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Determining the Baseline Clinical Knee Measurements in the Multi-Ethnic Malaysian Children Aged 1-3 Years Old: A Population Study

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ABSTRACT

Introduction: Understanding knee alignment development in early childhood is essential to differentiate normal growth from pathology. However, local normative data are lacking. This study investigates knee development patterns in healthy Malaysian children aged three years and below.

Materials and methods: Three hundred healthy children were randomly selected from clinics, daycare centres, and screening programs in Klang Valley and equally divided into three age groups (0–12, 13–24, 25–36 months). Clinical assessments included intercondylar distance (ICD), tibiofemoral angle (TFA), mid-arm, and head circumference. One-way ANOVA, Kruskal-Wallis test, Pearson correlation, and multiple linear regression were used for analysis.

Results: Significant age-related changes were observed in ICD and TFA. Median ICD decreased from 5.00cm (0 – 12 months) to 1.00cm (13 – 24 months) and 0.00cm (25–36 months) ($p<0.05$). TFA shifted from varus (8.74°) to neutral (0.23°) and then to valgus (-4.91°) ($p<0.05$). No gender differences were found, but at 0 – 12 months, Malay children had greater varus angulation (9.55°) compared to Chinese (7.44°) and Indian (7.67°) children ($p<0.05$). ICD and TFA were negatively correlated with anthropometric measures ($p<0.01$). Multiple regression analysis revealed that ICD and height were independent predictors of TFA ($p<0.001$).

Conclusion: This study presents normative data on knee alignment in Malaysian children under three. Knee angulation progresses from varus in infancy to neutral by age two and valgus by age three. Clinicians can utilise population-specific normative data to track physiological bowing and identify cases requiring specialist referral when knee varus persists beyond the age of two.

Keywords:
varus, valgus, intercondylar distance, tibiofemoral angle

INTRODUCTION

Bowleg, or genu varus, is a common condition in children and often leads to unnecessary referrals to tertiary centres due to difficulties in distinguishing between physiological (normal) and pathological conditions[1]. Early knee joint development shows considerable variability, which complicates the clinical decision-making process in identifying conditions requiring medical intervention[2]. There is a lack of region-specific baseline data, which increases the ambiguity in diagnosing bowleg conditions among Malaysian children[3].

Intercondylar distance (ICD) and tibiofemoral angle (TFA) are established metrics for assessing the severity of genu varus[4]. Both parameters are useful in differentiating between normal developmental variations and conditions like Blount's disease or rickets, which require treatment[4]. The dynamic changes in ICD and TFA during the early years of childhood make them ideal indicators for evaluating the natural progression of knee development[5].

Ethnic, gender, and anthropometric differences may influence the baseline clinical measurements in children, potentially impacting ICD and TFA[6-8]. While previous studies have highlighted variations in knee alignment across different populations[6,9,10], there is limited research on how ethnicity and gender in multi-ethnic populations, such as Malaysia, might affect the early stages of knee development.

This study aims to establish normative values for ICD and TFA in Malaysian children. By understanding the influence of ethnicity, gender, and anthropometry on knee measurements, clinicians can improve the diagnostic accuracy and reduce unnecessary medical referrals.

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MATERIALS AND METHODS

This cross-sectional population study was conducted in the Klang Valley, Malaysia, where normal healthy children were recruited after obtaining informed and written consent from the parents. The participants were divided into three equal age groups: A (0-12 months), B (13-24 months), and C (25-36 months), with equal representation of males and females. Inclusion criteria were children between 1-3 years old, height and weight within the 3rd and 97th percentiles and head circumference within the 5th and 95th percentiles according to the World Health Organization. Children with skeletal and neuromuscular disorders, history of lower limb fractures, gross lower limb deformity and malnourished (mid-arm circumference less than 13.9cm) were excluded from the study. The study was approved by the Research Ethics Committee (JEP-2023-149) and National Medical Research Register (NMRR ID-24- 00533-VTI).

Sample size is calculated using G*power software [ver. 3.1.9.7, Düsseldorf, Germany]. Several parameters are used for sample size calculation where alpha is set at 0.05, effect size at 0.20, and power at 80%. After considering 20% of non-responder, the calculated sample size is 291 subjects. According to the Department of Statistics Malaysia[11], the ratio for three major ethnicities in Malaysia (around Klang Valley) is approximately 60% Malay; 25% Chinese; 15% Indian, therefore we determine that there will be 60 Malays, 25 Chinese and 15 Indians participants for each age groups, bringing to the final sample size to 300 patients. Each age group was made up of an equal number of boys (n=50) and girls (n=50), ensuring a balanced representation, with 100 children in each group.

