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ORIGINAL ARTICLE

VALIDITY AND RELIABILITY OF VICON™ MOTION CAPTURE CAMERA OVER THE TRADITIONAL ANTHROPOMETRIC METHOD

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ABSTRACT

Anthropometric study is one of the oldest branches of study in ergonomics where it serves a purpose in study of proportion and size for human body. One of the common methods used in anthropometric measurement is traditional measurement or direct measurement. However, Malaysia is still left behind other countries in development of national anthropometric database. Researchers in Malaysia are still relying on the traditional anthropometric (TA) measurement. There are several important factors that contribute to problems in TA such as accuracy, time, posture, identification of landmarks, instrument positions and orientations, and pressure exerted due to measuring equipment. In view of the fact that the difficulties of obtaining human anthropometry, it becomes necessary to propose a method which has less contact executed to respondent. This study aims to propose a new anthropometric measurement method using motion capture camera (MCC) method, later to develop the database for youth male population. A pilot test was done in order to confirm the measuring procedure as well as the flow of the study. Next, the Minitab statistical software used to check the validity and reliability of data using the tests of a) Accuracy-Pearson/Spearman Correlation b) Bias-Paired T-Test c) Test-Retest Reliability-Pearson/Spearman Correlation d) Precision-Mean Absolute Difference and Relative Error Measurement. Results showed that the validity and reliability of this motion camera has successfully obtained and the anthropometric data for youth male respondents has successfully constructed. These findings can be used and expended to the national anthropometric database to be utilised in ergonomics design.

Keywords: *traditional anthropometry, non-contact anthropometry measurements, validity and reliability, ergonomics design*

INTRODUCTION

Malaysia is one of the multicultural countries located at the South East Asia. Malaysia is known for its fast growth economy while competing with its neighbors includes Indonesia, Singapore, Thailand and Brunei. According to the statistic provided by Department of Statistics Malaysia (2016), the current population of Malaysia is 31 million[1]. With the current number of population, it is important for a developed country like Malaysia to have its own anthropometric database for its own people. Anthropometry is a measurement of each visible part of human body from head to toe. Anthropometric data continues to be understood as a very basic core of ergonomics in an effort to resolve challenges of fitting people to machine[2]. This measurement can be used in ergonomics to specify physical dimensions of workspaces, workstations, and equipment as well as applied to product design. Meanwhile, ergonomics is an analysis or study of people along with their relationship-utilizing environment close to them[3]. Anthropometric of whole population is important in ergonomics to specify physical measurements of ergonomics design, automotive, workstation, tool, equipment, outfit, and furniture to match a person and also to prevent physical mismatch involving the dimensions of compartment or equipment with the appropriate user dimensions. It is undeniable that all industries from automotive, primary, manufacturing, and service industry will get the benefits from the ergonomic study. Unfortunately, there is an insufficient written document of Malaysian anthropometric data[4]. In addition, the lack of Malaysian anthropometry database leads to a problem where no complete and reliable database of Malaysian adult that can be referred in researches. Thus, the researcher has to rely on data from other Asian countries such as Japan and Korea. This might lead to slight differences between actual sizes of Malaysian population[5]. In automotive industry, this database is useful for designers and manufacturers to analyse and improve car design.

In attaining a proper database of the Malaysian anthropometry, studies had only been done using the TA approach. By far, there is no documentation for highly sophisticated method such as camera, motion camera, 3D scanner, and other computer mechanisms used in Malaysian measurement whilst there is a rising passion for overcoming the constraints of direct anthropometry via the use of computer based technique[6]. Thus, to fully exploit this potential, the anthropometry measures using MCC has been used in order to determine the comparison of validity and reliability of data obtained using TA and MCC methods. Validity and reliability of data obtained from the MCC needs to be checked whether it achieves the 'gold standard' set by the TA measurement. It is important to know the capability of the MCC before deciding on human body dimension that needs to be measured. Therefore, this research aims to compare the validity and reliability of MCC and TA measurements as well as to construct the anthropometry database of youth male respondents using the MCC method.

Traditional or manual anthropometric measurement has been used since 1870 where this early study aims to find measurement of average man[6]. Nowadays, there are many other methods available for anthropometric study such as photography, body scanning, and linear dimension method[7]. In Malaysia, most of researchers are depending on the TA measurement. Only a few that relies on photographic method such as the usage of anthropometric grid[4-5,9-17].

