TIBIOFEMORAL ANGLE DEVELOPMENT IN A COHORT OF NIGERIAN CHILDREN DURING THE FIRST THREE YEARS OF LIFE

By

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A Thesis in the Department of Physiotherapy,
Submitted to the Faculty of Clinical Sciences
In Partial Fulfillment of the Requirement for the Degree of

Doctor of Philosophy in Physiotherapy (Orthopaedic and Sports)

of the
University of Ibadan

June 2013

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CERTIFICATION

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This thesis is dedicated to my beloved and supportive wife, **FUNMI.**

ABSTRACT

Knowledge of Tibio-Femoral Angle (TFA) development facilitates clinical decisions in managing childhood knee mal-alignment. Findings from cross-sectional studies on TFA development in Nigerian children vary in values and the age at which the initial varus changes to valgus pattern. It has been suggested that longitudinal studies would provide more reliable description of TFA development in children than cross-sectional surveys. This longitudinal study was therefore conducted to examine the TFA development in a cohort of Nigerian children during the first three years of life, compare TFA between boys and girls and determine the relationship between TFA and selected anthropometric variables.

One hundred and fifty two apparently healthy children without any obvious congenital deformities were consecutively recruited within 21 days of life into this study from three infant welfare clinics in Sagamu Local Government Area. The TFA was measured directly using a universal goniometer and indirectly by measuring Inter-Condylar Distance (ICD) and Inter-Malleolar Distance (IMD). Limb and trunk lengths were measured using non-extensible measuring tape. Height and weight were measured using infantometer/height meter and weighing scale respectively. Measurements were taken on each child at first contact and monthly until three years of age. Data were analysed using descriptive statistics, t-test and Pearson's correlation at $p = 0.05$.

Participants were 71 boys and 81 girls. At first contact, TFA pattern was varus with a mean of 13.2 ± 3.8^0. Using goniometry, TFA pattern remained varus in all children until 15 months of age; decreased gradually and turned neutral (0^0) at 18 months. The knee angle became valgus in 85.0% of the children at 19 months, and in all the children at 33 months. Mean valgus knee angle rose from -2.4±2.5^0 at 19 months to -8.5±2.5^0 at 27 months and decreased slightly to -7.7±2.2^0 at 36 months. Using ICD/IMD, TFA showed a similar course of development from maximum ICD (varus) at first contact (2.5±0.7cm) to minimum ICD (0.1±0.4cm) at 15 months. At 16 months, the children had predominantly valgus pattern (IMD) with few remaining as varus (16.7%) and neutral (23.3%). Ninety percent of children had changed to valgus pattern by 19 months. The mean IMD (valgus) increased from -0.1±0.8cm at 16 months to -2.0±1.5cm at 29 months. There was no significant difference in the TFA values by sex or side of lower limb. The TFA values by goniometry correlated significantly with those by ICD/IMD (r = 0.77) and each of weight (r = -0.77), height (r = -0.84), trunk length (r = -0.88) and limb length (r = -0.88).

The tibiofemoral angle development in the cohort of Nigerian children was maximum varus during the first 21 days of life, thereafter decreased and became neutral at 18 months, turned valgus at 19 months, increasing till three years of age; similar to that described for American and Korean children. A valgus angle before 15 months of age may be considered unusual. The tibiofemoral angle values herein presented may be used when assessing lower limb alignment in Nigerian children during the first three years of life.

Keywords: Tibiofemoral Angle, Intercondylar and Intermalleolar distances, Nigerian children.

Word count: 497

ACKNOWLEDGEMENTS

"Not by might, nor by power, but by my spirit, saith the Lord of hosts" (Zechariah 4:6). Thanks be unto God who gives me grace to pursue this dream and His unlimited protection throughout the programme.

Appreciation goes to my supervisor, Dr. Akinpelu A.O (who also is the H.O.D) for making this dream come to pass. Thank you ma, for your mentoring. I appreciate the contributions of my co-supervisor, Professor Omotade O.O; thank you sir. Thanks to all Lecturers in the Department of Physiotherapy, College of Medicine, University of Ibadan. I recognize all your contributions.

I want to acknowledge Mrs. I.S Afolabi, The Head, Physiotherapy Department, Olabisi Onabanjo University Teaching Hospital, Sagamu. Thank you for your understanding and support. To other members of staff, I say a big thank you.

I must but appreciate all the participants of this research and their parents. Thank you for your consistency and participation. Thanks to all my research assistants, Mr. Fabiyi B.A, Mrs. Ogunsanya and Mr. Keripe. Thank you for your cooperation.

I need to appreciate the support of my wife- Mrs. Funmi Oyewole throughout the programme. Thanks for your spiritual, moral and financial support. God will surely bless you and grant the desire of your heart.

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CHAPTER ONE

INTRODUCTION

1.1 Introduction

The developing child is the centre of potential adoration as well as a point of critical evaluation by well meaning relatives and friends. One of the situations in which the child is watched and appraised closely is when he begins to stand and walk. Any abnormality observed in the overall appearance of the child is certain to arouse comment and become a source of worry to the parents (Tella, 2000). Apparent bowing appearance (physiological genu varus) of the lower extremities is a common condition seen in children in the first few years of life, particularly after they have begun to walk. Pediatricians, family physicians, orthopaedists and physiotherapists are frequently called on to evaluate these children for excessive bowing (Davids et al, 2001).

The patterns of Tibio-Femoral Angle (TFA) in children and adolescents from different parts of the world have been studied, using various measuring methods (Salenius and Vankka, 1975; Cheng et al, 1991; Heath and Staheli, 1993; Arazi et al, 2001). The angle is evaluated using roentgenographic (Salenius and Vankka, 1975; McCarthy et al, 2001; Bowen et al, 2002), photographic measurement (Heath and Staheli, 1993; Qureshi et al, 2000a), and clinical methods. Clinical methods include goniometric measurement (Cheng et al, 1991; Arazi et al, 2001; Shultz et al, 2006) and intercondylar and intermalleolar distances (Cheng et al, 1991; Lin et al, 1999; Qureshi et al, 2000b). The clinical methods are reliable and adequate for day-to-day practice (Cahuzac et al, 1995). These studies have reported differences in the patterns of development and in the normal limit of tibiofemoral angles of children from different populations thus suggesting racial differences (Health and Staheli, 1993; Arazi et al, 2001). Normal Chinese children were observed to be bowlegged at birth, maximally knock-kneed at age 3 and to have neutral knee angles (0^0) by age 8 years. Health and Staheli, (1993) observed that American children were maximally bowlegged at age 6 months and progressed toward neutral knee angles (0^0) by age 18 months. Maximum valgus angle of 8^0 was observed at age 4 years, followed by a gradual decrease to a mean of less than 6^0 at 11 years. Korean children were reported to be varus in angle before age 1 year, neutral at 1½ years, increasing genu valgum with maximum value of 7.8^0 at 4 years, followed by a gradual decrease to approximately $5\text{-}6^0$ of genu valgum of the adult level at 7-8 years of age (Yoo et al, 2008). In normal French children aged 10-16 years, Cahuzac et al (1995) reported no gender difference in TFA pattern of boys and girls at 10-13 years. However, at age 14-16 years, the valgus angle in girls remained 5.5^0 while that of boys reduced to 4.4^0. Arazi et al (2001) reported that the maximal mean valgus angle was 9.6 degrees at 7 years for Turkish boys and 9.8 degrees at 6 years for Turkish girls.

The patterns of tibiofemoral angles have been documented in Nigerian children in three studies (Omololu et al, 2003; Oginni et al, 2004; Ezeuko et al, 2010) and in Nigerian adolescents in one study (Tella et all, 2010). Two of the studies assessed TFA in children aged 1-10 and 0-5 years respectively using clinical methods (goniometric and intermalleolar and intercondylar distances) (Omololu et al, 2003; Ezeuko et al, 2010), while one assessed children aged 0-12 years, using photographic method (Oginni et al, 2004). The fourth one evaluated adolescents aged 11-19 years using goniometric methods (Tella et al, 2010). Omololu et al, (2003) reported maximally bowed knee at ages 1-3 years (0.27^0-1.95^0) and this reduced to neutral 0^0 at age 5 years in girls and age 7 years in boys. Both sexes had no bowing after age of 7 years. The valgus angle was found to be constant at about 11 degrees from ages 7-10 years in both sexes. Ezeuko et al, (2010) who also used clinical methods reported that the children had varum by the first year of life, prevalently genu valgum in type by the second year, valgum by the third year, neutral by the fourth and fifth year. In another survey from Nigeria, Oginni et al, (2004) reported that knees were maximally bowed in the first 6 months. At 21 to 23 months, the distribution of angles became strongly bimodal: about half were varus and half were valgus, with few in between. After this period, the TFA became valgus in all the children with few exceptions. The authors therefore inferred that the change from varus to valgus in individual infants must be sudden (a few weeks), although the changeover of the whole population appears smooth and gradual. These authors also reported that the children became maximally and uniformly knock-kneed (-7.1° ± 1.4°) between 3 and 3½ years, with little change thereafter. Most Nigerian adolescents had genu valgus with the normal range of valgus angle values of 11.06° – 11.20° for males and 11.62° – 11.79° for females (Tella et al, 2010).

The developmental patterns reported for Nigerian children in these studies differed in many aspects probably due to the fact that the TFA was measured once and different age groups were studied. It has been suggested that longitudinal cohort studies would provide more reliable data on developmental pattern of TFA than cross sectional studies

(Yoo et al, 2008; Saini et al, 2010). Longitudinal studies on TFA in Nigerian children are not readily available for referencing. This study therefore investigated the pattern of TFA in children by following up a cohort of children from neonatal period to age 3 years so as to provide more reliable data on the developmental pattern of TFA in Nigerian children.

1.2 Statement of the Problem

Tibiofemoral angle development follows a general pattern in which the children present with varus angle from birth till about 18 months, after this the angle changes to valgus (Salenius and Vankka, 1975; Health and Staheli, 1993; Qureshi et al, 2000a; Oginni et al, 2004; Yoo et al, 2008). However, the values of TFA and the age at which the angle changes from varus to valgus angle vary in different populations. Available data on TFA in Nigerian children were based on cross-sectional surveys, which involved measurement once (Omololu et al, 2003; Oginni et al, 2004; Ezeuko et al, 2010). These studies also involved different age groups. One of these studies suggested that the transition from varus to valgus angle occur within a few weeks between age 21 and 23 months (Oginni et al, 2004). A longitudinal cohort study would be required to provide evidence for this and other reported aspects of developmental pattern of tibiofemoral angle in Nigerian children. Such studies are not readily available, hence this study. Knowledge of developmental pattern of tibiofemoral angles will facilitate the differentiation of physiological variation from pathological deformity which may require further evaluation and treatment. This study was therefore designed to answer the following questions:

1. What would be the pattern of tibiofemoral angle of children during the first three years of life?
2. When exactly would the TFA pattern change from varus to valgus in Nigerian children?
3. What are the exact values of TFA at contact (birth to 3 weeks), 6, 12, 18, 24, 30, and 36 months?
4. Would TFA values differ between male and female Nigerian children?

1.3 Aims of the Study

The aims of the study are:

1. To describe the developmental pattern of tibiofemoral angle in children during the first 3 years of life.
2. To determine the age of transition of TFA from initial varus to valgus pattern.
3. To compare pattern of tibiofemoral angle of male and female children.
4. To determine the age-reference values of tibiofemoral angle of children at selected periods of time (birth- three weeks, 6, 12, 18, 24, 30, and 36 months) during the first three years of life.
5. To compare values of tibiofemoral angle of male and female children at selected periods of time during the first 3 years of life.
6. To determine the values of intercondylar/intermalleolar distance of children at selected periods of time during the first 3 years of life.
7. To compare values of intercondylar/intermalleolar distance of male and female children at selected periods of time during the first 3 years of life.

1.4 Objectives of the Study

The objectives of the study are:

1. To determine the relationship between limb length and tibiofemoral angle of children at selected periods of time during the first 3 years of life.
2. To determine the relationship between trunk-limb length ratio and tibiofemoral angle of children at selected periods of time during the first 3 years of life.
3. To determine the relationship between trunk length and tibiofemoral angle of children at selected periods of time during the first 3 years of life.
4. To determine the relationship between body weight and tibiofemoral angle of children at selected periods of time during the first 3 years of life.
5. To determine the relationship between body height and tibiofemoral angle of children at selected periods of time during the first 3 years of life.
6. To determine the relationship between intercondylar/intermalleolar distances and tibiofemoral angle of children at selected periods of time during the first 3 years of life.

1.5 Hypotheses

1.5.1 Major Hypotheses

1. There would be no significant difference in the values of tibiofemoral angle or its index (intercondylar/intermalleolar distance) of male and female children or right and left lower limbs of males and females at selected periods of time during the first 3 years of life.

2. There would be no significant relationship between limb length, trunk length, trunk-limb length ratio, body weight, height, intercondylar/intermalleolar distance and tibiofemoral angle among the participants.

1.5.2 Sub-hypotheses

1. There would be no significant difference in the tibiofemoral angles of male and female children at birth to 3 weeks of life.
2. There would be no significant difference in the tibiofemoral angles of male and female children at each of 6, 12, 18, 24, 30 and 36 months of life.
3. There would be no significant difference in the intercondylar distance of male and female children at birth to 3 weeks of life.
4. There would be no significant difference in the intercondylar distance of male and female children at each of 6, 12 and 18months of life.
5. There would be no significant difference in the intermalleolar distance of male and female children at each of 24, 30 and 36 months of life.
6. There would be no significant difference between right and left lower limb tibiofemoral angles of male children at birth to 3 weeks of life.
7. There would be no significant difference between right and left lower limb tibiofemoral angles of male children at each of 6, 12, 18, 24, 30 and 36 months of life.
8. There would be no significant difference between right and left lower limb tibiofemoral angles of female children at birth to 3 weeks of life.

9. There would be no significant difference between right and left lower limb tibiofemoral angles of female children at each of 6, 12, 18, 24, 30 and 36 months of life.
10. There would be no significant relationship between limb length and tibiofemoral angle of children at birth to 3 weeks of life.
11. There would be no significant relationship between limb length and tibiofemoral angle of children at each of 6, 12, 18, 24, 30 and 36 months of life.
12. There would be no significant relationship between trunk-limb length ratio and tibiofemoral angle of children at birth to 3 weeks of life.
13. There would be no significant relationship between trunk-limb length ratio and tibiofemoral angle of children at each of 6, 12, 18, 24, 30 and 36 months of life.
14. There would be no significant relationship between trunk length and tibiofemoral angle of children at birth to 3 weeks of life.
15. There would be no significant relationship between trunk length and tibiofemoral angle of children at each of 6, 12, 18, 24, 30 and 36 months of life.
16. There would be no significant relationship between body weight and tibiofemoral angle of children at birth to 3 weeks of life.
17. There would be no significant relationship between body weight and tibiofemoral angle of children at each of 6, 12, 18, 24, 30 and 36 months of life.
18. There would be no significant relationship between body height and tibiofemoral angle of children at birth to 3 weeks of life.
19. There would be no significant relationship between body height and tibiofemoral angle of children at each of 6, 12, 18, 24, 30 and 36 months of life.

20. There would be no significant relationship between intercondylar/intermalleolar distances and tibiofemoral angle of children at birth to 3 weeks of life.
21. There would be no significant relationship between intercondylar/intermalleolar distances and tibiofemoral angle of children at each of 6, 12, 18, 24, 30 and 36 months of life.

1.6 Delimitation

This study was delimited to apparently healthy infants without any obvious congenital limb deformity.

1.7 Limitation

The limitation to this study is that participants were not screened for Blount's disease at any time during the study period.

1.8 Significance of the study

Available data on tibiofemoral angle in Nigerian children are based on studies which involved measurement once (cross-sectional studies). Subsequently there have been some inconsistencies in the findings of these studies, especially in respect of the time of transition from knee varus to valgus presentation. This is the first attempt of a longitudinal study that follows up a group of children for three years. The outcomes of this study provides reliable data on the developmental pattern of tibiofemoral angle of Nigerian children during the first three years of life, which would hopefully facilitate clinical decisions on tibiofemoral angle pattern and values that are normal and abnormal by healthcare providers in Nigeria. This would also help minimize the need for repeated radiological examinations and exposure to radiation. It would also facilitate communication of clinical decisions on interventions for children who are three years old or younger. The outcome of this study has also indicated that excessive bowing might not require treatment except pathology identified as it corrects spontaneously.

CHAPTER TWO

LITERATURE REVIEW

2.1 Knee Dynamics

In the presence of active muscle contraction, dynamic forces are created that produce motion and increase joint stability (Robertson et al, 2003). Knee range of motion varies with activity. During walking the knee flexes approximately 15 degrees during pre-swing prior to toe-off. Many athletic activities require 130 or more degrees of flexion. Anterio-posterior (AP) translation depends on the degree of knee flexion, internal–external rotation, and joint compression. Anterio-posterior movement is maximal between 30 and 90 degrees of flexion and decreases beyond 90 degrees. Average translations of the tibia on the femur during flexion and extension are 6 mm anteriorly and 3 mm posteriorly (Garg and Walker, 1990; Andriacchi et al, 1998). The average varus–valgus rotation during gait is 10 degrees with maximum valgus rotation of the tibia occurring at heel strike and maximum varus rotation during swing phase. Internal–external rotation during gait averages 8 degrees. Internal tibial rotation is maximal during swing phase and external rotation maximal during stance. No significant medio-lateral translation occurs during gait (walking or passive motion).

Walking creates ground-reaction forces that are transmitted to the tibia. Active muscle contraction creates moments to resist these externally generated moments and thus control the knee motion. The combination of the muscle forces together with the ground-reaction force produces the joint-reaction force (Robertson et al, 2003). A pure compressive load occurs when joint-reaction forces are perpendicular to the joint surface. When joint-reaction forces are not perpendicular to the joint surface, shear movements will occur unless restraints are present (Robertson et al, 2003).

In addition to the knee's passive restraints, contraction of muscles that cross the knee joint provide dynamic restraints. The dynamic (active) and passive stabilizers interact synergistically to stabilize the knee. Forces acting on the knee during activities, such as walking and stair climbing, are complex (Schipplein and Andriacchi, 1991; Andriacchi, 1994). There must be constant change in knee muscle activity to create controlled and stable movement. The muscles' dynamic actions together with the passive restraints control motion (Robertson et al, 2003). For example, an externally applied load producing knee flexion (and posterior translation) will be counterbalanced by contraction of the quadriceps muscle. This prevents posterior tibia translation and arrests flexion, which occurs every time one stops while walking or running. To further illustrate the complexity and dynamic adaptability of the knee, Anterior Cruciate Ligament (ACL)-deficient individuals frequently will adapt a gait that reduces the level of quadriceps contraction normally obtained near full extension. This minimizes the strain on the secondary restraints (medial meniscus).

