Anthropometric Measurements of Malaysian Population for Passenger Cabin Design of Transport Aircraft

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ABSTRACT

In order to improve the passengers' flying comfort, the aircraft cabin features should be ergonomically developed and designed. The key element for design ergonomics is the anthropometric measurements of the target users, which are vital in ensuring a good fit between their body characteristics and the resultant product or system design. Based on this notion, this study aims to establish the database for the measurement of body dimensions of the Malaysian population that is useful in design process of most cabin features. A total of 100 volunteers have participated in this study and their body dimensions are measured using standard measurement tools during a few conducted data collection sessions. Several standard anthropometric measurements of the Malaysian population for sitting and standing body postures have been derived from the descriptive statistics of the collected measurement data. They include stature, standing eye height, standing shoulder height, standing elbow height, standing hip breadth, standing shoulder breadth, sitting shoulder height, sitting elbow height, sitting eye height, sitting buttock-popliteal length and also sitting buttock-knee length. Furthermore, based on the comparison analysis with the referenced Malaysian anthropometric database, it can be concluded that the body characteristics of the Malaysian population are changing with time and the body measurements are expected to further increase in future. This means that the design sizing of the aircraft cabin features might need to be adjusted accordingly to be able to provide a comfortable flying experience for the future Malaysian passengers.

Keywords: *Anthropometry; Malaysian Population; Anthropometric Database; Ergonomics; Cabin Comfort*

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Introduction

As air transportation progressively becomes a more common transport means for many people across the globe, the level of market competition between the airlines has also intensified since they are vying for the same target passengers towards their offered services. It has been established that air passengers tend to develop a service loyalty for airlines that provide a pleasant and comfortable flying experience [1]. Passengers' flight experiences are primarily influenced by the passenger cabin design and also in-flight services, which motivate many airlines to invest on searching for more comfortable aircraft interior design and improved in-flight service to differentiate them from other market competitors. For instance, there have been conducted studies to develop new and innovative cabin features with the notion of improved passengers' flying comfort such as the standing cabin concept [2] and automated in-flight food delivery and waste collection [3]. In essence, passengers' comfort during flight are highly affected by six major factors: anthropometry, climate, sound, vibrations, light and smell [4]. This study is focused on the anthropometry factor, which by definition is a field of research that deals with measurement of body dimensions including body size, shape, strength and working capacity [5], either for design purposes or body composition.

The prominence of human anthropometry factor in context of aircraft passenger cabin comfort relates to the fundamental of design ergonomics that aims for the developed product or system designs to have a good fit with body conditions of the target users. In other words, to enhance the passengers' flight comfort level, cabin features have to be ergonomically designed to match with the characteristics of the passengers' body. There are three primary principles of the design ergonomics: *design for extreme individuals* (i.e. designing for the maximum or minimum of the population using anthropometry data of the 95th percentile male or the 5th percentile female, respectively), *design for adjustable range* (i.e. design to accommodate 90% of the population using anthropometry data of 95th percentile male and 5th percentile female), and *design for average* (i.e. design with the anthropometry data of 50th percentile of male and female) [6]. Several studies have highlighted the importance of anthropometric body measurements to improve aircraft cabin design comfort such as for passenger seat design [7] and also seating arrangement [8]. Therefore, there is an ongoing need to establish anthropometric database for population of the passengers that can be applied in the ergonomic design process of aircraft cabin features.

It has been noted that the anthropometric body dimensions of different populations from different countries can significantly vary with each other [9]. Because of this, it necessitates that each population has its own anthropometric measurements database. For the Malaysian population, a few previous studies have published the measured database of the anthropometric body dimensions under several different categorizations. Among others, they include Malaysian anthropometric databases for sitting anthropometry [10], young adults [11] and adults of different ethnicity [12]. In essence, the work in this study is intended to add and update available anthropometric databases of Malaysian population with more recent measurements of the body dimensions and to conduct simple comparison analysis against the selected reference database for observation in terms of the trend of changes. Findings from this study can assist in designing a better suited ergonomic cabin design for the Malaysian population. While the commercial transport aircraft is catering for various types of passengers, it is a common practice in public transport design that its cabin will be tailored to the majority of expected passengers. This particular situation has been highlighted in several other studies such as the coach design for a high-speed train in South Korea that is tailored to the anthropometric data of local population [13]. With this notion in mind, the anthropometric data for the Malaysian population can be very useful for the local domestic airlines in deciding on their custom cabin design.