It is an undeniable fact that effective use of computer mechanism may result in more accurate result[14]. However, these computer mechanism methods namely linear dimension and body scanning are still unavailable or not being documented in Malaysia. Moreover, many factors involved in the measurement of human subjects, which can lead to the emergence of various forms of error. Several important sources include posture, identification of landmarks, instrument position and orientations, and pressure exerted due to measuring equipment[18]. As a result of difficulties in obtaining human anthropometry, it becomes necessary to propose a method that has less contact on the respondent.

Hence, this research intended to propose a method of using MCC with prerequisite aim to evaluate the validity and reliability of the MCC method over traditional measurement method. In studying the anthropometry measurement techniques of traditional and noncontact motion camera, it is important to identify its validation and reliability of the data. In addition, the potential advantages of any techniques had to be proven by obtaining reliable and accurate data. Numbers of studies successfully validated in terms of measurements error and accuracy of this non-contact anthropometry measurement systems over the traditional and other systems. These studies suggested how crucial these alternative systems have to be compared and validated[19-21]. Validation in general can be described as in what way attentively the MCC measurement is equivalent to the standard of the TA measurement data and vice versa. These are related to the accuracy, bias, test retest reliability, and precision.

METHODS

This study was conducted in five stages. First stage involved the development of human body dimension worksheet and confirmation of selected human body where the selected values were 50. At this stage, the anthropometry set, measuring tape and ruler for TA method and Vicon™ Motion Capture Camera system for MCC were confirmed to be used. In the second stage, a simple random sampling was done from the name of students in Fakulti Kejuruteraan Pembuatan (FKP) at Universiti Teknikal Malaysia Melaka (UTeM) in Melaka, Malaysia. Sixty respondents were selected and participated in this study. Formal written consent was obtained from the respondents.

The third stage of the study was the pilot study. The pilot study was used to evaluate and confirm the flow of data gathering. This pilot study involved one measurer, two respondents, and five basic body dimensions. The body dimensions consist of span, stature, axilla height, chest height, and waist height. MCC method was used to measure respondent one, TA was used to measure respondent two, and both measurements were taken twice with different time interval between each other.

Stage four consisted of the reliability and validity which included the test of accuracy, bias, test-retest, and precision on the 15 selected respondents. Data obtained from both methods were compared and verified using commercially available Minitab software. Minitab calculated the validity of both methods in order to pertain how accurate MCC measurements were matched to TA. This behaviour outlined by the accuracy and bias test. Minitab as well used as the tool to measure the reliability known as consistency of values for repeated set of MCC data assessed by test-retest reliability and precision. Lastly, the final stage of the study was the development of anthropometric measurement database for 60 respondents using the MCC method.

RESULTS

Pilot Study

Mean absolute deviation (MAD) were calculated for both methods. Both methods recorded MAD values of less than 0.5, which can be considered small and accepted to be proceeded with the validity and reliability test.

Validity and Reliability Test Normality Test

First and foremost, before conducting any test on the validity and reliability, normality test comes first. The normality test done on the data was Ryan Joiner normality test (similar to *Saphiro Wilk* test) which assesses normality by calculating the correlation between data test and normal scores of the data. As previously explained in the methodology, 15respondents were taken for these four tests as well as the normality test with each of the respondent has 50measurements. Hypothesis statement for this experiment was stated below:

H_o : The population distribution is normal.
H_A : The population distribution is not normal.

Minitab software was used to perform the Ryan Joiner test on each set of data for both measurements. Figure 1 shows one of the results obtained from the test. This is the sample result for M1 measurement, which is the span height for 15respondents.

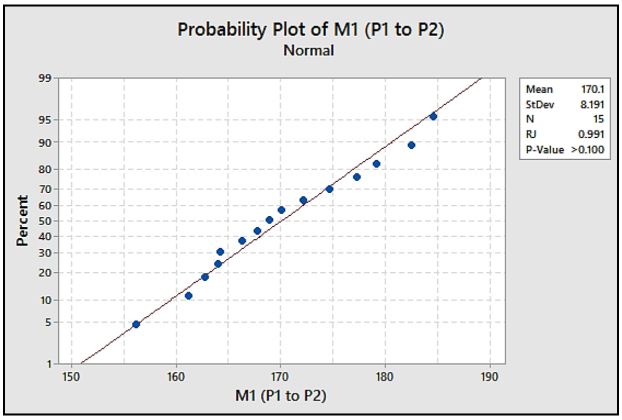

FIGURE 1- Probability plot for 15 respondents
Table 1 shows the result of Ryan Joiner normality test on each of 50measurements involved for MCC and TA measurements.

