	5.1	28.3	41.2	54.2	7.9	27.1	40.6	54.0	8.2
18. Shoulder breadth (biacromial)	28.5	35.6	42.7	4.3	28.0	35.0	41.9	4.2	22.1	33.0	43.9	6.6	22.0	33.3	44.5	6.8
19. Hip breadth	34.5	45.5	56.4	6.7	34.3	44.9	55.5	6.4	30.3	43.5	56.6	8.0	30.7	43.4	56.2	7.8
20. Chest (bust) depth	15.3	25.3	35.2	6.0	15.4	25.7	36.0	6.3	11.0	22.7	34.5	7.1	11.3	23.1	35.0	7.2
21. Abdominal depth	15.9	28.6	41.3	7.7	15.7	28.4	41.1	7.7	12.0	28.1	44.2	9.8	13.3	28.6	43.8	9.3
22. Shoulder-elbow length	28.8	33.9	39.0	3.1	27.7	33.4	39.1	3.5	22.5	30.0	37.5	4.6	21.5	29.6	37.8	5.0
23. Elbow-fingertip length	37.9	44.4	50.8	3.9	38.4	44.6	50.7	3.7	27.4	38.5	49.5	6.7	28.2	38.7	49.2	6.4
24. Upper limb length	60.6	70.4	80.3	6.0	61.2	71.0	80.7	5.9	55.1	65.9	76.6	6.5	55.7	67.1	78.5	6.9
25. Shoulder-grip length	49.2	54.5	59.9	3.2	49.0	54.6	60.2	3.4	39.5	49.5	59.5	6.1	40.1	49.9	59.6	5.9
26. Head length	14.9	18.5	22.2	2.2	14.8	18.6	22.5	2.3	12.9	18.4	23.9	3.3	12.4	17.8	23.2	3.3
27. Head breadth	17.4	22.2	27.0	2.9	17.6	22.3	27.0	2.9	13.7	20.6	27.4	4.2	13.6	20.4	27.3	4.2
28. Hand length	17.8	20.1	22.4	1.4	17.7	19.9	22.2	1.3	11.0	17.6	24.3	4.0	11.1	17.2	23.4	3.8
29. Hand breadth	7.9	10.4	13.0	1.6	7.5	10.2	12.9	1.7	6.8	10.6	14.4	2.3	6.8	10.5	14.2	2.3
30. Foot length	20.8	24.8	28.7	2.4	20.8	24.9	29.0	2.5	16.8	22.3	27.8	3.4	17.2	23.0	28.8	3.5
31. Foot breadth	8.7	11.3	13.9	1.6	8.8	11.5	14.1	1.6	7.6	10.7	13.7	1.9	7.6	11.0	14.3	2.0
32. Span	129.9	154.3	178.8	14.9	128.7	153.2	177.8	14.9	117.1	143.9	170.7	16.3	116.3	144.1	171.9	16.9
33. Elbow span	63.1	75.7	88.3	7.7	63.4	75.4	87.5	7.3	59.3	72.8	86.3	8.2	60.3	72.8	85.4	7.6
34. Vertical grip reach (standing)	158.1	193.4	228.6	21.4	159.0	193.5	227.9	20.9	151.6	191.8	232.0	24.4	141.7	184.4	227.1	26.0
35. Vertical grip reach (sitting)	105.1	131.6	158.1	16.1	105.7	130.4	155.2	15.1	88.3	123.0	157.7	21.1	87.0	123.3	159.5	22.0
36. Forward grip reach	57.0	65.6	74.2	5.2	55.7	65.1	74.5	5.7	52.1	63.9	75.7	7.2	53.6	64.4	75.3	6.6

Table 4

Statistic descriptive of stature and weight dimensions.

Group	Stature (in cm)				Weight (in kg)				BMI ^a
	Mean	SD	Max	Min	Mean	SD	Max	Min	
Children (6–9 years)									
Male Chinese	117.8	10.4	153	100	22.3	8.3	53	15	16.1
Female Chinese	121.9	8.4	143.5	97	26.7	7.1	47	17	17.9
Male non-Chinese	121.7	10.4	141	92	29.5	9.2	64	15	19.9
Female non-Chinese	122.8	20.3	162	97	30.9	8.9	55	18	20.5
Children (10–12 years)									
Male Chinese	139.1	9.2	155	116	36.9	8.9	55	21	19.1
Female Chinese	140.9	10.2	163	110	37.6	7.8	61	20	18.9
Male non-Chinese	140.3	9.9	163	107	40.6	11.3	74	15	20.6
Female non-Chinese	137	15.5	163	100	36.3	12.3	61	17	19.4
Elderly									
Male Chinese	159.9	11.9	179	137	58.8	11.3	79	40	22.9
Female Chinese	153.5	15.4	178	125	52.1	15.3	78	25	22.1
Male non-Chinese	158.9	12.7	179	137	58.5	11.3	79	40	23.2
Female non-Chinese	149.7	15.5	178	124	50.3	14.6	78	25	22.4

^a Body Mass Index (in kg/m²) = weight (in kg)/squared-stature (in m²).

