Journal of the Society of Automotive Engineers Malaysia
Volume 4, Issue 2, pp 191-207, May 2020
e-ISSN 2550-2239 & ISSN 2600-8092

Development of Anthropometric Database for ASEAN NCAP: A Case Study of Malaysian Children Aged 6 Years Old

N. I. Mohd Zaki[*1,2], S. M. Che Husin[1,2], M. K. Abu Husain[1,2],
N. Abu Husain[1,2], A. Ma'aram[1], A. Jusuf[3], J. Carmai[4], Y. Ahmad[5] and K. A. Abu Kassim[5]

[1]Universiti Teknologi Malaysia, 81310 UTM Johor Bahru, Johor, Malaysia
[2]ACTS Smart Solutions Sdn. Bhd., Universiti Teknologi Malaysia, Jalan Sultan Yahya Petra, 54100 Kuala Lumpur, Malaysia
[3]Institut Teknologi Bandung, Jl. Tamansari 64, Bandung 40116, Jawa Barat, Indonesia
[4]School of Engineering, King Mongkut's University of Technology North Bangkok, Wongsawang Bangsue, Bangkok 10800, Thailand
[5]Malaysian Institute of Road Safety Research (MIROS), 43000 Kajang Selangor, Malaysia

[*]*Corresponding authors: noorirza.kl@utm.my*

ORIGINAL ARTICLE ***Open Access***

Article History:

Received
19 Nov 2019

Received in revised form
10 Mar 2020

Accepted
11 Mar 2020

Available online
1 May 2020

Abstract – *With the rapid growth of human populations throughout the globe, physical characteristics of human body composition may have significant variation, particularly in height and weight. Access to this information is vital for any product development programs, especially when it comes to safety aspects; hence it is particularly important to the New Car Assessment Program for Southeast Asian Countries (ASEAN NCAP) as the champion of vehicle safety in ASEAN region. This paper aims to describe the development of anthropometric database for ASEAN NCAP. Tasks such as identification of important anthropometric parameters, methodology of measurement and data analysis are explained. A total of 42 anthropometric parameters were measured using direct measuring methods; however only 8 parameters are discussed in this paper. As a case study, a total of 143 Malaysian children aged 6 years old have participated in the anthropometric measurement activity. Statistical information including the mean, standard deviation, 5th percentile, 50th percentile and 95th percentile for each parameter for various body dimensions were tabulated. The collected data and mean of 42 parameters are utilised further for the development of digital 3D-models (using SolidWorks) of the Malaysian children aged 6 years old.*

Keywords: Anthropometry, ASEAN population, adults and children, ASEAN NCAP

1.0 INTRODUCTION

Anthropometry is the study of human body dimension, usually measured in static or dynamic position to assess the proportion and composition of the human body (Petrak and Naglic, 2017). Static anthropometry is referring to the standard measurement taken when body parts are held in a static position and fixed points, whereas dynamic anthropometry is a measurement of human body parts taken with the body at work, in motion or specific posture (Institute of Industrial Engineers, 2006). Anthropometric data can be obtained via manual measurement or using body scanner technologies, where the data acts as a compendium of human body dimension for a specific population. The anthropometric data is universally applicable for various fields of works such as industrial and automotive design, including vehicle safety assessment. It is essential to obtain the anthropometric data for ergonomic design guideline as well as to improve comfortability, safety, performance and efficiency of a product (Pheasant, 1998; Dawal et al., 2012).

The New Car Assessment Programme for Southeast Asian Countries (ASEAN NCAP) is using Hybrid III 50th percentile male (HIII-50M), and Q1.5 & Q3 dummies, as adults and children surrogates in their frontal-impact crash testing. Similar dummies (representing children aged between 6 and 10 years old) are also used for Child Restraint System (CRS) installation assessment procedure (ASEAN NCAP, 2018a; ASEAN NCAP, 2018b). Historically, Hybrid III adult dummy represents the anthropometry parameters (stature & body weight) of the US adult population in the 1970s. A follow-up study indicated a substantial change in the distribution of body weights among the US adult population. With the rapid growth of human populations throughout the globe, physical characteristics of human body composition may have significant variation, particularly in height and weight (Pheasant and Haslegrave, 2006; Tesedo Nieto et al., 2011; Dawal et al., 2012). These variances are subjected to human diversity factors such as age, genetics, ethnicity, health, diet intake and lifestyle (Hsu et al., 2016; Taifa and Desai, 2017). Another survey conducted on Chinese population found that both the statures and body weights were relatively lower than the reference values of these dummies – indicating a mismatch of anthropometric measures between the populations of the USA and China (Cao et al., 2016). Anthropometric variations may result in a number of design issues related to ergonomics, safety and comfort level of vehicle occupants. Furthermore, without the use of accurate anthropometric data, the performance of product design is limited. Therefore, the need to establish ASEAN anthropometric data for ASEAN NCAP is significant since it involves the safety aspect of vehicle design.

Table 1 shows previous anthropometric studies performed particularly in ASEAN countries. Based on these studies, it can be concluded that there are limited works on the anthropometric database that can represent the ASEAN population. Therefore, it is useful to develop a more comprehensive database covering Malaysia, Indonesia and Thailand to represent the ASEAN's adult and children population. ASEAN NCAP, as a well-known champion of vehicle safety in the ASEAN region, could benefit significantly from this study especially in fulfilling specific considerations towards the ASEAN NCAP requirements. The developed database would help in the development of test manikins for installation checks and other relevant purposes. It may also add another dimension in the human anthropometric study in ASEAN. Besides, relevant stakeholders may want to consider the findings when developing new products (especially related to vehicle safety applications such as child safety seats, restraint system, etc.) in the future. Nonetheless, it is also essential to utilise the anthropometric database in the ergonomic design of products, design for vehicle safety (such as blind-spot reduction), and general vehicle design applications.