Anthropometric Measurements: Methodology

As mentioned before, the study of anthropometry largely involves measuring various dimensions of the human body. Though there are several different sets of body dimensions that are published in anthropometry databases of different studies, standard definition for each of the measurements is mostly consistent. Example illustration for several standard human body dimensions is shown in Figure 1, which essentially covers both sitting and standing body positions.

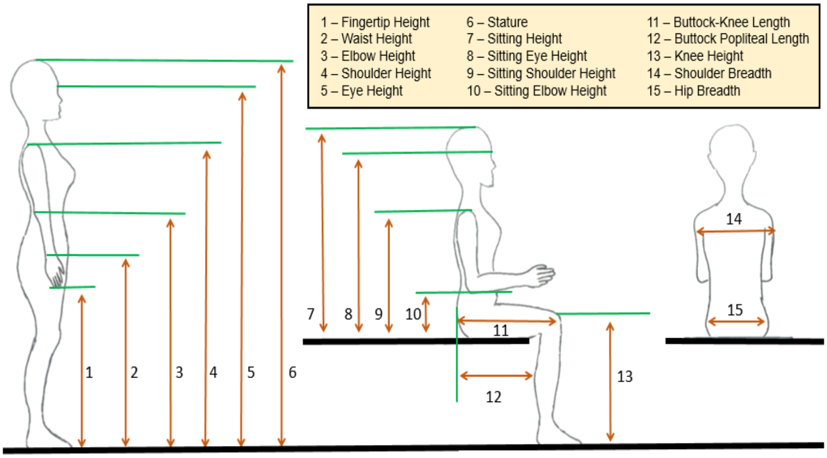

Figure 1: Example standard measurements for human body dimensions.

There are many more standard human body dimensions used in design ergonomics than those illustrated in Figure 1. For instances, over 240 different anthropometric measures have been defined by the United States Army in their widely-referenced United States Army Anthropometric Survey (ANSUR) [14] and few studies have also stated that more than 300 measurements are required to have the complete human body dimensions [15, 16]. These body dimensions basically include the linear measurements such as breadth, height and length; angular measurements between planes and lines that crosses the human body such as flexion or extension on the sagittal plane; force measurements like grip, pinch and torque strength; and the circumferences of the head, neck and chest [17]. The measurements of these body dimensions can be directly made using standard measuring tools such as flexible measuring tapes, callipers and rulers.

For this study, the interest lies on the establishment of anthropometric database for sitting and standing posture dimensions, which will be very useful in developing and designing aircraft cabin features for comfort of passengers. A total of 100 voluntary participants from the Malaysian public, aging between 18 to 40 years old, have been gathered during the data collection and have their body measured (50 males and 50 females). Standard traditional measurement tools are used in this study and the measurement process is shown in Figure 2. As indicated in many studies, these standard measurement tools are mostly as reliable and accurate as the high-tech anthropometric tools, in addition to being simpler, cheaper and also portable [18]. Each measurement is made three times to reduce any uncertainties or errors with the measured value and the average is recorded. Additionally, the participants have been asked to wear thin or light clothing to ease and improve the accuracy of the measuring process.

Figure 2: Anthropometric measurement of a voluntary participant.

Although additional data has been collected, only 11 commonly used anthropometric measurements of the body dimensions for sitting and standing human postures are reported in this study. These anthropometric measures can be directly referred to the previous Figure 1 and their corresponding reference number is listed in Table 1. MINITAB statistical software is applied to perform the data analysis of recorded anthropometric measurements of the participants once the data collection process is completed. The data analysis in MINITAB and also Microsoft Excel determines the essential descriptive statistics such as mean, standard deviation, standard error of mean, coefficient of variation, 5th percentile, 50th percentile, 95th percentile, minimum and maximum, which are all often referenced and used in ergonomic design process. These descriptive statistics establish the database of the anthropometric body dimensions for the sample population in this study (i.e. the voluntary participants). A comparison analysis is conducted between this resultant anthropometric database and other available databases of Malaysian population to deduce any notable trends with regards to observed changes in the measurements.