The results show that all of the measurements follow the normal distribution, as the number of p value is > 0.100. Hence null hypothesis was accepted and it indicates that all 50measurements collected have normal distribution.

Accuracy Test

Accuracy can be defined as the degree on closeness of result between measurements to the true values. To test the accuracy of the measurement, Pearson's product moment coefficient was used for normal distributed data and Spearman's correlation coefficient was calculated for non-normally set of data. Figure 2 shows one of the examples from the result obtained for M1 measured by the MCC and TA.

Correlation: M1 (P1 to P2) MCC, M1 (P1 to P2) TA

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Pearson correlation of M1 (P1 to P2) MCC and M1 (P1 to P2) TA = 0.967
P-Value = 0.000
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FIGURE 2- Pearson's correlation result for M1 measurement using MCC and TA.

Table1- Ryan Joiner normality test index

Distance Measurement	*p-value* MCC	*p-value* TA	Distance Measurement	*p-value* MCC	*p-value* TA
M1	> 0.100	> 0.100	**M64**	> 0.100	> 0.100
M3	> 0.100	> 0.100	**M65**	> 0.100	> 0.100
M4	> 0.100	> 0.100	**M66**	> 0.100	> 0.100
M5	> 0.100	> 0.100	**M67**	> 0.100	> 0.100
M6	> 0.100	> 0.100	**M68**	> 0.100	> 0.100
M7	> 0.100	> 0.100	**M23**	> 0.100	> 0.100
M8	> 0.100	> 0.100	**M24**	> 0.100	> 0.100
M9	> 0.100	> 0.100	**M80**	> 0.100	> 0.100
M10	> 0.100	> 0.100	**M61**	> 0.100	> 0.100
M82	> 0.100	> 0.100	**M62**	> 0.100	> 0.100
M2	> 0.100	> 0.100	**M54**	> 0.100	> 0.100
M84	> 0.100	> 0.100	**M58**	> 0.100	> 0.100
M18	> 0.100	> 0.100	**M59**	> 0.100	> 0.100
M19	> 0.100	> 0.100	**M60**	> 0.100	> 0.100
M55	> 0.100	> 0.100	**M25**	> 0.100	> 0.100
M56	> 0.100	> 0.100	**M75**	> 0.100	> 0.100
M57	> 0.100	> 0.100	**M30**	> 0.100	> 0.100
M83	> 0.100	> 0.100	**M31**	> 0.100	> 0.100
M11	> 0.100	> 0.100	**M32**	> 0.100	> 0.100
M12	> 0.100	> 0.100	**M26**	> 0.100	> 0.100
M13	> 0.100	> 0.100	**M27**	> 0.100	> 0.100
M14	> 0.100	> 0.100	**M28**	> 0.100	> 0.100
M15	> 0.100	> 0.100	**M29**	> 0.100	> 0.100
M16	> 0.100	> 0.100	**M76**	> 0.100	> 0.100
M17	> 0.100	> 0.100	**M63**	> 0.100	> 0.100

Abbreviations and Notes: *MCC =Motion Capture Camera, TA = Traditional Anthropometry.*

Table 2 summaries the results obtained for Pearson's product moment coefficient and Spearman's correlation coefficient. From Table 2, M80 and M82 show the lowest results, which are 0.582 and 0.528. Value for r, $0.4 < r < 0.5$ shows that this test has moderate correlation. M56, M13, M17, M67, M68, M58, M59, M75, and M32 have strong correlation where the values for r are between 0.6 and 0.79. Other measurements show very strong correlation where the values of r are> 0.8.

Table 2 – Pearson's/Spearman's product moment correlation result for accuracy

Body Dimension	Pearson's/Spearman's Product Moment Correlation Coefficient (r)	p-value	Body Dimension	Pearson's/Spearman's Product Moment Correlation Coefficient (r)	p-value
M1	0.967	<0.001	**M64**	0.819	<0.001
M3	0.987	<0.001	**M65**	0.912	<0.001
M4	0.942	<0.001	**M66**	0.936	<0.001
M5	0.942	<0.001	**M67**	0.789	<0.001
M6	0.915	<0.001	**M68**	0.771	0.001
M7	0.937	<0.001	**M23**	0.818	<0.001
M8	0.976	<0.001	**M24**	0.927	<0.001
M9	0.845	<0.001	**M80**	0.528	0.043
M10	0.994	<0.001	**M61**	0.925	<0.001
M82	0.582	0.023	**M62**	0.978	<0.001
M2	0.971	<0.001	**M54**	0.947	<0.001
M84	0.670	0.006	**M58**	0.721	<0.001
M18	0.982	<0.001	**M59**	0.690	0.004
M19	0.987	<0.001	**M60**	0.934	<0.001
M55	0.815	<0.001	**M25**	0.950	<0.001
M56	0.772	0.001	**M75**	0.620	0.014
M57	0.874	<0.001	**M30**	0.960	<0.001
M83	0.809	<0.001	**M31**	0.976	<0.001
M11	0.972	<0.001	**M32**	0.637	0.011
M12	0.890	<0.001	**M26**	0.954	<0.001
M13	0.750	<0.001	**M27**	0.856	<0.001
M14	0.935	<0.001	**M28**	0.930	<0.001
M15	0.939	<0.001	**M29**	0.823	<0.001
M16	0.928	<0.001	**M76**	0.811	<0.001
M17	0.762	0.001	**M63**	0.864	<0.001