Each child underwent a physical examination where height, weight, head circumference, mid-arm circumference, intercondylar distance and tibiofemoral angle were recorded. The clinical method of knee measurement has been shown to be reliable in previous study[3]. All measurements were performed by a trained personnel member and the mean values of two measurements were taken as the final value, to ensure consistency and accuracy.

The intercondylar distance (ICD) was measured as the distance between the medial femoral condyles using measuring tape with the knees fully extended, as described by Ekwedigwe *et al*[12]. Each child was placed in a supine position with both medial malleoli touching. This position was chosen as children below three years old may struggle to maintain a standing position during measurements.

The tibiofemoral angle was measured clinically using a standard goniometer. Each child was subjected to the same supine position described in the ICD measurement. Bony landmarks were palpated and marked, including the anterior superior iliac spine, the centre of the patella, and the midpoint of the ankle joint. A straight line was drawn connecting these points to define the tibiofemoral axis, and the angle was measured using a goniometer for both lower limbs[13]. In cases of genu valgus, where the medial femoral condyles would naturally contact each other, the child's positioning was adjusted. To avoid distortion of the measurement, the ankles were permitted to rest in their natural alignment during assessment.

Statistical analyses were conducted utilising SPSS software version 27. Descriptive statistics were performed to present the basic characteristics of the study population. Subsequently, a one-way ANOVA, accompanied by the Tukey post hoc test, was employed to compare continuous variables across the age groups, while Kruskal-Wallis test followed by pairwise comparison was used when data was abnormally distributed. To explore the relationships between anthropometric measurements—such as height, weight and knee measurements, Pearson correlation coefficients were computed. Further correlation analysis was performed using multiple regression analyses to assess the effects of growth on knee measurements. A significance level of p<0.05 was established, indicating that any p-value below this threshold would be considered statistically significant.

RESULTS

The participants were recruited from Hospital Tunku Ampuan Besar Tuanku Aishah Rohani (211 subjects), Taska Si Manja Pintar (12 subjects), Taska Hospital Canselor Tuanku Muhriz (15 subjects), Klinik Kesihatan Botanik (49 subjects) and child health screening program in Taman Keramat (13 subjects).

Fig. 1 provides a detailed representation of the age distribution among the study participants, illustrating the anthropometric measurements within the cohort. Children included in the study were within the normal centiles of their growth charts, and this was corroborated by the increasing trend of the mean values for height, weight, midarm and head circumferences, as they grew older.

The median ICD of various age groups is illustrated in Fig. 2a, providing a detailed overview of the differences observed across these developmental stages. For children under 12 months, the ICD and interquartile range (IQR) measures 5.00 (2.38) cm, indicating a relatively wider distance at this early age. However, as children progress to the 13-24 months age range, there is a notable decrease in the ICD, with an average measurement of 1.00 (2.00) cm. Furthermore, the lowest recorded ICD value is found in the 25 to 36-month age group, where most children had an ICD of zero. A Kruskal-Wallis test indicated that there was a significant difference in intercondylar distance across three age groups, χ^2 (2, N = 300) = [210.29], p = < .001.

Fig. 2b shows the TFA among Malaysian children in different age groups. Notably, children who are below 12 months of age exhibited a varus angulation, measuring at

Table I: Anthropometric and knee measurements of Malaysian children according to race. Results were expressed as means ± SD or median (interquartile range). Values with asterisks * indicate statistical significance within the same age group (p<0.05). M – Malay (n=60), C – Chinese (n=25), I – Indian (n=15).

