1997

Utilizing the Ryder's and the Thigh-Foot Angle Tests to Establish Normal Values of Femoral Anteversion and Tibiofibular Torsion in Children Aged 5 Through 10 Years

Timothy M. Dahlke
Grand Valley State University

Wendi L. Jabs
Grand Valley State University

Follow this and additional works at: http://scholarworks.gvsu.edu/theses

Part of the Physical Therapy Commons

Recommended Citation
http://scholarworks.gvsu.edu/theses/318

This Thesis is brought to you for free and open access by the Graduate Research and Creative Practice at ScholarWorks@GVSU. It has been accepted for inclusion in Masters Theses by an authorized administrator of ScholarWorks@GVSU. For more information, please contact scholarworks@gvsu.edu.
UTILIZING THE RYDER'S AND THE THIGH-FOOT ANGLE
TESTS TO ESTABLISH NORMAL VALUES OF FEMORAL
ANTEVERSION AND TIBIOFIBULAR TORSION IN CHILDREN
AGED 5 THROUGH 10 YEARS

by

Timothy M. Dahlke
Wendi L. Jabs

THESIS

Submitted to the Department of Physical Therapy
at Grand Valley State University
Allendale, Michigan
in partial fulfillment of the requirements
for the degree of

MASTER OF SCIENCE IN PHYSICAL THERAPY

1997
UTILIZING THE RYDER'S AND THE THIGH-FOOT ANGLE TESTS TO ESTABLISH NORMAL VALUES OF FEMORAL ANTEVERSION AND TIBIOFIBULAR TORSION IN CHILDREN AGED 5 THROUGH 10 YEARS

ABSTRACT

The purpose of this research was to begin to establish normative data for femoral anteversion and tibiofibular torsion using the Ryder's and the Thigh-Foot Angle (TFA) tests. A secondary purpose was to establish the intertester and intratester reliability of the authors' measurements. Thirty-three normal children within the ages of 5 through 10 years volunteered for this study. All subjects' data were separated into the appropriate age groups. All data were pooled and mean/standard deviations and intertester/intratester reliability coefficients were determined. A small decreasing general trend in femoral anteversion with increasing age was found. However, no significant trend was noted in the tibiofibular torsion measurements. Intratester reliabilities for the Ryder's and TFA tests ranged from \( r = 0.38 \) to 0.84 while intertester reliabilities for those tests ranged from \( r = 0.15 \) to 0.51. This study may assist the health care practitioner in evaluating and treating children with abnormal femoral anteversion or tibiofibular torsion.
ACKNOWLEDGMENTS

The authors would like to express their appreciation to the following individuals for generously giving their time and assistance, as well as the much needed support:

Gordon Alderink, M.S., P.T. for his suggestions for this study's topic, his never-ending supply of red ink, and his unending dedication to enhancing the field of Physical Therapy as well as his own knowledge. We hope you continue to inspire future students as you have with us.

Sheldon Kopperl, Ph.D. for his commitment to this study and his cooperation in helping us make our grammar write. If there is one thing we've learned is to not use split infinitives.

Neal Rogness, Ph.D. for his numerically objective feedback and advice, of which we never doubted its validity or reliability. You never lost faith in us, even though we thought that finishing our thesis before graduation was statistically impossible.

Angela N. Dahlke, my loving wife, who put up with all of my "I'm so stressed out" shenanigans. Thank you so much for all of your support and the extra effort of going out of your way to make the whole thesis process more manageable. I couldn't have done it without you!

I love you sweetie, Timbo

Heath C. Jabs, my supportive and loving husband and fellow Physical Therapy classmate, who understood first hand all the pressures involved with this project. Thank you for listening to me all those times when you had your own thesis to think about. We finally made it through this!

All my love, Your Wendi
# TABLE OF CONTENTS

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>ABSTRACT</td>
<td>ii</td>
</tr>
<tr>
<td>ACKNOWLEDGEMENTS</td>
<td>iii</td>
</tr>
<tr>
<td>PREFACE</td>
<td>vi</td>
</tr>
<tr>
<td>Glossary of Terms</td>
<td>vi</td>
</tr>
<tr>
<td>LIST OF TABLES</td>
<td>vii</td>
</tr>
<tr>
<td>LIST OF GRAPHS</td>
<td>viii</td>
</tr>
<tr>
<td>LIST OF FIGURES</td>
<td>ix</td>
</tr>
<tr>
<td>CHAPTER</td>
<td></td>
</tr>
<tr>
<td>I.  INTRODUCTION</td>
<td>1</td>
</tr>
<tr>
<td>Background</td>
<td>1</td>
</tr>
<tr>
<td>Problem Statement and Significance</td>
<td>2</td>
</tr>
<tr>
<td>Purpose</td>
<td>2</td>
</tr>
<tr>
<td>II. LITERATURE REVIEW</td>
<td>4</td>
</tr>
<tr>
<td>Normal Development of Femoral Anteversion and Tibial Torsion</td>
<td>4</td>
</tr>
<tr>
<td>Abnormal Development of Femoral Anteversion and Tibial Torsion</td>
<td>5</td>
</tr>
<tr>
<td>Clinical Presentation</td>
<td>6</td>
</tr>
<tr>
<td>Femoral Torsion Values Previously Reported</td>
<td>8</td>
</tr>
<tr>
<td>Tibial Torsion Values Previously Reported</td>
<td>8</td>
</tr>
<tr>
<td>Hip Rotation Values Previously Reported</td>
<td>9</td>
</tr>
<tr>
<td>Measurement Tools and Methods</td>
<td>9</td>
</tr>
<tr>
<td>Ryder's Test</td>
<td>12</td>
</tr>
<tr>
<td>Thigh-Foot Angle (TFA) Test</td>
<td>14</td>
</tr>
<tr>
<td>Conclusion</td>
<td>15</td>
</tr>
<tr>
<td>III. METHODOLOGY</td>
<td>17</td>
</tr>
</tbody>
</table>
PREFACE

GLOSSARY OF TERMS

Normal—used in reference to subjects; refers to absence of known lower extremity anomalies, congenital lower extremity conditions, previous lower extremity derotational surgery and/or therapeutic intervention pertaining to lower extremity malalignment correction.

Torsion—a fixed rotation of the distal end of the bone relative to the proximal end.

Femoral torsion—inclination of the axis of the femoral neck with reference to the transcondylar plane to the distal femur that is plus or minus two standard deviations from the mean for the child's age group.

Tibiofibular or tibial torsion—state of torsion, either medial or lateral, in the long axis of the tibiofibular unit.

Version—rotation of a bone that is normal in direction and magnitude.

Femoral anteversion—angle in the transverse plane formed by a line drawn through the centers of the femoral condyles in reference to a line drawn through the axis of the femoral neck and head.

Medial femoral torsion—abnormal increase in femoral anteversion.

Lateral femoral torsion—abnormal decrease in femoral version.

Intertester—variation between different testers.

Intratester—variation between different measurements by the same tester.

Ryder's test—clinical evaluation procedure used to measure femoral anteversion.

Thigh-Foot Angle test—clinical evaluation procedure that provides a composite measurement of tibial and fibular version.
Gait—human locomotion or ambulation.

Subtalar neutral—position in the subtalar joint of the foot from which the calcaneus will invert twice as many degrees as it will evert.
## LIST OF TABLES

<table>
<thead>
<tr>
<th>Table</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>4-1. Age categories with gender distribution</td>
<td>25</td>
</tr>
<tr>
<td>4-2. Mean and standard deviation of internal hip rotation for each age group</td>
<td>26</td>
</tr>
<tr>
<td>4-3. Mean and standard deviation of external hip rotation for each age group</td>
<td>27</td>
</tr>
<tr>
<td>4-4. Mean and standard deviation of total hip rotation for each age group</td>
<td>28</td>
</tr>
<tr>
<td>4-5. Mean and standard deviation of femoral anteversion for right and left extremities</td>
<td>29</td>
</tr>
<tr>
<td>4-6. Mean and standard deviation of external tibiofibular torsion for right and left extremities</td>
<td>30</td>
</tr>
<tr>
<td>4-7. Reliability Coefficients—Ryder's tests</td>
<td>32</td>
</tr>
<tr>
<td>4-8. Reliability Coefficients—Thigh-Foot Angle tests</td>
<td>33</td>
</tr>
<tr>
<td>Graph</td>
<td>Description</td>
</tr>
<tr>
<td>---------</td>
<td>------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>5-1.</td>
<td>Mean right and left values for external tibiofibular torsion across ages.</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>5-2.</td>
<td>Mean right and left values for anteversion across ages.</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>Figures</td>
<td>Page</td>
</tr>
<tr>
<td>------------------------------------------------------------------------</td>
<td>------</td>
</tr>
<tr>
<td>3-1. Use of Ryder's Test to Measure Femoral Anteversion</td>
<td>20</td>
</tr>
<tr>
<td>3-2. Use of TFA Test to Measure Tibiofibular Torsion</td>
<td>20</td>
</tr>
</tbody>
</table>
CHAPTER 1

INTRODUCTION

Background

Torsional malalignment in the long bones of the lower extremities is a common orthopedic problem in the pediatric population (Engel and Staheli, 1974; Killam, 1989; Ritter, DeRosa and Babcock, 1976; Staheli and Engel, 1972). These osteologic abnormalities often lead to a variety of postural malalignments and/or gait deviations, thus bringing concern to both parents and clinicians. These bony abnormalities become a concern when children begin to manifest such problems as bowleggedness, pigeon toeing, patellar subluxation, club foot and many others. In order to address these concerns, both a successful evaluation and a proper understanding of "normal" osteologic development must be present.