***Abbreviations and Notes**: MCC =Motion Capture Camera, TA = Traditional Anthropometry, r indicates Pearson correlation test.*

Bias Test

Bias is defined as the tendency of a value obtained from the MCC measurement process either it tends to over or underestimate value comparing to TA. This test was assessed by determining the magnitude and direction of the difference between MCC and TA means and their statistical significance was evaluated. Hypothesis statement for this experiment are as follow:

H_o : There is no significant difference between mean
H_A : There is significant difference between mean

Figure 3 presents the example of paired t-test used on the mean between MCC and TA using Minitab software.

Paired T-Test and CI: M1 (P1 to P2) MCC, M1 (P1 to P2) TA

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Paired T for M1 (P1 to P2) MCC - M1 (P1 to P2) TA

                    N    Mean  StDev  SE Mean
M1 (P1 to P2) MCC  15  170.07   8.19     2.12
M1 (P1 to P2) TA   15  170.43   7.67     1.98
Difference         15  -0.360  2.109    0.545


95% CI for mean difference: (-1.528, 0.808)
T-Test of mean difference = 0 (vs ≠ 0): T-Value = -0.66  P-Value = 0.519
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FIGURE 3- Paired t-test result for M1 measurements

Table 3 shows the results obtained for paired t-test which include mean, standard deviation, differences, t-value, and p-value.

Table 3 - Paired t-test result for bias

Distance	Mean MCC (cm)	± SD (cm)	Mean TA (cm)	± SD (cm)	Difference (cm)	t-value	p-value
M1	170.07	8.19	170.43	7.67	-0.36	-0.66	0.519
M3	167.55	6.88	168.25	7.21	-0.706	-2.3	0.037
M4	128.93	4.84	128.43	5.07	0.496	1.13	0.276
M5	123.56	5.18	122.51	4.91	1.045	2.33	0.035
M6	95.92	5.83	94.82	4.72	1.098	1.75	0.102
M7	80.6	5.82	80.79	5.61	-0.19	-0.65	0.523
M8	27.89	4.28	28.45	4.43	-0.56	-2.26	0.040
M9	24.967	1.335	25.207	1.499	-0.24	-1.16	0.267
M10	51.05	5.84	51.01	5.9	0.039	0.23	0.819
M82	11.631	1.264	10.933	1.398	0.697	2.58	0.022
M2	208.9	1.56	209.6	1.59	-0.7	-0.65	0.523
M84	17.38	7.76	20.43	7.81	-3.05	-1.87	0.083
M18	144.1	6.55	144.93	6.64	-0.826	-2.58	0.022
M19	142.44	7.3	143.4	7.34	-1.612	-3.19	0.007*
M55	33.39	4.73	32.77	3.79	0.614	0.87	0.400
M56	31.92	5.14	31.01	3.63	0.902	1.06	0.306
M57	36.24	4.71	35.51	4.45	0.732	1.22	0.242
M83	6.642	1.173	6.513	1.258	0.129	0.66	0.519
M11	136.05	6.63	136.53	6.29	-0.479	-1.18	0.259
M12	87.4	4.43	88.33	5.09	-0.932	-1.55	0.142
M13	81.91	5.5	83.38	5.66	-1.47	-1.44	0.171
M14	49.939	3.248	51.107	3.639	-1.168	-3.49	0.004*
M15	46	3.345	48.9	3.512	-2.9	-1.01	0.331
M16	33.356	2.578	33.787	2.422	-0.431	-1.74	0.104
M17	6.991	1.214	7.827	1.032	-0.836	-4.08	0.001*
M64	29.37	17.8	20.97	3.56	8.39	1.82	0.091
M65	23.64	4.74	21.59	4.34	2.052	3.66	0.003*
M66	25.3	4.66	23.64	4.43	1.656	3.9	0.002*
M67	20.978	0.973	20.187	1.328	0.791	3.74	0.002*
M68	26.974	1.724	26.687	1.903	0.288	0.9	0.383
M23	87.35	6.17	85.05	6.71	2.3	2.28	0.039
M24	74.31	5.75	72.7	5.78	1.61	2.83	0.013
M80	18.219	1.081	17.713	1.564	1.046	2.99	0.010
M61	31.294	2.617	30.547	2.234	0.748	2.86	0.013
M62	47.27	8.36	45.62	7.99	1.65	3.62	0.003*
M54	12.064	1.674	12.033	1.736	0.031	0.22	0.833
M58	49.01	4.83	47.05	4.95	1.956	2.07	0.057
M59	40.986	3.8	40.96	3.252	0.026	0.04	0.972
M60	36.15	4.2	35.25	4	0.894	2.31	0.037
M25	62.341	3.674	63.48	3.78	-1.139	-3.74	0.002*
M75	20.106	1.636	18.767	1.692	1.339	3.57	0.003*
M30	52.22	4.16	52.58	4.2	-0.36	-1.17	0.26
M31	19.638	2.965	18.953	2.765	0.685	4.36	0.001*
M32	14.56	1.339	13.867	1.331	0.693	2.36	0.033
M26	55.378	3.666	55.42	3.449	-0.042	-0.15	0.884
M27	43.131	2.718	43.593	2.781	-0.463	-1.21	0.245
M28	59.95	4.61	57.99	3.6	1.96	4.15	0.001*
M29	50.08	5.72	47.65	2.96	2.432	2.55	0.023
M76	21.519	3.395	20.88	3.381	0.639	1.19	0.255
M63	43.106	2.323	43.66	1.939	-0.554	-1.83	0.088

