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Foot Anthropometry for Shoe Design among Preschool Children in Malaysia

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ABSTRACT

Foot anthropometry provides statistical data on the distribution of foot dimension in the population used to optimize products. Foot anthropometry plays an important role designing good fitting footwear. Changes in life styles, nutrition, and ethnic compositions of the populations have led to the changes in the distribution of foot dimension and thus it requires regular updating of foot anthropometry data collection. This study examined foot anthropometry data of preschool children in Malaysia. The purpose of this study was to develop fit size to shoe design. The data were collected from twelve pre-schools in Selangor, Malaysia. Three-hundred and three pre-school children (129 boys and 174 girls) were randomly selected for this study. Standard anthropometric technique and tools were used. The respondents' foot lengths (left and right), foot widths (left and right), as well as ankle circumference and foot heights were measured and analyzed using SPSS program. The results showed that there were significant relationships among all the foot anthropometry measurements. The results also revealed there that was no difference between the foot anthropometry among the urban and rural pre-school children. The study found that there was a significant difference between the length of the right and left foot. The study also revealed that there was a significant difference between the width of the right and left foot. The data gathered in this study could be further used to develop footwear sizing system.

Keywords: Anthropometry, children, foot, shoe

INTRODUCTION

The human foot is a flexible structure of our body that consists of 26 bones. Shoes are necessary apparatus used to cover feet and protect them from injury. Shoes sizes which are not based on foot anthropometry measurement will cause pain to the consumers when they are worn. Moreover, improper shoes sizes will result in foot injury and deformity. One of the causes of strain in foot muscle and tendons is improper shoes size (Luximon dan Goonetilkels, 2005).

Shoes and stockings are used to protect foot from injury. In the production of shoes and stocking, standardization of size is an important concern. In order to satisfy a wide range of consumers, it is necessary to develop a standard that will enable choice of footwear sizes applicable to individual and group needs (Ujevic and Herzanjak, 2004).

Anthropometry as an anthropology method is concerned with the measurement and testing of the human body and the relationship of dimensions among its individual parts (Ujevic *et al.*, 2006). Anthropometry measurement is a necessary tool in developing standardized sizes. In the production of fashionable clothing

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and footwear, the anthropometric measurements are applied in the field of construction and modelling processes. Shoes and stockings design use anthropometric measurements in the foot area. Foot anthropometric measurements which are applied to design shoes and stockings should represent a sample of specific population which includes children, youth, and elderly. Malaysia is one of the Asian countries whereby residents have small body sizes. Southeast Asians and African children have smaller foot shape compared to Australian children (Kouchi, 1998). For Malaysian children, it is difficult to get clothing and shoes that could fit them well because of their relatively smaller body size and shape. Thus, Asian clothing size is relatively smaller than European clothing size because Asians have smaller body sizes (Naimah *et al*., 2007). Furthermore, children clothing and shoes in the Malaysian market are based on the foreign sizes such as US and UK standard sizes. The imported standard shoe sizes are adjusted to fit the Malaysian children. Unfortunately, these adjusted sizes still do not fit well with the foot shape and size of Malaysian children (Naimah *et al*., 2007). Other groups, such as the elderly and youth, also face similar problem in finding the right shoe size. There are many shoe designs in the Asian market that do not follow the standard or real foot anthropometric standard. According to Chaiwanichsiri, Tantisiriwat dan Janchai (2008), many individuals of the older generation could not find shoes that could fit to their feet well. Parents who have children aged 5 and 6 years old are also facing problem in finding fit clothing and footwear sizes for their children. According to Naimah *et al.* (2007), there is currently no standardized sizing system for children in the clothing industry in Malaysia.