Torsional abnormalities may result from muscle weakness or imbalances, limited muscle or joint mobility, joint instability and/or decreased neuromuscular control, all of which may contribute to the large spectrum of gait deviations (Engel and Staheli, 1974; Killam, 1989; Staheli, Corbett, Wyss and King, 1985; Stuberg, Temme, Kaplan, Clarke and Fuchs, 1991). Torsional characteristics in the long bones of the lower extremity do not necessarily equal abnormality or malalignment. In fact, the normal osteologic growth of the long bones, as well as musculoskeletal changes that occur during the developing years, differs slightly from child to child. Several researchers, using a variety of methods, have hypothesized as to what those "normal" variations and changes were regarding femoral anteversion and tibiofibular torsion in children.
Problem Statement and Significance

Despite previous research, there currently is an inadequate database of normative values for femoral anteversion using the Ryder's test and tibiofibular torsion using the Thigh-Foot Angle (TFA) test for each subsequent year in children aged 5 through 10. Using a standard goniometer applied directly on the client, the Ryder's test and the TFA test can be used as quick screens that are appropriate for the clinical setting. The appropriateness of the Ryder's test and the TFA test for the clinical setting is based on their simplicity and time effectiveness. Normal values of femoral anteversion and tibiofibular torsion have been established in past research via computed tomography, roentgenograms and ultrasound. However, these methods may not be clinically appropriate. Therefore, more research related to the collecting of "normal" torsional data, using clinically appropriate measurement procedures, needs to be completed. This may also lead to a better understanding of osteological development.

The determination and confirmation of normative data of femoral anteversion and tibiofibular torsion using a clinically practical screen can aid in the treatment plan of those individuals who have torsional deformities and gait abnormalities. By comparing the data obtained in an evaluation with the established norms, a clinician can determine when and what kind of intervention may be necessary.

Purpose

The first purpose of this study was to begin to establish normative data for femoral anteversion and tibiofibular torsion of both male and female children ranging from 5 through 10 years of age using the Ryder's and the TFA tests, respectively. The authors' second purpose was to establish the intertester and intratester reliability of their
measurements. This information will increase the knowledge base in the rehabilitation fields in the area of evaluation as well as increase the usefulness of these tests.
CHAPTER 2
LITERATURE REVIEW

Normal Development of Femoral Anteversion and Tibial Torsion

During the normal skeletal development of children, many asymptomatic normal variations may occur in the lower extremities. It was historically believed that children who presented with "knock knees" or "bow legs" had rickets (Kite, 1960). Later, reports claimed that persistent prone sleeping positions or diapers that were too large were to blame for lateral rotation of the legs (Kite, 1960). Today, some research suggests that during fetal development, the intrauterine positioning initiates structural modeling of bone. During this period, the limb buds initially rotate to bring the great toe medial, which presents as the first sign of torsion (Engel and Staheli, 1974; Staheli, 1987). The hips are flexed and laterally rotated, while the tibiofibular complex is medially rotated. Femoral anteversion rapidly increases at mid-gestation and then increases at a lesser rate to reach around 40 degrees perinatally (Cusick and Stuberg, 1992). Internal tibial torsion at birth is approximately 15 degrees (Scoles, 1988).

During the first 18 months following birth, the child will experience a period of rapid growth. The epiphyses are increasing the bone length, the zone of calcification is forming, osteoid seams are being laid down, and resorption of bone is taking place at a rate greater than ever again. It is at this time that the child is also susceptible to forces causing abnormal development (Bunch, 1977). Wolff's law states that bone is laid down and remodeled along the lines of greatest stress. Therefore, normal development is highly dependent on the proper balance of muscle forces, joint and muscle nutrition and
blood supply. Since femoral anteversion and internal tibial torsion are a part of normal intrauterine development, one can expect all children to have them. However, when the degree of torsion is insufficient or exceeds what would be considered the normal range for that age group then problems could occur. If the intrauterine positioning is severe or asymmetric, the normal physiologic rotation may be increased or decreased (Swanson, Greene and Allis, 1963). There are several other factors which could lead to abnormal torsion, most of which relate to a misdirection of growth. These factors will be discussed below.

Abnormal Development of Femoral Anteversion and Tibial Torsion

Swanson et al. (1963) thoroughly discussed the mechanics of abnormal long bone rotations. These authors stated that the growth of the epiphysis is modified by "gravity, muscle imbalance, joint contractures, hereditary factors, nutrition, blood supply, disuse, infection and trauma" (p. 172). Torsional deformities can result when any of those factors cause a torque force perpendicular to the epiphyseal growth plane (Swanson et al., 1963). Furthermore, Bunch (1977) suggested that paralysis or spasticity of a particular muscle group could significantly alter the magnitude of normal vector forces which lead to proper skeletal development. For example, Chang, Vojnic, Quanbury, Eng and Letts (1978) studied children with cerebral palsy and their typical internal rotation gait pattern. Those authors found that overactive phasic medial hamstrings led to the femoral anteversion deformity which resulted in an internal foot progression gait pattern.

Habitual positioning has been suspected to encourage abnormal torsion in the long bones. For example, previous traditional casting methods for dislocated hips in a position of maximal internal rotation and slight abduction have resulted in the development of excessive anteversion (Bunch, 1977). Many invalidated reports have also been made
regarding the adverse effects of "W" or reverse tailor sitting, in which the child sits with hips internally rotated and knees completely flexed. It has been hypothesized that this persistent position may increase the torque placed on the distal femoral epiphyses and consequently encourage femoral anteversion (Bunch, 1977; Cusick and Stuberg, 1992; Kite, 1960; Staheli, 1987; Swanson et al., 1963). The prone sleeping position, which is commonly encouraged by parents, may also perpetuate or promote deformity in the tibia and/or the femur, especially within the first three months of life when the infant is less physically active and mobile (Swanson et al., 1963).

Genetic predisposition to rotational deformities has also been proposed. Fortunately, most congenital rotational variations that persist into adulthood rarely produce physical disability (Staheli, 1987).

Clinical Presentation

Although most abnormal long bone torsions spontaneously resolve without intervention, some do persist through childhood and into adulthood. Those that do persist present characteristic static and dynamic patterns. Often a deformity in one limb segment will produce secondary compensations in other segments. For example, increased anteversion of the femur is often correlated with excessive external tibial torsion, whereas lateral femoral rotation is often correlated with internal tibial torsion. Furthermore, the child with increased anteversion shows excessive medial and limited lateral hip rotation range of motion (Staheli, 1983). These deformities may be unilateral or bilateral. Those which are unilateral tend to be more noticeable, yet less severe (Swanson et al., 1963).

Many studies have attempted to determine predictable clinical presentations given particular abnormal torsional development (Cusick and Stuberg, 1992; Fabry, Cheng, and Molenaers, 1994; Fabry, MacEwen and Shands, 1973; Killam, 1989; Kumar and
MacEwen, 1982; Ritter et al., 1976; Staheli, 1983; Staheli, 1987; Swanson et al., 1963). For example, anteversion has been documented as presenting with true or apparent bowleggedness, intoeing or pigeon-toeing, patello-femoral malalignment, chondromalacia patella and patellar subluxation or dislocation. The patella may be medially rotated, and the individual may present with excessive medial and limited lateral hip rotation. Fabry et al. (1994) found that at an average age of 7 years, 70% of intoeing was caused primarily by increased femoral anteversion and the remaining 30% by internal tibial torsion.

Internal tibial torsion has been found to be more common in the left and external tibial torsion more common in the right lower extremity (Staheli, 1989). Persistent internal tibial torsion can contribute to intoeing in young children, but usually corrects spontaneously as the child grows. Persistent internal tibial torsion is usually brought to the physician’s attention by parents when their child begins to walk with an intoeing gait between 6 and 18 months old. Tibial torsion deformities have also been associated with club foot (Wynne-Davies, 1964), Osgood-Schlatter’s disease (Turner, 1994) and medial type osteoarthritis of the knee (Yagi and Sasaki, 1986). Ficat and Hungerford (as cited in Butler-Manuel, Guy and Heatley, 1992) found an association between tibial torsional deformities and patello-femoral instability. Staheli (1987) reported that in most cases one foot was turned out as a result of internal tibial torsion in conjunction with metatarsus adductus on the opposite side. External tibial torsion is less common than internal tibial torsion and rarely presents as a problem in the first few years of life (Kling and Hensinger, 1983). Excessive external tibial torsion has been associated with knock knees and a positive foot-progression angle and, thus, toeing-out (Kite, 1960; Staheli, 1987; Staheli et al., 1985; Swanson et al., 1963). The normal gait pattern involves some
external rotation of the feet, therefore it is important to note that toeing-out is only considered abnormal when it exceeds 30 degrees (Engel and Staheli, 1974).