***Abbreviations and Notes**: MCC =Motion Capture Camera, TA = Traditional Anthropometry, SD = Standard deviation, t indicates the T-test. Asterisk p-values indicate significant findings.*

Based on Table 3, 11measurements which are M19, M14, M17, M65, M66, M67, M62, M25, M75, M31, and M28 have low p-value which are near to <0.001 indicate that there are significant differences. This suggested that there might be bias between measurement techniques. Other 39 measurements show that there is no statistically significant bias.

Test-Retest Reliability Test

Test-retest reliability is a measure of consistency of the same measurement using the same technique over time. In other words, the same measurer given the same test twice at different times and observed the score or measured value. Pearson's product moment correlation used over normal distributed data while Spearman's moment correlation used on non-normally distributed data. Figure 4 shows the sample of the outcome obtained from the correlation test.

Correlation: M1 (P1 to P2) MCC 1, M1 (P1 to P2) MCC 2

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Pearson correlation of M1 (P1 to P2) MCC 1 and M1 (P1 to P2) MCC 2 = 0.965
P-Value = 0.000
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FIGURE 4-Pearson's correlation result for M1 measurement using MCC

Table 4 shows the summary of data obtained from Pearson's and Spearman's moment correlation tests for MCC and TA methods. From Table 4, all fifty measurements for both MCC and TA methods have strong correlation value for the first and second measurements taken where all r values are>0.6 which indicate strong correlation.

Table 4 – Pearson's/Spearman's product moment correlation result for test re-tests reliability