Nowadays, studies related to foot anthropometric data for Malaysian children are still limited. These studies include "Malaysian Sizing" by Prof Dr. Amir Feisal Merican from CRYSTAL, University of Malaya, "Sistem Pensaizan Kanak-Kanak dan Remaja di Malaysia" by Puan Naimah Mohd. Salleh from Universiti Putra Malaysia and "The Importance of Body Sizing System" by Puan Norsaadah Zakaria from Department of Textile Technology, UiTM. Nevertheless, the studies did not focus on gathering foot anthropometric data, and were more generally on anthropometric measurements. The fact that there are possible differences in the foot anatomy across different nationalities, it is essential to define Malaysian children anthropometric data. The present study was aimed to collect foot anthropometric data of Malaysian children, in order to determine the proper shoe size for the shoe design.

OBJECTIVES OF THE STUDY

General Objective

This study was conducted to collect foot anthropometric data for Malaysian children, aged between 5 and 6 years old, for the purpose of designing shoe sizes that better fit their feet.

Specific Objectives

In more specific, this study was undertaken to:

- obtain children foot anthropometric measurements.
- measure the relationship between foot anthropometric measurements.
- measure the differences in the foot measurements between the rural and urban children.
- measure the differences in the foot measurements between the right and left foot.

LITERATURE REVIEW

Anthropometric Measurements

Human beings have unique body shapes and different levels of body development. Although they may have biological relationship such as between siblings or twins but their body shapes and sizes are not exactly the same. Therefore, the construction of consumer products need to fit various human body shapes, so as to give and provide consumers with comfort and satisfaction, especially footwear products.

In addition to several industries (e.g. furniture, tools, mechanical engineering, road building, personal protective wear and work safety equipment, and automotive), the garment and footwear industry are particularly interested in the results of the anthropometric measurement studies (Ujevic and Hrzenjak, 2004). Anthropometric measurements have become a reference to clothing and footwear manufacturers because these measurements are capable of providing them with the accurate measurements based on body shapes (Beazley, 1997). As a consequence, they tend to provide perfect products for consumers.

Three groups of information essential for the production of clothing and footwear are determined by systematic mass measurement and statistical treatment, such as the systems of clothing and footwear designation, standard and proportional measurements and share of individual clothing and footwear (Ujevic *et al*., 2004). Shoe and stocking designation system is has become foundation for manufacturers, consumers, and the entire population. The system prescribes shoes and stocking sizes and determines methods of size designation. There is no universal footwear size labelling system, but each country prescribes them based on the anthropometric measurements. Measurements are made every 10 to 15 years so as to improve and promote standardization (Beazley, 1997). This is necessary because changes in the life style and environment directly affect the measurement of the human bodies. The desire of each footwear and garment manufacturer is to meet the demand of unknown consumers. Therefore, shoes and stockings are made according to the specific standards and in as many sizes as possible.

Footwear designers normally use foot length, foot width, foot height, and ankle circumference to design shoes (Waterson and Sell, 2006). These measurements are ergonomic inputs which are necessary to design footwear products that offer comfort and flexibility to the users when their bodies are in motion (Waterson and Sell, 2006). However, girths are rarely measured for fitting footwear. The differences in girth measurements between foot and shoes can cause significant mismatch if the corresponding widths and heights are not accounted for in the foot shape (Rossi, 2000). The height measurement in the mid foot region is important for designing the vamp of shoes (Janisse, 1992). On the other hand, the forefoot shape depends on the fashion of shoes (Cheng and Perng, 1999). Therefore, it is important to have a system that relates foot height to foot length to provide an ideal platform for shoe design.

Significance of the Anthropometry Measurements

The health of our feet is largely affected by the shoes that we wear. An accurate choice of shoe size and shape will be able maintain the health and vitality of feet. On the contrary, improper choice of shoe size is a common cause of foot and ankle problems (such as blisters and hardened heels) (Chaiwanichsiri, Tantisiriwat and Janchai, 2008). Meanwhile, wrong shoe size is also another cause of foot injury, pain, and deformity. A detailed knowledge of foot shape and foot structure is particularly important for those involved in the design and construction of shoes (Mauch *et al.*, 2008). Furthermore, small variations in foot shape must be incorporated into shoe design to meet the requirement for shoe fit comfort. According to Rossi and Tennant (1984), a one-sixth inch difference in the ball of foot measurement can create a faulty fit in the forefoot region of a shoe.