4.3. Comparison of the 50th percentile mean values for Chinese and non-Chinese samples

A comparison of the 36 dimensions measured between Chinese and non-Chinese sub-group for both male and female samples in both children and elderly population groups, as shown in [Tables 5 and 6](#). The Student's t-test for independent mean difference was

used. It shows that more than 50 percent of the dimensions have been significantly different, at the male and female children of 6–9 years sub-group. The non-Chinese tends to be higher, wider, and bigger than its counterpart. At the children of 10–12 years sub-group at both male and female, it seems that there is no significant difference between Chinese and non-Chinese sub-group.

More interestingly, comparing the Chinese and non-Chinese

Table 5
Comparison of the 50th percentile values for Chinese and non-Chinese for children population (all dimensions in cm).

Dimension	Children (6–9 years)									Children (10–12 years)										
	Male					Female				Male					Female					
	Chinese		non-Chinese		p	Chinese		non-Chinese		p	Chinese		non-Chinese		p	Chinese		non-Chinese		p
	50th	SD	50th	SD		50th	SD	50th	SD		50th	SD	50th	SD		50th	SD	50th	SD	
1. Stature	117.8	10.4	121.7	10.4	0.02	121.9	8.4	122.8	20.3	0.39	139.1	9.2	140.3	10.0	0.31	141.0	10.2	137.0	15.5	0.97
2. Eye height	101.2	12.5	111.3	11.1	0.00	110.0	8.1	116.4	16.5	0.02	126.9	8.3	126.7	10.4	0.78	130.7	10.9	121.1	18.8	0.99
3. Shoulder height	90.2	10.8	99.3	12.2	0.00	97.6	8.8	101.1	15.7	0.11	112.3	8.4	112.4	12.3	0.48	113.6	9.3	104.0	16.7	0.99
4. Elbow height	68.1	8.2	76.6	8.7	0.00	74.7	5.5	84.6	14.8	0.00	87.0	7.0	84.7	11.0	0.88	87.2	7.2	85.0	14.3	0.89
5. Hip height	59.2	9.5	67.8	10.2	0.00	67.0	6.3	74.1	15.1	0.00	76.7	7.1	75.8	9.3	0.68	79.9	8.2	75.6	15.6	0.99
6. Knuckle height	46.1	6.5	51.0	6.4	0.00	50.8	4.7	57.6	8.9	0.00	59.5	6.5	58.4	8.4	0.48	60.1	6.0	56.2	9.1	0.99
7. Fingertip height	39.3	5.9	44.4	5.8	0.00	43.8	3.0	51.7	9.0	0.00	50.7	5.3	48.5	6.3	0.37	51.3	5.3	50.3	8.0	0.83
8. Sitting height	61.0	5.2	64.9	6.4	0.01	63.0	4.7	67.0	8.6	0.01	70.6	5.1	68.0	6.6	0.98	70.9	5.8	67.5	9.1	0.99
9. Sitting eye height	52.1	7.2	53.4	7.1	0.20	54.0	4.1	59.0	9.4	0.00	60.1	5.3	58.6	7.6	0.77	60.6	6.4	62.3	9.7	0.09
10. Sitting shoulder height	37.2	6.6	41.9	7.3	0.00	41.1	4.0	43.5	8.6	0.03	46.9	5.5	45.5	7.0	0.79	45.7	5.8	42.6	9.6	0.99
11. Sitting elbow height	14.9	3.2	15.5	4.6	0.19	16.8	3.7	17.8	6.1	0.18	18.4	3.9	17.5	4.6	0.85	18.1	4.3	18.0	6.1	0.55
12. Thigh thickness	10.3	2.8	9.9	2.8	0.79	8.8	1.9	9.9	2.8	0.02	10.7	2.6	11.8	3.9	0.31	10.9	2.3	10.7	2.9	0.69
13. Buttock-knee length	35.2	6.0	40.2	6.2	0.00	40.0	3.2	43.7	8.1	0.01	46.0	4.3	44.4	6.5	0.92	46.6	5.3	42.9	8.8	0.99
