FOOT MODEL FOR CLINICAL APPLICATION

by

Prabhav Saraswat

A dissertation submitted to the faculty of
The University of Utah
in partial fulfillment of the requirements for the degree of

Doctor of Philosophy

Department of Bioengineering
The University of Utah
May 2010
THE UNIVERSITY OF UTAH GRADUATE SCHOOL

SUPERVISORY COMMITTEE APPROVAL

of a dissertation submitted by

Prabhav Saraswat

The dissertation has been read by each member of the following supervisory committee and by majority vote has been found to be satisfactory.

<table>
<thead>
<tr>
<th>Date</th>
<th>Name</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Chair: Bruce A. MacWilliams</td>
</tr>
<tr>
<td></td>
<td>Jeffrey A. Weiss</td>
</tr>
<tr>
<td></td>
<td>Richard D. Rabbitt</td>
</tr>
<tr>
<td></td>
<td>Stacy M. Bamberg</td>
</tr>
<tr>
<td></td>
<td>Jacques D’Astous</td>
</tr>
<tr>
<td></td>
<td>Nicholas A. Brown</td>
</tr>
</tbody>
</table>
To the Graduate School Council of the University of Utah:

I have read the dissertation of Prabhav Saraswat in its final form and have found that (1) its format, citations, and bibliographic style are consistent and acceptable; (2) its illustrative materials including figures, tables, and charts are in place; and (3) the final manuscript is satisfactory to the supervisory committee and is ready for submission to The Graduate School.

_________________________  ________________________________
  Date                  Bruce A. MacWilliams
                      Chair: Supervisory Committee

Approved for the Major Department

_________________________
  Richard D. Rabbitt
  Department Chair

Approved for the Graduate Council

_________________________
  Charles A. Wight
  Dean of the Graduate School
ABSTRACT

Several multisegment foot models to measure the motion of intrinsic joints of the foot have been reported. Use of these models in clinical decision making is limited due to lack of variability measures and untested adaptability for pathologic subjects and multiple data-collection sites. Therefore, a new clinical foot model was developed to reduce the variability associated with foot models due to marker placement error. Kinetics of foot models have not been developed in previous foot models due to difficulty in measuring ground reaction forces in multiple parts of the foot. Therefore, a strategy for segmenting ground reaction force by use of a synchronized pressure plate coupled with a dimensionally matched force plate was developed.

Model application was carried out on typically developing and pathologic (planovalgus foot) pediatric subjects at two data collection sites. Intraclinician and interclinician variability in model outcomes (joint angles, moments and power during walking) have been quantified for both control and pathologic groups. Model outcomes were compared between the two groups to demonstrate the capability of reflecting differences between normal and impaired foot function.

Several musculoskeletal models exist for full-body gait analysis but these treat the foot as a single segment and ignore the motion of intrinsic joints. To date, no multi-segment kinematic foot model has been used as part of a musculoskeletal model. We hypothesize that a multisegment foot model can be constructed, scaled to match a
subject and driven with subject data from an existing kinematic model to estimate internal muscle activation patterns. A three-segment musculoskeletal model for the right foot was developed. Model geometry was optimized with moment arm measured from cadaver testing. The model was driven by kinematic and kinetic gait data from 5 normal pediatric subjects and muscle activation levels required to produce joint motions were calculated using an inverse dynamic analysis approach. To evaluate the model outcomes, the computed muscle activation patterns were compared with measured electromyography (EMG) activation patterns reported in the literature.
# TABLE OF CONTENTS

ABSTRACT ....................................................................................................................... iv  
LIST OF TABLES .......................................................................................................... ix  
LIST OF FIGURES ........................................................................................................ x  
ACKNOWLEDGEMENTS ............................................................................................. xi  

Chapters

1. INTRODUCTION .......................................................................................................... 1  
   - Relevance .............................................................................................................. 2  
   - Prevalence ............................................................................................................. 2  
   - Anatomy ............................................................................................................... 3  
   - Gait Analysis ......................................................................................................... 4  
   - Limitations of Current Gait Analysis to Detect Foot Deformity ......................... 4  
   - Background and Significance .............................................................................. 5  
     Multisegment Kinematic Foot Model ................................................................. 5  
     Multisegment Kinetic Foot Model ..................................................................... 6  
     Musculoskeletal Model ..................................................................................... 6  
   - Specific Aims ......................................................................................................... 7  

2. REPEATABILITY OF KINEMATIC FOOT MODEL .............................................. 10  
   - Abstract ............................................................................................................... 11  
   - Introduction .......................................................................................................... 12  
     - Purpose .............................................................................................................. 14  
   - Methods ............................................................................................................... 14  
     - Proposed Model ............................................................................................. 14  
     - Model Evaluation ......................................................................................... 15  
     - Plaster Mold .................................................................................................... 17  
     - Data Collection .............................................................................................. 19  
     - Data Processing ............................................................................................. 22  
     - Statistical Analysis ....................................................................................... 22  
   - Results ............................................................................................................... 23  
     - Static Measure of Marker Placement Variability ......................................... 23  
     - Walking Kinematics and Dynamic Variability .............................................. 24
<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Model Outcome Comparison with Previous Models</td>
<td>28</td>
</tr>
<tr>
<td>Discussion</td>
<td>28</td>
</tr>
<tr>
<td>Plaster Mold</td>
<td>28</td>
</tr>
<tr>
<td>Walking Kinematics</td>
<td>31</td>
</tr>
<tr>
<td>Comparison with Other Models</td>
<td>31</td>
</tr>
<tr>
<td>Limitations</td>
<td>32</td>
</tr>
<tr>
<td>Summary</td>
<td>33</td>
</tr>
<tr>
<td>3. MODEL KINETICS AND PATHOLOGIC APPLICATION</td>
<td>34</td>
</tr>
<tr>
<td>Abstract</td>
<td>35</td>
</tr>
<tr>
<td>Introduction</td>
<td>35</td>
</tr>
<tr>
<td>Methods</td>
<td>37</td>
</tr>
<tr>
<td>Subjects</td>
<td>37</td>
</tr>
<tr>
<td>Data Collection</td>
<td>38</td>
</tr>
<tr>
<td>Kinematic Computations</td>
<td>38</td>
</tr>
<tr>
<td>Kinetic Computations</td>
<td>38</td>
</tr>
<tr>
<td>Data Analysis</td>
<td>42</td>
</tr>
<tr>
<td>Statistical Analysis</td>
<td>42</td>
</tr>
<tr>
<td>Results</td>
<td>43</td>
</tr>
<tr>
<td>Discussion</td>
<td>49</td>
</tr>
<tr>
<td>4. MUSCULOSKELETAL MODEL</td>
<td>52</td>
</tr>
<tr>
<td>Abstract</td>
<td>53</td>
</tr>
<tr>
<td>Introduction</td>
<td>54</td>
</tr>
<tr>
<td>Methods</td>
<td>55</td>
</tr>
<tr>
<td>Base Musculoskeletal Model</td>
<td>55</td>
</tr>
<tr>
<td>Subject-Specific Adaptation</td>
<td>62</td>
</tr>
<tr>
<td>Results</td>
<td>68</td>
</tr>
<tr>
<td>Discussion</td>
<td>73</td>
</tr>
<tr>
<td>5. MODEL INTEGRATION</td>
<td>76</td>
</tr>
<tr>
<td>Appendices</td>
<td></td>
</tr>
<tr>
<td>A. IRB: ASSENT FORM</td>
<td>80</td>
</tr>
<tr>
<td>B. IRB: PARENTAL PERMISSION FORM</td>
<td>83</td>
</tr>
<tr>
<td>C. BODYBUILDER PROGRAM FOR FOOT KINEMATICS</td>
<td>89</td>
</tr>
<tr>
<td>D. MATLAB PROGRAM FOR FOOT KINETICS</td>
<td>100</td>
</tr>
</tbody>
</table>
### LIST OF TABLES

<table>
<thead>
<tr>
<th>Table</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.1 Anatomical location of anatomical markers</td>
<td>18</td>
</tr>
<tr>
<td>2.2 Anatomical position of technical markers</td>
<td>20</td>
</tr>
<tr>
<td>2.3 Model segment coordinate system definitions based on static calibration trial</td>
<td>21</td>
</tr>
<tr>
<td>2.4 Maximum and range of motion observed by three models during walking</td>
<td>29</td>
</tr>
<tr>
<td>3.1 Results of independent samples t-test for key variables</td>
<td>48</td>
</tr>
<tr>
<td>4.1 Muscles included in the model</td>
<td>59</td>
</tr>
<tr>
<td>4.2 Ligaments included in the model</td>
<td>60</td>
</tr>
<tr>
<td>4.3 Optimization setting for each marker degree of freedom</td>
<td>65</td>
</tr>
</tbody>
</table>
## LIST OF FIGURES

<table>
<thead>
<tr>
<th>Figure</th>
<th>Description</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.1</td>
<td>Static trials.</td>
<td>17</td>
</tr>
<tr>
<td>2.2</td>
<td>Variability in the static segment attitudes.</td>
<td>25</td>
</tr>
<tr>
<td>2.3</td>
<td>Comparison of intraclinician marker placement variability between two sites.</td>
<td>26</td>
</tr>
<tr>
<td>2.4</td>
<td>Variability in static segment attitude using SHCG model and previous model</td>
<td>26</td>
</tr>
<tr>
<td>2.5</td>
<td>Average standard deviations (SD) of intersegmental angles.</td>
<td>27</td>
</tr>
<tr>
<td>2.6</td>
<td>Comparison of average standard deviation of intersegmental angles.</td>
<td>27</td>
</tr>
<tr>
<td>3.1</td>
<td>Segmentation of foot pressure data.</td>
<td>41</td>
</tr>
<tr>
<td>3.2</td>
<td>Validation of proportionality assumption.</td>
<td>44</td>
</tr>
<tr>
<td>3.3</td>
<td>Joint angle during walking for two groups.</td>
<td>45</td>
</tr>
<tr>
<td>3.4</td>
<td>Joint moments and power during a gait cycle.</td>
<td>46</td>
</tr>
<tr>
<td>3.5</td>
<td>Interclinician variability in peaks of joint moment.</td>
<td>47</td>
</tr>
<tr>
<td>4.1</td>
<td>The musculoskeletal model with five segments.</td>
<td>56</td>
</tr>
<tr>
<td>4.2</td>
<td>Marker data from a motion capture system.</td>
<td>66</td>
</tr>
<tr>
<td>4.3</td>
<td>Graphical representation of tibialis anterior.</td>
<td>70</td>
</tr>
<tr>
<td>4.4</td>
<td>Moment arms (meter) over a range of ankle flexion motion.</td>
<td>71</td>
</tr>
<tr>
<td>4.5</td>
<td>EMG-measured muscle activation pattern.</td>
<td>72</td>
</tr>
<tr>
<td>4.6</td>
<td>Activation pattern of brevis muscles of the foot during walking.</td>
<td>74</td>
</tr>
<tr>
<td>5.1</td>
<td>Flowchart of interrelation between three models.</td>
<td>77</td>
</tr>
</tbody>
</table>
ACKNOWLEDGEMENTS

I want to express my gratitude to my advisor, Dr. Bruce MacWilliams, whose expertise, understanding and patience added considerably to my graduate experience. I appreciate his vast knowledge and skills in motion analysis and his generous assistance in writing manuscripts. I would like to thank motion analysis lab members Amy Shuckra, Barbara Johnson and Soffee Lowell for their continuous assistance during my project.

I would like to thank Dr. Nick Brown for providing assistance in conceptualizing the musculoskeletal model. A special thanks goes out to Michael S. Andersen, without whose assistance the model could not be adapted for multiple subjects. I would like to thank my committee members for their helpful criticism and encouragement. I would also like to thank Dr. Stephen Piazza for taking time out from his busy schedule to serve as external reviewer.

I would also like to recognize that this research would not have been possible without the financial assistance from Shriners Hospital for Children, and express my gratitude to the hospital.

I am grateful to my undergraduate advisor, Dr. Jayanta Kumar Dutt, without whose guidance, I would not have considered a graduate career in Bioengineering.

Finally, I am forever indebted to my parents and brother for their unconditional support and encouragement to pursue my interests, even when the interests were beyond boundaries of language, culture and geography.
CHAPTER 1

INTRODUCTION
Relevance

Many adults and children are diagnosed annually with foot disorders, pathologies and deformities that are challenging to evaluate and treat. These can result from congenital neurologic conditions (e.g., cerebral palsy, myelomeningocele), trauma (e.g., posterior tibial tendon insufficiency, crush injuries), or acquired disease (e.g., stroke, diabetes). Classifications of the resulting deformities include charcot foot, club foot (equinovarus), pes planus, pes cavus and planovalgus. Current clinical motion analysis methods do not measure motion of intrinsic joints of the foot and are therefore incapable of measuring these deformities. Foot models capable of providing accurate and reliable methods for quantitative assessment of these patients may significantly improve the pre-treatment planning, surgical and rehabilitative care and posttreatment evaluation. Such models may also be used for analyzing more complex cases such as partial foot amputation. In this study, specific interest for model application was focused on the planovalgus foot due to its high prevalence in children and adults with cerebral palsy.

Prevalence

One of the largest bodies of pediatric patients seen for clinical gait analysis is children with cerebral palsy (CP). The prevalence of CP in the United States is 2.5 per 1,000, with estimations ranging between 500,000 to 700,000 persons afflicted, 40% of whom are less than 20 years of age. The incidence of CP in newborns is one per 1,000, creating 3,500 to 4,000 new cases annually (Sussman, 1992). A number of foot disorders are associated with CP including pes planus, pes cavus, hindfoot inversion/eversion, forefoot adductus and hallux valgus. Combinations of these disorders are often present.
The most common deformity is the planovalgus foot: a combination of pes planus (flat foot), hindfoot inversion (or varus) and forefoot adductus (Bennet et al., 1982). Foot deformities are a major concern for the cerebral palsy patient.

**Anatomy**

The foot is a complex arrangement of 28 separate (nonsesamoidal) bones (including the tibia and fibula) connected to form 30 articulating surfaces. Pressures are dynamically distributed over the plantar surface of the foot such that throughout the gait cycle, different segments of the foot are being loaded in time varying patterns. One popular concept of foot function in gait analysis is the “three rocker” model. In the normal foot, initial contact is made on the heel and the foot rolls into plantar-flexion as the entire foot makes contact with the ground. This is known as the “heel rocker.” Progression is continued using the “ankle rocker” as weight is shifted from the heel to the forefoot. In this phase, the entire plantar surface contacts the ground and is supple to accommodate varying surfaces. As weight is further shifted forward, the rounded contours of the metatarsals create the “forefoot” rocker during which push-off occurs, initiating the swing phase of gait. Interplay between muscles and bones transform the supple foot into a rigid lever, supporting the enter body weight. This cascade of events describes an efficient mechanism of weight transfer dependent upon muscle control, flexibility and normal anatomy. In the pathological foot, many of these characteristics are absent or altered, resulting in less efficient compensatory mechanics. Understanding the pathomechanics in individual patients is a key component to formulating appropriate treatment plans.
**Gait Analysis**

Gait analysis is the systematic study of human walking to understand body mechanics. A typical gait lab has several cameras placed around a walkway that track the reflective markers attached to a subject’s skin. Markers are typically attached to palpable anatomical landmarks. A model is applied to the marker trajectories recorded by cameras to estimate the underlying motion of the bones. The model outcomes provide quantitative information about joint function during walking that is used to assess, plan and treat individuals with conditions affecting their ability to walk.

In addition to joint motion, joint kinematics (i.e., moments and powers) are also computed by an inverse dynamics-based model. Force plates are embedded in the floor to measure ground reaction forces. These force plates provide both reaction force vectors and centers of pressure, which are used in the inverse dynamics analysis.

Kinetic models provide net joint moments that can be interpreted as activity patterns of muscle groups. To detect the individual muscle activation pattern during walking electromyography (EMG), either surface or indwelling electrodes are used. Deviations from normal kinematic, kinetic and EMG patterns are used to understand and quantify pathologies either to guide subject-specific treatment strategies or to objectively measure outcomes.

**Limitations of Current Gait Analysis**

**to Detect Foot Deformity**

Traditional gait models have modeled the body as a series of rigid links starting at the trunk or pelvis and ending at the feet (Davis et al., 1991; Kadaba et al., 1990). These
models consider the foot as a single segment with motion occurring solely at the ankle joint. These models grossly oversimplify foot anatomy; internal kinematics and kinetics of various regions of the foot are not measured (Lundberg, 1989). Current gait analysis protocols also do not include measurement of EMG activation pattern for intrinsic muscles of foot. While some intrinsic foot muscles can be reached by indwelling EMG electrodes, most of them cannot practically be directly measured. Therefore, gait motion analysis data cannot be used for clinical decision making for subjects with significant foot deformities without some subjective interpretation of the true function of the foot.

**Background and Significance**

**Multisegment Kinematic Foot Model**

There are a number of published kinematic foot models (D'Andrea, 1993; Dul et al., 1985; Hunt et al., 2001; Kidder et al., 1996; Leardini et al., 1999; Liu, 1997; Lundberg, 1989; Moseley et al., 1996; Sampath, 1998; Scott et al., 1991; Scott et al., 1993; van den Bogert et al., 1994) with many common traits. Most of these models, however, have been developed in the context of healthy adult feet. Many are associated with protocols that would require motion camera repositioning and would not allow simultaneous whole-body gait data collection. Additionally, most of these models suffer from an inherent inaccuracy that arises from a reliance on identification of and accurate placement of markers on anatomical landmarks. The inherent inaccuracy of anatomical markers arises from the necessary proximity of markers on the foot. When markers are placed close together as is necessary in the foot, small errors in marker placement result in large errors in angular computations.
Multisegment Kinetic Foot Model

Analysis of net joint moments and powers is routinely used in gait analysis to assist with clinical decision making and in research to understand function and surgical outcomes. If similar measures could be determined in the joints of the foot, this could potentially lead to better clinical decision making and better understanding of both the normal and pathological functions of the foot. Although there have been several kinematic foot model, efforts have been limited towards developing kinetics of the foot model, mainly due to technological hurdles. The problem is that more than one segment of the foot contacts the ground simultaneously during stance phase of walking. To compute ground reaction forces acting on multiple segments of the foot, additional information is required that can be garnered neither by a conventional gait laboratory setup nor by traditional software. The coupled pedobarograph and force plate system (Macwilliams et al., 2003) can be used for ground reaction force distribution among segments. This method is not being used in clinical practice due to lack of integrated hardware and software for force plate and pedobarograph coupling.

Musculoskeletal Model

In the past decade, human musculoskeletal modeling has been a major part of biomechanical research. There are several full body human musculoskeletal models available both commercially and in open source development (Damsgaard et al., 2006; Delp et al., 1990; Dhang et al., 2004; Hoy et al., 1990). These models, however, are not part of current clinical decision making, but research in this area suggests it to be a potential tool in clinical decision making in the near future. These currently available
musculoskeletal models are very descriptive for the upper and lower human body, but they still rely on oversimplification of the foot as a single rigid segment.

**Specific Aims**

The aims of the research contained in this dissertation were to:

(1) Develop a multisegment kinematic foot model meeting the following criteria:

(a) minimize the required numbers of anatomical markers

(b) accommodate a wide range of foot deformities

(c) be appropriate for pediatric subjects

(d) not require foot radiographs

(e) reduce the effect of skin motion

(f) be able to detect the differences between normal and impaired foot function

(g) demonstrate adequate repeatability

   (i) when applied longitudinally with the same subject and clinician (Intraclinician)

   (ii) when applied to the same subject by different clinicians (Interclinician)

   (iii) when applied in similar subject groups at different collection sites (Interlab)

   (iv) when applied to pathologic subjects
(2) Develop software and processes to enable kinetic measures from the multisegment foot model developed in Aim 1 and report kinetic repeatability in both typically developed and pathologic subjects.

(3) Develop a working musculoskeletal foot model with subject-specific adaptation that integrates the multisegment foot model from Aim 1 to demonstrate proof of concept.

To satisfy Aim 1, we propose a model that relies on virtual points, landmarks that are identified by small hemispherical (4mm D) markers during a static trial. Use of small markers minimizes the marker placement error and can improve interclinician and intersession variability. The model variability was tested at two different data collection sites for a normal and pathologic pediatric population. The multicenter approach tested the model robustness against lab setting and experience of lab clinicians. This research is presented in Chapter 2.

To satisfy Aim 2, regarding kinetic computations of the model and application to pathologic subjects, a segmentation process for ground reaction force was developed. The coupled pedobarograph and dimensionally matched force plate were synchronized with a motion data collection system. Custom software and data processing techniques were developed to segment the ground reaction force for multiple segments of the foot and perform the inverse dynamic analysis to compute net joint moments and powers. The model application was carried out on a typically developing as well as a pathologic pediatric population to ensure that the model has the same repeatability in a normal and pathologic foot. Model outcomes from the normal and pathologic group were compared
to demonstrate that the model is capable of reflecting differences between normal and impaired foot function. This research is presented in Chapter 3.

To satisfy Aim 3, a multisegment musculoskeletal foot model was developed as a proof of concept that: The musculoskeletal model can be integrated with the clinical gait analysis. A model was developed for normal right feet that can be scaled for individual subjects. This model is a first step towards developing a validated musculoskeletal model that can be integrated into clinical gait analysis. Model application was carried out by using walking marker data from 5 normal pediatric subjects and muscle activation patterns were computed for each subject. The utilization of a musculoskeletal model adds a significant layer of complexity to routine assessment of kinematics and kinetics. The work presented here in Chapter 4 is an attempt to demonstrate a proof of concept of the potential of such models. Significant refinement and validation of these models remain before they can be used as a clinical tool.
CHAPTER 2

REPEATABILITY OF KINEMATIC FOOT MODEL
Abstract

Several multisegment foot models to measure the motion of intrinsic joints of the foot have been reported. Use of these models in clinical decision making is limited due to lack of rigorous validation including interclinician and interlab variability measures and variability testing for pathologic populations. A model with quantified variability can significantly improve the confidence in the results of such foot models. This study proposes a new clinical foot model with the underlying strategy of using small hemispherical markers (SHMs) for anatomical landmark identification and using technical markers located at optimal sites for dynamic motion tracking. Twenty control and pathologic pediatric subjects (Site1: n=10 control, n=5 pathologic; Site 2: n=5 control) were evaluated by three clinicians (Site 1: n=2; Site 2: n=1) at two data collection sites. A plaster mold method was used to quantify intraclinician and interclinician marker placement variability by directly comparing marker data between sessions for each subject. Motion of three foot segments (Hindfoot, Forefoot and Hallux) during walking was computed in three planes. Intraclinician and interclinician variability in model outcomes (joint angles during walking) has been quantified. Results indicate that the proposed model definition and use of SHMs to identify anatomical landmarks leads to reduced marker placement variability compared to similar measures in previous models. Methodology of using separate marker sets to establish anatomical coordinate systems (SHMs) and technical coordinate systems (RSMs) also resulted in small inter- and intraclinician variability in model outcomes (i.e., intersegmental joint angle patterns) during walking.
**Introduction**

Traditional gait models treat the body as a series of rigid links starting at the trunk and ending at the feet (Davis et al., 1991; Kadaba et al., 1990). These models consider the foot as a single segment with all motions attributed to a two degree of freedom ankle joint, grossly oversimplifying foot anatomy and failing to incorporate any segmental motions distal to the ankle joint. The human shank and foot complex is a multijoint mechanism that determines the critical interaction between the lower limb and the ground during locomotion. Cavanagh et al. (1997) characterized the foot structure by 27 measurements taken from standardized lateral and dorsi-plantar weight bearing plain radiographs from 50 healthy adult subjects. They concluded that, in normal subjects, only about 35% of the variance in dynamic plantar pressure can be explained by static radiographic measurements. Only dynamic analysis of the patient during activity allows clinicians to distinguish between normal and pathological foot function (Cavanagh et al., 1997; Gage et al., 1996; Lundberg, 1989).

Several foot models have since been published to measure multi-segment foot motions (Abuzzahab et al., 1997; Carson et al., 2001; D'Andrea, 1993; Dul et al., 1985; Gilchrist et al., 1996; Hunt et al., 2001; Kidder et al., 1996; Leardini et al., 1999; Lundberg, 1989; Macwilliams et al., 2003; Moseley et al., 1996; Rattanaprasert et al., 1999; Sampath, 1998; Scott et al., 1991; Scott et al., 1993; Stebbins et al., 2006). Since the coordinate systems of all of the bones can not be defined and tracked by traditional use of markers attached to skin, foot models combine several bones to form each segment. In most models, the foot is partitioned into three segments; hindfoot, forefoot and hallux. The fundamental challenge with foot modeling is marker placement error,
which is amplified in angular calculation due to close proximity of markers on small segments. Initially foot models were limited by lack of rigorous definition of the anatomical axes (D'Andrea, 1993; Dul et al., 1985; Moseley et al., 1996; Scott et al., 1991). Some models involved x-ray exposure of patients using radiographic images to reference external markers to the anatomical geometry of the underlying bones (Kidder et al., 1996; Sampath, 1998). These explicitly stated that some measurements were difficult to obtain from the radiographic views and others impossible, such as forefoot position in the coronal plane. Other studies, aimed to establish anatomically based coordinate systems, suggested collecting extra trials using either a special jig (Liu, 1997) or use of optimization routines to calculate joint axes (van den Bogert et al., 1994).

Some investigations have questioned the reliability of foot bone tracking from external markers because of the skin-movement (Cappozzo, 1996; Maslen et al., 1994; Reinschmidt, 2009; Tranberg et al., 1998). However, Tranberg et al. (1998) reported very small displacements of skin markers, mostly in the vicinity of the ankle joint. Some anatomical landmarks (e.g., medial malleoli, navicular) were reported to have more skin motion than others (first metatarsal markers) during walking. Instead of skin attached markers, Leardini’s model (Leardini et al., 1999) used rigid clusters of reflective markers to trace foot segments. Due to the magnification of skin motion errors created by this approach, the rigid cluster method has since been abandoned by this group. A repeatability study of the Oxford model (Carson et al., 2001; Stebbins et al., 2006) on pediatric subjects observed higher variability of intersegmental angles as compared to previous values reported for adult subjects and expressed the need for a better protocol for marker placement, especially for pediatric subjects.
Purpose

All foot models suffer from a common problem: reliability on anatomical landmark identification with markers in relatively close proximity. In this scenario, compared to typical spacing in long bones, small errors in marker location result in relatively large errors in angular calculations. Most previous models are lacking in terms of quantifying the inherent variability arising from error in marker placement, effect of multiple clinicians and multiple data collection sites. The purpose of the work presented here is to develop a foot model aimed at improving accuracy and repeatability and test it for intraclinician and interclinician repeatability in multiple sites.

Methods

Proposed Model

Specific aims for the model development were the following: (1) to facilitate clinical application by minimizing the required numbers of anatomical markers, (2) to provide marker placement flexibility to accommodate a wide range of foot deformities, (3) to be appropriate for pediatric subjects, (4) to not require foot radiographs for anatomical coordinate system alignment, (5) to reduce the effect of skin motion and (6) to be able to detect the differences between normal and impaired foot function.

To address these aims, we have developed a foot model that incorporates a static calibration trial that allows anatomical landmark identification relative to technical coordinate systems, the Shriners Hospitals for Children Greenville foot model (SHCG) (Davis et al., 2006; Davis et al., 2008; Saraswat et al., 2009). Locations of anatomic landmarks are saved relative to technical coordinate systems formed by three technical
markers on each segment. The relationship between technical and anatomic coordinate systems from the static calibration trial is used to calculate anatomic segment motion during dynamic trials. The process of referencing the anatomical coordinate system to technical coordinate system enables a flexible modeling approach. Since technical markers are not constrained to specific anatomical landmarks, they can be placed freely on the segment of interest to accommodate deformities and optimize visibility during walking. Observations about skin motions (Cappozzo, 1996; Maslen et al., 1994; Reinschmidt, 2009; Tranberg et al., 1998) were taken into account while choosing technical marker locations. Points with potentially large skin motion were allowed to be chosen for static anatomical landmarks but not for technical markers.

Anatomic landmarks were located by small (4mm D) hemispherical markers (SHMs) during the static calibration trial. Since SHMs have a 4 mm D base as compared to a 14 mm D base in regular (9mm D) spherical markers (RSMs), they may potentially provide better accuracy and repeatability in anatomical landmark identification as clinicians can more easily visualize and accurately locate the point of interest on the skin as the marker is applied, and the centroid of the marker is on the skin rather than a marker radius plus base thickness above (Davis et al., 2008). RSMs were used as technical markers to track segment motion to achieve better visibility during dynamic trials.

**Model Evaluation**

Model repeatability was quantified with both static and dynamic measures. The effect of marker placement variability on model outcomes was quantified by use of a plaster mold to repeatably position the feet during static capture. Multiple static trials on
the same subject were directly compared to compute intraclinician and interclinician variability.

Within-subject variability of intersegmental joint angles during walking trials was quantified by carrying out the model application on the same subject multiple times by multiple clinicians. Intertrial, intraclinician and interclinician variability were measured.

**Subjects**

Fifteen control subjects (n=15 subjects, 30 feet) between the age of 8 and 14 were evaluated in two collaborating sites (Shriners Hospitals for Children, Salt Lake City, UT [SLC] and Greenville, SC [GNV]) with two clinicians performing data collection at SLC and one at GNV on each subject. Control group subjects were screened for exclusion criteria including previous limb trauma or a concurrent condition affecting gait. Ten subjects at SLC (age 10.7 ± 1.56 years, 7 female, 3 male) and 5 subjects at GNV (age 11.37 ± 2.29 years, 3 female, 2 male) were evaluated. Ten subjects (SLC: n=5, GNV: n=5) were reevaluated after 2-4 weeks to examine intraclinician repeatability.

Five pathologic subjects (n= 5 subjects, 10 feet, age 10.3 ± 0.69 years, 1 female, 4 male) were also evaluated at SLC. Pathologic group subjects were screened by inclusion criteria of age (8-14 years) and clinical interpretation of single or bilateral planovalgus feet. The model was applied to both feet regardless of clinical condition; however, only those feet clinically described as planovalgus were included in the data analysis. Two out of five pathologic subjects (SLC: n= 4 feet) were reevaluated after 2-4 weeks to examine intraclinician repeatability.
**Plaster Mold**

The quantification of marker placement variability to understand inherent modeling errors and evaluate techniques of referencing the anatomy is a nontrivial problem. Henley et al. (Henley et al., 2004; Henley, 2008) developed a plaster mold method to ensure reproducibility of foot placement and segment orientation. This method was adopted in the current study to examine the repeatability of placing SHMs to identify anatomical landmarks. Approximately 2 cm deep plaster molds (Figure 2.1a) of the plantar surface of each of the subjects’ feet were molded to hold the foot in a consistent position while seated. Seat height was adjusted to ensure 90° knee flexion angles and interpatellar distance was measured and kept consistent between trials. A triad of markers fixed to the casting board provided a reference for each static trial. Efficacy of the plaster mold method to achieve consistent foot position was previously evaluated (Davis et al., 2008). SHMs were used to identify seven anatomical landmarks on each foot (Table 2.1).

**Figure 2.1:** Static trials (a) The first static trial is collected with small hemispherical markers (4mm D) on anatomical landmarks of feet while seated with the feet pressed in the plaster mold (b) The second static trial is collected while standing with both the anatomical and technical markers on.
Table 2.1 Anatomical location of anatomical markers

<table>
<thead>
<tr>
<th>Marker</th>
<th>Segment</th>
<th>Anatomical Landmark</th>
<th>Critical Alignment</th>
</tr>
</thead>
<tbody>
<tr>
<td>ANK</td>
<td>Shank</td>
<td>Lateral Malleolus</td>
<td>Anterior/Posterior</td>
</tr>
<tr>
<td>MMAL</td>
<td>Shank</td>
<td>Medial Malleolus</td>
<td>Anterior/Posterior</td>
</tr>
<tr>
<td>CALPT</td>
<td>Hindfoot</td>
<td>Peroneal Trochlea</td>
<td>Superior/Inferior</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Anterior/Posterior</td>
</tr>
<tr>
<td>MT23B</td>
<td>Forefoot</td>
<td>Mid pt of bases of 2nd and 3rd metatarsals</td>
<td>Medial/Lateral</td>
</tr>
<tr>
<td>MT23H</td>
<td>Forefoot</td>
<td>Mid pt of heads of 2nd and 3rd metatarsals</td>
<td>Medial/Lateral</td>
</tr>
<tr>
<td>MT1BM</td>
<td>Forefoot</td>
<td>Most medial aspect of base of 1st metatarsal</td>
<td>Superior/Inferior</td>
</tr>
<tr>
<td>MT1HM</td>
<td>Forefoot</td>
<td>Most medial aspect of head of 1st metatarsal</td>
<td>Superior/Inferior</td>
</tr>
</tbody>
</table>
**Data Collection**

Similar hardware (Vicon MX, Vicon Motion Systems, Centennial CO, USA) were used to record spatial positions of markers in each lab. Three types of trials were collected:

**Plaster model trial**

With subjects sitting and their feet in the plaster mold, seven anatomic location markers were applied on the feet (Table 2.1, SHM). This static trial was used to record the position of anatomical landmarks relative to three reference markers fixed on the casting board (Figure 2.1a). This allowed the direct comparison of absolute segment attitudes between sessions.