Distance	r MCC	p-value	r TA	p-value	Distance	r MCC	p-value	r TA	p-value
M1	0.965	<0.001	0.963	<0.001	**M64**	0.920	<0.001	0.965	<0.001
M3	0.982	<0.001	0.997	<0.001	**M65**	0.930	<0.001	0.948	<0.001
M4	0.925	<0.001	0.981	<0.001	**M66**	0.900	<0.001	0.932	<0.001
M5	0.990	<0.001	0.903	<0.001	**M67**	0.990	<0.001	0.963	<0.001
M6	0.957	<0.001	0.935	<0.001	**M68**	0.910	<0.001	0.987	<0.001
M7	0.966	<0.001	0.978	<0.001	**M23**	0.856	<0.001	0.965	<0.001
M8	0.949	<0.001	0.954	<0.001	**M24**	0.952	<0.001	0.956	<0.001
M9	0.713	0.003	0.852	<0.001	**M80**	0.985	<0.001	0.921	<0.001
M10	0.979	<0.001	0.979	<0.001	**M61**	0.953	<0.001	0.932	<0.001
M82	0.737	0.002	0.739	0.002	**M62**	0.847	<0.001	0.967	<0.001
M2	0.996	<0.001	0.997	<0.001	**M54**	0.935	<0.001	0.987	<0.001
M84	0.952	<0.001	0.967	<0.001	**M58**	0.925	<0.001	0.951	<0.001
M18	0.996	<0.001	0.996	<0.001	**M59**	0.956	<0.001	0.921	<0.001
M19	0.960	<0.001	0.958	<0.001	**M60**	0.923	<0.001	0.862	<0.001
M55	0.990	<0.001	0.963	<0.001	**M25**	0.915	<0.001	0.966	<0.001
M56	0.980	<0.001	0.987	<0.001	**M75**	0.921	<0.001	0.832	<0.001
M57	0.940	<0.001	0.864	<0.001	**M30**	0.825	<0.001	0.965	<0.001
M83	0.880	<0.001	0.945	<0.001	**M31**	0.861	<0.001	0.962	<0.001
M11	0.820	<0.001	0.965	<0.001	**M32**	0.935	<0.001	0.987	<0.001
M12	0.950	<0.001	0.986	<0.001	**M26**	0.941	<0.001	0.865	<0.001
M13	0.970	<0.001	0.932	<0.001	**M27**	0.963	<0.001	0.954	<0.001
M14	0.800	<0.001	0.941	<0.001	**M28**	0.978	<0.001	0.963	<0.001
M15	0.910	<0.001	0.936	<0.001	**M29**	0.956	<0.001	0.987	<0.001
M16	0.810	<0.001	0.865	<0.001	**M76**	0.853	<0.001	0.856	<0.001
M17	0.980	<0.001	0.856	<0.001	**M63**	0.864	<0.001	0.953	<0.001

***Abbreviations and Notes**: MCC =Motion Capture Camera, TA = Traditional Anthropometry, r indicates Test-Retest correlation test*

Precision Test

Precision is described as the magnitude of the variation between the same or repeated measurements utilizing the same measurement method coming from the same measurer. MAD and corresponding relative error magnitude (REM) used between MCC and TA values for a given distance. MAD is expressed clearly as the average of absolute differences involving values of two sets of measurements. REM is calculated as MAD divided by the grand mean across both set of measurements and multiplied by 100. All calculations were performed using Microsoft Excel software. Table 5 shows the summary of the results obtained for MAD and REM values.

Table 5 - MAD & REM result for precision test

	MAD MCC to MCC (cm)	REM MCC to MCC (%)	MAD TA to TA (cm)	REM TA to TA		MAD MCC to MCC (cm)	REM MCC to MCC	MAD TA to TA (cm)	REM TA to TA
M1	1.04	0.61	0.90	0.53	**M64**	0.56	3.16	0.60	3.95
M3	0.97	0.57	0.55	0.32	**M65**	0.75	2.72	0.95	3.34
M4	0.93	0.72	0.55	0.43	**M66**	0.95	3.34	0.85	2.75
M5	1.12	0.90	0.95	0.78	**M67**	0.91	7.05	1.00	8.71
M6	0.85	0.89	0.60	0.73	**M68**	0.93	0.62	1.60	1.12
M7	0.64	0.79	0.50	0.73	**M23**	0.96	6.35	1.50	0.92
M8	0.81	2.86	0.60	2.21	**M24**	0.97	0.57	0.50	0.32
M9	0.69	2.82	0.45	1.88	**M80**	0.93	0.72	0.55	0.43
M10	0.59	1.16	0.65	1.27	**M61**	1.12	0.90	0.95	0.78
M82	0.59	4.91	0.35	3.28	**M62**	0.85	0.89	0.60	0.73
M2	1.09	0.52	0.45	0.21	**M54**	0.64	0.79	0.55	0.73
M84	0.60	3.93	0.60	3.48	**M58**	0.81	2.86	0.60	2.21
M18	0.83	0.57	0.60	0.41	**M59**	0.81	2.86	0.65	2.21
M19	1.02	3.26	0.40	1.23	**M60**	0.95	6.85	1.05	7.25
M55	0.52	0.52	1.30	1.45	**M25**	0.85	5.62	1.05	7.56
M56	0.86	2.16	0.85	2.16	**M75**	1.12	0.90	0.95	0.78
M57	0.95	1.76	1.10	2.16	**M30**	0.85	0.89	0.60	0.73
M83	0.74	3.59	1.10	5.36	**M31**	0.64	0.79	0.50	0.73
M11	0.76	6.13	0.95	7.01	**M32**	0.81	2.86	0.65	2.21
M12	0.79	4.76	0.95	6.35	**M26**	0.93	0.72	0.55	0.43
M13	0.64	2.76	1.20	5.63	**M27**	1.12	0.90	0.95	0.78
M14	1.26	11.32	0.95	8.05	**M28**	0.85	0.89	0.60	0.73
M15	0.95	6.85	1.05	7.25	**M29**	0.85	5.62	1.05	7.56
M16	0.85	5.62	1.00	7.56	**M76**	1.16	5.65	1.15	4.85
M17	1.16	5.36	1.20	4.85	**M63**	0.56	3.16	0.60	3.95
					Overall	0.86	2.86%	0.81	2.82%