14. Buttock-popliteal length	29.5	5.5	34.5	5.5	0.00	34.2	3.2	38.3	6.9	0.00	39.3	5.1	37.5	5.9	0.94	39.6	4.1	37.7	6.2	0.99
15. Knee height	37.7	5.7	40.2	7.5	0.05	42.2	6.3	44.4	9.3	0.10	44.8	4.4	42.2	5.0	0.99	44.4	4.8	45.1	9.0	0.26
16. Popliteal height	31.4	4.2	33.1	4.7	0.01	32.7	4.3	36.7	6.9	0.00	37.5	3.2	36.8	5.0	0.79	37.5	4.6	36.1	6.5	0.94
17. Shoulder breadth (bideltoid)	29.9	3.4	32.1	4.6	0.00	31.2	3.5	35.9	9.4	0.00	34.4	4.9	33.8	6.2	0.52	35.5	6.1	35.4	8.4	0.53
18. Shoulder breadth (biacromial)	22.7	4.8	25.7	7.0	0.00	24.3	5.0	28.4	9.0	0.00	28.5	4.9	27.8	6.8	0.73	29.2	6.8	26.6	8.2	0.98
19. Hip breadth	24.1	3.9	26.5	5.9	0.01	26.0	3.9	29.3	9.0	0.02	31.1	5.5	27.8	5.2	0.99	29.8	5.9	30.5	8.5	0.27
20. Chest (bust) depth	14.6	2.6	14.5	3.9	0.57	15.1	2.6	15.8	5.7	0.24	17.0	3.1	16.5	3.5	0.76	16.1	3.5	17.1	4.9	0.58
21. Abdominal depth	16.0	3.2	17.4	4.8	0.02	16.7	2.5	17.5	6.3	0.23	17.8	4.5	19.2	4.5	0.07	16.9	4.6	16.8	6.4	0.61
22. Shoulder-elbow length	22.5	3.8	25.2	6.6	0.02	24.6	3.9	25.0	8.7	0.40	29.0	4.0	28.6	6.2	0.65	29.0	4.0	26.3	8.0	0.99
23. Elbow-fingertip length	30.0	4.2	33.6	5.1	0.03	31.8	2.8	35.9	11.4	0.02	37.7	3.9	37.4	4.4	0.51	38.8	4.6	34.0	9.6	0.99
24. Upper limb length	48.3	7.9	52.1	7.0	0.00	50.7	5.1	52.8	11.1	0.14	60.8	4.5	59.9	7.4	0.67	61.3	6.4	51.7	10.1	0.99
25. Shoulder-grip length	37.7	6.9	43.3	6.8	0.00	42.3	4.5	48.7	10.3	0.00	48.6	5.4	50.7	7.6	0.06	51.6	5.9	47.1	10.6	0.99
26. Head length	16.3	2.7	17.8	3.1	0.00	16.7	1.7	18.6	2.8	0.00	18.3	2.6	18.2	3.3	0.56	17.7	2.4	18.2	3.2	0.13
27. Head breadth	15.8	3.8	16.8	4.3	0.04	17.2	3.2	19.2	6.8	0.05	17.4	2.5	17.2	4.5	0.74	18.5	4.4	18.8	5.9	0.36
28. Hand length	12.4	1.7	13.9	2.0	0.00	14.2	1.7	15.8	3.3	0.00	15.7	1.7	15.2	2.4	0.59	16.1	2.2	14.7	3.2	0.99
29. Hand breadth	6.1	0.8	6.6	1.1	0.00	6.6	0.8	6.2	1.8	0.89	7.2	0.9	7.0	1.2	0.82	7.2	1.3	7.1	2.0	0.65
30. Foot length	17.1	2.5	19.3	2.8	0.00	19.3	2.2	19.4	3.1	0.43	21.7	1.9	21.9	3.8	0.77	21.2	1.8	20.3	3.6	0.98
31. Foot breadth	6.8	1.5	7.7	1.4	0.00	7.7	1.2	8.5	2.4	0.03	8.9	1.3	8.4	1.3	0.96	8.6	1.4	8.5	2.2	0.64
32. Span	108.2	14.0	122.2	13.7	0.00	118.0	11.0	130.3	21.2	0.00	137.5	8.8	136.3	13.9	0.69	141.4	11.1	129.3	22.0	0.99
33. Elbow span	61.8	11.8	63.4	9.5	0.00	61.7	5.7	67.7	12.6	0.00	70.0	6.2	70.4	9.7	0.40	72.8	7.0	68.0	11.5	0.99
34. Vertical grip reach (standing)	132.1	15.2	146.1	16.9	0.00	143.4	11.8	160.0	24.8	0.00	164.0	9.4	166.7	17.4	0.17	167.5	14.4	156.0	22.6	0.99
35. Vertical grip reach (sitting)	83.9	12.5	86.6	10.6	0.00	81.8	7.1	86.9	16.4	0.02	94.1	7.1	93.4	10.6	0.65	96.1	9.7	85.7	15.7	0.99
36. Forward grip reach	45.3	8.6	51.6	9.0	0.00	49.9	7.1	59.8	13.2	0.00	56.4	6.6	57.3	8.5	0.53	59.9	7.5	59.0	13.3	0.59

