Mismatch in Anthropometric Parameters of Malaysian Manufacturing Workers

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Abstract The software Digital Enterprise Lean Manufacturing Interactive Application (DELMIA) is a virtual simulation software that was used in digital product manufacturing. In contrast with Computer Aided Three-dimensional Interactive Application (CATIA), DELMIA ergonomics feature is built with Human Task Simulation which can simulate the design workspace virtually. However, population available for the human manikin population are excluding Malaysian population. This study is aiming to investigate the gap and the error of anthropometry data in Malaysian manufacturing workers between the Japanese and American population in DELMIA V5R2016. A sample population of 241 people at manufacturing industries was taken in this study. The total number of anthropometric parameters used for experimentation are 100 parameters obtained from literature studies. The American and Japanese population are chosen to represent the Caucasian and Asian population for comparison of 15 randomly selected parameters of anthropometry. There are several mismatches found in the anthropometry parameter between the three comparisons of the population where the percentage of error and gap in between populations are more than 5%. In conclusion, this study recommended that future research increase the sample size of the anthropometry subjects for database comparison. For future research, it is recommended to use other methods available for measurement such as digital measurement for the anthropometry database to compare the accuracy with the traditional measuring method.

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1 Introduction

Malaysia especially, ergonomics is lacking to the certain extent and it was considered a new field compared to other developed countries such as Japan and United States [23]. In DOSH definition of ergonomics, it is about integrating knowledge derived from the human sciences to match jobs, systems, products and environments to the physical and mental abilities and limitations [23]. Since then, Malaysian researchers mostly from the ergonomics field are struggling in researching this field as the conceptual knowledge and technology implementation are still far behind other well-developed countries especially in manufacturing side. National Institution of Occupational Safety and Health (NIOSH) had established an ergonomics department from 1992 until now and Mustafa et al. [22] research shows that only 35.6% of manufacturing industries has the high awareness of ergonomics. This statement proved that the manufacturing industries are still ongoing and the needs of the software analysis are on demand. Previously, ergonomics analysis is being done using expert evaluation and this is time-consuming and hard to be accomplished. Some manufacturing companies are very restrictive in terms of confidentiality. Outsiders or expert are not welcomed into manufacturing companies unless there are agreements such as Memorandum of Association (MOA) between industries and institutions. Hence, using software analysis is an easy way to obtain good analysis on ergonomics without having the extra additional costs for expert evaluation. This study aims to investigate the accuracy of anthropometry data in Malaysian manufacturing workers to be inserted into DELMIA software.

1.1 Anthropometry Definition

The word “anthropometry” is derived from the Greek words “Anthropos” (man) and “metron” (measure) and means the measurement of the human body [4]. Anthropometry focuses on the measurement of bodily features such as body shape and body composition (“static anthropometry”), the body’s motion and strength capabilities and use of space (“dynamic anthropometry”). Anthropometric measurements are used widely in a variety of scientific and technical fields. Within the field of ergonomics, the application of anthropometric measurements is primarily associated with different aspects of design for human use.

Anthropometry in the definition is the science of measurement and the art of application that establishes the physical geometry, mass properties, and strength capabilities of the human body [6]. From previous research and study, the measurement of anthropometry is crucial to fit the design to the user. The utilization of anthropometric data will enable designers to accommodate a desired portion of the potential user population in their designs [25]. There is a lack of data in terms of anthropometry in Malaysia as the country has many different ethnicities [13]. Hence, the study in workers posture was inclusive with the study of anthropometry as well as to differentiate the percentile range of the measurement in the Malaysian population.

Anthropometric Data for Malaysian Population. Anthropometric data are the data referred to a group of quantifiable physical dimensions and parts of the human body [2]. There are various fields involved with the use of anthropometric data since quite a long time, then, such as forensics and physical anthropology. Nowadays, the anthropometrics data have been used within the areas of attire sizing and ergonomics workspace design instead of the others. Anthropometry of the Malaysia population database is still not available, hence, to redesign workstation in DELMIA V5R2016, the anthropometry or measurements of manikin must be inserted manually.