***Abbreviations and Notes**: MCC =Motion Capture Camera, TA = Traditional Anthropometry, MAD = Mean Absolute Difference, REM = Relative Error Magnitude, % = Percentage.*

It can be concluded that the precision of the MCC are comparable with the TA as the overall MAD value with the difference of only 0.05 cm and REM value with the difference value of only 0.04%.

DISCUSSION

From all of the tests that have been done to test the validity and reliability of data obtained from the MCC compared to TA, the results were satisfying. Accuracy test shows that the correlation for all distances, only M80 and M82 values were found statistically low to moderate correlation. Depicted that 48 out of 50 measurements with high correlation and considered this test passed and accepted. For bias test, where paired t-test comparing mean between MCC and TA measurements for each distance shows that 11out of 50with statically difference for values of M19, M14, M17, M65, M66, M67, M62, M25, M75, M31, and M28. In addition, the test-retest reliability of MCC measurement was excellent and comparable to TA. All and all, MCC is shown to be a method that as precise as TA that used to measure and develop anthropometric database.

Anthropometric Database Using MCC

From all data obtained for the sixty respondents, the mean, standard deviation, coefficient of variation, 5th, 50th and 95th percentile values had been calculated. All calculations were performed using Microsoft Excel software. Table 6 shows the database that has been developed.

From the coefficient of variation column in Table 6, the highest value for Coefficient Variation (CV) is 23.59. The value is slightly lower than the assumed CV that has been used before to pre-determine the sample size which is 25. Hence, the minimum number of sample respondents that should be used in this study is minimum of 53 samples. Thus, it is proven that 60 respondents used in the database development are enough to fulfill the requirement of ISO 15535:2003.

Table 6 – Anthropometric database for 60 youth male respondents for 50 body dimensions