Notes: bolded figures show significant difference in means at $\alpha \leq 5\%$.

elderly sub-group, similar to the children of 10–12 years group, there is no significant difference, at both male and female group.

4.4. Empirical prediction of anthropometric dimensions using Drilis and Contini approach

According to [Peacock et al. \(2012\)](#) and [Hartono and Gunawan \(2015\)](#), particular body dimensions are significantly associated either with stature or body weight. Before the body dimensions can be used as a measure of prediction, it is necessary to assess their validity and reliability in Indonesian special population context. For content validity testing, it refers to the extent to which a measure represents meanings of a given concept ([Babbie, 1992](#)). Here, the instrument of 36 body dimensions were adopted from [Pheasant and Haslegrave \(2006\)](#) and [Chuan et al. \(2010\)](#). Their thoroughness suggests that 36 body dimensions do measure and represent the anthropometry of certain population. For reliability testing, the measure was assessed using Cronbach's Alpha. The cut-off value was set to 0.7. The result of two special population data was deemed satisfactory (as shown in [Table 7](#)). The data from two populations (i.e., children and elderly) were then analyzed independently to determine the number of factors to extract. Methods used were principal components with varimax rotation ([Pitt et al., 1995](#)). According to factor analysis, at the children group, it indicated that there were two major factors extracted, and these

explained about 62% of the variance. The first factor included the dimensions of numbers 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 13, 14, 16, 23, 24, 32, 33, 34, 35, and 36, which were related to limb segment (please see [Fig. 1](#) for the description of body dimension numbers). The second factor included the dimensions of numbers 25, 28, 29, 30, and 31, those were related to girth and width segment. Similar to the children group, there were two factors which explained 60% of the variance for the elderly group. The first factor included the dimensions 1 to 11, 13, 14, 17, 18, 22, 23, 24, 25, 28, 30, 32, 33, 34, 35 and 36, which were related to limb segment, while the second factors consisted of dimensions 12, 15, 19, 20, 21, 26, 27, 29 and 31. This finding confirmed the generic model of the relationship between limb segment and stature, and girth/width segment and weight, respectively (see [Peacock et al., 2012](#); [Hartono, 2016](#)).

By using correlation analysis, it was found that the stature was highly correlated with limb lengths, whilst the body weight was found to be a good predictor of width or girth measures ([Hartono and Gunawan, 2015](#)). [Tables 8 and 9](#) show the significant correlations (with significant value of 0.05) and ratios of common body measures with stature and weight for both male and female samples, applies to children (at both 6–9 and 10–12 years) and elderly groups for both Chinese and non-Chinese sub-group.

The common significant body dimensions associated with stature were eye height, shoulder height, elbow height, hip height, fingertip height, sitting eye height, span, and vertical grip reach

Table 6

Comparison of the 50th percentile values for Chinese and non-Chinese for elderly population (all dimensions in cm).

Dimension	Elderly									
	Male					Female				
	Chinese		non-Chinese		p	Chinese		non-Chinese		p
	50th	SD	50th	SD		50th	SD	50th	SD	
1. Stature	159.9	11.9	158.9	12.7	0.47	153.5	15.0	149.7	15.5	0.04
2. Eye height	148.6	12.5	148.0	13.0	0.65	139.8	15.7	137.9	15.1	0.22
3. Shoulder height	130.8	11.1	130.3	11.3	0.64	114.4	13.9	113.7	13.5	0.45
4. Elbow height	97.1	6.9	98.5	6.5	0.48	91.2	10.6	93.0	10.7	0.18
5. Hip height	89.7	7.4	90.4	7.3	0.43	84.4	10.8	82.9	11.2	0.12
6. Knuckle height	67.8	6.3	68.2	6.1	0.45	63.7	8.9	63.3	7.7	0.56
7. Fingertip height	59.0	5.9	58.7	5.8	0.45	55.7	8.7	55.7	8.3	0.81
8. Sitting height	79.5	6.7	78.9	6.5	0.56	66.5	11.7	66.7	12.3	0.58
9. Sitting eye height	65.7	6.8	65.9	6.5	0.64	59.8	9.8	59.0	10.1	0.62
10. Sitting shoulder height	54.4	6.8	53.1	6.3	0.44	48.3	7.7	48.4	7.7	0.91
11. Sitting elbow height	23.4	5.2	22.8	5.3	0.45	18.1	5.6	18.6	6.1	0.51
12. Thigh thickness	15.1	2.9	14.9	3.2	0.51	12.6	3.7	12.5	3.9	0.76
13. Buttock-knee length	57.7	4.2	57.5	4.0	0.81	54.3	7.6	54.5	7.5	0.78
14. Buttock-popliteal length	48.6	4.5	48.3	4.4	0.84	45.8	5.9	45.8	5.7	0.89
15. Knee height	54.8	4.6	54.5	4.6	0.56	52.9	6.1	51.9	6.1	0.14
16. Popliteal height	42.2	4.8	41.6	4.6	0.42	41.9	5.7	42.1	5.2	0.23
17. Shoulder breadth (bideltoid)	46.9	5.3	46.4	5.1	0.51	41.2	7.9	40.6	8.2	0.18
18. Shoulder breadth (biacromial)	35.6	4.3	35.0	4.2	0.52	33.0	6.6	33.3	6.8	0.58
19. Hip breadth	45.5	6.7	44.9	6.4	0.44	43.5	8.0	43.4	7.8	0.61
20. Chest (bust) depth	25.3	6.0	25.7	6.3	0.51	22.7	7.1	23.1	7.2	0.59
21. Abdominal depth	28.6	7.7	28.4	7.7	0.62	28.1	9.8	28.6	9.3	0.64
22. Shoulder-elbow length	33.9	3.1	33.4	3.5	0.48	30.0	4.6	29.6	5.0	0.24
23. Elbow-fingertip length	44.4	3.9	44.6	3.7	0.51	38.5	6.7	38.7	6.4	0.56
24. Upper limb length	70.4	6.0	71.0	5.9	0.39	65.9	6.5	67.1	6.9	0.16
25. Shoulder-grip length	54.5	3.2	54.6	3.4	0.61	49.5	6.1	49.9	5.9	0.54
26. Head length	18.5	2.2	18.6	2.3	0.58	18.4	3.3	17.8	3.3	0.43
27. Head breadth	22.2	2.9	22.3	2.9	0.75	20.6	4.2	20.4	4.2	0.78
28. Hand length	20.1	1.4	19.9	1.3	0.56	17.6	4.0	17.2	3.8	0.68
29. Hand breadth	10.4	1.6	10.2	1.7	0.74	10.6	2.3	10.5	2.3	0.78
30. Foot length	24.8	2.4	24.9	2.5	0.76	22.3	3.4	23.0	3.5	0.41
31. Foot breadth	11.3	1.6	11.5	1.6	0.71	10.7	1.9	11.0	2.0	0.38
32. Span	154.3	14.9	153.2	14.9	0.62	143.9	16.3	144.1	16.9	0.57
33. Elbow span	75.7	7.7	75.4	7.3	0.68	72.8	8.2	72.8	7.6	0.79
34. Vertical grip reach (standing)	193.4	21.4	193.5	20.9	0.54	191.8	24.4	184.4	26.0	0.01
35. Vertical grip reach (sitting)	131.6	16.1	130.4	15.1	0.48	123.0	21.1	123.3	22.0	0.91
36. Forward grip reach	65.6	5.2	65.1	5.7	0.51	63.9	7.2	64.4	6.6	0.41