2.2 Tibiofemoral Angle

The development of the tibiofemoral angle in Caucasian children follows a certain pattern, in which there is first a pronounced varus in newborn infants and subsequently an extreme valgus position (Salenius and Vankka, 1975). This pattern of the tibiofemoral angle is one of considerable genu varus or bowing at birth, approximately

15 degrees. There is gradual spontaneous correction to zero degrees at one and one-half to two years of age. During the next year, a valgus of 10 degrees to 12 degrees develops which gradually corrects to the normal adult value of 5 to 6 degrees valgus at about the age of seven years. This process is identical in boys and girls (Salenius and Vankka, 1975; Heath and Staheli, 1993). Children from some other nations such as Korea, Pakistan, and Nigeria follow similar pattern of tibiofemoral development with little variations in values and time of change-over from one type to the other (Qureshi et al, 2000a; Oginni et al, 2004; Yoo et al, 2008). However, significant differences between Chinese children and children of other races were reported in the pattern of tibiofemoral angle (Cheng et al, 1991).

2.2.1 Physiologic Genu varus and valgus

Developmental (physiologic) bowing that causes exaggeration of normal age-related angulation changes at the knee joint is a common condition seen in orthopaedic clinics (Brook and Gross, 1995). Neonates and infants normally have varus angulation of the lower extremities that is believed to be secondary to in-utero moulding (**Cheema et al, 2003**). There is gradual correction of this angulation as a child starts walking. The bowing is found to be corrected within 6 months of walking or by 18–24 months of age. This is followed by valgus angulation during the second and third years of life that reverts to the adult pattern ($5\text{-}6^0$ valgus) by age 6 or 7 years (Salenius and Vannka, 1975; Health and Staheli, 1993; Oginni et al, 2004; Yoo et al, 2008). Thus, any varus angulation at the knee joint after the age of two years is abnormal.

The observed exaggerated varus angulation during the second year of life is deemed to be developmental (physiologic) bowing. This condition is reported to be typical of children who begin walking at an early age and is more common in heavier white children as well as in African-American children (**Cheema et al, 2003**). Radiography of developmental bowing shows varus angulation centered at the knee, which is measured by drawing lines parallel to the midshafts of the femur and tibia on a standing anteroposterior radiograph and calculating the angle of intersection (Salenius and Vannka, 1975). A mild enlargement and depression of the proximal tibia metaphyses posteromedially without fragmentation ("metaphyseal beaking") was reported. The medial tibial cortices are observed to be thickened secondary to buttressing, and the ankle joints are tilted with the medial side higher. Similar but less striking changes may be seen in the femurs (**Cheema et al, 2003**). Developmental bowing is expected to correct itself without treatment, but follow-up is needed to ensure that the bowing resolves and that tibia vara do not develop.

2.2.2 Pathologic Genu varus and valgus

Tibia vara or Blount disease is the most frequent non-physiologic cause of genu varum in children and a common condition that is believed to be related to an abnormal compression on the medial aspect of the proximal tibial physis causing growth suppression (Brook and Gross, 1995). The growth at the epiphysis becomes asymmetric, leading to the typical varus angulation (Stricker and Sama, 2001; Dahl, 2002). Factors such as early walking, obesity, and African-American descent have been shown to be predisposing factors for this disease (Brook and Gross, 1995; Stricker and Sama, 2001;

Dahl, 2002). Obesity and early walking exaggerate the physiologic varus angulation. African-American children are believed to have excessive ligamentous laxity and begin to walk earlier than their Caucasian counterparts. Early diagnosis and treatment of this disease is vital to avoid progressive worsening (Cheema et al, 2003). Three major types of tibia vara have been recognized, depending on age at presentation: infantile, juvenile, and adolescent. Infantile tibia vara is the most common, while the later-onset types may represent an unrecognized or untreated variant of the infantile form (Brook and Gross, 1995; Stricker and Sama, 2001; Cheema et al, 2003).

Tibia vara is best diagnosed with standing anteroposterior radiography of both legs (Stricker and Sama, 2001). The radiographs will demonstrate genu varum, and abnormality of the proximal tibia consisting of depression and irregularity or fragmentation of the metaphysis posteromedially and deficiency of the epiphysis medially. The physis may be widened medially due to arrested growth or laterally due to traction injury (Dahl, 2002). More advanced cases will show lateral subluxation of the tibia, and genu recurvatum may also be seen (Cheema et al, 2003).

Whereas developmental bowing is typically symmetric, Blount disease is usually unilateral or asymmetric. Measurement of the metaphyseal-diaphyseal angle has been used to more accurately diagnose this condition and to differentiate it from developmental bowing. The metaphyseal-diaphyseal angle is the angle between a line drawn parallel to the top of the proximal tibial metaphysis and another line drawn perpendicular to the long axis of the tibial shaft. In physiologic bowing, this angle is 5°

± 2.8 (range, 0°–11°). In Blount disease, the angle is 16° ± 4.3 (range, 8°–22°). It has been suggested that children with angles greater than 11° have Blount disease. Children with indeterminate angles (8°–11°) may require follow-up radiography to clarify the diagnosis (Levine and Drennan, 1982).

A six-stage classification system for Blount disease was described by Langenskiold in 1952. His concepts have been a standard of assessment to the present time, even though a study of the reliability of orthopaedists in using the classification revealed problems in staging intermediate groups. Langenskiold himself cautioned that this classification system was not intended to help determine prognosis or treatment. Others have developed radiographic criteria, such as the metaphyseal diaphyseal angle for the early diagnosis of structural tibia vara. However, surgery consisting of osteotomies of the tibia and fibula is the usual treatment of choice in stage 3 disease or higher (Langenskiold, 1989). Bowing can recur postoperatively, requiring repeat surgery. Magnetic resonance (MR) imaging has been performed to evaluate the growth plate in Blount disease and may be useful in surgical planning (Synder et al, 2001; Craig et al, 2002). It may also be used to predict development of Blount disease in patients with severe physiologic bowing (Iwasawa et al, 1999).

Congenital bowing of the tibia is an unusual condition that is believed to result from an abnormal intrauterine position, although localized skeletal dysplasia or fetal vascular insufficiency may also play a role in some cases. This type of tibia bowing is usually convex posteriorly and medially; less commonly, it is convex laterally. The fibula is also bow and foot shows marked dorsiflexion at birth. At radiography, there is cortical thickening along the concavity of the curvature, and there may be diaphyseal broadening. There is a good prognosis for remodeling during growth, but protective bracing may be necessary in some cases. Leg-length discrepancy secondary and directly proportional to bowing of the tibial-fibular segment is usually seen (Hofmann and Wenger, 1981) and may require osteotomies and leg-lengthening procedures. Epiphysiodesis of the contralateral side may also be performed.

Rickets result from deficient mineralization of normal osteoid and interruption of the normal orderly development and mineralization of growth plates. Vitamin D–resistant (hypo-phosphatemic) and nutritional rickets are the most common types. The bones are soft, with consequent bowing of long bones on weight bearing. However, the predominant changes are metaphyseal, with widening of the zone of provisional calcification due to the presence of unmineralized osteoid. Cupping, fraying, and splaying of metaphyses occurs with growth and continued weight bearing (Stricker and Sama, 2001; Cheema et al, 2003).

Radiologic changes in rickets occur predominantly at sites of rapid growth, including the proximal humerus, distal radius, and distal femur and both ends of the tibia. Thus, a skeletal survey for rickets can be accomplished with anteroposterior radiography of the knees, wrists, and ankles. The radiologic appearance of rickets varies somewhat depending on the cause of the disease. For example, in renal rickets, the metaphyseal changes are usually less severe, varying with the growth rate of the child. Renal rickets is usually seen in older children, whereas nutritional rickets is more common in infants (Steinbach and Noetzli, 1964; Swischuk and Hayden, 1979; Zaleske, 1996). The primary treatment modality for rickets is dietary and medical. The bowing usually responds to the restoration of metabolic balance. In the rare cases that do not, corrective osteotomy may be necessary (Do, 2001).

Achondroplasia is the most common hereditary disorder that causes dwarfism. It is most often autosomal, dominant in transmission but with a high rate of spontaneous mutation. The disorder is characterized by shortening and thickening of the long bones with metaphyseal flaring and cupping, an embossed frontal bone, craniofacial deformity, and vertebral malformation (Yoo et al, 2010). The lower extremities are bowed, and treatment of severe bowing requires valgus osteotomies. The phalanges are short, broad, and cupped. The iliac bones are short and rectangular with narrow sacro-sciatic notches and short, wide pubic and ischial bones. There are bullet-shaped vertebral bodies with posterior scalloping and narrowing of lumbar interpedicular distances. The intervertebral disks are widened, resulting in normal trunk length, and the thorax is slender due to the short ribs with flared anterior ends. The head is large, with frontal bossing and a depressed nasal bridge (Cheema et al, 2003).

Neurofibromatosis is a common genetic disorder. Osseous lesions are seen in neurofibromatosis type 1 (NF1) in addition to cutaneous, nervous system, and ocular abnormalities. These osseous lesions affect the skull, spine, ribs, pelvis, and long bones. The proportionate short stature, macrocephaly, long-bone dysplasia, progressive scoliosis, and sphenoid wing dysplasia are prototypical skeletal manifestations of NF1.

Long-bone dysplasia most often affects the tibia and presents with anterolateral bowing often leading to fracture and nonunion or pseudoarthrosis (Stevenson et al, 2008). Pathologic fracture with nonunion may result in pseudoarthrosis of the tibia and sometimes of the fibula, with pencil pointing of the bone fragments. Focal narrowing and intramedullary sclerosis or cystic change at the apex of the angulation is often seen; a finding that is consistent with hamartomatous fibrous tissue. The tibia is typically involved at the junction of the middle and distal thirds. The underlying mechanism is mesodermal dysplasia. When dysplasia without fracture is diagnosed, prophylactic bracing may be used to prevent development of pseudoarthrosis. Once fracture has occurred, treatment consists of osteotomy with grafting with the goal of achieving union (Sponseller, 1996). The precise mechanism for defective healing and pseudarthrosis is not known. Disuse osteoporosis and secondary deformities of the talus and calcaneus are seen distal to the pseudarthrosis. Aberrations in limb growth can also be seen in neurofibromatosis (Crawford and Schorry, 1999; Hefti et al, 2000).

Campomelic dysplasia is a rare, often lethal, congenital osteochondrodysplasia, short-limbed dwarfism characterized by anterior bowing of the long bones of the lower limbs. Characteristic features are skeletal hypoplasias and anomalies affecting the face, head, scapulae, spine, pelvis, and upper and lower limbs. The limbs are short with anterior bowing of the legs and/or thighs, often with pretibial skin dimples (Iravani et al, 2000). The hips are frequently dislocated. Clubbed feet and joint contractures may be seen. There is bowing of the forearm bones with small hands. The pelvis will show absence of sacral alae, narrow iliac bones, acetabular hypoplasia, and poor pubic ossification as well as widely separated short ischial bones. The head is macrocephalic, with flattened facies and nasal bridges, high forehead, low-set ears often with associated deafness, hypertelorism, long philtrum, small mouth, and micrognathia. The chest is bell shaped with thin, wavy ribs and slender clavicles. The tracheal caliber is narrow owing to defective tracheobronchial cartilage, and characteristic vertebral anomalies are present. Camptomelic dysplasia is classified as a bent-bone dysplasia (Cheema et al, 2003). Treatment is usually supportive.

Osteogenesis imperfecta is one of the more common heritable disorders of the connective tissue. There are four major types of osteogenesis imperfecta described in the literature; each type with a different mode of inheritance depending on the basis of the specific collagen defect. The characteristics of Type 1 are fractures of varying severity, blue sclerae, abnormal tooth development, and wormian bones in the skull. Type 1 osteogenesis imperfecta comprises most of the cases previously classified as osteogenesis imperfecta tarda. Types 2 and 3 are characterized by severe skeletal involvement and poor postnatal survival rates which correspond to the cases previously classified as osteogenesis congenita. Type 2 or 3 is also characterized by blue sclerae and fractures at birth or even in utero. Type 4 exhibits normal sclerae and variable skeletal findings. With advances in genetics, many specialists now believe that this classification system is too narrow and misleading and that osteogenesis imperfecta is actually a more complex abnormality that is more accurately characterized in terms of clinical findings (Cheema et al, 2003). In all four types of osteogenesis imperfecta, bowing of the long bones results from softening caused by osteoporosis and multiple fractures. Bowing typically involves all the long bones (Ablin, 1998), and osteotomies and pinning are commonly performed for bowing. Some success has been achieved through medical treatment with bisphosphonates (Glorieux et al, 1998). However, although the density of the bones increases and clinical improvement is seen, fractures continue to occur (Cheema et al, 2003).

2.3 Factors affecting Tibiofemoral Angle

The time walking chair was introduced to the children and the time the children gain independent walking, as well as the period of dependent walking, has been reported to be significantly related to the occurrence of physiological knock knee (Lin et al, 1999). Age has been shown to affect TFA. A steady increase in TFA angle in both sexes from age 6 years to the end of development was observed by Arazi et al (2001). A significant negative correlation between TFA, body weight and height was observed by previous authors. Oginni et al, (2004) found significant correlation only in the first 6 months of life while Arazi et al, (2001) found significant correlation between 3 and 17 years of age. However, Cahuzac et al, (1995) reported no significant correlation between TFA, body weight and height and leg length during 10 to 16 years of age.

The effect of gender on TFA has been controversial. Some authors reported no difference between both genders (Cheng et al 1991; Heath and Staheli 1993) while some reported differences at a particular age (Cahuzac et al, 1995; Arazi et al, 2001; Oginni et al, 2004; Tella et al, 2010). Salenius and Vankka (1975) used radiological measurements to demonstrate that both boys and girls have similar development of tibiofemoral angle. Also, Cahuzac et al, (1995) reported no significant differences between boys and girls until they were 14 years old ($p > 0.3$). Boys after 14 years of age showed a gradual and significant decrease of the valgus angle to 4.41^0 ($p < 0.001$). At 6 years old, boys were more bow-legged than girls ($p = 0.0004$). Also, Arazi et al, (2001) reported significant differences between girls and boys in three age periods. These were at 13 years ($z = 2.46$, $p = 0.014$), 14 years ($z = 3.48$, $p = 0.000$), and 16 years ($z = 2.89$, $p = 0.004$). Oginni et al, (2004) also reported that from 8 years of age, the girls were significantly more knock-kneed than the boys. The differences in the above studies might be due to methodologies employed in assessing the knee angle. Lin et al, (1999) observed that the prevalence of physiological knock knee did not significantly correlate with gender.

2.4 Measurement of Tibiofemoral Angle

Four methods of measurement of the tibiofemoral angles (TFA) were found in the literature. These are roentgenographic (McCarthy et al, 2001; Bowen et al, 2002), photographic measurement (Heath and Staheli, 1993; Qureshi et al, 2000a; Oginni et al, 2008), goniometric measurement (Arazi et al, 2001; Shultz et al, 2006; Tella et al, 2010) and intermalleolar and intercondylar distances (Lin et al, 1999; Omololu et al, 2003; Ezeuko et al, 2010).

2.4.1 Roentgenographic measurement

The tibiofemoral angle was measured on the roentgenogram by previous authors by drawing a longitudinal axis midway between the femoral and tibial diaphyseal cortices.

The angle between these two longitudinal lines was measured in degrees (McCarthy et al, 2001; Bowen et al, 2002). In the case of newborn infants drawing the lines may be difficult because their femora are not straight; therefore, the femoral line drawn represented the best estimate of the longitudinal axis of the femur (Salenius and Vankka, 1975). See plate 1 below.

2.4.2 Photographic measurement

The photographic measurement is taken by placing skin markers (5mm) dots over the anterior superior iliac spine (ASIS), centre of the ankle joint and the centers of the patellae. A photograph that included the ASIS and lower extremities is then obtained. Two axes are drawn for each lower extremity, one connecting the ASIS and the center of patella and between the patella and a point measured midway between the medial and lateral malleoli. The knee angle is then measured using the patella as the fulcrum (Heath and Staheli, 1993; Oginni et al, 2004).

Plate 1: The teleradiograph of the lower extremity. The radiographs were obtained in standing position, if the subject is compliant, including hip, knee, and ankle joints in a single exposure. The anatomical tibiofemoral angle (aTFA) was defined as the angle (α) between the anatomical axes of femur and tibia (Yoo et al, 2008).

2.4.3 Goniometric measurement

The Universal goniometer has been used to measure tibiofemoral angle (TFA). Children less than 2 years are examined supine in anatomical position. One arm of the goniometer is aligned to an imaginary line drawn from the anterior superior iliac spine to the middle of the patella (femoral alignment) and the second arm aligned to a line joining the middle of the patella to the middle of the ankle (centre point between medial and lateral malleoli), tibia alignment. The centre of the patella served as fulcrum for the goniometer. The angle sustained between the femoral shaft and the tibia shaft on the goniometer is recorded as the tibiofemoral angle in degrees (Omololu et al, 2003). In older children, the subject is in standing and the goniometer axis is positioned over the knee center in the frontal plane, the angle formed by a line from the knee center to a landmark midway between the ASIS and greater trochanter, and a line from the knee center to the ankle center (mid-malleolar distance) is measured to the nearest degree (Shultz et al, 2006).

2.4.4 Intermalleolar and Intercondylar Distances

The Intermalleolar distance is measured with a Non-Elastic Tape measure. Children are examined supine in anatomical position with the medial condyles just touching, the pelvic square and hip and knees in maximal extension. This is usually measured in centimeters to give values for valgus angle (Omololu et al, 2003).

Intercondylar distance (ICD) is measured with a Non-Elastic Tape measure with children examined supine in anatomical position with the medial malleoli just touching, the pelvic square and hip and knees in maximal extension. This is usually measured in centimeters to give values for varus angle (Omololu et al, 2003).