Table 1: Study on anthropometry, particularly in ASEAN countries

Title/ Author	Subjects	Age	Location	Dimension	Equipment	Major Finding	Critical Review
Anthropometric Measurements Among Four Asian Countries in Designing Sitting and Standing Workstations. *Rahman et al.* (2018)	Malaysian - 314 samples Thai - 400 samples Indonesian - 377 samples Filipinos - 1805 samples (Gender not reported)	18 - 45 years old	Malaysia, Thailand, Indonesia and Philippines	36 anthropometric dimensions	Used conventional methods (i.e. measuring tape, weighing scale, measuring chair, Scientific Martin pelvimeter, TTM bone caliper)	• The results indicated that the Indonesians were the tallest among the four countries, whereas the Filipinos were the shortest for both male and female. • Filipinos and Malaysian data were almost similar and appear to have the smallest values for eye and elbow height.	• The study focuses on comparison in anthropometric dimensions of four ASEAN countries (gender), where the anthropometric database developed is used to improve industrial workstation and facilities ergonomically.
An Anthropometric Comparison of Current Anthropometric Test Devices (ATDs) with Malaysian Adults. *Md Isa et al.* (2016)	708 male samples 613 female samples	15 - 80 years old	Malaysia	Stature and body weight	• Human body measuring kit • Anthropometer	• The results revealed that the current Malaysian midsize male population differs from the ATD's statures and body weights by about 35 and 40 percentile points. • The statures of both Chinese and Malaysian populations are slightly shorter than the reference ATDs, while US adults are larger than reference ATDs.	• The anthropometric parameter selected for this study focus only on stature and body weight. • Current ATDs used in automotive crash test not fully represent current Malaysian adult.
Incorporating Malaysian's Population Anthropometry Data in the Design of an Ergonomic Driver's Seat. *Md Deros et al.* (2015)	1405 male and female (anthropometric data) 100 male and female (driver's seat discomfort)	Not reported	Malaysia	8 sitting anthropometric dimension	Direct measuring method (i.e. anthropometer, ruler, calipers and measuring tape)	• Questionnaire surveys used to gather respondents' awareness level and their perception towards parameter that influence driver's seat design. • Driver's seat adjustability is the most influential parameter in determining driver's seat comfort, followed by cushion, and back rest. • New driver's seat design is established using 3D Digital Human Modelling (DHM) software, CATIA.	• The anthropometric data are used to develop and design an ergonomic driver's seat. The parameters are selected with consideration to optimize comfort level and safety of driver's seat.

Title/ Author	Subjects	Age	Location	Dimension	Equipment	Major Finding	Critical Review
Anthropometric Data of Malaysian Workers. *Hassan et al.* (2015)	863 - male samples 261 – female samples	Not reported	NIOSH, Malaysia	23 static anthropometric dimensions	• Anthropometer and anthropometric grid	• The result found that there are significant different of anthropometric dimensions between gender. • The anthropometric dimensions for each gender is established to be used for designing safer and healthier workplace for Malaysian worker.	• Covers only 10 industrial sectors classified under the Law of Malaysia Occupational Safety and Health Act 514.
Three-Dimensional (3D) Anthropometry Study of the Malaysian Population. *Bong et al.* (2014)	160 - female samples	18 - 65 years old	Malaysia	6 anthropometric dimensions (circumference)	Used conventional methods (i.e. measuring tape, Holtain skinfold calipers) and 3D body scanner	• The anthropometric measurement (circumference) taken with manual and 3D body scanner (Size USA and ISO 8559 size reference) are compared using paired sample t-test analysis. • Result shows that mean ± standard deviations of SizeUSA is higher than manual measurements, compare to ISO 8559.	• Covers only Malaysian females and limited to circumference parameters, hence the result cannot be generalized to represent whole body anthropometric measurement for Malaysian population.
Incorporating Anthropometrics Data in Designing Driver's Seat for Malaysian Made Compact Cars. *Md Deros et al.* (2014)	26 males, 19 females (for survey of driver's seat comfort); 1216 Malaysian (anthropometry data)	20 - 30 years old (survey); 15-65 years old (anthropometry data)	Malaysia	62 anthropometric dimensions	L-shape ruler, measuring tape anthropometer	• Measured maximum and minimum values of seat adjustment horizontal sliding distance (SLD) and Accelerator Heel Point (AHP) for driver's seat comfort (based on the chosen compact cars). • All the cars studied are able to accommodate 90 % of car drivers from the Malaysian population, except for extreme population (5th and 95th percentile) may experience discomfort.	• Only popliteal height parameter is chosen for anthropometric data comparison between car models.
Comparison of Malaysian and SAE J833 Anthropometric Proportions for Vehicle Package Design. *Rashid et al.* (2013)	105 male samples 105 female samples	17 - 60 years old	Malaysia	23 anthropometric dimensions	Measurement taken using manual measurement methods as described in the ISO 3411:2007	• Comparison made between anthropometric data of Malaysian population with SAE J833 database for each gender • Malaysian population has longer dimension for upper body segment, whereas data from SAE J833 indicated longer dimension for lower body segment.	• Comparison only cover 5th Female, 50th Male and 95th Male percentiles and the anthropometric data collected are for designing ergonomic driver cockpit area for Malaysian population.