Notes: bolded figures show significant difference in means at $\alpha \leq 5\%$.**Table 7**

Reliability test for children and elderly anthropometric measures.

Children		Elderly	
Cronbach's Alpha	Cronbach's Alpha based on Standardized Items	Cronbach's Alpha	Cronbach's Alpha based on Standardized Items
0.928	0.934	0.961	0.972

(standing). At all samples, eye height and shoulder height were found to be highly correlated with stature. It means these two measures can be confidently predicted by known stature. Scale ratio takes place to perform the predicted measures (Pheasant and Haslegrave, 2006; Peacock et al., 2012). Related to body weight, all samples show that thigh thickness and abdominal depth were deemed to be significant measures to be associated with.

4.5. Comparison of selected new and old anthropometric data based on significant correlation

The new anthropometric data taken from children and elderly population group were compared, in terms of weight and stature ratio, to the previous data. The previous anthropometric data have been adopted from Chuan et al. (2010) and Hartono and Gunawan

(2015). With respect to the significant correlations between measures as shown in Table 10 and the available published data, there were seven body dimensions taken, i.e., eye height, shoulder height, hip height, fingertip height, sitting eye height, thigh thickness, and abdominal height. Among those five data sets, they tend to have the same ratio values, except for the children data of 6–9 years in the section of weight ratio both Chinese and non-Chinese. Both Chinese and non-Chinese 6–9 years children have higher weight ratio. It may be due to the growing years from birth to early adulthood period, in which children tend to have higher rate for limb segments compared to other body dimensions. According to Kroemer (2006), during the middle childhood (6–12 years), there will be more on horizontal growth and gradual changes in physical appearance.

Table 8
Significant correlations and ratios with stature and weight for male and female subjects for children.