**Static calibration trial**

With subjects standing, lower extremity markers of the full body gait model (Davis et al., 1991) including knee alignment device (KAD) were applied. Technical markers were added to the feet (Table 2.2, RSM, Figure 2.1b) to determine anatomical and technical coordinate relations. The positions of the SHM markers were saved relative to technical markers (RSM) for each segment (shank, hindfoot and forefoot). Hallux segment motion was tracked by a marker triad (Figure 2.1b: 3 SHMs fixed on a triangular base). The long axis of the triad was aligned with the hallux during marker triad placement to reflect toe valgus. The hindfoot varus/valgus angle was measured by goniometer while the subject stood on a flat platform. This goniometric measure was used in the hindfoot coordinate system definition (Table 2.3).
**Table 2.2:** Anatomical position of technical markers

<table>
<thead>
<tr>
<th>Marker</th>
<th>Segment</th>
<th>Anatomical Position</th>
</tr>
</thead>
<tbody>
<tr>
<td>TIB</td>
<td>Shank</td>
<td>Tibial wand</td>
</tr>
<tr>
<td>TIBU</td>
<td>Shank</td>
<td>Top marker on anterior surface of tibia</td>
</tr>
<tr>
<td>TIBL</td>
<td>Shank</td>
<td>Lower marker on anterior surface of tibia</td>
</tr>
<tr>
<td>PCAL</td>
<td>Hindfoot</td>
<td>Posterior Calcaneus</td>
</tr>
<tr>
<td>LCAL</td>
<td>Hindfoot</td>
<td>Lateral Calcaneus</td>
</tr>
<tr>
<td>MCAL</td>
<td>Hindfoot</td>
<td>Medial Calcaneus</td>
</tr>
<tr>
<td>MT1B</td>
<td>Forefoot</td>
<td>Base of 1st metatarsal</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(avoid FHL tendon)</td>
</tr>
<tr>
<td>MT1H</td>
<td>Forefoot</td>
<td>Head of 1st metatarsal</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(avoid FHL tendon and metatarso-phalangeal joint)</td>
</tr>
<tr>
<td>MT5H</td>
<td>Forefoot</td>
<td>Head of 5th metatarsal</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(avoid FDL tendon and metatarso-phalangeal joint)</td>
</tr>
<tr>
<td>TOE1,2,3</td>
<td>Hallux</td>
<td>Toe Triad placed on the nail of Big Toe</td>
</tr>
</tbody>
</table>
Table 2.3: Model segment coordinate system definitions based on static calibration trial

<table>
<thead>
<tr>
<th>Segment</th>
<th>Marker Used</th>
<th>Anatomical Segment Axes</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Tibia</strong></td>
<td>KJC (Knee Joint Center)</td>
<td>( Z = \text{KJC-AJC} )</td>
</tr>
<tr>
<td></td>
<td>AJC (Ankle Joint Center)</td>
<td>( \text{tempY} = \text{MMAL-ANK} )</td>
</tr>
<tr>
<td></td>
<td><strong>SHM</strong>: MMAL, ANK</td>
<td>( X = Z \times \text{tempY} )</td>
</tr>
<tr>
<td></td>
<td></td>
<td>( Y = Z \times \text{tempX} )</td>
</tr>
<tr>
<td><strong>Hindfoot</strong></td>
<td><strong>RSM</strong>: PCAL, MCAL, LCAL</td>
<td>( V_1 = (\text{CCAL-PCAL}) ) projected on ground</td>
</tr>
<tr>
<td></td>
<td>CCAL=(LCAL+MCAL)/2</td>
<td>( V_2 = [\text{CALPT}-(\text{PCAL})] ) projected on ground</td>
</tr>
<tr>
<td></td>
<td><strong>SHM</strong>: CALPT</td>
<td><strong>Calcaneal pitch</strong> ( \phi ) measured between vectors ( V_1 &amp; V_2 ) in sagittal plane formed by ( V_1 ) &amp; Ground Z axis</td>
</tr>
<tr>
<td></td>
<td></td>
<td>( X = \text{Rotate } V_1 ) by ( \phi )</td>
</tr>
<tr>
<td></td>
<td></td>
<td>( \text{tempZ} = \text{Ground Z axis} ) offset by varus/valgus angle measured by goniometer.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>( Y = \text{tempZ} \times X )</td>
</tr>
<tr>
<td></td>
<td></td>
<td>( Z = X \times Y )</td>
</tr>
<tr>
<td><strong>Forefoot</strong></td>
<td><strong>SHM</strong>: MT23B, MT23H,</td>
<td>( X = ) Projection of [MT1HM-MT1BM] on plane formed by [MT23H-MT23B] and Ground Z axis</td>
</tr>
<tr>
<td></td>
<td>MT1BM, MT1HM</td>
<td>( \text{tempZ} = ) Ground Z axis</td>
</tr>
<tr>
<td></td>
<td></td>
<td>( Y = \text{tempZ} \times X )</td>
</tr>
<tr>
<td></td>
<td></td>
<td>( Z = X \times Y )</td>
</tr>
<tr>
<td><strong>Hallux</strong></td>
<td><strong>Marker Triad</strong> (Figure 2.1b)</td>
<td>( X = \text{TOE2 - TOE1 (Along long axis)} )</td>
</tr>
<tr>
<td></td>
<td>TOE1,TOE2,TOE3</td>
<td>( \text{tempY} = \text{TOE3-TOE1} )</td>
</tr>
<tr>
<td></td>
<td></td>
<td>( Z = X \times \text{tempY} )</td>
</tr>
<tr>
<td></td>
<td></td>
<td>( Y = Z \times X )</td>
</tr>
</tbody>
</table>
Dynamic Trial

SHMs identifying anatomic landmarks of the foot were removed and dynamic trials collected while the subjects walked at a self-selected velocity along a 10 m runway.

Data Processing

Kinematic computations were performed using a model written in commercially available software (BodyBuilder, Vicon, Centennial, CO, USA). Anatomical coordinate system definitions for each segment are described in Table 2.3. Joint angles were computed for three articulations of the segments. Joint rotations were computed using flexion, inversion, transverse rotation Cardan angle sequence. To compare the data between walking trials, each trial was time normalized by interpolating the gait cycle duration into 51 points. Point average and standard deviations were calculated at each 2% of the gait cycle.

Statistical Analysis

Static Measure from Plaster Mold Trial

Intraclinician repeatability was evaluated by comparing repeated sessions of the same clinician (SLC: n=2, GNV: n=1) applying the model to the same subject (SLC: n=5 control and n=2 pathologic; GNV: n=5 control). Interclinician repeatability was evaluated by comparing different clinicians (SLC: n=2) applying the model to the same subject (SLC: n=10 control, n=5 pathologic).
Dynamic measure

For each session, five walking trials (n=5) were used to compute average and standard deviations at each time point. The average of these 51 standard deviations (at 2% of gait cycle) was used as a measure of intertrial variability. Two sessions of the same clinician performing data collection on the same subject were used to compute intraclinician variability. Average data from two sessions when two different clinicians performed the data collection protocols on the same subject were used to compute inter-clinician variability.

Model results for the control group were also compared to two previously published foot models: the Oxford Model (Stebbins et al., 2006) and Milwaukee Model (Kidder et al., 1996). Average maximum and range of motion for each segment were computed and compared to previously published model data.

Results

Static Measure of Marker Placement Variability

The plaster mold method was used to ensure consistent foot placement and segment orientations so that the placement of SHMs could be measured in a repeatable fashion without the influence of intersegmental changes. Successful implementation of the plaster mold method was verified in a previous study (Davis et al., 2008) in which average error in marker position when the subject stepped in and out of the mold between two static trials was observed to be $1.64 \pm 0.91 \text{ mm}$, which is comparable to the $2.39 \text{ mm}$ average error reported by Henley et al. (Henley et al., 2004; Henley, 2008).
Once the foot placement repeatability in the plaster mold was ensured, data was directly compared between static trials of two sessions. Figure 2.2 shows the marker placement variability expressed in terms of absolute segmental attitude for control and pathologic groups. Both intraclinician and interclinician average marker placement variability for both groups (control and pathologic) were less than 4° for all angles, which is comparable to results in which a similar protocol was carried out on normal adult feet (Davis et al., 2008).

Figure 2.3 shows the intraclinician marker placement variability observed in control subjects at two sites. At both sites, intraclinician variability was observed to be less than 4° for all angles. Figure 2.4 shows the variability in absolute segment attitude by use of the SHCG model compared to a similar measure in a previous model (Henley, 2008). Model definition differences (aimed at reducing the required number of anatomical alignment) and use of SHMs to identify anatomical landmarks reduced the marker placement error.

**Walking Kinematics and Dynamic Variability**

Intersegmental angles in three planes were computed for three joints during a gait cycle for each trial. Figure 2.5 shows the three variability measures (Intertrial, Intraclinician and Interclinician) observed in model outcomes at two sites. Model outcome variability was also compared between the control and pathologic group (Figure 2.6).
Figure 2.2: Variability in the static segment attitudes within the same clinician and between multiple clinicians performing multiple marker placements on the same subject for the normal and pathologic groups.
Figure 2.3: Comparison of intraclinician marker placement variability between two sites

Figure 2.4: Variability in static segment attitude using SHCG model and previous model reported by Henley et al. (Henley, 2008)
Figure 2.5: Average standard deviations (SD) of intersegmental angles over a gait cycle for intertrial, intraclinician and interclinician variability. Variability is shown for three relative angles (hindfoot/shank, forefoot/hindfoot and hallux/forefoot).

Figure 2.6: Comparison of average standard deviation of intersegmental angles for control and pathologic group.
Model Outcome Comparison with Previous Models

Table 2.4 shows the mean and within-subject standard deviation for (i) maximum and (ii) range of motion in three planes for each joint from three models: Current SHCG Model, Oxford Model (Stebbins et al., 2006) and Milwaukee Model (Kidder et al., 1996). The Oxford model did not provide Hallux segment results and Milwaukee Foot model provided data from single subject, hence no standard deviations are shown for this model.

Discussion

A novel clinical foot model, the Shriners Hospitals for Children Greenville (SHCG) model, is proposed with the underlying strategy of using static calibration trial for anatomical landmark identification relative to technical markers. The SHCG model also requires less anatomical alignments as compared to previous models. The number of anatomical markers and their critical alignment direction has been minimized (Table 2.1). The optimal placement of technical markers to avoid landmarks with large skin motion minimizes the effect of skin motion on model outcomes. Use of static calibration trial also provided the increased flexibility of technical marker placement to accommodate wider range of foot pathology. For example, anatomical locations that may not be accessible during walking (in pathological cases) can be identified relative to technical markers in static calibration and then referenced during dynamic trial.

Plaster Mold

The plaster mold method enabled accurate determination of the variability arising from marker placement error (Figure 2.2). Such quantification of model variability has
Table 2.4: Maximum and range of motion observed by three models during walking in (pediatric) control subjects

<table>
<thead>
<tr>
<th>Joint Angle</th>
<th>Current Model (n=10)</th>
<th>Oxford Foot Model (n=15)</th>
<th>Milwaukee Foot Model (n=1)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean (SD)</td>
<td>Mean (SD)</td>
<td>Mean</td>
</tr>
<tr>
<td><strong>Hindfoot/Shank</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Max</td>
<td>Varus 8 (2)</td>
<td>9(5)</td>
<td>-6</td>
</tr>
<tr>
<td></td>
<td>Flexion 18 (4)</td>
<td>11(3)</td>
<td>31</td>
</tr>
<tr>
<td></td>
<td>Rotation 16 (7)</td>
<td>14(8)</td>
<td>9</td>
</tr>
<tr>
<td><strong>Hindfoot/Shank</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Range</td>
<td>Varus 11(2)</td>
<td>11(2)</td>
<td>12</td>
</tr>
<tr>
<td></td>
<td>Flexion 22(2)</td>
<td>24(3)</td>
<td>18</td>
</tr>
<tr>
<td></td>
<td>Rotation 9(1)</td>
<td>12(3)</td>
<td>21</td>
</tr>
<tr>
<td><strong>Forefoot/Hindfoot</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Max</td>
<td>Varus 7(2)</td>
<td>7(5)</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>Flexion -16(5)</td>
<td>10(3)</td>
<td>-38</td>
</tr>
<tr>
<td></td>
<td>Rotation 7(6)</td>
<td>5(7)</td>
<td>3</td>
</tr>
<tr>
<td><strong>Forefoot/Hindfoot</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Range</td>
<td>Varus 9(2)</td>
<td>9(2)</td>
<td>33</td>
</tr>
<tr>
<td></td>
<td>Flexion 29(3)</td>
<td>21(3)</td>
<td>9</td>
</tr>
<tr>
<td></td>
<td>Rotation 13(2)</td>
<td>10(2)</td>
<td>22</td>
</tr>
<tr>
<td><strong>Hallux/Forefoot</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Max</td>
<td>Varus -3(6)</td>
<td>-</td>
<td>18</td>
</tr>
<tr>
<td></td>
<td>Flexion 69(4)</td>
<td>-</td>
<td>39</td>
</tr>
<tr>
<td></td>
<td>Rotation 8(6)</td>
<td>-</td>
<td>14</td>
</tr>
<tr>
<td><strong>Hallux/Forefoot</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Range</td>
<td>Varus 15(4)</td>
<td>-</td>
<td>21</td>
</tr>
<tr>
<td></td>
<td>Flexion 59(5)</td>
<td>-</td>
<td>35</td>
</tr>
<tr>
<td></td>
<td>Rotation 17(4)</td>
<td>-</td>
<td>19</td>
</tr>
</tbody>
</table>
not been reported in earlier models. This measure provides a unique insight into the marker placement error inherent in all foot models. Marker positions were not directly compared because not all of them are relevant in terms of model outcomes. For example, anterior/posterior position of forefoot markers is not important, since forefoot coordinate definition uses these markers for medial/lateral and superior/inferior alignment only. Therefore, angular inclinations instead of absolute marker locations were used to quantify variability due to marker placement. Less than 4° average error was observed for both groups (control and pathologic) as a measure of both interclinician and intraclinician marker placement variability, which is smaller than the reported variability by an earlier model (Henley, 2008). This indicates that the use of the SHCG model reduces the effect of marker placement error on model outcomes (Figure 2.4). It also suggests that the model can only be used to quantify differences of more than 4°. Any change less than 4° may be attributed to marker placement uncertainty and should not be regarded as a clinically significant difference. Variability in the pathologic group was comparable to the control group, demonstrating that the model retained acceptable repeatability when applied to deformed feet. Comparison of intraclinician marker placement variability in two sites showed no significant difference (Figure 2.3), demonstrating that model outcomes are equally repeatable when implemented in multiple sites. Previous models have not reported either variability within pathologic populations or variability between multiple sites.
Walking Kinematics

The small intraclinician and interclinician variability arising from marker placement error leads to small variability in walking kinematics, as shown in Figure 2.5. Within-subject average SD for ankle and forefoot joint is less than 6°. The hallux segment attitude showed higher variability, which reflects the higher error associated with the use of marker triad as compared to more rigorous segment coordinate system definition used in hindfoot and forefoot. Variations larger than 4° are likely true individual differences in walking patterns. Model outcomes have more interclinician variability than intraclinician variability, which is expected. Similar to marker placement repeatability measures in static (Plaster Mold) data, no significant differences were found comparing walking kinematics between two sites. Model variability observed in the pathologic group also showed no significant difference as compared to the control group (Figure 2.6). Intertrial variability shown in Figure 2.5 and 2.6 is true variability in walking patterns for subjects. As expected, model outcomes from multiple sessions carried out by multiple clinicians increase the variability. In both the control and pathologic groups and second data collection sites, maximum variability were less than 6°, which indicates the robustness of model against pathology and multiple data-collection sites.

Comparison with Other Models

As shown in Table 2.4, the Oxford and SHCG models have comparable range of motion for both hindfoot and forefoot joints for the control group. The SHCG model results show combined standard deviations due to intraclinician and interclinician
variability within a subject. The Oxford model reported variability due to multiple visits (intraclinician variability only). The SHCG model still showed lesser or equivalent standard deviations for hindfoot and forefoot segments, which indicates the robustness of the current model against the error due to multiple clinicians. Therefore, use of this model will allow the direct comparison of model outcomes of subjects from different data collection sites to facilitate multicenter research. Results of the intersegmental angle peaks during walking are different from the two models, which likely reflect the differences in model segment definition. For example, differences in forefoot relative to hindfoot flexion can be attributed to the fact that the hindfoot segment reflects the calcaneal pitch and the forefoot segment reflects the medial arch of forefoot in the SHCG model. Neither of these inclinations was included in the Oxford model definition. Range of motion and maximum deflection are not comparable between the current model and Milwaukee model due to the differences in segment definitions. However, the Milwaukee model showed similar distribution of motion among the three axes of hallux segment as observed by the SHCG model.

**Limitations**

Skin motion is inherent in any model of this type where markers are attached to skin for tracking motion. Although technical marker positions were defined to minimize skin motion errors, this is not quantified. Another factor that may limit the application of this model in other laboratories is the requirement of a camera system with adequate resolution to track SHMs (4mm D) when viewing a calibration volume suitable for full body gait analysis.
Summary

The casting method provided a useful quantification of the effect of marker placement error on model results that has not been analyzed in earlier models. The model repeatability within a clinician was documented for two sites. Interclinician repeatability was measured for the control as well as pathologic (planovalgus feet) pediatric population. It was observed that the model is equally repeatable for the control and pathologic groups. Comparison of model outcomes with previously published models demonstrates that the SHCG model is able to track the motion of all three segments and does not under- or over-estimate the range of motion for any segments.
CHAPTER 3

MODEL KINETICS AND PATHOLOGIC APPLICATION
Abstract

Planovalgus deformity is prevalent in cerebral palsy patients but very few studies have quantitatively reported differences between planovalgus and normal foot function. In this study, a 3-segment (hindfoot, forefoot, toes) kinematic and kinetic model was applied on typically developing (n=10 subjects, 20 sides) and planovalgus (n=5 subjects, 10 sides) pediatric subjects by two clinicians for each subject. Interclinician repeatability was measured for both groups and demonstrated that the model outcomes are equally repeatable in pathologic and control populations. Model outcomes were compared between the two groups to demonstrate the capability of reflecting differences between normal and impaired foot function. Supporting clinical expectations, the ankle joint was observed to show less motion in the planovalgus group; however, contrary to clinical expectations, no significant difference was observed in forefoot joint range of motion. The model was able to detect static differences in the planovalgus foot, including excessive hindfoot valgus and reduced forefoot flexion angle (flat foot). Joint moment peaks from the two groups did not show significant differences, but hindfoot and forefoot joints generated significantly less power in the planovalgus group as compared to the control.

Introduction

Gait analysis is routinely used in clinical decision making and in research to understand function and surgical outcomes. Standard gait models treat the foot as a single rigid segment and neither the motions nor the forces within the various joints of the foot are computed (Davis et al., 1991; Kadaba et al., 1990). Therefore, these models are not...
adequate for analyzing foot deformities. Although there have been several kinematic foot models (Kidder et al., 1996; Leardini et al., 1999; Macwilliams et al., 2003; Stebbins et al., 2006), efforts have been limited towards developing kinetics of a multisegment foot model (Macwilliams et al., 2003) due to the difficulty in distributing ground reaction forces into foot segments.

The first aim of the study was to describe kinetics of a foot model with three segments (hindfoot, forefoot and toes) that uses a synchronized and coupled pedobarograph and force platform to distribute the ground reaction force into multiple segments of foot. The second aim of the study was to report typically developing (TD) kinematic and kinetic outcomes from the model. The third aim was to apply the model to feet clinically characterized as planovalgus (PV), a combination of pes planus (flat foot) and hindfoot eversion (valgus). This is an ideal population to test the model sensitivity because it is the most common foot deformity in ambulatory cerebral palsy (CP) patients and accounts for between 25-30% of all surgical procedures (Andreacchio et al., 2000; Bennet et al., 1982). Two hypotheses were tested: (1) the model is equally repeatable in TD and PV groups and (2) the model is sensitive enough to demonstrate pathological changes between TD and PV feet.

Despite the prevalence of the planovalgus foot, little research has been undertaken to quantify the extent of deviation in foot pathology compared to normal. The two most common expectations of planovalgus foot are excessive hindfoot valgus and forefoot motion (Olson et al., 1983) during walking, but these assumptions of excessive motion have not been confirmed. Previous study on planovalgus feet (Hunt et al., 2000) observed no significant correlation between indicators of planovalgus feet and excessive hindfoot
valgus motion and emphasized the need for developing kinetics of a multisegment foot model. In a comparative study between control and flatfoot population, statistically significant but clinically insignificant (<2°) differences were found in hindfoot flexion peaks and range of motion in the hindfoot and forefoot during stance phase (Hunt et al., 2004). Significant differences were also reported in ankle joint moment (Hunt et al., 2004) but the moment distribution over multiple segments of foot has not been investigated.

Therefore in the current study, range of motion and peak intersegmental angles was compared to quantify the extent of deviation in planovalgus feet. Joint moment and power peaks were also analyzed for both TD and PV groups to understand foot kinetics. Quantification of deviations in planovalgus feet may help understand pathologic foot function and assist in designing clinical interventions.

**Methods**

**Subjects**

Ten typically developing and 5 pathologic pediatric subjects between the ages of 8 and 14 were each evaluated by two clinicians. Control subjects (7 female, 3 male, 20 feet, average age 10.6 ± 1.57 years) were screened to exclude any previous major lower limb musculoskeletal trauma or congenital conditions that may affect walking. Pathologic subjects (1 female, 4 male, 10 feet, average age 10.3 ± 0.69 years) were screened by inclusion criteria of clinical interpretation of single or bilateral planovalgus feet. All subjects presented with bilateral PV feet.
Data Collection

Ten cameras (Vicon MX, Vicon Motion Systems) were used to record spatial positions of markers during static and dynamic (walking) trials. A 0.5x2m pedobarograph mat (FScan, RS Scan International, Belgium) was coupled with a dimensionally matched AMTI force plate to measure the ground reaction force. Data collection of the pressure plate system was synchronized with the force plate through an external trigger signal from the motion camera system. Both pressure plate and motion camera data collection were carried out at 100 Hz. Walking trials were collected such that at any instant during the trial, only one foot was in contact with the coupled force plate to avoid double stance force plate measure.

Kinematic Computations

Kinematic computations were performed using a model (Saraswat et al., 2009) written in commercially available software (BodyBuilder, Vicon, Centennial, CO). Joint angles were computed for intersegmental joints of three foot segments (hindfoot, forefoot, toes). Joint rotations were computed using flexion, inversion, transverse rotation Cardan angle sequence.

Kinetic Computations

The kinetic computation combines the marker position data collected by the camera system, ground reaction force data from the force plate and the pressure data from the pedobarograph. An inverse dynamic analysis program was written in Matlab to compute joint moments and power over a gait cycle for three foot joints.
Inertial Properties

Segment inertial properties were defined by assuming each bone to be cylindrically shaped. Bone length in the longitudinal direction and radii in two orthonormal directions were used to define mass moment of inertia. These bone inertial properties were combined using the parallel axis theorem to calculate segment inertia. Inertial properties were computed using a CT scan from a single cadaver foot and were uniformly scaled using the body weight and height of each subject.

Segmentation of Ground Reaction Force

For kinetic computation, each segment of the foot that contacts the ground must have a specified six component ground reaction force vector consisting of a normal force ($F_z$), medial/lateral and anterior/posterior shear forces ($F_x$ and $F_y$), normal moment ($M_z$) and a center of pressure location ($COP_x$ and $COP_y$). All six components for each of the three segments were derived by combining pressure plate and force plate measurements. Synchronization and uniform frequency (100 Hz) data collection eliminated the need for temporal and spatial synchronization and made the process feasible to be used in a clinical gait analysis protocol.

Figure 3.1 represents the steps involved in the segmentation of pressure data. In the first step, the area covering one stance phase is segmented using a mask (Figure 3.1b). Single gait cycle pressure data are further segmented into three segments (hindfoot, forefoot and toes) shown in Figure 3.1c. Then, the center of pressure and normal force for each segment is computed from this segmented pressure data. Shear forces for each
segment were calculated by distributing the force vector by a weighting scheme based on the normal force in each segment.

Normal force $F_n$ is the sum of each of its $N$ segments

$$F_n = \sum_{i=1}^{N} F_{n_i} \quad \ldots(1)$$

The shear force $F_s$ for any given segment $i$ is given by

$$F_{s_{x_i}} = F_s \left( \frac{F_{n_i}}{F_n} \right) \quad F_{s_{y_i}} = F_s \left( \frac{F_{n_i}}{F_n} \right) \quad M_{z_i} = M_z \left( \frac{F_{n_i}}{F_n} \right) \quad \ldots(2)$$

The same proportionality scheme was applied to each shear components, which include medial/lateral shear force, anterior/posterior shear force and moment in the plane normal to the plantar surface.

**Validation of Proportionality Scheme**

As a validation scheme for the proportionality assumption, ten walking trials were collected for 2 subjects (typically developed adults) each. During the trial, subjects walked over two adjacent force plates such that the hindfoot and forefoot were in contact with separate force plates during stance. Reflective markers were placed at the base of the 1st and 5th metatarsal and matched with the line separating two force plates to ensure correct segmentation of the ground reaction force. Shear forces from the two force plates were compared with the shear forces computed using proportionality assumption.
Figure 3.1: Segmentation of foot pressure data (a) Output from pedobarograph (b) Pressure data after segmenting a single step cycle (c) Pressure data segmented in 3 segments (hindfoot, forefoot and toes) of the foot.
Inverse Dynamic Analysis

Once the model segment locations (coordinate system and intersegmental angles), inertial properties and ground reaction forces were defined, segments were linked together to form a kinetic chain. Joint reaction forces and joint moments were calculated starting from the toes segment and progressing proximally using Newton-Euler equations (Davis et al., 1991; Gregersen et al., 2003; McGibbon et al., 1998).

Data Analysis

To compare the data between walking trials, each trial was time normalized by interpolation of one gait cycle duration into 51 points. To compute the group average, a representative trial from each subject was selected and the point average of these representative trials was computed at each 2% of the gait cycle.

Statistical Analysis

A database of means and variability of model outcomes was established by carrying out the data collection and processing protocol for n=10 control pediatric subjects (age 10.6 ± 1.57 years). Model application was also carried out on n=5 subjects (age 10.3 ± 0.69 years) with planovalgus foot deformity to test model sensitivity. Data were compared between different clinicians by a paired analysis. Model sensitivity was assessed by statistical comparison of model outcomes. In order to comprehend the meaning of clinical results, it is first necessary to have an understanding of how the model functions in typically developing subjects.
Results

The proportionality assumption for shear force distribution was tested by comparing shear force directly measure by force plates and shear forces computed by using a proportionality scheme (Figure 3.2). Average and maximum difference between two measures was less than 5% and 13%, respectively, which was considered small enough for clinical application.

Figure 3.3 and Figure 3.4 show the kinematic and kinetic model outcomes for control subjects as shaded areas; average model outcomes for the PV group are shown as a solid black line. Two clinicians carried out the model data collection protocol on each subject, thereby reflecting the clinical practice in the labs and measuring interclinician variability. The percentage standard error as a measure of interclinician variability in peak joint moments and power during a gait cycle for control and pathologic group are shown in Figure 3.5. Hindfoot and forefoot moment and power variability was less than 15%. Higher variability observed for the toe segment was expected due to high variability in toe marker data (Saraswat 2009). Although pathologic (PV) group variability was slightly smaller than the TD group (Figure 3.5), the difference was not statistically significant.

While comparing the kinematic outcomes between groups (Figure 3.3) significant differences were observed in hindfoot range of motion and peaks, forefoot flexion and adduction peak and toe flexion peak. Table 3.1 shows the results of independent sample t-tests for these variables. Kinetic outcomes were also compared between two groups.
Figure 3.2: Validation of proportionality assumption during stance phase of gait cycle: Comparison of force and moment distribution by use of two force plates and by use of proportionality assumption

Total Force
Hindfoot Force (Two Force Plates)
Hindfoot Force (Proportionality Assumption)
Forefoot Force (Two Force Plates)
Forefoot Force (Proportionality Assumption)
Figure 3.3: Joint angle during walking for two groups, Grey: Normal group with shaded area as standard deviation. Black: Pathologic group
Figure 3.4: Joint moments and power during a gait cycle: Grey: Control group with shaded area as standard deviation. Black: Pathologic group
Figure 3.5: Interclinician variability in peaks of joint moment in three planes and joint power for three segments
Table 3.1: Results of independent samples t-test for key variables for detection of planovalgus feet

<table>
<thead>
<tr>
<th>Variable</th>
<th>Normal Group</th>
<th>Pathologic Group</th>
<th>Avg. Diff.</th>
<th>p-value</th>
<th>Clinical Significance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hindfoot Valgus</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Peak</td>
<td>3.3 ±2.6</td>
<td>6.8 ±2.2</td>
<td>3.2°</td>
<td>0.014</td>
<td>✗</td>
</tr>
<tr>
<td>Range</td>
<td>12.7 ±3.5</td>
<td>10.1 ±2.3</td>
<td>2.6°</td>
<td>0.046</td>
<td>✗</td>
</tr>
<tr>
<td>Hindfoot Flexion</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Peak</td>
<td>41.8 ±4.0</td>
<td>36.5 ±5.2</td>
<td>5.2°</td>
<td>0.005</td>
<td>✓</td>
</tr>
<tr>
<td>Range</td>
<td>26.6 ±8.3</td>
<td>20.8 ±4.5</td>
<td>5.8°</td>
<td>0.020</td>
<td>✓</td>
</tr>
<tr>
<td>Hindfoot Rotation</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Peak</td>
<td>18.7 ±5.7</td>
<td>9.4 ±6.9</td>
<td>9.2°</td>
<td>0.001</td>
<td>✓</td>
</tr>
<tr>
<td>Range</td>
<td>11.5 ±2.7</td>
<td>9.2 ±2.1</td>
<td>2.3°</td>
<td>0.030</td>
<td>✗</td>
</tr>
<tr>
<td>Forefoot Flexion Peak</td>
<td>37.2 ±5.5</td>
<td>28.0 ±11.8</td>
<td>9.2°</td>
<td>0.039</td>
<td>✓</td>
</tr>
<tr>
<td>Forefoot Adduction Peak</td>
<td>6.8 ±6.2</td>
<td>0.3 ±8.8</td>
<td>6.5°</td>
<td>0.026</td>
<td>✓</td>
</tr>
<tr>
<td>Toe Flexion Peak</td>
<td>71.4 ±11.1</td>
<td>57.5 ±13.4</td>
<td>13.9°</td>
<td>0.005</td>
<td>✓</td>
</tr>
<tr>
<td>Ankle Joint Power Peak</td>
<td>2.65 ±0.95</td>
<td>1.5 ±0.4</td>
<td>0.95</td>
<td>0.001</td>
<td>✓</td>
</tr>
<tr>
<td>Forefoot Joint Power Peak</td>
<td>1.00 ±0.44</td>
<td>0.6 ±0.2</td>
<td>0.40</td>
<td>0.001</td>
<td>✓</td>
</tr>
</tbody>
</table>
Although no significant differences were observed in joint moments between the two groups, hindfoot and forefoot joint powers were significantly smaller in the planovalgus group.

**Discussion**

A multisegment foot model has been proposed describing the strategy for ground reaction force segmentation. Model application to typically developing children and children with planovalgus feet yielded the first known data of kinetic outcome’s inter-clinician variability in both a control and a pathological population. The model was observed to be equally repeatable in both groups (Figure 3.5) indicating its robustness in cases with foot deformity. Joint moment patterns for the TD group were found to be qualitatively similar to an earlier study (Macwilliams et al., 2003) except for a few minor differences that can be explained by differences in segment definition. Similar to the previous results, ankle and forefoot joints were observed to generate power during late stance phase while toes absorbed power.

To demonstrate that the model is capable of reflecting differences between control and impaired foot function, model outcomes were compared between TD and PV groups (Table 3.1). Significant differences were found in both kinematics as well as kinetics but only differences larger than the variability observed (Kinematics: ~ 4°, Kinetics: ~15%) were considered to be clinically significant.

Contrary to common expectations of larger hindfoot valgus and flexion motion in planovalgus feet (Olson et al., 1983), the PV group exhibited a smaller range of motion at the ankle joint in all three planes than the TD group. Hunt et al. 2004 also observed
reduced motion in PV feet but the differences observed were very small (< 2°). Differences observed in the current model are large enough (5.8°) to be considered clinically significant (Table 3.1) in the hindfoot flexion range, which may indicate improved sensitivity of the Shriners Hospital for Children Greenville (SHCG) foot model (Saraswat et al., 2009).

Another characteristic of planovalgus foot, excessive hindfoot valgus and smaller forefoot flexion (flat foot) were also significant in the planovalgus group (Table 3.1). Although hindfoot valgus peak (3.2° difference) was not large enough to be considered clinically significant, forefoot flexion peak (9.2° difference) was clinically significant. The planovalgus group was found to be more (9.2°) externally rotated at hindfoot.