2.5 Studies on Developmental Pattern of Tibiofemoral Angle in Children (Table 1).

Through literature search (Pubmed.org, Pubmed Central, Highwire, Hinari and Goggle) 26 studies on developmental pattern of tibiofemoral angle from 1974 to 2011 were found. Three studies were conducted before 1990 (Engel and Staheli, 1974; Salenius and Vankka, 1975; Vankka and Salenius, 1982). All the studies were cross sectional surveys except for three (Salenius and Vankka, 1975; Vankka and Salenius, 1982; Bowen et al, 2002) which were longitudinal in nature. Two studies reported pattern and prevalence of varus/valgus pattern for soccer players and primary school children (Karimi-Mobarake et al, 2005; Yaniv et al, 2006). All the studies involved male and female children except one which involved only male children (Yaniv et al, 2006). The participants in most cases were children and adolescents with theexception of one study which involved adult population (Igbigbi and Msamati, 2002). The age ranged between birth and 21 years of age with the exception of one which studied adult population aged 18 – 55 years. Five studies were from Africa, four from America, twelve from Asia and five from Europe. The number of participants in the studies under review ranged from 20 to 5466. The longitudinal studies had low sample sizes of 20 to 98 participants with the exception of one which examined 111 out of 1279 children for 2-3 times (Salenius and Vankka, 1975). All the studies used clinical, radiographic or photographic method or a combination of the methods to evaluate the tibiofemoral angle. Seventeen studies used clinical method, five used radiographic method, two used photographic method and two used both clinical and photographic methods.

Most studies described the pattern as varus followed by valgus pattern. The age at which each occurs i.e. varus/valgus pattern and the transition age from varus to valgus pattern differ from study to study. For instance, some studies reported maximum varus at six months of age with gradual decrease until 18 months and followed by valgus pattern (Salenius and Vankka, 1975; Cheng et al, 1991; Health and Staheli, 1993; Oginni et al, 2004; Yoo et al, 2008). Some reported varus pattern between one and two years of age followed by valgus pattern (Vankka and Salenius, 1982; Subharwal et al, 2008), while Omololu et al, (2003) reported maximum varus between one and three years followed by valgus pattern.

2.5.1 Normal limit of tibiofemoral Angle

In a roentgenographic investigation of 1,480 white children by Salenius and Vankka, (1975), a mean varus of 16.5 degrees present at birth was noted to decrease to 10-12 degrees at one year. Heath and Staheli, (1993) observed greatest mean varus angle of 15.9^0 at six months of age by photographic measurement while 10^0 was observed for Nigerian (Oginni et al, 2004) and Pakistani children (Qurrechi et al, 2000a). Cheng et al, (1991) observed a significant degree of varus of 5 degrees in normal Chinese children aged between 3 and 11 years by clinical measurement. Omololu et al, (2003) also used clinical method and reported low mean varus angle of 0.27-1.95 degree between ages 1-3 years.

Different maximal mean valgus angle values and ranges were reported in different studies. Four studies reported mean maximal valgus values of 6 to 12 between age 2 and 6 years (Engel and Staheli, 1974; Salenius and Vankka, 1975; Cheng et al, 1991; Oginni et al, 2004) and 5–6 degrees in children between ages 7 and 12 years reported by Salenius and Vankka, (1975). Contrary to this report, Heath and Staheli, (1993) observed at least 2.5 degrees of valgus in American children at age 11 years. Similar results were reported by Cahuzac et al, (1995) in European children. They observed a valgus angle of 5.5 degrees until age 13 years. Arazi et al, (2001) reported significantly higher degrees of mean valgus angle than did previous reports. They observed maximal mean valgus angle of 9.6 degrees at 7 years for Turkish boys and 9.8 degrees at 6 years for Turkish girls. This was similar to the finding of Omololu et al, (2003) who reported valgus angle of 11^0 from age 7-10 years in both gender. These differences can result from racial differences, techniques of measurement, and observer-related factors. Intra-examiner or inter-examiner variability may be responsible for some errors in measurement, especially with clinical methods (Wright and Feinstein, 1992).

2.5.2 Normal limit of Intermalleolar (IM) and Intercondylar (IC) Distances

Significant differences in the values of IC and IM distances have been reported in studies performed in different countries. Cheng et al, (1991) reported a mean IC/IM distance of zero cm at age 8 years in Chinese children. Conversely, Heath and Staheli, (1993) noted mean IM distances >2 cm at age 5–11 years with a minimal mean value of 2 cm at age 7 years in white American children. Cheng et al, (1991) also observed that girls had a slightly greater value of IC distance than boys at all ages. Arazi et al, (2001) observed significantly lower values in IC/IM distance measurement. A steady decrease in IM distance was observed from 3 years to 17 years of age. IM distance persisted in all age groups except boys aged 10 years (IC, 0.1 cm; SD, 1.3 cm). Omololu et al, (2003) reported a mean IC distances of 0.2 cm at 1 year of age which did not vary significantly at 10 years of age in Nigerian children. The greatest IM distances of 2.5cm and 2.2cm were noted between ages 2 and 4 years.

2.5.3 Prevalence of Genu Valgus and Genu Varus

Karimi-Mobarake et al, (2005) reported the prevalence of genu varus to be 7.9% and genu valgus 2% in Iranian children. Genu varus in boys was twice that of girls while genu valgus was 3 times more in girls than in boys. A 64% prevalence of physiological knock knee (PKK) has been reported for Taiwanese children at age 3–4 years (Lin et al, 1999). Most of them (56%) were mild (IMD, 2–5 cm), whereas 8% were moderate (IMD, 5–9 cm). The prevalence decreased to 44% (mild, 41%; moderate, 3%) at ages between 4 and 5 years, and 34% (mild, 31%; moderate, 3%) at ages between 5 and 6 years. There were no severe cases in all groups of children.

In summary, the developmental pattern of tibiofemoral angle described by most previous studies is varus in infancy followed by valgus. However, there are variations in the time of transition from varus to valgus and in TFA values reported for different ages. These variations might be attributed to differences in research designs (most being cross-sectional studies), measurement methods (Wright and Feinstein, 1992) and races (Arazi et al, 2001). Cohort studies in which children are followed up from birth to many years might provide less varied findings.

Table 1: Studies on Developmental Pattern of Tibiofemoral Angle in Children

S/N	Author and year	Country	Age (year)	Sample size	Study type	Method of Measuring TFA	Indices of TFA	Result
1	Engel and Staheli, 1974	USA	0.5-3		Survey	Photographic	TFA	Pattern: Max valgus at 2-3yrs Value: valgus 6-7^0
2	Salenius and Vankka, 1975	Finland	0-16	1279	Longitudinal	Roentgenographic	TFA	Pattern: pronounced varus at <1yr, valgus at 1.5-3yrs value: 5-6^0 at 6-7yrs.
3	Vankka and Salenius, 1982	Finland	1-4	20	Longitudinal	Roentgenographic	TFA	Pattern: Varus pattern till 2yrs & valgus pattern after 2yrs. Value:16-32^{0}varus and 15-20^{0}valgus
4	Cheng et al, 1991	China	0-12	2630	Survey	Clinical	TFA, IMD, ICD	Bowlegged at 6 months, knock knee at 3yrs & reduce to normal at 8yrs
5	Health and Staheli, 1993	USA	0.5-11	196	Survey	Clinical & photographic	TFA, IMD, ICD	Pattern: Maximally bowlegged at 6 months, neutral at 18months. Valgus at 4yrs. Value: 0^{0}at 18months 8^0 valgus at 4yrs decrease to<6^0 at 11yrs
6	Cahuzac et al, 1995	France	10-16	427	Survey	Clinical	TFA, ICD, IMD	Constant valgus (5.5^0) for girls. Varus evolution (4.4^0) during the last two yrs of Growth for boys. IMD of <8 cm or an ICD of <4 cm for girls & IMD of <4 cm or an ICD of <5 cm boys.
7	Lin et al, 1999	Taiwan	3-6	305	Survey	Clinical	IMD	High prevalence of physiological knock knee

8	Qureshi et al, 2000a	Pakistan	0-12.5	318	Survey	Photographic	TFA	Pattern: Greatest mean varus under 6 months, followed by a transitional phase to valgus between the ages of 1 to 2 years. Maximum valgus was measured at 4 years. Value: Varus angle 10.01^0 at <6months and max valgus of 5.96^0 at 4yrs. 3.080at ≥12yrs
9	Qureshi et al, 2000b	Pakistan	0-12.5	318	Survey	Clinical	IMD, ICD	Max varus at 6 months, extreme valgus at age 3 years. Mean IMD at 6 months was 2.96±2.01 cm, mean ICD at 1 year was 0.88±2.22 cm. Max mean ICD 3.29±1.18 cm was noted at 3 yrs. ICD gradually decreased thereafter to 0.86±1.74 cm by 12.5 yrs.
10	Arazi et al, 2001	Turkey	3-17	590	Survey	Clinical	TFA, IMD, ICD	Maximal mean valgus angle was 9.6^0 at 7 yrs for boys and 9.8^0 at 6 yrs for girls.
11	Bowen et al, 2002	USA	<4	98	Longitudinal	Roentgenographic	MDA,TV, FV,LV	Tibia varus exceeds femoral varus in all children. Children with %DT >50% and an MDA of ≥16° went on to progress.
12	Igbigbi and Msamati, 2002	Malawi	18-55	323	Survey	Clinical	TFA	X=$174.14±3.47^0$ for males & $174.46±4.30^0$ for females
13	Javid, 2003	Iran		2263	Survey	Clinical	TFA, IMD, ICD	A valgus alignment. The TFA was 5.5±1.2 ranging from 3.1 to 8.3 (5.7±1.3 in girls and 5.2±1.05 in boys). The IM-ICD varied from -3.9 - 2.6 centimeters.
14	Omololu et al, 2003	Nigeria	1-10	2166	Survey	Clinical	TFA, ICD, IMD	Max bowed at 1-3yrs, neutral at 5yrs in girls &7yrs in boys, progress to valgus

								($x=11^0$). ICD=.2cm at 1yr, IMD=2.5&2.2cm btw 2&4yrs
15	Oginni et al 2004	Nigeria	0-12	2036	Survey	Clinical and photographic	TFA	Varus at 1st 6 months & valgus after 23 months. Changes suddenly from varus to valgus within a few weeks, usually at 21 to 23 months of age. maximally and uniformly knock-kneed (-7.1° ± 1.4°) btw 3 & 3.5 yrs
16	Karimi-Mobarake et al, 2005	Iran	7-11	3000	Survey	Clinical	IMD, ICD	Prevalence of genu varum was 7.9% and genu valgum was 2%. Genu varum in boys was twice that in girls but genu valgum in girls was 3 times more than that in boys.
17	Yaniv et al, 2006	Israel	10-21	106	Survey	Clinical	IMD,ICD	High prevalence of knee varus in soccer players
18	Sabharwal et al, 2008	USA	1-18	253	Survey	Radiographic	TFA, LDFA, MPTA	Varus btw 1 &3 yrs & valgus btw 2 &7yrs.After 7yrs, are within adult values.
19	Yoo et al, 2008	Korea	<16	452	Survey	Radiographic	TFA	Genuvarum before 1yr, neutral at 1.5yrs, increasing genuvalgum with max value (7.8^0) at 4 yr, followed by a gradual decrease (5-6°) at 7 -8 yrs.
20	Kaspiris et al	Greece	3-9	316	Survey	Clinical	TFA, IMD	The average value of the tibiofemoral angle starts around 7^o at the age of 3 years and gradually decreases to under 4^o at the age of 7 to 8 years. The average value of the IM distance ranges from greater than 3.5 cm at the age of 3 years and progressively falls to under 2 cm at the age of 7 to 8 years.
21	Fakoor et al, 2010	Iran	3-16	853	Survey	Clinical	TFA, ICD, IMD	Valgus angle was observed in all with mean TFA 6.16 ± 1.45^0
22	Ezeuko et al, 2010	Nigeria	0-5	1450	Survey	Clinical	ICD, IMD	Varum by the first year of life, prevalently genu valgum in type by the second year, valgum by the third year,

								neutral by the fourth and fifth year.
23	Tella et al, 2010	Nigeria	11-19	5466	Survey	Clinical	TFA	Most participants (92.6%) had genu valgus. The normal valgus angle values were 11.06º – 11.20º for males and 11.62º – 11.79ºfor females.
24	Saini et al, 2010	India	2- 15	215	Survey	Clinical	TFA, ICD, IMD	Physiological varus rarely persists beyond 2 years of age. A progressive increase in knee valgus after 2 years of age, with peak valgus 8° at 6 years of age. Thereafter, the valgus decreases and, after the age of 10 years, stabilizes to 4–5° in most of the children. Indian girls show, overall, more valgus alignment of the knees as compared to boys.
25	Abdel Rahman and Badahdah, 2011	Saudi	2-12	300	Survey	Clinical	TFA	Knock knees that decreased with increase in age toward normal lower limbs alignment with no gender difference.
26	Heshmatipour and Karimi, 2011	Iran	8-11	2268	Survey	Clinical	ICD and IMD	ICD= 2.4 ± 6.05 and 3.83 ± 8.1 mm IMD= 5.63 ± 10.74 and 7.51 ± 11.22 mm in supine and standing positions respectively.

Key: TFA=Tibiofemoral angle, ICD= Intercondylar distance, IMD= Intermalleolar distance, MDA= metaphysical–diaphyseal angle, TV = tibial varus, FV = femoral varus, LV = limb varus, LDFA = lateral distal femoral angle, and MPTA= medial proximal tibial angle

CHAPTER THREE

SUBJECTS, MATERIALS AND METHODS

3.1.1 Participants

Participants for this study were apparently healthy new born babies without any obvious deformity (congenital hip dislocation, club foot, calcanio-valgus, pes planovalgus, pes planus). They were recruited into the study within three weeks of life from Olabisi Onabanjo University Teaching Hospital. And two health centres (Agura and Makun Health centres).

3.1.2 Materials

The following instruments were used during the course of carrying out this study:

1. Goniometer (Fieldtex product Inc, USA): A small pliable universal goniometer (half-circle protractor with two arms) was used to measure tibiofemoral angle of the participants.
2. Weighing scale: A weighing scale (Docbel Industries, 3/17, Asaf Ali Road, New Delhi-110002) with a bowl was used to measure the weight of the participants that were below 1 year or that were not up to age of standing.
3. Infantometer (Schafer, D-77656 Offenburg NR 120301): this was used to measure the length of children who were not up to age of standing.
4. Height and Weight Metre (Hardik Medi-Tech, Nirankari Colony, Delhi-110 009): this was used to measure the weight and height of children who were independent in standing.

5. Non-extensible measuring Tape (Butterfly brand, China): this was used to measure trunk length, limb length, intercondylar and intermalleolar distances.
6. Marker Pen: non-toxic washable maker pen was used to mark the land marks.

3.2 Methods

3.2.1 Sample Size and Sampling Technique

The sample size (N) for this study was estimated using the formula:

$N = 4\mu^2 (Z_{crit})^2 / D^2$ (Eng, 2003).

Where:

N= sample size of the single study group

μ= the assumed standard deviation for the group = 5 (range of previous studies, Omololu et al, 2003; Oginni et al, 2004)

Z crit= 95% confidence interval = 1.96

D= is the total width of the expected confidence interval = 2

Sample size (N) = 96.

Therefore, the minimum sample size was 96 newly born infants. To compensate for attrition and to cater for longitudinal nature of the study, a total sample of 152 newly born infants were selected using consecutive sampling technique.

3.2.2 Research Design

A longitudinal survey research design was used for this study.

3.2.3 Location of Research

The initial data collection was conducted in the premises of Child Survivor's Clinic, Obstetrics Ward of Olabisi Onabanjo University Teaching Hospital, Sagamu and two health centers (Agura and Makun). The follow up visits were done in the homes of the children.

3.2.4 Procedure

Ethical approval was sought and obtained for this study from the Institutional Review Committee of Olabisi Onabanjo University Teaching Hospital, Sagamu and University of Ibadan/University College Hospital Institutional Review Committee (appendix B & C). Informed consent was sought from parents or guardians of the participants (Appendix A). Permission was sought from the management of the Olabisi Onabanjo University Teaching Hospital, Sagamu and selected health centers where the participants were recruited. The nature, purpose and procedure of the study were explained to the parents of the participants in details. Each of the participants was screened for congenital deformity, physical manifestations of neurological and musculoskeletal problem by the researcher. Those who satisfied the screening were involved in the study. Participants were recruited within 3 weeks of birth and were followed up at monthly interval until age 3 years. The biodata of each participant were taken; sex, age, weight and height.

3.2.4.1 Data Collection

The following data were collected on each participant:

1. Weight: A weighing scale with bowl was used to measure the weight of the participants who were yet to reach standing age with minimal clothing lying inside the scale (plate 2). Weight metre was used for children who were able to stand independently with minimal clothing standing on the scale (plate 4). The weight was recorded in kilogramme to nearest 0.01kg. The accuracy of the scale was checked regularly with known weight. This was measured twice and the average was used in the computation.
2. Length/Height: The length of children who were not yet standing was measured in supine position with infantometer (plate 3) and the height of children who could stand independently in standing using a height meter (plate 4). The length/height was recorded in meter and to the nearest 0.01 meter. This was measured twice and the average was used in the computation.
3. Trunk length: This was measured in prone position for children <1year from 7^{th} cervical spine to sacrum and in standing for children ≥1year with non-extensible measuring tape. This was recorded in centimeter to the nearest 0.1 centimeter. This was measured twice and the average was used in the computation.
4. Limb length: This was measured from anterior superior iliac spine (ASIS) to base of medial malleoli with non-extensible measuring tape in supine for children <1year and in standing for children ≥1year. This was recorded in centimeter to the nearest 0.1 centimeter. This was measured twice and the average was used in the computation.