Children must wear proper shoe sizes according to their foot measurement and shape. It is very important that children's shoes fit properly because ill fitting shoes can impede the normal development of maturing foot (Echarri and Forriol, 2003). Although foot shape consideration is important to produce comfortable shoes, comprehensive studies investigating foot morphology tend to emphasize on adults, particularly military personnel (Hawes and Sovak, 1994). Footwear manufacturers apply foot shape as their reference to develop shoes and stockings (Kouchi, 1998). Studies concerning the morphology of children's feet are

limited. The data are also limited to dimensions of the foot (foot length and ball circumference) and leg (tibial and femur length and calf circumference) to monitor childhood growth rates (Kok, Bax and Smits, 2005).

A study by Stavles *et al.* (2005), which examined the dynamic footprints recorded both feet of 5866 Mediterranean boys and girls, aged between 6-17 years, found that the proportion of high and low arched foot types decreased with increasing age in boys and girls. Although critical changes of the foot occur during pre-school development, considerable changes in foot shape also take place during school age up to late adolescence. These changes are important data to produce suitable and comfortable shoe sizes for consumers.

Variability of foot shape is due to numerous factors. Factors contributing to this variability include genetics, environmental, socio-economic, lifestyle, and different manners of wearing shoes (Razeghi and Batt, 2002). Kouchi (1998) analyzed foot shape characteristics to identify differences due to ethnic backgrounds. Kouchi found that the Japanese feet are much similar to the feet of Indonesians than the Caucasoid or Australoid's feet. The Japanese typically have a wider foot for foot length as compared to the Caucasoid and Australoid, but a smaller foot length for height than those of the Southeast Asians and Africans (Kouchi, 1998). These differences occurred due to both genetic and environmental factors. According to the study by Wunderlich and Cavanagh (2001), adult foot shapes vary based on gender differences. In the study, all foot anthropometric data of each gender were separately analyzed. The study by Chaiwanichsiri *et al.* (2008) found that the foot dimensions between genders demonstrated that at the same foot length, men had larger foot width and circumference, as well as upper ball, ach, toe depth and ankle height than women, while the arch length had the same proportion with the foot length in both genders. Therefore, measurements need to be taken for both genders because they have differences in the foot measurement.

The Development of Children's Body Shape

Designers of children's clothes and footwear should be aware that a child's body shape changes as they grow and that they should also be able to recognize the body shape of a child at a particular age. Well-designed children's clothes and footwear take into account the continuous changing body shape. Good designers focus on the body parts which are rapidly and continuously changing when designing proper sizes for children's products (Aldrich, 1999). A child's rapid growth and changing shape from birth to adulthood mean that small increments in size have to be made. This is usually done in monthly intervals. The decrease in the rate of growth varies from approximately eight cm per year at three years of age to five cm per year at ten years old (Aldrich, 1999). Aldrich also stated that manufacturers have decided to accept a six cm height growth interval as a base for a coding scheme. This interval is approximately the average growth per year for this period. As a consequence, manufacturers should have the knowledge about the real measurements of children's bodies before designing their shoes and garments in accordance to their rapid growth and development for a certain age. Therefore, this study is important to meet the need of children's shoe sizes which continuously change because of their rapid growth and development.

METHODOLOGY

The sample of the study consisted of 303 children aged between 5 and 6 years old selected through the-stratified random sampling. Five Tabika Kemajuan Masyarakat (KEMAS) located in the urban area and seven in the rural area in the state of Selangor were selected as the location of the study. The Tabika KEMAS located in Puchong were selected to represent the urban area whereas the Tabika KEMAS in Hulu Langat represented the rural area. Information was obtained from Jabatan KEMAS Selangor.