**Femoral Torsion Values Previously Reported**

Many methods of measurement have been used to assess femoral torsion. According to many sources, femoral anteversion is greatest in the newborn at about 35 to 40 degrees (Cusick and Stuberg, 1992; Fabry et al., 1973; Lewis, Samilson and Lucas, 1964; Staheli, 1987; Swanson et al., 1963). Thereafter, studies have reported various results. However, all agree that femoral anteversion normally decreases on the average of 1 to 1.5 degrees per year until around age 16 or until skeletal maturity has been reached (Lewis et al., 1964; Scoles, 1988). The most rapid decrease occurs within the first 4 years (Shands and Steele, 1958) with an average value of 25 degrees of femoral anteversion still remaining by age 8 (Fabry et al., 1973; Shands and Steele, 1958). Upon skeletal maturity, femoral anteversion in normal adults ranges between 8 and 15 degrees (Fabry et al., 1973; Lewis et al., 1964; Staheli, 1987; Swanson et al., 1963.)

**Tibial Torsion Values Previously Reported**

At birth, the tibia, and consequently the tibiofibular complex, is medially rotated about its long axis. It has the greatest variability in the newborn. Some studies have indicated a range of internal tibial torsion at birth of about 15 degrees (Schwarze and Denton, 1993) to 20 degrees (Staheli et al., 1985). The tibia normally develops a lateral torsion during early childhood to an average adult value of 20 to 30 degrees (Bunch, 1977; Engel and Staheli, 1974; Jakob, Haertel and Stussi, 1980; Kumar and MacEwen, 1982; Malekafzali and Wood, 1979; Staheli, 1987; Staheli et al., 1985; Swanson et al.,
1963; Wynne-Davies, 1964). The large range in normal values can be attributed partly to
the variety of measurement methods used in past research.

**Hip Rotation Values Previously Reported**

Svenningsen, Terjesen, Auflem, and Berg (1990) found the mean internal hip
rotation of 4 year old females to be 60 degrees and that of males to be 51 degrees. At age
11, females averaged 50 degrees and males averaged 46 degrees of internal hip rotation.
Those authors also found the average external hip rotation in 4 year old females to be 44
degrees and that in males to be 48 degrees. The average external hip rotation in 11 year
old children in that study was found to be 42 degrees in both males and females. The
females had significantly greater internal hip rotation values in all ages.

**Measurement Tools and Methods**

**Femoral Anteversion**

Swanson et al. (1963) suggested the use of roentgenograms and anteversion
radiographs, both of which introduce radiation to the client. Lewis et al. (1964)
suggested that most of those methods involved an anteroposterior and a lateral radiograph
in conjunction with the use of a protractor to measure the images on the film. Measured
values are then used in a mathematical formula or table to calculate the true value of
femoral anteversion. Beal (1969) used a modified version of the Magilligan technique
which consisted of two radiographs to determine femoral anteversion in patients with
spastic paraplegia and diplegia. In his study, two radiographs of the proximal femur were
obtained perpendicular to each other without moving the limb. In 1973, Fabry et al.
replicated the Dunlap-Shands method of measuring femoral anteversion using a single x-
ray per limb. A posteroanterior roentgenogram of the pelvis and hips were made with the
client prone. The hips were fully extended and the knees were flexed to 90 degrees. These authors studied normal children and found an average of 26, 26, 23, 24, 21 and 20 degrees of femoral anteversion for ages 5 through 10 respectively. In 1980 Jakob et al. suggested the use of computerized tomography (CT) to compare the femoral neck axis with that of the distal femoral condyles for determination of femoral torsion. Although no data were presented in Jakob et al.'s research, they stated that their methods had good reliability in comparison with cadaveric measurements. In 1987, researchers developed yet another method for measuring anteversion in which three CT scans were used (Murphy, Simon, Kijewski, Wilkinson and Griscom, 1987). Those researchers compared the validity of the method of measuring anteversion using CT scans in current clinical use and their method, also using CT scans, with those of human cadaver femora. They found that the mean of the more popular method consistently underestimated the true values by 13 degrees, while their method underestimated it by a mean of two degrees. The traditional method had a variance of 13 degrees, whereas Murphy et al.'s (1987) method had a variance of 0.4 degrees. A breakthrough in technology in 1992 allowed researchers to use an ultrasonographic technique using posterior lines of reference rather than the usual anterior lines of reference (Kumar, Joseph, Verghese and Ghosh, 1992). A high degree of validity between the ultrasonographic measurements and direct measurements on the same femora was found. Although values obtained were consistently lower with their posterior reference lines than the traditional anterior reference lines, Kumar et al. (1992) stated that it was valid enough to recommend its use clinically. This method provided a less expensive measurement option over CT scans and did not expose subjects to harmful radiation.
Tibiofibular Torsion

In 1963 Swanson et al. suggested measuring tibial torsion with the client in short sitting and ankles at 90 degrees, relating the tibial tubercle to the transmalleolar axis using a goniometer. No reliability nor validity studies have been performed using this method. Nonetheless, Swanson et al. (1963) stated that normal external tibial torsion values ranged from 0 to 40 degrees, the higher numbers occurring in adulthood. The following year Wynne-Davies developed a tropometer, which allowed for greater positioning accuracy when reading from the protractor (Wynne-Davies, 1964). Today technology has enabled clinicians to measure tibial torsion statically by protractors and radiographs, ultrasound, magnetic resonance imaging and dynamically in a gait laboratory (Turner, 1994). One of the most popular methods was developed by Staheli and Engel (1972) in which a transmalleolar axis was used in conjunction with the firm surface the client was sitting on. Those authors reported a reproducibility within an acceptable range when this method was retested on 25 subjects (50 limbs). Those authors stated no measurements varied more than 4 degrees. However, they did not provide any specific reliability values. Staheli and Engel (1972) reported the mean measurements of external tibial torsion for each age group 5 through 10 years respectively as 11, 9, 11, 11, 13 and 14 degrees.

Many of the methods described to measure femoral anteversion and tibiofibular torsion in this section are not clinically applicable in a physical therapy departmental setting. Furthermore, these methods are costly to the clients and researchers, are time consuming, require elaborate equipment, have not been shown to be reliable, and even may expose the clients to excessive harmful radiation.
Ryder's Test

The Ryder's Test, also known as the trochanteric prominence angle test and the Craig's test, is used to clinically estimate the magnitude of femoral torsion or anteversion. Anteversion is the angle formed by the intersection of the coronal plane passing through the femoral condyles and the oblique plane passing through the femoral head and neck (Ruwe, Gage, Ozonoff, and DeLuca, 1992). This test was originally developed by Ryder and Crane in 1953. They designed a special positioning apparatus that was used to make an abduction radiograph. Here, the client was positioned supine with the hip and knee in 90 degrees of flexion and the thigh abducted 30 degrees. Two radiographs were then made, one in the anteroposterior plane to determine the projected angle of inclination and the other in the abduction plane to determine the projected angle of anteversion. Using a standardized table of trigonometric calculations, the true angle of anteversion was determined. They found errors of ± 10 degrees (Ryder and Crane, 1953). Although the evaluation method named for that research has changed, credit is still given to those authors for the idea of positioning the client with the knees at 90 degrees.

Historically, however, one must go back to 1940 when Robert Netter published his doctoral thesis, prior to Ryder and Crane's research in 1953. Netter estimated femoral anteversion by palpation of the maximum lateral prominence of the greater trochanter (as cited in Ruwe et al., 1992). The client was positioned supine on the table with the knees flexed to 90 degrees over the edge of the examination table (tibia vertical). The hip was internally rotated until the greater trochanter was felt to be at its maximum prominence. The angle of anteversion was then measured via goniometer as the arc through which the tibia moved from its original vertical position to one in which the greater trochanter (hip internal rotation) was at its maximum prominence laterally. Netter determined intertester
and intratester reliabilities to both be within 5 to 10 degrees. However, his method was never compared with other methods (Ruwe et al., 1992). Intratester and intertester reliability of the Ryder's test were recently assessed on 18 adult naval midshipmen in Jonson and Gross's study (1997). They found an intratester reliability of \( r = 0.94 \) and an intertester reliability of \( r = 0.85 \).

Ruwe et al. (1992), using the Ryder's test, measured 35 male and 24 female pathologic clients. The client was positioned prone on the examining table with the hips extended and knees flexed to 90 degrees. The examiner stood on the opposite side of the lower extremity being evaluated and palpated the greater trochanter while internally rotating the hip. The point at which the maximum prominence of the greater trochanter was palpated indicated that the neck of the femur was parallel to the floor. The angles subtended between the bisecting long axis of the tibia and true vertical represented the true angle of femoral anteversion. Ruwe et al. (1992) compared their data with true intraoperatively-determined femoral anteversion and found the mean difference on the right side to be 3.5 degrees with a standard deviation of 3.9 degrees and that on the left to be 4.1 degrees with a standard deviation of 3.2 degrees. The authors concluded that the amount of error was acceptable and still provided enough accuracy to assist clinical decision making (Ruwe et al., 1992). Those authors also assessed intertester reliability of the trochanteric prominence angle test. They found a reliability coefficient of \( r = 0.774 \) degrees between their testers. This method offered clinicians the ability to determine femoral anteversion quickly, accurately, and consistently.