Plate 2: Measurement of weight of children who are not of standing age

Plate 3: Measurement of length of children who are not of standing age using infantometer

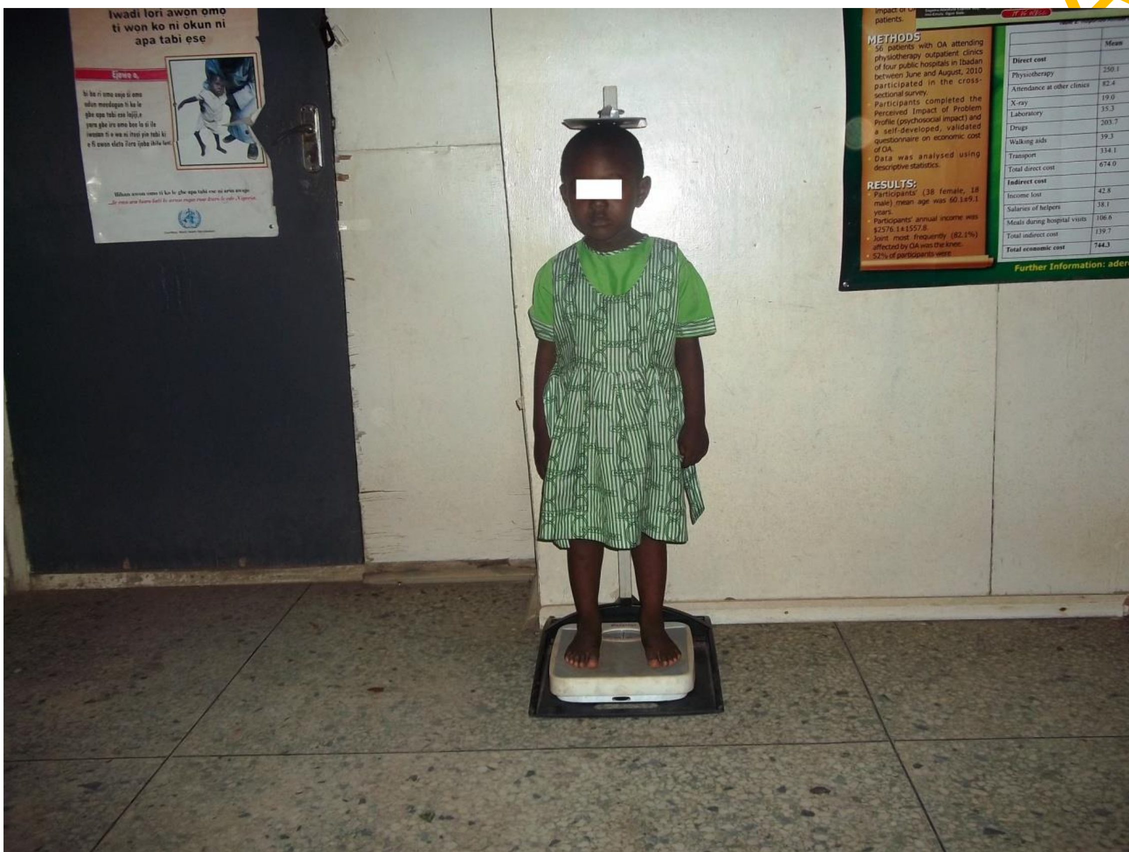

Plate 4: Measurement of height and weight of children who could stand independently

5. Intercondylar distance (ICD): This was measured with a non-extensible measuring tape. Each participant was examined supine in anatomical position with the medial malleoli just touching and pelvic square with hip and knees in maximal extension (Omololu et al, 2003). This was measured in centimeter to the nearest 0.1 centimeter. This gives values for varus angle. This was measured twice and the average was used in the computation (plate 5).
6. Intermalleolar distance: This was measured with a Non-extensible measuring tape. Each participant was examined supine in anatomical position with the medial tibial condyles just touching and pelvic square with hip and knees in maximal extension (Omololu et al, 2003). This was measured in centimeter to the nearest 0.1 centimeter. This gives values for valgus angle. This was measured twice and the average was used in the computation (plate 7).
7. Tibiofemoral angle (TFA): This was measured with each child in supine using a universal goniometer (plate 8). On each lower limb, the anterior superior iliac spine, the center of patella and the midpoint between the malleoli were identified with the non-toxic washable maker (plate 9). The fulcrum of the goniometer was placed on the centre of patella and the arms of the goniometer were aligned to the marked points on the superior iliac spine and midpoint of the two malleoli (plate 10). The acute angle sustained between the femoral shaft and the tibia shaft on the goniometer was recorded as the tibiofemoral angle in degree (Omololu et al, 2003). This was measured twice and the average was used in the computation.

Plate 5: Measurement of Intercondylar Distance using measuring tape

Plate 6: Tape Measure for measurement of Intercondylar and Intermalleoli Distances

Plate 7: Measurement of Intermalleolar Distance using measuring tape

Plate 8: Goniometers for measurement of Tibiofemoral Angle

Plate 9: Marking of land mark for goniometric measurement of tibiofemoral angle

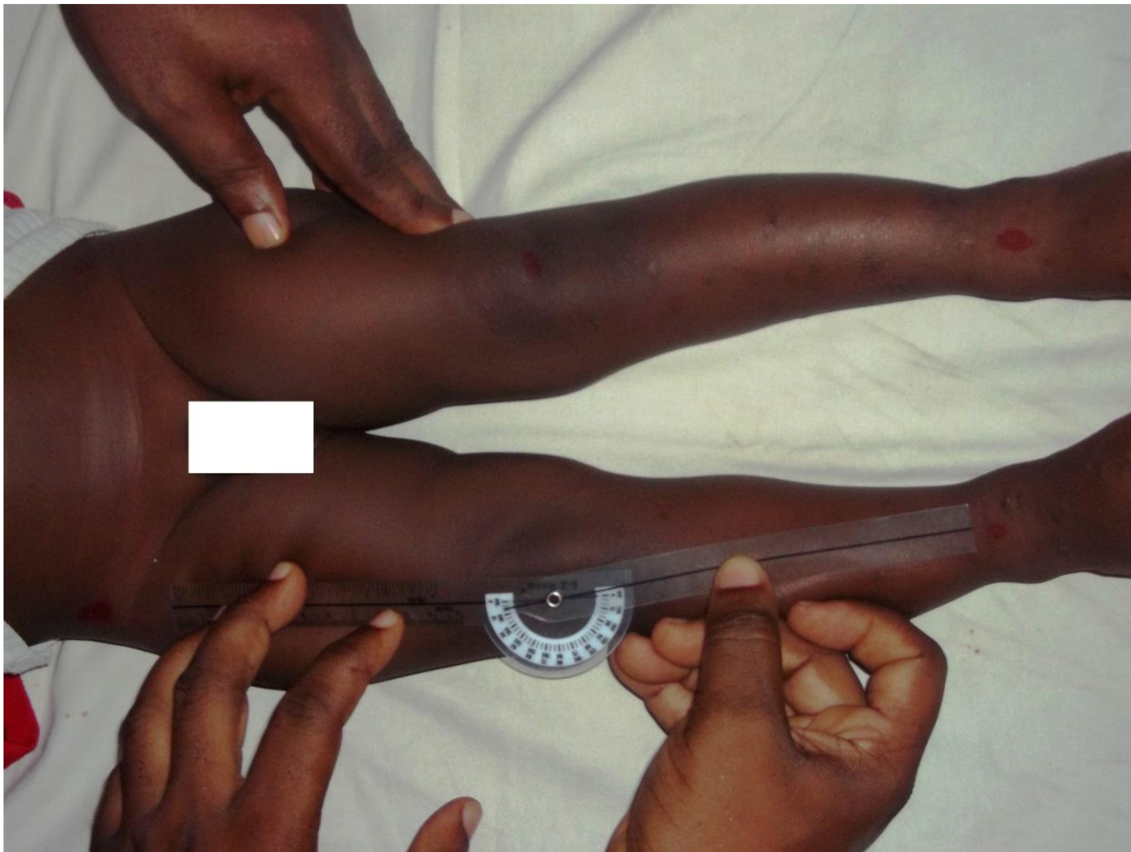

Plate 10: Goniometric measurement of tibiofemoral angle

8. Assessment of Inter-rater and Intra-rater Variability of Goniometric Measurement of TFA and Intercondylar and Intermalleolar distances: Three raters measured 32 limbs of 16 participants on the same day and one of the raters repeated the measurements a day after. Two of the raters (rater 1 & 2) were physiotherapists and the 3rd was an orthopaedic surgeon. Rater 1 & 2 had 11 and 18years clinical experience dealing with children while rater 3 had one year post specialty qualification.

3.2.4.2 Duration of Research

The research process ran through out the neonatal period of each child until 3 years of age with monthly interval follow up.

3.3 Data Analysis

Data obtained was analyzed using:

1. Descriptive statistics:
   (a) Mean and standard deviation were used to summarize the data.
   (b) The 95% confidence interval (2SD) was used to determine reference/normal values of TFA, ICD, and IMD.
   (c) Graph was used to describe the pattern of TFA with respect to time (graph of time series). This was also used to find sex difference in pattern of TFA

(d) Trimodal analysis was performed to determine transition age from one pattern of TFA to the other.

2. Inferential statistics :

(a) Pearson's correlation was used to determine relationship between limb length, trunk length, trunk-limb length ratio, body weight and height, intercondylar/intermalleolar distances and tibiofemoral angle.

(b) Independent t-test was used to determine gender differences of the measured parameters.

(c) Paired t-test was used to determine differences between left and right of measured parameters

(d) Inter-rater and intra-rater reliability were determined using one way random single measure intraclass correlation coefficients (ICCs) with associated 95% confidence intervals to gauge the precisions of the ICCs. ICC values were interpreted as follows: <0.2, poor agreement; 0.21 to 0.4, fair agreement; 0.41 to 0.6, moderate agreement; 0.61 to 0.8, good agreement; and 0.81 to 1.0, very good agreement (Singh et al, 2011).

Level of significance was set at alpha=0.05.

CHAPTER FOUR

RESULTS AND DISCUSSION

4.1 RESULTS

The cohort comprised of 71 boys and 81 girls. One hundred and thirty four children were from Yoruba tribe, 12 from Igbo tribe, 4 from Hausa tribe and 2 from other tribes. Sixty eight infants were recruited into the study at age 0-7 days, 46 at age 8-14 days and 38 at age 15-21 days. A total of 4528 (1989 from boys and 2539 from girls) pair limb measurements were taken. Figure 4.1 shows the attendance per month. A total of 86 children were seen 37 times (initial contact and monthly visits for 36 months), 32 children were seen 30-36 times, 12 children were seen 10-25 times, 8 children were seen 3-6 times and 14 were seen only at initial contact. Only 113 children completed the study; 39 children have defaulted by the 36th month, giving an attrition rate of 25.7%. The attrition was as a result of death (3 children), withdrawal from the study (1 child), untraceable contact addresses (13 children) and parents relocating to other towns (22 children).

4.1.1 Anthropometric Characteristics of Participants

The anthropometric characteristics of participants are presented in tables 4.2-4.4. The weight, height, limb length and trunk length were increasing with age in this cohort of children. There was no significant sex difference between the anthropometric variables of boys and girls with exception of ages 2-5 and 13 months for weight; 5,7and 9 months for height; 27 months for limb length and 5 and 6 months for trunk length respectively.

4.1.2: Inter-rater and Intra-rater Reliability of TFA and ICD/IMD

The interrater reliability was good for goniometric measurements of TFA (ICC=0.70; 95% CI=0.53-0.83) and very good for intercondylar/intermalleoli distances (ICC=0.96; 95%CI=0.92-0.96). The intra-rater reliability was very good for both goniometric measurement of TFA (ICC=0.98; 95%CI=0.95-0.99) and intercondylar/intermalleolar distances measurements (ICC=0.99; 95%CI=0.98-1.00) (Table 4.5).

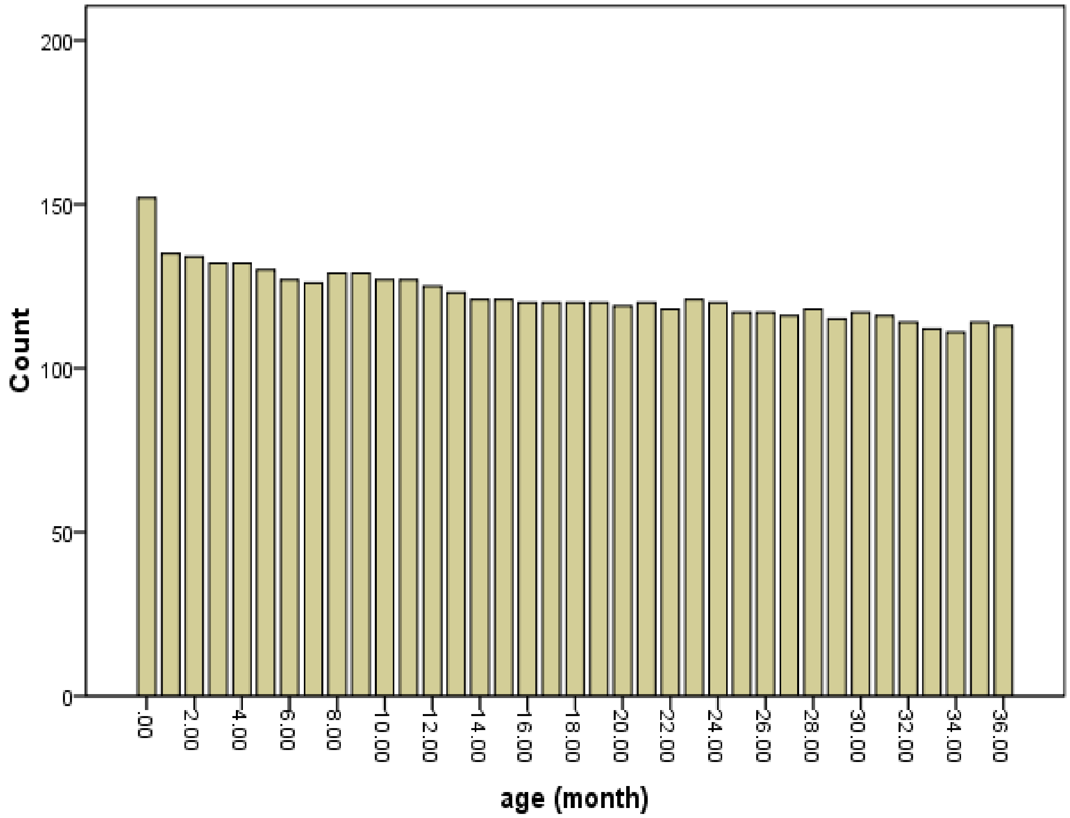

Fig 4.1: Participants' monthly attendance

Table 4.2: Anthropometric Characteristics of Participants at Ages 0-12 months (mean ± standard deviation)

Age	weight		p-value	height		p-value	limb length		p-value	trunk length		p-value	trunk-limb length ratio		p-value
(months)	male	female		male	female		male	female		male	female		male	female	
0	3.2±0.5	3.2±0.4	0.88	0.5±0.0	0.5±0.0	0.42	18.8±1.1	18.9±1.2	0.43	19.0±1.2	19.0±1.1	0.90	1.01±0.05	1.01±0.06	0.56
1	4.1±0.8	3.9±0.5	0.07	0.5±0.0	0.5±0.0	0.15	20.5±1.4	20.3±1.0	0.25	20.3±1.1	20.0±0.9	0.10	0.99±0.04	0.99±0.04	0.67
2	5.3±0.9	5.0±0.7	0.03*	0.6±0.0	0.6±0.0	0.19	22.1±1.6	22.1±1.2	0.81	21.6±1.5	21.5±1.2	0.51	0.98±0.05	0.97±0.06	0.33
3	6.1±1.0	5.7±0.7	0.02*	0.6±0.0	0.6±0.0	0.07	23.6±1.8	23.4±1.3	0.65	23.5±1.6	23.3±1.2	0.39	1.00±0.05	1.00±0.04	0.61
4	6.7±1.1	6.3±0.7	0.02*	0.6±0.3	0.6±0.2	0.16	24.5±1.8	24.5±1.4	0.98	24.9±1.6	24.5±1.2	0.07	1.02±0.04	1.00±0.04	0.01*
5	7.2±1.0	6.8±0.8	0.01*	0.6±0.0	0.6±0.0	0.00*	26.8±2.0	26.7±1.3	0.16	27.2±1.5	26.7±1.2	0.00*	1.02±0.04	1.00±0.04	0.35
6	7.4±1.1	7.2±0.8	0.24	0.7±0.3	0.6±0.2	0.06	26.8±2.0	26.7±1.3	0.70	27.2±1.5	26.7±1.2	0.04*	1.02±0.05	1.00±0.03	0.01*
7	7.7±1.0	7.5±0.9	0.12	0.7±0.0	0.7±0.0	0.02*	28.2±1.8	28.3±1.6	0.63	28.3±1.4	28.1±1.3	0.54	1.00±0.03	0.99± 0.03	0.10
8	7.9±1.0	7.7±1.0	0.27	0.7±0.0	0.7±0.0	0.07	29.5±1.8	29.4±1.5	0.87	29.2±1.4	29.0±1.2	0.42	0.99±0.04	0.98±0.03	0.32
9	8.1±1.0	7.9±1.0	0.13	0.7±0.0	0.7±0.0	0.02*	30.4±1.9	30.3±1.5	0.81	30.0±1.6	30.0±1.3	0.08	0.99±0.03	0.98±0.03	0.02*
10	8.3±1.0	8.1±1.0	0.19	0.7±0.0	0.7±0.0	0.16	31.4±1.7	31.3±1.7	0.73	30.8±1.3	30.5±1.4	0.24	0.98±0.03	0.98±0.03	0.17
11	8.6±1.0	8.3±1.0	0.17	0.7±0.0	0.7±0.0	0.29	31.8±1.8	31.8±1.7	0.93	31.7±1.4	31.5±1.4	0.48	1.00±0.03	0.99±0.03	0.32
12	8.6±1.0	8.5±1.0	0.45	0.7±0.0	0.7±0.0	0.28	32.3±1.8	32.4±1.8	0.69	32.3±1.6	32.3±1.5	0.88	1.00±0.02	0.99±0.02	0.11

*significant at $p<0.05$

Table 4.3: Anthropometric Characteristics of Participants at Ages 13-24 months (mean ± standard deviation)