Planovalgus foot is expected to show larger motion at tarso-metatarsal joint but no significant differences were observed between the two groups. The forefoot was observed to be more abducted (6.5°) in the planovalgus group, which is commonly expected in flatfoot. Peak toe flexion was also observed to be smaller (13.9°) in the planovalgus group, demonstrating that the absence of a medial forefoot arch affects both tarso-metatarsal as well as metatarso-phalangeal flexion joint angle.

Model application was carried out by two clinicians on each subject to measure interclinician variability. Interclinician variability in kinetic model outcomes was tested for both groups (Figure 3.5) and was less than 15% for hindfoot and forefoot and not significantly different between groups. Higher variability observed in toe moments was likely a reflection of high variability in kinematic outcomes for toes. Smaller joint moments were expected at the hindfoot and forefoot in the planovalgus group due to proximal shift in center of pressure to accommodate midtarsal break but no significant
difference was observed in joint moment peaks from the two groups. Joint powers, on the other hand, were significantly smaller in the planovalgus group for hindfoot and forefoot joints. It can be concluded from the results that differences in joint kinetics are primarily due to change in joint motion, i.e., slow and small range of motion.
CHAPTER 4

MUSCULOSKELETAL MODEL

Submitted to Journal of Biomechanics
**Abstract**

Several full body musculoskeletal models have been developed for research applications and these models may potentially be developed into useful clinical tools to assess gait pathologies. Existing full-body musculoskeletal models treat the foot as a single segment and ignore the motions of the intrinsic joints of the foot. This assumption limits the use of such models in clinical cases with significant foot deformities. Therefore, a three-segment musculoskeletal model of the foot was developed to match the segmentation of a recently developed multisegment kinematic foot model. All the muscles and ligaments of the foot spanning the modeled joints were included. Muscle pathways were adjusted with an optimization routine to minimize the difference between the muscle flexion-extension moment arms from the model and moment arms reported in literature. The model was driven by walking data from 5 normal pediatric subjects (aged 10.6±1.57 years) and muscle forces and activation levels required to produce joint motions were calculated using an inverse dynamic analysis approach. Due to the close proximity of markers on the foot, small marker placement error during motion data collection may lead to significant differences in musculoskeletal model outcomes. Therefore, an optimization routine was developed to enforce joint constraints, optimally scale each segment length and adjust marker positions. To evaluate the model outcomes, the muscle activation patterns during walking were compared with electromyography (EMG) activation patterns reported in the literature. Model-generated muscle activation patterns were observed to be similar to the EMG activation patterns.
Introduction

Musculoskeletal models consist of a set of body segments connected by joints with specified degrees-of-freedom (dof) and spanned by muscles and ligaments with specified origins, insertions and pathways (Damsgaard et al., 2006; Delp et al., 1990; Hoy et al., 1990). Joint or segmental motions and external forces are specified and an optimization routine is employed to determine muscle and ligament forces (Crowninshield, 1978; Crowninshield et al., 1981; Dul et al., 1984a; Dul et al., 1984b; Erdemir et al., 2007; Praagman et al., 2006; Rasmussen, 2005). These models are increasingly used in research but have not been adopted for routine clinical practice. A musculoskeletal model driven by motion analysis data has the potential to be developed into a useful clinical tool to assess gait pathologies. Model outcomes can be used to study how specific muscles contribute to movement coordination and suggest or assess interventions to correct pathologic walking patterns. Several musculoskeletal models exist for full-body gait analysis (Damsgaard et al., 2006; Delp et al., 1990; Dhang et al., 2004; Hoy et al., 1990) but these treat the foot as a single segment and ignore the motion of intrinsic joints. This assumption limits the use of such models in clinical cases with significant foot deformities.

There exist several multisegment kinematic foot models that measure the motions of intrinsic joints (Kidder et al., 1996; Leardini et al., 1999; Macwilliams et al., 2003; Stebbins et al., 2006). Models vary in terms of the number of segments, definitions of segments, coordinate alignments and use of static offsets. These models have been validated and are being used to research pathological conditions. To date, no multisegment kinematic foot model has been used as part of a musculoskeletal model.
To complement existing full-body musculoskeletal models, we propose to develop a three-segment musculoskeletal foot model. We hypothesize that a multi-segment foot model can be constructed, scaled to match a subject and driven with subject data from an existing kinematic model to estimate internal muscle forces and match muscle activation patterns. The model details and results from a preliminary analysis on 5 pediatric control subjects are presented. The model can be used to compute the contributions of intrinsic foot muscles during various lower extremity tasks and represents the first step toward development of a validated musculoskeletal foot model.

**Methods**

A three-segment musculoskeletal foot model (Figure 4.1) was developed using commercial software (AnyBody Technology, Aalborg, DEN) to match the segmentation (hindfoot, forefoot and toes) of a recently developed kinematic foot model (Saraswat et al., 2009). This enables marker data from the kinematic model to drive the musculoskeletal model segments.

**Base Musculoskeletal Model**

The first step was to develop the basic foot geometry and specify the model input parameters (i.e., inertia, muscle and ligament properties). The model geometry was optimized to improve anatomical accuracy.
Figure 4.1: The musculoskeletal model with five segments: (femur, shank, hindfoot, forefoot, toes) and muscles and ligaments spanning the joints depicted as lines. Ground reaction force vectors for each segment of the foot are also depicted.
Musculoskeletal Geometry

The model geometry consists of rigid bone segments connected by simplified joints. Muscle and ligament geometries were defined by origin, via and end points fixed to the bone segments following an anatomical text (Gray, 1974).

Segments

Several bones were joined together to form each modeled foot segment. Five segments were included: (i) Femur, (ii) Shank (Tibia and Fibula), (iii) Hindfoot (Calcaneus, Talus, Navicular, Cuboid and 3 Cuneiforms), (iv) Forefoot (5 Metatarsals) and (v) Toes (Hallux and 4 toes) (Figure 4.1). Although each toe was modeled as a separate segment, all five toes were driven by the same motion. The kinematic model (Saraswat et al., 2009) measures the motion of the hallux only; this same motion was used to move all five toes, but their flexion axes were defined separately. Inclusion of the shank and femur segments was necessary to complete definitions of muscle and ligament insertions and pathways. By using a CT scan of normal anatomy, an image file was created for each model segment to give a graphical representation of the bones.

Segment inertial properties were defined by assuming each bone to be cylindrical. Bone longitudinal length and average radius in two orthonormal directions were used to define the mass moments of inertia. These inertial properties were combined using the parallel axis theorem to calculate the segmental inertial properties. Anatomical landmarks on which skin markers were attached during data collection were extracted from the bone image files using 3D image software (Meshworks 1.0.3, Floating Point Solutions Pvt. Ltd.).
Muscles

Muscle pathways were initially defined by following an anatomical text (Gray, 1974) with manual extraction from the image file. Points specified in the local coordinate system of the 3D bone image were transformed into the model segment coordinate system. Sixteen muscles were included (Table 4.1). Intrinsic muscles were not included if they spanned a fixed joint within a segment. Absent muscles are abductor digiti minimi, abductor hallucis, adductor hallucis, dorsal/plantar interosseus, lumbircals and plantaris.

Ligaments

Ligaments contribute to joint reaction forces when they are stretched. Ligaments spanning a joint within a segment were not included. Fourteen ligaments were included in this model (Table 4.2).

Model Parameters

Muscles were modeled using Hill’s muscle model (Hill, 1938). This model includes the following assumptions: (i) Muscles can create only tensile forces, (ii) all muscle fibers are parallel and are inserted with the same pennation angle on the tendon, and (iii) the muscle cross sectional area and the volume remains constant. Fatigue mechanisms and activation dynamics were not included in the model.
Table 4.1: Muscles included in the model

<table>
<thead>
<tr>
<th>Muscle Action</th>
<th>Muscles</th>
<th>Strength*</th>
<th>$\gamma^{**}$ (deg)*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ankle Plantarflexion</td>
<td>Medial Gastroc</td>
<td>1115</td>
<td>17</td>
</tr>
<tr>
<td></td>
<td>Lateral Gastroc</td>
<td>490</td>
<td>8</td>
</tr>
<tr>
<td></td>
<td>Soleus</td>
<td>2830</td>
<td>25</td>
</tr>
<tr>
<td></td>
<td>Peroneus Longus (PL)</td>
<td>755</td>
<td>10</td>
</tr>
<tr>
<td></td>
<td>Peroneus Brevis (PB)</td>
<td>350</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>Tibialis Posterior (TP)</td>
<td>1270</td>
<td>12</td>
</tr>
<tr>
<td>Toe/Forefoot Extension</td>
<td>Extensor Hallucis Brevis (EHB)</td>
<td>40</td>
<td>14.5</td>
</tr>
<tr>
<td></td>
<td>Extensor Digitorum Brevis 2 (EDB2)</td>
<td>24</td>
<td>7.8</td>
</tr>
<tr>
<td></td>
<td>Extensor Digitorum Brevis 3 (EDB3)</td>
<td>15</td>
<td>7.1</td>
</tr>
<tr>
<td></td>
<td>Extensor Digitorum Brevis 4 (EDB4)</td>
<td>13</td>
<td>9.1</td>
</tr>
<tr>
<td></td>
<td>Extensor Digitorum Brevis 5 (EDB5)</td>
<td>13</td>
<td>9.1</td>
</tr>
<tr>
<td></td>
<td>Extensor Hallucis Longus (EHL)</td>
<td>110</td>
<td>6</td>
</tr>
<tr>
<td></td>
<td>Extensor Digitorum Longus (EDL)</td>
<td>340</td>
<td>8</td>
</tr>
<tr>
<td>Ankle Dorsiflexion</td>
<td>Tibialis Anterior (TA)</td>
<td>600</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>Peroneus Tertius (PT)</td>
<td>90</td>
<td>13</td>
</tr>
<tr>
<td>Toe/Forefoot Flexors</td>
<td>Flexor Hallucis Brevis (FHB)</td>
<td>120</td>
<td>7.8</td>
</tr>
<tr>
<td></td>
<td>Flexor Digitorum Brevis 2 (FDB2)</td>
<td>53</td>
<td>15.4</td>
</tr>
<tr>
<td></td>
<td>Flexor Digitorum Brevis 3 (FDB3)</td>
<td>45</td>
<td>11.7</td>
</tr>
<tr>
<td></td>
<td>Flexor Digitorum Brevis 4 (FDB4)</td>
<td>38</td>
<td>7</td>
</tr>
<tr>
<td></td>
<td>Flexor Digitorum Brevis 5 (FDB5)</td>
<td>10</td>
<td>7</td>
</tr>
<tr>
<td></td>
<td>Flexor Hallucis Longus (FHL)</td>
<td>320</td>
<td>10</td>
</tr>
<tr>
<td></td>
<td>Flexor Digitorum Longus (FDL)</td>
<td>310</td>
<td>7</td>
</tr>
</tbody>
</table>

* All muscle properties are for representative model (Body Weight-75kg. Height – 1.44 m)

**$\gamma$- Pennation Angle
Table 4.2: Ligaments included in the model

<table>
<thead>
<tr>
<th>Joint</th>
<th>Ligament</th>
<th>Yield Strength*</th>
<th>Yield Strain*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ankle</td>
<td>Tibionavicular</td>
<td>107</td>
<td>0.09</td>
</tr>
<tr>
<td></td>
<td>Tibiocalcaneal</td>
<td>351</td>
<td>0.28</td>
</tr>
<tr>
<td></td>
<td>Posterior Tibiotalar</td>
<td>405</td>
<td>0.25</td>
</tr>
<tr>
<td></td>
<td>Anterior Talofibular</td>
<td>222</td>
<td>0.14</td>
</tr>
<tr>
<td></td>
<td>Calcaneofibular</td>
<td>289</td>
<td>0.13</td>
</tr>
<tr>
<td>Mid foot</td>
<td>Plantar Fascia</td>
<td>210</td>
<td>0.053</td>
</tr>
<tr>
<td></td>
<td>5 Dorsal Tarso-metarsal</td>
<td>150.7</td>
<td>1.15</td>
</tr>
<tr>
<td></td>
<td>3 Plantar Tarso-metarsal</td>
<td>250</td>
<td>0.10</td>
</tr>
</tbody>
</table>

* All properties are for representative model (Body Weight-75kg. Height – 1.44 m)

**γ** - Pennation Angle
Muscle Properties

Optimum muscle forces are proportional to the physiological cross-sectional area (Brand, 1986). Established data were used for muscles spanning the ankle (Brand, 1986; Friederich et al., 1990; Wickiwicz, 1983). For the remaining muscles, optimum muscle force was set to be proportional to the muscle cross-section area (Kura et al., 1997).

Fiber length and pennation angle have been well established in the literature for ankle muscles (Brand, 1986; Friederich et al., 1990; Wickiwicz, 1983). For intrinsic foot muscles, these were taken from a comprehensive study (Kura et al., 1997) that utilized 11 cadaver feet (Table 4.1).

Ratio of fast/slow twitch fibers have been reported for some ankle muscles and most have a ratio of 0.4-0.6 (Johnson, 1973). Therefore, a default value of 0.5 was used for the muscles where the data was not available.

Ligament Properties

Ligaments were modeled as springs that provide tensile force when stretched beyond their slack length. Five ligaments were attached at the ankle joint and eight at the forefoot joint. Ligament and plantar fascia properties (yield force, yield strain and initial length) were extracted from the literature (Siegler, 1988; Wright, 1964) (Table 4.2).

Optimization of Muscle Moment Arms

The geometric configuration of the model was adjusted by optimizing the moment arms for a group of muscles. This step was carried out for ankle muscle flexion-extension moment arms. Initially defined insertion point locations were allowed to move within a
small range (±1 cm) to minimize the difference between the muscle moment arm generated by the model and the moment arms reported from cadaver testing (Spoor et al., 1990) using a least-square objective function.

**Subject-Specific Adaptation**

The base geometric model was created from a single normal adult foot for which CT data were available. Muscle moment arms were optimized for the base model only. In order to apply this model to the general population, and particularly to pediatric subjects, the model geometry and parameters must be suitably scaled. Model adaptation was completed on five normal pediatric subjects (age 10.6±1.57 years). The steps involved in computing model outcomes for each subject are explained in the following sections.

**Scaling**

Several scaling methods have been successfully tested in a full-body gait model (Rasmussen, 2005). Here, the simplest scaling method, known as the uniform scaling model, was used. Each segment in the musculoskeletal model consists of mass properties and a number of nodes used to define joint centers and muscle insertion points. For subject-specific modeling, both the mass properties and node positions require scaling. The uniform scaling method uses the following equations for geometric and strength scaling (Rasmussen, 2005):
\[ S = \begin{bmatrix} K_L & 0 & 0 \\ 0 & K_L & 0 \\ 0 & 0 & K_L \end{bmatrix} \quad F = F_0 k_m^{2/3} \ldots (1) \]

where \( S \) is the scaling matrix for the bone segments and muscle insertion points. \( K_L \) is the ratio of subject to base model height. \( k_m \) is the ratio of subject to base model mass. \( F \) and \( F_0 \) are the maximal muscle strength for subject and base model, respectively. This strength scaling algorithm assumes that muscle strength is proportional to cross-sectional area and body mass is proportional to volume. The segment is geometrically scaled equally in all directions.

**Driving the Model**

Motion and external forces acting on the model were input using marker trajectories collected over a gait cycle and ground reaction forces on the foot segments during stance.

**Segment Scaling and Marker Coordinate Optimization**

Musculoskeletal models can be driven either by computed intersegmental joint angles or by marker trajectories. Driving the model by marker trajectories involves the assumption that markers are placed at accurate landmarks as specified in the model definition, and in turn ignores the inherent error in marker placement during the data capture. Driving the model by precalculated intersegmental joint angles neglects any translations at the joints and assumes that the model- and marker-based reference frames are identical, which may not be the case. Therefore, an optimization routine was
developed to account for marker placement error and enforce joint constraints (Andersen et al., 2009b; Andersen et al., 2009a).

A 16 dof kinematic leg model comprised of the femur, shank, hindfoot, forefoot and toes was developed to match the segments defined in the kinematic model (Saraswat et al., 2009). The knee, ankle and forefoot/hindfoot joints were modeled as spherical joints and the toes/forefoot joint as a revolute joint. An optimization routine was constructed to scale each segment length and marker positions to minimize the total sum of squared differences between the segment-fixed markers on the model and the marker trajectories measured by the motion capture system (Vicon MX, Vicon Motion Systems) over the whole walking trial. After each segment is scaled according to the uniform scaling method, the optimization routine optimally adjusts the size of each segment separately according to the marker trajectories. Table 4.3 shows the optimization setting for each marker in three directions. Some markers that are prone to placement errors were optimized in all directions (e.g., lateral calcaneus). Markers that are placed on easily located anatomical landmarks, and hence are less prone to marker placement error, were not adjusted (e.g., metatarsal head). Efficacy of the optimization routine is apparent as motion- and segment- based markers converge (Figure 4.2). Marker position and segment scaling optimization was carried out for each subject’s trial.
Table 4.3: Optimization setting for each marker degree of freedom

<table>
<thead>
<tr>
<th>Segment</th>
<th>Anatomical Landmark for marker</th>
<th>X*</th>
<th>Y**</th>
<th>Z***</th>
</tr>
</thead>
<tbody>
<tr>
<td>Femur</td>
<td>Hip Joint Center</td>
<td>Off</td>
<td>Off</td>
<td>Off</td>
</tr>
<tr>
<td>Femur</td>
<td>Lateral knee epicondyle</td>
<td>On</td>
<td>Off</td>
<td>Off</td>
</tr>
<tr>
<td>Femur</td>
<td>Patella</td>
<td>On</td>
<td>Off</td>
<td>On</td>
</tr>
<tr>
<td>Shank</td>
<td>Tibial wand</td>
<td>On</td>
<td>On</td>
<td>On</td>
</tr>
<tr>
<td>Shank</td>
<td>1\textsuperscript{st} marker on anterior surface of tibia</td>
<td>On</td>
<td>On</td>
<td>On</td>
</tr>
<tr>
<td>Shank</td>
<td>2\textsuperscript{nd} marker on anterior surface of tibia</td>
<td>On</td>
<td>On</td>
<td>On</td>
</tr>
<tr>
<td>Shank</td>
<td>Lateral Malleolus</td>
<td>On</td>
<td>On</td>
<td>On</td>
</tr>
<tr>
<td>Hindfoot</td>
<td>Posterior Calcaneus</td>
<td>Off</td>
<td>Off</td>
<td>Off</td>
</tr>
<tr>
<td>Hindfoot</td>
<td>Calcaneal Tubercle</td>
<td>On</td>
<td>Off</td>
<td>Off</td>
</tr>
<tr>
<td>Hindfoot</td>
<td>Lateral Calcaneus</td>
<td>On</td>
<td>On</td>
<td>On</td>
</tr>
<tr>
<td>Hindfoot</td>
<td>Medial Calcaneus</td>
<td>On</td>
<td>On</td>
<td>On</td>
</tr>
<tr>
<td>Forefoot</td>
<td>Mid pt of 2\textsuperscript{nd} and 3\textsuperscript{rd} metatarsals base</td>
<td>Off</td>
<td>Off</td>
<td>Off</td>
</tr>
<tr>
<td>Forefoot</td>
<td>Mid pt of 2\textsuperscript{nd} and 3\textsuperscript{rd} metatarsals heads</td>
<td>Off</td>
<td>Off</td>
<td>Off</td>
</tr>
<tr>
<td>Forefoot</td>
<td>Medial aspect of 1\textsuperscript{st} metatarsal base</td>
<td>On</td>
<td>Off</td>
<td>Off</td>
</tr>
<tr>
<td>Forefoot</td>
<td>Medial aspect of 1\textsuperscript{st} metatarsal head</td>
<td>Off</td>
<td>Off</td>
<td>On</td>
</tr>
<tr>
<td>Hallux</td>
<td>Toe Triad placed on the nail of Big Toe</td>
<td>On</td>
<td>On</td>
<td>Off</td>
</tr>
</tbody>
</table>

On→ Optimized, Off→ Not optimized

* Anterior/ Posterior, ** Medial/Lateral, *** Superior/ Inferior direction
Figure 4.2: Marker data from a motion capture system collected on subjects (black) and segment fixed marker positions (white) were optimized resulting in near convergence.
Calculation of Ground Reaction Force for Three Foot Segments

Inverse dynamic analysis requires that each foot segment contacting the ground have a ground reaction force vector. The resultant force on the three segments was derived by combining data from a coupled six axis force plate (AMTI, Watertown, MA, USA) and pedobarograph (RSscan, Olen, BE) measured during gait. Pressure data from one gait cycle was segmented into the three corresponding segments of the foot. Segmented pressure data was used to calculate the center of pressure and ground reaction force vector for each segment (Macwilliams et al., 2003). Each arrow in Figure 4.1 shows the segmented ground reaction force acting on a foot segment. A single ground reaction force was distributed among the toes by using artificial muscles with high strength that were included in the muscle recruitment optimization.

Model Parameter Calibration

Tendon Length Optimization

Muscle forces are highly sensitive to optimal tendon length. A calibration analysis was carried out for each individual to calculate optimal tendon length. The calibration analysis evaluates the range of motion (one gait cycle) and computes the muscle length variation. It subsequently changes the user-defined value of optimal tendon length such that the length of the contractile element equals the optimum fiber length when the origin-insertion length is at its mean value. The rationale is that muscles should attain their optimum fiber lengths somewhere safely within the interval of a representative movement.
Ligament Length Optimization

Similar to muscles, ligament slack length is also calibrated by calculating the range of ligament origin-insertion length throughout a gait cycle. Ligament optimal length is set to the mean of this range.

Muscle Force Calculation

The basic optimality assumption is that muscles are recruited in such a way that fatigue is postponed as long as possible by minimizing maximum muscle activity (Rasmussen et al., 2001):

\[
\min_{f} \max_{i} \left( \frac{f_{i}^{M}}{N_{i}} \right), \quad i \in \{1, \ldots, n^{M} \}
\]

s.t.

\[
Cf = r \quad \quad \quad \quad \quad \ldots \quad (2)
\]

\[
f_{i}^{(M)} \geq 0
\]

for \( i \in \{i, \ldots, n^{(M)} \} \), where \( f_{i}^{M} \) is the force produced by \( i^{th} \) muscle and \( N_{i} \) is the normalization factor, which is instant muscle strength. This normalized muscle force is called muscle activity. \( C \) is a matrix of coefficients depending on current position of body segments, \( f \) is a vector of unknown forces (muscle and reaction forces) and \( r \) consists of external (ground reaction) forces and inertia.

Results

The moment arm optimization process resulted in a more anatomically accurate model. Muscle via points were initially defined by following anatomical text using bone surface landmarks (Figure 4.3a). Therefore, the effect of tendon and soft tissue thickness
were not initially included, but are adjusted for with optimization. Figure 4.3 shows the graphical representation of moment arm of tibialis anterior before and after optimization. Figure 4.4 illustrates the efficacy of the moment arm optimization routine. Moment arms for ten muscles are shown before and after optimization along with the cadaver tested moment arms (Spoor et al., 1990), which were used as a target for optimization. For all muscles, the postoptimization moment arms are within ±5 mm of the cadaveric moment arms.

The process of marker position and segment scaling optimization does not affect the gross motion of the segments significantly. The average difference for n=3 subject trials between the raw joint angle and optimized joint angle was less than 2.5° for each joint in all three planes. The differences between the two analyses can be attributed to soft tissue artifact, the introduced simplified joint constraints, the assumption that the markers are rigidly attached to the segments and the uniform scaling law. The optimized model results in smoother joint angle curves and therefore reduces unrealistic accelerations.

Muscle activation patterns for each subject are compared to EMG activation pattern from the literature (Perry, 1992) over the walking trials (Figure 4.5). Activation patterns for the ankle flexor/extensor muscles were observed to be similar to EMG patterns. The differences between the EMG pattern and model results in the toe extensors may be explained by the fact that muscles were recruited to produce flexion extension motion only; artificial reaction forces were provided to drive motion in the other two axes.
Figure 4.3: Graphical representation of tibialis anterior (TA) muscle (a) before and (b) after moment arm optimization. All muscles with reported moment arm data underwent similar optimization.
Figure 4.4: Moment arms (meter) over a range of ankle flexion motion. After optimization, the model moment arm approaches the target moment arm data measured by cadaver testing (Spoor et al., 1990).
Figure 4.5: EMG-measured muscle activation pattern (shaded, Perry, 1992) for a single gait cycle compared to muscle activation patterns computed by the musculoskeletal model for n=5 pediatric subjects (lines).
If model geometry (muscle moment arms) is optimized for the remaining dof, then model outcomes may be more reliable. The EMG activation patterns are not available for brevis foot muscles and, therefore, model results provide the first insight into these activation patterns (Figure 4.6). In general, brevis activation patterns are coincident with their counterpart longus muscles.

**Discussion**

In recent years, several efforts have been made to measure multisegmental motions of the foot during walking. This study adds to that body of work by using this multisegment foot motion and ground reaction forces to investigate the role of the intrinsic muscles of the foot during walking. The goal of this work is to provide a first step towards developing a multisegmental musculoskeletal foot model that may be used for clinical motion analysis. The model results demonstrate that multisegment musculoskeletal models can be adapted for subject-specific gait application.

Optimization routines are employed in several capacities. Muscle moment arm optimization improves the anatomic accuracy of the model by utilizing data from cadaveric experiments. The segment scaling and marker position optimization plays a crucial part in adapting the model for subject-specific application. Its efficacy was tested using trials from five different subjects and demonstrated by the convergence of the two marker sets. Finally, optimization is used to solve the redundancy problem to predict muscle forces. For most muscles, predicted and measured muscle activation patterns matched qualitatively, but further analysis is necessary to demonstrate and quantify activation and muscle force validity.
Figure 4.6: Activation pattern of brevis muscles of the foot during walking.
This preliminary model has several limitations. Moment arm optimization was only carried out in the sagittal plane. The same routine needs to be carried out for the other two joint axes to improve the applicability of model. Although there have been some studies to measure inversion-eversion moment arm of ankle muscle (Lee et al., 2008), there is no comprehensive data available for moment arms of other foot muscles in nonsagittal planes. Thus, more cadaveric testing is necessary before this model may be completed. Use of this model to generate muscle activation patterns for pathological populations is still a distant task. The current model can incorporate static joint offsets for pathologic feet, but musculoskeletal changes such as bony deformations and muscle properties due to neurological conditions are beyond the scope of the current project.
CHAPTER 5

MODEL INTEGRATION
The research described in this dissertation was aimed towards integrating a multi-segment foot model in full body gait analysis and extend the use of those data to analyze kinetics and musculoskeletal activation patterns of intrinsic foot joints. These models may significantly improve the confidence in recommending intervention for foot pathology.

Figure 5.1 demonstrates how the three models (Kinematic, Kinetic and Musculoskeletal) are interrelated. Foot joint motion computed in the kinematic model (Chapter 2) was used as an input for an inverse dynamics analysis to compute joint kinetics (Chapter 3) and to drive the musculoskeletal model (Chapter 4). Distributed ground reaction forces computed for the kinetic analysis (Chapter 3) were also used as in input to the musculoskeletal model to compute the muscle activation pattern (Chapter 4).

![Figure 5.1: Flowchart of interrelation between three models](image-url)
In Chapter 2, a novel clinical foot model was developed with the underlying strategy of using small hemispherical markers for anatomical landmark identification and using technical markers located at optimal sites to track dynamic motion. The model was tested for interclinician and intraclinician variability at two data collection sites for normal as well as pathologic subjects. The model was found to be equally repeatable in two data collection sites and variability measures were smaller than previous models. This work resulted in the first kinematic foot model with reported interclinician and intersite variability. As variability measures proved to be acceptably small in all measures, this is the first reported multisegment foot model validated for use with multiple clinicians, which is critical for using a model for longitudinal measures in a clinical laboratory and in different laboratories, which is critical for using a model for multicenter research.

In Chapter 3, kinetics of the foot were described with strategies to distribute ground reaction forces into foot segments. Additionally, both kinematics and kinetics were studied in a single type of foot deformity: the planovalgus foot. Both interclinician and intraclinician variability were determined. This is the first model to report any variability measures in a pathologic population. It is also the first model to report any variability measures of multisegmental foot kinetics. The model application was carried out on both normal and pathologic subjects to test the differences between groups. Model outcomes were found to be equally repeatable in both groups and showed acceptable variability due to multiple clinicians. The model was able to detect differences in joint motion as well as joint powers. Model outcomes detected the static deformities of the foot (i.e., excessive hindfoot valgus and absence of medial longitudinal arch). Contrary to
common expectations, the planovalgus foot was shown to have a smaller range of motion at hindfoot and forefoot in the sagittal plane. The differences between groups were larger than the variability observed in the model outcomes, which was not observed in a similar study. This demonstrates that the proposed model strategy leads to better accuracy and repeatability in model outcomes, which in turn results in clinically significant differences.

In Chapter 4, a multisegment musculoskeletal foot model was developed as a first step towards making the process of subject-specific model application appropriate for clinical application. Optimization routines were employed in several capacities. Muscle moment arm optimization was carried out to improve anatomic accuracy. A segment scaling and marker position optimization process was developed, which is a crucial part in adapting the model for subject-specific application. Finally, optimization was used to compute muscle activation patterns for walking by using marker data from 5 normal pediatric subjects. Excellent qualitative agreement between computed muscle activation patterns and measured EMG were found in most muscles illustrating the future potential of this model.

In conclusion, it has been shown that the multisegment foot model with quantified variability can be successfully used to detect the difference between normal and pathologic foot function. Use of such a model will significantly improve the confidence in gait analysis recommendations for foot pathologies. The musculoskeletal model opens a new area of research with the possibility of simulating surgeries to interpret outcomes. A streamlined approach for subject-specific musculoskeletal model application has been demonstrated. Further testing and model geometry (moment arm for three joints in three planes) is required before such a model can be implemented for clinical application.
APPENDIX A

IRB: ASSENT FORM
Assent to Participate in a Study

Purpose of the Research

We are asking you to take part in a research study because we are trying to learn how different parts of your foot move when you walk. To do this we will put some markers on your body and then have you walk over some platforms which measure force. The markers are taped onto your skin so they will stay on while you walk.

Procedures

If you agree to be in this study, small markers will be placed at various locations on your skin. A plaster cast of your feet will be made. You will place your foot in the cast while the markers are put on. You will then walk in a straight line. While you walk, cameras around the room will record the markers and a type of scale in the floor will measure the forces on the bottom of your feet. You will walk several times (about 10) for short distances (about 20 feet) so that several recordings can be made. Afterward the markers will be taken off and a different person will put them back on. Then you will repeat the walking. The whole study will take about one and one half hours to complete. You may be asked to come back another day and repeat the study again, but we will use the same cast next time.

Risks

For this study, markers are attached to the skin with special tape that should not cause any rash on your skin. Before this is done, we will ask if you ever get rashes from tape or Band-Aids. If so, we will not do the study. It may hurt a little when the small pieces of tape are removed from your skin. This is like taking off very small Band-Aids.

Benefits

We will not be able to help you right away with anything that we learn from this study. We hope that by doing this study we can help some other kids.

Alternative Procedures and Voluntary Participation

If you don’t want to be in this study, you don’t have to participate. Remember, being in this study is up to you and no one will be upset if you don’t want to participate or even if you change your mind later and want to stop. Please talk this over with your parents before you decide whether or not to participate. We will also ask your parents to give their permission for you to take part in this study. But even if your parents say “yes”, you can still decide not to do this.
Confidentiality

All information which is collected about you during this research will be kept strictly confidential. All data will be stored on a protected computer system to which only the members of the movement analysis lab have access. Paper documents, including this form, will be kept in a secure file by the director of the movement analysis laboratory.

Person to Contact

If you have any questions about this research, please contact Bruce MacWilliams at (801) 536-3800, or after normal business hours though the hospital switchboard at (801) 536-3500.

Consent

Signing my name at the bottom means that I agree to be in this study. My parents and I will be given a copy of this form after I have signed it.

Printed Name of Child

Signature of Child  Date

Printed Name of Witness

Signature of Witness  Date
APPENDIX B

IRB: PARENTAL PERMISSION FORM
Parental Permission and Authorization Document

Background
Currently, technology exists and is being used in our laboratory to make measurements of how children walk. The models used for these analyses can only measure how the ankle moves. The foot is made up of many different bones and joints which all move when we walk. We have created a different model to examine the foot in more detail. This study is being conducted to test and develop this model, which will estimate the motions and forces of various portions of the foot during walking.

The purpose of this study is to show that this model can estimate the motions of the foot. A baseline set of data will be collected from a group of healthy volunteers between the ages of 8-14. Other sets of data will be collected from a group of Shriners Hospital for Children (SHC) patients in the same age group with single or bilateral (both feet) planovalgus foot. (Planovalgus foot is a combination of pes planus (flat foot), hindfoot inversion (or varus) and forefoot adductus). The results will be compared to see if there are any differences between the healthy group and the planovalgus group. This will give us an indication of how well our model is working.