Several kinds of literature were presented in this paper to show the importance of incorporating anthropometric concern in designing processes. Anthropometric data on the general population is essential in ergonomics to specify the physical dimensions of workspace, equipment, furniture and clothing to fit the user and to avoid a physical mismatch between the dimensions of products and equipment and corresponding user dimensions [3]. There is a lack of anthropometric data involving major ethnic groups in Malaysia [14]. Population means the group of people that share the same ancestors, same occupations, same geographical locations or age groups. The people of different races or different ethnic groups such as different cultures, customs, language and others, is called as user population. The most important step in designing the workstation is to decide the user population. The good ergonomic design makes provision for the range of variability to be expected in the user population. Variation in user population can also affect design for safety. In many research, the ergonomist uses anthropometric measurements and try to include at least 90% of the population. To achieve this effort, designer attempt to design the workplace by including people dimension between the 5th and 95th percentiles and only one way is by providing adjustable devices.

1.2 DELMIA Software

Definition. The software Digital Enterprise Lean Manufacturing Interactive Application (DELMIA) is a virtual simulation software that was used in digital product manufacturing and one of it is aerospace [7]. The software is enabling the users to plan and test the product, systems or even the whole factory design in a virtual environment without committing the real tasks [5]. In a way, this helps industries to save costing of raw materials in early designing parts or products [5]. In this research, DELMIA V5 provides the part design, assembly, layout simulation and ergonomics analysis applications. The difference between DELMIA V5 and Computer-Aided Three-Dimensional Interactive Application (CATIA) is that it contains simulation, application of ergonomics and it can interact manikin with the assembly layout or workstation design. In the workstation improvements of the manufacturing process, the virtual environment will be redesigned following the original workstation design and evaluate the current workstation design with the new insert population manikin to compare virtually using the Rapid Upper Limb Assessment (RULA) tool available in DELMIA V5R2016 software. In Figs. 1 and 2 show the features of the manikin and RULA analysis available in CATIA V5 and also DELMIA V5 that had been developed by Dassault Systemes company.

Fig. 1 Example of manufacturing worker's posture

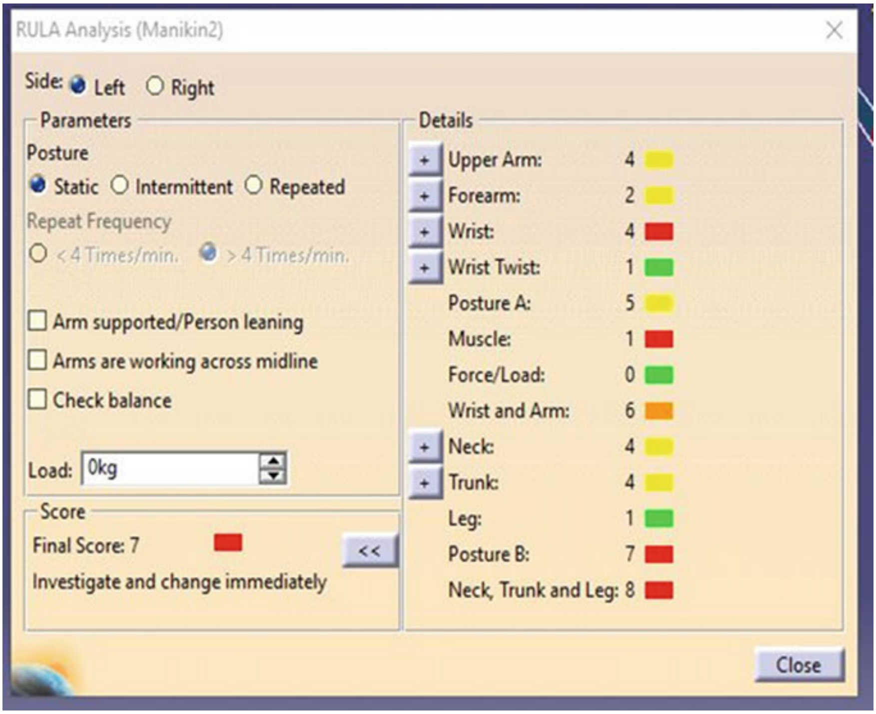

Fig. 2 RULA analysis of posture using software

2 Methodology

One of the most well-known tools for assessing anthropometric measurement is by traditional measuring method. However, the larger the sample size for the data collection, the longer the time taken in completing the task. Hence, most researchers such as Lu and Wang [18] was using 3D scanner where anthropometry measurement was done automatedly. Apart from that, the limitation of automated measuring using 3D scanner was that the parameters that can be measured are only 14 parameters. This is not compatible with this study which uses 100 parameters overall.