Age (months)	weight male	weight female	p-value	height male	height female	p-value	limb length male	limb length female	p-value	trunk length male	trunk length female	p-value	trunk-limb length ratio male	trunk-limb length ratio female	p-value
13	8.9±1.0	8.6±1.0	0.05*	0.7±0.0	0.7±0.0	0.18	32.6±1.8	32.6±1.8	0.91	32.8±1.9	32.6±1.6	0.61	1.01±0.02	1.00±0.02	0.31
14	9.1±1.1	9.0±1.0	0.93	0.7±0.0	0.7±0.0	0.33	32.8±1.9	32.9±2.0	0.90	32.9±1.9	32.9±1.8	0.89	1.00±0.02	1.00±0.02	0.34
15	9.5±1.2	9.3±1.1	0.44	0.8±0.0	0.7±0.0	0.22	33.4±2.1	33.1±2.0	0.51	33.4±2.1	33.1±2.0	0.45	1.00±0.02	1.00±0.02	0.70
16	9.7±1.1	9.6±1.0	0.72	0.8±0.3	0.8±0.0	0.98	33.5±1.9	33.9±1.7	0.25	33.4±2.4	33.9±1.6	0.23	1.00±0.02	1.00±0.01	0.25
17	9.9±1.2	9.9±1.0	0.86	0.8±0.3	0.8±0.0	0.79	33.3±2.1	34.8±2.0	0.26	34.5±2.1	34.7±1.8	0.56	1.01±0.02	1.00±0.02	0.05*
18	10.0±1.2	10.0±1.1	0.79	0.8±0.0	0.8±0.0	0.77	35.1±2.0	35.4±2.1	0.45	35.2±2.0	35.3±1.9	0.80	1.00±0.02	1.00±0.02	0.06
19	10.1±1.1	10.0±1.0	0.76	0.8±0.0	0.8±0.0	0.97	35.8±2.2	36.0±2.1	0.62	35.8±2.1	35.9±2.0	0.88	1.00±0.01	1.00±0.02	0.23
20	10.1±1.1	10.0±1.2	0.64	0.8±0.0	0.8±0.0	0.72	36.8±2.1	37.3±2.6	0.25	36.4±2.0	36.9±2.2	0.26	0.99±0.02	0.99± 0.02	0.61
21	10.1±1.2	10.1±1.4	0.85	0.8±0.0	0.8±0.0	0.56	38.5±2.3	38.8±2.3	0.47	37.8±1.9	38.1±2.0	0.39	0.98±0.03	0.98±0.03	0.94
22	10.2±1.2	10.1±1.3	0.69	0.8±0.0	0.8±0.0	0.71	39.6±2.3	39.9±2.2	0.42	39.0±1.9	39.2±1.9	0.74	0.99±0.02	0.98±0.03	0.15
23	10.1±1.2	10.2±1.4	0.71	0.8±0.0	0.8±0.0	0.88	40.5±2.2	40.9±2.2	0.35	40.0±2.0	40.3±1.8	0.36	0.99±0.02	0.99±0.02	0.65
24	10.4±1.3	10.3±1.3	0.70	0.8±0.0	0.8±0.0	0.73	41.3±2.3	41.8±2.3	0.24	40.9±2.2	41.2±1.9	0.43	0.99±0.02	0.99±0.02	0.25

*significant at $p<0.05$

Table 4.4: Anthropometric Characteristics of Participants at Ages 25-36 months (mean ± standard deviation)

Age (months)	weight male	weight female	p-value	height male	height female	p-value	limb length male	limb length female	p-value	trunk length male	trunk length female	p-value	trunk-limb length ratio male	trunk-limb length ratio female	p-value
25	10.5±1.3	10.6±1.4	0.78	0.8±0.0	0.8±0.0	0.44	41.9±2.3	42.5±2.2	0.17	41.6±2.0	42.0±2.0	0.32	0.99±0.02	0.99±0.02	0.16
26	10.8±1.2	10.8±1.4	0.82	0.8±0.0	0.8±0.0	0.46	42.2±2.3	43.0±2.3	0.10	42.0±2.0	42.5±2.0	0.12	0.99±0.01	0.99±0.02	0.37
27	11.0±1.2	11.1±1.3	0.61	0.9±0.0	0.9±0.0	0.61	42.5±2.5	43.5±2.4	0.04	42.2±2.3	43.0±2.1	0.07	1.00±0.02	0.99±0.01	0.14
28	11.2±1.2	11.2±1.3	0.93	0.9±0.0	0.9±0.0	0.32	43.3±2.4	44.0±2.3	0.11	42.8±2.0	43.3±1.9	0.15	0.99±0.02	0.99±0.02	0.35
29	11.2±1.1	11.3±1.2	0.79	0.9±0.0	0.9±0.0	0.33	43.8±2.3	44.5±2.5	0.14	43.3±1.9	43.7±2.1	0.22	0.99±0.02	0.98±0.02	0.29
30	11.3±1.2	11.4±1.3	0.66	0.9±0.0	0.9±0.0	0.24	44.3±2.5	45.2±2.5	0.45	43.6±2.0	44.3±2.1	0.10	0.99±0.02	0.98±0.02	0.13
31	11.4±1.2	11.5±1.3	0.62	0.9±0.0	0.9±0.0	0.29	45.3±2.5	45.8±2.5	0.22	44.3±2.0	44.7±1.9	0.31	0.98±0.02	0.98±0.02	0.34
32	11.6±1.2	11.8±1.3	0.55	0.9±0.0	0.9±0.0	0.39	45.5±2.5	46.2±2.5	0.14	44.8±2.1	45.3±2.0	0.18	0.99±0.02	0.98±0.02	0.49
33	11.6±1.2	11.8±1.3	0.45	0.9±0.0	0.9±0.0	0.46	45.9±2.5	46.5±2.6	0.24	45.3±1.9	45.6±2.1	0.35	0.99±0.02	0.98±0.02	0.31
34	11.7±1.2	11.8±1.4	0.50	0.9±0.0	0.9±0.0	0.59	46.2±2.5	46.8±2.7	0.21	45.6±2.1	46.1±2.2	0.24	0.99±0.02	0.98±0.02	0.51
35	11.9±1.1	12.1±1.3	0.4	0.9±0.0	0.9±0.0	0.47	46.6±2.6	47.4±2.8	0.12	46.3±2.3	46.5±2.2	0.67	0.99±0.02	0.98±0.02	0.00*
36	11.9±1.2	12.1±1.4	0.43	0.9±0.0	0.9±0.0	0.35	47.1±2.7	48.0±2.8	0.11	46.7±2.2	47.1±2.2	0.42	0.99±0.02	0.98±0.02	0.01*

*significant at $p<0.05$

Table 4.5: Inter-rater and Intra-rater Reliability of TFA and ICD/IMD

	Inter-rater		Intra-rater	
	ICC	95% CI	ICC	95% CI
TFA	0.70	0.53-0.83	0.98	0.95-0.99
ICD/IMD	0.96	0.92-0.96	0.99	0.98-1.00

Key: ICC= Intra-class coefficient,
CI= Confidence interval

4.1.3: Pattern of TFA Development

Tibiofemoral Angle related with age is shown in figure 4.2. The children showed maximum varus knee angle at birth. The varus knee angle ranged from 5^0 to 25^0 at birth-3weeks. Majority (80.9%) of the children had TFA value between 10^0 and 15^0. Six participants had extremely low values (5^0-6^0) and 16 children (10.6%) had extremely high values (20^0 - 25^0). The mean varus knee angle during first 3 weeks of life was 13.2 ± 3.8^0 and this fell steeply to 6.7 ± 1.4^0 at 3 months, then more slowly to 5.6 ± 0.7^0 at 9 months. The varus angle rose to 6.3 ± 1.1^0 at 13 months and thereafter decreased until 18 months (0.3 ± 2.1^0) (fig. 4.2). A trimodal analysis showed that at 18 months, majority (65.8%) of the children had neutral knee angle (0^0), 24 (20.0%) children had varus knee angle and 17 (14.2%) children had valgus knee angle (figure 4.3). At 19 months, the TFA of 102 (85%) children had changed to valgus knee angle (figure 4.3). All children had changed to valgus knee angle by age 25 months with few exceptions. Four out of the five children with excessive varus knee angle were found to be unilateral and which corrected spontaneously before 33 months. The mean valgus knee angle rose steadily from -2.4 ± 2.5^0 at 19 months to -8.5 ± 2.5^0 at 27 months and then decreased thereafter (figure 4.2).

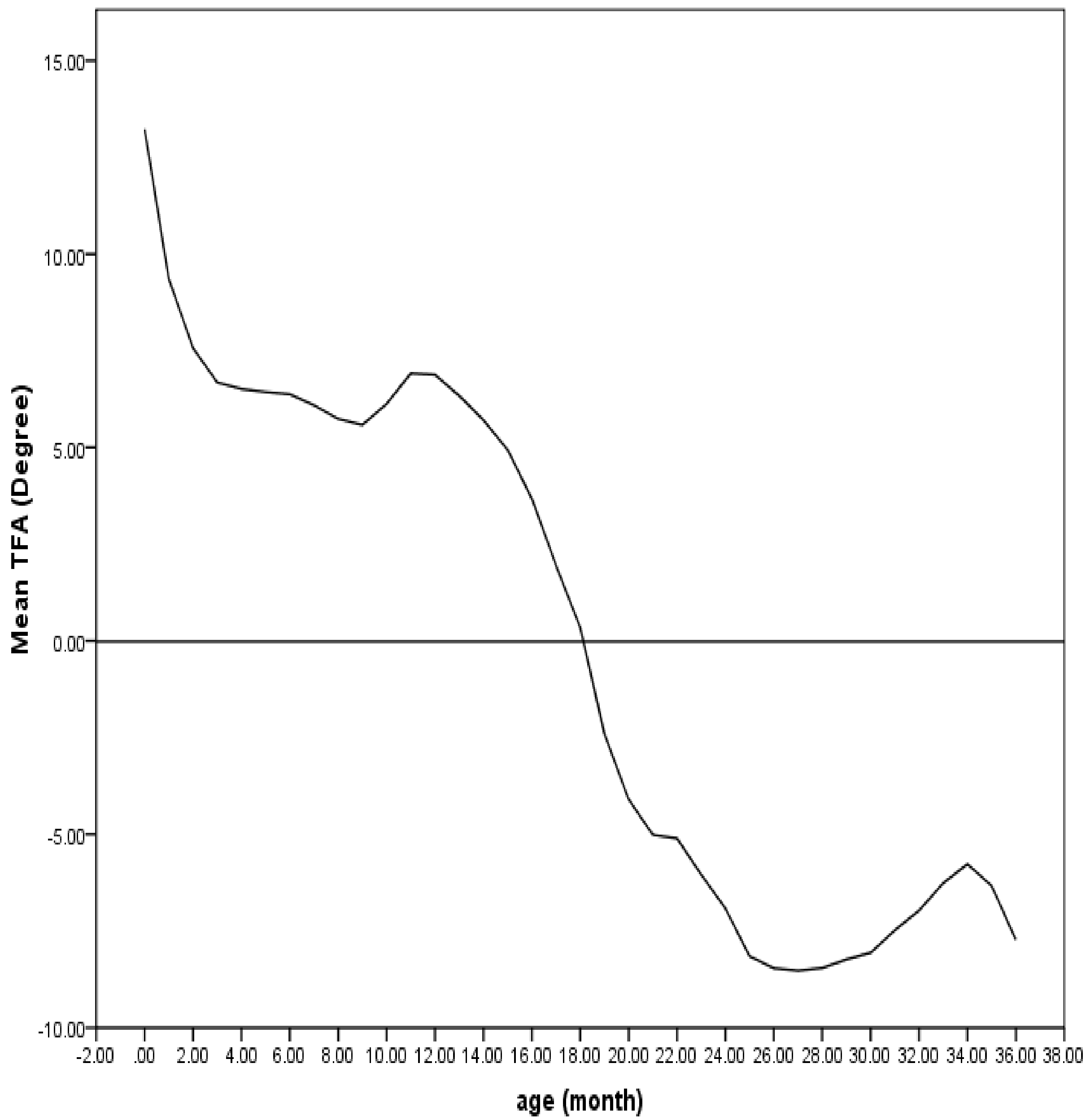

Figure 4.2: Trend inTibiofemoral Angle with Age of the participants

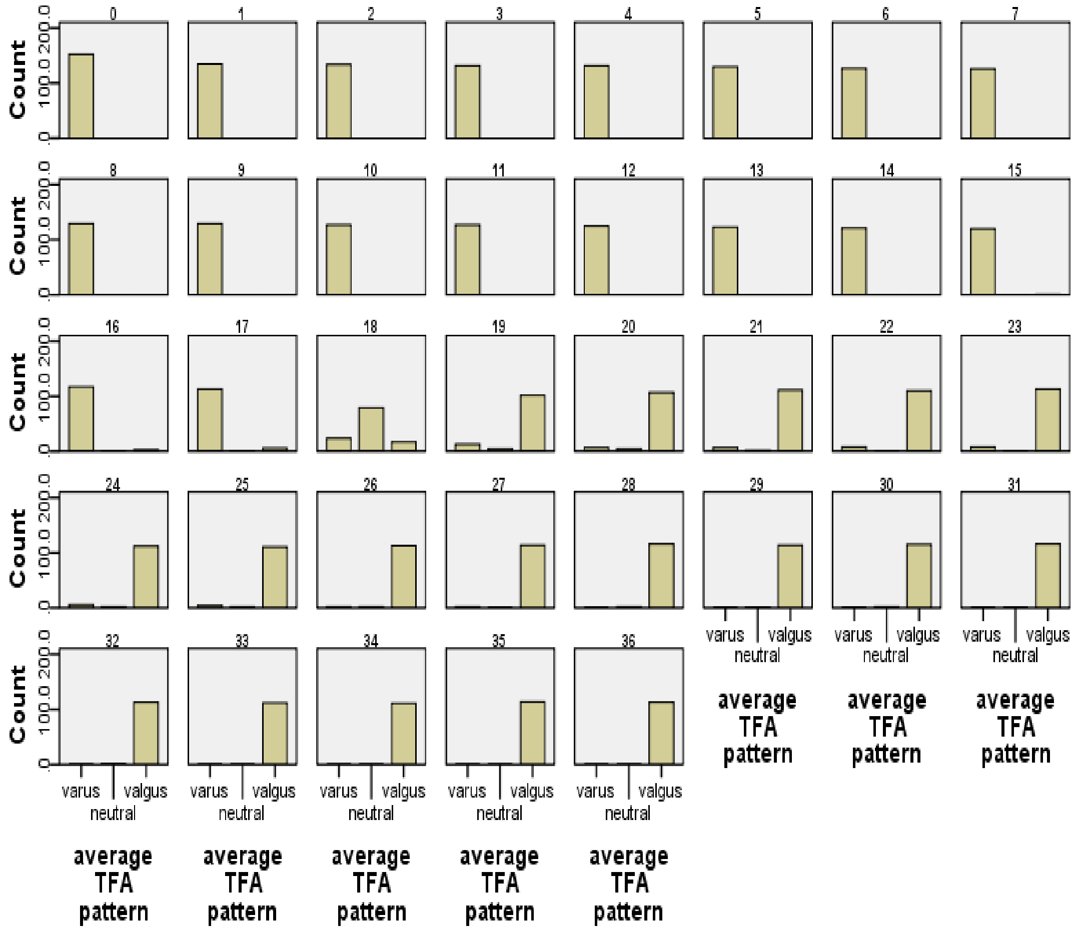

Figure 4.3: Trimodal Pattern of Changes in TFA by Age in Months

Legend:

In ages 0-17 majority of children were varus in their presentation

In ages 18 majority of children were neutral in their presentation

In ages 19-36 majority of children were valgus in their presentation

4.1.4 Pattern of Intercondylar and Intermalleolar Distances (ICD/IMD) Development

Intercondylar/Intermalleolar Distances (ICD/IMD) depicted a course of tibiofemoral angle development similar to that shown by goniometric measurement; from extreme varus knee pattern (ICD) during first three weeks of life (2.5±0.7cm) which reduced gradually to 0.6±0.2cm at age 9 months (Fig.4.4). The ICD slightly rose to 0.8±0.5cm at age 12 months and decreased thereafter to 0.1±0.4cm at age 15 months. A trimodal analysis showed that half of the children (50.4%) had neutral knee pattern (0cm) at age 15 months (Fig. 4.5). At age 16 months, the knee pattern was predominantly valgus, with 60% of the children recording IMD, 16.7% recording ICD (varus pattern) and 23.3% recording 0cm (neutral knee pattern). By age 19 months, the knee pattern in majority of the children (90%) was valgus. The mean IMD rose gradually from -0.1±0.8cm at age 16 months to -2.0±1.5cm at age 29 months, and thereafter decreased to values ranging between -1.6 to -1.9 cm.