The authors chose to use the Ryder's test because it is easiest to use within the confines of a typical physical therapy department setting, does not involve costly equipment, is time efficient and valid in measurement of femoral anteversion in comparison with intraoperatively-determined anteversion.
**Thigh-Foot Angle (TFA) Test**

The Thigh-Foot Angle is the angle between the long axis of the foot, held in subtalar neutral, through the second metatarsal and the long axis of the thigh (Engel and Staheli, 1974; Schwarze and Denton, 1993; Staheli et al., 1985; Stuberg et al., 1991). It represents a composite measurement of tibiofibular torsion and structural alignment distal to the talocrural joint. King and Staheli (1984) described the goniometric method which follows. The client was placed prone with the hip in extension, the knees together and flexed to 90 degrees. The ankle was carefully positioned in subtalar neutral. Extra precaution was taken to avoid hamstring-mediated tibiofibular torsion through relaxation of the client's leg. A goniometer with 1-degree increments was aligned to the bisection of the approximate long axis of the femur and a line bisecting the calcaneus and ray of the second metatarsal. This method was similar to the transmalleolar axis method, but its mean values were about five degrees lower than those of the transmalleolar axis method (Staheli et al., 1985). Stuberg et al. (1994) reported an intertester reliability using this method that was comparable to clinical goniometric variances. They stated that the clinician "should expect an error of one to four degrees as being routine for goniometry in normals" (p. 211). Stuberg et al. (1991) also compared intertester reliability when using the TFA test and found an error of approximately five degrees. Engel and Staheli (1974) and Staheli et al. (1985), using the TFA test, determined the mean angle in skeletal maturity to average between 7 and 13 degrees of external tibiofibular torsion. Schwarze and Denton (1993) used the TFA on 1000 neonates less than 3 days old. They found a mean of 17 degrees internal torsion in boys and 15 degrees internal torsion in girls.

One study compared the results of obtaining torsional data (using the TFA test) with a goniometer versus computed tomography (Stuberg et al., 1991). Their data
indicated that the mean difference between the two methods was 4 to 6 degrees. The authors concluded that the degree of difference obtained by the two methods may not be clinically significant due to the five degrees of marginal error acquired with a goniometer. Schwarze and Denton (1993) compared the results of the TFA test and the transmalleolar test on 1000 neonates and found no clinically significant difference in the values they obtained for internal tibial torsion.

The TFA test will be used in this study because it is easier to manage than the transmalleolar axis and appears to be the most clinically practical measurement. When care is taken to properly position the foot, the TFA test provides a quick and easily obtainable measure of tibiofibular torsion.

Since the TFA test is a composite measurement of both tibiofibular rotation and hindfoot version, any talus or midfoot abnormalities may interfere with accuracy (Scoles, 1988). Other factors may also contribute to inaccurate measures of tibial torsion as identified by Cusick and Stuberg (1992). Those factors may include normal infantile hyperextensibility of the knee joint ligaments and capsule, hamstring or popliteal muscle activity or shortening and release of the screwhome mechanism upon knee flexion.

**Conclusion**

Past literature suggests that there currently is an inadequate database of normative values of femoral anteversion and tibiofibular torsion in normal children aged 5 through 10 years. Literature also presents a need for measurement methods appropriate for the physical therapy department setting such as the Ryder's test and the Thigh-Foot Angle test. Several other methods have previously been suggested and utilized; however, those methods often used elaborate and costly equipment, exposed the client to potentially harmful radiation, were time consuming and were not proven reliable nor valid in
measurement. Therefore, it is the authors' intentions to begin to establish normative values in children aged 5 through 10 years using the Ryder's and the Thigh-Foot Angle tests. The authors also propose to calculate the inter- and intratester reliability of those tests.
CHAPTER 3

METHODOLOGY

This research project was a normative descriptive study of femoral anteversion and tibiofibular torsion of children aged 5 through 10 years of age, using the Ryder's and the Thigh-Foot Angle tests respectively. Presently, there are no normative data for these age groups using the above mentioned tests. The authors' choice in using the Ryder's test and the Thigh-Foot Angle test in our study is based on their clinical applicability. Using these methods, data can easily be obtained using a standard goniometer and accurate palpation.

"The purpose of normative research is to describe typical or standard values for characteristics of a given population" (Fortney and Watkins, 1993). It was thus the authors' focus to obtain "normal" values of femoral anteversion and tibiofibular torsion of a given population, in order to provide clinicians with a standard to use as a basis for their lower extremity evaluations and treatments.

"Samples for normative studies must be large, random, and representative of the population's heterogeneity" (Portney and Watkins, 1993). Since the authors used a small sample of convenience, this study only marks the initial stages of establishing a normative database.

Subjects and Study Sites

A small sample of convenience was used for this study. Healthy volunteers for each age year ranging from 5 to 10 years old were sought, producing a total of 33
subjects. A letter (Appendix A) was sent to various elementary school systems, day care centers and summer camps located in the midwest region of Michigan regarding recruitment of children and permission to use their facility for data collection. A follow-up telephone call was made to those sites as needed. Once permission was granted to conduct part of this study at their facility, arrangements were made with the director of the facility as to the distribution of the health screening questionnaires (Appendix B) and consent forms (Appendix C) to the parents/legal guardians. The authors made every attempt to be present during the distribution and completion of those forms to answer any questions that arose. Due to inadequate cooperation from facilities, recruitment of volunteers was also made via friends and family.

Volunteers were not discriminated against based on their race or gender. However, the sample was restricted to normal, healthy subjects. The exclusionary criteria included (a) previous orthopedic intervention of lower extremities such as braces, surgical correction, casting, or physical therapy; (b) neuromuscular involvement such as cerebral palsy, multiple sclerosis, or motor nerve neuropathies; (c) known congenital bony abnormalities; (d) progressive disorders which may affect the development of muscle or bone such as severe scoliosis; (e) any previous traumatic injuries to the legs such as ligament or muscle strain/sprain; and (f) age (younger than 5 or older than 10 years). The exclusionary criteria (a) through (e) were established to minimize obtaining false positive data of our lower extremity measurements due to possible changes in the long bone formation these established criteria may cause. Exclusionary criterion (f) was established to maintain consistency with the scope of this study.
Instrumentation

The instrument the authors used was a standard 12-inch goniometer. A goniometer is a hinged device with one stationary and one moving arm, used typically to measure joint angles. According to Stuberg et al. (1991), a range of five degrees is commonly reported as the margin of error for goniometric measurements. In a study by Boone, Azen, Lin, Spence, Baron and Lee (1978) the intertester reliability of lower extremity goniometric measurements was found to have a reliability coefficient of $r = .58$. Their intratester reliability coefficient for lower extremity goniometric measurements was $r = .80$. Although a goniometer cannot measure actual torsion in the long bones of the lower extremities, it was used in conjunction with the Ryder's test and the Thigh-Foot Angle test to obtain estimates of torsional data.

Ryder's test and TFA test

The Ryder's test is a procedure used to determine the magnitude of femoral torsion by indirectly measuring the angle formed between the axis of the head and neck of the femur and the axis of the femoral condyles (Figure 3-1) (Cusick and Stuberg, 1992).

The Thigh-Foot Angle test is a procedure used to determine the magnitude of tibiofibular torsion by measuring the angle formed between a line bisecting the thigh and the longitudinal axis of the hind-foot (Figure 3-2) (Cusick and Stuberg, 1992).
Figure 3-1. Degree of anteversion estimated using the Ryder's Test.

(Taken from Magee, 1992)

Figure 3-2. Degree of tibiofibular torsion estimated using the TFA Test.

(Taken from Cusick and Stuberg, 1992)
**Procedures**

Prior to data collection, a pilot study was conducted using five volunteers. This was done to improve consistency between testers, to determine the best experimental set-up, and to determine how many subjects could be tested per hour. The subjects were chosen from the Grand Valley Physical Therapy class of 1997. The pilot study was conducted in the home of one of the authors.

Prior to test administration, each volunteer's parent or legal guardian completed the health screening questionnaire (Appendix B) and the consent form (Appendix C). Once subjects were obtained, the collection of data occurred on the site of the particular facility. Considering that the age of the subjects and the environment would not affect the measurement results, the authors accommodated the children's or parents' request for a specific environment at that facility to conduct the measurements. The authors briefly introduced themselves to each subject as well as delivered an educational presentation and brief explanation of the measurement procedures before they were administered.

Each subject was tested by one of two test administrators consecutively. The first tester proceeded with all of the measurements on the child which were then repeated by the second tester. Each measurement was performed three times and recorded on the data collection form (Appendix D) that coincided with the number designated for each child on their health screening questionnaire. To minimize the tester's memory bias, all the left lower extremity measurements were taken first for trial one and then all the right lower extremity measurements. The second and third trials were followed immediately beginning with the left lower extremity. In addition, the data forms were folded to expose the current trial only and, thus, further minimize additional memory bias.