Measurement	Group A (0-12 months)			Group B (13-24 months)			Group C (25-36 months)		
	M	C	I	M	C	I	M	C	I
Height (cm)*	65.33 ± 6.24	64.39 ± 7.78	63.70 ± 7.83	79.42 ± 4.93	77.96 ± 3.94	83.83 ± 3.52*	86.61 ± 4.97	89.59 ± 4.47	91.95 ± 5.57*
Weight (kg)*	7.10 ± 1.44	7.02 ± 1.82	6.55 ± 2.34	9.78 ± 1.50	9.72 ± 1.05	11.28 ± 1.36*	11.48 ± 1.79	12.56 ± 2.14*	12.35 ± 1.72
Mid arm circumference (cm)	14.69 ± 1.50	14.78 ± 1.55	13.65 ± 2.46	15.41 ± 1.55	14.95 ± 1.12	15.43 ± 1.37	15.65 ± 1.63	15.52 ± 1.30	15.18 ± 1.24
Head circumference (cm)	41.88 ± 2.98	41.93 ± 3.28	40.39 ± 4.73	46.06 ± 2.06	46.41 ± 1.73	47.02 ± 1.41	47.84 ± 1.45	48.47 ± 1.88	47.16 ± 1.62
ICD (cm)	5.00 (2.57)	5.00 (1.50)	5.00 (2.00)	0.75 (2.38)	1.50 (2.5)	0.00 (1.00)	0.00 (0.0)	0.00 (0.00)	0.00 (0.00)
TFA (degree)*	9.55 ± 2.60*	7.44 ± 2.57	7.67 ± 2.06	-0.08 ± 5.44	1.44 ± 3.80	-0.53 ± 2.29	-5.02 ± 3.38	-5.00 ± 2.93	-4.3 ± 2.44

Table II: Correlation coefficient among anthropometric measures among Malaysian children according to age group. All coefficients were significantly different (p<0.01).

Height	Weight	Mid arm circumference	Head circumference	TFA	ICD
r	r	r	r	r	r
ICD -0.798**	-0.738**	-0.264**	-0.695**	0.825**	-
TFA -0.794**	-0.711**	-0.246**	-0.668**	-	0.825**

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

Table III: Multiple regression analysis model for explaining the variance of tibiofemoral angle (TFA) in Malaysian children. Independent variables were gender, height, weight, mid arm circumference, head circumference and intercondylar distance (ICD).

Variables	Unstandardised Coefficients				
	B	Std. Error	Beta	t	Sig.
Gender	0.480	0.422	0.036	1.138	0.256
Height (cm)	-0.282	0.054	-0.471	-5.195	< 0.001
Weight (kg)	0.247	0.237	0.097	1.044	0.298
Midarm circumference (cm)	0.170	.0174	0.041	0.981	0.328
Head circumference (cm)	-0.021	0.105	-0.011	-0.197	0.844
Intercondylar distance (cm)	1.453	0.141	0.524	10.309	< 0.001