Title/ Author	Subjects	Age	Location	Dimension	Equipment	Major Finding	Critical Review
Anthropometric Database for the Learning Environment of High School and University Students. *Dawal et al.* (2012)	41 high school students (21 male samples, 20 female samples) 143 university students (74 male samples, 69 female samples)	13 - 17 years (high school students) 18 – 28 years (university students)	Kuala Lumpur	20 static anthropometric dimensions	Used conventional methods (i.e. measuring tape, weighing scale, measuring chair, Scientific Martin pelvimeter, TTM bone caliper)	• There are significant differences between gender of high school and university students for several parameters. • All data for male students are relatively higher than female students. However, mean BMI for female high school students are greater than for male high school student.	• The study compares anthropometric measurement of high school and university students in context of designing products, devices and equipment for ergonomic learning environments.
Anthropometric Study Among Adults of Different Ethnicity in Malaysia. *Karmegam et al.* (2011a)	150 - male samples 150 - females samples	18 - 24 years	Sultan Azlan Shah Polytechnic in Perak	33 anthropometric dimensions	Harpenden standard anthropometer	• There are significant differences in most of the anthropometric measurement taken for each three ethnics. • The post-hoc Scheffe test indicated that the majority of the parameters of anthropometry of Malay males have the largest body size compared to the Chinese and Indian. Meanwhile, Chinese females have the largest body size compared to the Malay and Indian population.	• The respondent participate in this study are students age 18-24 years which does not represent each ethnic population in Malaysia.
Anthropometry of Malaysian Young Adults. *Karmegam et al.* (2011b)	595 - male samples 437 - female amples	18 - 24 years	Sultan Azlan Shah Polytechnic in Perak	34 anthropometrical dimensions	Harpenden standard anthropometer	• Malaysian anthropometric data collected in this study are presented according to each gender (1^{st}, 5^{th}, 50^{th}, 95^{th} and 99^{th} percentile). • The Malaysian anthropometric data are compared with Thailand adults (South), where the results revealed that there are 11 and 12 significant differences between the male and female adults, respectively.	• The study only covers young adult age 18-24 years. The comparison of anthropometric measurement between Malaysian and Southern Thai adults only cover for 15 parameters.

Title/ Author	Subjects	Age	Location	Dimension	Equipment	Major Finding	Critical Review
Malaysian Sitting Anthropometry for Seat Fit Parameters. *Daruis et al.* (2010)	216 males and females	18 - 40 years old	Malaysia	16 anthropometrical dimensions	Direct measuring method (i.e. anthropometer, ruler, calipers and measuring tape)	• The anthropometric data collected for each gender are compared with previous studies (local anthropometric studies, Thailand, Filipino and Swedish). • There are some differences between current anthropometric data with other local studies for Malaysian (sitting height, sitting elbow height, etc.). • The current findings are found to be significantly larger than the Filipino, but smaller compart to the Thailand and Swedish.	• The anthropometric dimension selected for this study are mean to fit parameter dimension for Malaysian automobile driver seat design. • The comparison between current study and previous studies only made for few anthropometric dimensions due to different method of measurement and limited data.

2.0 METHODOLOGY

2.1 Development of Methodology

Development of the methodology incorporated four phases as demonstrated in Figure 1 which include:

(a) Phase 1: Determination of Anthropometric Parameter
(b) Phase 2: Data Collection
(c) Phase 3: Data Analysis
(d) Phase 4: Development of ASEAN Manikin Model

Based on Figure 1, three objectives of this study – (i) to establish anthropometric data of ASEAN adults and children for ASEAN NCAP; (ii) to compare and analyse developed anthropometric data with other ASEAN countries; and (iii) to develop 3D-model manikin using collected anthropometry data for future ASEAN NCAP use, are expected to be achieved after completing Phase 2, Phase 3 and Phase 4, subsequently. The details for each phase are as follows.