Initially, the authors gently rotated each hip internally and externally five times to serve as a warm-up and minimize possible soft tissue restrictions. Hip rotation was then
measured and recorded by rotating the hip internally and externally to its maximum end point. The stationary arm of the goniometer was placed perpendicular to the treatment surface. The moving arm was placed along the tibial crest with the axis of rotation occurring at the approximate center of the knee joint in the frontal plane. The pelvis was stabilized by the tester while moving the leg into internal/external rotation. Once the maximum range of movement had been identified, the stabilizing hand was removed from the pelvis and assisted in maintaining the position of the leg while positioning and measuring the angle between the two axes with the goniometer. Once total hip excursion had been determined, the authors then measured and recorded femoral anteversion values using the Ryder's test. To obtain the femoral anteversion values, the authors internally rotated the hip until the greater trochanter was felt at its maximum prominence. While maintaining the leg in this position, the tester placed the stationary arm of the goniometer perpendicular to the treatment surface and the moving arm along the tibial crest. The arc through which the tibia moved in relation to vertical was then measured with the goniometer (Figure 3-1).

With the child in the prone position, the authors then measured and recorded the tibiofibular torsional values using the TFA test. To obtain the tibiofibular torsional values the authors positioned both the ankle and subtalar joints in neutral. The angle formed by the bisecting line of the thigh and the longitudinal axis of the foot was then measured with a goniometer. The longitudinal axis of the foot was identified as a line bisecting the calcaneus and ray of the second metatarsal. The Ryder's test and the Thigh-Foot Angle test were performed for the left, then the right, extremity three times.

In order to better ensure intertester reliability in this study, the subjects were tested by each of the two testers separately, without knowledge of the other tester's results. Intratester reliability was addressed by comparing the results of the first and third
trials on each child for internal, external, and total hip rotation, as well as femoral antversion and tibiofibular torsion.

**Data Analysis**

Data analysis was completed using SPSS for Windows. This Windows program enabled the authors to develop descriptive statistics (mean and standard deviation) to describe age group data, as well as analyze the data using the Pearson product - moment correlation coefficient. The mean and standard deviations were calculated for all measurement variables using all three trials of each tester. The mean values were then used to determine the intratester and intertester reliabilities for both the Ryder's and TFA tests. These reliabilities were calculated using a two-tailed bivariate correlation, specifically, the Pearson product - moment correlation coefficient. The Pearson product - moment correlation coefficient is the most commonly reported measure of correlation for calculating r-values (Portney and Watkins, 1993). This statistic is appropriate to use when a study has continuous variables with underlying normal distributions on the interval scale (Portney and Watkins, 1993). Therefore, the authors chose to use this statistic to calculate r-values for both intertester and intratester reliability with respect to the Ryder's and TFA tests. It is important to mention that the Pearson Product - Moment Correlation Coefficient does not account for systematic error of variation. The Pearson Product - Moment Correlation Coefficient does not break down the variance into effects due to differences between subjects, differences between testers and error variance.
CHAPTER 4

RESULTS

The purpose of this study was to begin to establish normative data for femoral anteversion and tibiofibular torsion of both male and female children ranging from 5 through 10 years of age using the Ryder's and the TFA tests, respectively. The authors also attempted to establish the intertester and intratester reliability of their measurements.

The subjects of this study included 19 males and 14 females for a total of 33 volunteers. The number of subjects for each age group were as follows: 5 year olds (n=3); 6 year olds (n=5); 7 year olds (n=13); 8 year olds (n=6); 9 year olds (n=5); and 10 year olds (n=1). Two subjects were excluded from this study because either they did not meet the age criteria or had a known congenital abnormality.

Due to the small sample size, all data from the sample population were pooled into each age group irrespective of the gender. Tables 4-1 provides subject demographic information. Table 4-1 describes the distribution of the males and females in their respective age groups. There was a fairly equal distribution of males and females. Table 4-2, 4-3, and 4-4 provide hip internal and external rotation information. Internal and external hip rotation ranges were both around 40 to 45 degrees for all ages. One can see that the amount of internal rotation and external rotation was fairly equal suggesting that these children had normal femoral torsion.

The results of the Ryder's and Thigh-Foot Angle tests to establish the age-related normative values for femoral anteversion and tibiofibular torsion are presented in Tables 4-5 and 4-6. These tables list descriptive statistics (mean and standard deviation)
Table 4-1

Age Categories With Gender Distribution

<table>
<thead>
<tr>
<th>Age</th>
<th>Males</th>
<th>Females</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age 5</td>
<td>2</td>
<td>1</td>
<td>3</td>
</tr>
<tr>
<td>Age 6</td>
<td>3</td>
<td>2</td>
<td>5</td>
</tr>
<tr>
<td>Age 7</td>
<td>8</td>
<td>5</td>
<td>13</td>
</tr>
<tr>
<td>Age 8</td>
<td>4</td>
<td>2</td>
<td>6</td>
</tr>
<tr>
<td>Age 9</td>
<td>1</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>Age 10</td>
<td>1</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Total</td>
<td>19</td>
<td>14</td>
<td>33</td>
</tr>
</tbody>
</table>
### Table 4-2

**Mean and Standard Deviation of Internal Hip Rotation**

**For Each Age Group**

<table>
<thead>
<tr>
<th>Age Group</th>
<th>Right LE Mean</th>
<th>Right LE Std. Dev.</th>
<th>Left LE Mean</th>
<th>Left LE Std. Dev.</th>
<th>Combined LE's Mean</th>
<th>Combined LE's Std. Dev.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age 5 (n = 3)</td>
<td>40.7</td>
<td>5.7</td>
<td>41.7</td>
<td>5.9</td>
<td>41.2</td>
<td>5.3</td>
</tr>
<tr>
<td>Age 6 (n = 5)</td>
<td>44.7</td>
<td>6.2</td>
<td>47.1</td>
<td>7.6</td>
<td>45.9</td>
<td>6.2</td>
</tr>
<tr>
<td>Age 7 (n = 13)</td>
<td>42.4</td>
<td>5.9</td>
<td>44.3</td>
<td>5.1</td>
<td>43.3</td>
<td>5.1</td>
</tr>
<tr>
<td>Age 8 (n = 6)</td>
<td>41.3</td>
<td>11.5</td>
<td>43.6</td>
<td>6.3</td>
<td>42.5</td>
<td>8.7</td>
</tr>
<tr>
<td>Age 9 (n = 5)</td>
<td>46.4</td>
<td>2.4</td>
<td>47.1</td>
<td>3.8</td>
<td>46.8</td>
<td>2.8</td>
</tr>
<tr>
<td>Age 10 (n = 1)</td>
<td>46.8</td>
<td>--------</td>
<td>44.2</td>
<td>--------</td>
<td>45.5</td>
<td>--------</td>
</tr>
</tbody>
</table>

Combined LE's = Left and Right Lower Extremities

Std. Dev. = Standard Deviation
Table 4-3

**Mean and Standard Deviation of External Hip Rotation**

*For Each Age Group*

<table>
<thead>
<tr>
<th></th>
<th>Right</th>
<th>Left</th>
<th>Combined LE's</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean</td>
<td>Std. Dev</td>
<td>Mean</td>
</tr>
<tr>
<td>Age 5 (n = 3)</td>
<td>45.4</td>
<td>2.2</td>
<td>42.4</td>
</tr>
<tr>
<td>Age 6 (n = 5)</td>
<td>44.8</td>
<td>11.3</td>
<td>43.0</td>
</tr>
<tr>
<td>Age 7 (n = 13)</td>
<td>43.3</td>
<td>5.6</td>
<td>44.7</td>
</tr>
<tr>
<td>Age 8 (n = 6)</td>
<td>41.6</td>
<td>4.2</td>
<td>42.0</td>
</tr>
<tr>
<td>Age 9 (n = 5)</td>
<td>43.9</td>
<td>1.7</td>
<td>44.5</td>
</tr>
<tr>
<td>Age 10 (n = 1)</td>
<td>37.3</td>
<td>------</td>
<td>45.2</td>
</tr>
</tbody>
</table>

Combined LE's = both right and left lower extremities  
Std. Dev. = Standard Deviation
Table 4-4

Mean and Standard Deviation of Total Hip Rotation

For Each Age Group

<table>
<thead>
<tr>
<th>Age</th>
<th>Right Mean</th>
<th>Right Std. Dev.</th>
<th>Left Mean</th>
<th>Left Std. Dev.</th>
<th>Combined LE's Mean</th>
<th>Combined LE's Std. Dev.</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>86.1</td>
<td>6.9</td>
<td>84.2</td>
<td>8.1</td>
<td>85.1</td>
<td>7.5</td>
</tr>
<tr>
<td>6</td>
<td>89.5</td>
<td>16.0</td>
<td>90.4</td>
<td>10.9</td>
<td>90.0</td>
<td>13.2</td>
</tr>
<tr>
<td>7</td>
<td>85.7</td>
<td>8.9</td>
<td>89.2</td>
<td>7.8</td>
<td>87.4</td>
<td>8.1</td>
</tr>
<tr>
<td>8</td>
<td>83.1</td>
<td>11.4</td>
<td>85.6</td>
<td>9.7</td>
<td>84.4</td>
<td>10.4</td>
</tr>
<tr>
<td>9</td>
<td>90.4</td>
<td>1.5</td>
<td>91.6</td>
<td>4.7</td>
<td>91.0</td>
<td>2.8</td>
</tr>
<tr>
<td>10</td>
<td>84.2</td>
<td>--------</td>
<td>89.3</td>
<td>--------</td>
<td>86.8</td>
<td>--------</td>
</tr>
</tbody>
</table>