2.1 Parameters and Sample Size

The parameters available from DELMIA V5R2016 is 103 parameters by Dassault Systemes [5], which includes bispinous breadth, tenth rib height and iliocristale height. These parameters are not available to be measured using traditional measuring tools. Hence, only 100 parameters are selected from DELMIA V5R2016. From the parameters obtained from software, the comparison of parameters was used by selecting from literature studies. The traditional measuring method is one of the most common procedures for measuring anthropometry with a large number of parameters and sample size in order to validate the population.

In this study, a convenience sample of 241 male workers of layup process. This is the total number of workers available for hand layup process department. The sample was taken overall. Furthermore, it had been discussed by Baharampour et al. [1] that 30–500 is adequate for this type of research (anthropometry sample), thus, 241 had fallen in the range of 30–500 samples. It is important that the required individuals to have given consent before conducting the collection as the parameters that needed to be measured were specific and required skinship to feel the location of several points. It was quite sensitive issues and measurement of the human body was quite taboo for the Malaysian culture leading to difficulties in data collections. In Malaysia, the largest number of parameter that had been done was 62 parameters done by Mohamad et al. [21], however in this study, it covers 100 parameters and the average duration to measure one sample was 45 min.

2.2 Anthropometry Measurements Tools

In Fig. 3 shows the essential measuring tools used in this study, however, the weighing scale had been changed into digital body weighing scale before the conduction of the collection for accuracy purpose. As for other tools, this study still uses the analogue tools such as large and small anthropometer set and measuring tape. This tools had been calibrated occasionally to ensure the reliability of the measurement. The tools were used for measuring the 100 parameters identified were large and small anthropometer, ruler, measuring tape, human measuring tape (for circumference measurement) and a weighing scale.

To control accuracy, the data collectors need to undergo training before collection. The measurements were carried out by the same person for this set of data to rule out the tolerance of human error in the readings. Method of measurement was studied and implemented according to standards and one of the sources is available in Tolonen et al. [26]. As in Fig. 4, shows the measuring of anthropometry takes place at the manufacturing company. To standardize the measurements units, this study used centimetres unit as the anthropometer scale unit. The measuring activities were done inside the production line; this is because to avoid messing up in the workers' time cycle. The measuring time with the addition of survey answering, took up almost 30 min for each respondent. Hence, the activities must be done near or in the line to reduce any non-value-added time for the workers.

Fig. 3 Anthropometry measuring tools

Fig. 4 Measuring the anthropometry

3 Results and Discussions

For anthropometry parameters identification, the study on literature gap was done. As for percentile calculation, the simple statistical analysis was used to calculate the percentile of the data of human population which in this case the manufacturing workers. Nonetheless, in this paper, only the standard deviation between the parameters was tabulated and discussed in order to see the mismatched between the populations of Malaysian, Japanese and American.

3.1 Literatures Gap in the Anthropometry Parameters Measured

From the comprehensive literature studies, the number of parameters used in studies was different towards each other. The highest number of parameter that had been conducted by Human Systems Information Analysis Center [10]. Surprisingly, the highest number of parameters was done in the United States, not by the Asian countries. As mention in a study done by Klamkay et al. [15], the parameters taken were 39 in total however it was done using the human population of Thailand.

From Table 1, Mohamad et al. [21] had done the anthropometry measurement using the highest number of parameters which was 62 using Malaysian population sample size. This study utilized the number of parameters taken by the previous research and the study found that only small parameters measured were compatible with the range of Japanese population. Concerns were expressed as the human

Table 1 Number of anthropometry parameters based on literature studies

Author(s)	Year	Number of parameters
Lin et al. [17]	2004	33
Human Systems Information Analysis Center [10]	1994	980
Hassan et al. [9]	2015	23
Md. Dawal et al. [20]	2012	21
Karmegam et al. [13]	2011	33
Masson et al. [19]	2015	14
Kothiyal and Tettey [16]	2001	23
Karmegam et al. [14]	2011	34
Klamkay et al. [15]	2008	39
Lu and Wang [18]	2008	14
Simmons and Istook [24]	2003	25
Mohamad et al. [21]	2016	62
Dassault Systemes [5]	2016	103