Study Procedure
All participants will have a physical examination of their feet, which will help us in verifying our recorded data. A plaster mold of the bottoms of their feet will be made and they will place their feet in this mold for static data collection. This allows us to accurately reposition their feet. Small reflective markers, which can be seen by camera system, will be attached to the skin with hypoallergenic tape. These markers will be placed on lower extremities (i.e. thigh, shank and foot). He/she will then walk in a straight line in the laboratory. While your child walks, cameras around the room will be recording the positions of the markers and platforms in the floor will record the forces on the bottoms of their feet. Your child will walk several times (about 10) for short distances (about 20 feet) so that multiple trials can be collected. The markers will then be removed and then put back on by a second examiner, and both static and walking data will be collected again. The entire study will take about one and a half hours to complete. If you choose to participate in this study, you may be asked to return sometime in the next three months. The study will be exactly the same both times except that the plaster cast will only have to be made during the first visit.

Risks
For this study, markers are attached to the skin with hypoallergenic tape. Before this is done, we will ask if your child has allergies to tape. If so, we will not proceed with the study. There may be some minor discomfort experienced when the small pieces of tape are removed from your child’s skin. This is similar to removing very small Band-Aids.

Benefits
There are no immediate anticipated benefits from participation in this study. The results are intended to be used to improve our long term understanding of certain foot problems.

Alternative Procedures
You need not have your child in this study. If your child has been referred to the lab for
foot pressure analysis, you may choose to have the standard clinical procedure, which includes walking, but without any markers attached.

Confidentiality
Your child’s participation in this study and all the medical records will be kept private and confidential according to all state and federal laws. All data will be stored on a protected computer system to which only the member of the movement analysis lab have access. Paper documents, including this form, will be kept in a secure file by the director of the movement analysis laboratory. No information identifying your child will be given without your permission. However, a report of this research study, which may include slides or photographs that do not identify your child, may be written for a scientific paper. Information gained from this study that is identified with the person will be released to no one other than the investigators, the person’s physician, the institution conducting the study and the United States Food and Drug Administration, which, through its regulatory powers, may inspect records involving research participants.

Person to Contact
If you have any questions, complains or concerns about this study, you may call the principal investigator, Bruce MacWilliams, Ph.D. at (801) 536-3800. After office hours you can contact him through the hospital switchboard at (801) 536-3500. If you think you may have been injured from being in this study, please call Bruce MacWilliams at (801) 536-3800. Bruce MacWilliams can be reached at this number during 9 am – 5 pm.

Institutional Review Board
Contact the Institutional Review Board (IRB) if you have questions regarding your rights as a research participant. Also, contact the IRB if you have questions, complaints or concerns which you do not feel you can discuss with the investigator. The University of Utah IRB may be reached by phone at (801) 581-3655 or by e-mail at irb@hsc.utah.edu.

Research Participant Advocate
You may also contact the Research Participant Advocate (RPA) by phone at (801) 581-3803 or by email at participant.advocate@hsc.utah.edu.

Research Related Injury
If your child is injured from being in this study, medical care is available at the University of Utah or Primary Children's Medical Center, as it is to all sick or injured people. The University of Utah does not have a program to pay you if your child is hurt or has other bad results from being in the study. The costs for any treatment or hospital care would be charged to you or your insurance company (if you have insurance), to the study sponsor or other third party (if applicable), to the extent those parties are responsible for paying for medical care your child receives. Since this is a research study, some health insurance plans may not pay for the costs. The University of Utah is a part of the government. If your child is injured in this study, and you want to sue the University or the doctors, nurses, students, or other people who work for the University, special laws may apply. The Utah Governmental Immunity Act is a law that controls when a person needs to bring a claim against the government, and limits the amount of money a person may recover. See Section 63G-7-101 to -904 of the Utah Code.
Also, in the event of injury or undesirable reaction from participation in research-related activities, Shriners Hospitals for Children can only provide those medical services available at the Shriners Salt Lake City Hospital. Shriners Hospitals for Children has no program for any financial compensation for a research-related injury or an undesirable reaction. If you believe that your child has sustained an injury as a result of participating in this research program, please also contact the investigators and/or Chief of Staff, Shriners Hospitals for Children, Salt Lake City Hospital, at (801) 536-3600. By signing this document you are not giving up your right to pursue legal action against any and all parties involved with this research.

Voluntary Participation
This study is voluntary, if you decide that your child will not participate, there will be no penalty or loss of benefits to your child that he/she would otherwise have. If your child is a patient, your child’s usual and normal care at Shriners Hospitals for Children, Salt Lake City Hospital, will continue. If after agreeing to have your child in the study, you or your child changes your mind, you only need to inform Dr. MacWilliams.

Costs to Participants and Compensation
Your child’s participation in this study is free, at no cost to you, and voluntary. Participants will not receive any compensation for participating in this study.

Authorization for Use of Your Protected Health Information
Signing this document means you allow us, the researchers in this study, and others working with us to use information about your health for this research study. You can choose whether or not you will participate in this research study. However, in order to participate you have to sign this consent and authorization form.

This is the information we will use:

Name
Address
Telephone number
Current and past medications or therapies
Information from a physical examination, such as range of motion and strength

Others who will have access to your information for this research project are the University’s Institutional Review Board (the committee that oversees research studying people) and authorized members of the University’s and Shriners Hospital’s workforce who need the information to perform their duties (for example: to provide treatment, to ensure integrity of the research, and for accounting or billing matters).

In conducting this study, we may share your child’s information with groups outside the Shriners Hospital. The information we share may include information that directly identifies your child. These are the groups:

Roy B. Davis, Shriners Hospitals for Children, Greenville.
United States Food and Drug Administration.

Information disclosed to groups outside the Shriners Hospital may no longer be covered by the federal privacy protections.
You may revoke this authorization. **This must be done in writing.** You must either give your revocation in person to the Principal Investigator or the Principal Investigator’s staff, or mail it to **Bruce MacWilliams, Movement Analysis Lab, Fairfax Road @ Virginia St. Shriners Hospital for Children, Salt Lake City, UT-84103. bmacwilliams@shrinenet.org.** If you revoke this authorization, we will not be able to collect new information about you, and you will be withdrawn from the research study. However, we can continue to use information we have already started to use in our research, as needed to maintain the integrity of the research.

This authorization does not have an expiration date.
Parental Permission-
I confirm that I have read this parental permission document have had the opportunity to ask questions. I understand that my participation is voluntary and that I am free to withdraw at any time, without giving any reason, without my medical care or legal rights being affected. I will be given a signed copy of the parental permission form to keep.

I agree to allow my child to participate in this research study and authorize you to use and disclose health information about my child for this study, as you have explained in this document.

________________________
Child’s Name

________________________
1st Parent/Guardian’s Name

________________________
1st Parent/Guardian’s Signature Date

Relationship to Child for 1st Parent/Guardian

________________________
2nd Parent/Guardian’s Name

________________________
2nd Parent/Guardian’s Signature Date

Relationship to Child for 2nd Parent/Guardian

Permission cannot be obtained from the second parent/guardian because (please check which one applies to the situation, 45 CFR 46.408):

☐ The parent/guardian is deceased.
☐ The parent/guardian is unknown.
☐ The parent/guardian is incompetent.
☐ The parent/guardian is not reasonably available.
☐ Only one parent has legal responsibility for the care and custody of the child.

________________________
Name of Person Obtaining Authorization and Consent

________________________
Signature of Person Obtaining Authorization and Consent Date
APPENDIX C

BODYBUILDER PROGRAM FOR FOOT KINEMATICS
{*Prabhav's Foot Model*}

{*VICON BodyLanguage*}

{*The model uses a total of 28 markers:*

Prefix for Left/Right Foot L/R
Lateral and Medial Epicondyles of the Knee KNE
Tibial Wand Marker TIB
Lateral Malleoli ANK
Medial Malleoli MML
Lateral and Medial Calcaneus L/MCAL
Posterior Calcaneus HEE
Base and Head of 1st metatarsal MT1B,MT1H
Head of 5th metatarsals MT5H
Hallux TOE1,TOE2,TOE3

Virtual Markers
Prefix for Left/Right Foot L/R
Proximal Mid pt of Metatarsal MT23B
Distal Mid pt of Metatarsal MT23H
Navicular marker MT1BM
Medial point of 1st metatarsal MT1HM
Calcaneal Tubercle CALTB

1) collect static and motion trials, using above markers
2) set $static = 1 in FOOT_P.MP and process static trial
4) set $static = 0 in FOOT_P.MP and process motion trial
5) write output angles L/R(TIBA,ANKA,MDFA,HLXA) to C3D or ASCII file*}

{*Start of macro section*}

{*======================*}

macro REPLACE4(p1,p2,p3,p4)
{"*Replaces any point missing from set of four fixed in a segment*}

s234 = [p3,p2-p3,p3-p4]
p1V = Average(p1/s234)*s234

s341 = [p4,p3-p4,p4-p1]
p2V = Average(p2/s341)*s341

s412 = [p1,p4-p1,p1-p2]
p3V = Average(p3/s412)*s412
s123 = [p2, p1-p2, p2-p3]
p4V = Average(p4/s123)*s123

p1 = (p1+p1V)/2 ? p1 ? p1V
p2 = (p2+p2V)/2 ? p2 ? p2V
p3 = (p3+p3V)/2 ? p3 ? p3V
p4 = (p4+p4V)/2 ? p4 ? p4V
endmacro

{******************************************}
{***  CREATETRIAD  ***}
{******************************************}
macro CREATETRIAD(SEG)
{* Creates triad points *}
$triadscale = 50
If Exist( SEG )
o_#SEG = o(SEG)
x_#SEG = {$triadscale*(3),0,0}*SEG
y_#SEG = {0,$triadscale*(3),0}*SEG
z_#SEG = {0,0,$triadscale*(3)}*SEG
Output(o_#SEG,x_#SEG,y_#SEG,z_#SEG)
endif
endmacro
{* End of macro section *}

{* Points which may not be present in every trial *}
OptionalPoints(LKNE,RKNE,LTIB,RTIB,LMML,RMML,LANK,RANK,LLCAL,RLCAL,LMCAL,RCALAL,LHEE,RHEE,LMT1B,RMT1B,LMT1H,RMT1H,LMT5H,RMT5H,LTOE1,RTOE1,LTOE2,RTOE2,LTOE3,RTOE3)
OptionalPoints(LMT23B,RMT23B,LMT23H,RMT23H,LMT1HM,RMT1HM,LMT1BM,RMT1BM,LCALTB,RCALTB)
OptionalPoints(LFEO,RFEO,LTIO,RTIO)

{* Check to see if PiG has been run. *}
If ExistAtAll(LFEO,RFEO,LTIO,RTIO) Then
    PiG = 1
Else
    PiG = 0
EndIf

Base= [{0,0,0},{1,0,0},{0,0,1},xyz]
LDummyTibia = \[LTIB,LTIBU-LTIBL,(LTIBU+LTIBL)/2-LTIB\]

If $Static == 1$

{Find mid-points of knee and ankle*}

If PiG == 1 Then
LKC = LFEO
LAJC = LTIO
EndIf

$L%LANK = LANK/LDummyTibia$
$L%LMML = LMML/LDummyTibia$

$L%LTibiaScale = DIST(LKJC,LAJC)$
PARAM($LTibiaScale,$%LMML,$%LANK$)
EndIf

If $Static == 0$
LKJC = LFEO
LAJC = LTIO
LMML = $%LMML*LDummyTibia$
LANK = $%LANK*LDummyTibia$
EndIf

LTibia = \[LTIO,LTIO-LFEO,LANK-LMML,zyx\]
LTIBG= <LTibia,Base>
OUTPUT(LMML)

LCCAL=((LLCAL+LMCAL)/2)
LDummyHindFoot = \[LHEE,LLCAL-LHEE,LCCAL-LHEE\]
If $Static == 1$

$LHindFoot_temp1=[LHEE,3(Base),LHEE-LCCAL,zyx]$

$LHindFoot_temp2=ROT(LHindFoot_temp1,1(LHindFoot_temp1),\frac{LVarValAngle*180}{3.14})$

$LHindFoot_temp3=[LHEE,3(base),1(Base),zyx]$

$LHEEb={LHEE(1),LHEE(2),0}$

$LHindFoot_temp4=[LHEE,LCALTB-LHEEb,3(Base),xyz]$

$LHFA=<LHindFoot_temp4,LHindFoot_temp3,xyz>=$

$LHindFoot_temp5=ROT(LHindFoot_temp1,2(LHindFoot_temp1),-LHFA(2))$

$LHindFoot_temp6=ROT(LHindFoot_temp6,3(LHindFoot_temp6),-LHFA(2))$

$LCAL1={0,0,\text{Triadscale}(20)}*LHindFoot_temp2$

$LCAL2={0,0,0}*LHindFoot_temp2$

$LCAL1=LCAL1/ LDummyHindFoot$

$LCAL2=LCAL2/ LDummyHindFoot$

$LCALTB=LCALTB/ LDummyHindFoot$

$\text{PARAM}($%LCAL1,$%LCAL2,$%LCALTB)$

EndIf

If $Static == 0$

$LHindFoot = [LHEE,LHEE-LCAL2,LCAL1-LHEE,xyz]$

CreateTriad(LHindFoot)

OUTPUT(LCAL1,LCAL2,LCALTB)

/* Midfoot */

/* ======= */

/* This segment has 3 real (P/D1MT,D5MT) markers*/

$LDummyMidfoot = [LMT1B,LMT1H-LMT1B,LMT1H-LMT5H]$

If $Static == 1$

$LDummySegment4 = [LMT23B,LMT23H-LMT23B,3(base),xyz]$

$LDummySegment5 = [LMT23B,3(Base),2(LDummySegment4),xyz]$

$LD23MT1 = \{0,\text{Triadscale}(20),0\}*LDummySegment5$

$LDummySegment6 = [LMT23B,3(Base),1(Base),xyz]$

$LP23MTz = \{0,0,\text{Triadscale}(20)\}*LDummySegment6$

$LMidfoot1 = [LMT23B,LD23MT1-LMT23B,3(Base),xyz]$

$LMidfoot2 = [LMT23B,LMT1HM-LMT1BM,1(LMidfoot1),xyz]$
$\text{LMidfoot3} = [\text{LMT23B},1(\text{LMidfoot1}),2(\text{LMidfoot2}),\text{xyz}]$

$\text{LP23MTy} = \{0,0,0\} \times \text{LMidfoot3}$

$\%\text{LMT23B} = \text{LMT23B} / \text{LDummyMidfoot}$

$\%\text{LMT23H} = \text{LMT23H} / \text{LDummyMidfoot}$

$\%\text{LP23MTz} = \text{LP23MTz} / \text{LDummyMidfoot}$

$\%\text{LP23MTy} = \text{LP23MTy} / \text{LDummyMidfoot}$

$\%\text{LMT1BM} = \text{LMT1BM} / \text{LDummyMidfoot}$

$\%\text{LMT1HM} = \text{LMT1HM} / \text{LDummyMidfoot}$

$\text{PARAM}(\%\text{LMT23B},\%\text{LMT23H},\%\text{LP23MTz},\%\text{LP23MTy},\%\text{LMT1BM},\%\text{LMT1HM})$

EndIf

If $\text{Static} == 0$

$\text{LMT23B} = \%\text{LMT23B} \times \text{LDummyMidfoot}$

$\text{LMT23H} = \%\text{LMT23H} \times \text{LDummyMidfoot}$

$\%\text{LP23MTz} = \%\text{LP23MTz} \times \text{LDummyMidfoot}$

$\%\text{LP23MTy} = \%\text{LP23MTy} \times \text{LDummyMidfoot}$

$\%\text{LMT1BM} = \%\text{LMT1BM} \times \text{LDummyMidfoot}$

$\%\text{LMT1HM} = \%\text{LMT1HM} \times \text{LDummyMidfoot}$

EndIf

$\text{LMidfoot} = [\text{LMT23b}, \text{LMT23B} - \text{LP23MTy}, \text{LP23MTz} - \text{LMT23B}, \text{xyz}]$

CreateTriad($\text{LMidfoot}$)

OUTPUT($\text{LP23MTy}, \text{LP23MTz}$)

{*
Hallux*
}

{*
======*
}

{*
This segment has 3 real marker*
}

{*
Define Hallux segment with lateral (y) axis aligned with Midfoot y-axis*
}

$L\text{Hallux} = [\text{LTOE1}, \text{LTOE1} - \text{LTOE2}, \text{LTOE1} - \text{LTOE3}, \text{xyz}]$

CreateTriad($L\text{Hallux}$)

{*
Archheight Calculations*
}

{*

If $\text{Static} == 1$

$L\text{HeelBase} = \{\text{LMCAL(1)}, \text{LMCAL(2)}, 0\}$

$L\text{MMT1Base} = \{\text{LMMT1(1)}, \text{LMMT1(2)}, 0\}$

$\%\text{LHeelBase} = L\text{HeelBase} / \text{LDummyHindFoot}$

$\%\text{LMMT1Base} = L\text{MMT1Base} / \text{LDummyMidfoot}$

$\text{PARAM}(\%\text{LHeelBase}, \%\text{LMMT1Base})$

EndIf


If $Static == 0$
    LHeelBase = $\%LHeelBase*LDummyHindFoot$
    LMMT1Base = $\%LMMT1Base*LDummyMidfoot$
EndIf
LMid=PERP(LMT1BM,LMMT1Base,LHeelBase)
LArchHt = DIST(LMT1BM,LMid)

{* Angle Outputs *}
{* ============= *}

{*Calculate joint angles, using Grood&Suntay sequence - flexion, abduction, rotation*}
{*LArchHeight = DIST(LMT23D,LMT23Dp)*}

LTIBA = <LTibia,1,xyz>
LANKA = <LHindFoot,LTibia,xyz>
LMDFA = <LMidfoot,LHindFoot,xyz>
LHLXA = <LHallux,LMidfoot,xyz>

LANKG = <LHF,1,xyz>
LMDFG = <LMF,1,xyz>
LHLXG = <LTS,1,xyz>

{*Output angles for plotting and saving*}
OUTPUT(LMT23B,LMT23H,LMT1BM,LMT1HM,LCALTB)
OUTPUT(LTIBA,LANKA,LMDFA,LHLXA,LANKG,LMDFG,LHLXG)

{*******
{****
{** Right Foot *

Base= [{0,0,0},{1,0,0},{0,0,1},xyz]

{* Tibia segment *}

{*Create a Dummy tibia segment using most visible tibia markers, present in all trials*}

RDummyTibia = [RTIB,RTIBU-RTIBL,(RTIBU+RTIBL)/2-RTIB]

If $Static == 1$
    {*Find mid-points of knee and ankle*}
If PiG == 1 Then
    RKJC = RFEO
    RAJC = RTIO

EndIf

$%RANK = RANK/RDummyTibia
$%RMML = RMML/RDummyTibia

$RTibiaScale = DIST(RKJC,RAJC)
PARAM($RTibiaScale,$%RMML,$%RANK)

EndIf

If $Static == 0
    RKJC = RFEO
    RAJC = RTIO
    RMML = $%RMML * RDummyTibia
    RANK = $%RANK * RDummyTibia
EndIf

RTibia = [RTIO,RFEO-RTIO,RMML-RANK,zyx]

CreateTriad(RTibia)
OUTPUT(RMML)

{* HindFoot *}
{* ========= *}
{* This segment has 3 real (L/MCAL,PCAL) markers*}

{*Create a Dummy HindFoot segment using most visible calcaneus markers, present in all trials*}

RCCAL=((RLCAL+RMCAL)/2)
RDummyHindFoot = [RHEE,RLCAL-RHEE,RCCAL-RHEE]

If $Static == 1
    Vec=LHEE-LLCAL
    VecB={Vec(1),Vec(2),0}
    RHindFoot_temp1=[RHEE,3(Base),RHEE-RCCAL,zyx]
    RHindFoot_temp2=ROT(RHindFoot_temp1,1(RHindFoot_temp1),-$RVarValAngle*180/3.14)
    RCAL1={0,0,$Triadscale*(20)}*RHindFoot_temp2
    RHindFoot_temp3=[RHEE,3(Base),1(Base),zyx]
RHEEb={RHEE(1),RHEE(2),0}
RHindFoot_temp4=[RHEE,RCALTB-RHEEb,3(Base),xyz]
RHFA=<RHindFoot_temp4,RHindFoot_temp3,zyx>
RHindFoot_temp5=ROT(RHindFoot_temp1,2(RHindFoot_temp1),-RHFA(2))
RCAL2={$Triadscale*(20),0,0}*RHindFoot_temp5
$%RCAL1=RCAL1/ RDummyHindFoot
$%RCAL2=RCAL2/ RDummyHindFoot
$%RCALTB=RCALTB/ RDummyHindFoot
PARAM($%RCAL1,$%RCAL2,$%RCALTB,RHFA)
EndIf

If $Static == 0
   RCAL2 = $%RCAL2* RDummyHindFoot
   RCAL1 = $%RCAL1* RDummyHindFoot
   RCALTB = $%RCALTB* RDummyHindFoot
EndIf

RHindFoot = [RHEE,RCAL2-RHEE,RHEE-RCAL1,xyz]
CreateTriad(RHindFoot)
OUTPUT(RCAL1,RCAL2,RCALTB)

{" Midfoot *}
{" ======= *
{" This segment has 3 real (P/D1MT,D5MT) markers*

RDummyMidfoot = [RMT1B,RMT1H-RMT1B,RMT1H-RMT5H]

If $Static == 1
   RDummySegment4 = [RMT23B,RMT23H-RMT23B,3(base),xyz]
   RDummySegment5 = [RMT23B,3(Base),2(RDummySegment4),xyz]
   RD23MT1 = {0,$Triadscale*(20),0}*RDummySegment5
   RDummySegment6 = [RMT23B,3(Base),1(Base),zyx]
   RP23MTz = {0,0,$Triadscale*(20)}*RDummySegment6
   RMidfoot1 = [RMT23B,RD23MT1-RMT23B,3(Base),xyz]
   RMidfoot2 = [RMT23B,RMT1HM-RMT1BM,1(RMidfoot1),xyz]
   RMidfoot3 = [RMT23B,1(RMidfoot1),2(RMidfoot2),xyz]
   RP23MTy = {0,$Triadscale*(20),0}*RMidfoot3
   $%RMT23B = RMT23B / RDummyMidfoot
   $%RMT23H = RMT23H / RDummyMidfoot
   $%RP23MTz = RP23MTz / RDummyMidfoot
   $%RP23MTy = RP23MTy / RDummyMidfoot
   $%RMT1BM=RMT1BM/RDummyMidfoot
   $%RMT1HM=RMT1HM/RDummyMidfoot
PARAM($%RMT23B,$%RMT23H,$%RP23MTz,$%RP23MTy,$%RMT1BM,$%RMT1HM)
EndIf

If $Static == 0
RMT23B = $%RMT23B*RDummyMidfoot
RMT23H = $%RMT23H*RDummyMidfoot
RP23MTz = $%RP23MTz*RDummyMidfoot
RP23MTy = $%RP23MTy*RDummyMidfoot
RMT1BM = $%RMT1BM*RDummyMidfoot
RMT1HM = $%RMT1HM*RDummyMidfoot
EndIf

RMidfoot = [RMT23B,RP23MTy-RMT23B,RMT23B-RP23MTz,yxz]
CreateTriad(RMidfoot)
OUTPUT(RP23MTy,RP23MTz)

{* Hallux *}
{* ========= *}
{* This segment has 3 real marker*}

{*Define Hallux segment with lateral (y) axis aligned with Midfoot y-axis*}
RHallux=[RTOE1,RTOE2-RTOE1,RTOE3-RTOE1,yzx]
CreateTriad(RHallux)

{* Angle Outputs *}
{* ============= *}

{* Archheight Calculations *}
{* }
If $Static == 1
RHeelBase={RMCAL(1),RMCAL(2),0}
RMMT1Base ={RMMT1(1),RMMT1(2),0}
$%RHeelBase = RHeelBase/RDummyHindFoot
$%RMMT1Base = RMMT1Base/RDummyMidfoot
PARAM($%RHeelBase,$%RMMT1Base)
EndIf
If $Static == 0
RHeelBase = $%RHeelBase*RDummyHindFoot
RMMT1Base = $%RMMT1Base*RDummyMidfoot
EndIf
RMid=PERP(RMT1BM,RMMT1Base,RHeelBase)
RArchHt = DIST(RMT1BM,RMid)
*}
RTIBA = <RTibia,1,xyz>
RANKA = <RHindFoot,RTibia,xyz>
RMDFA = <RMidfoot,RHindFoot,xyz>
RHLXA = <RHallux,RMidfoot,xyz>

RANKG = <RHF,1,xyz>
RMDFG = <RMF,1,xyz>
RHLXG = <RTS,1,xyz>

{*Output angles for plotting and saving*}
OUTPUT(RMT23B,RMT23H,RMT1BM,RMT1HM,RCALTB)
OUTPUT(RTIBA,RANKA,RMDFA,RHLXA,RANKG,RMDFG,RHLXG)

{* RRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRR *}
APPENDIX D

MATLAB PROGRAM FOR FOOT KINETICS
%% Computes Joint Moments for 3-segment Foot Model %%

clear all;
test=c3dservers;
fname=open3d(test);

freqoff=0;
SubjectNo=1;

if SubjectNo==1
    mip.BodyMass=56;
    mip.Height=1.542;
end

if SubjectNo==2
    mip.BodyMass=38;
    mip.Height=1.392;
end

if SubjectNo==3
    mip.BodyMass=47;
    mip.Height=1.596;
end

if SubjectNo==4
    mip.BodyMass=39;
    mip.Height=1.350;
end

if SubjectNo==5
    mip.BodyMass=38;
    mip.Height=1.535;
end

if SubjectNo==6
    mip.BodyMass=32;
    mip.Height=1.347;
end

if SubjectNo==7
    mip.BodyMass=33;
    mip.Height=1.430;
end

if SubjectNo==8
    mip.BodyMass=26;
mip.Height=1.305;
end

if SubjectNo==9
    mip.BodyMass=32;
    mip.Height=1.420;
end

if SubjectNo==10
    mip.BodyMass=39;
    mip.Height=1.615;
end

FFrame=test.GetVideoFrame(0);
LFrame=test.GetVideoFrame(1);
AnalogData=getanalogchannels(test,FFrame,LFrame);
MarkerData=get3dtargets(test,0,FFrame,LFrame);

area=5.08*7.62*.1*.1;
disp('Load Excel Data for Foot Pressure..');
[Ft,FtotalHF,FtotalMF,FtotalTS,COPxT,COPYT,COPx,COPY,COPxHF,COPYHF,COPxF,
MF,COPYMF,COPxTS,COPYTS,Foot]=pressure(area,freqoff);

%% COP from Force Plate Data
for i=1:1:size(AnalogData.Mx1,1)/10
    if AnalogData.Mx1(10*i)==0
        %if abs(double(AnalogData.Mx1(10*i)))<100000
        c3dCOPx(i,1)=0;
        c3dCOPy(i,1)=0;
    else
        c3dCOPx(i,1)=double(AnalogData.Mx1(10*i))/double(AnalogData.Fz1(10*i));
        c3dCOPy(i,1)=-double(AnalogData.My1(10*i))/double(AnalogData.Fz1(10*i));
    end
end

%% Transformation to Global Coordinates-
for i=1:1:size(AnalogData.Mx1,1)/10
    if c3dCOPx(i,1)==0
        tempc3dCOPxG(i,1)=0;
        tempc3dCOPyG(i,1)=0;
    else
        tempc3dCOPxG(i,1)=991.5-c3dCOPx(i);
        tempc3dCOPyG(i,1)=1039-c3dCOPy(i);
count1=0;
HSscan=0;
for i=1:1:size(COPx,2)-1
    if COPx(i)==0
        if COPx(i+1)~=0
            count1=count1+1;
            HSscan(count1)=i+1;
        end
    end
end

count2=0;
HSc3d=0;
a=tempc3dCOPxG;
for i=1:1:size(a,1)-1
    if a(i)==0
        if a(i+1)==0
            count2=count2+1;
            HSc3d(count2)=FFrame+i+1;
        end
    end
end

if count2>1
    delay1=(HSc3d(1)-HSscan(1));
    delay2=(HSc3d(2)-HSscan(1));
    if abs(delay1)<abs(delay2)
        delay=delay1;
    else
        delay=delay2;
    end
else
    delay =HSc3d(1)-HSscan(1);
end

Ft=zeros(LFrame,1);

FtotalHF=zeros(LFrame,1);
FtotalMF=zeros(LFrame,1);
FtotalTS=zeros(LFrame,1);

for i=1:size(tempFt)
    Ft(delay+i)=tempFt(i);
    FtotalHF(delay+i)=tempFtotalHF(i);
    FtotalMF(delay+i)=tempFtotalMF(i);
    FtotalTS(delay+i)=tempFtotalTS(i);
end

COPxG=zeros(LFrame,1);
COPyG=zeros(LFrame,1);
COPxHFG=zeros(LFrame,1);
COPyHFG=zeros(LFrame,1);
COPxMFG=zeros(LFrame,1);
COPyMFG=zeros(LFrame,1);
COPxTSG=zeros(LFrame,1);
COPyTSG=zeros(LFrame,1);

for i=1:size(COPx,2)
    if COPx(i)==0
        COPxG(delay+i)=0;
        COPyG(delay+i)=0;
    else
        COPxG(delay+i)=-7.702*COPx(i)+1974.4;
        COPyG(delay+i)=5*COPy(i)+883.55;
    end
end

for i=1:size(COPx,2)
    if COPxFH(i)==0
        COPxFHGF(delay+i)=0;
        COPyFHGF(delay+i)=0;
    else
        %COPxFHGF(delay+i)=-7.554*COPxFH(i)+1970.3;
        %COPyFHGF(delay+i)=5*COPyFHF(i)+882.67;
        COPxFHGF(delay+i)=-7.702*COPxFH(i)+1974.4;
        COPyFHGF(delay+i)=5*COPyFHF(i)+883.55;
    end
end
for i=1:size(COPx,2)
    if COPxMF(i)==0
        COPxMFG(delay+i)=0;
        COPyMFG(delay+i)=0;
    else
        COPxMFG(delay+i)=-7.702*COPxMF(i)+1974.4;
        COPyMFG(delay+i)=5*COPyMF(i)+882.67;
    end
end

for i=1:size(COPx,2)
    if COPxTS(i)==0
        COPxTSG(delay+i)=0;
        COPyTSG(delay+i)=0;
    else
        COPxTSG(delay+i)=-7.702*COPxTS(i)+1974.4;
        COPyTSG(delay+i)=5*COPyTS(i)+883.55;
    end
end

mip=averagemale(mip,mip.BodyMass,mip.Height);

MassTibia=mip.tibia.mass;
MassHF=mip.hindfoot.mass;
MassMF=mip.midfoot.mass;
MassTS=mip.toes.mass;

sagTibia=MassTibia*mip.tibia.sag^2;
lonTibia=MassTibia*mip.tibia.lon^2;
traTibia=MassTibia*mip.tibia.tra^2;

sagHF=MassHF*mip.hindfoot.sag^2;
lonHF=MassHF*mip.hindfoot.lon^2;
traHF=MassHF*mip.hindfoot.tra^2;

sagMF=MassMF*mip.midfoot.sag^2;
lonMF=MassMF*mip.midfoot.lon^2;
traMF=MassMF*mip.midfoot.tra^2;

sagTS=MassTS*mip.toes.sag^2;
lonTS=MassTS*mip.toes.lon^2;
traTS=MassTS*mip.toes.tra^2;

Itibia=[sagTibia 0 0 traTibia 0 0 lonTibia];
IHF=[sagHF 0 0 traHF 0 0 lonHF];
IMF=[sagMF 0 0; traMF 0 0 lonMF];
ITS=[sagTS 0 0; traTS 0 0 lonTS];

if Foot=='L'
    TIBA=double(MarkerData.LTIBA);
    ANKG=double(MarkerData.LANKG);
    MDFG=double(MarkerData.LMDFG);
    HLXG=double(MarkerData.LHLXG);
else
    TIBA=double(MarkerData.RTIBA);
    ANKG=double(MarkerData.RANKG);
    MDFG=double(MarkerData.RMDFG);
    HLXG=double(MarkerData.RHLXG);
end

for i=1:1:size(TIBA,1)
    for j=1:1:size(TIBA,2)
        if isnan(TIBA(i,j))==1
            TIBA(i,j)=0;
        end
        if isnan(ANKG(i,j))==1
            ANKG(i,j)=0;
        end
        if isnan(MDFG(i,j))==1
            MDFG(i,j)=0;
        end
        if isnan(HLXG(i,j))==1
            HLXG(i,j)=0;
        end
    end
end

for i=1:1:3
    x=1:1:size(TIBA,1);
    [Tibia,s]=fit(x',TIBA(:,i),'smoothingspline');
    vTibia=differentiate(Tibia,x');
    [VelTibia,s]=fit(x',vTibia,'smoothingspline');
    aTibia=differentiate(VelTibia,x');
    alphaTibia(:,i)=aTibia;
    veloTibia(:,i)=vTibia;

    x=1:1:size(ANKG,1);
    [Ank,s]=fit(x',ANKG(:,i),'smoothingspline');
    vAnk=differentiate(Ank,x');
[VelAnk,s]=fit(x',vAnk,'smoothingspline');
aAnk=differentiate(VelAnk,x');
alphaHF(:,i)=aAnk;
veloHF(:,i)=vAnk;

x=1:1:size(MDFG,1);
[MF,s]=fit(x',MDFG(:,i),'smoothingspline');
vMF=differentiate(MF,x');
[VelMF,s]=fit(x',vMF,'smoothingspline');
aMF=differentiate(VelMF,x');
alphaMF(:,i)=aMF;
veloMF(:,i)=vMF;

x=1:1:size(HLXG,1);
[Toes,s]=fit(x',HLXG(:,i),'smoothingspline');
vToes=differentiate(Toes,x');
[VelToes,s]=fit(x',vToes,'smoothingspline');
aToes=differentiate(VelToes,x');
alphaTS(:,i)=aToes;
veloTS(:,i)=vToes;

end

for i=FFrame:1:LFrame
    if Ft(i)==0
        HFRatio(i)=0;
        MFRatio(i)=0;
        TSRatio(i)=0;
    else
        HFRatio(i)=FtotalHF(i)/Ft(i);
        MFRatio(i)=FtotalMF(i)/Ft(i);
        TSRatio(i)=FtotalTS(i)/Ft(i);
    end
end