Std. Dev. = Standard Deviation
Combined LE's = both left and right lower extremities
Table 4-5

Mean and Standard Deviation of Femoral Anteversion

For Right and Left Extremities

<table>
<thead>
<tr>
<th>Age</th>
<th>Left LE</th>
<th>Right LE</th>
<th>Combined</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean</td>
<td>Std. Dev</td>
<td>Mean</td>
</tr>
<tr>
<td>5 (n = 3)</td>
<td>21.9</td>
<td>6.2</td>
<td>20.7</td>
</tr>
<tr>
<td>6 (n = 5)</td>
<td>23.3</td>
<td>8.6</td>
<td>21.3</td>
</tr>
<tr>
<td>7 (n = 13)</td>
<td>20.1</td>
<td>3.6</td>
<td>18.7</td>
</tr>
<tr>
<td>8 (n = 6)</td>
<td>22.1</td>
<td>3.2</td>
<td>21.1</td>
</tr>
<tr>
<td>9 (n = 5)</td>
<td>19.2</td>
<td>3.1</td>
<td>18.1</td>
</tr>
<tr>
<td>10 (n = 1)</td>
<td>18.2</td>
<td>--------</td>
<td>18.3</td>
</tr>
</tbody>
</table>
Table 4-6

**Mean and Standard Deviation of External Tibiofibular Torsion**

For Right and Left Extremities

<table>
<thead>
<tr>
<th>Age</th>
<th>Left LE</th>
<th>Right LE</th>
<th>Combined LE's</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean</td>
<td>Std. Dev.</td>
<td>Mean</td>
</tr>
<tr>
<td>Age 5 (n = 3)</td>
<td>9.70</td>
<td>3.00</td>
<td>10.60</td>
</tr>
<tr>
<td>Age 6 (n = 5)</td>
<td>7.70</td>
<td>2.20</td>
<td>10.30</td>
</tr>
<tr>
<td>Age 7 (n = 13)</td>
<td>9.00</td>
<td>3.10</td>
<td>9.20</td>
</tr>
<tr>
<td>Age 8 (n = 6)</td>
<td>8.80</td>
<td>1.50</td>
<td>9.50</td>
</tr>
<tr>
<td>Age 9 (n = 5)</td>
<td>10.50</td>
<td>2.50</td>
<td>10.90</td>
</tr>
<tr>
<td>Age 10 (n = 1)</td>
<td>8.70</td>
<td>---------</td>
<td>9.70</td>
</tr>
</tbody>
</table>
of femoral anteversion and tibiofibular torsion values for all subjects. All values were separated into the left and right lower extremities, as well as combining the left and right extremity data for each age group.

The intratester and intertester reliability were completed using a 2-tailed bivariate correlation, or more specifically, the Pearson product-moment correlation coefficient. The authors considered r-values of greater than .70 as clinically significant. In order to rank the significance of each reliability coefficient, the authors categorized the r-values into good (r = 0.75 to 1.00), moderate to good (r = 0.50 to 0.75), fair (r = 0.25 to 0.50) and poor (r = 0.00 to 0.25). The reliabilities for anteversion and tibiofibular torsion were calculated separately with the left and right extremities and then calculated with the extremity data pooled together to obtain a combined mean value for each age group. Table 4-7 and 4-8 provide reliability data for the Ryder's test and the TFA test, respectively.

Intratester reliability for the left lower extremity anteversion was fair (r = 0.49) for one tester and good (r = 0.78) for the second tester. Intratester reliability for the right lower extremity anteversion was fair (r = 0.38) for one tester and good (r = 0.76) for the second tester. The left and right extremity data were also combined to obtain an intratester reliability for each tester. Those combined intratester reliability values were moderate to good (r = 0.64) for one tester and good (r = 0.84) for the second tester.

The tibiofibular torsion intratester reliability for the left lower extremity was moderate to good (r = 0.63 and r = 0.52) for both testers. The tibiofibular torsion intratester reliability for the right lower extremity was fair (r = 0.46 and r = 0.44) for both testers. The left and right lower extremity data were also combined for the TFA test to
Table 4-7

**Reliability Coefficients—Ryder’s Tests (n = 33)**

<table>
<thead>
<tr>
<th></th>
<th>Left LE</th>
<th>Right LE</th>
<th>Combined</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Intratester</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tester 1</td>
<td>0.49</td>
<td>0.38</td>
<td>0.64</td>
</tr>
<tr>
<td>Tester 2</td>
<td>0.78</td>
<td>0.76</td>
<td>0.84</td>
</tr>
<tr>
<td>Intertester</td>
<td>0.44</td>
<td>0.15</td>
<td>0.37</td>
</tr>
</tbody>
</table>

**R-Value Scale**

- $r = 0.75$ to $1.00$ (good)
- $r = 0.50$ to $0.75$ (moderate to good)
- $r = 0.25$ to $0.50$ (fair)
- $r = 0.00$ to $0.25$ (poor)
Table 4-8

Reliability Coefficients—Thigh-Foot Angle Tests (n = 33)

<table>
<thead>
<tr>
<th></th>
<th>Left LE</th>
<th>Right LE</th>
<th>Combined</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Intratester</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tester 1</td>
<td>0.63</td>
<td>0.46</td>
<td>0.64</td>
</tr>
<tr>
<td>Tester 2</td>
<td>0.52</td>
<td>0.44</td>
<td>0.55</td>
</tr>
<tr>
<td><strong>Intertester</strong></td>
<td>0.41</td>
<td>0.51</td>
<td>0.47</td>
</tr>
</tbody>
</table>

R-Value Scale

- $r = 0.75$ to $1.00$ (good)
- $r = 0.50$ to $0.75$ (moderate to good)
- $r = 0.25$ to $0.50$ (fair)
- $r = 0.00$ to $0.25$ (poor)
produce a combined intratester reliability for each tester. Those intratester reliabilities were moderate to good for both testers ($r = 0.64$ and $r = 0.55$).

Intertester reliability for the left lower extremity anteversion was fair ($r = 0.44$) and for the right lower extremity was poor ($r = 0.15$). The left and right lower extremity intertester reliabilities were combined to produce a combined intertester reliability that was fair ($r = 0.37$). The intertester reliability for the left lower extremity tibiofibular torsion was fair ($r = 0.41$) and for the right lower extremity was moderate to good ($r = 0.51$). Again, those data for both of the extremities were combined to produce a combined intertester reliability that was fair ($r = 0.47$) with respect to the TFA test.
CHAPTER 5

DISCUSSION

Discussion and Comparison of Results to Other Studies

Previous research, using tests other than the Ryder’s test, which determined femoral anteversion, has indicated a general decreasing trend in anteversion values in normal children ages 5 through 10. For example, Fabry et al. (1973) studied normal children using radiographs and found an average of 26, 26, 23, 24, 21 and 20 degrees of femoral anteversion for ages 5 through 10, respectively. This current research separated the lower extremity data into right and left and also combined the lower extremity data to obtain the mean anteversion value of each age group. A general trend can be observed from the graphical analyses that are similar to previous research however, a trend analysis was not performed. (See Graph 5-1.) Small decreasing general trends in femoral anteversion as the age of the children increased were observed in this study. For example, the mean left anteversion values for ages 5 through 10 respectively were 22, 23, 20, 22, 19, and 18 degrees, while the right anteversion values were 21, 21, 19, 21, 18, and 18 degrees. When the lower extremity data were combined, anteversion values were 21, 22, 19, 21, 19, and 18 for the respective age groups 5 through 10. Since a test of covariance was not performed, a relationship between age and femoral anteversion was not determined based on our data. Although the authors did not find any previous research indicating differences between left and right lower extremities for femoral anteversion, the results of this study indicated a trend toward a consistently greater amount of femoral anteversion in the left lower extremity than the right lower extremity.
Graph 5-1. Mean right and left values for femoral anteversion across ages.
Previous research using the transmalleolar axis method of measuring tibiofibular torsion has demonstrated a general increasing trend of external tibiofibular torsion as age increased from ages 5 through 10 years. For example, Staheli and Engel (1972) measured normal children and found mean values of tibiofibular torsion from ages 5 through 10, respectively, to be 11, 9, 11, 11, 13, and 14 degrees. However, the authors of this current study did not observe a trend in tibiofibular torsion using the TFA test in either the left or right lower extremities as the age of the subjects increased. The authors also noted that the tibiofibular torsion values were higher in the right lower extremity for all age groups than the values obtained in the left lower extremity. (See Graph 5-2.) Coincidentally, Staheli (1989) reported that external tibial torsion was more common in the right lower extremity when a pathology was suspected.