Table 1: Measured human body dimensions

Category	Anthropometric Dimension	Reference to Figure 1
Standing Position	Stature	6
	Eye Height	5
	Shoulder Height	4
	Elbow Height	3
Sitting Position	Eye Height	8
	Shoulder Height	9
	Elbow Height	10
	Buttock-Knee Length	11
	Buttock-Popliteal Length	12
	Shoulder Breadth	14
	Hip Breadth	15

Results and Discussion

The number of voluntary participants involved in this study has been affected by the COVID-19 pandemic situation in Malaysia. Due to imposed movement restrictions by the Malaysian government and also notably low willingness of the general public to participate during this pandemic, this study has been able to gather only 100 volunteers through conducted body measurement sessions in between the months of August and November 2020. A brief summary of the demographics data of the participants according to age and gender is presented in Table 2. It should be noted that the ethnicity of voluntary participants in this study happens to be all Malays. The mean age for the male participants is 24.62 years old with standard deviation of 4.52 (minimum = 20 years old, maximum = 40 years old) whereas for the female participants, the mean age is 23.57 years old with standard deviation of 5.49 (minimum = 18 years old, maximum = 40 years old). Moreover, the resultant anthropometric database based on recorded body dimensions of the voluntary participants is presented in Table 3 and Table 4 for males and females, respectively.

Table 2: Gender and age groups of the voluntary participants

Gender	Age Group	Number of Participants
Male	18 to 20	5
	21 to 30	38
	31 to 40	7
Female	18 to 20	15
	21 to 30	31
	31 to 40	4

From Table 3 and Table 4, it can be observed that the mean values for the reported anthropometric body dimensions of Malaysian males in this study are consistently higher than those for Malaysian females, with an exception of sitting elbow height. This can be also clearly seen from the presented box-plots of the collected measurement data in the Figure 3 and Figure 4 for the standing and sitting positions, respectively. On the whole, comparative finding between mean measurement values for reported body dimensions of Malaysian males and females is essentially consistent with the resultant measurement data from other studies such as [11], [19] and [20].

For a proper dimensional differences analysis between the Malaysian males and females, independent statistical *t*-test can be conducted [21, 22]. The results of the *t*-test are shown in Table 5, which is obtained from the MINITAB software, and they are used to deduce whether there is a significant difference between the means of each body dimensions for males and females. It should be noted that the standard alpha, $\alpha = 0.05$ is applied for the *t*-test and the null hypothesis is mean measurement for the particular body dimension of females is larger than or equal to that of males. According to the results in Table 5, the body dimensions for Malaysian males in this study are significantly larger than Malaysian females for stature, standing eye height, standing shoulder height, standing elbow height, sitting eye height, sitting shoulder height and shoulder breadth. This condition has been indicated by *p*-value close to 0, which means that the null hypothesis can be rejected and the alternative hypothesis that the mean measurement for the particular body dimension of females is smaller to that of males is accepted instead. On contrary, there is no significant difference in the measurements of sitting elbow height, sitting buttock-knee length, sitting buttock-popliteal length and hip breadth between males and females as implied by their corresponding *p*-value. This is in line with the close data distribution observation of these body dimensions between males and females in Figure 3 and Figure 4.

Table 3: Descriptive statistics for anthropometric measurements of Malaysian males (n = 50)

Dimension	Mean (cm)	Standard Deviation (cm)	5th percentile (cm)	50th percentile (cm)	95th percentile (cm)
Stature	171.23	4.22	162.80	170.70	177.70
Standing Eye Height	158.83	4.32	151.75	158.50	166.40
Standing Shoulder Height	141.78	4.42	131.00	141.00	148.30
Standing Elbow Height	108.15	4.22	99.50	108.50	114.50
Sitting Eye Height	73.37	4.16	63.85	73.20	80.00
Sitting Shoulder Height	57.15	3.55	51.30	56.90	62.50
Sitting Elbow Height	21.99	2.45	17.75	22.50	24.80
Sitting Buttock-Knee Length	58.58	5.03	50.60	59.60	65.30
Sitting Buttock-Popliteal Length	46.62	4.24	38.80	47.20	52.90
Shoulder Breadth	44.20	3.08	39.20	44.10	48.95
Hip Breadth	38.03	3.91	31.05	37.60	44.40