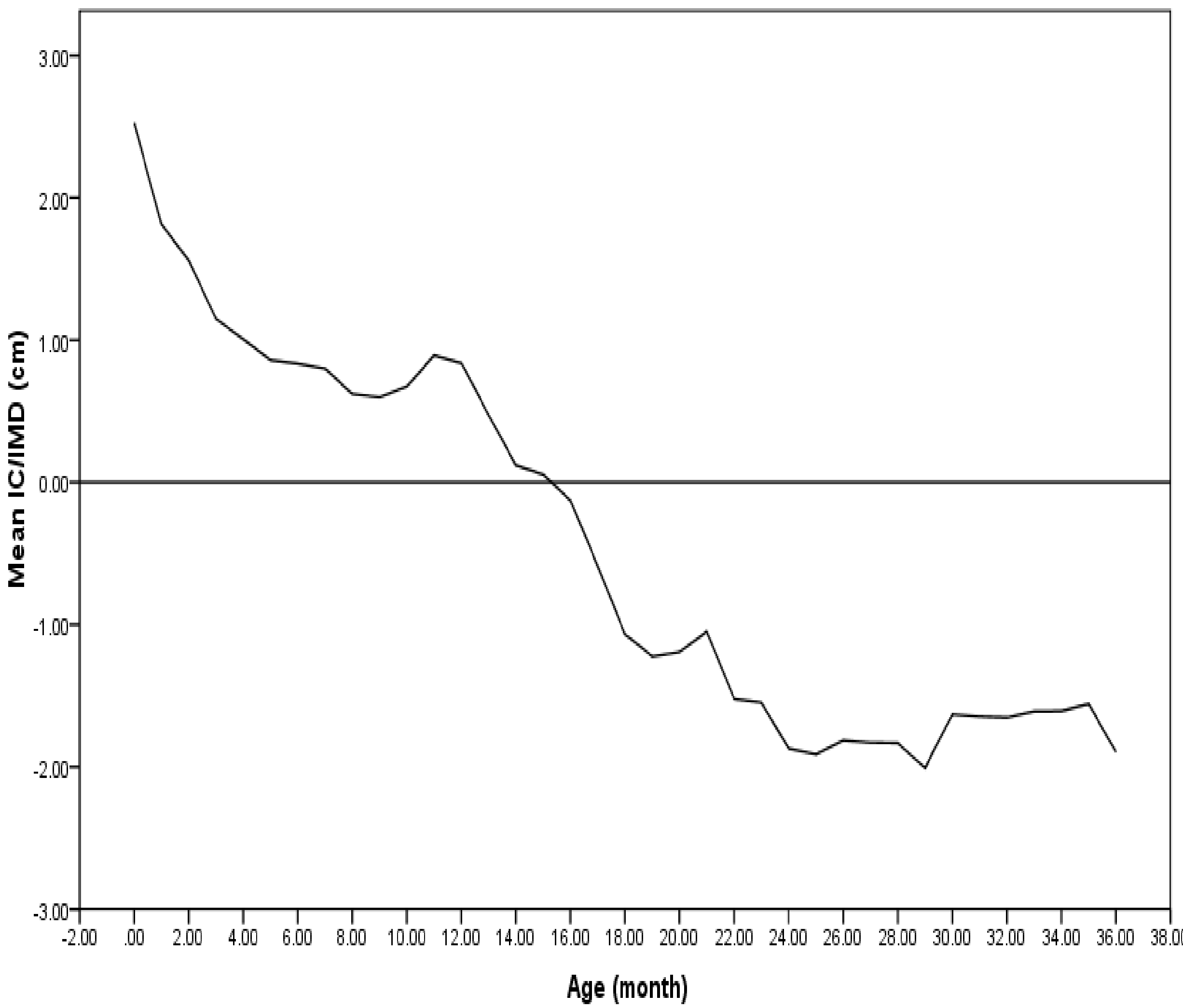

Figure 4.4: Trend in Intercondylar/intermalleolar Distances by Age

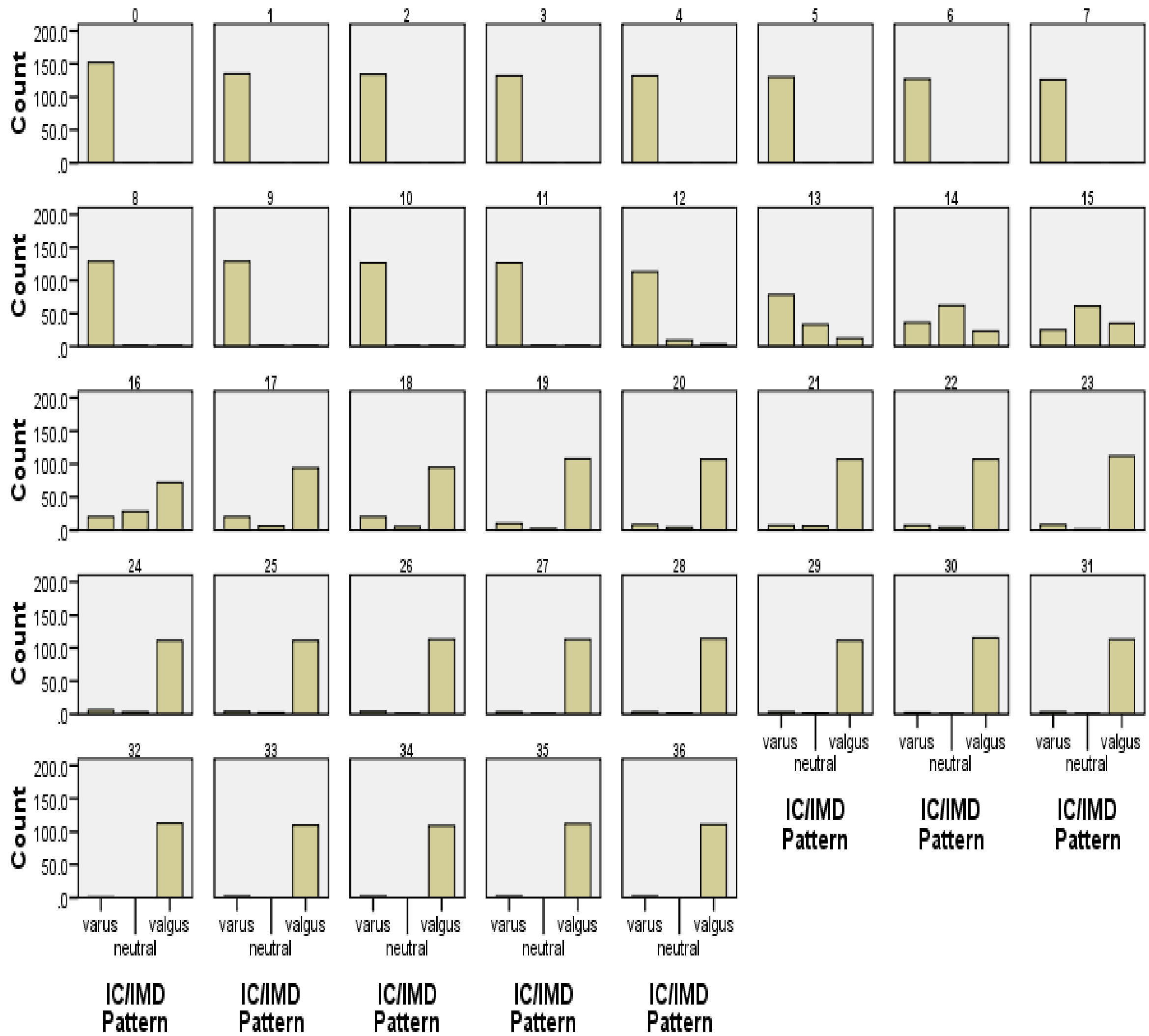

Figure 4.5: Trimodal Pattern of Changes in Intercondylar/Intermalleoli Distances by Age in Months

Legend:

In ages 0-12 majority of children were varus in their presentation

In ages 14-15 majority of children were neutral in their presentation

In ages 16-36 majority of children were valgus in their presentation

4.1.5 TFA and ICD/IMD Developmental Pattern in Male and Female Participants

Tibiofemoral angle related with age by gender was shown in figure 4.6. Boys and girls show similar pattern of development of tibiofemoral angle. An extreme varus knee at birth which tended to neutral (0^0) at 18 months and changed to valgus knee at 19 months then rose thereafter. There was no significant difference in the TFA values of boys and girls during the first three years of life except at the 26th and 29th months when girls (-9.2 ± 2.0^0 and -8.6 ± 2.0^0) had higher values than boys (-7.5 ± 4.1^0 and -7.8 ± 2.5^0).

The ICD/IMD showed similar knee pattern in boys and girls (Fig. 4.7). Extreme varus knee pattern during first three weeks of life, neutral (0cm) at age 15 months and valgus pattern at age 16 months, which increased thereafter. The mean ICM/IMD values differed significantly ($p<0.05$) in the two sexes only in ages 2 to 4, 21 and 26 months, with boys having higher values of ICD at 2- 4 months and girls having higher values at age 21and 26 months.

4.1.6 Right and Left Tibiofemoral Angle Difference in Pattern of Development

There was no significant difference between the right and left tibiofemoral angle patterns of development ($p=0.08$), except at age 0-3 weeks ($p=0.03$) [figure 4.8]. The right and left tibiofemoral angles were highly correlated ($r=0.99$, $p=0.00$) and therefore the average of both were used in the computation for analysis.

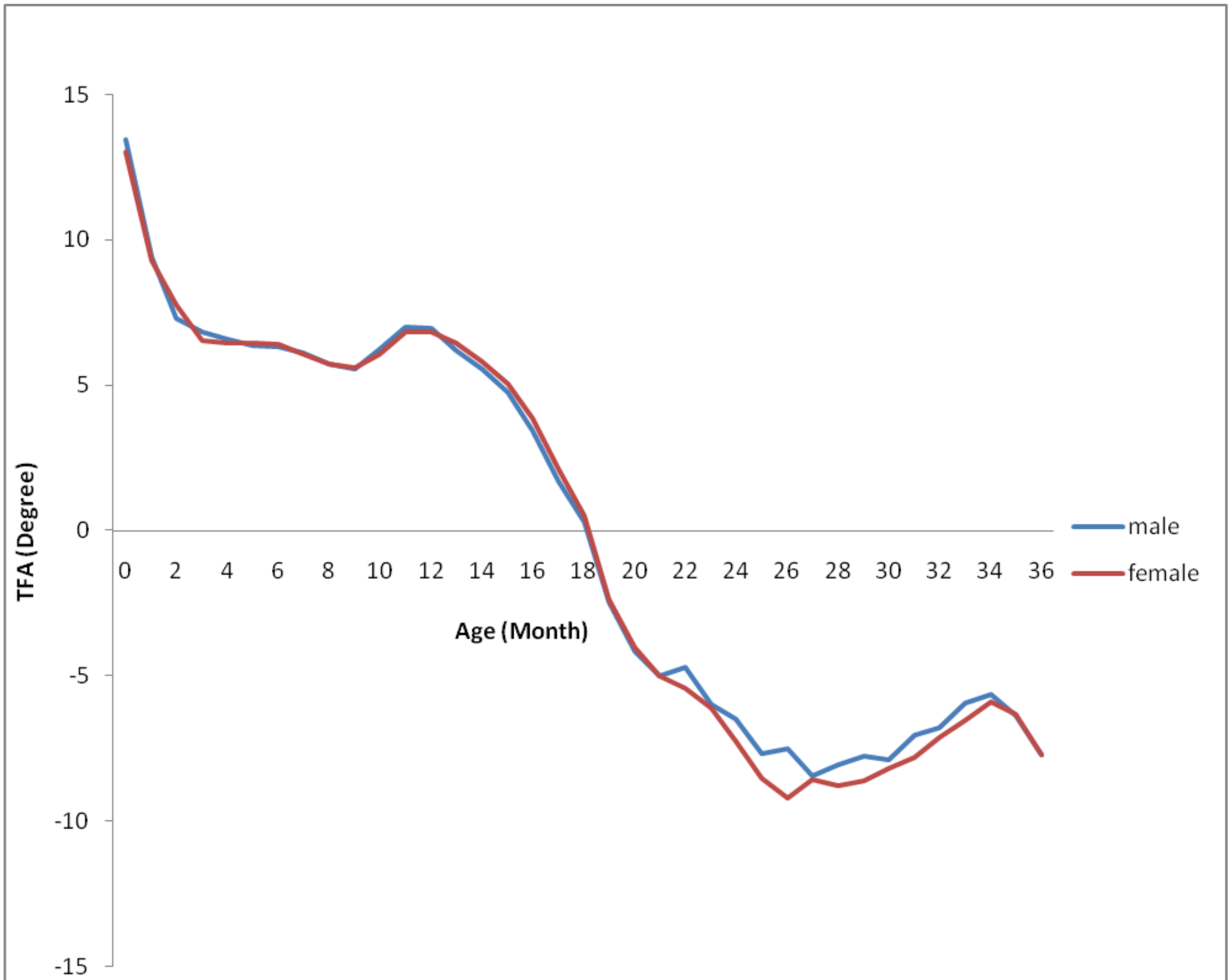

Fig. 4.6:Trend in Tibiofemoral Angle with Age by Gender of the participants

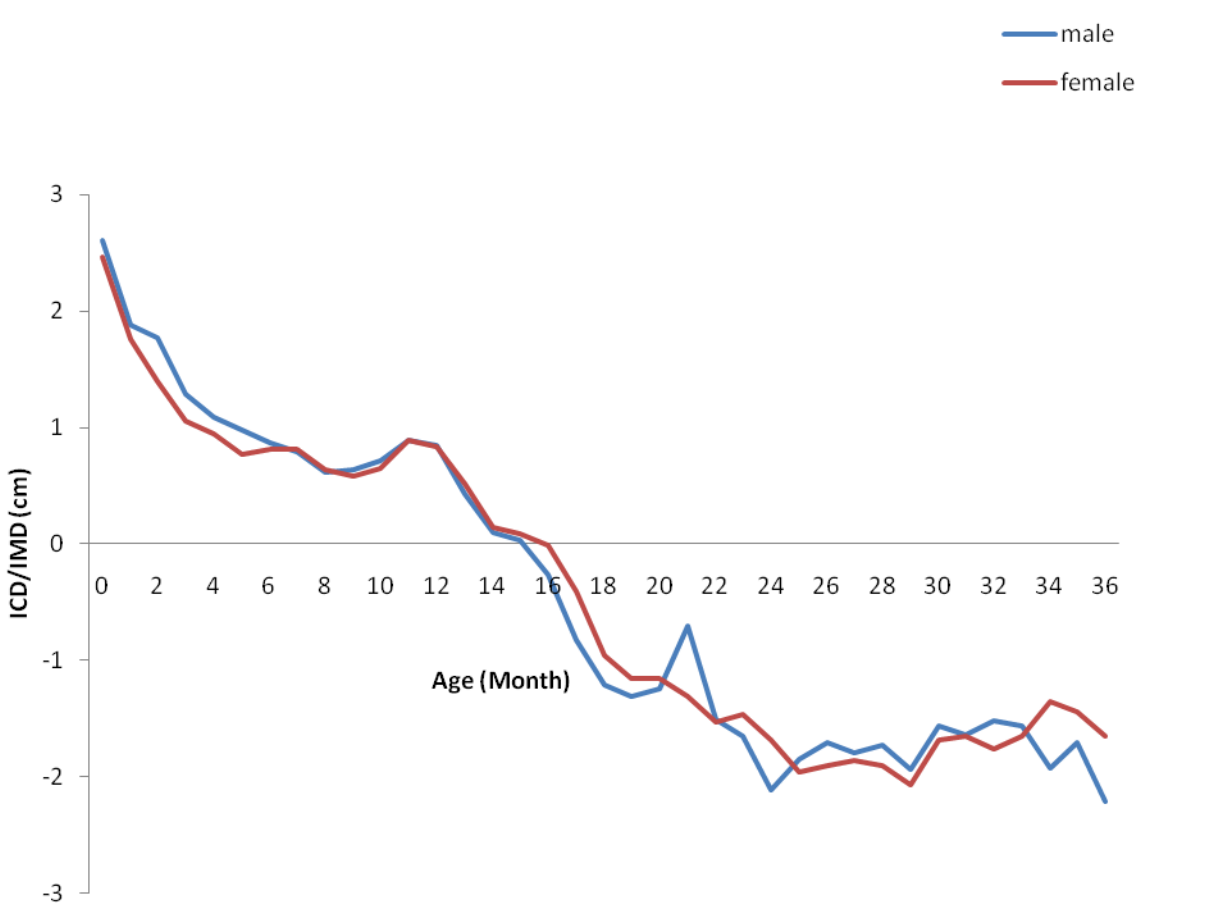

Figure 4.7: Trend in Intercondylar/Intermalleolar Distances with Age by Gender of the participants

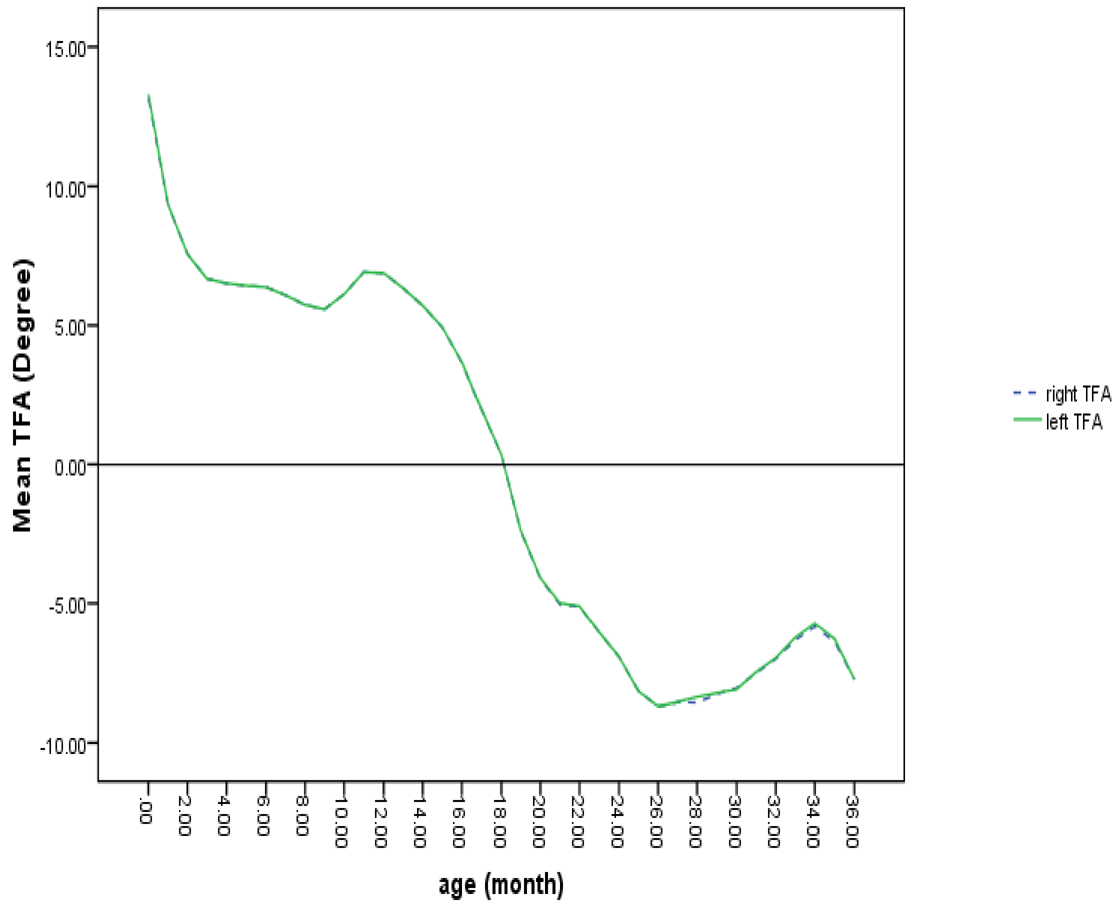

Figure 4.8: Trend in Left and Right Tibiofemoral Angle with Age

4.1.7 Correlation between TFA, ICD/IMD and Anthropometric variables of Participants

There was significant correlation between tibiofemoral angle, intercondylar/intermalleolar distance and anthropometric variables of the participants (Table 4.6-4.8). Trunk to limb length ratio had significant low correlation matrixes with knee angle (TFA and ICD/IMD). The weight, height and limb length had significant high inverse correlation matrixes with intercondylar/intermalleoli distances and tibiofemoral angle with exception of ages 25-36 months. There was also significant high correlation between tibiofemoral angle and intercondylar/intermalleoli distances but low for ages 25-36 months.

4.1.8 Reference Values for TFA and IC/IMD

Table 4.9 shows generated reference values in 3 monthly intervals from this study. Both sexes were combined because there were no gender differences in the values of TFA and ICD/IMD. The mean and 95% confidence intervals (±2SD) were provided because the data was normally distributed.