In 1992, Ruwe et al. assessed the intertester reliability of the Ryder's test. They reported a reliability coefficient of $r = 0.774$. In 1997, Jonson and Gross reported an intertester reliability of $r = 0.85$ and an intratester reliability of $r = 0.94$. The authors in this current study determined the intertester reliability coefficient to be $r = 0.44$ and $r = 0.15$ for the left and right lower extremities, respectively, and a combined intertester reliability of $r = 0.37$. The authors felt that this reliability was unsatisfactory. The authors speculate one reason the intertester reliability for the Ryder's test was so low compared to the studies by Ruwe et al. (1992) and Jonson and Gross (1997), could be due to the current authors' relative lack of experience. Therefore, the authors suggest that in order to maintain a higher degree of consistency in measuring, the same clinician should attempt to make the measurement for each client. This may eliminate possible discrepancies between clinicians in determining objective measurements of femoral...
Graph 5-2. Mean right and left values for external tibiofibular torsion across ages.
anteversion. The individual limb intratester reliabilities ranged from $r = 0.38$ to $r = 0.78$ and the combined intratester reliabilities were $r = 0.64$ and $r = 0.84$, which showed improvement over the intertester reliabilities.

Until recently, very few studies had been performed regarding the intratester and intertester reliabilities of the TFA test. In 1991, Stuberg et al. reported an intertester reliability using the TFA test that was comparable to clinical goniometric variances of 1 to 4 degrees. Those authors found no significant difference between testers for the TFA test. Intertester reliability in this study was $r = 0.41$ and $r = 0.51$ for the left and right lower extremities, respectively, while the combined intertester reliability was $r = 0.47$. Intratester reliability for the TFA test has not been well documented in the literature. Intratester reliability of the TFA test in this study was as low as $r = 0.44$ and as high as $r = 0.63$ for the two extremities. The two lower extremities were combined to calculate the combined intratester reliabilities for each tester and were determined to be $r = 0.64$ and $r = 0.55$. Since the authors found no intratester and intertester reliability coefficients in the literature, the intratester and intertester data the authors obtained may be a valuable asset towards future research.

The authors speculate one reason why the intertester reliability data for the TFA test is better than the Ryder's test may be due to the increased experience the testers had in performing the TFA test over the Ryder's test. In addition, the TFA test is more accurate to perform since the anatomical landmarks are more easily obtained and the tester does not have to remove his palpating hand from the landmark when measuring, which must be done with the Ryder's test. Furthermore, the authors observed that the combined reliability values for both the Ryder's and the TFA tests were greater than an
average of the left and right lower extremity reliability values. Scatterplots were performed to investigate the cause of this discrepancy. Upon visual examination, the authors speculated that when the data points for the right and left lower extremities were combined, these values formed a tighter clustering and caused outlying data points to have less of an effect on the reliability. Thus, the remaining mean values represented a more linear correlation which resulted in a higher combined reliability coefficient. An example of this combined intratester reliability occurrence, with respect to a scatterplot of femoral anteversion, may be found in Appendix E.

The age group values for femoral anteversion and tibiofibular torsion obtained in the present study differed from what was reported in the literature. These discrepancies may be attributed to femoral anteversion and tibiofibular torsion having been measured by a variety of methods other than the Ryder's and TFA tests (Beals, 1969; Fabry et al., 1973; Kumar et al., 1992; Murphy et al., 1987; Staheli and Engel, 1972; Swanson et al., 1963). Other discrepancies may have been due to different exclusionary criteria, racial differences, geographical selectivity, and gender. Also, Stuberg et al. (1991) stated that a range of 5 degrees is commonly reported as the margin of error for goniometric measurements. Therefore, it would be important to take that potentially large margin of error into consideration when comparing the present study's goniometric values with those from other studies.

Limitations

Attempts were made by the authors to maintain consistency in collecting the measurements on the subjects. However, this study presented some limitations that may
have led to measurement error. The authors found limitations inherent in both hip rotation and anteversion measurements, as well as tibiofibular measurements that were performed during this study.

A possible source of random error with respect to hip rotation and anteversion measurements was in the subjective positioning of the goniometer at the center of the knee joint. In addition, some children presented with tibia which were shorter than the arm of the goniometer which may have altered the measurement accuracy of both hip rotation and femoral anteversion values. Furthermore, the thickness of the soft tissues overlying the greater trochanter may have affected the accuracy of palpation and led to a possible source of random error in the obtained anteversion measurements. According to Portney and Watkins (1993), reliability focuses on the degree of error that is present within the measurement system. Therefore, it is the presence of random error that brings about a concern for reliability.

A possible source of error with respect to tibiofibular torsion measurements was the element of subjectivity in the positioning of the goniometer parallel to the second metatarsal. There was also subjectivity in the positioning of the ankle and subtalar joints in neutral prior to obtaining tibiofibular torsion values.

A limitation that may have affected all of the authors' measurements was the large amount of variability in the attention span of individuals in this age range of 5 to 10 years. This variability led to a unique challenge in maintaining the attention of several of the children. Some of the children were easily distracted and had the tendency to move around frequently during data collection. In addition, the average of five degrees of random error, which is inherent in the goniometer (Stuberg et al., 1991), may affect the
results established by the Ryder's and the TFA tests.

Past research also acknowledges possible sources of error with respect to the hip rotation, femoral anteversion, and tibiofibular measurements the authors obtained in this study. The results of the TFA test may be misinterpreted as showing abnormal internal tibiofibular torsion, which may be due to knee hyperextensibility in the joint capsule and ligaments which may alter the screwhome mechanism (Cusick and Stuberg, 1992). Other variables which may affect the results include knee joint capsule bias towards medial rotation in neonates, overactive or shortened medial hamstrings or popliteus muscles, release of the screwhome mechanism with knee flexion which allows medial tibiofibular rotation, and medial genicular position due to habitual postures (Bunch, 1977; Cusick and Stuberg, 1992; Kite, 1960; Staheli, 1987; Swanson et al., 1963). Although these studies identified the above sources of error, it was not likely knee pathology was present in the subjects involved in this study. Therefore, it was not likely the results were misinterpreted.

A small sample size and geographical restrictions to the midwest region of Michigan are two additional limitations. These limitations decrease the validity of generalizing this normative data to the pediatric population with respect to the torsional changes of the lower extremity long bones.

**Suggestions for Further Study**

Further research is suggested to expand upon the initial normative data collected for this study. The authors recommend it should include a larger sample size and a more diverse demographic region to increase the validity of making generalizations to the
pediatric population. To improve upon the intratester reliability in this study, the authors suggest retesting the subjects approximately one week later rather than using data obtained on the same day. In addition, the use of a pelvic stabilization belt may improve upon the intertester and intratester reliabilities of both the Ryder's and TFA tests. Re-examining inter- and intratester reliability using the Ryder's and Thigh-Foot Angle tests is warranted. One might use both experienced and less experienced clinicians. Further research may also explore trends regarding gender or right/left extremity differences in the age range of 5 through 10 years. In addition, other studies may compare the relationship of femoral anteversion with external tibiofibular torsion, internal hip rotation, and external hip rotation, since past research has indicated a correlation between these variables (Staheli, 1983). Lastly, external hip rotation and internal tibiofibular torsion has been correlated using old methods of measurement (Staheli, 1983). Therefore, it would be interesting to see if that correlation would continue to exist using the Thigh-Foot Angle test.

**Clinical Implications**

This study introduces an additional set of normative data on children using clinically practical assessment tools, such as the Ryder's and TFA tests. These assessment tools are clinically efficient in that they do not need costly, elaborate, or highly technical equipment, unlike those used by other researchers that utilized computed tomography, x-rays, or roentgenograms to determine femoral anteversion or tibiofibular torsion (Beals, 1969; Fabry et al., 1973; Jakob et al., 1980; Lewis et al., 1964; Murphy et al., 1987; Swanson et al., 1963). The determination and confirmation of normative data
of femoral anteversion and tibiofibular torsion using a clinically practical screen can aid in the treatment plan of those individuals who have torsional deformities and gait abnormalities. By comparing the data obtained in an evaluation with the established norms in this and future studies, a clinician may determine when and what kind of intervention may be necessary.

Since this study demonstrated fair to poor reliability between testers (intertester) for both individual lower extremities and combined extremities using the Ryder's test, the authors suggest that it should not be used in situations in which the measurements need to be taken by a number of clinicians on a single client. This would be especially important when measuring treatment outcome. However, since the intratester reliability in this study demonstrated a consistently fair to good r-value within the two testers, a clinician should become familiar with the Ryder's test technique before using it to measure and document objective anteversion data.

The intertester reliability coefficients for the TFA test for the individual and combined left and right lower extremities fell within the ranges of fair and moderate to good. Similarly the intratester reliabilities for the TFA test also fell within the same ranges of fair and moderate to good. The authors suggest that the TFA test could be useful as an indicator of tibiofibular torsion, but clinicians should be cautious since reliability of measurements were not consistently high.

The authors suggest that when using the Ryder's and TFA tests in the clinic it would be important not to rely solely on these test results when deciding whether a permanent change in the individual's rehabilitation regimen is necessary. Studies have demonstrated a high correlation between postural malalignments and/or gait deviations
with abnormal femoral anteversion and tibiofibular torsion test results (Engel and Staheli, 1974; Killam, 1989; Ritter et al., 1976; and Staheli and Engel, 1972). Although this correlation exists, the authors recommend a thorough evaluation to rule out other contributing factors to those clinical manifestations, such as muscle weaknesses or imbalances, limited muscle or joint mobility, and decreased neuromuscular control (Engel and Staheli, 1974; Killam, 1989; Staheli et al., 1985; and Stuberg, et al., 1991).