Table 4: Descriptive statistics for anthropometric measurements of Malaysian females (n = 50)

Dimension	Mean (cm)	Standard Deviation (cm)	5th percentile (cm)	50th percentile (cm)	95th percentile (cm)
Stature	155.73	4.85	144.50	157.00	161.00
Standing Eye Height	146.03	4.46	136.85	145.20	152.60
Standing Shoulder Height	130.70	9.55	121.00	130.40	137.35
Standing Elbow Height	97.47	4.05	90.6	96.60	104.00
Sitting Eye Height	69.48	3.72	62.35	70.20	75.30
Sitting Shoulder Height	54.49	4.23	46.35	54.60	61.45
Sitting Elbow Height	22.18	3.10	16.90	22.30	26.75
Sitting Buttock-Knee Length	57.23	3.54	50.50	57.10	62.80
Sitting Buttock-Popliteal Length	46.39	4.13	37.35	46.60	51.55
Shoulder Breadth	41.48	4.26	34.95	40.00	48.30
Hip Breadth	39.06	5.57	30.15	38.70	49.95

Table 5: Body dimensional differences analysis between males and females

Dimension	Absolute Difference in Means (in cm)	*T*-value	*p*-value
Stature	15.50	-17.047	0.000
Standing Eye Height	12.80	-14.501	0.000
Standing Shoulder Height	11.08	-7.444	0.000
Standing Elbow Height	10.68	-12.921	0.000
Sitting Eye Height	3.89	-4.929	0.000
Sitting Shoulder Height	2.66	-3.408	0.000
Sitting Elbow Height	0.19	0.340	0.633
Sitting Buttock-Knee Length	1.35	-1.554	0.062
Sitting Buttock-Popliteal Length	0.23	-0.268	0.395
Shoulder Breadth	2.72	-3.667	0.000
Hip Breadth	1.03	1.0681	0.856

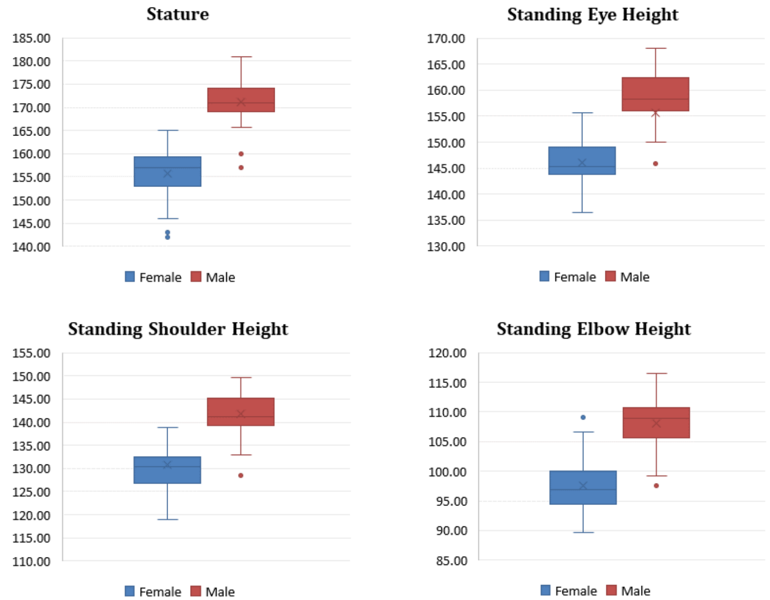

Figure 3: Boxplots of measurement data for Malaysian males and females in standing position (in cm).