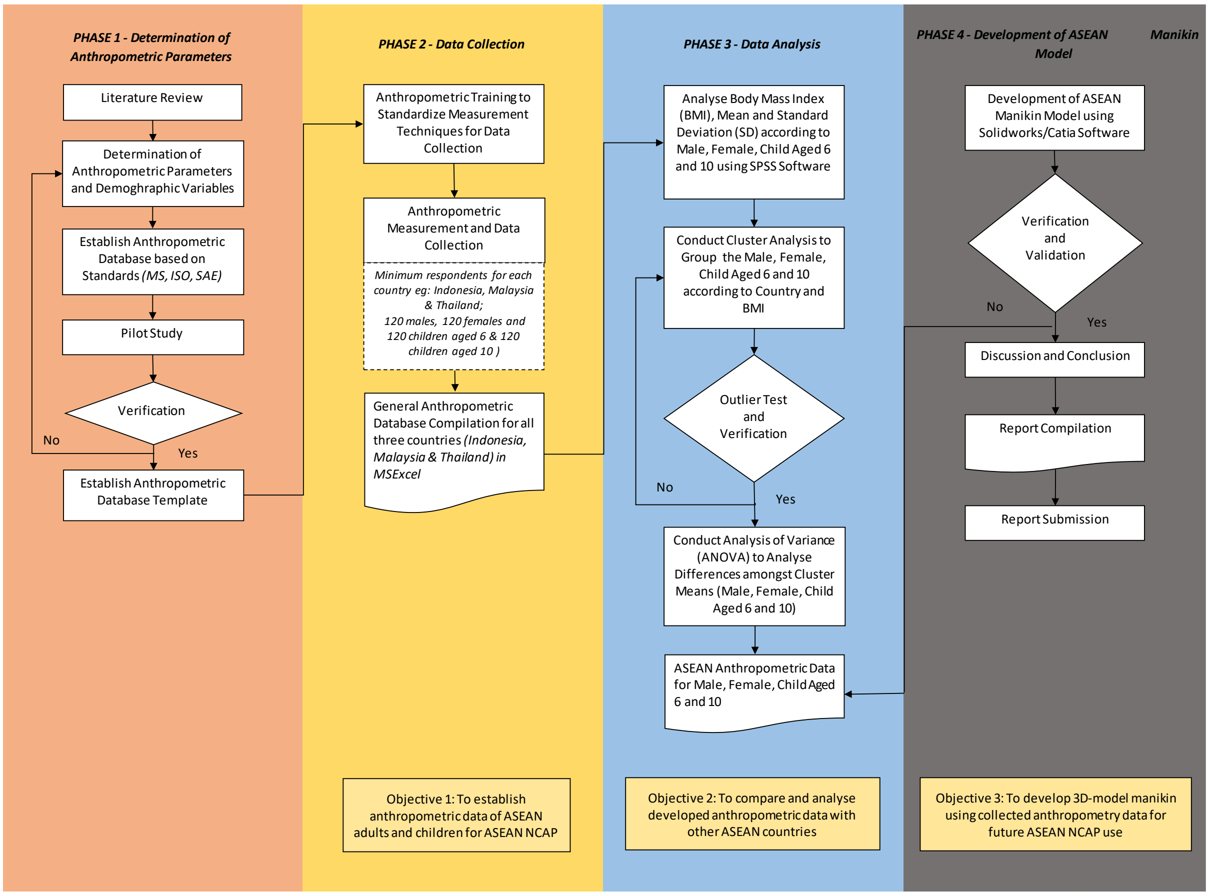

Figure 1: Flowchart for methodology of anthropometric data for ASEAN

Phase 1: Determination of Anthropometric Parameters

The procedure starts from determination of anthropometric database based on standards including International Organization for Standardization (ISO 7250:2003 – Basic Human Body Measurements for Technological Design) as presented in International Organisation for Standardisation (2017), and Society of Automotive Engineers (SAE J833 – Standard Human Physical Dimension) to ensure the comparability of the anthropometric database created with all measurements taken as per standard. Several steps were taken to ensure the validity and reliability of anthropometric parameters. Initially, the human body has divided into five segments, comprises the head, body and torso for sitting, arm and hand, leg and foot as shown in Figure 2. The selected parameters are being chosen based on each segment. Finally, a total of 42 anthropometric parameters were selected as presented in Figure 3. Table 2 shows the body description for each anthropometric parameter. Then, the anthropometric database template was established after the verification process.

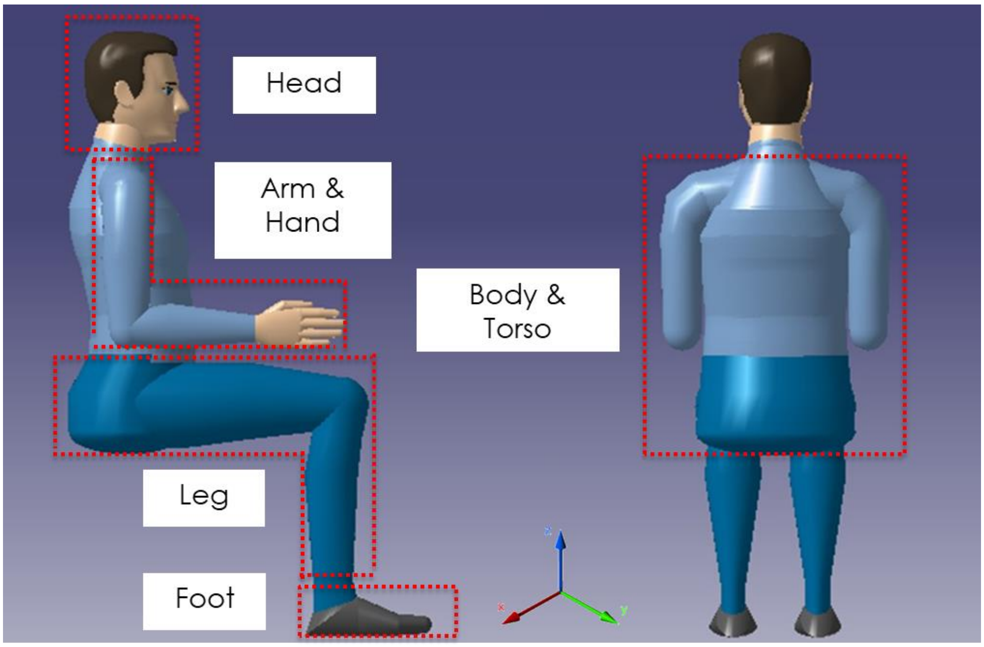

Figure 2: Sitting posture with five segments of body measurement

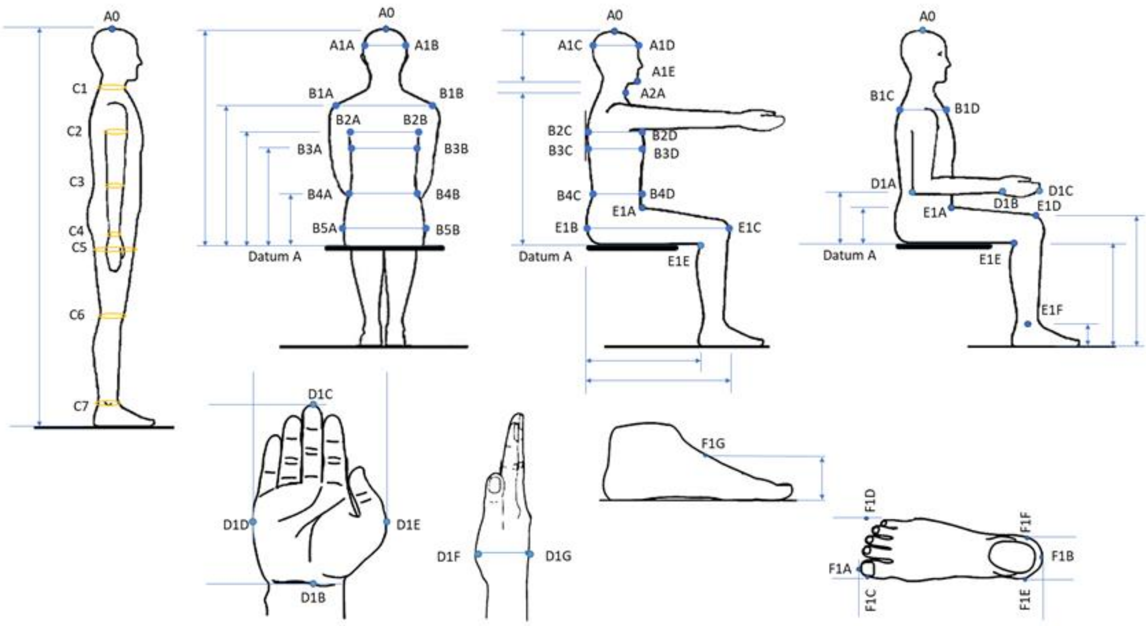

Figure 3: Illustration of 42 body dimensions

Table 2: Description of 42 anthropometric parameters (Pheasant, 1998)