Conclusion

The literature has demonstrated an inadequate database of normative data on femoral anteversion and tibiofibular torsion using the Ryder's and the Thigh-Foot Angle tests, respectively, for normal children aged 5 through 10 years. In addition, very little intratester and intertester reliability data have been reported on the Ryder's test and even less regarding the Thigh-Foot Angle test. This study introduced an additional set of data on normal children using the Ryder's and TFA tests that may be added to the existing database. Results of this study found a small decreasing general trend in femoral anteversion with increasing age. However, no significant trend was noted in the tibiofibular torsion measurements. Intratester reliabilities for the Ryder's and TFA tests ranged from "fair" to "good" while intertester reliabilities for those tests ranged from "poor" to "moderate to good". This study serves as a springboard for additional research to establish normative data and reliability values for the Ryder's and TFA tests. Through the determination and confirmation of an established normative database for femoral anteversion and tibiofibular torsion, a clinician can determine when and what kind of intervention may be necessary in the treatment plan of individuals who have torsional deformities or gait abnormalities.
REFERENCES


May 25, 1996

Dear Sir or Madam:

We are students in our final year in the Master's degree program in Physical Therapy at Grand Valley State University. One of the requirements of the Master's program is to complete a final project. Our chosen project is on measuring a component of the two long bones of the legs of normal children. Specifically, our focus is on those aged 5 through 10 years.

Our study will involve simply positioning the child on his/her stomach and measuring certain angles of his/her legs with a plastic ruler-type device called a goniometer. We will only need a small area in which to set up our portable assessment table at your facility. We will maintain flexibility in order to accommodate the needs of your facility, the parents and the children when scheduling an appropriate time to perform the measurements. Before we begin our project, a signed consent form from the parent/legal guardian, as well as a health screening questionnaire to determine child eligibility, must be completed.

We anticipate initial data collection to begin in late June, 1996 following our study's approval by Grand Valley State University's Human Subjects Review Committee.

We are asking for your assistance in obtaining children for our final project. Please contact us at your earliest convenience if you would be interested in obtaining more details. We can be reached at the telephone numbers listed above.

Thank you for your time.

Sincerely,
Timothy M. Dahlke, SPT
Wendi L. Jabs, SPT
APPENDIX B

PARTICIPANT QUESTIONNAIRE SCREENING TOOL

Date________

Participant's name____________ Parent/Legal Guardian's Name____________

Participant's: Birthdate________ Gender____ Telephone_________________

Has you child ever had or consulted a doctor for any of the following? Please explain any yes answers below in the space provided.

1. Corrective devices for the hips, legs, or feet Yes__ No__
2. Diagnosed with any neuromuscular disorders (ie: cerebral palsy, multiple sclerosis, etc.) Yes__ No__
3. Any previous traumatic injuries to the legs (ligament strain/sprain, fractures, muscle tears, etc.) Yes__ No__
4. Medical or surgical procedure on hips, legs, or feet Yes__ No__
5. Known congenital or progressive abnormalities (hip dislocation, scoliosis) Yes__ No__

Please list all surgical procedures and explain all yes answers
__________________________________________________________________________
__________________________________________________________________________

I understand that the presence of any of the above conditions may affect the results of these tests and may lead to the exclusion of my child's data from the study. As a result of this questionnaire, my child may also be asked not to perform in this study.

Parent/Legal Guardian's Signature_______________________ Date____________
APPENDIX C

GRAND VALLEY STATE UNIVERSITY RESEARCH CONSENT FORM

Title of Project: Utilizing the Ryder's and the Thigh-Foot Angle Tests to establish normal values of Femoral anteversion and Tibiofibular torsion in Children aged 5 through 10 years

Principle Investigators: Timothy M. Dahlke and Wendi L. Jabs

PURPOSE OF RESEARCH

I have been informed that this study will determine average values of the twist (torsion) of the two main long bones of the leg (femur and tibia). Obtaining these values will add to the already existing information in the rehabilitative and medical settings and will assist clinicians in the assessment and treatment of possible problems with walking.

PROCEDURE

My child will be expected to attend one or two physical therapy assessment session(s). I am aware that the procedures include using a noninvasive measurement tool. I understand there will be several measurements taken for each leg. Assessment will take no longer than 20 minutes. I understand that I may be present when the measurements are taken. Otherwise, I hereby give permission for the measurements to be taken without my presence.

RISKS AND DISCOMFORTS

I understand that because some measurements involve taking the hip joint to end range of motion, my child may experience some minimal stretch or strain feeling during or after the measurements. The procedures of this study are not expected to exaggerate possible preexisting conditions or pathologies.

BENEFITS

I understand that my child's participation in the study will have no direct benefit to him/her or to me. The major potential benefit is to collect the measurements of
individuals without pathology using tests commonly used in the clinical setting. The measurements the testers obtain may be useful in understanding theories of development. Additionally, these measurements may lead to research on subjects with abnormal torsion.

CONFIDENTIALITY

I understand that the information obtained from this study will be confidential and used only for research. My child's data results will be stored in the investigators research file and identified only by a code number.

If the data is used for publication in the medical literature or for teaching purposes, no names will be used, and other identifiers, such as torsional measurements will be used only with my special written permission. I understand that I may see the torsional measurements before giving this permission.

REQUEST FOR MORE INFORMATION

I understand that I may ask more questions about the study at any time. Timothy Dahlke at (616)735-0605 and Wendi Jabs at (616)453-2851 are available to answer my questions or concerns.

If during the study, or later, I wish to discuss my child's participation in or concerns regarding this study with a person not directly involved, I am aware that Paul Huizenga of the Human Subjects Review Committee (616-895-3525) is available to talk with me. A copy of this consent form will be given to me upon my request.

REFUSAL OR WITHDRAWAL OF PARTICIPATION

I understand that my child's participation is voluntary and that he/she may refuse to participate or may withdraw consent and discontinue participation in the study at any time. I also understand that Timothy Dahlke and Wendi Jabs may terminate my child's participation in this study at any time after they have explained the reasons for doing so.

INJURY STATEMENT

I understand that by my agreement for my child to participate in this study I am not waiving any of my legal rights.

I have explained to ___________________________ the purpose of the research, the procedures required, and the possible risks and benefits to the best of my ability.
I confirm that Timothy Dahlke and Wendi Jabs have explained to me the purpose of the research, the study procedures that my child will undergo, and the possible risks and discomforts as well as benefits that he/she may experience. I have read and understand this consent form. Therefore, I agree to give my consent for my child to participate as a subject in this research project.
APPENDIX D

DATA COLLECTION FORM

Trial 1

<table>
<thead>
<tr>
<th></th>
<th>Left LE</th>
<th>Right LE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Internal hip rotation</td>
<td>______ degrees</td>
<td>______ degrees</td>
</tr>
<tr>
<td>External hip rotation</td>
<td>______ degrees</td>
<td>______ degrees</td>
</tr>
<tr>
<td>Total hip excursion</td>
<td>______ degrees</td>
<td>______ degrees</td>
</tr>
<tr>
<td>Femoral anteversion</td>
<td>______ degrees</td>
<td>______ degrees</td>
</tr>
<tr>
<td>Tibiofibular rotation</td>
<td>______ degrees</td>
<td>______ degrees</td>
</tr>
</tbody>
</table>

Gender: M F
Age: 5 6 7 8 9 10 yrs ___ mos.

Trial 2

<table>
<thead>
<tr>
<th></th>
<th>Left LE</th>
<th>Right LE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Internal hip rotation</td>
<td>______ degrees</td>
<td>______ degrees</td>
</tr>
<tr>
<td>External hip rotation</td>
<td>______ degrees</td>
<td>______ degrees</td>
</tr>
<tr>
<td>Total hip excursion</td>
<td>______ degrees</td>
<td>______ degrees</td>
</tr>
<tr>
<td>Femoral anteversion</td>
<td>______ degrees</td>
<td>______ degrees</td>
</tr>
<tr>
<td>Tibiofibular rotation</td>
<td>______ degrees</td>
<td>______ degrees</td>
</tr>
</tbody>
</table>

Trial 3

<table>
<thead>
<tr>
<th></th>
<th>Left LE</th>
<th>Right LE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Internal hip rotation</td>
<td>______ degrees</td>
<td>______ degrees</td>
</tr>
<tr>
<td>External hip rotation</td>
<td>______ degrees</td>
<td>______ degrees</td>
</tr>
<tr>
<td>Total hip excursion</td>
<td>______ degrees</td>
<td>______ degrees</td>
</tr>
<tr>
<td>Femoral anteversion</td>
<td>______ degrees</td>
<td>______ degrees</td>
</tr>
<tr>
<td>Tibiofibular rotation</td>
<td>______ degrees</td>
<td>______ degrees</td>
</tr>
</tbody>
</table>

Comments: __________________________________________________________
___________________________________________________________
APPENDIX E

Scatterplot of Left Femoral Anteversion

Representation of data points using trials 1 and 3 from tester 1, for femoral anteversion of the left lower extremity.
Representation of data points using trials 1 and 3 from tester 1, for femoral anteversion of the right lower extremity.
Scatterplot of Combined Femoral Anteversion

Representation of data points using trials 1 and 3 from tester 1, for femoral anteversion of both the left and right lower extremities