Dimension	Children (6–9 years)										Children (10–12 years)									
	<i>p-value</i>		<i>W_Cor</i>		<i>S_Cor</i>		<i>W_Rat</i>		<i>S_Rat</i>		<i>p-value</i>		<i>W_Cor</i>		<i>S_Cor</i>		<i>W_Rat</i>		<i>S_Rat</i>	
	C	NC	C	NC	C	NC	C	NC	C	NC	C	NC	C	NC	C	NC	C	NC	C	NC
Male																				
Eye height	0	0	0.56	0.68	0.98	0.81	4.55	3.77	0.86	0.91	0	0	0.27	0.25	0.94	0.91	3.43	3.12	0.91	0.9
Shoulder height	0	0	0.77	0.81	0.93	0.79	4.05	3.37	0.77	0.82	0	0	0.3	0.4	0.94	0.95	3.04	2.76	0.81	0.8
Elbow height	0	0	0.75	0.75	0.91	0.97	3.06	2.60	0.58	0.63	0	0	0.34	0.43	0.87	0.83	2.36	2.08	0.63	0.6
Hip height	0	0	0.77	0.78	0.89	0.76	2.66	2.30	0.5	0.56	0	0	0.35	0.43	0.82	0.78	2.08	1.87	0.55	0.54
Fingertip height	0	0	0.69	0.67	0.86	0.9	1.77	1.50	0.33	0.36	0.01	0.02	0.21	0.45	0.78	0.91	1.37	1.19	0.36	0.35
Sitting eye height	0	0	0.56	0.6	0.87	0.85	2.34	1.81	0.44	0.44	0	0	0.25	0.44	0.84	0.72	1.63	1.44	0.43	0.42
Span	.02	0	0.34	0.39	0.68	0.9	4.86	4.14	0.92	1	0	0	0.29	0.31	0.69	0.64	3.72	3.35	0.99	0.97
Vertical grip reach (standing)	0	0	0.59	0.67	0.79	0.81	5.94	4.95	1.12	1.2	0	0	0.39	0.34	0.71	0.72	4.44	4.10	1.18	1.19
Thigh thickness	0	0	0.94	0.83	0.77	0.77	0.46	0.34	0.09	0.08	0	0	0.71	0.68	0.45	0.34	0.29	0.29	0.08	0.08
Abdominal depth	0	0	0.91	0.8	0.75	0.81	0.72	0.59	0.14	0.12	0	0	0.73	0.66	0.14	0.36	0.48	0.47	0.13	0.14
Female																				
Eye height	0	0	0.67	0.73	0.96	0.91	4.12	3.76	0.9	0.95	0	0	0.55	0.3	0.94	0.94	3.48	3.33	0.93	0.88
Shoulder height	.01	0.01	0.52	0.66	0.86	0.9	3.66	3.27	0.8	0.82	0	0	0.54	0.51	0.91	0.88	3.02	2.86	0.81	0.76
Elbow height	0	0	0.7	0.74	0.85	0.95	2.80	2.74	0.61	0.69	0	0	0.42	0.43	0.58	0.57	2.32	2.34	0.62	0.62
Hip height	0	0	0.63	0.68	0.92	0.88	2.51	2.40	0.55	0.6	0	0	0.47	0.39	0.67	0.78	2.12	2.08	0.57	0.55
Fingertip height	0	0	0.71	0.52	0.93	0.88	1.64	1.67	0.36	0.42	0.01	0	0.49	0.37	0.77	0.48	1.36	1.39	0.36	0.37
Sitting eye height	0	0	0.67	0.74	0.86	0.92	2.02	1.91	0.44	0.48	0	0.02	0.31	0.42	0.65	0.68	1.61	1.71	0.43	0.45
Span	0	0	0.49	0.73	0.77	0.78	4.42	4.21	0.97	1.06	0	0	0.39	0.39	0.81	0.84	3.76	3.56	1	0.94
Vertical grip reach (standing)	0	0	0.43	0.66	0.76	0.79	5.37	5.17	1.18	1.3	0	0	0.28	0.32	0.76	0.75	4.45	4.29	1.19	1.14
Thigh thickness	0	0	0.81	0.79	0.81	0.64	0.33	0.32	0.07	0.08	0	0	0.81	0.62	0.44	0.03	0.29	0.29	0.08	0.08
Abdominal depth	0	0	0.78	0.78	0.73	0.53	0.62	0.56	0.14	0.14	0	0	0.76	0.63	0.32	0.14	0.45	0.47	0.12	0.12

Notes: p-value is a significant value with $\alpha \leq 5\%$; W_cor = weight correlation; S_cor = stature correlation; W_rat = weight ratio = particular dimension (in cm)/weight (in kg); S_rat = stature ratio = particular dimension (in cm)/stature (in cm); C=Chinese; NC = non-Chinese; bolded figures show high correlation.

Table 9
Significant correlations and ratios with stature and weight for male and female subjects for elderly.

Dimension	Elderly									
	<i>p-value</i>		<i>W_Cor</i>		<i>S_Cor</i>		<i>W_Rat</i>		<i>S_Rat</i>	
	C	NC	C	NC	C	NC	C	NC	C	NC
Male										
Eye height	0	0	0.28	0.26	0.93	0.92	2.37	2.39	0.93	0.92
Shoulder height	0	0	0.31	0.41	0.94	0.95	2.1	2.21	0.82	0.83
Elbow height	0	0	0.35	0.34	0.87	0.83	1.85	1.98	0.61	0.64
Hip height	0	0	0.36	0.43	0.81	0.79	1.54	1.64	0.56	0.55
Fingertip height	.01	0.03	0.21	0.44	0.79	0.91	1.1	1.12	0.37	0.37
Sitting eye height	0	0	0.25	0.45	0.84	0.72	1.12	1.23	0.41	0.4
Span	0	0	0.26	0.31	0.68	0.65	2.68	2.71	1.02	0.99
Vertical grip reach (standing)	0	0	0.41	0.34	0.71	0.72	3.35	3.41	1.16	1.11
Thigh thickness	0	0	0.73	0.69	0.41	0.34	0.26	0.28	0.07	0.08
Abdominal depth	0	0	0.74	0.68	0.15	0.35	0.49	0.51	0.12	0.11
Female										
Eye height	0	0	0.56	0.29	0.95	0.93	2.31	2.35	0.94	0.97
Shoulder height	0	0	0.54	0.51	0.91	0.88	1.99	1.98	0.83	0.84
Elbow height	0	0	0.42	0.42	0.59	0.57	1.83	1.81	0.64	0.65
Hip height	0	0	0.48	0.39	0.67	0.79	1.54	1.48	0.57	0.58
Fingertip height	.01	0	0.49	0.37	0.78	0.48	1.12	1.27	0.43	0.45
Sitting eye height	0	0.03	0.32	0.41	0.65	0.68	1.1	1.13	0.45	0.51
Span	0	0	0.39	0.39	0.81	0.83	2.71	2.76	1.03	1.04
Vertical grip reach (standing)	0	0	0.27	0.31	0.74	0.75	3.41	3.45	1.18	1.19
Thigh thickness	0	0	0.81	0.62	0.44	0.03	0.28	0.29	0.08	0.09
Abdominal depth	0	0	0.76	0.64	0.31	0.12	0.48	0.51	0.15	0.16