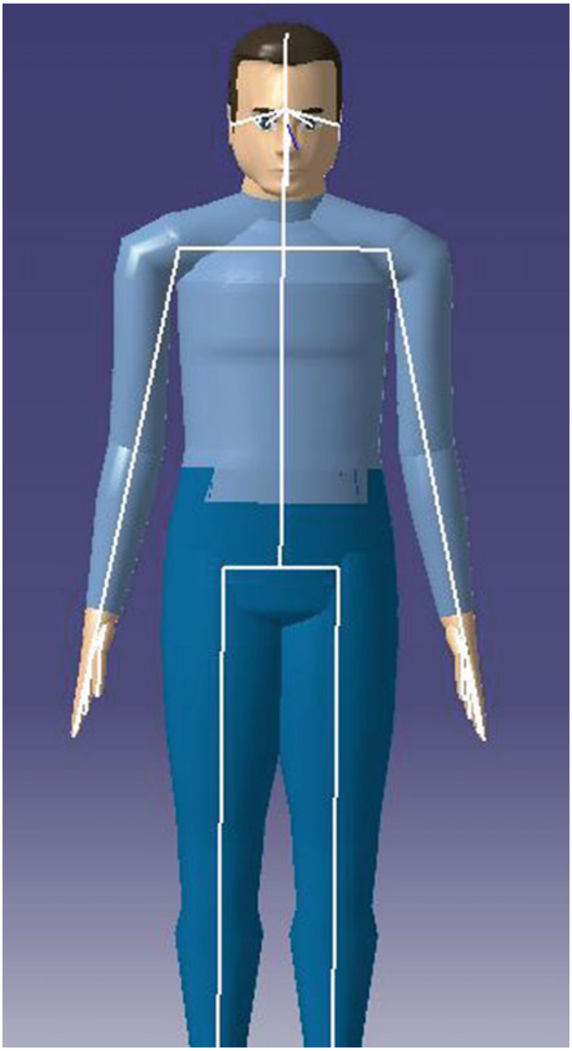

Fig. 5 Human manikin distortion and unable to be analyze

manikin become distorted or unable to be used when the manual anthropometry measurement is keyed in the software as in Fig. 5.

3.2 Mismatch in Standard Deviation of Anthropometric Data

In this study, refereeing Table 2 is the standard deviation of the 100 parameters when compared with the standard deviations of the Japanese and American population that are available in the DELMIA software. From the results obtained, it showed that when the insertion of anthropometry data for the human manikin, it is needed to select the population of Malaysia in the software. Furthermore, the unavailability of the Malaysian population, compel researchers to used Japanese or any other default population available in the software. In this study, surprisingly it is found that the data of anthropometry of Malaysian compared to other population are slightly and majorly different for each parameter as in Table 2.

Previously, research done by Hashim et al. [8], Kamat et al. [11] and Kamat et al. [12] were using CATIA V5 software which was also developed by Dassault Systemes company. In CATIA or DELMIA, the software is adequate with Ergonomics features that use manikin of human-related to analysis such as Rapid Upper Limb analysis and Postural analysis.

Nonetheless, this study found that there is a mismatch between the parameters of the anthropometry when the data was key in into the human manikin in software.

Table 2 Standard deviation, minimum and maximum value from 15 randomly selected anthropometry parameters

Anthropometry parameters	Std. Dev	Min	Max	Std. Dev	Min	Max	Std. Dev	Min	Max
	Malaysian			Japanese			American		
Bitragion breadth headboard	0.92	11.7	18.1	0.60	11.9	16.7	0.60	12.9	16.9
Bizigomatic breadth headboard	1.21	11	17.3	0.64	11.5	16.6	0.64	11.7	16.9
Calf circumference	5.16	26.5	73.8	2.24	28.2	46.1	2.54	27.7	48.0
Calf height	3.24	21.5	56.6	1.83	24.8	39.5	2.37	25.9	44.8
Chest circumference below breast	11.36	64.6	120.1	5.43	69.4	112.9	6.54	66.5	118.8
Heel ankle circumference	2.06	23.4	39	1.63	25.7	38.7	1.63	27.4	40.4
Infraorbitale to back of head	0.89	13.6	20.5	0.70	15.0	20.6	0.70	15.3	20.9
Midshoulder height, sitting	3.86	43.7	84.6	2.50	53.3	73.3	2.82	51.8	74.3
Promenton to back of head	1.38	11.1	21.8	1.03	14.5	22.7	1.03	15.3	23.5
Pronasale to top of head	1.53	12	27.6	0.84	12.7	19.4	0.84	11.8	18.6
Span	7.64	153	192	6.90	148.5	203.7	8.19	149.6	215.1
Stomion to top of head	1.23	15.5	22.4	0.78	16.1	22.3	0.78	15.5	21.8
Thumbtip reach	4.54	38.2	83.5	3.00	66.5	90.5	3.92	64.4	95.8
Waist circumference, omphalion	15.11	54.2	144	6.02	58.8	107.0	8.64	51.7	120.8
Waist depth	4.71	10.5	39.9	1.98	12.8	28.7	2.56	12.4	32.9