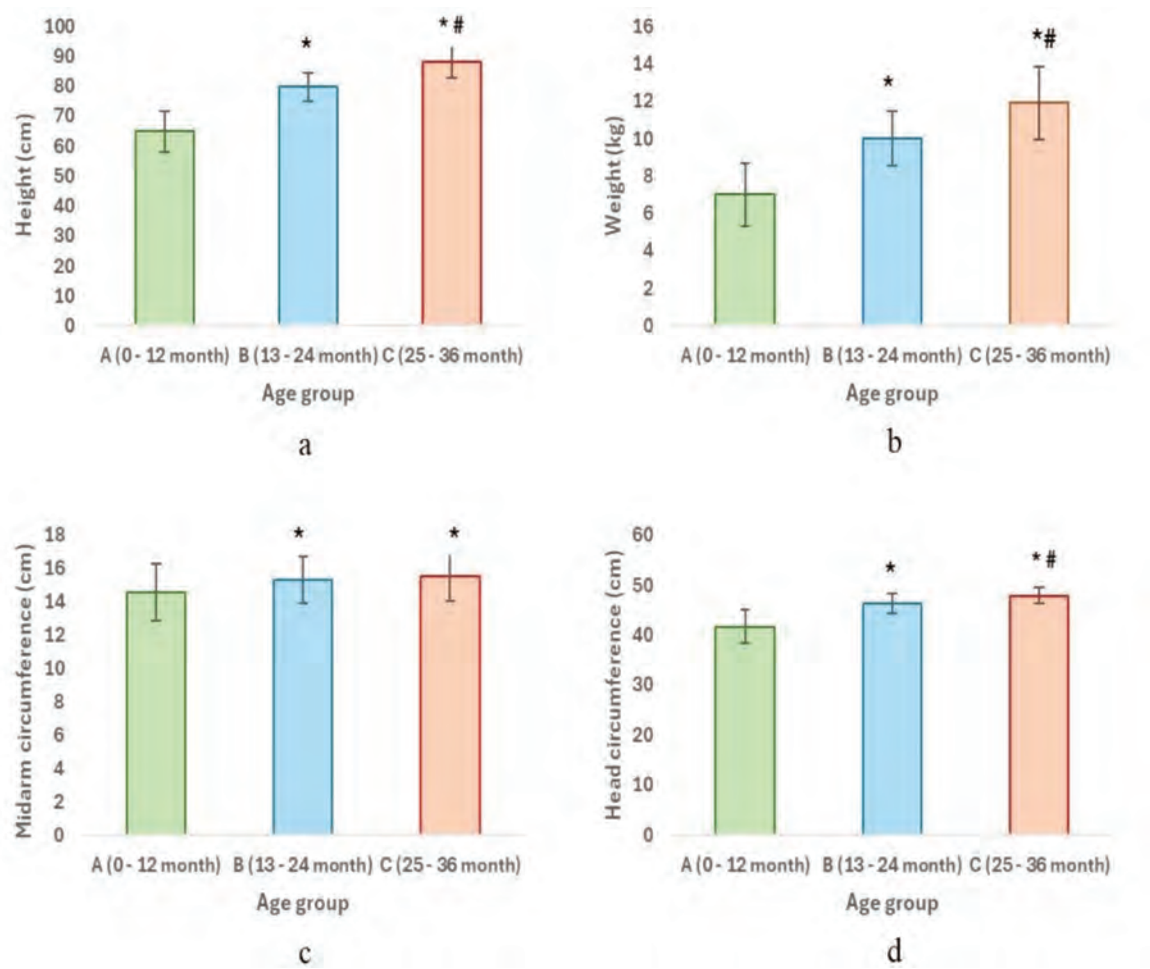

Fig. 1: Growth patterns of Malaysian children across different developmental stages based on height (a), weight (b), midarm (c) and head (d) circumference. Data was analysed with a one- way ANOVA followed by group comparisons using post hoc Tukey's multiple comparison test. 0-12 months (green bar), 13-24 months (blue bar), 25-36 months (red bar). Values represent mean ± standard deviation (S.D) (n=300). Asterisk indicates significance compared to group 0-12 months (*) and 13-24 months (#) ($p<0.01$).

8.74 ± 2.69°. In contrast, for children aged between 13 to 24 months, the TFA showed a significant decrease, reaching 0.23 ± 4.74°. Furthermore, children aged 25 to 36 months displayed a significant shift towards valgus angulation, with a measurement of -4.91 ± 3.13°, indicating an inward angulation of the knees.

Age-wise comparisons of various anthropometric and knee measurements between boys and girls were conducted to analyse differences and trends across different age groups, allowing for a deeper understanding of how these physical attributes evolve as children grow older. Our results showed that there were differences between genders whereby the boys had higher weight ($p<0.05$) and midarm ($p<0.01$) as well as head circumference ($p<0.05$). Although, there were no significant differences in terms of height ($p=0.42$), intercondylar distance ($p=0.78$) and tibiofemoral angle ($p=0.44$).

However, when analysing the data in terms of race, a significant difference in the TFA can be observed among the Malay, Chinese, and Indian groups at the 0–12 month. Specifically, it was found that the Malay children exhibited a more pronounced varus alignment compared to both the Chinese and Indian children (Table I). Some anthropometric variances were also found; Indian children were significantly taller at age 13-24 month and 25-36 month, as well as heavier at age 13-24 month, in comparison to other races. Fig. 3 depicts the ICD and TFA trend with increasing age, among the three races in Malaysia.