Notes: p-value is a significant value with $\alpha \leq 5\%$; W_cor = weight correlation; S_cor = stature correlation; W_rat = weight ratio = particular dimension (in cm)/weight (in kg); S_rat = stature ratio = particular dimension (in cm)/stature (in cm); C=Chinese; NC = non-Chinese; bolded figures show high correlation.

5. Discussion and analysis

This study has been done with a focus on special population, i.e., children and elderly. The children itself has been split into 2 parts, namely, (i) 6–9 years and (ii) 10–12 years. Related to elderly, it is critical as the numbers of aging people and their percentage in the overall population become larger, thus the need for complete, reliable, quantitative, and valid information about this population arises (Kroemer, 2006). Despite their physical limit, elderly people

simply liking to do work, returning to work after raising children and enjoying longer lives. When it comes to the children anthropometry, especially at the range of 6–12 years, it deals with horizontal growth and gradual changes in physical appearance. Nowadays, facilities for children are ubiquitous, ranging from learning into playing devices.

A study on children and elderly anthropometry raises more attention due to its unique characteristics, thus, it is called as special population. The changes in body size especially during

Table 10

Comparison of old and new anthropometric data.

Dimension	Children 6–9 years (New)				Children 10–12 years (New)				Elderly (New)				Adult (Hartono and Gunawan, 2015)		Adult (Chuan et al., 2010)	
	W_Rat		S_Rat		W_Rat		S_Rat		W_Rat		S_Rat		W_Rat	S_Rat	S_Rat	
	C	NC	C	NC	C	NC	C	NC	C	NC	C	NC	Overall		C	Overall
Male																
Eye height	4.55	3.77	0.86	0.91	3.43	3.12	0.91	0.9	2.37	2.39	0.93	0.92	2.36		0.93	0.93
Shoulder height	4.05	3.37	0.77	0.82	3.04	2.76	0.81	0.8	2.1	2.21	0.82	0.83	2.09		0.83	0.83
Hip height	2.66	2.30	0.5	0.56	2.08	1.87	0.55	0.54	1.54	1.64	0.56	0.55	1.42		0.56	0.55
Fingertip height	1.77	1.50	0.33	0.36	1.37	1.19	0.36	0.35	1.1	1.12	0.37	0.37	0.94		0.37	0.37
Sitting eye height	2.34	1.81	0.44	0.44	1.63	1.44	0.43	0.42	1.12	1.23	0.41	0.4	1.24		0.49	0.46
Thigh thickness	0.46	0.34	0.09	0.08	0.29	0.29	0.08	0.08	0.26	0.28	0.07	0.08	0.22		0.08	0.1
Abdominal depth	0.72	0.59	0.14	0.12	0.48	0.47	0.13	0.14	0.49	0.51	0.12	0.11	0.31		0.12	0.13
Female																
Eye height	4.12	3.76	0.9	0.95	3.48	3.33	0.93	0.88	2.31	2.35	0.94	0.97	2.9		0.92	0.93
Shoulder height	3.66	3.27	0.8	0.82	3.02	2.86	0.81	0.76	1.99	1.98	0.83	0.84	2.58		0.82	0.83
Hip height	2.51	2.40	0.55	0.6	2.12	2.08	0.57	0.55	1.54	1.48	0.57	0.58	1.77		0.57	0.56
Fingertip height	1.64	1.67	0.36	0.42	1.36	1.39	0.36	0.37	1.12	1.27	0.43	0.45	1.19		0.38	0.38
Sitting eye height	2.02	1.91	0.44	0.48	1.61	1.71	0.43	0.45	1.1	1.13	0.45	0.51	1.43		0.46	0.46
Thigh thickness	0.33	0.32	0.07	0.08	0.29	0.29	0.08	0.08	0.28	0.29	0.08	0.09	0.25		0.08	0.1
Abdominal depth	0.62	0.56	0.14	0.14	0.45	0.47	0.12	0.12	0.48	0.51	0.15	0.16	0.37		0.12	0.13

Notes: W_cor = weight correlation; S_cor = stature correlation; W_rat = weight ratio; S_rat = stature ratio; C=Chinese; NC = non-Chinese; bolded figures tend to be higher than other values at the same category of ethnic group.

childhood may vary from one individual to others, due to genetic factor, health, nutrition and environmental issues (Wall, 1993; Kroemer, 2006). Moreover, in general, body size increases rapidly during infancy (up to 2 years), and then more slowly until the start of puberty. In most males, growth accelerates at around 11 years, and reaches its peak at about 14 years, and then slows until adult stature is attained in the early to middle 20s. Whilst, for females, the fastest growth at around 12 years, and full adult stature is often complete at 16 years. Hence, a study on children anthropometry is of interest, especially how this dynamic growth fits the socio-technical system.