Table 4.6: Correlation Matrixes between TFA, ICD/IMD and Anthropometric Variables for participants of ages 0-12 months

	Wt	Ht	LL	TL	TLR	ICD/IMD
Ht	0.94**					
LL	0.92**	0.97**				
TL	0.91**	0.96**	0.98**			
TLR	-0.15**	-0.16**	-2.46**	-0.40		
IC/IMD	-0.63**	-0.65**	-0.64**	-0.64**	0.08**	
TFA	-0.58**	-0.59**	-0.55**	-0.54**	0.14**	0.72**

Key:
* *Significant correlation at p = 0.01 (2-tailed)
Wt= weight Ht=height
LL=limb length,
TL= Trunk Length TLR= Trunk Limb Ratio,
IC/IMD= Intercondylar/Intermalleolar Distances,
TFA= Tibio-Femoral Angle

Table 4.7: Correlation Matrixes between TFA, ICD/IMD and Anthropometric Variables for participants of ages 13-24 months

	Wt	Ht	LL	TL	TLR	ICD/IMD
Ht	0.71**					
LL	0.58**	0.91**				
TL	0.60**	0.90**	0.98**			
TLR	-0.13**	-0.35**	-0.48**	-0.30**		
IC/IMD	-0.12**	-0.28**	-0.34**	-0.33**	0.15**	
TFA	-0.29**	-0.58**	-0.72**	-0.71**	0.33**	0.52**

Key:
** Significant correlation at p = 0.01 (2-tailed)
Wt= weight Ht=height
LL=limb length,
TL= Trunk Length TLR= Trunk Limb Ratio,
IC/IMD= Intercondylar/Intermalleolar Distances,
TFA= Tibio-Femoral Angle

Table 4.8: Correlation Matrixes between TFA, ICD/IMD and Anthropometric Variables for participants of ages 25-36 months

	Wt	Ht	LL	TL	TLR	ICD/IMD
Ht	0.78**					
LL	0.74**	0.94**				
TL	0.75**	0.93**	0.95**			
TLR	-0.26**	-0.42**	-0.54**	-0.25**		
IC/IMD	-0.08**	-0.03	-0.03	-0.03	0.03	
TFA	-0.04	0.05	0.02	0.06*	0.12**	0.34**

Key:
** Significant correlation at p = 0.01 (2-tailed)
* Significant correlation at p = 0.05 (2-tailed)
Wt= weight Ht=height
LL=limb length,
TL= Trunk Length TLR= Trunk Limb Ratio,
IC/IMD= Intercondylar/Intermalleolar Distances,
TFA= Tibio-Femoral Angle

Table 4.9: Reference Values for TFA and IC/IMD in 3 Months Interval

	Tibiofemoral Angle (^{0})			ICD/IMD (cm)		
Age(month)	Mean	-2SD	+2SD	Mean	-2SD	+2SD
0-<1	13.2	12.6	13.8	2.5	2.4	2.6
1-3	7.9	7.7	8.1	1.5	145	1.6
4-6	6.4	6.4	6.5	0.9	0.9	0.9
7-9	5.8	5.7	5.9	0.7	0.6	0.7
10-12	6.6	6.5	6.8	0.8	0.8	0.8
13-15	5.7	5.5	5.8	0.2	0.2	0.3
16-18	2.0	1.8	2.2	-0.6	-0.8	-0.4
19-21	-3.8	-4.1	-3.5	-1.2	-1.4	-1.0
22-24	-6.0	-6.4	-5.7	-1.7	-1.8	-1.5
25-27	-8.4	-8.7	-8.1	-1.9	-2.0	-1.7
28-30	-8.3	-8.5	-8.0	-1.8	-2.0	-1.7
31-33	-6.9	-7.1	-6.7	-1.6	-1.8	-1.5
34-36	-6.6	-6.8	-6.4	-1.7	-1.9	-1.5

Key: ICD/IMD=Intercondylar/intermalleoli distances
SD=Standard deviation

4.1.9 Hypothesis Testing

Sub-hypothesis 1

There would be no significant difference in the tibiofemoral angles of male and female children at birth to 3 weeks of life.

Test Statistic: t-test

α-level: 0.05

Observed p-value: 0.50

Judgment: Since the observed p-value was greater than α-level, I failed to reject the hypothesis.

Sub-hypothesis 2

There would be no significant difference in the tibiofemoral angles of male and female children at each of 6, 12, 18, 24, 30 and 36 months of life.

Test Statistic: t-test

α-level: 0.05

Observed p-value: 0.59, 0.61, 0.34, 0.21, 0.46 and 0.97 at ages 6, 12, 18, 24, 30 and 36 months respectively.

Judgment: Since the observed p-values were greater than α-level, I failed to reject the hypothesis.

Sub-hypothesis 3

There would be no significant difference in the intercondylar distance of male and female children at birth to 3 weeks of life.

Test Statistic: t-test

α-level: 0.05

Observed p-value: 0.24

Judgment: Since the observed p-value was greater than α-level, I failed to reject the hypothesis.

Sub-hypothesis 4

There would be no significant difference in the intercondylar distance of male and female children at each of 6, 12 and 18 months of life.

Test Statistic: t-test

α-level: 0.05

Observed p-value: 0.36, 0.91 and 0.35 at ages 6, 12 and 18 months respectively.

Judgment: Since the observed p-values were greater than α-level, I failed to reject the hypothesis.

Sub-hypothesis 5

There would be no significant difference in the intermalleolar distance of male and female children at each of 24, 30 and 36 months of life.

Test Statistic: t-test

α-level: 0.05

Observed p-value: 0.22, 0.43 and 0.04 at ages 24, 30 and 36 respectively.

Judgment: Since the observed p-values were greater than α-level ages 24 and 30 and less at age 36 months, I failed to reject the hypothesis at ages 24 and 30 months and the hypothesis was rejected at age 36 month.

Sub-hypothesis 6

There would be no significant difference between right and left lower limb tibiofemoral angles of male children at birth to 3 weeks of life.

Test Statistic: Paired t-test

α-level: 0.05

Observed P-value: 0.15

Judgment: Since the observed p-value was greater than α-level, I failed to reject the hypothesis.

Sub-hypothesis 7

There would be no significant difference between right and left lower limb tibiofemoral angles of male children at each of 6, 12, 18, 24, 30 and 36 months of life.

Test Statistic: Paired t-test

α-level: 0.05

Observed p-value: 0.32, 1.00, 1.00, 0.79, 0.17 and 0.36 at ages 6, 12, 18, 24, 30 and 36 months respectively.

Judgment: Since the observed p-values were greater than α-level, I failed to reject the hypothesis.

Sub-hypothesis 8

There would be no significant difference between right and left lower limb tibiofemoral angles of female children at birth to 3 weeks of life.

Test Statistic: Paired t-test

α-level: 0.05

Observed p-value: 0.10

Judgment: Since the observed p-value was greater than α-level, I failed to reject the hypothesis.

Sub-hypothesis 9

There would be no significant difference between right and left lower limb tibiofemoral angles of female children at each of 6, 12, 18, 24, 30 and 36 months of life.

Test Statistic: Paired t-test

α-level: 0.05

Observed p-value: 1.00, 1.00, 0.32, 1.00, 0.32 and 0.32 at ages 6, 12, 18, 24, 30 and 36 months respectively.

Judgment: Since the observed p-values were greater than α-level, I failed to reject the hypothesis.

Sub-hypothesis 10

There would be no significant relationship between limb length and tibiofemoral angle of children at birth to 3 weeks of life.

Test Statistic: Pearson's moment correlation α-level: 0.05

Observed p-value: 0.98

Judgment: Since the observed p-value was greater than α-level, I failed to reject the hypothesis.

Sub-hypothesis 11

There would be no significant relationship between limb length and tibiofemoral angle of children at each of 6, 12, 18, 24, 30 and 36 months of life.

Test Statistic: Pearson's moment correlation

α-level: 0.05

Observed p-value: 0.39, 0.06, 0.85, 0.34, 0.05 and 0.01 at ages 6, 12, 18, 24, 30 and 36 months respectively.

Judgment: Since the observed p-values were greater than α-level ages 6-24 and less at ages 30 and 36 months, the hypothesis was rejected at ages 30 and 36 months and I failed to reject the hypothesis at ages 6-24 months.

Sub-hypothesis 12

There would be no significant relationship between trunk-limb length ratio and tibiofemoral angle of children at birth to 3 weeks of life.

Test Statistic: Pearson's moment correlation

α-level: 0.05

Observed p-value: 0.11

Judgment: Since the observed p-value was greater than α-level, I failed to reject the hypothesis.

Sub-hypothesis 13

There would be no significant relationship between trunk-limb length ratio and tibiofemoral angle of children at each of 6, 12, 18, 24, 30 and 36 months of life.

Test Statistic: Pearson's moment correlation

α-level: 0.05

Observed p-value: 0.29, 0.93, 0.11, 0.53, 0.01 and 0.09 at ages 6, 12, 18, 24, 30 and 36 months respectively.

Judgment: Since the observed p-values were greater than α-level at ages 6-24 and 36 but less for age 30 month, the hypothesis was rejected for age 30 month and I failed to reject the hypothesis for ages 6-24 and 36 months.

Sub-hypothesis 14

There would be no significant relationship between trunk length and tibiofemoral angle of children at birth to 3 weeks of life.

Test Statistic: Pearson's moment correlation

α-level: 0.05

Observed p-value: 0.14

Judgment: Since the observed p-value was greater than α-level, I failed to reject the hypothesis.

Sub-hypothesis 15

There would be no significant relationship between trunk length and tibiofemoral angle of children at each of 6, 12, 18, 24, 30 and 36 months of life.

Test Statistic: Pearson's moment correlation

α-level: 0.05

Observed p-value: 0.74, 0.03, 0.48, 0.42, 0.24, and 0.01 at ages of 6, 12, 18, 24, 30 and 36 months respectively.

Judgment: Since the observed p-values were greater than α-level at ages 6 and 18-30 months but less at ages 12 and 36 months, the hypothesis was rejected at ages 12 and 36 months and I failed to reject the hypothesis at ages 6 and 18-30 months.

Sub-hypothesis 16

There would be no significant relationship between body weight and tibiofemoral angle of children at birth to 3 weeks of life.

Test Statistic: Pearson's moment correlation

α-level: 0.05

Observed p-value: 0.15

Judgment: Since the observed p-value was greater than α-level, I failed to reject the hypothesis.

Sub-hypothesis 17

There would be no significant relationship between body weight and tibiofemoral angle of children at each of 6, 12, 18, 24, 30 and 36 months of life.

Test Statistic: Pearson's moment correlation

α-level: 0.05

Observed p-value: 1.00, 0.01, 0.01, 0.96, 0.20 and 0.09 at ages 6, 12, 18, 24, 30 and 36 months respectively.

Judgment: Since the observed p-values were greater than α-level at ages 6 and 24-36 months but less at ages 12-18 months, the hypothesis was rejected at ages 12-18 months and I failed to reject the hypothesis at ages 6 and 24-36 months.

Sub-hypothesis 18

There would be no significant relationship between body height and tibiofemoral angle of children at birth to 3 weeks of life.

Test Statistic: Pearson's moment correlation

α-level: 0.05

Observed P-value: 0.77

Judgment: Since the observed p-value was greater than α-level, I failed to reject the hypothesis.

Sub-hypothesis 19

There would be no significant relationship between body height and tibiofemoral angle of children at each of 6, 12, 18, 24, 30 and 36 months of life.

Test Statistic: Pearson's moment correlation

α-level: 0.05

Observed p-value: 0.81, 0.03, 0.26, 1.00, 0.08 and 0.01 at ages 6, 12, 18, 24, 30 and 36 months respectively.

Judgment: Since the observed p-values were greater than α-level at ages 6 and 18-30 months but less at ages 12 and 36 months, the hypothesis was rejected at ages 12 and 36 months and I failed to reject the hypothesis at ages 6 and 18-30 months.

Sub-hypothesis 20

There would be no significant relationship between intercondylar/intermalleolar distances and tibiofemoral angle of children at birth to 3 weeks of life.

Test Statistic: Pearson's moment correlation

α-level: 0.05

Observed P-value: 0.01

Judgment: Since the observed p-value was less than α-level, the hypothesis was rejected.

Sub-hypothesis 21

There would be no significant relationship between intercondylar/intermalleolar distances and tibiofemoral angle of children at each of 6, 12, 18, 24, 30 and 36 months of life.

Test Statistic: Pearson's moment correlation

α-level: 0.05

Observed p-value: 0.01 in all ages

Judgment: Since the observed p-values were less than α-level in all ages, the hypothesis was rejected.

4.2 Discussion

4.2.1 Inter-rater and Intra-rater Reliability of TFA and ICD/IMD

The intra-class correlation coefficients of 0.70-0.99 provide evidence that goniometric measurement and intercondylar/intermalleolar distance are reliable. Previous studies have also documented the reliability of clinical measurement of knee angle (Cheng et al, 1991; Shultz et al, 2006; Yoo et al, 2008). This suggests that the knee angle can be assessed in day to day clinical routine using these clinical methods.

4.2.2 Pattern of Tibiofemoral Angle Development

The finding that majority of the children in this study recorded highest value of TFA at birth to three weeks of life suggests that most Nigerian children are born with extreme varus knee angle. This finding is similar to the reports of previous studies (Salenius and Vankka, 1975; Heath and Staheli, 1993; Oginni et al, 2004). None of the 152 infants involved in this study presented a valgus knee angle before age 15 months, suggesting that a measurable valgus knee angle in a Nigerian child before age 15 months may be regarded as abnormal.

Results of this study showed that in most of the children, the initial varus knee angle became predominantly neutral (0^0) at age 18 months and valgus by age 19 months. The valgus angle continued to increase from the 20th month till the 36th month. Although the majority of the children in the present study are Yorubas, the other major tribes in the country were also represented. It is hence likely that if this study were conducted in other parts of the country, the same findings will be obtained. The age of transition from varus to valgus angle in this study, (18-19 months) is lower than the age (21-23 months) reported for Nigerian children by Oginni et al, (2004). The difference in the two studies could be due to the methods of TFA measurement; Oginni et al, (2004) used mainly photographic method while this study used goniometric method. It could also be due to the fact that in the study by Oginni et al, (2004) measurement was taken once whereas in this longitudinal study, repeated measurements were taken. The age of transition from varus to valgus obtained in this study also differed from that (12-24 months) reported by Qureshi et al, (2000a) for Pakistani children.

The present study corroborates previous studies that reported neutral knee angle at age 18 months (Salenius and Vankka, 1975; Heath and Staheli, 1993; Yoo et al, 2008). Ten of the 18 children whose knee angle remained varus or neutral at 19 months had family history of genu varus deformity. The outcomes of this study indicate that the TFA developmental pattern in Nigerian children may be described in three phases: phase 1 (birth to 15 months) or phase of varus angle; phase 2, (16-19 months) or phase of transition from varus to valgus angle and phase 3 (20-36 months) or phase of increasing valgus. The average age at which independent walking was attained in this study was 12 months which is much earlier than the age of knee angle transition from varus to valgus. This finding agrees with the report of Oginni et al (2004). The data in the present study suggest that having an extremely low or high value of TFA at birth does not determine the TFA value at 12 months, the average age of independent walking. In fact, none of those children with extremely low or high value of TFA values at birth demonstrated extremely low or high values at the age of 12 months.

The mean value of TFA at birth-3weeks (13.2^o) in the present study was slightly higher than that reported for Korean infants (12^o) but less than that of Finish infants (16.5^o) [Salenius and Vankka, 1975; Yoo et al, 2008]. It was also less than 15.9^o reported for American children but higher than 10^o reported earlier for Nigerian and Pakistani (10.01^o) children at age 6 months (Heath and Staheli, 1993; Qureshi et al, 2000a; Oginni et al, 2004). The slight differences might be due to the way the data were presented in the present and previous studies. This study presented the data at monthly intervals while some of the previous studies presented it at 6- monthly intervals. The slight rise in the values of TFA at age 10 months is noteworthy. Many of these children have started dependent walking around this age. It has been suggested that duration of period of dependent walking correlates with knee angle in children (Lin et al, 1999).

The finding that the age of peak valgus knee angle during the study period (3years) was 27 months is similar to the age (36 months) reported by previous studies from Nigeria (Oginni et al, 2004), China (Cheng et al, 1991) and Saudi (Abdel Rahman and Badahdah, 2011). Nigerian children had earlier peak valgus angle than Indian (6 years), American (4 years) and Korean (4 years) children. The peak valgus knee angle (8.5^0) was similar at these ages (Heath and Staheli, 1993; Yoo et al, 2008; Saini et al, 2010). Although the use of different techniques to estimate the knee angles might be responsible for variations in observations in different studies, it is more likely that these variations are possibly due to the ethnic and racial differences that might exist in different population groups.

4.2.3 Pattern of Intercondylar and Intermalleolar Distances (ICD/IMD) Development

Measurement of intercondylar/intermalleolar distances showed a similar pattern of development to that of goniometry measurement in children from extreme varus knee at birth which decreases with age until 15 months in the present study. By 16 months children have predominantly valgus knee angle and the varus knee angle does not disappear in the population until 19 months. Seven out of the 12 children that remained varus or neutral knee angled had family history of genu varus. Similar pattern was also reported by previous studies (Heath and Staheli, 1993; Qureshi et al, 2000b; Ezeuko et al, 2010).

Few previous studies that measured ICD/IMD reported values for age groups rather than specific ages (Heath and Staheli, 1993; Qureshi et al, 2000b). This makes it difficult to compare values from previous studies with the mean values for specific ages in this present study. However, the mean ICD value (2.5cm) at birth in this study was similar to that of American children (2.6cm) and Pakistan children (2.96cm) at 6 months (Heath and Staheli, 1993; Qureshi et al, 2000b). The mean ICD value at 6 months (0.83 cm) in the present study is lower than that of these previous studies (Heath and Staheli, 1993; Qureshi et al, 2000b). This difference in the observed values may be due to racial differences.

All the new born had varus knee angle with mean intercondylar distance of 2.5 cm ranging from 0.5cm to 4.0 cm, decreasing to mean of 0.1 cm at 15 months. This was similar to that of Chinese children who had maximum varus knee at birth (3.0 cm) ranging from 0 to 5.5 cm and decreasing to 0 cm at age 12 months (Cheng et al, 1991). In Nigerian children, the medial condyles touch late (15 months) compares with Chinese and American children (12 months). In the present study, the children had peak valgus knee angle (-2.0 cm) at age 29 months which was similar to that of Chinese (-2.8 cm), American (-3.5) and Pakistanis (-3.96 cm) children but Nigerian children peak earlier (Cheng et al, 1991; Heath and Staheli, 1993; Qureshi et al, 2000b).

4.2.4 Difference in TFA and ICD/IMD Developmental Pattern and Values of Male and Female Children

Significant sex differences were not found in the present study in the values of tibiofemoral angle; though, the boys presented with higher values (p=0.88). This may imply that the same reference can be used for both sexes. This observation was similar to previous reports which reported no sex difference in knee angle of children less than 4 years (Heath and Staheli, 1993; Qureshi et al, 2000a; Oginni et al, 2004; Abdel Rahman and Badahdah, 2011). However, in adolescence sex differences in the values of TFA have been reported (Cahuzac et al, 1995; Arazi et al, 2001; Tella et al, 2010).