Standing Posture (Weight, Stature and Circumferences)			
No	**Parameter**	**Description**	**Coordinates**
1	Weight	Body weight	
2	Stature	Vertical distance from a standing surface to the top of the head.	Base - A0
3	Neck circumference	Circumference of the neck at the infra-thyroid landmark (Adam's apple).	C1
4	Axillary arm circumference (upper arm)	Circumference of the upper arm perpendicular to its long axis at the level of the anterior scye landmark on the upper arm.	C2
5	Elbow circumference	Circumference of the elbow in a plane perpendicular to the long axis of the arm at the level of the olecranon center landmark, with the arm straight at the side.	C3
6	Wrist circumference	Circumference of the wrist perpendicular to the long axis of the forearm at the level of the stylion landmark.	C4
7	Thigh circumference (crotch level)	Circumference of the thigh at its juncture with the buttock.	C5
8	Knee circumference	Horizontal circumference of the knee at the level of the mid-patella landmark (standing).	C6
9	Ankle circumference	Minimum horizontal circumference of the ankle.	C7
Sitting Posture (Head and Neck, Body and Torso, Arm and Hand, Leg, and Foot)			
No	**Parameter**	**Description**	**Coordinates**
10	Sitting Height	Vertical distance between the sitting surface and the top of the head.	Datum A to A0
11	Head Height	Vertical distance between the menton landmark at the bottom of the chin and the horizontal plane tangent to the top of the head.	A0 to A1E
12	Head Breadth	Maximum horizontal breadth of the head above the attachment of the ears.	A1A to A1B
13	Head Length	Maximum length of the head between the glabella landmark and the opisthocranion.	A1C to A1D
14	Sitting Neck Height	Vertical distance between the sitting surface and the infrathyroid landmark (Adam's apple).	Datum to A2A
15	Sitting shoulder height (acromial)	Vertical distance between the sitting surface and acromion landmark on the tip of the shoulder.	Datum A to B1A
16	Sitting shoulder breadth (biacromial)	Posterior distance between the right and the left acromion landmarks on the tips of the shoulders.	B1A to B1B
17	Sitting shoulder depth (acromial)	Horizontal distance between the front and the back at the same shoulder acromial level.	B1C to B1D
18	Sitting interscye height	Vertical distance between the sitting surface and axillary fold posterior landmarks.	Datum A to B2A
19	Sitting intescye breadth	Distance across the back between the top of the right and left axillary fold posterior landmarks.	B2A to B2B
20	Sitting intescye depth	Horizontal distance between the front and back at interscye level	B2C to B2D
21	Sitting chest height	Vertical distance between the sitting surface and the bust point on women and the nipple on men.	Datum A to B3A
22	Sitting chest breadth	Maximum horizontal breadth of chest at the level of the bust point/thelion.	B3A to B3B
23	Sitting chest depth	Horizontal distance between the chest at the level of the bust point on women and the nipple on men, and the back at the same level.	B3C to B3D
24	Sitting waist height	Vertical distance between the sitting surface and the center of the navel (omphalion).	Datum A to B4A
25	Sitting waist breadth	Horizontal breadth of the waist at the level of the center of the navel (omphalion).	B4A to B4B
26	Sitting waist depth	Horizontal distance between the front and back of the waist at the level of the center of the navel (omphalion).	B4C to B4D
27	Sitting hip breadth	Lateral maximum hip or tight breadth (whichever is broader) of a seated subject.	B5A to B5B
28	Sitting elbow height	Vertical distance between the sitting surface and radial landmark below the elbow.	Datum A to D1A
29	Sitting elbow - wrist forward length	Horizontal distance between the back of the tip of the elbow to the wrist	D1A to D1B

Sitting Posture (Head and Neck, Body and Torso, Arm and Hand, Leg, and Foot)			
No	**Parameter**	**Description**	**Coordinates**
30	Hand length	Length of the hand between the stylion landmark on the wrist and the tip of the middle finger.	D1B to D1C
31	Hand breadth (across thumb)	Maximum breadth of the hand between the metacarpal I and the metacarpal V.	D1D to D1E
32	Hand thickness	Vertical distance between the standing surface and top of hand.	D1F to D1G
33	Sitting thigh clearance height	Vertical distance between the sitting surface and the highest point on the top of the thigh.	Datum A to E1A
34	Sitting knee length (hip to knee)	Horizontal distance between the most posterior point on buttock and the front of the knee as measured in the sitting position with the knees flexed 90 degrees.	E1B to E1C
35	Sitting knee height (top of knee)	Vertical distance between the bottom of the planted foot and the suprapatellar landmark (located standing).	E1D to Base
36	Sitting popliteal height = datum A	Vertical distance between the foot surface and the bottom of the thigh just behind the knee. The subject is seated with the thighs parallel and the knees flexed 90 degrees.	Datum A to Base
37	Sitting popliteal length	Horizontal distance between the most posterior point on the buttock and the back of the knee as measured in the sitting position with the knees flexed 90 degrees.	E1B to E1E
38	Sitting ankle height (ankle to base)	Vertical distance between the standing surface and the lateral malleolus on the outside of the ankle.	E1F to Base
39	Foot length	Distance between the tip of the longest toe and the back of the hell of the standing foot.	F1A to F1B
40	Foot breadth	Maximum breadth of the standing foot between the first and the fifth metatarsophalangeal landmark protrusions.	F1C to F1D
41	Heel breadth	Maximum horizontal distance between the medial and lateral points on the inside and outside at the heel.	F1E to F1F
42	Foot thickness	Vertical distance between the standing surface and top of foot.	F1G to Base

Phase 2:

(a) Data Collection

This paper presented the anthropometric database for children aged 6 in Malaysia. The 42 anthropometric parameters have been measured using direct measuring methods (i.e. height and weighting scale, ruler and measuring tape). Anthropometry measurement was performed with the basic sitting posture, subjects sit straight with feet together, shoulders are relaxed, while arms and hand are in 90-degree positions as shown in Figure 2. The children are required to sit straight on the chair with minimal movement to ensure the children body is not moving during the measurement activity. The sampling size was calculated based on the population taken from Department of Statistics Malaysia (2019).