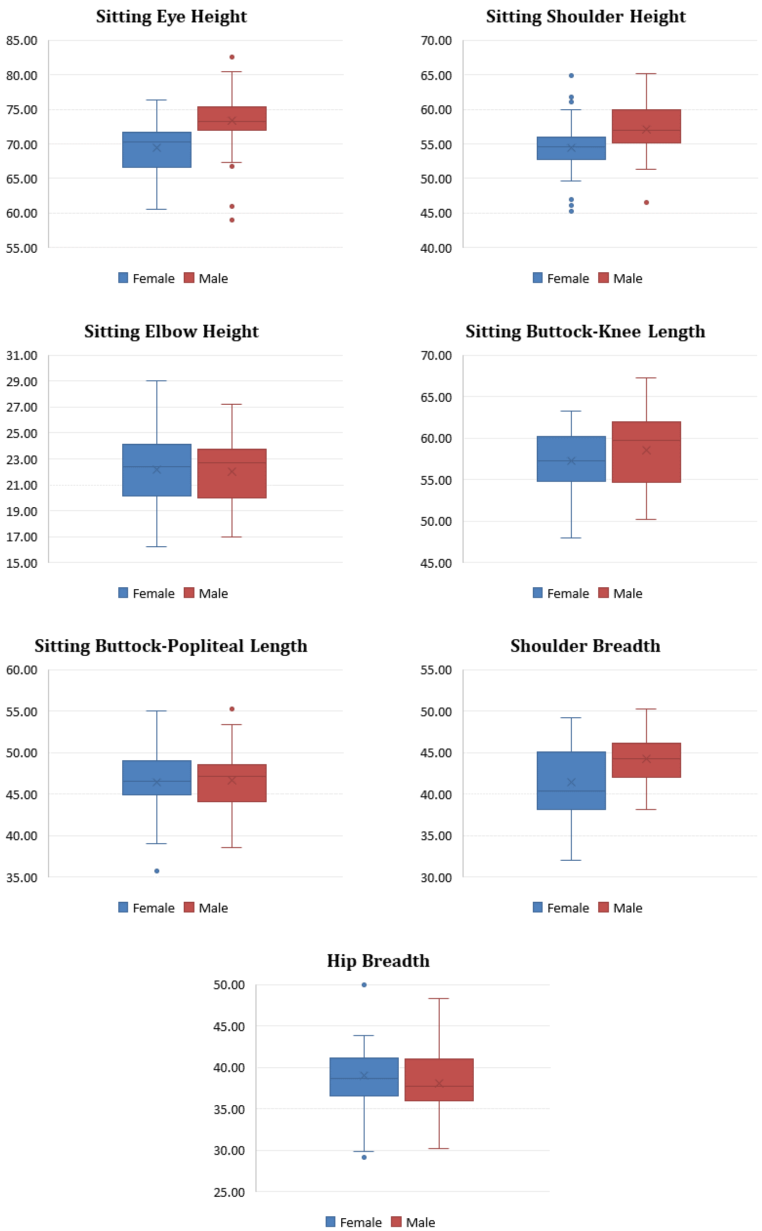

Figure 4: Boxplots of measurement data for Malaysian males and females in sitting position (in cm).

Furthermore, it is also of great interest for this study to compare these anthropometric body dimensions of Malaysian population (males and females) with published existing database. The findings from this comparison analysis can provide valuable insight on any underlying trends for changes in the body dimensions of the population with time. For this comparison analysis, existing anthropometric database for the Malaysian population that has been published in 2011 is selected as the reference measurements. The comparison summary is presented in Table 6.

In general, it can be inferred from Table 6 that measurements of most body dimensions for the Malaysian population are increasing over time, in this case throughout almost 10 years since the referenced database is published in 2011. For Malaysian males, all body dimensions have shown some increments in the average measurement value except for sitting buttock-knee length and sitting buttock-popliteal length. With increased average stature measurement, this could mean that the current Malaysian males have generally slightly longer lower leg length. In the meantime, for Malaysian females, the comparison only indicates two decreasing measurements from 2011 to the current ones, which are average stature height and standing elbow height. However, the differences are markedly small and less than 1 cm. On the other hand, observed increases in other body dimensions for Malaysian females are notably more than 1 cm. Overall, it can be taken that on average, current Malaysian population (males and females) seems to be getting slightly bigger in terms of most of their body dimensions and the most significant increase in their body dimensions is for the hip breadth.