Prior to this study, it had been noted that the importance of having Malaysian population inside the software such as CATIA and DELMIA because the software analysis eases the ergonomics analysis that been studied here in Malaysia as the sample for the research that will be conducted in future is using Malaysian population. As stated by Mustafa et al. [22], the manufacturing that has a high awareness of ergonomics adaptation is only 35.6% overall in Malaysia. This statement proved that the manufacturing industries are still not fully adopting and integrating ergonomics into the whole manufacturing processes and portray the demand for ergonomics analysis in the future.

Percentage Error and Percentage Gap of Anthropometry Parameter for the Malaysian, Japanese and American Population. From the experimentation done by measuring the anthropometry of 241 samples, the data of percentage error and gap in between the population is calculated and tabulated in Table 3. From Table 3, it can be concluded that there are mismatches in the anthropometry parameters measurements between population. Supposedly, the percentage error data must be zero to be accepted in the human manikin range in software. An error box will rise in the software if the measurement fell over or less than the range of the minimum and maximum values. From the percentage gap between Japanese and American, all randomly selected anthropometry parameters were less than 10% of the gap, however, for two parameters (which were Span and Waist circumference, omphalion) the gap was more than 10% respectively, 10.3% and 21.0%. This also showed that in between American and Japanese population, there are mismatches in anthropometry.

Table 3 Percentage error and gap for 15 randomly selected anthropometry parameters

Anthropometry parameters	% Error			% Gap		
	M-J*	M-A*	J-A*	M-J*	M-A*	J-A*
Bitragion breadth headboard	52.8	52.8	0.0	1.6	1.6	0.0
Bizigomatic breadth headboard	89.5	89.5	0.0	1.18	1.2	0.0
Calf circumference	130.4	103.2	13.4	29.38	27.0	2.4
Calf height	76.9	36.6	29.5	20.46	16.1	4.3
Chest circumference below breast	109.2	73.7	20.4	12.06	3.2	8.9
Heel ankle circumference	26.6	26.6	0.0	2.56	2.6	0.0
Infraorbitale to back of head	27.3	27.3	0.0	1.3	1.3	0.0
Midshoulder height, sitting	54.4	36.9	12.8	20.9	18.3	2.6
Promenton to back of head	34.4	34.4	0.0	2.46	2.5	0.0
Pronasale to top of head	81.8	81.8	0.0	8.88	8.9	0.0
Span	10.8	6.7	18.7	16.2	26.5	10.3
Stomion to top of head	57.8	57.8	0.0	0.66	0.7	0.0
Thumbtip reach	51.2	15.7	30.7	21.3	13.9	7.4
Waist circumference, omphalion	151.0	74.9	43.5	41.64	20.7	21.0
Waist depth	138.0	84.1	29.3	13.56	8.9	4.6

*Where M refers to Malaysian, J refers to Japanese and A refers to American

4 Conclusion

The main goal of the current study was to investigate the accuracy of anthropometry data in Malaysian manufacturing workers. Hence, it had been proven that there is a mismatch in between parameters of the anthropometry and mismatch in the human population. Different populations contribute to different range set of anthropometries parameters. The most obvious finding to emerge from this study is that the need to have a complete database of anthropometry for Malaysian population. Apart from that, this database is mostly required in the software because of the adequacy of the software analysis, so that, the software analysis is accurate and reliable to be concluded for any result of any studies regarding ergonomics analysis. In general, to be compatible with the software, the parameters taken for the measurement must be according to the software requirements which is 103 parameters. However, there are three parameters are unable to be measured which are bispinous breadth, tenth rib height and iliocristale height. Hence, this study was covering 100 parameters of anthropometry.

Therefore, for recommendations for this study, there is in need to be in control with the measuring procedures and also the accuracy of the tools for measuring. This study recommends the use of sample size up to 500 to observe the range standard deviation of parameters is significant or not. Last but not least, there is an encouragement for the Malaysian population feature in the software that can be used for ergonomics analysis apart from Dassault Systemes software.

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