In this study, the probability sampling method was used to reach out to the population. The main benefit of using this method is that there will be an equal probability of selection for all respondents in the population without bias (Ross, 2005). Derived from the calculation of measurement sample size (Raosoft, 2004); a minimum recommended sampling size of 68 respondents was needed with a margin of error was 10 % with 90 % confidence level and response distribution for each category was 50 %. In order to achieve the required sample size, a minimum of 120 respondents to participate in this measurement was set for each category. A total of 143 randomly selected children aged 6 has participated. Before the actual data collection has been conducted, a pilot test was carried out to ensure the measurement of the anthropometric parameters followed the International Organisation for Standardisation (ISO) 7250-1:2017 Basic Human Body Measurements for Technological Design requirement.

(b) Malaysian Children Growth Chart

According to Chen (1985) and Bong et al. (2014), growth charts for children aged 6 years old are shown in Figures 4 and 5, respectively. Chen (1985) developed Malaysian Children Growth Chart that covered from 0 months until 69 months, while Bong et al. (2014) developed the school children growth chart from aged 6.5 until 17 years old based on weight and height data. Since the scope of this research is for children aged 6 years old, the weight and height of respondents are capped within the combination range studied by Chen (1985) and Bong et al. (2014) according to the gender of children. Based on both references, the weight of boys is capped between 14.84 until 32.93 kilograms whereas the weight of girl is between 14.92 until 30.24 kilograms. This makes the general normal weight for children aged 6-year-old is capped between 14.84 until 32.93 kilograms. Similarly, the height of boy is capped between 106.5 until 135.45 centimetres and the height of girl is capped between 104 until 130.37 centimetres respectively. Therefore, the general range for normal height of children aged 6-year-old is capped between 104 until 135.45 centimetres. For this study, the taken data was screened and trimmed according to weight and height values as stated above.