The pattern of ICD/IMD development and values was the same in the entire sample (p=0.88) which was similar to the finding of Heshmatipour and Karimi, (2011). The implication of this is that the same reference values may be used for both genders when assessing the knee angle of children. However, when stratified by age, values of ICD/IMD were significantly different between sexes in five ages (2-4, 21 and 26 months) with boys having higher values of ICD at 2- 4 months and girls having higher values at age 21and 26 months. This was in agreement with previous studies which found difference in certain age groups (Cheng et al, 1991; Fakoor et al, 2011). The differences in values of ICD at these ages might be due to fact that boys are generally thinner between ages two to four and bigger between age 21-26 months than girls. The ICD/IMD measurements had been shown to be influenced by body fat (Wright and Feinstein, 1992).

4.2.5 Right and Left Limb Tibiofemoral Angle Difference in Pattern of Development and Values

The values of right and left TFA and pattern of development ware identical in the whole population. Even at age zero months that shows marginal difference between right and left TFA was highly correlated with each other. This may imply that both limbs develop at the same rate in the pattern and values of knee angle. Thus, any obvious discrepancy that may be observed between the limbs may be pathological. The same observation of non-significant difference between the limbs TFA pattern and values for younger children had been reported for Nigerian children (Oginni et al, 2004).

4.2.6 Tibiofemoral Angle and Anthropometrics Variables

Significant correlations between anthropometric variables and knee angle (TFA and ICD/IMD) were observed in the present study at ages 0-24 months. The correlations of knee angle with height, weight and other anthropometrics in the youngest infants may be probably due to correlation with age: height, weight, and knee angle are all changing rapidly with age in this cohort. This observation was in agreement with previous studies (Arazi et al, 2001; Oginni et al, 2004). However, some studies observed no significant correlation between knee angle and anthropometric variables (Cahuzac et al, 1995; Saini et al, 2010).

A high degree of correlation between intercondylar/intermalleolar distances and tibiofemoral angle, with a Pearson correlation coefficient for boys of r = 0.74, and for girls of r = 0.79 was similar to observations from previous studies (Cheng et al, 1991; Cahuzac et al, 1995; Qureshi et al, 2000a; Arazi et al, 2001; Saini et al, 2010). This interesting correlation indicates that either of these two measurements can be used to document the status and monitor the progress of the patient. However, there is controversy about which clinical measurement is more accurate and easier for routine physical examination to evaluate the knee angle in children. Cheng et al, (1991) noted that the ICD/IMD measurement is easier to apply clinically and is as reliable. Qureshi et al, (2000a) reported that both methods were reliable because of high correlation between the TFA and ICD/IMD. Conversely, Cahuzac et al, (1995) reported that the TFA measurement is more accurate than distance measurement because the standard deviation of the ICD/IMD is greater than the mean values; while Arazi et al, (2001) shared the same opinion because of observed difficulties about regarding the positioning of the subjects, when the distance measurement was performed. Results from this study suggested that both clinical measurements (TFA and ICD/IMD) were reliable because the two methods demonstrated high correlation between each other.

4.2.7 Reference Values for TFA and ICD/IMD

The age-reference values established in the present study are of increase importance in providing practical screening for Nigerian children. Such screening may influence decisions regarding the necessity for further clinical and/or radiological assessment to rule out or look for bone diseases. The age-reference values may help the surgeon to decide more confidently about the wait and watch policy for the knee angle to correct spontaneously or to more appropriately select the time and type of surgery. It may also guide surgeons, physiotherapists and other clinicians to identify children that would require screening for pathological conditions such as Blount's disease. Moreover, a relevant and correct understanding of the development of the knee angle and limb alignment would prevent unreasonable apprehension by parents and relatives.

CHAPTER FIVE

SUMMARY, CONCLUSION AND RECOMMENDATIONS

5.1 SUMMARY

The purpose of this study was: to determine the pattern of presentation of tibiofemoral angle, the age of transition from initial presentation of tibiofemoral angle to the other type, the values of tibiofemoral angle, to compare pattern and values of tibiofemoral angle of male and female children, and to determine the relationship between anthropometric variables (weight, height, body mass index, limb and trunk length) intercondylar/intermalleoli distances and tibiofemoral angle of children during the first 3 years of life time. This is sequel to an observation that racial differences exist in developmental pattern of tibiofemoral angle (TFA) in children and that a cohort measurement of TFA is more meaningful and reliable than a cross-sectional survey in such study. In addition, previous studies from Nigeria could not state the specific age of transition from one pattern of TFA development to the other being cross-sectional in nature. The present study was initiated with the aim of bridging this gap of knowledge.

The development of the tibiofemoral angle in Caucasian children follows a certain pattern, in which there is first a pronounced varus knee in newborn infants and subsequently an extreme valgus knee position (Salenius and Vankka, 1975). This pattern of the tibiofemoral angle is one of considerable genu varus or bowing at birth, approximately 15 degrees. There is gradual spontaneous correction to zero degrees at one and one-half to two years of age. During the next year, a valgus knee of 10 degrees to 12 degrees develops which gradually corrects to the normal adult value of 5 to 6 degrees valgus at about age seven years. This process is identical in boys and girls

(Salenius and Vankka, 1975; Heath and Staheli, 1993). Children from some other nations such as Korea, Pakistan, and Nigeria follow similar pattern of tibiofemoral development with little variations in values and time of change over from one type to the other (Qureshi et al, 2000a; Oginni et al, 2004; Yoo et al, 2008). However, significant differences between Chinese children and children of other races were reported in their pattern of tibiofemoral angle (Cheng et al, 1991).

A longitudinal survey research design was used in this study. Consecutive sample of 152 healthy children without any obvious congenital deformities were recruited at birth or within three weeks of life from three infant welfare clinics in Sagamu local government area. Their TFA, intercondylar and intermalleoli distances and anthropometric variables were measured at contact and at monthly intervals until three years of age. Descriptive statistics of mean, standard deviation, time series graph; inferential statistics of t-test and Pearson's correlation were used to analyze the data.

The results from 4528 TFA measurements revealed that the children had extreme varus knee angle (13.2 ± 3.8^0) at birth which approached neutral (0^0) at age 18 months and changed to valgus knee angle (-2.4 ± 2.5^0) at 19 months and the valgus knee angle increased until age 27 months (-8.5 ± 2.5^0) which decreased thereafter. Measurement of intercondylar/intermalleoli distances (IC/IMD) showed a similar course of development from maximum varus knee at birth (2.5±0.7cm) which decreased thereafter to 0.1±0.4cm at age 15 months. At age 16 months, the children had predominantly valgus knee pattern (60%) with few remaining as varus knee (16.7%) and neutral (23.3%).

Ninety percent of children had changed to valgus knee pattern by age 19 months. The mean valgus ICD/IMD rose gradually from -0.1±0.8cm at age 16 months to -2.0±1.5cm at age 29 month, then decreases with values ranged between -1.6 to -1.9 cm. There was no significant gender difference observed in the whole population in both TFA and ICD/IMD pattern of development. There were significant correlations between TFA, ICD/IMD and anthropometric variables of the participants.

These findings are similar to findings from earlier studies from Nigeria and other parts of the world (Salenius and Vankka, 1975; Heath and Staheli, 1993; Qureshi et al, 2000a; Oginni et al, 2004; Yoo et al, 2008). Despite the various methods used in measuring TFA (i.e. radiographic, photographic, goniometric and distance measurements), all these studies agreed on the chronological pattern of knee angle (i.e. varus at birth, neutral at 18-23 months and changed to valgus at 19-23 months) in infancy and early childhood (Salenius and Vankka, 1975; Heath and Staheli, 1993; Qureshi et al, 2000; Oginni et al, 2004; Yoo et al, 2008). In the light of agreement of all these methods using various methods in assessing TFA pattern, clinical method should be an option over radiological methods to avoid unnecessary exposure to radiation. The influence of walking on transition from varus to valgus angle pattern is interesting in the present study. The children in the present study started walking at mean age of 12 months. It has been suggested that early walker children tend to changed from varus knee angle to valgus knee angle pattern earlier than late walker children because the related femoral bicondylar angle does not develop to the normal valgus condition in non-walking children (Lin et al, 1999, Oginni et al, 2004).

The mean value of TFA at birth (13.2^o) in the present study was slightly higher than that reported for Korean infants (12^o) but less than that of Finish infants (16.5^o) [Salenius and Vankka, 1975; Yoo et al, 2008]. It was also less than 15.9^o reported for American children but higher than 10^o reported earlier for Nigerian and Pakistani (10.01^o) children at age 6 months (Heath and Staheli, 1993; Qureshi et al, 2000a; Oginni et al, 2004). The slight differences may be due to the way the data were presented in each study (this study presented the data in at monthly intervals while some of the previous studies presented it in at 6 months intervals) or rather to racial variation. The slight rise in the values of TFA at age 10 months is note worthy. Many of these children have started dependent walking around this age. It has been suggested that duration of period of dependent walking is correlated with knee angle in children (Lin et al, 1999). The data in the present study suggest that having an extremely low or high value of TFA at birth does not determine the TFA value at age 12 months. In fact, none of those children with extremely low or high value of TFA values at birth demonstrated extremely low or high values at age 12 months. The peak mean valgus at 27 months (-8.5^0) in the present study was similar to previous study from Nigeria (-7.1) by Oginni et al, 2004 and to that of Chinese (-8^0) and Saudi (-9.5^0) children at age 3years (Cheng et al, 1991; Abdel Rahman and Badahdah, 2011). The Indian (-8^0), American (-8^0) and Korean (-7.8^0) children (at ages 4 and 6 years) have similar peak valgus knee angle but Nigerian children peak earlier than children from these nations (Heath and Staheli, 1993; Yoo et al, 2008; Saini et al, 2010). Although the use of different techniques to estimate the knee angles might be responsible for variations in observations in different studies, it is more likely that these variations are possibly due to the ethnical and racial differences that might exist in different population groups.

5.2 CONCLUSIONS

The following specific conclusions were drawn from the findings of the study:

1. The chronological development of the TFA in a cohort of Nigerian infants is maximal varus knee angle at birth, neutral at 18months, and valgus knee angle at 19 months, increasing till age 36 months.
2. Measurable valgus knee angle before 15 months may be considered as abnormal.
3. Sex or side of lower limb has no influence on the pattern and values of tibiofemoral angle.
4. There are significant relationship between tibiofemoral angle, intercondylar/intermalleoli distances and anthropometric variables.

5.3 RECOMMENDATIONS

1. The age-referenced values generated in this study are recommended for practical evaluation of Nigerian children when evaluating lower limb alignment.
2. It is recommended that this study be replicated in other zones of Nigeria.

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Appendix A

INFORMED CONSENT

Title of Research: Developmental Pattern of Tibiofemoral Angle in Nigerian Children during the First 3 Years of Life.

This study is being conducted by Mr. Oyewole O.O, a Physiotherapist of the Olabisi Onabanjo University Teaching Hospital, Sagamu and postgraduate student of the University of Ibadan. The purpose of this research is to establish pattern of tibiofemoral angle in Nigerian children.

A total number of 120 children are expected to be recruited for this study. Each child will be required to come to the research centre once a month where some measurement including your child's weight, height, tibiofemoral angle, limb length, trunk length, intermalleoli and intercondyli distances will be measured with weighing scale, infantometer, goniometer and tape measure respectively. In total, I expect your child to be involved in this research for 3 years. Your child should not spend more than 45 minutes at each research centre visit. You are assured of no harm, injury or violation of any kind to your child during the process of measurements. All information collected in this study will be given code number and no name will be recorded. This cannot be linked to your child in anyway and your child's name or any identifier will not be used in any publication or reports from this study. Your child participation in this research is entirely voluntary. You will be compensated for lost wages; cost of transport to and from the research site but you will not be paid any fee for your child's participation in this research.

You can also choose to withdraw your child from the research at anytime. Please note that some of the information that has been obtained about your child before you chose to withdraw may have been modified or used in reports and publications. These cannot be removed anymore. However the researcher promise to make good faith effort to comply with your wishes as much as is practicable. During the course of this research, you will be informed about any information that may affect your child continued participation or your child health. I will greatly appreciate your help in allowing your child to take part in this study.

Statement of person obtaining informed consent

I have fully explained this research to…………………………………………………………….

and have given sufficient information, including about risk and benefit, to make an informed decision.

DATE……………………….

SIGNATURE……………………………….

NAME………………………………………………………….

Statement of person giving consent

I have read the description of the research or have had it translated into language I understand. I have also talked it over with the researcher to my satisfaction. I understand that my child's participation is voluntary. I know enough about the purpose, methods, risks and benefits of the research study to judge that I want my child to take part in it. I understand that I may freely stop my child being part of this study at any time. I have received a copy of this consent form and additional information sheet to keep for myself.

DATE…………………………

SIGNATURE…………………………………..

NAME……………………………………………………

Detailed contact information including contact address, telephone, fax, e-mail and other contact information of the researcher(s), institutional HREC and the head of the institution

This research has been approved by the Ethics Committee of the University of Ibadan and Olabisi Onabanjo University Teaching Hospital and the chairman of these committees can be contacted at BIODE Building, 2nd Floor, Room T10,Institute for Advanced Medical Research and Training, College of Medicine, University of Ibadan, EXT: 2451,E-Mail: uiuchirc@yahoo.com and Medicine department, OACHS, Olabisi Onabanjo University, Sagamu, E-mail: yomiogun2002@yahoo.com respectively.

In addition, if you have any question about your participation in this research you can contact the principal investigator, Mr. Oyewole OO at his office in Physiotherapy department, Olabisi Onabanjo University Teaching Hospital, Sagamu, Ogun state. The phone number is 08033970714. You can also contact my supervisor Dr. Akinpelu AO and the Head of the Physiotherapy department, University of Ibadan.

Appendix B

INSTITUTE FOR ADVANCED MEDICAL RESEARCH AND TRAINING (IMRAT)

COLLEGE OF MEDICINE, UNIVERSITY OF IBADAN, IBADAN, NIGERIA.

Telefax: 234-2-2412170; 234-2-2410088 /3310, 3120, 3114, 3594, Fax: 234-2-2413545

[redacted]

UI/UCH EC Registration Number: **NHREC/05/01/2008a**

NOTICE OF FULL APPROVAL AFTER FULL COMMITTEE REVIEW

Re: Developmental Pattern of Tibiofemoral Angle in Nigerian Children during the First 3 Years of Life

UI/UCH Ethics Committee assigned number: UI/EC/09/0068

Name of Principal Investigators: Mr. O. O. Oyewole

Address of Principal Investigator: Department of Physiotherapy, College of Medicine, University of Ibadan

Date of receipt of valid application: 14/05/2009

Date of meeting when final determination of research was made: **N/A**

This is to inform you that the research described in the submitted protocol, the consent forms, and other participant information materials have been reviewed and *given full approval by the UI/UCH Ethics Committee.*

This approval dates from 03/07/2009 to 02/07/2010. If there is delay in starting the research, please inform the UI/UCH Ethics Committee so that the dates of approval can be adjusted accordingly. Note that no participant accrual or activity related to this research may be conducted outside of these dates. *All informed consent forms used in this study must carry the* UI/UCH EC *assigned number and duration of* UI/UCH EC *approval of the study.* In multiyear research, endeavour to submit your annual report to the UI/UCH EC early in order to obtain renewal of your approval and avoid disruption of your research.

The National Code for Health Research Ethics requires you to comply with all institutional guidelines, rules and regulations and with the tenets of the Code including ensuring that all adverse events are reported promptly to the UI/UCH EC. *No changes are permitted in the research without prior approval by the* UI/UCH EC *except in circumstances outlined in the Code. The* UI/UCH EC *reserves the right to conduct compliance visit to your research site without previous notification.*

UI/UCH EC 03 JUL 2009 APPROVED

Dr. A. A. Adenipekun,
Chairman, Medical Advisory Committee,
University College Hospital, Ibadan, Nigeria
Vice- Chairman, UI/UCH Ethics Committee
E-mail:uiuchirc@Yahoo.com

Research Units: ▪Genetics & Bioethics ▪Malaria ▪Environmental Sciences ▪Epidemiology Research & Service ▪Behavioural & Social Sciences ▪Pharmaceutical Sciences▪Cancer Research & Services ▪HIV/AIDS.

Appendix C

OLABISI ONABANJO UNIVERSITY TEACHING HOSPITAL, SAGAMU
P. M. B. 2001, SAGAMU, NIGERIA.

Our Ref: OOUTH/DA. 326/394 Your Ref: Date: 11th August, 2009

Mr. O. O. Oyewole,
Department of Physiotherapy,
OOUTH,
Sagamu.

RE: DEVELOPMENTAL PATTERN OF TIBIOFEMORAL ANGLE IN NIGERIA CHILDREN DURING THE FIRST THREE (3) YEARS OF LIFE

I should like to inform you that the Scientific and Ethics Review Committee of this Hospital has granted you an approval on your research proposal as titled above.

2. Please, regard this letter as the Certificate of Ethical Approval.

3. Many thanks.

Dr. H. A. Ajibode,
Chairman, Medical Advisory Committee
for: Chief Medical Director

SAVE A LIFE: DONATE TO OOUTH

Appendix D

DEPARTMENT OF PHYSIOTHERAPY

COLLEGE OF MEDICINE
UNIVERSITY OF IBADAN, IBADAN, NIGERIA

FAX: 234-02-2411768
TELEX: Campus 31128 NG

MAILING ADDRESS:
COLLEGE OF MEDICINE (UCH)
P.M.B. 5017, G.P.O.
IBADAN, NIGERIA.
TELEPHONE: 02-2410088, 2413503.
2410109, 2410212,
Exts: 3366,3367,3357,3207.

HEAD OF DEPARTMENT

May 15, 2009

The Director,
Primary Health Care,
Sagamu Local Government,
Sagamu.

Dear Sir/Ma,

RE: OYEWOLE, OYELEYE OLUFEMI (MATRIC NO. 129875)

I write to introduce the above named Ph.D. student in our department. He is in the data collection phase of his study titled **"DEVELOPMENTAL PATTERN OF TIBIOFEMORAL ANGLE IN NIGERIAN CHILDREN DURING THE FIRST THREE YEARS OF LIFE"**

We shall be very grateful if you would kindly offer him the necessary assistance to facilitate the data collection. As expected, the data collected will be treated with utmost confidentiality and used for research purposes only.

Thank you for your anticipated assistance and cooperation in this regard.

HEAD
DEPARTMENT OF PHYSIOTHERAPY
COLLEGE OF MEDICINE
UNIVERSITY OF IBADAN NIGERIA

B.O.A. Adegoke, Ph.D.
Ag. Head of Department

O/C kindly allow the bearer to carry out his assignment in these facilities. Thank you. 25/5/09

PRIMARY ... SAGAMU LOCAL GOVT