TABLE 1
Location and sample

Area	Name of Tabika	Number of respondents	Percentage (%)
Urban			
Puchong	T.K Al-Ikhsan	29	9.57
	T.K An-Nurindah	29	9.57
	T.K Bt.13 Puchong	40	13.2
	T.K Ibnul-Quyum	25	8.25
	T.K Permai Bistari	32	10.56
Rural			
Hulu Langat	T.K Anggerik A	24	7.92
	T.K Anggerik B	15	4.95
	T.K FASA 1, B.B.B	25	8.25
	T.K Seksyen 2A	24	7.92
	T.K Seksyen 2B	18	5.94
	T.K Seksyen 4A	22	7.26
	T.K Seksyen 4B	20	6.6
	Total	303	100

Note: T.K = Tabika Kemas

Study Instrument and Data Collection

A questionnaire was used for data collection. The research questionnaire consists of two main parts, i.e. (i) Demographic characteristics of the respondents (age, gender, ethnic, and family income) and (ii) Foot anthropometric measurements (foot height, ankle circumference, right foot plantar surface length, left foot plantar surface length, right foot plantar surface width, and left foot plantar surface width). The measurements were recorded in the metric unit - centimetres (cm).

The respondents were required to take off their shoes and stockings when the measurements were made. Foot height and ankle circumference were measured using the standard tape measurement. Both the measurements were taken on the right side of the body (Carter, 2002). The length and width measurements were taken by sketching both the right and left feet on an A4 paper. The measurements were marked using a pencil and were measured with a ruler. The mean measurement was also recorded. All the measurements were taken by the researchers who were trained in foot anthropometric measurements. The measurements were taken according to the procedures described in the American Standard for Testing Material (ASTM, 1970), Anthropometric Standardization Reference Manual (1991) and Anthropometry Procedures Manual (2004).

Data Analysis

All data were analyzed using the SPSS software for window version 13.0 (Statistical Package for Social Science 13.0). Descriptive statistic was also used to get the mean, standard deviation, as well as maximum and minimum values. Pearson correlation test was computed to identify the relationship between foot anthropometric measurements. Both feet were compared using the paired t-test to determine the differences for both. Meanwhile, t-test was also used to identify the differences in the foot measurements between the rural and urban children.

RESULTS AND DISCUSSION

This section discusses the findings for the respondents' demographic, mean, standard deviation, maximum and minimum values, relationship between female and male children's

foot anthropometric measurements, differences between the right and left feet, as well as the differences in the foot anthropometric measurements between the rural and urban children.

Table 2 shows the respondents' socio-demographic information. The number of female children (57.4%) was found to be higher than the number of male children (42.6%). A total of 234 (77.2%) respondents aged 6 years old, whereas the rest aged 5. The monthly income of the respondents' families was found to range between RM800 and RM6500, with an average income of RM2549 per month. Most (24.7%) of the respondents' families had the monthly income in the range of RM1500-RM2000. Meanwhile, 17.5% of the respondents had the family income below RM1500, while the rest of the families earned more than RM2001 per month.

The Foot Anthropometry of Male and Female Children

Tables 3A and 3B show 6 foot anthropometric measurements for the male (boys) and female (girls) children aged 5 and 6 years old. The foot anthropometric measurements were reported in terms of their means, standard deviation, as well as maximum and minimum values.

Table 3A presents the foot anthropometric measurements for the boys aged 5 and 6 year old, indicating that the foot height of the 6 year-old boys was bigger than those aged 5. On the other hand, the 5 year-old boys had the maximum foot height measurement i.e. 7.7 cm, as compared to the 6 year-old group, with the maximum value of 7.5 cm. For the ankle circumference measurements, the 6 years-old group was reported to have the mean value of 16.43 cm compared to that of the 5 years-old group, i.e. 16.36 cm. This is also similar to the trend in the foot height measurements, whereby the maximum value for the ankle circumference was reported to be 29 cm for 5 year-old group. As for the right and left feet plantar surface width measurements, 5 year-old group reported to have 7.23 cm for both the measurements. The left and right feet plantar surface length measurements for 6 years old boys had the highest mean, i.e. 17.82 cm for both feet.