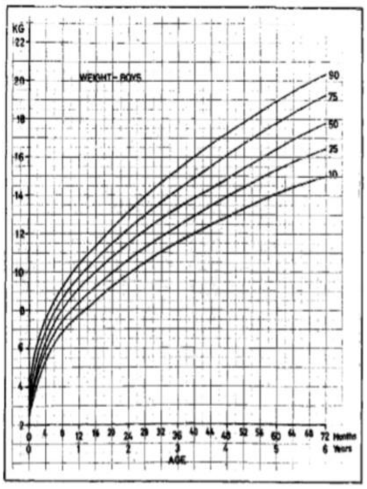

Figure 4(a): Weight Growth Chart for male newborn until aged 6

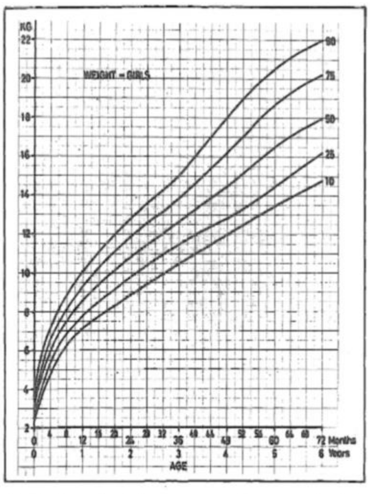

Figure 4(b): Weight Growth Chart for female newborn until aged 6

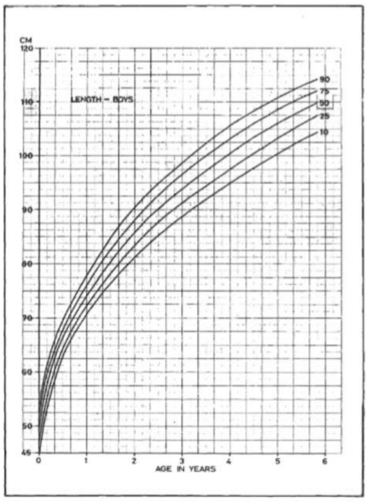

Figure 4(c): Height Growth Chart for male newborn until aged 6

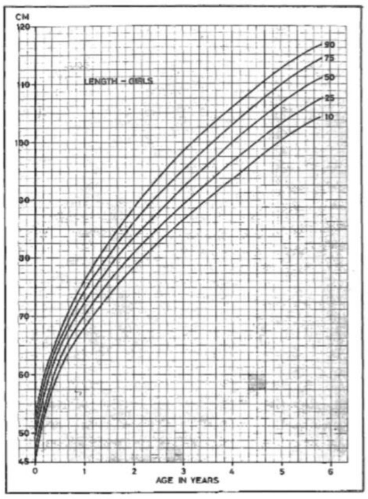

Figure 4(d): Height Growth Chart for female newborn until aged 6

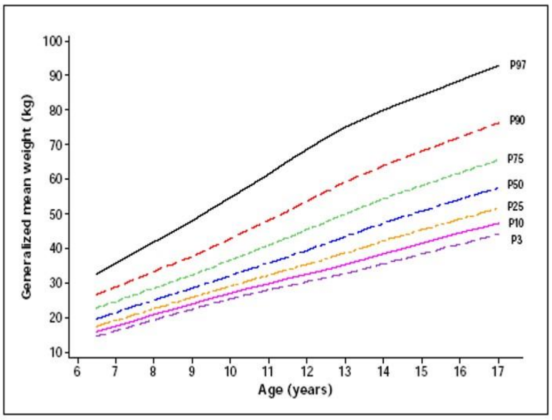

Figure 5(a): Weight Growth Chart for male children aged 6 until 17

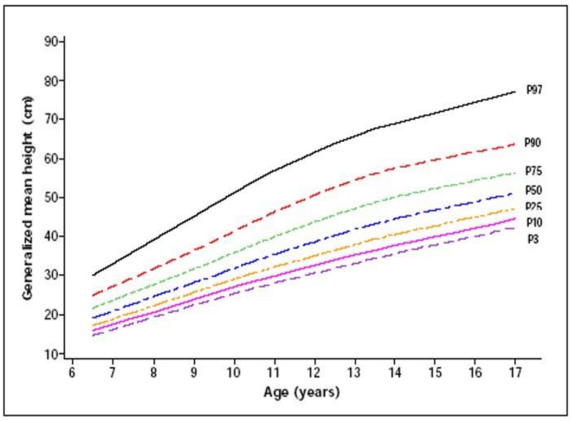

Figure 5(b): Weight Growth Chart for female children aged 6 until 17

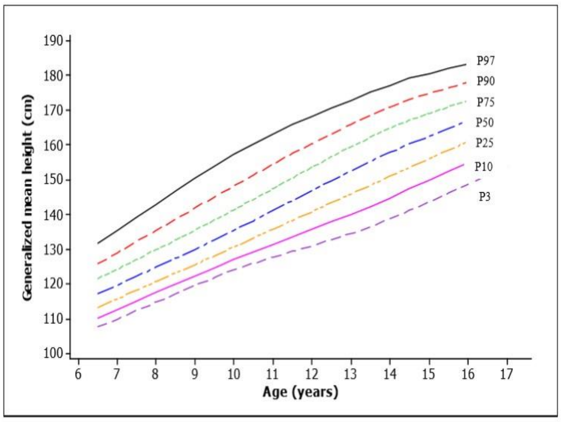

Figure 5(c): Height Growth Chart for male children aged 6 until 17

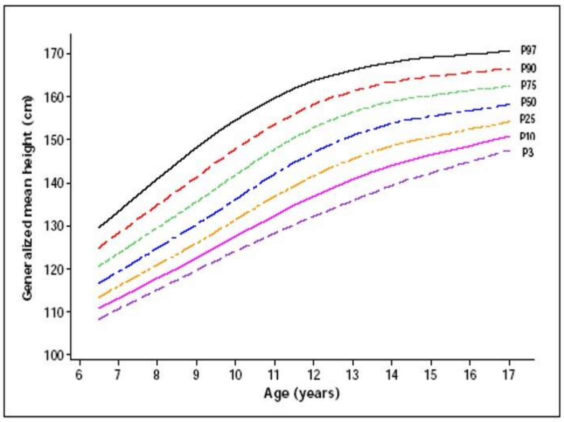

Figure 5(d): Height Growth Chart for female children aged 6 until 17

Phase 3: Data Analysis

The anthropometric data were analysed using Microsoft Excel and SPSS software version 25. For screening, Microsoft Excel is used to select the range of weight and height while the SPSS software is used to calculate the accuracy of collected data by trimming the outliers and also to conduct statistical analysis as described in Section (a) below.

(a) Statistical Analysis

In order to trim the outliers, two-steps cluster analysis was used and the results are displayed using Q-Q plot and matrix scatter plot. The statistical data analyses for basic descriptive statistics (including mean, standard deviation, 5th percentile, 50th percentile and 95th percentile) for 42 anthropometric parameters were tabulated. These descriptive statistics for body dimensions were calculated to determine the characteristics and measurements of the subjects. The Statistical Package for the Social Science (SPSS) Ver. 25 (IBM Corporation, 2017) was used for data entry and descriptive statistical analysis.

Then, the mean values of 42 anthropometric parameters were utilized further for development of digital 3D-models (using SolidWorks) of the ASEAN population for ASEAN NCAP's future use.

Phase 4: Development of ASEAN Manikin Model

ASEAN manikin model is developed using SolidWorks software and can be used to verify the utilization of existing dummies and assist in test manikin development for future ASEAN NCAP use. Samples of ASEAN Manikin Model for Malaysian children aged 6 for each percentile is illustrated in next section.

3.0 RESULT AND DISCUSSION

3.1 Trimming for Outliers

Data trimming was conducted using the two-steps cluster for a total of 143 children aged 6-year-old. It was found that 56 outliers have to be removed in order to obtain the acceptable range of weight and height as suggested by the Malaysian Growth Chart (Chen, 1985; Bong et al., 2014). This makes the total valid data for further analysis is 87 out of 143 samples respondents. Figure 6 shows the Q-Q plot before and after the trimming process for both weight and height aspects. From Figure 6 (b), it can be seen clearly that the range of weight and height is at the acceptable range suggested by Chen (1985) and Bong et al. (2014) with a mean of weight and height is 17.59 kg and 110.25 cm respectively.