The correlation and determination coefficients of the anthropometric measurements in relation to intercondylar distance (ICD) and tibiofemoral angle (TFA) are presented in Table II. Notably, ICD exhibited a negative and strong correlation with several anthropometric indicators, particularly height ($r = -0.798$), weight ($r = -0.738$), and head circumference ($r = -0.695$), with statistical significance at $p<0.01$. This suggests that the intercondylar distance tends to

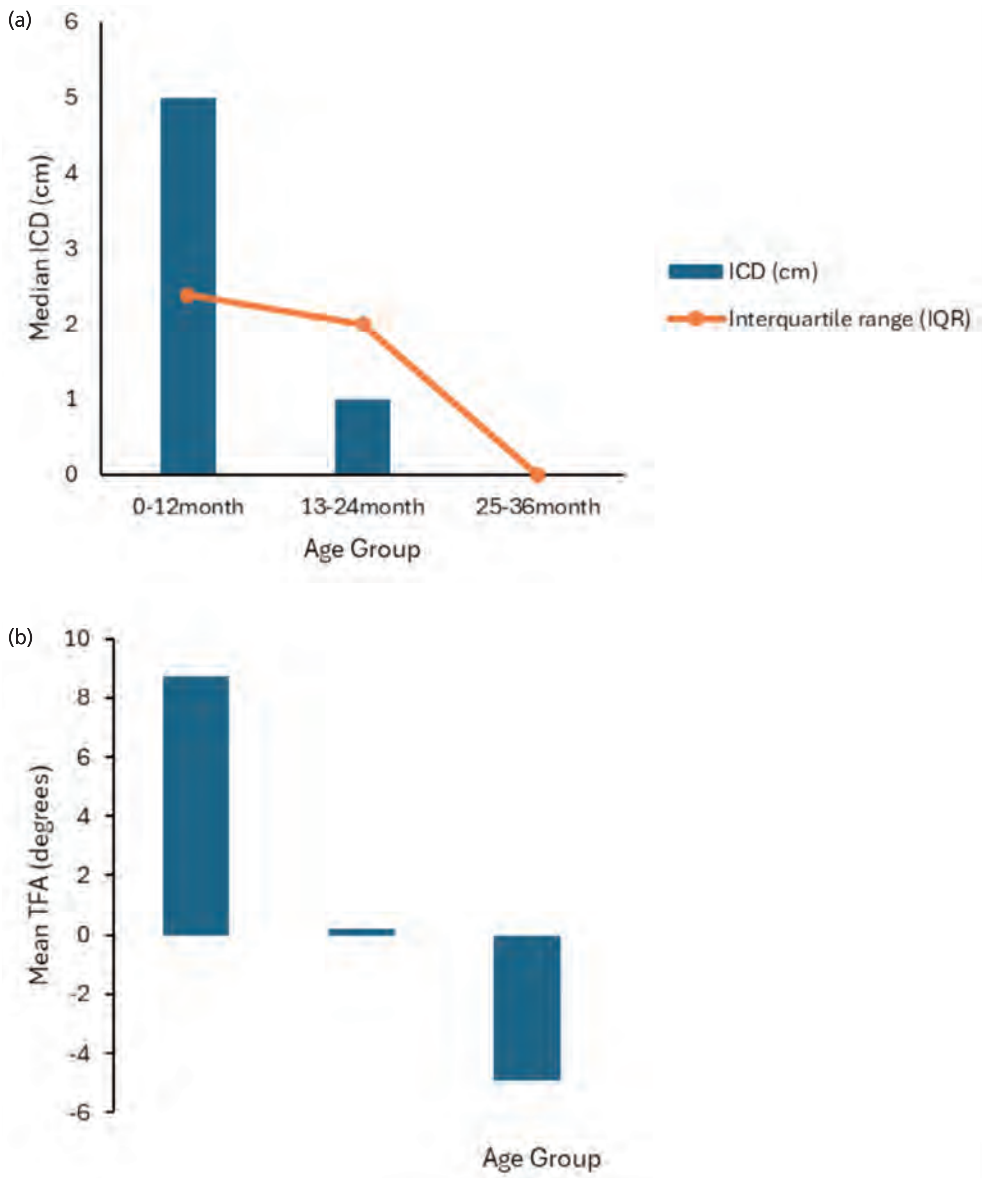

Fig. 2: (a) intercondylar distance (ICD) and interquartile range (IQR) in each age group. Data was analysed with an independent sample Kruskal-Wallis test and pairwise comparison between age groups. Values represent as median (IQR) (n=300). (b) tibiofemoral angle (TFA) in each age group. Data was analysed with one-way ANOVA followed by group comparisons using post hoc Tukey's multiple comparison test. Values represent as mean ± standard deviation (S.D) (n=300).

decrease as these specific anthropometric parameters, such as height, weight and head circumference, increase over time in the population studied. However, less significant relationships were seen between mid-arm circumference and ICD. In addition, ICD demonstrated a strong and positive correlation with TFA (r=0.825), p<0.01. This indicates that an increase in ICD is associated with increased TFA. A similar pattern was observed between TFA and the anthropometric indicators.