No	Body Dimension	Mean	Standard Deviation	Coefficient Variation	Percentiles 5th	50th	95th
M1	SPAN	174.10	7.27	4.17	162.96	174.60	186.70
M2	OVERHEAD REACH	214.18	7.56	3.53	200.69	215.30	225.40
M3	STATURE	168.86	6.09	3.61	159.98	168.50	177.53
M4	AXILLA HEIGHT	128.26	4.99	3.89	120.52	128.20	136.12
M5	CHEST HEIGHT, STANDING	123.82	5.13	4.14	116.22	124.05	132.50
M6	WAIST HEIGHT OMPHALION	98.45	8.83	8.97	91.74	97.80	107.94
M7	CROCTCH HEIGHT, STANDING	80.55	6.15	7.64	73.27	80.40	90.11
M8	ACROMION-RADIAL LENGTH	28.94	3.58	12.37	23.81	28.65	34.53
M9	RADIALE-STYLION LENGTH	25.62	2.48	9.67	22.28	25.85	28.52
M10	SLEEVE OUTSEAM	54.56	3.73	6.84	49.39	54.15	60.02
M11	ACROMIAL HEIGHT, STANDING	137.80	6.55	4.75	129.60	139.20	145.39
M12	TROCHANTERION HEIGHT	86.29	4.91	5.69	79.20	86.35	92.83
M13	BUTTOCK HEIGHT	82.42	5.68	6.89	72.56	83.35	91.42
***M14**	KNEE HEIGHT, MIDPATELLA	51.27	7.58	14.79	43.79	50.00	55.67
M15	LATERAL FEMORAL EPICONDYLE HEIGHT	50.07	3.08	6.16	45.99	50.45	55.54
M16	CALF HEIGHT	34.98	2.81	8.03	30.60	35.20	39.83
***M17**	LATERAL MALLEOLUS HEIGHT	7.89	1.07	13.52	6.19	7.90	9.80
M18	NECK HEIGHT, LATERAL	144.06	6.09	4.23	136.92	144.45	151.72
***M19**	CERVICALE HEIGHT, STANDING	146.41	5.68	3.88	136.99	146.25	155.34
M23	SITTING HEIGHT	86.77	5.15	5.93	80.97	86.65	95.00
M24	EYE HEIGHT, SITTING	75.97	3.82	5.03	70.78	75.85	83.01
***M25**	MIDSHOULDER HEIGHT, SITTING	61.37	4.33	7.05	56.94	61.05	66.62
M26	KNEE HEIGHT, SITTING	53.67	3.93	7.32	48.54	54.30	57.56
M27	POPLITEAL HEIGHT	42.64	3.04	7.12	37.84	42.90	46.80
***M28**	BUTTOCK-KNEE LENGTH	57.07	3.30	5.78	52.17	57.25	62.11
M29	BUTTOCK-POPLITEAL LENGTH	46.13	3.07	6.66	41.30	46.15	51.22
M30	ACROMIAL HEIGHT, SITTING	57.03	3.96	6.94	51.91	57.05	63.08
***M31**	WAIST HEIGHT, SITTING, OMPHALION	17.65	3.34	18.92	11.20	18.20	21.81
M32	THIGH CLEARANCE	13.70	1.85	13.52	11.29	13.50	17.12
M54	SHOULDER LENGTH	14.58	1.55	10.64	12.17	14.55	17.01
M55	CHEST BREADTH	29.05	3.21	11.05	25.00	28.65	35.05
M56	WAIST BREADTH	27.88	3.81	13.66	22.78	27.85	35.62
M57	HIP BREADTH, STANDING	33.48	3.12	9.31	29.10	33.30	39.42
M58	BIDELTOID BREADTH	44.55	5.61	12.58	38.20	44.25	52.47
M59	BIACROMIAL BREADTH	40.40	3.33	8.24	36.42	40.60	44.66
M60	INTERSCYE 1	30.90	4.96	16.04	25.15	29.75	39.01
M61	SHOULDER-ELBOW LENGTH	33.91	2.56	7.55	30.70	33.80	37.32
***M62**	HIP BREADTH, SITTING	38.65	5.48	14.19	32.69	37.75	47.54
M63	FOREARM-HAND LENGTH	46.32	2.17	4.68	42.50	46.60	49.71
M64	CHEST DEPTH	20.50	2.81	13.69	16.78	20.30	26.71
***M65**	WAIST DEPTH	19.69	4.13	20.97	15.20	18.75	26.02
***M66**	BUTTOCK DEPTH	21.20	3.36	15.85	16.38	20.85	26.97
***M67**	BALL OF FOOT LENGTH	20.99	2.01	9.60	18.70	20.45	25.42
M68	FOOT LENGTH	24.77	2.70	10.89	19.70	25.40	27.01
M75	HEAD LENGTH	18.38	0.77	4.18	17.20	18.45	19.70
M76	ABDOMINAL EXTENSION DEPTH, SITTING	20.72	4.97	23.99	15.19	20.05	28.13
***M80**	HEAD BREADTH	15.94	1.05	6.56	14.70	16.00	17.16
***M82**	FOOT BREADTH, HORIZONTAL	9.71	0.81	8.35	8.69	9.75	10.92
M83	HEEL BREADTH	6.43	0.60	9.29	5.49	6.40	7.31
M84	BIMALLEOLAR BREADTH	13.77	3.25	23.59	9.10	14.35	19.02

***Abbreviations and Notes**: M = Measurement human body. Asterisks M values indicate measurement with unsatisfying results of test*

Lastly, the anthropometric data collected in this study shows that 90% stature values for Malaysian citizen lies between 159.98cm and 177.51mm. This anthropometric database is practical to be used by all designers and engineers in developing an ergonomic product, workstation or facilities. Consequently, all designers really need to incorporate the anthropometry awareness within the design to help prevent long-term health problem towards the user as well as to ensure comfort and safety.

CONCLUSION

In conclusion, results obtained had proven that the MCC method statistically passed the tests of accuracy, bias, test-retest reliability, and accuracy. Hence, this useful finding stated that MCC could be used as one of other available with valid and reliable data provided for anthropometric measurements. In addition, this successful development of database for youth male could serve and provide useful standard references for automotive ergonomics design specifically for male youth 18 to 25 years old group respondents as well as to other researchers in any of anthropometric study area.

ABBREVIATIONS

MCC =Motion Capture Camera, TA = Traditional Anthropometry, SD = Standard deviation MAD = Mean Absolute Difference, REM = Relative Error Magnitude, % = Percentage.

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COMPETING INTERESTS

There is no conflict of interest.

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