Table 3B shows the foot anthropometric measurements for the 5 and 6 years old girls. Based on the data presented in the table, the mean foot anthropometric measurements for

TABLE 2
Respondents' socio-demographic background

Variable		n=303	(%)
Ethnic group	Malay	297	98
	Chinese	1	0.3
	Indian	5	1.7
Gender	Boy	129	42.6
	Girl	174	57.4
Age (Years)	5	69	22.8
	6	234	77.2
Area	Rural	148	48.8
	Urban	155	51.2
Family monthly income (RM)	≤ 1500	53	17.5
	1501-2000	75	24.7
	2001-2500	60	19.8
	2501-3000	55	18.2
	≥ 3001	60	19.8

TABLE 3A
Mean, standard deviation (SD), minimum and maximum of boys foot anthropometric measurements

Measurements (cm)	5 years (n=27)				6 years (n=102)			
	Min	Max	Mean	S.D	Min	Max	Mean	S.D
Foot height	3.9	7.7	5.52	0.7	4	7.5	5.87	0.69
Ankle circumference	12.5	29	16.36	1.73	13.05	20.7	16.43	1.33
Left foot plantar surface width	5.2	8.6	7.23	0.65	5.65	8.4	7.19	0.49
Right foot plantar surface width	5.65	8.7	7.23	0.64	5.2	8.6	7.19	0.5
Right foot plantar surface length	14.6	20.65	17.12	1.22	14.9	19.9	17.82	1
Left foot plantar surface length	14.8	20.5	17.18	1.18	14.9	19.9	17.82	1

the 6 year-old group was bigger than that of the 5 years-old. For all the measurements, the 6 years-old group was reported to have a higher minimum value, while the 5 years-old group was shown to have higher maximum values. The differences in these measurements might be affected by several factors such as the environment, socio-economic status, as well as genetic and lifestyle factors (Razeghi and Batt, 2002).

The Relationship between Foot Anthropometric Measurements of Boys and Girls

Table 4 shows the relationships between foot anthropometric measurements. Results from the analysis show that there are significant relationships between each foot anthropometric measurement. Based on the Davis Relationship Strength Description Value, there is a very strong relationship between the right foot plantar surface width measurement with the left foot plantar surface width measurement ($r = 0.928^{**}$, $p < .001$) and the right foot plantar surface length measurement with the left foot plantar surface length measurement ($r = 0.929^{**}$, $p < .001$). Meanwhile, there is a strong relationship between right foot plantar surface length measurement with the right foot plantar surface width measurement ($r = 0.668^{**}$, $p < .001$), the left foot plantar surface length measurement with the right foot plantar surface width measurement ($r = 0.665^{**}$, $p < .001$), the left foot plantar surface width measurement with the right foot plantar surface length measurement ($r = 0.621^{**}$, $p < .001$) and the ankle circumference measurements with the left foot plantar surface width measurement ($r = 0.529^{**}$, $p < .001$).

TABLE 3B
Mean, standard deviation (S.D), minimum and maximum of girls foot anthropometric measurements

Measurements (cm)	5 years (n=42)				6 years (n=132)			
	Min	Max	Mean	S.D	Min	Max	Mean	S.D
Foot height	3.7	7.7	5.41	0.7	3.8	7.45	5.76	0.74
Ankle circumference	12.3	27	16.31	1.49	13.05	20.7	16.43	1.49
Left foot plantar surface width	5	8.5	7.01	0.46	5.65	8.3	7.1	0.46
Right foot plantar surface width	5.45	8.6	7.03	0.56	5.2	8.5	7.12	0.5
Right foot plantar surface length	14.6	22.15	17.23	1.03	14.9	19.9	17.81	1.03
Left foot plantar surface length	15	22	17.2	1.03	14.9	19.9	17.81	1.01