After years, when it comes to aging, some may show rapid change in anthropometry, due to numerous alterations in musculoskeletal features such as bones become stiffer and more brittle, and shrinking of spinal discs that influence the height of limb segments.

Interestingly, comparing the Chinese and non-Chinese elderly sub-group, there was no significant difference, at both male and female group. It applied to the children anthropometry of 10–12 years sub-group at both male and female, as well. More interestingly, at the early stage of children growth (i.e., 6–9 years sub-group), it has been found that the non-Chinese group tend to have bigger dimensions than the Chinese one. In addition, the male and female children of 6–9 years (both Chinese and non-Chinese sub-group) had higher weight ratio, compared to elderly. It was easily recognized that children tend to have higher rate for limb segments compared to other body dimensions within their growing periods (Kroemer, 2006).

According to BMI, it is shown that both special populations (i.e., children and elderly, at both male and female samples) were located at the healthy weight zone (18.5–24.99), except for male and female Chinese children of 6–9 years sub-group (i.e., 16.1 and 17.9, respectively). Though, this value is not far away from the healthy range. According to WHO (2017), those BMI are still acceptable as they are within the healthy BMI range (i.e., around 14–19).

More interestingly, both female and male elderly for Chinese and non-Chinese samples showed BMI nearly the upper limit of 24.99. They may have gained more weight due to less exercise and activity. Moreover, within the age bracket, some elderly show rapid change in anthropometry within few years, for instance, in stature because of posture and shrinking of spinal discs, and in weight

because of changes in nutrition, metabolism, and health (Kroemer, 2006).

In general, the male children tend to have bigger body dimensions than the female one. Apart from what have been known that male children grow faster at about 11 (Kroemer, 2006), it may be influenced by better physical activities. Compared to others, male children do more physical activities and exercises.

In general, stature was highly correlated with eye height, shoulder height, elbow height, hip height, fingertip height, sitting eye height, span, and vertical grip reach (standing) in all population groups. More specifically, there were two measures (i.e., eye height and shoulder height) can be confidently predicted by a given stature. Related to body weight, thigh thickness and abdominal depth were deemed to be closely correlated with. The finding shows that, with a very limited time or other resources (e.g., the number of subjects), several body dimensions of a particular population were able to be predicted confidently, given a precise stature or body weight. Inherently, stature and body weight are basic measures, and easy to collect by layman or less experienced person. Even, a simple meter tape can be used for measuring stature, and a simple weighing scale can be utilized (Hartono and Gunawan, 2015).

The data set of anthropometric body dimensions are utilized to design specific products considering these two different special populations. At the elderly group, the targeted products may include office chairs and tables, bedroom and dining room furniture, kitchen tops and storage space, placement of electric switches, door handles, and windows (Kothiyal and Tetey, 2001). At the children group in the school age, according to Saptari et al. (2013), the products designed may cover backpacks, toys, desks, chairs, and writing utensils.

6. Conclusion, limitation and further research

Given more valid procedures and sufficient sample size, the human body dimensions can be predicted in the near future by proposing mathematical modeling, which is revisiting the Drillis and Contini's ratio (1966), and has been proposed by Peacock et al. (2012).

Following the previous research (see Peacock et al., 2012; Hartono, 2015), this study confirms the findings that body weight was found to be a predictor of width and girth measures, whereas stature was found to be highly correlated with limb lengths. More

specifically, this study provides more insight about which body segments can be predicted more precisely through either stature or body weight, according to statistical testing. Practically, the findings can be applied to any product or system design taking into account anthropometric measures, especially for special populations (i.e., children and elderly).

However, this study is limited and far from complete. The generalization of the findings from the study is limited due to the relatively small sample size. In this study, the relative small sample size is shown at the Chinese male children anthropometric data. Furthermore, the study on other special population settings should be of interest, such as pregnant woman, disability, and ethnic group-based Indonesian anthropometry.

For further studies, it is essential to include and take into account unique ethnic groups for Indonesian. Major ethnic groups within different special populations may be of interest, such as Javanese, Madurese and Balinese. Another factor such as geographical such as Papua will be of interest. Papua people have different face and posture, compared to Indonesian majority. It may be due to different region where they live, i.e., more mountainous and forest areas. Another interesting potential is that how to validate the linear model and apply the sufficient anthropometric data into products. Moreover, more information about individual differences on anthropometry (Kroemer, 2006) is of interest. Anthropometry demands strict timeliness. According to Hu et al. (2015), large-scale anthropometric measurement study should be conducted every 10 years.

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Appendix A. Supplementary data

Supplementary data related to this article can be found at <https://doi.org/10.1016/j.ergon.2018.01.004>.

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