A multiple regression analysis was calculated to predict TFA based on gender, height, weight, head circumference, mid-arm circumference, and ICD. A significant regression equation was found (F (6, 293) = 136.23, p<0.001), with an R2 of 0.736. Table III showed that the TFA was strongly influenced by factors such as height (p<0.001) and ICD (p<0.001). However, other factors such as gender, weight, mid-arm and head circumference were not significant.

DISCUSSION

The data presented in the study is based on a comprehensive analysis of 300 healthy children, which provides a robust representation of the growth patterns within this demographic. The results of this study provide an overview of how various anthropometric parameters correlate with clinical knee measurements in Malaysian children. These findings offer insights into the normal developmental trends across different age groups and ethnicities, further

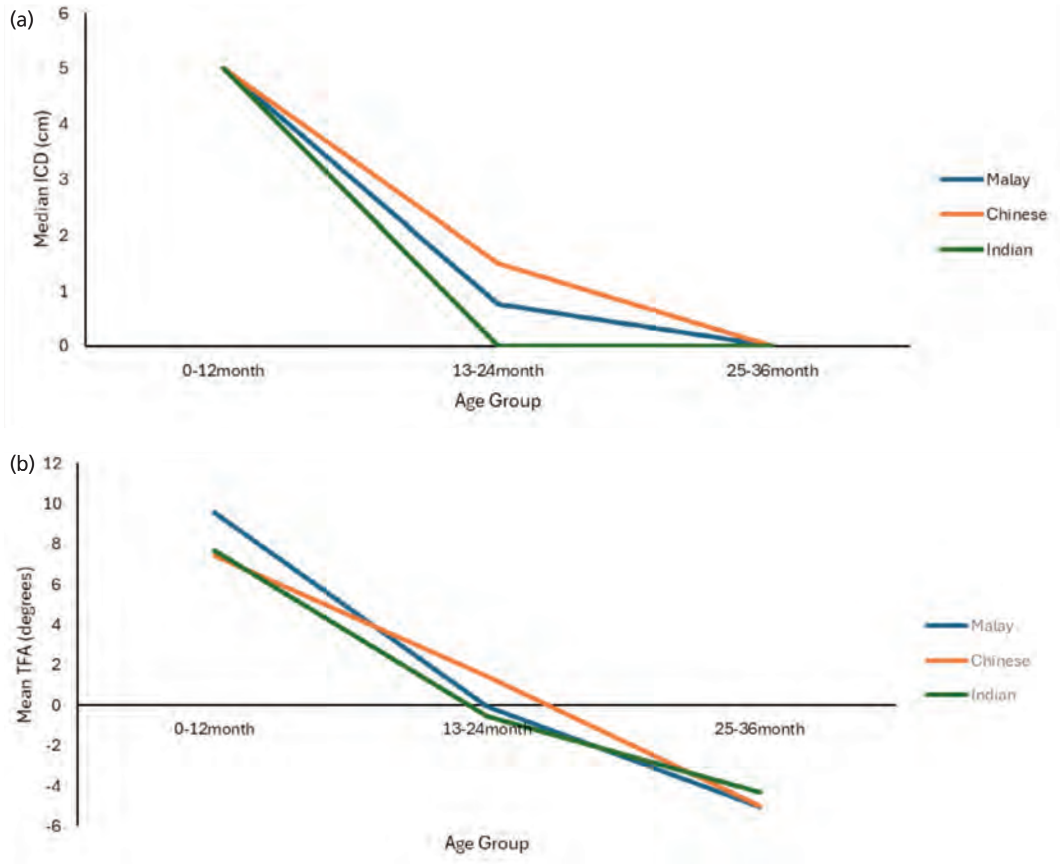

Fig. 3: (a and b) The trend of ICD and TFA values with increasing age among the three different races.

supporting the use of knee angle (TFA) and intercondylar distance (ICD) as clinical markers for assessing genu varus. Both TFA and ICD can complement each other in monitoring genu varus[14].