TABLE 4
Children foot anthropometric measurement correlation coefficient

	Measurement	1	2	3	4	5	6
1	Foot height	1					
2	Right foot plantar surface width	.342**	1				
3	Left foot plantar surface width	.354**	.928**	1			
4	Right foot plantar surface length	.472**	.668**	.621**	1		
5	Left foot plantar surface length	.498**	.665**	.688**	.929**	1	
6	Ankle circumference	.231**	.420**	.529**	.317**	.470**	1

** Correlation is significant at the 0.01 level (2-tailed)

There are moderately strong relationships between the foot height measurement with the right foot plantar surface width measurement ($r = 0.342^{**}$, $p < .001$), the left foot plantar surface width measurement ($r = 0.354^{**}$, $p < .001$), the right foot plantar surface length measurement ($r = 0.472^{**}$, $p < .001$), and the left foot plantar surface length measurement ($r = 0.498^{**}$, $p < .001$). Similarly, there are moderately strong relationships between foot circumference measurements with the right foot plantar surface width measurement ($r = 0.420^{**}$, $p < .001$), and the right foot plantar surface length measurement ($r = 0.470^{**}$, $p < .001$). The findings also reported a weak relationship between the foot height measurement with ankle circumference ($r = 0.231^{**}$, $p < .001$). These relationships indicate that the growth and foot bone development are parallel in both feet (right and left). When the measurement changes at one side of the feet, the same measurement will also change for the other foot. Therefore, it is important that both feet are measured for shoe design.

These measurements are related to each other because they are usually used for construction of shoes. According to Waterson and Sell (2006), shoe designers need these measurements in order to produce sizes that can fit their consumers. Meanwhile, Pearson correlation tests are used to identify the measurements that have relationship with each other for creation of garment sizes, including shoe size (Beazley, 1997).

Differences in the Left Foot Anthropometric and Right Foot Anthropometric Measurements

Table 5A shows there is a significant difference between the right foot plantar surface width measurement with the left foot plantar surface width measurement ($t = 2.096$, $p < .05$). However, the difference can be dismissed as it is at the weak level. On one hand, these differences do not change consumers' shoe sizes. The consumer shoe size is still within the same range or the same size. On the other hand, researchers ought to give an important attention to these measurements because a one-sixth inch difference in the ball of foot measurements can create a faulty fit in the forefoot region of a shoe (Rossi and Tenant, 1984).

Table 5B shows there is a significant difference between the right foot plantar surface length measurement and the left foot plantar surface length measurement. However, the difference in the value is at the weak level ($t = 2.361$, $p < .05$). At the same time, the difference also does not change the shoe sizes of consumers. Nevertheless, researchers still need to pay attention to these minor differences in the measurements in order to produce the best fit for consumers' shoes.

All the measurements must be elaborated for fit design and suitable shoe sizing to accommodate all individual needs. Therefore, these measurements are important in designing footwear products, particularly for a more accurate design of shoes, stockings, and artificial feet.

TABLE 5A
Differences between the right foot plantar surface width and the left foot plantar surface width

Width surface	Mean	SD	t	p
Right foot	7.05	0.57	2.096	0.037
Left foot	7.07	0.55		

TABLE 5B
Differences between the right and the left foot plantar surface lengths

Length surface	Mean	SD	t	p
Right foot	17.54	0.56	2.361	0.019
Left foot	17.59	0.55		

The Difference between the Foot Anthropometric Measurements of the Rural and Urban Children

The paired simple t-test was computed to identify the differences in the foot anthropometric measurements between the rural and urban respondents. The results show that there is no significant difference for all the foot anthropometric measurements between the rural and urban respondents. As a result, the mean values for all the foot anthropometric measurements of the rural and urban children aged 5 and 6 years old are statistically similar. The results gathered in this study show no difference because most of the respondents are from the Malay ethnic group. It is important to note that those in the Malay ethnic group normally have a similar lifestyle, regardless of whether they are from the urban or rural areas. According to Razeghi and Batt (2002), environment and individual lifestyle will cause changes in foot shape.