COPHF=[COPxHFG,COPYHFG,zeros(size(COPxHFG))];
COPMF=[COPxMFG,COPYMFG,zeros(size(COPxMFG))];
COPTS=[COPxTSG,COPYTSG,zeros(size(COPxTSG))];

writeflag=0;
for i=FFrame:1:LFrame

if Foot=='L'
    TOE1=double(MarkerData.LTOE1(i-FFrame+1,:));
    TOE2=double(MarkerData.LTOE2(i-FFrame+1,:));
    TOE3=double(MarkerData.LTOE3(i-FFrame+1,:));
else
    TOE1=double(MarkerData.RTOE1(i-FFrame+1,:));
    TOE2=double(MarkerData.RTOE2(i-FFrame+1,:));
    TOE3=double(MarkerData.RTOE3(i-FFrame+1,:));
end

if Foot=='L'
    MT23B=double(MarkerData.LMT23B(i-FFrame+1,:));
    MT23H=double(MarkerData.LMT23H(i-FFrame+1,:));
    MT1BM=double(MarkerData.LMT1BM(i-FFrame+1,:));
    MT1HM=double(MarkerData.LMT1HM(i-FFrame+1,:));
    P23MTy=double(MarkerData.LP23MTy(i-FFrame+1,:));
    P23MTz=double(MarkerData.LP23MTz(i-FFrame+1,:));
else
    MT23B=double(MarkerData.RMT23B(i-FFrame+1,:));
    MT23H=double(MarkerData.RMT23H(i-FFrame+1,:));
    MT1BM=double(MarkerData.RMT1BM(i-FFrame+1,:));
    MT1HM=double(MarkerData.RMT1HM(i-FFrame+1,:));
    P23MTy=double(MarkerData.RP23MTy(i-FFrame+1,:));
    P23MTz=double(MarkerData.RP23MTz(i-FFrame+1,:));
end

if Foot=='L'
    LCAL=double(MarkerData.LLCAL(i-FFrame+1,:));
    MCAL=double(MarkerData.LMCAL(i-FFrame+1,:));
    HEE=double(MarkerData.LHEE(i-FFrame+1,:));
    CCAL=(LCAL+MCAL)/2;
    ANK=double(MarkerData.LANK(i-FFrame+1,:));
    MML=double(MarkerData.LMML(i-FFrame+1,:));
    CAL1=double(MarkerData.LCAL1(i-FFrame+1,:));
    CAL2=double(MarkerData.LCAL2(i-FFrame+1,:));
    AJC=double(MarkerData.LTIO(i-FFrame+1,:));
else
    LCAL=double(MarkerData.RLCAL(i-FFrame+1,:));
    MCAL=double(MarkerData.RMCAL(i-FFrame+1,:));
end
HEE=double(MarkerData.RHEE(i-FFrame+1,:));
CCAL=(LCAL+MCAL)/2;
ANK=double(MarkerData.RANK(i-FFrame+1,:));
MML=double(MarkerData.RMML(i-FFrame+1,:));
CAL1=double(MarkerData.RCAL1(i-FFrame+1,:));
CAL2=double(MarkerData.RCAL2(i-FFrame+1,:));
AJC=double(MarkerData.RTIO(i-FFrame+1,:));
end

if Foot=='L'
    COMTS=TOE1';
    COMMF=(MT23B'+MT23H')/2;
    COMHF=(LCAL'+MCAL')/2;
else
    COMTS=TOE1';
    COMMF=(MT23B'+MT23H')/2;
    COMHF=(LCAL'+MCAL')/2;
end

HFJC=AJC;

D1=sqrt((MT1HM(1,1)-MT1BM(1,1))^2+(MT1HM(1,2)-MT1BM(1,2))^2+(MT1HM(1,3)-MT1BM(1,3))^2);
D23=sqrt(((MT23H(1,1)-MT23B(1,1))^2+(MT23H(1,2)-MT23B(1,2))^2+(MT23H(1,3)-MT23B(1,3))^2);
Unitvector(1,1)=(MT23H(1,1)-MT23B(1,1))/D23;
Unitvector(1,2)=(MT23H(1,2)-MT23B(1,2))/D23;
Unitvector(1,3)=(MT23H(1,3)-MT23B(1,3))/D23;
MFJC(1,1)=MT23H(1,1)-D1*Unitvector(1,1);
MFJC(1,2)=MT23H(1,2)-D1*Unitvector(1,2);
MFJC(1,3)=MT23H(1,3)-D1*Unitvector(1,3);

TJC=2*TOE1-TOE2;

COMTSvec(i,:)=COMTS';
COMMFvec(i,:)=COMMF';
COMHFvec(i,:)=COMHF';

HFJvec(i,:)=HFJC;
MFJvec(i,:)=MFJC;
TJvec(i,:)=TJC;
end

for i=1:1:size(HFJC,1)
for j=1:size(HFJC,2)
    if isnan(HFJC(i,j))==1
        HFJC(i,j)=0;
    end
    if isnan(MFJC(i,j))==1
        MFJC(i,j)=0;
    end
end

for i=1:size(COMHFvec,1)
    for j=1:size(COMHFvec,2)
        if isnan(COMHFvec(i,j))==1
            COMHFvec(i,j)=0;
        end
        if isnan(COMMFvec(i,j))==1
            COMMFvec(i,j)=0;
        end
        if isnan(COMTSvec(i,j))==1
            COMTSvec(i,j)=0;
        end
    end
end

for i=1:3
    x=FFrame:1:size(COMHFvec,1);
    [HF,s]=fit(x',COMHFvec(FFrame:size(COMHFvec,1),i),'smoothingspline');
    vHF=differentiate(HF,x');
    [VelHF,s]=fit(x',vHF,'smoothingspline');
    aHF=differentiate(VelHF,x');
    accHF(:,i)=aHF;
end

for i=1:3
    x=FFrame:1:size(COMMFvec,1);
    [MF,s]=fit(x',COMMFvec(FFrame:size(COMMFvec,1),i),'smoothingspline');
    vMF=differentiate(MF,x');
    [VelMF,s]=fit(x',vMF,'smoothingspline');
    aMF=differentiate(VelMF,x');
    accMF(:,i)=aMF;
end

for i=1:3
    x=FFrame:1:size(COMTSvec,1);
    [TS,s]=fit(x',COMTSvec(FFrame:size(COMTSvec,1),i),'smoothingspline');
    vTS=differentiate(TS,x');
end
[VelTS,s]=fit(x',vTS,'smoothingspline');
aTS=differentiate(VelTS,x');
accTS(:,i)=aTS;
end

for i=FFrame:1:LFrame
    z0=-68.23;
    warning off MATLAB:divideByZero
    My=double(AnalogData.My1((i-FFrame+1)*10))+double(AnalogData.Fx1((i-
FFrame+1)*10))*z0;
    x=-My/double(AnalogData.Fz1((i-FFrame+1)*10));
    warning off MATLAB:divideByZero
    Mx=double(AnalogData.Mx1((i-FFrame+1)*10))-double(AnalogData.Fy1((i-
FFrame+1)*10))*z0;
    y=Mx/double(AnalogData.Fz1((i-FFrame+1)*10));
    Tz=double(AnalogData.Mz1((i-FFrame+1)*10))+double(AnalogData.Fx1((i-
FFrame+1)*10))*y-double(AnalogData.Fy1((i-FFrame+1)*10))*x;

    if isnan(Tz)==1
        Tz=0;
    end

    FHF(1,i)=double(AnalogData.Fy1((i-FFrame+1)*10))*HFRatio(i);
    FHF(2,i)=double(AnalogData.Fx1((i-FFrame+1)*10))*HFRatio(i);
    FHF(3,i)=double(AnalogData.Fz1((i-FFrame+1)*10))*HFRatio(i);
    MHF(1,i)=0;
    MHF(2,i)=0;
    MHF(3,i)=Tz*HFRatio(i);

    FMF(1,i)=double(AnalogData.Fy1((i-FFrame+1)*10))*MFRatio(i);
    FMF(2,i)=double(AnalogData.Fx1((i-FFrame+1)*10))*MFRatio(i);
    FMF(3,i)=double(AnalogData.Fz1((i-FFrame+1)*10))*MFRatio(i);
    MMF(1,i)=0;
    MMF(2,i)=0;
    MMF(3,i)=Tz*MFRatio(i);

    FTS(1,i)=double(AnalogData.Fy1((i-FFrame+1)*10))*TSRatio(i);
    FTS(2,i)=double(AnalogData.Fx1((i-FFrame+1)*10))*TSRatio(i);
    FTS(3,i)=double(AnalogData.Fz1((i-FFrame+1)*10))*TSRatio(i);
    MTS(1,i)=0;
    MTS(2,i)=0;
    MTS(3,i)=Tz*TSRatio(i);

    if Foot=='L'
TOE1 = double(MarkerData.LTOE1(i-FFrame+1,:));
TOE2 = double(MarkerData.LTOE2(i-FFrame+1,:));
TOE3 = double(MarkerData.LTOE3(i-FFrame+1,:));

X1 = TOE1 - TOE3;
Y1 = TOE1 - TOE2;
tempX1 = vecnorm(X1);
NormY1 = vecnorm(Y1);
Z1 = cross(tempX1, NormY1);
NormZ1 = vecnorm(Z1);
NormX1 = cross(NormY1, NormZ1);
G_R_Toe = [NormX1; NormY1; NormZ1];

MT23B = double(MarkerData.LMT23B(i-FFrame+1,:));
P23MTy = double(MarkerData.LP23MTy(i-FFrame+1,:));
P23MTz = double(MarkerData.LP23MTz(i-FFrame+1,:));

Y2 = MT23B - P23MTy;
Z2 = P23MTz - MT23B;
NormY2 = vecnorm(Y2);
tempZ2 = vecnorm(Z2);
X2 = cross(NormY2, tempZ2);
NormX2 = vecnorm(X2);
NormZ2 = cross(NormX2, NormY2);
G_R_MF = [NormX2; NormY2; NormZ2];

CAL1 = double(MarkerData.LCAL1(i-FFrame+1,:));
CAL2 = double(MarkerData.LCAL2(i-FFrame+1,:));
HEE = double(MarkerData.LHEE(i-FFrame+1,:));

Y3 = HEE - CAL2;
Z3 = CAL1 - HEE;
NormY3 = vecnorm(Y3);
tempZ3 = vecnorm(Z3);
X3 = cross(NormY3, tempZ3);
NormX3 = vecnorm(X3);
NormZ3 = cross(NormX3, NormY3);
G_R_HF = [NormX3; NormY3; NormZ3];

else
  TOE1 = double(MarkerData.RTOE1(i-FFrame+1,:));
  TOE2 = double(MarkerData.RTOE2(i-FFrame+1,:));
  TOE3 = double(MarkerData.RTOE3(i-FFrame+1,:));
X1 = TOE3-TOE1;
Y1 = TOE2-TOE1;
tempX1 = vecnorm(X1);
NormY1 = vecnorm(Y1);
Z1 = cross(tempX1, NormY1);
NormZ1 = vecnorm(Z1);
NormX1 = cross(NormY1, NormZ1);
G_R_Toe = [NormX1; NormY1; NormZ1];

MT23B = double(MarkerData.RMT23B(i-FFrame+1,:));
P23MTy = double(MarkerData.RP23MTy(i-FFrame+1,:));
P23MTz = double(MarkerData.RP23MTz(i-FFrame+1,:));

Y2 = P23MTy - MT23B;
Z2 = MT23B - P23MTz;
NormY2 = vecnorm(Y2);
tempZ2 = vecnorm(Z2);
X2 = cross(NormY2, tempZ2);
NormX2 = vecnorm(X2);
NormZ2 = cross(NormX2, NormY2);
G_R_MF = [NormX2; NormY2; NormZ2];

CAL1 = double(MarkerData.RCAL1(i-FFrame+1,:));
CAL2 = double(MarkerData.RCAL2(i-FFrame+1,:));
HEE = double(MarkerData.RHEE(i-FFrame+1,:));

HEE = double(MarkerData.RHEE(i-FFrame+1,:));
TIO = double(MarkerData.RTIO(i-FFrame+1,:));
FEO = double(MarkerData.RFEO(i-FFrame+1,:));
TOE = double(MarkerData.RMT23H(i-FFrame+1,:));

Y3 = CAL2 - HEE;
Z3 = HEE - CAL1;
NormY3 = vecnorm(Y3);
tempZ3 = vecnorm(Z3);
X3 = cross(NormY3, tempZ3);
NormX3 = vecnorm(X3);
NormZ3 = cross(NormX3, NormY3);
G_R_HF = [NormX3; NormY3; NormZ3];

end
JointForceTS(:,i) = mip.toes.mass * accTS(i-FFrame+1,:)'. *[0,0,-mip.toes.mass*9.81]' - FTS(:,i);
JointForceMF(:,i) = mip.midfoot.mass * accMF(i-FFrame+1,:)'. *[0,0,-mip.midfoot.mass*9.81]' - FMF(:,i) + JointForceTS(:,i);
JointForceHF(:,i) = mip.hindfoot.mass * accHF(i-FFrame+1,:)'. *[0,0,-mip.hindfoot.mass*9.81]' - FHF(:,i) + JointForceMF(:,i);

ITSg = G_R_Toe'*ITS;
JointMomentTStotal(:,i) = ITSg * alphaTS(i-FFrame+1,:)'.
-(cross((COPTS(i,:)-TJCvec(i,:)),FTS(:,i)))'.
-cross((COMTSvec(i,:)'-TJCvec(i,:)'),[0,0,-mip.toes.mass*9.81]').
-MTS(:,i);

IMFg = G_R_MF'*IMF;
JointMomentMFtotal(:,i) = IMFg * alphaMF(i-FFrame+1,:)'.
-(cross((COPMF(i,:)-MFJCvec(i,:)),FMF(:,i)))'.
-cross((COMMFvec(i,:)'-MFJCvec(i,:)'),[0,0,-mip.midfoot.mass*9.81]').
-MMF(:,i) + JointMomentTStotal(:,i) - cross((TJCvec(i,:)'-MFJCvec(i,:)'),-JointForceTS(:,i));

IHFg = G_R_HF'*IHF;
JointMomentHFtotal(:,i) = IHFg * alphaHF(i-FFrame+1,:)'.
-(cross((COPHF(i,:)-HFJCvec(i,:)),FHF(:,i)))'.
-cross((COMMFvec(i,:)'-HFJCvec(i,:)'),[0,0,-mip.hindfoot.mass*9.81]').
-MHF(:,i) + JointMomentMFtotal(:,i) - cross((MFJCvec(i,:)'-HFJCvec(i,:)'),-JointForceMF(:,i));

JointMomentTS0(:,i) = ITSg * alphaTS(i-FFrame+1,:)';
JointMomentMF0(:,i) = IMFg * alphaMF(i-FFrame+1,:)';
JointMomentHF0(:,i) = IHFg * alphaHF(i-FFrame+1,:)';

JointMomentTS1(:,i) = -cross((COPTS(i,:)-TJCvec(i,:)),FTS(:,i)))';
JointMomentMF1(:,i) = -cross((COPMF(i,:)-MFJCvec(i,:)),FMF(:,i)))';
JointMomentHF1(:,i) = -cross((COPHF(i,:)-HFJCvec(i,:)),FHF(:,i)))';

JointMomentTS2(:,i) = -cross((COMTSvec(i,:)'-TJCvec(i,:)'),[0,0,-mip.toes.mass*9.81]);
JointMomentMF2(:,i)=-cross((COMMFvec(i,:)'-MFJCvec(i,:)'),[0,0,-mip.midfoot.mass*9.81]);
JointMomentHF2(:,i)=-cross((COMMFvec(i,:)'-HFJCvec(i,:)'),[0,0,-mip.hindfoot.mass*9.81]);

JointMomentTS3(:,i)=-MTS(:,i);
JointMomentMF3(:,i)=-MMF(:,i);
JointMomentHF3(:,i)=-MHF(:,i);

JointMomentTS4(:,i)=0;
JointMomentMF4(:,i)=JointMomentTStotal(:,i);
JointMomentHF4(:,i)=JointMomentMFtotal(:,i);

JointMomentTS5(:,i)=0;
JointMomentMF5(:,i)=-cross((TJCvec(i,:)'-MFJCvec(i,:)'),-JointForceTS(:,i));
JointMomentHF5(:,i)=-cross((MFJCvec(i,:)'-HFJCvec(i,:)'),-JointForceMF(:,i));

JointMomentTSinv(:,i)=G_R_Toe*JointMomentTStotal(:,i);
JointMomentMFinv(:,i)=G_R_MF*JointMomentMFtotal(:,i);
JointMomentHFinv(:,i)=G_R_HF*JointMomentHFtotal(:,i);

JointMomentTS(:,i)=JointMomentTSinv(:,i)/(mip.BodyMass*1000);
JointMomentMF(:,i)=JointMomentMFinv(:,i)/(mip.BodyMass*1000);
JointMomentHF(:,i)=JointMomentHFinv(:,i)/(mip.BodyMass*1000);

end

if writeflag==1

    target1=strcat('COP',Foot);
    target2=strcat('COMHF',Foot);
    target3=strcat('COMMF',Foot);
    target4=strcat('COMTS',Foot);
    target5=strcat('COPHF',Foot);
    target6=strcat('COPMF',Foot);
    target7=strcat('COPTS',Foot);

    if Foot=='L'
        FootO='R';
    else
        FootO='L';
    end

target8=strcat('HindFootMoment',Foot);
target9=strcat('MidFootMoment',Foot);
target10=strcat('ToesMoment',Foot);

target11=strcat('GRFHF',Foot);
target12=strcat('GRFMF',Foot);
target13=strcat('GRFTS',Foot);

Id = test.GetParameterIndex('POINT', 'LABELS');
nItems = test.GetParameterLength(Id);

disp('Writing Centre of Mass...');

for i=1:1:nItems
    if strcmp(test.GetParameterValue(Id,i),target2)==1
        nIndex=i;
    end
end

k=1;
a1=single(zeros(1,size(COMHFvec,1)));
a2=single(zeros(1,size(COMHFvec,1)));
a3=single(zeros(1,size(COMHFvec,1)));

for i=FFrame:1:size(COMHFvec,1)
    if isnan(COMHFvec(i,1))==1
        a1(k)=single(COMHFvec(i,1));
    else
        a2(k)=single(COMHFvec(i,2));
        a3(k)=single(COMHFvec(i,3));
    end
    k=k+1;
end

nRet=test.SetPointDataEx(nIndex,0,FFrame,a1);
nRet=test.SetPointDataEx(nIndex,1,FFrame,a2);
nRet=test.SetPointDataEx(nIndex,2,FFrame,a3);

%disp('Finished Writing COMHF.');

for i=1:1:nItems
    if strcmp(test.GetParameterValue(Id,i),target3)==1
        nIndex=i;
    end
end
clear a1 a2 a3;
k=1;
a1=single(zeros(1,1:size(COMMFvec,1)));a2=single(zeros(1,1:size(COMMFvec,1)));a3=single(zeros(1,1:size(COMMFvec,1)));
for i=FFrame:1:size(COMMFvec,1)
    if isnan(COMMFvec(i,1))==1
        a1(k)=single(COMMFvec(i,1)));
        a2(k)=single(COMMFvec(i,2));
        a3(k)=single(COMMFvec(i,3));
    end
    k=k+1;
end
nRet=test.SetPointDataEx(nIndex,0,FFrame,a1);
nRet=test.SetPointDataEx(nIndex,1,FFrame,a2);
nRet=test.SetPointDataEx(nIndex,2,FFrame,a3);
%disp('Finished Writing COMMF.');

for i=1:1:nItems
    if strcmp(test.GetParameterValue(Id,i),target4)==1
        nIndex=i;
    end
end
%disp(['Writing COMTS... on Marker Number ',num2str(nIndex)]);
clear a1 a2 a3;
k=1;
a1=single(zeros(1,1:size(COMTSvec,1)));a2=single(zeros(1,1:size(COMTSvec,1)));a3=single(zeros(1,1:size(COMTSvec,1)));
for i=FFrame:1:size(COMTSvec,1)
    if isnan(COMTSvec(i,1))==1
        a1(k)=single(COMTSvec(i,1));
        a2(k)=single(COMTSvec(i,2));
        a3(k)=single(COMTSvec(i,3));
    end
    k=k+1;
end
nRet=test.SetPointDataEx(nIndex,0,FFrame,a1);
nRet=test.SetPointDataEx(nIndex,1,FFrame,a2);
nRet=test.SetPointDataEx(nIndex,2,FFrame,a3);
%disp('Finished Writing COMTS.');
disp('Writing Centre of Pressures...');
for i=1:1:nItems
    if strcmp(test.GetParameterValue(Id,i),target1)==1
        nIndex=i;
    end
end
%disp(['Writing COP... on Marker Number ',num2str(nIndex)]);
clear a1 a2 a3;
k=1;
a1=single(zeros(1,size(COPxG,1)));
a2=single(zeros(1,size(COPyG,1)));
a3=single(zeros(1,size(COPxG,1)));
for i=FFrame:1:size(COPxG,1)
    if isnan(COPxG(i,1))==1
        else
            a1(k)=single(COPxG(i,1));
            a2(k)=single(COPyG(i,1));
        end
    k=k+1;
end
nRet=test.SetPointDataEx(nIndex,0,FFrame,a1);
nRet=test.SetPointDataEx(nIndex,1,FFrame,a2);
nRet=test.SetPointDataEx(nIndex,2,FFrame,a3);
%disp('Finished Writing COP.');

for i=1:1:nItems
    if strcmp(test.GetParameterValue(Id,i),target5)==1
        nIndex=i;
    end
end
%disp(['Writing COPHF... on Marker Number ',num2str(nIndex)]);
clear a1 a2 a3;
k=1;
a1=single(zeros(1,size(COPxHFG,1)));
a2=single(zeros(1,size(COPyHFG,1)));
a3=single(zeros(1,size(COPxHFG,1)));
for i=FFrame:1:size(COPxHFG,1)
    if isnan(COPxHFG(i,1))==1
        else
            a1(k)=single(COPxHFG(i,1));
            a2(k)=single(COPyHFG(i,1));
        end
    k=k+1;
end
nRet=test.SetPointDataEx(nIndex,0,FFrame,a1);
nRet=test.SetPointDataEx(nIndex,1,FFrame,a2);
nRet=test.SetPointDataEx(nIndex,2,FFrame,a3);
%disp('Finished Writing COPHF.');
for i=1:1:nItems
    if strcmp(test.GetParameterValue(Id,i),target6)==1
        nIndex=i;
    end
end
%disp(['Writing COPMF... on Marker Number ',num2str(nIndex)]);
clear a1 a2 a3;
k=1;
a1=single(zeros(1,size(COPxMFG,1)));
a2=single(zeros(1,size(COPyMFG,1)));
a3=single(zeros(1,size(COPxMFG,1)));
for i=FFrame:1:size(COPxMFG,1)
    if isnan(COPxMFG(i,1))==1
        else
            a1(k)=single(COPxMFG(i,1));
            a2(k)=single(COPyMFG(i,1));
        end
        k=k+1;
    end
nRet=test.SetPointDataEx(nIndex,0,FFrame,a1);
nRet=test.SetPointDataEx(nIndex,1,FFrame,a2);
nRet=test.SetPointDataEx(nIndex,2,FFrame,a3);
%disp('Finished Writing COPMF.');
for i=FFrame:1:size(COPxTSG,1)
    if isnan(COPxTSG(i,1))==1
        else
            a1(k)=single(COPxTSG(i,1));
            a2(k)=single(COPyTSG(i,1));
        end
        k=k+1;
    end
end
nRet=test.SetPointDataEx(nIndex,0,FFrame,a1);
nRet=test.SetPointDataEx(nIndex,1,FFrame,a2);
nRet=test.SetPointDataEx(nIndex,2,FFrame,a3);
%disp('Finished Writing COPTS.');

disp('Writing Moments...');

KHF=isnan(JointMomentHF);
KMF=isnan(JointMomentMF);
KTS=isnan(JointMomentTS);
for i=1:1:size(JointMomentHF,1)
    for j=1:1:size(JointMomentHF,2)
        if KHF(i,j)==1
            JointMomentHF(i,j)=0;
        end
        if KMF(i,j)==1
            JointMomentMF(i,j)=0;
        end
        if KTS(i,j)==1
            JointMomentTS(i,j)=0;
        end
    end
end

for i=1:1:nItems
    if strcmp(test.GetParameterValue(Id,i),target8)==1
        nIndex=i;
    end
end
clear a1 a2 a3;
k=1;
a1=single(zeros(1,size(JointMomentHF,2)));
a2=single(zeros(1,size(JointMomentHF,2)));
a3=single(zeros(1,size(JointMomentHF,2)));
for i=FFrame:1:size(JointMomentHF,2)
a1(k)=single(JointMomentHF(1,i));
a2(k)=single(JointMomentHF(2,i));
a3(k)=single(JointMomentHF(3,i));
k=k+1;
end
nRet=test.SetPointDataEx(nIndex,0,FFrame,a1);
nRet=test.SetPointDataEx(nIndex,1,FFrame,a2);
nRet=test.SetPointDataEx(nIndex,2,FFrame,a3);

for i=1:1:nItems
    if strcmp(test.GetParameterValue(Id,i),target9)==1
        nIndex=i;
    end
end
clear a1 a2 a3;
k=1;
a1=single(zeros(1,size(JointMomentMF,2)));
a2=single(zeros(1,size(JointMomentMF,2)));
a3=single(zeros(1,size(JointMomentMF,2)));
for i=FFrame:1:size(JointMomentMF,2)
    a1(k)=single(JointMomentMF(1,i));
a2(k)=single(JointMomentMF(2,i));
a3(k)=single(JointMomentMF(3,i));
k=k+1;
end
nRet=test.SetPointDataEx(nIndex,0,FFrame,a1);
nRet=test.SetPointDataEx(nIndex,1,FFrame,a2);
nRet=test.SetPointDataEx(nIndex,2,FFrame,a3);

for i=1:1:nItems
    if strcmp(test.GetParameterValue(Id,i),target10)==1
        nIndex=i;
    end
end
clear a1 a2 a3;
k=1;
a1=single(zeros(1,size(JointMomentTS,2)));
a2=single(zeros(1,size(JointMomentTS,2)));
a3=single(zeros(1,size(JointMomentTS,2)));
for i=FFrame:1:size(JointMomentTS,2)
    a1(k)=single(JointMomentTS(1,i));
a2(k)=single(JointMomentTS(2,i));
a3(k)=single(JointMomentTS(3,i));
k=k+1;
nRet=test.SetPointDataEx(nIndex,0,FFrame,a1);
nRet=test.SetPointDataEx(nIndex,1,FFrame,a2);
nRet=test.SetPointDataEx(nIndex,2,FFrame,a3);

disp('Writing GRFs...');

for i=1:1:nItems
    if strcmp(test.GetParameterValue(Id,i),target11)==1
        nIndex=i;
    end
end
clear a1 a2 a3;
k=1;
a1=single(zeros(1,size(FHF,2)));
a2=single(zeros(1,size(FHF,2)));
a3=single(zeros(1,size(FHF,2)));
for i=FFrame:1:size(FHF,2)
    a1(k)=single(FHF(1,i));
    a2(k)=single(FHF(2,i));
    a3(k)=single(FHF(3,i));
k=k+1;
end
nRet=test.SetPointDataEx(nIndex,0,FFrame,a1);
nRet=test.SetPointDataEx(nIndex,1,FFrame,a2);
nRet=test.SetPointDataEx(nIndex,2,FFrame,a3);

for i=1:1:nItems
    if strcmp(test.GetParameterValue(Id,i),target12)==1
        nIndex=i;
    end
end
clear a1 a2 a3;
k=1;
a1=single(zeros(1,size(FMF,2)));
a2=single(zeros(1,size(FMF,2)));
a3=single(zeros(1,size(FMF,2)));
for i=FFrame:1:size(FMF,2)
    a1(k)=single(FMF(1,i));
    a2(k)=single(FMF(2,i));
    a3(k)=single(FMF(3,i));
k=k+1;
end
nRet=test.SetPointDataEx(nIndex,0,FFrame,a1);
nRet=test.SetPointDataEx(nIndex,1,FFrame,a2);
nRet=test.SetPointDataEx(nIndex,2,FFrame,a3);

for i=1:1:nItems
    if strcmp(test.GetParameterValue(Id,i),target13)==1
        nIndex=i;
    end
end
clear a1 a2 a3;
k=1;
a1=single(zeros(1,size(FTS,2)));a2=single(zeros(1,size(FTS,2)));a3=single(zeros(1,size(FTS,2)));for i=FFrame:1:size(FTS,2)
    a1(k)=single(FTS(1,i));a2(k)=single(FTS(2,i));a3(k)=single(FTS(3,i));k=k+1;
end
nRet=test.SetPointDataEx(nIndex,0,FFrame,a1);
nRet=test.SetPointDataEx(nIndex,1,FFrame,a2);
nRet=test.SetPointDataEx(nIndex,2,FFrame,a3);
savec3d(test,fname,-1);
end
%% Function for combing pressure plate data with Force Plate Data %%
function [Ft,FtotalHF,FtotalMF,FtotalTS,COPxT,COPyT,COPx,COPy,COPxHFL,COPyHFL,COPxMFL,COPyMFL,COPxTSL,COPyTSL,Foot]=pressure(area,freqoff,MarkerData,FFrame)

[FileName,PathName,FilterIndex] = uigetfile('');
disp(strcat('Loading...',PathName,FileName));
M=xlsread(strcat(PathName,FileName));
for i=size(FileName,2):-1:1
if FileName(i)=='.'
    Foot=FileName(i-1);
    break;
end
end

p=0;k=1;
while k<size(M,1)
p=p+1;
% Turn on for Frequency offset%
if freqoff==1
    if rem(p,5)==0
        k=k+258;
    end
end
for i=1:1:256
    for j=1:1:63
        Plate(i,j,p)=M(k+i,j);
    end
    k=k+258;
end
[COPxT,COPyT,COPL,Ft]=calCOP(Plate,area);
PW=zeros(size(Plate,1),size(Plate,2));
for k=1:1:size(Plate,3)
    PW=PW+Plate(:,:,k);
end
subplot(1,3,1);
imshow(PW);

subplot(1,3,2);
imshow(PW);
LeftFoot = roipoly(PW);
% RightFoot = roipoly(PW);

Left = LeftFoot * PW;
subplot(1,3,2);
imshow(Left);

PWL = map(Plate, LeftFoot);

[COPx, COPy, COPL, Ft] = calCOP(PWL, area);

COPL = zeros(size(Left, 1), size(Left, 2));

for k = 1:1:size(PWL, 3)
    Fsum = 0; Fxsum = 0; Fysum = 0;
    for i = 1:1:size(PWL, 1)
        for j = 1:1:size(PWL, 2)
            Fsum = Fsum + PWL(i,j,k) * area;
            Fxsum = Fxsum + PWL(i,j,k) * area * i;
            Fysum = Fysum + PWL(i,j,k) * area * j;
        end
    end
    if Fsum == 0
        COPx(k) = 0;
        COPy(k) = 0;
    else
        COPx(k) = Fxsum / Fsum;
        COPy(k) = Fysum / Fsum;
        COPL(round(COPx(k)), round(COPy(k))) = 1;
    end
end

subplot(1,3,3);
imshow(COPL);
waitforbuttonpress;

[Lefto,imin,imax,jmin,jmax] = crp(Left);

% figure;
subplot(1,1,1);

HindFoot = roipoly(Lefto);
for i = 1:1:size(Lefto, 1)
    for j = 1:1:size(Lefto, 2)
Lefto2(i,j)=Lefto(i,j);
if Lefto2(i,j)==0
else
    if HindFoot(i,j)==1
        Lefto2(i,j)=0.25;
    end
end
end
end
MidFoot=roipoly(Lefto2);
for i=1:1:size(Lefto2,1)
    for j=1:1:size(Lefto2,2)
        Lefto3(i,j)=Lefto2(i,j);
        if Lefto3(i,j) ==0
            else
                if MidFoot(i,j)==1
                    Lefto3(i,j)=0.5;
                end
            end
        end
    end
end
Toes=roipoly(Lefto3);