Research on TFA and ICD in children below three years old is limited. In comparison, our findings showed a similar trend with a longitudinal study done by Oyewole *et al*[15]. Nigerian children were found to have less varus knees in the early years of life (5.6° at 9 months), compared to Malaysian children with 8.74° at 0-12 months. Also, Malaysian children were found to be less valgus (-4.91°) than Nigerian children (-7.7°) at 2-3 years old. In another study performed in Malay children only, Mohd-Karim *et al* found a higher degree of valgus knee alignment (-8.73) at age 3 years old[3]. Apart from that, the ICD values in our study were found to be higher (5.0cm) than Nigerian children (2.5cm) during the early age. Differences between studies may be due to different measurement techniques, population variability and genetic factors.

Our previous systematic review suggested that normal children had neither measurable ICD nor demonstrable varus (TFA) after 19 months old, whereas an ICD of more than 4cm after that age may warrant further investigation for pathologic cause[4]. The present study supported that notion, as ICD in Malaysian children was only at around 1cm in the 13-24 months group, while the TFA was neutral. No children had a measurable ICD in the 25-36 months group, and they all had 'negative' TFA measurements suggesting that the transition time from varus to valgus was at 2 years old. These improving trends highlight the nature of 'physiological' bowing which will improve at this age, as reported by other studies[14,16,17]. Furthermore, our data included both genders and the three main races, which would provide a clear guideline to the clinicians in the country. Apart from the Malay children below age 1 displaying a more varus angulation than other races, their growth pattern was similar in the subsequent years.

A strong negative correlation was observed between height and ICD ($r = -0.798$, $p<0.01$). As the children grew taller, their ICD decreased significantly. This inverse relationship suggests that as skeletal growth progresses, particularly in the lower limbs, the natural development of the knee structure brings the legs closer together, reducing the ICD[18]. The data supports the notion that taller children have less bowing of legs, indicating a more neutral alignment. This finding aligns with the hypothesis that the growth of the femur and tibia contributes to the alignment of the knee joint, facilitating the reduction of ICD as height increases[19].

Similarly, a negative correlation between weight and ICD was also identified (r = - 0.738, p<0.01). Heavier children had narrower ICDs, reflecting that as children increase in body mass, their skeletal structures support a more centralised alignment[18]. This relationship could be explained by the proportional development of muscle mass and skeletal structures needed to bear increasing body weight, which aids in stabilising the legs and reducing bowing[14]. The findings suggest that weight, in conjunction with height, plays a critical role in the natural correction of genu varus during early childhood. Although, excessive increase in weight or being overweight may be counterproductive and lead to pathological bowing such as tibia vara.

A significant negative correlation was also found between head circumference and ICD (r = -0.695, p<0.01). This suggests that larger head circumference is associated with a decrease in intercondylar distance. Head circumference can be an indicator of overall growth and development, reflecting not only brain growth but also general body growth[20]. The inverse relationship indicates that as a child matures physically and neurologically, their leg structure aligns more closely, reducing the ICD[15,21]. This finding highlights the interconnectedness of overall growth patterns in early childhood development.

Our findings of strong positive correlation between ICD and TFA at this age group are in parallel with previous studies[15,22]. Regression analysis for TFA revealed a high R^2 value, which underscores the robustness of the regression model in understanding the factors that influence TFA in our study. The value (R^2) of 0.736, indicated that approximately 73.6% of the variance in TFA can be explained by the included predictors. This strong statistical significance suggests that the model effectively captures the variability in TFA. We can conclude that while height and ICD are important, other commonly assessed variables may not have the same level of influence on TFA.

There were some limitations in this study. The study's cross-sectional design limits the ability to track individual growth trajectories. Future longitudinal studies should examine knee development over time, incorporating a larger sample size for better ethnic subgroup analysis. However, the present study was able to reflect the diversity of Malaysia's demographics by including the three primary ethnic groups: Malay, Chinese, and Indian. By incorporating this ethnic composition, the study provided insights into a deeper understanding of developmental differences across various groups within the community.

CONCLUSION

This study confirms significant age-related variations in ICD and TFA during early childhood. While no gender-based differences were observed, ethnic variation was evident, with Malay children demonstrating greater varus alignment within the first year of life compared to Chinese and Indian. Clinicians may use this population-specific normative data to monitor physiological bowing and refer to a specialist when knee varus does not improve beyond age 2 years old.

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CONFLICT OF INTEREST

Authors have no conflicts of interest.

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