Table 6: Comparison of mean anthropometric measurements for Malaysians

Body Dimension	Males (in cm)		Females (in cm)	
	From [11]	This Study	From [11]	This Study
Stature	168.01	171.23	156.07	155.73
Standing Eye Height	156.41	158.83	144.80	146.03
Standing Shoulder Height	139.57	141.78	129.36	130.70
Standing Elbow Height	106.02	108.15	98.28	97.47
Sitting Eye Height	71.85	73.37	67.66	69.48
Sitting Shoulder Height	55.74	57.15	52.32	54.49
Sitting Elbow Height	19.20	21.99	19.30	22.18
Sitting Buttock-Knee Length	60.49	58.58	54.48	57.23
Sitting Buttock-Popliteal Length	49.05	46.62	45.70	46.39
Shoulder Breadth	43.28	44.20	37.51	41.48
Hip Breadth	31.35	38.03	31.75	39.06

Based on these findings, it can be expected that the body dimensions of the Malaysian population to grow further in future. This certainly will have an impact on flying comfort of Malaysian passengers and the designs of current aircraft cabin features may require some adjustments to be able to comfortably accommodate expected changes in their anthropometric body characteristics.

Conclusion

The anthropometric human body measurement is a key element in developing ergonomic design for products and systems. This is also applicable for aircraft cabin features, which must be ergonomically designed to appropriately match with the body characteristics of the passengers in order to provide an adequate level of flying comfort. Based on the collected measurement data of 100 people in this study, the anthropometric database for the Malaysian males and females has been established for few essential body dimensions in sitting and standing body positions. In addition, from the comparison analysis with the referenced anthropometric database of Malaysian population, it can be taken that the mean body characteristics of the Malaysian population appear to be getting bigger in average size. This realization is important to be included in the considerations while designing new cabin features for future Malaysian passengers.

It should be noted that the anthropometry data collection for this research study is currently still ongoing to have more data to establish a better representative database for the Malaysian population. The current presented data in this paper is however believed to be adequate for the initial study to highlight the trends between males and females, and also the changes with time. In the next part of this study, relationships between the body anthropometry data and the aircraft cabin design features will be further explored to establish the requirements for ergonomic passenger cabin design.

On the whole, it is concluded that the average body anthropometry dimensions of the Malaysian population are notably changing with time and there is a need to periodically update the database for use in the ergonomic design process of products including the aircraft cabin features. It can also be concluded that the measurement of body dimensions for males are averagely bigger than those for females.

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References

[1] P. Vink, C. Bazley, I. Kamp and M. Blok, "Possibilities to improve the aircraft interior comfort experience," *Applied Ergonomics*, vol. 43, no. 2, pp. 354-359, 2012.

[2] N. Dasuki and F. I. Romli, "Quality function deployment for new standing cabin concept of commercial transport aircraft," *Journal of Mechanical Engineering*, vol. SI5, no. 2, pp. 247-257, 2018.

[3] F. D. Ishak, F. I. Romli and K. Abdul Rahman, "Public survey on new in-flight food delivery and waste collection system," *Journal of Mechanical Engineering*, vol. SI5, no. 4, pp. 142-152, 2018.

[4] J. Bouwens, S. Hiemstra-van Mastrigt and P. Vink, "Ranking of human sense in relation to different in-flight activities contributing to the comfort experience of airplane passengers," *International Journal of Aviation, Aeronautics and Aerospace*, vol. 5, no. 2, Article 9, 2018.

[5] S. Dawal, H. Zadry, S. Azmi, S. Rohim and S. Sartika, "Anthropometric database for learning environment of high school and university students," *International Journal of Occupational Safety and Ergonomics*, vol. 18, no. 4, pp. 461-472, 2012.

[6] I. W. Taifa and D. Desai, "Anthropometric measurements for ergonomic design of students furniture in India," *Engineering Science and Technology, an International Journal*, vol. 20, no. 1, pp. 232-239, 2017.