HFo=HindFoot.*Lefto;
MFo=MidFoot.*Lefto;
TSo=Toes.*Lefto;

for i=1:1:imin
    for j=1:1:jmin
        Left(i,j)=0;
        HF(i,j)=0;
        MF(i,j)=0;
        TS(i,j)=0;
    end
end
p=1;
for i=imin:1:imax
    for j=jmin:1:jmax
        Left(i,j)=Lefto(p,q);
        HF(i,j)=HFo(p,q);
        MF(i,j)=MFo(p,q);
        TS(i,j)=TSo(p,q);
        q=q+1;
    end
    p=p+1;
end
for i=imax:1:size(Left,1)
    for j=jmax:1:size(Left,2)
        Left(i,j)=0;
        HF(i,j)=0;
        MF(i,j)=0;
        TS(i,j)=0;
    end
end

HFL=map(PWL,HF);
MFL=map(PWL,MF);
TSL=map(PWL,TS);

[COPxHFL,COPyHFL,COPHFL,FtotalHF]=calCOP(HFL,area);
[COPxMFL,COPyMFL,COPMFL,FtotalMF]=calCOP(MFL,area);
[COPxTSL,COPyTSL,COPTSL,FtotalTS]=calCOP(TSL,area);

HF1=im2bw(HF);
MF1=im2bw(MF);
TS1=im2bw(TS);
a=1*HF1+7*MF1+2*TS1;
[ao,x1,x2,y1,y2]=crp(a);
%figure;
subplot(1,2,1);
imshow(label2rgb(a,@spring));

COPHFL1=im2bw(COPHFL);
COPMFL1=im2bw(COPMFL);
COPTSL1=im2bw(COPTSL);
b=1*COPHFL1+7*COPMFL1+2*COPTSL1;
p=1;
for i=x1:1:x2
    q=1;
    for j=y1:1:y2
        bo(p,q)=b(i,j);
        q=q+1;
    end
    p=p+1;
end
subplot(1,2,2);
imshow(label2rgb(b,@spring));
APPENDIX E

ANYBODY PROGRAM FOR MUSCULOSKELETAL FOOT MODEL
*** 3-Segment Foot Model developed by Prabhav Saraswat ***

Main = {

    AnyFolder C3DFileData = {
        #include "Trial06.Header.any"
        #include "Trial06.Analog.any"
        #include "Trial06.PointsMarkers.any"
        #include "Trial06.PointsProcessed.any"
    };

    AnyIntVar FirstFrame = Main.C3DFileData.Header.FirstFrameNo;
    AnyIntVar LastFrame = Main.C3DFileData.Header.LastFrameNo;
    AnyIntVar nStep = LastFrame-FirstFrame+1;
    AnyFloatVar tStart = FirstFrame/Main.C3DFileData.Header.VideoFrameRate;
    AnyFloatVar tEnd = LastFrame/Main.C3DFileData.Header.VideoFrameRate;

    //Includes some settings for the visual representation of model
    #include "DrawSettings.any"

    // This study is used for creating marker trajectories of the recorded markers
    AnyBodyStudy1 MarkerModelStudy = {
        // This is a model of containing only the free floating markers
        AnyFolder MarkerModel = {
            // Create segments for each of the markers and drive them according to data
            // If you are running on a new data set you will need to make changes in this
            include statement
            #include "MarkerListMoverInclude.any"
        };
        RecruitmentSolver = MinMaxNRSimplex;
        nStep = Main.nStep;
        Gravity = {0.0000, 0.00000, -9.81};
        tStart = Main.tStart;
        tEnd = Main.tEnd;
    };

    // This study is used for creating the an input file for the gaitapplication2 study
    AnyBodyStudy1 MarkerPlacementStudy = {
        #include "MarkerPlacementModel.any"
        RecruitmentSolver = MinMaxNRSimplex;
        nStep = Main.nStep;
        Gravity = {0.0000, 0.00000, -9.81};
        tStart = Main.tStart;
tEnd = Main.tEnd;

    AnyString ModelString =
    AnyString StudyString =
    Main.MarkerPlacementStudy.MarkerPlacementModel.DataForConfigFiles.StudyGait1;
};

// This study is used for displaying and running the inverse dynamic analysis of the optimized motion created by the gaitapplication2
// This study makes use of the optimized joint angles
#include "HumanModel.any"
    AnyBodyStudy1 OptStudy = {
        #include "OptModel.any"
        RecruitmentSolver = MinMaxNRSimplex;
        nStep=Main.nStep-1;
        Gravity = {0.001, 0.001,-9.81};
        RecruitmentLpPenalty=1e-4;
        tStart=Main.tStart;
        tEnd= Main.tEnd-1/100;
    };
    //This study is used for calibration using the gait motion
    //This study makes use of the optimized joint angles
    AnyBodyCalibrationStudy CalibStudy = {
        #include "CalibModel.any"
        nStep=Main.nStep-1;
        tStart=Main.tStart;
        tEnd= Main.tEnd-1/100;
    };
    AnyOperationSequence OperationSequence ={
        AnyOperation &CalibTendon = Main.CalibStudy.TendonLengthAdjustment;
        AnyOperation &CalibLigament = Main.CalibStudy.LigamentLengthAdjustment;
        AnyOperation &InvDyn = Main.OptStudy.InverseDynamicAnalysis;
    };

    AnyFixedRefFrame GlobalRef={
        Origin={0,0,0};
        Axes=Main.Orientation;
        //AnyDrawRefFrame drwref = {};
    };

    #include "MADrivers.any"
    AnyBodyStudy MASTudy = {
AnyFolder &Model = Main.HumanModel;
AnyFolder &Drivers = Main.MADrivers;
RecruitmentSolver = MinMaxSimplex;
tEnd=50;
nStep=51;
Gravity = {0.000, 0.000,-9.81};

#include "AnkleMA.any"
//include "MidFootMA.any"
//include "ToesMA.any"
//include "MP3JointMA.any"

}; // Main

***********************************************************************
===============================================================
//MarkerListMover.any

AnyFolder Markers = {
AnyVar ScaleFactor = 0.001000;
AnyFixedRefFrame GlobalRef= {
   Axes = Main.Orientation;
};
AnyFolder RFEP = {
   AnyString Label = "RFEP";
   AnyFolder &HeaderFolder =Main.C3DFileData.Header;
   AnyFolder &DataFolder=Main.C3DFileData.ProcessedData.RFEP;
   #include "MarkerMover.any "
};
AnyFolder RTHI = {
   AnyString Label = "RTHI";
   AnyFolder &HeaderFolder =Main.C3DFileData.Header;
   AnyFolder &DataFolder=Main.C3DFileData.ProcessedData.RTHI;
   #include "MarkerMover.any "
};
AnyFolder RKNE = {
   AnyString Label = "RKNE";
   AnyFolder &HeaderFolder =Main.C3DFileData.Header;
   AnyFolder &DataFolder=Main.C3DFileData.ProcessedData.RKNE;
   #include "MarkerMover.any "
};
AnyFolder RTIB = {

AnyString Label = "RTIB";
AnyFolder &HeaderFolder =Main.C3DFileData.Header;
AnyFolder &DataFolder=Main.C3DFileData.ProcessedData.RTIB;
#include "MarkerMover.any "
};
AnyFolder RTIBU = {
AnyString Label = "RTIBU";
AnyFolder &HeaderFolder =Main.C3DFileData.Header;
AnyFolder &DataFolder=Main.C3DFileData.ProcessedData.RTIBU;
#include "MarkerMover.any "
};
AnyFolder RTIBL = {
AnyString Label = "RTIBL";
AnyFolder &HeaderFolder =Main.C3DFileData.Header;
AnyFolder &DataFolder=Main.C3DFileData.ProcessedData.RTIBL;
#include "MarkerMover.any "
};
AnyFolder RANK = {
AnyString Label = "RANK";
AnyFolder &HeaderFolder =Main.C3DFileData.Header;
AnyFolder &DataFolder=Main.C3DFileData.ProcessedData.RANK;
#include "MarkerMover.any "
};
AnyFolder RHEE = {
AnyString Label = "RHEE";
AnyFolder &HeaderFolder =Main.C3DFileData.Header;
AnyFolder &DataFolder=Main.C3DFileData.ProcessedData.RHEE;
#include "MarkerMover.any "
};
AnyFolder RLCAL = {
AnyString Label = "RLCAL";
AnyFolder &HeaderFolder =Main.C3DFileData.Header;
AnyFolder &DataFolder=Main.C3DFileData.ProcessedData.RLCAL;
#include "MarkerMover.any "
};
AnyFolder RMCAL = {
AnyString Label = "RMCAL";
AnyFolder &HeaderFolder =Main.C3DFileData.Header;
AnyFolder &DataFolder=Main.C3DFileData.ProcessedData.RMCAL;
#include "MarkerMover.any "
};
AnyFolder RTOE1 = {
AnyString Label = "RTOE1";
AnyFolder &HeaderFolder =Main.C3DFileData.Header;
AnyFolder &DataFolder=Main.C3DFileData.ProcessedData.RTOE1;

#include "MarkerMover.any"

AnyFolder RTOE2 = {
    AnyString Label = "RTOE2";
    AnyFolder &HeaderFolder = Main.C3DFileData.Header;
    AnyFolder &DataFolder = Main.C3DFileData.ProcessedData.RTOE2;
    #include "MarkerMover.any"
};

AnyFolder RTOE3 = {
    AnyString Label = "RTOE3";
    AnyFolder &HeaderFolder = Main.C3DFileData.Header;
    AnyFolder &DataFolder = Main.C3DFileData.ProcessedData.RTOE3;
    #include "MarkerMover.any"
};

AnyFolder RMT23B = {
    AnyString Label = "RMT23B";
    AnyFolder &HeaderFolder = Main.C3DFileData.Header;
    AnyFolder &DataFolder = Main.C3DFileData.ProcessedData.RMT23B;
    #include "MarkerMover.any"
};

AnyFolder RMT23H = {
    AnyString Label = "RMT23H";
    AnyFolder &HeaderFolder = Main.C3DFileData.Header;
    AnyFolder &DataFolder = Main.C3DFileData.ProcessedData.RMT23H;
    #include "MarkerMover.any"
};

AnyFolder RMT1BM = {
    AnyString Label = "RMT1BM";
    AnyFolder &HeaderFolder = Main.C3DFileData.Header;
    AnyFolder &DataFolder = Main.C3DFileData.ProcessedData.RMT1BM;
    #include "MarkerMover.any"
};

AnyFolder RMT1HM = {
    AnyString Label = "RMT1HM";
    AnyFolder &HeaderFolder = Main.C3DFileData.Header;
    AnyFolder &DataFolder = Main.C3DFileData.ProcessedData.RMT1HM;
    #include "MarkerMover.any"
};

AnyFolder RCALTB = {
    AnyString Label = "RCALTB";
    AnyFolder &HeaderFolder = Main.C3DFileData.Header;
    AnyFolder &DataFolder = Main.C3DFileData.ProcessedData.RCALTB;
    #include "MarkerMover.any"
};
// MarkerMover.any: File used for creating markers in an easy way

AnySeg Seg=

    Mass=0;
    Jii={0.0,0.0,0.0};
AnyRefNode node=

    sRel={0,0,0};
    AnyDrawNode drw={ScaleXYZ={0.005,0.005,0.005};RGB={0,0,0};};
};

AnyKinLinear Lin=

    Ref=0;
    AnyRefFrame &ref1=..GlobalRef;
    AnyRefFrame &ref2=.Seg;
};

AnyKinRotational Rot=

    AnyRefFrame &ref1=..GlobalRef;
    AnyRefFrame &ref2=.Seg;
    Type=RotVector;
};

AnyKinEqSimpleDriver RotDrv=

    AnyKinRotational &ref1 = .Rot;
    DriverPos={0,0,0};
    DriverVel={0,0,0};
};

/// A lowpass butterworth filter
AnyFunButterworthFilter LowPassFilter =

    FilterForwardBackwardOnOff = On;
    AutomaticInitialConditionOnOff = On;
    N = 2;
    AnyVar CutOffFrequency=10;
    AnyVar SampleFreq=Main.C3DFileData.Header.VideoFrameRate ;
    W = {1/(SampleFreq*0.5)*CutOffFrequency};
    Type = LowPass;
};

// filter the data
AnyVector FilteredX = LowPassFilter(.ScaleFactor*DataFolder.Pos'[0]);
AnyVector FilteredY = LowPassFilter(.ScaleFactor*DataFolder.Pos'[1]);
AnyVector FilteredZ = LowPassFilter(.ScaleFactor*DataFolder.Pos[2]);

AnyKinEqInterPolDriver LinDrv={
  AnyKinLinear &ref1= .Lin;
  T=.HeaderFolder.Frames/.HeaderFolder.VideoFrameRate;
  Data={.FilteredX,.FilteredY,.FilteredZ};
  Type=Bspline;
  BsplineOrder = 4;
};

// Only use this output file when you want to create markers trajectory files otherwise
// leave it out commented or it may overwrite existing trajectories
AnyOutputFile MarkerPositionFile = {
  FileName = .Label + ".txt";
  AnyVar px= .Seg.r[0];
  AnyVar py= .Seg.r[1];
  AnyVar pz= .Seg.r[2];
  SepSign = " ";
  NumberFormat = { Digits = 15; };
};

/**
  // Marker PlacementModel.any

  // This model is used to place the markers on the correct locations this is done
  // in the file "LocalMarkerCoordinatesAndSize.any" and for setting the model in the
  // correct
  // initial position

  AnyFolder HumanModel={
    AnyFolder &Mannequin=.MarkerPlacementModel.Mannequin;
    #include "FootSegmentsRightOptMA_modified.any"
    #include "FootJointsRight.any"
    #include "ScalingZ.any"
    #include "ScalingUniform.any"
    #include "ScalingUniform_MF_TS_together.any"
    #include "..\..\..\Body\AAUHuman\Scaling\ScalingLengthMass.any"
    #include "..\..\..\Body\AAUHuman\Scaling\ScalingLengthMassFat.any"
*/
Scaling = {
    //This is the file which set the segments lengths
    #include "StandardParameters.any"
    #include "LocalMarkerCoordinatesAndSize.any"
    #include "AnyMan.any"
};

AnyFolder MarkerPlacementModel={

    AnyFolder &HumanModel=.HumanModel;
    AnyFolder DataForConfigFiles = {
        //calculate the euler parameters for the segments
        AnyKinRotational ThighRightRot={ AnySeg &Femur =
            ..HumanModel.FootSegmentsRight.Femur; Type=EulerParam; };
        AnyKinRotational ShankRightRot={ AnySeg &Shank =
            ..HumanModel.FootSegmentsRight.Shank; Type=EulerParam; };
        AnyKinRotational HindFootRightRot={ AnySeg &HindFoot =
            ..HumanModel.FootSegmentsRight.HindFoot; Type=EulerParam; };
        AnyKinRotational MidFootRightRot={ AnySeg &MidFoot =
            ..HumanModel.FootSegmentsRight.MidFoot; Type=EulerParam; };
        AnyKinRotational ToesRightRot={ AnySeg &Toes =
            ..HumanModel.FootSegmentsRight.Toes; Type=EulerParam; };

        AnyKinLinear ThighRightLin={ AnySeg &Femur =
            ..HumanModel.FootSegmentsRight.Femur; };
        AnyKinLinear ShankRightLin={ AnySeg &Shank =
            ..HumanModel.FootSegmentsRight.Shank; };
        AnyKinLinear HindFootRightLin={ AnySeg &HindFoot =
            ..HumanModel.FootSegmentsRight.HindFoot; };
        AnyKinLinear MidFootRightLin={ AnySeg &MidFoot =
            ..HumanModel.FootSegmentsRight.MidFoot; };
        AnyKinLinear ToesRightLin={ AnySeg &Toes =
            ..HumanModel.FootSegmentsRight.Toes; };
    }

    AnyVec3 RGB={1,0,0};  //color of initial markers
    #include "MarkerTopology.any"

    AnyFolder &lm=.HumanModel.Scaling.LocalMarkerCoordinates;
    AnyFolder &sp=.HumanModel.Scaling.ScalingParameters;

    //This string is the input file for the GaitApplication2.exe file
    //it will optimized the scaling of the thigh shank and foot, the markers are static
    //normally it is a good idea to sue this input file initially before letting the optimizer
//determine the position of the markers
AnyFolder ModelGait1={
    AnyString OptSetting= " off off off ";
    #include "DataForConfigFile.any"
};

AnyString StudyGait1={ //this data is to be used by the StudyGait2.txt file
    "MODELTYPE GAITHREESEGMENTFOOT",
    "KINTOL 1e-12",
    "KINMAXITER 200",
    "STUDYTYPE SCALE",
    "TSTART" + " " +strval(Main.tStart),
    "TEND" + " " +strval(Main.tEnd),
    "NSTEP" + " " +strval(Main.nStep-1)
};

};

//Create segments for each of the markers and drive them according to data
//which can be found in the files p1.any - p15.any
#include "MarkerListMoverInclude.any"
#include "Mannequin.any" // this file controls the initial position of the model and the posture

//Environment around the human
AnyFolder EnvironmentModel ={ 
    //Model of the floor and force plates
    AnyFixedRefFrame GlobalRef ={ 
        //AnyDrawRefFrame drw ={};
        Origin={0,0,0};
    }; 
};

//Connection between environment and the human
AnyFolder ModelEnvironmentConnection = {
    //Drivers for the model
    #include "JointsAngleDrivers.any"
}; //MarkerPlacementModel
// FootSegmentsRightOptMA

AnyFolder FootSegmentsRight = {
  AnyVar LegLength = .Scaling.AnthroData.LegLength;
  AnyVar FootLength = .Scaling.AnthroData.FootLength;
  AnyVar FootWidth = .Scaling.AnthroData.FootWidth;
  
  AnyVar ScaleFactorX_G = FootLength/.21979;
  AnyVar ScaleFactorY_G = FootWidth/.08793;
  AnyVar ScaleFactorZ_G = LegLength/.87562;

  AnyMat33 ScaleMat1 = {{1,0,0},{0,1,0},{0,0,ScaleFactorZ_G}};
  AnyMat33 ScaleMat2 = {{ScaleFactorX_G,0,0}, {0,1,0},{0,0,1}};

  // Femur
  // Use same coordinate system as tibia (x=anterior, y=medial, z=superior)
  AnySeg Femur = {
    AnyFunTransform3DLin &Scale = ..Scaling.GeometricalScaling.Thigh.ScaleFunction;
    r0 = {0.1359,0.0951,0.2924}; //* .ScaleMat1; //with offset
    
    Axes0 = {{0.1420,0.9884,0.0545},{-0.9816,0.1477,-0.1209},{-0.1276,-0.0363,0.9912}};
    Mass = 0.1*..Scaling.AnthroData.BodyMass;
    // Geometry = Cylinder with z=long axis, COM at 0.567 of length
    AnyVar Length = 0.4544* .ScaleFactorZ_G ; //m
    AnyVar Radius = 0.0980; //m
    AnyVar Izz = 0.5*Mass*Radius*Radius;
    AnyVar Ixx = 0.25*Mass*Radius*Radius + 1/12*Mass*Length*Length;
    AnyVar Iyy = Ixx;
    Jii = [Ixx,Iyy,Izz];

  // *** Joints ***
  AnyRefNode HipJointNode = {sRel = .Scale(0.0,0.0,0.1515); //* .ScaleMat1;
    
    AnyDrawNode DrwNode = {ScaleXYZ = {0.01, 0.01, 0.01};RGB ={1,0,0};};
  };
  AnyVec3 UnscaledKneeJointNode = {0.0,0.0,-0.3029};
  AnyRefNode KneeJointNode = {
    sRel = .Scale(UnscaledKneeJointNode);//* .ScaleMat1;
    // Femur_R_Shank
    ARel = {{0.9912,0.0088,-0.1320},{-0.0104,0.9999,-0.0118},{0.1319,0.0131,0.9912}};
    AnyDrawNode DrwNode = {ScaleXYZ = {0.01, 0.01, 0.01};RGB ={1,0,0};};
  };
};
// *** Muscle attachments ***
// Gastroc Origin: Lateral head: posterior surface of lateral condyle of femur and
// highest
// of three facets on lateral condyle. Medial head: posterior surface of femur above
medial condyle
// Treat as separate muscles
AnyVar MedialPosteriorCondyle1Unscaledx = -7.09519e-003;
AnyVar MedialPosteriorCondyle1Unscaledy = 1.42048e-002;
AnyVar MedialPosteriorCondyle1Unscaledz = -2.84495e-001;
AnyFloat MedialPosteriorCondyle1Unscaled =
{MedialPosteriorCondyle1Unscaledx,MedialPosteriorCondyle1Unscaledy,MedialPosteriorCondyle1Unscaledz};
AnyRefNode MedialPosteriorCondyle1 = {sRel =
.Scale(.MedialPosteriorCondyle1Unscaled);};

AnyVar LateralPosteriorCondyle1Unscaledx = -0.0007;
AnyVar LateralPosteriorCondyle1Unscaledy = -0.0262;
AnyVar LateralPosteriorCondyle1Unscaledz = -0.2797;
AnyFloat LateralPosteriorCondyle1Unscaled =
{LateralPosteriorCondyle1Unscaledx,LateralPosteriorCondyle1Unscaledy,LateralPosteriorCondyle1Unscaledz};
AnyRefNode LateralPosteriorCondyle1 = {sRel =
.Scale(.LateralPosteriorCondyle1Unscaled);};

// *** Muscle via nodes ***
// Wrap gastrocs about the most prominent posterior points on condyles
AnyVar MedialPosteriorCondyle2Unscaledx = -3.25952e-002;
AnyVar MedialPosteriorCondyle2Unscaledy = 2.71048e-002;
AnyVar MedialPosteriorCondyle2Unscaledz = -3.14095e-001;
AnyFloat MedialPosteriorCondyle2Unscaled =
{MedialPosteriorCondyle2Unscaledx,MedialPosteriorCondyle2Unscaledy,MedialPosteriorCondyle2Unscaledz};
AnyRefNode MedialPosteriorCondyle2 = {sRel =
.Scale(.MedialPosteriorCondyle2Unscaled);};

AnyVar LateralPosteriorCondyle2Unscaledx = -2.63696e-002;
AnyVar LateralPosteriorCondyle2Unscaledy = 3.33304e-002;
AnyVar LateralPosteriorCondyle2Unscaledz = -3.07870e-001;
AnyFloat LateralPosteriorCondyle2Unscaled =
{LateralPosteriorCondyle2Unscaledx,LateralPosteriorCondyle2Unscaledy,LateralPosteriorCondyle2Unscaledz};
AnyRefNode LateralPosteriorCondyle2 = {sRel =
.Scale(.LateralPosteriorCondyle2Unscaled);};

AnyRefNode FemurSTLNode = {
sRel = .Scale({0.1114,-0.1378,-0.2857});  // ...ScaleMat1;
// Femur_R_G
ARel = {{0.1420,-0.9816,-0.1276},{0.9884,0.1477,-0.0363},{0.0545,-
0.1209,0.9912}};
AnyDrawSTL DrwSTL = {
  FileName = "STL\femur_t.stl";
  AnyVar LegLength = ...Scaling.AnthroData.LegLength;
  AnyVar ScaleFactor=LegLength/.87562;
  ScaleXYZ = ..Scale({0.001, 0.001, 0.001});
  RGB = {1,0.9,0};
};
}; // End of Femur

// Shank
// -----
// Shank origin defined as center of malleoli
// superior (z) is defined from origin to knee joint center
// anterior (x) is perpendicular to this and line through epicondyles
AnySeg Shank = {
  AnyFunTransform3DLin &Scale =
 ..Scaling.GeometricalScaling.Shank.ScaleFunction;
  r0 = {0.1161,0.1306,-0.1491};  // ...ScaleMat1;
  // G_R_Shank
  Axes0 = {{0.1377,0.9902,0.0236},{-0.9905,0.1375,0.0080},{0.0047,-
0.0245,0.9997}};
  Mass = 0.0465*..Scaling.AnthroData.BodyMass;
  // Geometry = Cylinder with z=long axis, COM at 0.567 of length
  AnyVar Length = 0.4024* .ScaleFactorZ_G;
  AnyVar Radius = 0.0434;
  AnyVar Izz = 0.5*Mass*Radius*Radius;
  AnyVar Ixx = 0.25*Mass*Radius*Radius + 1/12*Mass*Length*Length;
  AnyVar Iyy = Ixx;
  Jii = {Ixx,Iyy,Izz};

// *** Joints ***
AnyVec3 UnscaledKneeJointNode = {0,0,0.1413};
AnyRefNode KneeJoint = {sRel = .Scale( UnscaledKneeJointNode);  // ...ScaleMat1;
  AnyDrawNode DrwNode = {ScaleXYZ = {0.02, 0.02, 0.02};RGB = {1,0,0}};};
AnyVec3 UnscaledAnkleJointNode = {0,0,-0.2826};
AnyRefNode AnkleJoint = {
  sRel = .Scale( UnscaledAnkleJointNode);  // ...ScaleMat1;
  // Shank_R_HindFoot
ARel = {{0.9562,0.1745,0.2352},{-0.1820,0.9832,0.0104},{-0.2294,-0.0528,0.9719}};

AnyDrawNode DrwNode = {ScaleXYZ = {0.005, 0.005, 0.005};RGB = {1,0,0};};

// *** Muscle attachments ***

// Soleus Origin: Posterior aspect of fibular head, upper 1/4 - 1/3 of posterior surface of fibula,
// middle 1/3 of medial border of tibial shaft, and from posterior surface of a tendinous arch spanning the two sites of bone origin
// Soleus is highest posterior muscle on tibia, both on tib and fib, but more on fib, center in interosseus
AnyVar PosteriorMedialProximalTibia1Unscaledx = -0.0083;
AnyVar PosteriorMedialProximalTibia1Unscaledy = -0.0030;
AnyVar PosteriorMedialProximalTibia1Unscaledz = 0.0673;
AnyFloat PosteriorMedialProximalTibia1Unscaled =
{PosteriorMedialProximalTibia1Unscaledx,PosteriorMedialProximalTibia1Unscaledy,PosteriorMedialProximalTibia1Unscaledz};

AnyRefNode PosteriorMedialProximalTibia1 = {sRel = .Scale(.PosteriorMedialProximalTibia1Unscaled);};

// Peroneus Brevis Origin: Lower two thirds lateral shaft of fibula
AnyVar PosteriorLateralDistalFibulaUnscaledx = -2.22980e-002;
AnyVar PosteriorLateralDistalFibulaUnscaledy = -3.05972e-002;
AnyVar PosteriorLateralDistalFibulaUnscaledz = -1.73689e-001;
AnyFloat PosteriorLateralDistalFibulaUnscaled =
{PosteriorLateralDistalFibulaUnscaledx,PosteriorLateralDistalFibulaUnscaledy,PosteriorLateralDistalFibulaUnscaledz};

AnyRefNode PosteriorLateralDistalFibula = {sRel = .Scale(.PosteriorLateralDistalFibulaUnscaled);};

// Peroneus Longus Origin: Head of fibula, upper 1/2 - 2/3 of lateral fibular shaft surface; also anterior and posterior intermuscular septa of leg
AnyVar PosteriorLateralProximalFibulaUnscaledx = -2.25992e-002;
AnyVar PosteriorLateralProximalFibulaUnscaledy = -3.83992e-002;
AnyVar PosteriorLateralProximalFibulaUnscaledz = 3.11008e-002;
AnyFloat PosteriorLateralProximalFibulaUnscaled =
{PosteriorLateralProximalFibulaUnscaledx,PosteriorLateralProximalFibulaUnscaledy,PosteriorLateralProximalFibulaUnscaledz};

AnyRefNode PosteriorLateralProximalFibula = {sRel = .Scale(.PosteriorLateralProximalFibulaUnscaled);};

// Tibialis Posterior Origin: Posterior aspect of interosseous membrane, superior 2/3 of medial posterior surface of fibula,
// superior aspect of posterior surface of tibia, and from intermuscular septum between muscles of posterior compartment and deep transverse septum
AnyVar PosteriorProximalInterosseusUnscaledx = -0.0102;
AnyVar PosteriorProximalInterosseusUnscaledy = -0.0119;
AnyVar PosteriorProximalInterosseusUnscaledz = 0.0367;
AnyFloat PosteriorProximalInterosseusUnscaled =
{PosteriorProximalInterosseusUnscaledx,PosteriorProximalInterosseusUnscaledy,PosteriorProximalInterosseusUnscaledz};
AnyRefNode PosteriorProximalInterosseus = {sRel = Scale(.PosteriorProximalInterosseusUnscaled);};
// Tibialis Anterior Origin: Lateral condyle of tibia, proximal 1/2 - 2/3 or lateral surface of tibial shaft,
// interosseous membrane, and the deep surface of the fascia cruris
AnyVar AnteriorLateralProximalTibiaUnscaledx = 0.0167;
AnyVar AnteriorLateralProximalTibiaUnscaledy = -0.0136;
AnyVar AnteriorLateralProximalTibiaUnscaledz = 0.0546;
AnyFloat AnteriorLateralProximalTibiaUnscaled =
{AnteriorLateralProximalTibiaUnscaledx,AnteriorLateralProximalTibiaUnscaledy,AnteriorLateralProximalTibiaUnscaledz};
AnyRefNode AnteriorLateralProximalTibia = {sRel = Scale(.AnteriorLateralProximalTibiaUnscaled);};
// Peroneus Tertius Origin: Arises with the extensor digitorum longus from the medial fibular shaft surface and the
// anterior intermuscular septum (between the extensor digitorum longus and the tibialis anterior)
AnyVar AnteriorDistalFibulaUnscaledx = -0.0158;
AnyVar AnteriorDistalFibulaUnscaledy = -0.0143;
AnyVar AnteriorDistalFibulaUnscaledz = -0.1818;
AnyFloat AnteriorDistalFibulaUnscaled =
{AnteriorDistalFibulaUnscaledx,AnteriorDistalFibulaUnscaledy,AnteriorDistalFibulaUnscaledz};
AnyRefNode AnteriorDistalFibula = {sRel = Scale(.AnteriorDistalFibulaUnscaled);};
// Extensor Hallucis Longus Origin: Middle half of anterior shaft of fibula. Below EDL, above peroneus tertius.
AnyVar AnteriorMedialProximalFibulaUnscaledx = -0.0056;
AnyVar AnteriorMedialProximalFibulaUnscaledy = -0.0297;
AnyVar AnteriorMedialProximalFibulaUnscaledz = -0.0371;
AnyFloat AnteriorMedialProximalFibulaUnscaled =
{AnteriorMedialProximalFibulaUnscaledx,AnteriorMedialProximalFibulaUnscaledy,AnteriorMedialProximalFibulaUnscaledz};
AnyRefNode AnteriorMedialProximalFibula = {sRel = Scale(.AnteriorMedialProximalFibulaUnscaled);};
// Extensor Digitorum Longus Origin: Upper two thirds of anterior shaft of fibula, interosseous membrane and superior tibiofibular joint.
// Highest of EDL, EHL, and Peroneus tertius.
AnyVar AnteriorProximalInterosseusUnscaledx = -0.0047;
AnyVar AnteriorProximalInterosseusUnscaledy = -0.0287;
AnyVar AnteriorProximalInterosseusUnscaledz = 0.0463;
AnyFloat AnteriorProximalInterosseusUnscaled =
\{\text{AnteriorProximalInterosseusUnscaled}_x,\text{AnteriorProximalInterosseusUnscaled}_y,\text{AnteriorProximalInterosseusUnscaled}_z\};
AnyRefNode AnteriorProximalInterosseus = \{sRel = 
.Scale(\text{AnteriorProximalInterosseusUnscaled});\};

// Flexor Hallucis Longus Origin: Lower two thirds of posterior fibula between median
crest and posterior border,
// lower intermuscular septum and aponeurosis of flexor digitorum longus
AnyVar PosteriorFibulaUnscaledx = -0.0228;
AnyVar PosteriorFibulaUnscaledy = -0.0185;
AnyVar PosteriorFibulaUnscaledz = -0.1207;
AnyFloat PosteriorFibulaUnscaled =
\{\text{PosteriorFibulaUnscaled}_x,\text{PosteriorFibulaUnscaled}_y,\text{PosteriorFibulaUnscaled}_z\};
AnyRefNode PosteriorFibula = \{sRel = \text{Scale}(\text{PosteriorFibulaUnscaled});\};

// Flexor Digitorum Longus Origin: Posterior shaft of tibia below soleal line and by
broad aponeurosis from fibula
AnyVar PosteriorTibiaUnscaledx = -0.0030;
AnyVar PosteriorTibiaUnscaledy = 0.0027;
AnyVar PosteriorTibiaUnscaledz = -0.1022;
AnyFloat PosteriorTibiaUnscaled =
\{\text{PosteriorTibiaUnscaled}_x,\text{PosteriorTibiaUnscaled}_y,\text{PosteriorTibiaUnscaled}_z\};
AnyRefNode PosteriorTibia = \{sRel = \text{Scale}(\text{PosteriorTibiaUnscaled});\};