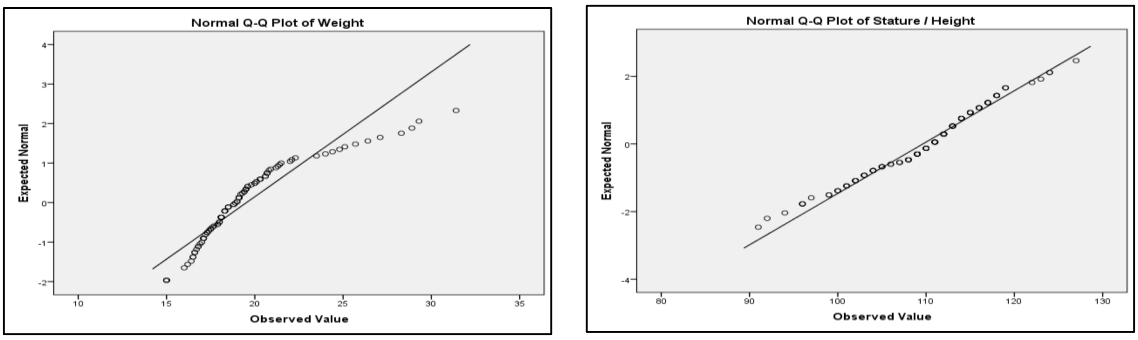

Figure 6(a): Before the trimming process for both weight and height aspects

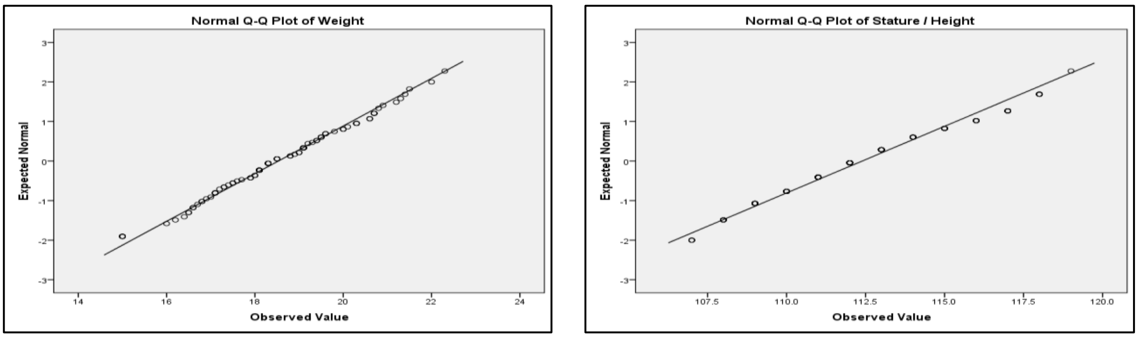

Figure 6(b): After the trimming process for both weight and height aspects

3.2 Anthropometry Data for Malaysian Children Aged 6

For the purpose of quick comparison between the Malaysian children aged 6 and the external measurement of existing crash test dummy (i.e., P6 and Q6 dummies), only 8 anthropometric parameters are tabulated in Table 3. For additional information, the P6 dummy is designed based on the US population while the Q6 dummy representing the combined anthropometric data of US, European and Japanese data (EEVC, 2008). The selected 8 anthropometric parameters are discussed with mean, standard deviation, 5th percentile, 50th percentile, and 95th percentiles. The weight and height of the children (50th percentile) are in normal range with the weight and height fall between suggested range by Malaysian Growth Chart (Chen, 1985; Bong et al., 2014). Standard deviation is calculated to measure the dispersion of a dataset relative to its mean. From Table 3, it can be concluded that the standard deviation (SD) is small with a maximum of SD is below than 3 for all parameters with the highest SD is 2.97 cm for the stature height.

Based on the comparison made between Malaysian children aged 6 with P6 and Q6 dummies, four parameters – which are the means of body weight, stature height, head length and sitting shoulder breadth of the 6-year-old children – are found respectively lower than the reference value of P6 and Q6 dummies. On the other hand, the measurement of 50th percentile children are almost similar to the Q6 dummy, except for weight, stature height, and sitting shoulder breadth which are found smaller than the Q6 dummy measurement. The measurement of 95th percentile Malaysian children indicates that their size is almost in the same range as the P6 dummy except for the head breadth, sitting hip breadth and sitting knee length weight which are slightly bigger in comparison to the P6 dummy.

Table 3: Anthropometric data for Malaysian children aged 6

Parameters	Mean	SD	5th Percentile	50th Percentile	95th Percentile	P6 Dummy	Q6 Dummy
Weight (kg)	18.53	1.66	15.40	18.30	21.36	22.0	23 (± 0.8)
Stature Height (cm)	112.39	2.97	108.00	112.00	118.00	117 (± 1)	114.3 (± 0.9)
Sitting Height (cm)	60.06	2.65	56.00	60.00	64.30	63.6 (± 1)	60.1 (+- 0.9)
Head Breadth (cm)	14.26	1.18	12.50	14.00	16.00	14.5 (± 0.5)	14.2 (+- 0.5)
Head Length (cm)	16.91	0.98	15.00	17.00	18.50	17.5 (± 0.5)	17.0 (+- 0.5)
Sitting shoulder breadth (cm)	26.00	1.79	23.50	26.00	29.60	29.5 (± 1)	30.5 (± 0.7)
Sitting hip breadth (cm)	22.84	1.94	19.70	23.00	26.60	23.9 (± 1)	22.3 (± 0.7)
Sitting knee length (cm)	36.40	1.55	34.00	36.00	38.80	37.5 (± 0.5)	36.6 (± 0.5)

3.3 Malaysian Children Aged 6 Manikin Model

3D manikin model of Malaysian children age 6-year old is developed using SolidWorks software to match with the anthropometric data collected for Malaysian population. Figure 6 shows the visual of manikin models for 5th, 50th and 95th percentile values of Malaysian children age 6-year old.

Figure 6: Visual representation of the 3D model for Malaysian children aged 6 (front view)

4.0 CONCLUSION

The mismatch of anthropometric data between different human populations in the world raises concern on product design aspects relating to many applications such as vehicle safety and ergonomics. In this paper, anthropometric database development for Malaysian children aged 6 is presented, with 3D manikin model of the children illustrated using SolidWorks. The results are also compared to existing child dummies, P6 and Q6. Comparison between anthropometric dimensions of Malaysian children aged 6 with 50^{th} percentile (MY-C06-50^{th}) to P6 dummy shows current MY-C06-50^{th} is smaller, with significance differences mainly on the weight, stature, sitting height, shoulder breadth and knee length. Meanwhile, the anthropometric dimension of MY-C06-50^{th} and Q6 dummy are almost similar, except for the weight, stature height and shoulder breath. Although the differences between MY-C06-50^{th} and Q6 dummy were modest, it is advisable to take the differences in anthropometry dimension into consideration, especially when developing new vehicle occupant safety enhancement (such as child restraint system, etc.), ergonomic design of automotive products, design for vehicle safety and other general vehicle design applications.

ACKNOWLEDGMENTS

The authors would like to acknowledge the support and guidance given by Universiti Teknologi Malaysia (UTM), Malaysian Institute of Road Safety Research (MIROS), ASEAN NCAP secretariat through ASEAN NCAP Collaborative Holistic Research (ANCHOR II) programme and our collaborator partners from Institut Teknologi Bandung and King Mongkut's University of Technology North Bangkok. Special thanks for ACTS Smart Solutions Sdn. Bhd. for their assistance throughout the completion of the project. Greatest gratitude to all volunteers, respondents and children from SKPP11(2) and SKPP9(2) who are contributing for the completion of data collection.

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