CONCLUSIONS

This study found that boys have larger foot anthropometric measurements than girls, whereas children of 6 years of age have larger foot anthropometric measurements than those aged 5. However, majority of the measurements for the 5 years old boys and girls gave higher maximum values as compared to those of the 6 years old children.

The study also concludes that all the foot anthropometric measurements have a relationship with each other based on the natural factor. These measurements are important in designing footwear products, especially the shoes. The findings from the paired t-test showed a significant difference between the right and left foot plantar surface width. Subsequently, the test shows that there is a significant difference between the right and left foot plantar surface length. However, both these differences are relatively small. As a consequence, consumers do not need to change to another size of shoes. These measurements are also reported in this study to produce an accurate measurement which will result in proper shoe sizes for children.

From this study, it is concluded that no differences are found in the foot anthropometric measurement between the rural and urban children. According to Chaiwanichsiri *et al*. (2008), t-test was used to determine the difference for the measurements between the individuals living in both areas. Similarities in the measurements are positive results which indicate that it is desirable to develop only one standard size for both areas.

Foot anthropometric data are particularly important to be used in producing shoe sizes that fit the feet shape of Malaysian children.

Designing proper shoe sizes will solve problems related to feet comfort and health. Thus, foot anthropometric data will help to produce ergonomic footwear products.

IMPLICATIONS OF THE STUDY

An implication of this study is the results could be utilized for better footwear product designs. The measurements represent real consumers' foot shapes, and the utilization of these measurements will definitely provide comfort to consumers' feet and produce products which can suit or fit their foot shape better. Foot anthropometric measurements are valuable to those involved in the product design line such as researchers, manufacturers, the government, university students, and medical officers. They can understand variations in the 3-D shape and structure of the feet. This is because of a detailed knowledge in foot shape and structure is particularly important for those involved in designing and construction of shoes (Mauch *et al*., 2008). Mauch *et al*. (2008) further added that the knowledge about foot is a fundamental prerequisite for a pair of shoes to be comfortable.

The foot anthropometric survey in the aimed population would produce accurate measurements. Accurate measurements are important in the process of products design. Moreover, these measurements can help consumers in making purchasing decision wisely. Foot anthropometric could be used not only to design footwear, but also to design other consumer-related products. It is important to note that an inaccurate measurement in the consumer product designs could result in a negative implication to consumers' health. Narrow shoes are significantly associated with corns, while short shoes are significantly associated with lesser toe deformity (Chaiwanichsiri *et al*., 2008). In addition, ill fitting shoes can alter the underlying bone structure through continual pressure, especially during childhood, resulting in severe foot deformities at old age (Echarri *et al*., 2003). Therefore, accurate and fitting shoes with foot shape in childhood could lead to complete foot development in the future.

RECOMMENDATIONS

Sample size needs to be extended to represent all the children in Malaysia. Other ethnic groups, such as Chinese and Indian, should be involved in the follow-up study. The study should also be extended to Sabah and Sarawak. This is to ensure that the data available will reflect the whole population of Malaysian children much better.

According to Xiong, Goonetilleke, Witana and Lee Au (2008), midfoot girth will give more accurate data to design shoe sizes. In this study, however, this measurement was not made. It is hoped that other researchers will include this measurement so as to produce better fitting shoe sizes to increase consumers' satisfaction and comfort. The much advanced technology available nowadays has provided better measurement tools to give more accurate and effective foot measurements. Moreover, advanced technology will reduce mistakes involved in measurements and therefore improve accuracy.

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