// *** Muscle Via Nodes ***
// Wrap gastroc around posterior tibial epicondyles
AnyVar MedialPosteriorCondyleUnscaledx = -2.38952e-002;
AnyVar MedialPosteriorCondyleUnscaledy = 1.57048e-002;
AnyVar MedialPosteriorCondyleUnscaledz = 8.98048e-002;
AnyFloat MedialPosteriorCondyleUnscaled =
\{\text{MedialPosteriorCondyleUnscaled}_x,\text{MedialPosteriorCondyleUnscaled}_y,\text{MedialPosteriorCondyleUnscaled}_z\};
AnyRefNode MedialPosteriorCondyle = \{sRel = 
.Scale(\text{MedialPosteriorCondyleUnscaled});\};

AnyVar LateralPosteriorCondyleUnscaledx = -0.0139;
AnyVar LateralPosteriorCondyleUnscaledy = -0.0136;
AnyVar LateralPosteriorCondyleUnscaledz = 0.0961;
AnyFloat LateralPosteriorCondyleUnscaled =
\{\text{LateralPosteriorCondyleUnscaled}_x,\text{LateralPosteriorCondyleUnscaled}_y,\text{LateralPosteriorCondyleUnscaled}_z\};
AnyRefNode LateralPosteriorCondyle = \{sRel = 
.Scale(\text{LateralPosteriorCondyleUnscaled});\};

// Keep Peroneals (brevis and longus) posterior and lateral
AnyVar ProximalPeronealGrooveUnscaledx = -2.53992e-002;
AnyVar ProximalPeronealGrooveUnscaledy = -1.83992e-002;
AnyVar ProximalPeronealGrooveUnscaledz = -2.84899e-001;
AnyFloat ProximalPeronealGrooveUnscaled =
{ProximalPeronealGrooveUnscaledx,ProximalPeronealGrooveUnscaledy,ProximalPeronealGrooveUnscaledz};
AnyRefNode ProximalPeronealGroove = {sRel =
.Scale(.ProximalPeronealGrooveUnscaled);};

AnyVar DistalPeronealGrooveUnscaledx = -6.0065e-003;;//PB
AnyVar DistalPeronealGrooveUnscaledy = -1.3509e-002;;//PB
AnyVar DistalPeronealGrooveUnscaledz = -2.94808e-001;;//PB
AnyVar DistalPeronealGrooveUnscaledxPL = -7.84599e-003;;//PL
AnyVar DistalPeronealGrooveUnscaledyPL = -1.44101e-002;;//PL
AnyVar DistalPeronealGrooveUnscaledzPL = -2.94816e-001;;//PL
AnyFloat DistalPeronealGrooveUnscaled =
{DistalPeronealGrooveUnscaledx,DistalPeronealGrooveUnscaledy,DistalPeronealGrooveUnscaledz};
AnyRefNode DistalPeronealGroove = {sRel =
.Scale(.DistalPeronealGrooveUnscaled);};

AnyFloat DistalPeronealGrooveUnscaledPL =
{DistalPeronealGrooveUnscaledxPL,DistalPeronealGrooveUnscaledyPL,DistalPeronealGrooveUnscaledzPL};
AnyRefNode DistalPeronealGroovePL = {sRel =
.Scale(.DistalPeronealGrooveUnscaledPL);};
// Keep TibPost posterior and medial, FDL in same groove
AnyVar TibialisPosteriorGrooveUnscaledx = -0.0040;
AnyVar TibialisPosteriorGrooveUnscaledy = 0.0246;
AnyVar TibialisPosteriorGrooveUnscaledz = -0.2934;
AnyVar TibialisPosteriorGrooveUnscaledxFDL = -0.0040;
AnyVar TibialisPosteriorGrooveUnscaledyFDL = 0.0246;
AnyVar TibialisPosteriorGrooveUnscaledzFDL = -0.2934;

AnyVar TibialisPosteriorGrooveUnscaledzFDL = -0.2934;
AnyVar TibialisPosteriorGrooveUnscaled =
{TibialisPosteriorGrooveUnscaledx,TibialisPosteriorGrooveUnscaledy,TibialisPosteriorGrooveUnscaledz};
AnyRefNode TibialisPosteriorGroove = {sRel =
.Scale(.TibialisPosteriorGrooveUnscaled);};

AnyFloat TibialisPosteriorGrooveUnscaledFDL =
{TibialisPosteriorGrooveUnscaledxFDL,TibialisPosteriorGrooveUnscaledyFDL,TibialisPosteriorGrooveUnscaledzFDL};
AnyRefNode TibialisPosteriorGrooveFDL = {sRel =
.Scale(.TibialisPosteriorGrooveUnscaledFDL);};

// Use shank to model retinaculum for these muscles
// Anterior Tibialis
AnyVar MedialRetinaculumUnscaledx = 3.46990e-002;
AnyVar MedialRetinaculumUnscaledy = 5.83012e-004;
AnyVar MedialRetinaculumUnscaledz = -2.61906e-001;

AnyFloat MedialRetinaculumUnscaled =
{MedialRetinaculumUnscaledx,MedialRetinaculumUnscaledy,MedialRetinaculumUnscaledz};
AnyRefNode MedialRetinaculum = {sRel = .Scale(.MedialRetinaculumUnscaled);};

// EHL
AnyVar CentralRetinaculumUnscaledx = 0.0222;
AnyVar CentralRetinaculumUnscaledy = -0.0065;
AnyVar CentralRetinaculumUnscaledz = -0.2645;
AnyFloat CentralRetinaculumUnscaled =
{CentralRetinaculumUnscaledx,CentralRetinaculumUnscaledy,CentralRetinaculumUnscaledz};
AnyRefNode CentralRetinaculum = {sRel = .Scale(.CentralRetinaculumUnscaled);};

// Peroneus Tertius and EDL
AnyVar LateralRetinaculumUnscaledx = 0.0082;
AnyVar LateralRetinaculumUnscaledy = -0.0235;
AnyVar LateralRetinaculumUnscaledz = -0.2652;
AnyVar LateralRetinaculumUnscaledxEDL = 0.0082;//EDL
AnyVar LateralRetinaculumUnscaledyEDL = -0.0235;//EDL
AnyVar LateralRetinaculumUnscaledzEDL = -0.2652;//EDL
AnyFloat LateralRetinaculumUnscaled =
{LateralRetinaculumUnscaledx,LateralRetinaculumUnscaledy,LateralRetinaculumUnscaledz};
AnyRefNode LateralRetinaculum = {sRel = .Scale(.LateralRetinaculumUnscaled);};
AnyFloat LateralRetinaculumUnscaledEDL =
{LateralRetinaculumUnscaledxEDL,LateralRetinaculumUnscaledyEDL,LateralRetinaculumUnscaledzEDL};
AnyRefNode LateralRetinaculumEDL = {sRel = .Scale(.LateralRetinaculumUnscaledEDL);};

AnyVar ATendonViaPointUnscaledx= -4.83964e-002;
AnyVar ATendonViaPointUnscaledy= 0.04;//1.36137e-003;
AnyVar ATendonViaPointUnscaledz = -2.83298e-001;
AnyFloat ATendonViaPointUnscaled =
{ATendonViaPointUnscaledx,ATendonViaPointUnscaledy,ATendonViaPointUnscaledz};
AnyRefNode ATendonViaPoint = {sRel = .Scale(.ATendonViaPointUnscaled);};

// *** Ligament Attachments ***
The deltoid ligament is attached to the apex and anterior and posterior borders of the medial malleolus.

AnyRefNode AnteriorMedialMalleolus = \{sRel = .Scale((0.0225,0.0254,-0.2826));\};
AnyRefNode ApexMedialMalleolus = \{sRel = .Scale((0.0190,0.0292,-0.2823));\};
AnyRefNode PosteriorMedialMalleolus = \{sRel = .Scale((0.0140,0.0315,-0.2824));\};

The anterior talofibular ligament passes from the anterior margin of the fibular malleolus.

AnyRefNode AnteriorLateralMalleolus = \{sRel = .Scale((-0.0068,-0.0284,-0.2969));\};

The posterior talofibular ligament runs from the depression at the medial and back part of the fibular malleolus.

AnyRefNode ApexLateralMalleolus = \{sRel = .Scale((-0.0126,-0.0291,-0.2954));\};

The calcaneofibular ligament runs from the apex of the fibular malleolus.

AnyRefNode PosteriorLateralMalleolus = \{sRel = .Scale((-0.0127,-0.0170,-0.2961));\};
// Talus Segment (57% mass of TNC)
AnyVar Mass_Talus = 0.00422*0.57*.Scaling.AnthroData.BodyMass;
// Geometry = Cylinder with x=long axis
AnyVar Length_Talus = 0.055; //m
AnyVar Radius_Talus = 0.019; //m
AnyVar Ixx_Talus = 0.5*Mass_Talus*Radius_Talus*Radius_Talus;
AnyVar Iyy_Talus = 0.25*Mass_Talus*Radius_Talus*Radius_Talus + 1/12*Mass_Talus*Length_Talus*Length_Talus;
AnyVar Izz_Talus = Iyy_Talus;
//Jii = {Ixx,Iyy,Izz};
AnyVar d_TalusX = 0.2/1000;
AnyVar d_TalusY = -34.0/1000;
AnyVar d_TalusZ = 12.9/1000;

// Calcaneus
AnyVar Mass_Calcaneus = 0.00423*.Scaling.AnthroData.BodyMass;
// Geometry = Cylinder
AnyVar Length_Calcaneus = 0.0740;
AnyVar Radius_Calcaneus = 0.0170;
AnyVar Ixx_Calcaneus = 0.5*Mass_Calcaneus*Radius_Calcaneus*Radius_Calcaneus;
AnyVar Iyy_Calcaneus = 0.25*Mass_Calcaneus*Radius_Calcaneus*Radius_Calcaneus + 1/12*Mass_Calcaneus*Length_Calcaneus*Length_Calcaneus;
AnyVar Izz_Calcaneus = Iyy_Calcaneus;
//Jii = {Ixx,Iyy,Izz};
AnyVar d_CalcaneusX = 0.2/1000;
AnyVar d_CalcaneusY = -34.0/1000;
AnyVar d_CalcaneusZ = 12.9/1000;

// Navicular (15% of TNC mass)
AnyVar Mass_Naviculur = 0.0465*0.15*.Scaling.AnthroData.BodyMass;
// Geometry = Elliptical cylinder with x=thickness
AnyVar Length_Naviculur = 0.0175;
AnyVar Radiusy_Naviculur = 0.0216;
AnyVar Radiusz_Naviculur = 0.0138;
AnyVar Ixx_Naviculur = Mass_Naviculur*(Radiusy_Naviculur*Radiusy_Naviculur + Radiusz_Naviculur*Radiusz_Naviculur)/4;
AnyVar Iyy_Naviculur = Mass_Naviculur*(Radiusz_Naviculur*Radiusz_Naviculur/4 + Length_Naviculur*Length_Naviculur/3);
AnyVar Izz_Naviculur = Mass_Naviculur*(Radiusy_Naviculur*Radiusy_Naviculur + Length_Naviculur*Length_Naviculur)/3;
//Jii = {Ixx,Iyy,Izz};
AnyVar d_NaviculurX = 15.4/1000;
AnyVar d_NaviculurY = -57.1/1000;
AnyVar d_NaviculurZ = -9.1/1000;

// Cuneiforms
AnyVar Mass_Cuneiforms = 0.0465*0.28*..Scaling.AnthroData.BodyMass;

// Geometry = Elliptical cylinder with x=thickness
AnyVar Length_Cuneiforms = 0.0083;
AnyVar Radiusy_Cuneiforms = 0.0180;
AnyVar Radiusz_Cuneiforms = 0.0092;

AnyVar Ixx_Cuneiforms =
Mass_Cuneiforms*(Radiusy_Cuneiforms*Radiusy_Cuneiforms +
Radiusz_Cuneiforms*Radiusz_Cuneiforms)/4;

AnyVar Iyy_Cuneiforms =
Mass_Cuneiforms*(Radiusz_Cuneiforms*Radiusz_Cuneiforms/4 +
Length_Cuneiforms*Length_Cuneiforms/3);

AnyVar Izz_Cuneiforms =
Mass_Cuneiforms*(Radiusy_Cuneiforms*Radiusy_Cuneiforms/4 +
Length_Cuneiforms*Length_Cuneiforms/3);

// Jii = {Ixx,Iyy,Izz};
AnyVar d_CuneiformsX = 15.0/1000;
AnyVar d_CuneiformsY = -63.2/1000;
AnyVar d_CuneiformsZ = -33.1/1000;

// Cuboid
AnyVar Mass_Cuboid = 0.00084*..Scaling.AnthroData.BodyMass;

// Geometry = Elliptical Cylinder, Length in x
AnyVar Length_Cuboid = 0.0348;
AnyVar Radiusy_Cuboid = 0.0122;
AnyVar Radiusz_Cuboid = 0.0142;

AnyVar Ixx_Cuboid = Mass_Cuboid*(Radiusy_Cuboid*Radiusy_Cuboid +
Radiusz_Cuboid*Radiusz_Cuboid)/4;

AnyVar Iyy_Cuboid = Mass_Cuboid*(Radiusz_Cuboid*Radiusz_Cuboid/4 +
Length_Cuboid*Length_Cuboid/3);

AnyVar Izz_Cuboid = Mass_Cuboid*(Radiusy_Cuboid*Radiusy_Cuboid/4 +
Length_Cuboid*Length_Cuboid/3);

// Jii = {Ixx,Iyy,Izz};
AnyVar d_CuboidX = -3.0/1000;
AnyVar d_CuboidY = -37.5/1000;
AnyVar d_CuboidZ = -35.0/1000;

Mass = Mass_Talus + Mass_Calcaneus + Mass_Naviculur + Mass_Cuneiforms +
Mass_Cuboid;

AnyVar Ixx = Ixx_Talus + Ixx_Calcaneus + Ixx_Naviculur + Ixx_Cuneiforms +
Ixx_Cuboid + Mass_Talus*d_TalusY*d_TalusY + Mass_Talus*d_TalusZ*d_TalusZ +
Mass_Naviculur*d_NaviculurY*d_NaviculurY +
Mass_Naviculur*d_NaviculurZ*d_NaviculurZ +
Mass_Cuneiforms*d_CuneiformsY*d_CuneiformsY +
Mass_Cuneiforms*d_CuneiformsZ*d_CuneiformsZ +
Mass_Cuboid*d_CuboidY*d_CuboidY + Mass_Cuboid*d_CuboidZ*d_CuboidZ;


Jii = {Ixx,Iyy,Izz};

AnyVec3 UnscaledAnkleJointNode = {0.0179,-0.0052,0.0376};
AnyRefNode AnkleJoint = {sRel = .Scale(.UnscaledAnkleJointNode);
  AnyDrawNode DrwNode = {ScaleXYZ = {0.01, 0.01, 0.01};RGB = {0,0,1};};
};

AnyVec3 UnscaledMidFootJointNode = {0.0704,0.0153,-0.0274};
AnyRefNode MidFootJoint = {
  sRel = .Scale(.UnscaledMidFootJointNode);
  // HindFoot_R_MidFoot
  ARel = {{0.4499,0.0966,0.8878},{0.4574,0.8289,-0.3220},{-0.7670,0.5510,0.3288}};
  AnyDrawNode DrwNode = {ScaleXYZ = {0.005, 0.005, 0.005};RGB = {0,.0,1};};
};

/// *** Muscle attachments (Calcaneus) ***
/// Gastroc Insertion: Tendo calcaneus to middle of three facets on posterior aspect of calcaneus
/// Soleus Insertion: Eventually unites with the gastrocnemius aponeurosis to form the Achilles tendon,
/// inserting on the middle 1/3 of the posterior calcaneal surface
AnyVar PosteriorTubercleCalcaneusUnscaledx = -4.73000e-002;
AnyVar PosteriorTubercleCalcaneusUnscaledy = -2.40330e-003;
AnyVar PosteriorTubercleCalcaneusUnscaledz = 1.91694e-002;
AnyRefNode PosteriorTubercleCalcaneus = {sRel = .Scale(.PosteriorTubercleCalcaneusUnscaled);};

// Extensor Hallucis and Digitoris Brevis Origin: Superior surface of anterior calcaneus
AnyVar AnteriorSuperiorSurface2CalcaneusUnscaledx = 0.0405;
AnyVar AnteriorSuperiorSurface2CalcaneusUnscaledy = -0.0151;
AnyVar AnteriorSuperiorSurface2CalcaneusUnscaledz = -0.0006;
AnyFloat AnteriorSuperiorSurface2CalcaneusUnscaled =
{AnteriorSuperiorSurface2CalcaneusUnscaledx,AnteriorSuperiorSurface2CalcaneusUnscaledy,AnteriorSuperiorSurface2CalcaneusUnscaledz};
AnyRefNode AnteriorSuperiorSurface2Calcaneus = {sRel = .Scale(.AnteriorSuperiorSurface2CalcaneusUnscaled);};
AnyVar AnteriorSuperiorSurface3CalcaneusUnscaledx = 0.0436;
AnyVar AnteriorSuperiorSurface3CalcaneusUnscaledy = -0.0067;
AnyVar AnteriorSuperiorSurface3CalcaneusUnscaledz = 0.0005;
AnyFloat AnteriorSuperiorSurface3CalcaneusUnscaled =
{AnteriorSuperiorSurface3CalcaneusUnscaledx,AnteriorSuperiorSurface3CalcaneusUnscaledy,AnteriorSuperiorSurface3CalcaneusUnscaledz};
AnyRefNode AnteriorSuperiorSurface3Calcaneus = {sRel = .Scale(.AnteriorSuperiorSurface3CalcaneusUnscaled);};

// Flexor Digitorum Brevis Origin: Medial process of posterior calcaneal tuberosity
// Abductor Hallucis Origin: Medial process of posterior calcaneal tuberosity & flexor retinaculum
AnyVar TuberosityMedialProcessCalcaneusUnscaledx = -0.0195;
AnyVar TuberosityMedialProcessCalcaneusUnscaledy = 0.0104;
AnyVar TuberosityMedialProcessCalcaneusUnscaledz = -0.0265;
AnyFloat TuberosityMedialProcessCalcaneusUnscaled =
{TuberosityMedialProcessCalcaneusUnscaledx,TuberosityMedialProcessCalcaneusUnscaledy,TuberosityMedialProcessCalcaneusUnscaledz};
AnyRefNode TuberosityMedialProcessCalcaneus = {sRel = .Scale(.TuberosityMedialProcessCalcaneusUnscaled);};

// Abductor Digiti Minimi Origin: Medial and lateral processes of posterior calcaneal tuberosity
AnyVar TuberosityCentralProcessCalcaneusUnscaledx = -0.0228;
AnyVar TuberosityCentralProcessCalcaneusUnscaledy = 0.0041;
AnyVar TuberosityCentralProcessCalcaneusUnscaledz = -0.0009;
AnyFloat TuberosityCentralProcessCalcaneusUnscaled =
{TuberosityCentralProcessCalcaneusUnscaledx,TuberosityCentralProcessCalcaneusUnscaledy,TuberosityCentralProcessCalcaneusUnscaledz};
AnyRefNode TuberosityCentralProcessCalcaneus = {sRel = .Scale(.TuberosityCentralProcessCalcaneusUnscaled);};

// *** Muscle wrapping (Calcaneus) ***
// FHL wraps under Sustentaculum tali
// Peroneals wrap under Peroneal Tuberacle
AnyVar PeronealTubercleCalcaneusUnscaledx = 2.23543e-002;//PB
AnyVar PeronealTubercleCalcaneusUnscaledy = -2.47996e-002;//PB
AnyVar PeronealTubercleCalcaneusUnscaledz = -1.24988e-002;//PB
AnyVar PeronealTubercleCalcaneusUnscaledxPL = 2.25398e-002;//PL
AnyVar PeronealTubercleCalcaneusUnscaledyPL = -2.33302e-002;//PL
AnyVar PeronealTubercleCalcaneusUnscaledzPL = -9.66485e-003;//PL
AnyFloat PeronealTubercleCalcaneusUnscaled =
{PeronealTubercleCalcaneusUnscaledx,PeronealTubercleCalcaneusUnscaledy,PeronealTubercleCalcaneusUnscaledz};
AnyRefNode PeronealTubercleCalcaneus = {sRel = .Scale(.PeronealTubercleCalcaneusUnscaled);};
AnyFloat PeronealTubercleCalcaneusUnscaledPL =
{PeronealTubercleCalcaneusUnscaledxPL,PeronealTubercleCalcaneusUnscaledyPL,PeronealTubercleCalcaneusUnscaledzPL};
AnyRefNode PeronealTubercleCalcaneusPL = {sRel = .Scale(.PeronealTubercleCalcaneusUnscaledPL);};
// Peroneus Longus wraps under Anterior Calcaneus in groove
AnyVar PeronealGrooveCalcaneusUnscaledx = 2.70212e-002;
AnyVar PeronealGrooveCalcaneusUnscaledy = -1.29073e-002;
AnyVar PeronealGrooveCalcaneusUnscaledz = -2.29653e-002;
AnyFloat PeronealGrooveCalcaneusUnscaled =
{PeronealGrooveCalcaneusUnscaledx,PeronealGrooveCalcaneusUnscaledy,PeronealGrooveCalcaneusUnscaledz};
AnyRefNode PeronealGrooveCalcaneus = {sRel = .Scale(.PeronealGrooveCalcaneusUnscaled);};

// *** Ligament Attachments (Calcaneus) ***
// Deltoid attachment at sustentaculum tali
// The Superomedical Plantar CalcaneoNavicular ligament connects the anterior margin of the sustentaculum tali of the calcaneus
// The Medial TaloCalcaneal ligament attaches to the back of the sustentaculum tali
AnyVar SustentaculumTaliCalcaneusUnscaledx = 0.019;
AnyVar SustentaculumTaliCalcaneusUnscaledy = 0.0220;
AnyVar SustentaculumTaliCalcaneusUnscaledz = 0.0094;
AnyFloat SustentaculumTaliCalcaneusUnscaled =
{SustentaculumTaliCalcaneusUnscaledx,SustentaculumTaliCalcaneusUnscaledy,SustentaculumTaliCalcaneusUnscaledz};
AnyRefNode SustentaculumTaliCalcaneus = {sRel = .Scale(.SustentaculumTaliCalcaneusUnscaled);};

// The CalcaneoFibular ligament attaches to a tubercle on the lateral surface of the calcaneus.
// The Lateral TaloCalcaneal ligament attaches to the lateral surface of the calcaneus
AnyRefNode CentralLateralTubercleCalcaneus = {sRel = .Scale({-0.0082,-0.0184,0.0115});};

// The Anterior TaloCalcaneal ligament extends to the superior surface of the calcaneus
AnyRefNode AnteriorSuperiorSurface1Calcaneus = {sRel = .Scale({0.0237,-0.0084,0.0013});};
// The Posterior TaloCalcaneal ligament attaches to the upper and medial part of the calcaneus
AnyRefNode PosteriorMedialSurfaceCalcaneus = {sRel = .Scale({-0.0029,0.0089,0.0182});};
// Interosseous TaloCalcaneal ligament attaches to a corresponding depression on the upper surface of the calcaneus
AnyRefNode AnteriorTubercleCalcaneus = {sRel = .Scale({0.0300,-0.0006,0.0083});};

// Bifurcated Ligament attached behind to the deep hollow on the upper surface of the calcaneus
AnyRefNode AnteriorLateralSuperiorHollowCalcaneus = {sRel = .Scale({0.0418,-0.0131,0.0355});};

// The Dorsal CalcaneoCuboid ligament passes between the contiguous surfaces of the calcaneus and cuboid
AnyRefNode AnteriorLateralSurfaceCalcaneus = {sRel = .Scale({0.0323,-0.0207,-0.0163});};

// Long Plantar attaches behind to the plantar surface of the calcaneus in front of the tuberosity
AnyRefNode ProximalPlantarTubercleCalcaneus = {sRel = .Scale({-0.0077,0.0023,-0.0226});};

// Plantar CalcaneoCuboid Ligament extends from the tubercle and the depression in front of it,
// on the forepart of the plantar surface of the calcaneus
AnyRefNode CentralPlantarTubercleCalcaneus = {sRel = .Scale({0.0106,0.0001,-0.0204});};

// The Inferior and Third Plantar Calcaneonavicular ligaments connect originate in notch between anterior and middle facets
AnyRefNode AnteriorMiddleFacetNotchCalcaneus = {sRel = .Scale({0.0514,0.0126,0.0299});};

// Plantarfascia Origin: The central portion is attached to the medial process of the tuberosity of the calcaneus,
// posterior to the origin of the Flexor digitorum brevis
// Share with FDB using "TuberosityMedialProcess"

// *** Muscle Via Nodes (Talus) ***
// FHL wraps behind talus in medial groove
AnyVar FHLGrooveTalusUnscaledx = 0.0018;
AnyVar FHLGrooveTalusUnscaledy = 0.0116;
AnyVar FHLGrooveTalusUnscaledz = 0.0275;
AnyVar FHLGrooveTalusUnscaled = {FHLGrooveTalusUnscaledx,FHLGrooveTalusUnscaledy,FHLGrooveTalusUnscaledz};
AnyRefNode FHLGrooveTalus = {sRel = .Scale(.FHLGrooveTalusUnscaled);};

AnyVar AnteriorMedialInferiorHeadTalusUnscaledx = 0.0371;
AnyVar AnteriorMedialInferiorHeadTalusUnscaledy = 0.0203;
AnyVar AnteriorMedialInferiorHeadTalusUnscaledz = 0.0107;

AnyVar AnteriorMedialInferiorHeadTalusUnscaledxFDL = 0.0371;
AnyVar AnteriorMedialInferiorHeadTalusUnscaledyFDL = 0.0203;
AnyVar AnteriorMedialInferiorHeadTalusUnscaledzFDL = 0.0107;

AnyFloat AnteriorMedialInferiorHeadTalusUnscaled = 
{AnteriorMedialInferiorHeadTalusUnscaledx,AnteriorMedialInferiorHeadTalusUnscaledy,AnteriorMedialInferiorHeadTalusUnscaledz};
AnyRefNode AnteriorMedialInferiorHeadTalus = {sRel = .Scale(.AnteriorMedialInferiorHeadTalusUnscaled)};

AnyFloat AnteriorMedialInferiorHeadTalusUnscaledFDL = 
{AnteriorMedialInferiorHeadTalusUnscaledxFDL,AnteriorMedialInferiorHeadTalusUnscaledyFDL,AnteriorMedialInferiorHeadTalusUnscaledzFDL};
AnyRefNode AnteriorMedialInferiorHeadTalusFDL = {sRel = .Scale(.AnteriorMedialInferiorHeadTalusUnscaledFDL)};

// *** Ligament Attachments (Talus) ***
// Deltoid ligament Anterior TibioTalar band at anterior surface of talus
AnyRefNode MedialAnteriorSurfaceTalus = {sRel = .Scale({0.0564,0.0119,0.0213})};
// Deltoid ligament Posterior TibioTalar band at posterior surface of talus
// The medial talocalcaneal ligament also connects the medial tubercle of the back of the talus
AnyRefNode PosteriorMedialTubercleTalus = {sRel = .Scale({0.0505,0.0224,0.0180})};
// The anterior talocalcaneal ligament extends from the front and lateral surface of the neck of the talus
AnyRefNode AnteriorLateralInferiorNeckTalus = {sRel = .Scale({0.0454,-0.0059,0.0110})};
// The posterior talocalcaneal ligament connects the lateral tubercle of the talus
AnyRefNode PosteriorLateralTubercle1Talus = {sRel = .Scale({-0.0004,-0.0036,0.0279})};
// The lateral talocalcaneal ligament passes from the lateral surface of the talus, immediately beneath its fibular facet
// The posterior talofibular ligament attaches to a prominent tubercle on the posterior surface of the talus
// immediately lateral to the groove for the tendon of the Flexor hallucis longus.
AnyRefNode PosteriorLateralTubercle2Talus = {sRel = .Scale({0.0170,-0.0233,0.0151})};
// Interosseous TaloCalcaneal Ligament is attached to the groove between the articular facets
// of the under surface of the talus
AnyRefNode UndersurfaceGrooveTalus = {sRel = .Scale({0.0298,0.0025,0.0164})};
// The anterior talofibular ligament attaches in front of its lateral articular facet.
AnyRefNode LateralArticularFacetTalus = {sRel = .Scale({0.0364,-0.0218,0.0358})};

// *** Muscle attachments (Navicular) ***
// Tibialis Posterior Insertion: Tuberosity of the navicular bone, and gives off fibrous expansions,
// one of which passes backward to the sustentaculum tali of the calcaneus,
// others forward and lateralward to the three cuneiforms, the cuboid,
// and the bases of the second, third, and fourth metatarsal bones.