[7] N. O. Aminian and F. I. Romli, "Ergonomics assessment of current aircraft passenger seat design against Malaysian anthropometry data," *International Journal of Engineering and Technology*, vol. 7, no. 4.13, pp. 18-21, 2018.

[8] F. Kremser, F. Guenzkofer, C. Sedlmeier, O. Sabbah and K. Bengler, "Aircraft seating comfort: the influence of seat pitch on passengers' well-being," *Work*, vol. 41, pp. 4936-4942, 2012.

[9] N. Mandahawi, S. Imrhan, S. Al-Shobaki and B. Sarder, "Hand anthropometry survey for the Jordanian population," *International Journal of Industrial Ergonomics*, vol. 38, no. 11-12, pp. 966-976, 2008.

[10] D. D. Daruis, B. Deros and M. Nor, "Malaysian sitting anthropometry for seat fit parameters," *Human Factors and Ergonomics in Manufacturing and Service Industries*, vol. 21, no. 5, pp. 443-455, 2011.

[11] K. Karmegam, M. S. Salit, M. Y. Ismail, N. Ismail, S. B. Mohd Tamrin, K. Gobalakrishnan, S. Palanimuthu and T. Palaniandy, "Anthropometry of Malaysian young adults," *Journal of Human Ergology (Tokyo)*, vol. 40, no. 1-2, pp. 37-46, 2011.

[12] K. Karmegam, S. M. Sapuan, M. Y. Ismail, N. Ismail, M. Shamsul Bahri, S. Shuib, G. K. Mohana, P. Seetha, P. TamilMoli and M. J. Hanapi, "Anthropometric study among adults of different ethnicity in Malaysia," *International Journal of the Physical Sciences*, vol. 6, no. 4, pp. 777-788,

2011.
[13] E. Jung, S. Han, M. Jung and J. Choe, "Coach design for the Korean high-speed train: a systematic approach to passenger seat design and layout," Applied Ergonomics, vol. 29, no. 6, pp. 507-519, 1998.
[14] S. A. Oyewole, J. M. Haight and A. Freivalds, "The ergonomic design of classroom furniture/computer work station for first graders in elementary school," *International Journal of Industrial Ergonomics*, vol. 40, no. 4, pp. 437-447, 2010.
[15] H. Hu, Z. Lia, J. Yana, X. Wanga, H. Xiaob, J. Duana and L. Zhenga, "Anthropometric measurement of the Chinese elderly living in the Beijing area," *International Journal of Industrial Ergonomics*, vol. 37, pp. 303-311, 2007.
[16] S. Pheasant and C. Haslegrave, Bodyspace: Anthropometry, Ergonomics and the Design of Work. Boca Raton: CRC Press, 2005.
[17] I. Dianat, J. Molenbroek and H. I. Castellucci, "A review of methodology and applications of anthropometry in ergonomics and product design," *Ergonomics*, vol. 61, no. 12, pp. 1696-1720, 2018.
[18] M. Al-Ansari and M. Mokdad, "Anthropometric for the design of Bahrain school furniture," *International Journal of Industrial Ergonomics*, vol. 39, pp. 728-735, 2009.
[19] N. I. Abd Rahman, S. Z. Md Dawal, N. Yusoff and N. S. Mohd Kamil, "Anthropometric measurements among four Asian countries in designing sitting and standing workstations," *Sadhana*, vol. 43, no. 10, 2018.
[20] M. S. Nurul Shahida, M. D. Siti Zawiah and K. Case, "The relationship between anthropometry and hand grip strength among elderly Malaysian," *International Journal of Industrial Ergonomics*, vol. 50, pp. 17-25, 2015.
[21] T. Kaewdok, S. Sirisawasd, S. Norkaew and S. Taptagaporn, "Application of anthropometric data for elderly-friendly home and facility design in Thailand," *International Journal of Industrial Ergonomics*, vol. 80, pp. 103037, 2020.
[22] A. S. Ayobami, O. O. Oluwatoyin, S. O. Stephen, E. L. Anderson and O. Modupeoluwa, "Assessment of sex from the anthropometric measurement of the foot in Ogbomosho North Local Government area," *International Journal of Human Anatomy*, vol. 2, no. 2, pp. 23-39, 2020.