AnyVar MedialTuberosityNavicularUnscaledx = 0.0491;//FHL
AnyVar MedialTuberosityNavicularUnscaledy = 0.0371;//FHL
AnyVar MedialTuberosityNavicularUnscaledz = 0.0115;//FHL

AnyVar MedialTuberosityNavicularUnscaledxFHL = 0.0491;//FHL
AnyVar MedialTuberosityNavicularUnscaledyFHL = 0.0371;//FHL
AnyVar MedialTuberosityNavicularUnscaledzFHL = 0.0115;//FHL

AnyFloat MedialTuberosityNavicularUnscaled =
{MedialTuberosityNavicularUnscaledx,MedialTuberosityNavicularUnscaledy,MedialTuberosityNavicularUnscaledz};
AnyRefNode MedialTuberosityNavicular = {sRel =
.Scale(.MedialTuberosityNavicularUnscaled);};

AnyFloat MedialTuberosityNavicularUnscaledFHL =
{MedialTuberosityNavicularUnscaledxFHL,MedialTuberosityNavicularUnscaledyFHL, MedialTuberosityNavicularUnscaledzFHL};
AnyRefNode MedialTuberosityNavicularFHL = {sRel =
.Scale(.MedialTuberosityNavicularUnscaledFHL);};

// *** Muscle Via Nodes ***
// Use Tib Post insertion to set paths for FHL and FDL
AnyVar SuperiorSurfaceNavicularUnscaledx = 0.0691;
AnyVar SuperiorSurfaceNavicularUnscaledy = 0.0170;
AnyVar SuperiorSurfaceNavicularUnscaledz = 0.0085;

AnyFloat SuperiorSurfaceNavicularUnscaled =
{SuperiorSurfaceNavicularUnscaledx,SuperiorSurfaceNavicularUnscaledy,SuperiorSurfaceNavicularUnscaledz};
AnyRefNode SuperiorSurfaceNavicular = {sRel =
.Scale(.SuperiorSurfaceNavicularUnscaled);};

// *** Ligament Attachments (navicular) ***
// Deltoid ligament TibioNavicular band at medial navicular, just distal to Tib Post
AnyRefNode AnteriorMedialTuberosityNavicular = {sRel =
.Scale({0.0606,0.0322,0.0082});};

// CalcaneoNavicular part of Bifurcated Ligament is attached to the lateral side of the navicular
AnyRefNode LateralSuperiorSurfaceNavicular = {sRel =
.Scale({0.0692,0.0021,0.0033});};

// The Superomedial Plantar CalcaneoNavicular ligament attaches to the medial and anterior plantar surface of the navicular.
AnyRefNode AnteriorMedialPlantarSurfaceNavicular = {sRel = .Scale({0.0631,0.0319,0.0039});};

// The Inferior Plantar CalcaneoNavicular ligament attaches to the lateral plantar surface of the navicular (beak)
AnyRefNode PosteriorLateralBeakNavicular = {sRel = .Scale({0.0512,0.0017,-0.0059});};

// The Third Plantar CalcaneoNavicular ligament attaches to the medial posterior plantar surface of the navicular
AnyRefNode PosteriorMedialPlantarSurfaceNavicular = {sRel = .Scale({0.0497,0.0305,-0.0032});};

// *** Ligament Via Nodes ***
// The Superomedial Plantar CalcaneoNavicular ligament wraps around medial navicular
AnyRefNode MedialPlantarProminence1Navicular = {sRel = .Scale({-0.0466,-0.0378,-0.0014});};
AnyRefNode MedialPlantarProminence2Navicular = {sRel = .Scale({-0.0542,-0.0305,0.0008});};

// *** Muscle Via Nodes (Cuneiforms)***
// FDL through notch created between 1st and 3rd cuneiforms
AnyVar AnteriorInferiorSurface2CuneiformsUnscaledx = 0.0622;
AnyVar AnteriorInferiorSurface2CuneiformsUnscaledy = 0.0226;
AnyVar AnteriorInferiorSurface2CuneiformsUnscaledz = -0.0536;
AnyFloat AnteriorInferiorSurface2CuneiformsUnscaled = {AnteriorInferiorSurface2CuneiformsUnscaledx,AnteriorInferiorSurface2CuneiformsUnscaledy,AnteriorInferiorSurface2CuneiformsUnscaledz};
AnyRefNode AnteriorInferiorSurface2Cuneiforms = {sRel = .Scale(.AnteriorInferiorSurface2CuneiformsUnscaled);};

// EHL
AnyVar AnteriorSuperiorSurface1aCuneiformsUnscaledx = 0.0824;
AnyVar AnteriorSuperiorSurface1aCuneiformsUnscaledy = 0.0287;
AnyVar AnteriorSuperiorSurface1aCuneiformsUnscaledz = -0.0095;
AnyFloat AnteriorSuperiorSurface1aCuneiformsUnscaled = {AnteriorSuperiorSurface1aCuneiformsUnscaledx,AnteriorSuperiorSurface1aCuneiformsUnscaledy,AnteriorSuperiorSurface1aCuneiformsUnscaledz};
AnyRefNode AnteriorSuperiorSurface1aCuneiforms = {sRel = .Scale(.AnteriorSuperiorSurface1aCuneiformsUnscaled);};

// EDL 2nd Ray
AnyVar LateralSuperiorSurface2CuneiformsUnscaledx = 0.0773;
AnyVar LateralSuperiorSurface2CuneiformsUnscaledy = 0.0076;
AnyVar LateralSuperiorSurface2CuneiformsUnscaledz = -0.0138;
AnyFloat LateralSuperiorSurface2CuneiformsUnscaled = {LateralSuperiorSurface2CuneiformsUnscaledx,LateralSuperiorSurface2CuneiformsUnscaledy,LateralSuperiorSurface2CuneiformsUnscaledz};
AnyRefNode LateralSuperiorSurface2Cuneiforms = {sRel = .Scale(LateralSuperiorSurface2CuneiformsUnscaled);};

// EDL 3rd Ray
AnyVar PosteriorSuperiorSurface3CuneiformsUnscaledx = 0.0686;
AnyVar PosteriorSuperiorSurface3CuneiformsUnscaledy = -0.0016;
AnyVar PosteriorSuperiorSurface3CuneiformsUnscaledz = -0.0119;
AnyFloat PosteriorSuperiorSurface3CuneiformsUnscaled = {PosteriorSuperiorSurface3CuneiformsUnscaledx, PosteriorSuperiorSurface3CuneiformsUnscaledy, PosteriorSuperiorSurface3CuneiformsUnscaledz};
AnyRefNode PosteriorSuperiorSurface3Cuneiforms = {sRel = .Scale(PosteriorSuperiorSurface3CuneiformsUnscaled);};

// *** Ligament Attachments (Cuneiforms) ***
// Ignore cuneonavicular ligaments since segments are rigidly joined.
// Dorsal TM Ligaments:
// The first metatarsal is joined to the first cuneiform by a broad, thin band;
// the second has three, one from each cuneiform bone; the third has one from the
// third cuneiform; the fourth has one from the third cuneiform and one from the
cuboid;
// and the fifth, one from the cuboid
// 1st Dorsal TM ligament
AnyRefNode AnteriorSuperiorSurface1Cuneiforms = {sRel = .Scale({0.0753,0.0384,-0.0120});};
// 2nd Dorsal TM ligament: 3 bands
// Medial band
AnyRefNode LateralSuperiorSurface1Cuneiforms = {sRel = .Scale({0.0859,0.0240,-0.0127});};
// Central Band
AnyRefNode AnteriorSuperiorSurface2Cuneiforms = {sRel = .Scale({0.0833,0.0151,-0.0129});};
// Lateral Band
AnyRefNode MedialSuperiorSurface3Cuneiforms = {sRel = .Scale({0.0744,0.0017,-0.0186});};
// 3rd Dorsal TM ligament
AnyRefNode AnteriorSuperiorSurface3Cuneiforms = {sRel = .Scale({0.0743,0.0004,-0.0235});};
// 4th Dorsal TM ligament
AnyRefNode LateralSuperiorSurface3Cuneiforms = {sRel = .Scale({0.0688,-0.0025,-0.0213});};
// Plantar TM Ligaments:
// The plantar ligaments consist of longitudinal and oblique bands, disposed with
// less regularity than the dorsal ligaments. Those for the first and second metatarsals
// are the strongest; the second and third metatarsals are joined by oblique bands to the
// first cuneiform; the fourth and fifth metatarsals are connected by a few fibers to the
cuboid
// 1st Plantar TM ligament: there may be three bands, but all are to the 1st cuneiform, approximate
// as one band, with slight lateral positioning
  AnyRefNode AnteriorLateralInferiorSurface1Cuneiforms = {sRel = .Scale({0.0521,0.0301,-0.0256});};
// 2nd Plantar TM ligament
  AnyRefNode AnteriorLateralSurface1Cuneiforms = {sRel = .Scale({0.0588,0.0254,-0.0242});};
// 3rd Plantar TM ligament
  AnyRefNode LateralSurface1Cuneiforms = {sRel = .Scale({0.0541,0.0250,-0.0207});};

// *** Muscle Attachments (Cuboid) ***
// Felxor Hallucis Brevis Origin: Cuboid, lateral cuneiform and tibialis posterior
// insertion over the two remaining cuneiforms
  AnyVar PosteriorMedialInferiorSurfaceCuboidUnscaledx = 0.0390;
  AnyVar PosteriorMedialInferiorSurfaceCuboidUnscaledy = 0.0107;
  AnyVar PosteriorMedialInferiorSurfaceCuboidUnscaledz = -0.0162;
  AnyFloat PosteriorMedialInferiorSurfaceCuboidUnscaled =
    {PosteriorMedialInferiorSurfaceCuboidUnscaledx,PosteriorMedialInferiorSurfaceCuboidUnscaledy,PosteriorMedialInferiorSurfaceCuboidUnscaledz};
  AnyRefNode PosteriorMedialInferiorSurfaceCuboid = {sRel = .Scale(.PosteriorMedialInferiorSurfaceCuboidUnscaled);};

// *** Muscle Via Nodes (Cuboid)***
// Peroneus Longus wraps below cuboid via groove
  AnyVar PeronealGrooveCuboidUnscaledx = 0.0322;
  AnyVar PeronealGrooveCuboidUnscaledy = -0.0036;
  AnyVar PeronealGrooveCuboidUnscaledz = -0.0356;
  AnyFloat PeronealGrooveCuboidUnscaled =
    {PeronealGrooveCuboidUnscaledx,PeronealGrooveCuboidUnscaledy,PeronealGrooveCuboidUnscaledz};
  AnyRefNode PeronealGrooveCuboid = {sRel = .Scale(.PeronealGrooveCuboidUnscaled);};

// EDL 4
  AnyVar PosteriorMedialSuperiorSurface1CuboidUnscaledx = 0.0568;
  AnyVar PosteriorMedialSuperiorSurface1CuboidUnscaledy = -0.0055;
  AnyVar PosteriorMedialSuperiorSurface1CuboidUnscaledz = -0.0145;
  AnyFloat PosteriorMedialSuperiorSurface1CuboidUnscaled =
    {PosteriorMedialSuperiorSurface1CuboidUnscaledx,PosteriorMedialSuperiorSurface1CuboidUnscaledy,PosteriorMedialSuperiorSurface1CuboidUnscaledz};
  AnyRefNode PosteriorMedialSuperiorSurface1Cuboid = {sRel = .Scale(.PosteriorMedialSuperiorSurface1CuboidUnscaled);};
// *** Ligament Attachments (Cuboid) ***
// Calcaneocuboid part of bifurcated ligament is fixed to the medial side of the cuboid
// AnyRefNode PosteriorMedialSuperiorSurface = {sRel = {-0.0025,0.0170,-0.0036};};
// AnyRefNode PosteriorMedialSuperiorSurface2Cuboid = {sRel =
// .Scale({0.0501,0.0115,-0.0129});};
// Dorsal calcaneocuboid ligament passes between the contiguous surfaces of the
calcaneus and cuboid
AnyRefNode LateralDorsalTuberosityCuboid = {sRel = .Scale({0.0471,-0.0118,-
0.0168});};
// Dorsal 4th MT - Central Band
AnyRefNode LateralSuperiorSurface1Cuboid = {sRel = .Scale({0.0420,-0.0131,-
0.0334});};
// Dorsal 5th MT - Central Band
AnyRefNode LateralSuperiorSurface2Cuboid = {sRel = .Scale({0.0364,-0.0134,-
0.0309});};
// Long Plantar attaches in front to the tuberosity on the plantar surface of the cuboid bone
AnyRefNode PlantarTuberosityCuboid = {sRel = .Scale({0.0294,0.0042,-0.0311});};
// Plantar CalcanealCuboid Ligament attaches to plantar surface of the cuboid behind
the peroneal groove
AnyRefNode MedialInferiorSurfaceCuboid = {sRel = .Scale({0.0408,0.0099,-
0.0321});};
AnyRefNode CalcaneusSTLNode = {
sRel = .Scale({0.0537,-0.1422,0.4789});
// Calcaneus_R_G
ARel = {{-0.0540,-0.9739,-0.2204},{0.9964,-0.0380,-0.0760},{0.0656,-
0.2237,0.9724}};
AnyDrawSTL DrwSTL = {
FileName = "STL\Calcaneus.stl";
ScaleXYZ = .Scale({0.001, 0.001, 0.001});
RGB = {0.7,1,0};
//Transparency = 0.5;
};
AnyRefNode TalusSTLNode = {
sRel = .Scale({0.0537,-0.1422,0.4789});
// Calcaneus_R_G
ARel = {{-0.0540,-0.9739,-0.2204},{0.9964,-0.0380,-0.0760},{0.0656,-
0.2237,0.9724}};

AnyDrawSTL DrwSTL = {
    FileName = "STL\Talus.stl";
    ScaleXYZ = .Scale({0.001, 0.001, 0.001});
    RGB = {0.7,1,0};
    //Transparency = 0.5;
};

AnyRefNode NavicularSTLNode = {
    sRel = .Scale({0.0537, -0.1422, 0.4789});
    //sRel = {-0.1105,0.1017,0.4648};
    // Calcaneus_R_G
    ARel = {{-0.0540,-0.9739,-0.2204},{0.9964,-0.0380,-0.0760},{0.0656,-
0.2237,0.9724}};
    AnyDrawSTL DrwSTL = {
        FileName = "STL\Navicular.stl";
        ScaleXYZ = .Scale({0.001, 0.001, 0.001});
        RGB = {0.7,1,0};
        //Transparency = 0.5;
    };}

AnyRefNode CuneiformsSTLNode = {
    sRel = .Scale({0.0537, -0.1422, 0.4789});
    // Calcaneus_R_G
    ARel = {{-0.0540,-0.9739,-0.2204},{0.9964,-0.0380,-0.0760},{0.0656,-
0.2237,0.9724}};
    AnyDrawSTL DrwSTL = {
        FileName = "STL\Cuneiforms.stl";
        ScaleXYZ = .Scale({0.001, 0.001, 0.001});
        RGB = {0.7,1,0};
        //Transparency = 0.5;
    };}

AnyRefNode CuboidSTLNode = {
    sRel = .Scale({0.0537, -0.1422, 0.4789});
    // Calcaneus_R_G
    ARel = {{-0.0540,-0.9739,-0.2204},{0.9964,-0.0380,-0.0760},{0.0656,-
0.2237,0.9724}};
    AnyDrawSTL DrwSTL = {
        FileName = "STL\Cuboid.stl";
        ScaleXYZ = .Scale({0.001, 0.001, 0.001});
        RGB = {0.7,1,0};
        //Transparency = 0.5;
    };
}
// HindFoot

}; // End of HindFoot

// Midfoot

AnySeg MidFoot = {

AnyFunTransform3DLin &Scale =
..Scaling.GeometricalScaling.MidFoot.ScaleFunction;
  r0 = {0.1297,0.0714,-0.5428};
//G_R_MidFoot
  Axes0 = {{0.3811,0.8569,-0.3472},{-0.2840,-0.2489,-0.9260},{-0.8798,0.4515,0.1485}};
// Approximate 30% of forefoot mass

  AnyVar Mass_MT1 = 0.30*0.00421*..Scaling.AnthroData.BodyMass;
  // Geometry = Eliptical Cylinder
  AnyVar Length_MT1 = 0.0644;
  AnyVar Radiusy_MT1 = 0.0100;
  AnyVar Radiusz_MT1 = 0.0122;
  AnyVar Ixx_MT1 = Mass_MT1*(Radiusy_MT1*Radiusy_MT1 + Radiusz_MT1*Radiusz_MT1)/4;
  AnyVar Iyy_MT1 = Mass_MT1*(Radiusz_MT1*Radiusz_MT1/4 + Length_MT1*Length_MT1/3);
  AnyVar Izz_MT1 = Mass_MT1*(Radiusy_MT1*Radiusy_MT1/4 + Length_MT1*Length_MT1/3);
  //Jii = {Ixx,Iyy,Izz};
  AnyVar d_MT1X = 28.7/1000;
  AnyVar d_MT1Y = 12.5/1000;
  AnyVar d_MT1Z = 5.0/1000;

// 2nd MT
// Approximate 25% of forefoot mass

  AnyVar Mass_MT2 = 0.25*0.00421*..Scaling.AnthroData.BodyMass;
  // Geometry = Eliptical Cylinder
  AnyVar Length_MT2 = 0.0764;
  AnyVar Radiusy_MT2 = 0.0061;
  AnyVar Radiusz_MT2 = 0.0058;
  AnyVar Ixx_MT2 = Mass_MT2*(Radiusy_MT2*Radiusy_MT2 + Radiusz_MT2*Radiusz_MT2)/4;
  AnyVar Iyy_MT2 = Mass_MT2*(Radiusz_MT2*Radiusz_MT2/4 + Length_MT2*Length_MT2/3);
  AnyVar Izz_MT2 = Mass_MT2*(Radiusy_MT2*Radiusy_MT2/4 + Length_MT2*Length_MT2/3);
  //Jii = {Ixx,Iyy,Izz};
  AnyVar d_MT2X = 8.6/1000;
AnyVar d_MT2Y = 5.6/1000;
AnyVar d_MT2Z = 4.0/1000;

// 3rd MT
// ------
AnyVar Mass_MT3 = 0.20*0.00421*..Scaling.AnthroData.BodyMass;
// Geometry = Eliptical Cylinder
AnyVar Length_MT3 = 0.0754;
AnyVar Radiusy_MT3 = 0.0103;
AnyVar Radiusz_MT3 = 0.0072;
AnyVar Ixx_MT3 = Mass_MT3*(Radiusy_MT3*Radiusy_MT3 + Radiusz_MT3*Radiusz_MT3)/4;
AnyVar Iyy_MT3 = Mass_MT3*(Radiusz_MT3*Radiusz_MT3/4 + Length_MT3*Length_MT3/3);
AnyVar Izz_MT3 = Mass_MT3*(Radiusy_MT3*Radiusy_MT3/4 + Length_MT3*Length_MT3/3);
// Jii = {Ixx,Iyy,Izz};
AnyVar d_MT3X = -3.7/1000;
AnyVar d_MT3Y = 9.0/1000;
AnyVar d_MT3Z = -2.8/1000;

// 4th MT
// ------
// 4th metatarsal motion and coordinates derived from the lateral forefoot (LatMT) segment.
AnyVar Mass_MT4 = 0.10*0.00421*..Scaling.AnthroData.BodyMass;
// Geometry = Eliptical Cylinder
AnyVar Length_MT4 = 0.0740;
AnyVar Radiusy_MT4 = 0.0073;
AnyVar Radiusz_MT4 = 0.0066;
AnyVar Ixx_MT4 = Mass_MT4*(Radiusy_MT4*Radiusy_MT4 + Radiusz_MT4*Radiusz_MT4)/4;
AnyVar Iyy_MT4 = Mass_MT4*(Radiusz_MT4*Radiusz_MT4/4 + Length_MT4*Length_MT4/3);
AnyVar Izz_MT4 = Mass_MT4*(Radiusy_MT4*Radiusy_MT4/4 + Length_MT4*Length_MT4/3);
// Jii = {Ixx,Iyy,Izz};
AnyVar d_MT4X = -13.9/1000;
AnyVar d_MT4Y = 19.0/1000;
AnyVar d_MT4Z = -5.7/1000;

// 5th MT
// 5th metatarsal motion and coordinates derived from the lateral forefoot (LatMT) segment.
AnyVar Mass_MT5 = 0.15*0.00421*..Scaling.AnthroData.BodyMass;
// Geometry = Eliptical Cylinder
AnyVar Length_MT5 = 0.0765;
AnyVar Radiusy_MT5 = 0.0076;
AnyVar Radiusz_MT5 = 0.0069;
AnyVar lxx_MT5 = Mass_MT5*(Radiusy_MT5*Radiusy_MT5 + Radiusz_MT5*Radiusz_MT5)/4;
AnyVar lyy_MT5 = Mass_MT5*(Radiusz_MT5*Radiusz_MT5/4 + Length_MT5*Length_MT5/3);
AnyVar lzz_MT5 = Mass_MT5*(Radiusy_MT5*Radiusy_MT5/4 + Length_MT5*Length_MT5/3);
//Jii = {lxx, lyy, lzz};
AnyVar d_MT5X = -30.2/1000;
AnyVar d_MT5Y = 39.5/1000;
AnyVar d_MT5Z = -2.0/1000;

Mass = Mass_MT1 + Mass_MT2 + Mass_MT3 + Mass_MT4 + Mass_MT5;
AnyVar lyy = lyy_MT1 + lyy_MT2 + lyy_MT3 + lyy_MT4 + lyy_MT5 + Mass_MT1*d_MT1X*d_MT1X + Mass_MT1*d_MT1Z*d_MT1Z + Mass_MT2*d_MT2X*d_MT2X + Mass_MT2*d_MT2Z*d_MT2Z + Mass_MT3*d_MT3X*d_MT3X + Mass_MT3*d_MT3Z*d_MT3Z + Mass_MT4*d_MT4X*d_MT4X + Mass_MT4*d_MT4Z*d_MT4Z + Mass_MT5*d_MT5X*d_MT5X + Mass_MT5*d_MT5Z*d_MT5Z;
Jii = {lxx, lyy, lzz};

AnyVec3 UnscaledMidFootJointNode = {-0.0388, 0.0049, -0.0106};
AnyRefNode MidFootJoint = {sRel = .Scale(UnscaledMidFootJointNode);
AnyDrawNode DrwNode = {ScaleXYZ = .Scale({0.005, 0.005, 0.005});RGB = {1,0,0};};
AnyVec3 UnscaledToeJointNode = {0.0339, 0.0267, -0.0185};
AnyRefNode ToeJoint = {
sRel = .Scale(UnscaledToeJointNode);
// ** MidFoot_R_Toe **
ARel = {{{0.9281,0.2110,-0.3068}, {-0.1966,0.9774,0.0775},{0.3162,-0.0116,0.9486}} ;
AnyDrawNode DrwNode = {ScaleXYZ = .Scale({0.005, 0.005, 0.005});RGB = {1,0,0};};
AnyVec3 UnscaledMP2JointNode = {0.0370,0.0051,-0.0079};
AnyRefNode MP2Joint = {
  sRel = .Scale(.UnscaledMP2JointNode);
//MidFoot_R_MP2Joint
  ARel = {{{0.7838,-0.0112,-0.6210},{0.1760,0.9629,0.2047},{0.5956,-0.2697,0.7567}} ;
};

AnyVec3 UnscaledMP3JointNode = {0.0359,-0.0082,-0.0040};
AnyRefNode MP3Joint = {
  sRel = .Scale(.UnscaledMP3JointNode);
//MidFoot_R_MP3Joint
  ARel = {{{0.7838,-0.0112,-0.6210},{0.1760,0.9629,0.2047},{0.5956,-0.2697,0.7567}} ;
};

AnyVec3 UnscaledMP4JointNode = {0.0297,-0.0243,-0.0041};
AnyRefNode MP4Joint = {
  sRel = .Scale(.UnscaledMP4JointNode);
//MidFoot_R_MP4Joint
  ARel = {{{0.5043,0.3891,-0.7709},{0.1260,0.8500,0.5115},{0.8543,-0.3551,0.3796}}} ;
};

AnyVec3 UnscaledMP5JointNode = {0.0129,-0.0404,-0.0073};
AnyRefNode MP5Joint = {
  sRel = .Scale(.UnscaledMP5JointNode);
//MidFoot_R_MP5Joint
  ARel = {{{0.5043,0.3891,-0.7709},{0.1260,0.8500,0.5115},{0.8543,-0.3551,0.3796}}} ;
};

// *** Muscle attachments (MT1) ***
// Peroneus Longus Insertion: Plantar posterolateral aspect of medial cuneiform and lateral side of 1st metatarsal base
AnyVar PosteriorLateralTubercleMT1Unscaledx = -0.0265;
AnyVar PosteriorLateralTubercleMT1Unscaledy = 0.0104;
AnyVar PosteriorLateralTubercleMT1Unscaledz = -0.0251;
AnyFloat PosteriorLateralTubercleMT1Unscaled = 
{PosteriorLateralTubercleMT1Unscaledx,PosteriorLateralTubercleMT1Unscaledy,PosteriorLateralTubercleMT1Unscaledz};
AnyRefNode PosteriorLateralTubercleMT1 = {sRel = .Scale(.PosteriorLateralTubercleMT1Unscaled);};

// Tibialis Anterior Insertion: Medial and plantar surfaces of 1st cuneiform and on base of first metatarsal
AnyVar PosteriorMedialTubercleMT1Unscaledx = -2.29423e-002;
AnyVar PosteriorMedialTubercleMT1Unscaledy = 3.32283e-002;
AnyVar PosteriorMedialTubercleMT1Unscaledz = -1.50300e-002;
AnyFloat PosteriorMedialTubercleMT1Unscaled = 
{PosteriorMedialTubercleMT1Unscaledx,PosteriorMedialTubercleMT1Unscaledy,PosteriorMedialTubercleMT1Unscaledz};
AnyRefNode PosteriorMedialTubercleMT1 = {sRel = .Scale(.PosteriorMedialTubercleMT1Unscaled);};

// *** Muscle Via Nodes ***
// FHL
AnyVar PosteriorInferiorTuberosityMT1Unscaledx = -0.0226;
AnyVar PosteriorInferiorTuberosityMT1Unscaledy = 0.0175;
AnyVar PosteriorInferiorTuberosityMT1Unscaledz = -0.0297;
AnyFloat PosteriorInferiorTuberosityMT1Unscaled = 
{PosteriorInferiorTuberosityMT1Unscaledx,PosteriorInferiorTuberosityMT1Unscaledy,PosteriorInferiorTuberosityMT1Unscaledz};
AnyRefNode PosteriorInferiorTuberosityMT1 = {sRel = .Scale(.PosteriorInferiorTuberosityMT1Unscaled);};

// FHL and FHB
AnyVar AnteriorInferiorNotchMT1Unscaledx = 0.0289;
AnyVar AnteriorInferiorNotchMT1Unscaledy = 0.0225;
AnyVar AnteriorInferiorNotchMT1Unscaledz = -0.0305;
AnyFloat AnteriorInferiorNotchMT1Unscaled = 
{AnteriorInferiorNotchMT1Unscaledx,AnteriorInferiorNotchMT1Unscaledy,AnteriorInferiorNotchMT1Unscaledz};
AnyRefNode AnteriorInferiorNotchMT1 = {sRel = .Scale(.AnteriorInferiorNotchMT1Unscaled);};

// EHL and EHB
AnyVar AnteriorSuperiorSurfaceMT1Unscaledx = -0.0220;
AnyVar AnteriorSuperiorSurfaceMT1Unscaledy = 0.0300;
AnyVar AnteriorSuperiorSurfaceMT1Unscaledz = -0.0039;
AnyFloat AnteriorSuperiorSurfaceMT1Unscaled = 
{AnteriorSuperiorSurfaceMT1Unscaledx,AnteriorSuperiorSurfaceMT1Unscaledy,AnteriorSuperiorSurfaceMT1Unscaledz};
AnyRefNode AnteriorSuperiorSurfaceMT1 = {sRel = .Scale(.AnteriorSuperiorSurfaceMT1Unscaled);};

AnyVar PosteriorSuperiorSurfaceMT1Unscaledx = 0.0258;
AnyVar PosteriorSuperiorSurfaceMT1Unscaledy = 0.0377;
AnyVar PosteriorSuperiorSurfaceMT1Unscaledz = -0.0106;
AnyFloat PosteriorSuperiorSurfaceMT1Unscaled = {PosteriorSuperiorSurfaceMT1Unscaledx,PosteriorSuperiorSurfaceMT1Unscaledy,PosteriorSuperiorSurfaceMT1Unscaledz};
AnyRefNode PosteriorSuperiorSurfaceMT1 = {sRel = .Scale(.PosteriorSuperiorSurfaceMT1Unscaled);};

// *** Ligaments (MT1) ***
//The first metatarsal is joined to the first cuneiform by a broad, thin band
//Dorsal is slightly lateral
AnyRefNode PosteriorLateralSuperiorTuberosityMT1 = {sRel = .Scale({-0.0226,0.0310,0.0049});};
//Plantar is slightly lateral
AnyRefNode PosteriorLateralInferiorTuberosityMT1 = {sRel = .Scale({-0.0256,0.0162,-0.03114});};

// *** Ligament Via Nodes ***
//Plantar Fascia shares Anterior Interior Notch

// *** Muscle via nodes (MT2) ***
// FDL 2
AnyVar PosteriorInferiorTuberosityMT2Unscaledx = -0.0329;
AnyVar PosteriorInferiorTuberosityMT2Unscaledy = 0.0085;
AnyVar PosteriorInferiorTuberosityMT2Unscaledz = -0.0174;
AnyFloat PosteriorInferiorTuberosityMT2Unscaled = {PosteriorInferiorTuberosityMT2Unscaledx,PosteriorInferiorTuberosityMT2Unscaledy,PosteriorInferiorTuberosityMT2Unscaledz};
AnyRefNode PosteriorInferiorTuberosityMT2 = {sRel = .Scale(.PosteriorInferiorTuberosityMT2Unscaled);};

// FDL 2 and FDB 2
AnyVar AnteriorInferiorNotchMT2Unscaledx = 0.0295;
AnyVar AnteriorInferiorNotchMT2Unscaledy = 0.0079;
AnyVar AnteriorInferiorNotchMT2Unscaledz = -0.0176;
AnyFloat AnteriorInferiorNotchMT2Unscaled = {AnteriorInferiorNotchMT2Unscaledx,AnteriorInferiorNotchMT2Unscaledy,AnteriorInferiorNotchMT2Unscaledz};
AnyRefNode AnteriorInferiorNotchMT2 = {sRel = .Scale(.AnteriorInferiorNotchMT2Unscaled);};

// EDL 2
AnyVar PosteriorMedialSuperiorTuberosityMT2Unscaledx = -0.0330;
AnyVar PosteriorMedialSuperiorTuberosityMT2Unscaledy = 0.0032;
AnyVar PosteriorMedialSuperiorTuberosityMT2Unscaledz = 0.0033;
AnyFloat PosteriorMedialSuperiorTuberosityMT2Unscaled =
{PosteriorMedialSuperiorTuberosityMT2Unscaledx,PosteriorMedialSuperiorTuberosityMT2Unscaledy,PosteriorMedialSuperiorTuberosityMT2Unscaledz};
AnyRefNode PosteriorMedialSuperiorTuberosityMT2 = {sRel = 
.Scale(.PosteriorMedialSuperiorTuberosityMT2Unscaled);};

AnyVar AnteriorSuperiorTuberosityMT2Unscaledx = 0.0258;
AnyVar AnteriorSuperiorTuberosityMT2Unscaledy = 0.0137;
AnyVar AnteriorSuperiorTuberosityMT2Unscaledz = -0.0031;
AnyFloat AnteriorSuperiorTuberosityMT2Unscaled =
{AnteriorSuperiorTuberosityMT2Unscaledx,AnteriorSuperiorTuberosityMT2Unscaledy, AnteriorSuperiorTuberosityMT2Unscaledz};
AnyRefNode AnteriorSuperiorTuberosityMT2 = {sRel = 
.Scale(.AnteriorSuperiorTuberosityMT2Unscaled);};

// *** Ligaments (MT2) ***
// The second has three dorsal attachments, one from each cuneiform bone.
// Central Band
AnyRefNode PosteriorSuperiorTuberosityMT2 = {sRel = .Scale({-
0.0351,0.0079,0.0039});};
// Medial Band shares EDL via AnteriorSuperiorTuberosityMT2 at PosteriorMedialSuperiorTuberosity
// Lateral Band
AnyRefNode PosteriorLateralSuperiorTuberosityMT2 = {sRel = .Scale({-
0.0330,0.0032,0.0033});};
// On the plantar side, the second metatarsal is joined by an oblique band to the first cuneiform.
AnyRefNode PosteriorLateralInferiorTuberosityMT2 = {sRel = .Scale({-
0.0353,0.0016,-0.0054});};
// *** Ligament Via Nodes ***
// Plantar Fascia shares Anterior Interior Notch
// *** Muscle Via Nodes (MT3) ***
// FDL 3
AnyVar PosteriorInferiorTuberosityMT3Unscaledx = -0.0338;
AnyVar PosteriorInferiorTuberosityMT3Unscaledy = 0.0015;
AnyVar PosteriorInferiorTuberosityMT3Unscaledz = -0.0059;
AnyFloat PosteriorInferiorTuberosityMT3Unscaled =
{PosteriorInferiorTuberosityMT3Unscaledx,PosteriorInferiorTuberosityMT3Unscaledy,PosteriorInferiorTuberosityMT3Unscaledz};
AnyRefNode PosteriorInferiorTuberosityMT3 = {sRel = 
.Scale(.PosteriorInferiorTuberosityMT3Unscaled);};

// FDL 3 and FDB 3
AnyVar AnteriorInferiorNotchMT3Unscaledx = 0.0279;
AnyVar AnteriorInferiorNotchMT3Unscaledy = -0.0050;
AnyVar AnteriorInferiorNotchMT3Unscaledz = -0.0150;
AnyFloat AnteriorInferiorNotchMT3Unscaled =
{AnteriorInferiorNotchMT3Unscaledx,AnteriorInferiorNotchMT3Unscaledy,AnteriorInferiorNotchMT3Unscaledz};
AnyRefNode AnteriorInferiorNotchMT3 = {sRel = .Scale(.AnteriorInferiorNotchMT3Unscaled)};

// EDL 3
AnyVar PosteriorMedialSuperiorTuberosityMT3Unscaledx = -0.0314;
AnyVar PosteriorMedialSuperiorTuberosityMT3Unscaledy = -0.0026;
AnyVar PosteriorMedialSuperiorTuberosityMT3Unscaledz = -0.0007;
AnyFloat PosteriorMedialSuperiorTuberosityMT3Unscaled =
{PosteriorMedialSuperiorTuberosityMT3Unscaledx,PosteriorMedialSuperiorTuberosityMT3Unscaledy,PosteriorMedialSuperiorTuberosityMT3Unscaledz};
AnyRefNode PosteriorMedialSuperiorTuberosityMT3 = {sRel = .Scale(.PosteriorMedialSuperiorTuberosityMT3Unscaled)};

AnyVar AnteriorSuperiorTuberosityMT3Unscaledx = 0.0270;
AnyVar AnteriorSuperiorTuberosityMT3Unscaledy = -0.0074;
AnyVar AnteriorSuperiorTuberosityMT3Unscaledz = 0.0009;
AnyFloat AnteriorSuperiorTuberosityMT3Unscaled =
{AnteriorSuperiorTuberosityMT3Unscaledx,AnteriorSuperiorTuberosityMT3Unscaledy,AnteriorSuperiorTuberosityMT3Unscaledz};
AnyRefNode AnteriorSuperiorTuberosityMT3 = {sRel = .Scale(.AnteriorSuperiorTuberosityMT3Unscaled)};

// EDL 4
AnyVar PosteriorLateralSuperiorTuberosityMT3Unscaledx = -0.0307;
AnyVar PosteriorLateralSuperiorTuberosityMT3Unscaledy = -0.0115;
AnyVar PosteriorLateralSuperiorTuberosityMT3Unscaledz = -0.0052;
AnyFloat PosteriorLateralSuperiorTuberosityMT3Unscaled =
{PosteriorLateralSuperiorTuberosityMT3Unscaledx,PosteriorLateralSuperiorTuberosityMT3Unscaledy,PosteriorLateralSuperiorTuberosityMT3Unscaledz};
AnyRefNode PosteriorLateralSuperiorTuberosityMT3 = {sRel = .Scale(.PosteriorLateralSuperiorTuberosityMT3Unscaled)};

// *** Ligaments (MT3) ***
// The third MT has one dorsal from the third cuneiform;
AnyRefNode PosteriorSuperiorTuberosityMT3 = {sRel = .Scale({-0.0325,-0.0072,-0.0023})};

// On the plantar side, the third metatarsal is joined by an oblique band to the first cuneiform.
AnyRefNode PosteriorMedialInferiorTuberosityMT3 = {sRel = .Scale({-0.0307,-0.0022,-0.0204})};
// *** Ligament Via Nodes ***
// Plantar Fascia shares Anterior Interior Notch
// *** Muscle Via Nodes (MT4) ***
// FDL 4
   AnyVar PosteriorInferiorTuberosityMT4Unscaledx = -0.0233;
   AnyVar PosteriorInferiorTuberosityMT4Unscaledy = -0.0192;
   AnyVar PosteriorInferiorTuberosityMT4Unscaledz = -0.0288;
   AnyFloat PosteriorInferiorTuberosityMT4Unscaled =
      {PosteriorInferiorTuberosityMT4Unscaledx,PosteriorInferiorTuberosityMT4Unscaledy,PosteriorInferiorTuberosityMT4Unscaledz};
   AnyRefNode PosteriorInferiorTuberosityMT4 = {sRel =
      .Scale(.PosteriorInferiorTuberosityMT4Unscaled)};

// FDL 4 and FDB 4
   AnyVar AnteriorInferiorNotchMT4Unscaledx = 0.0229;
   AnyVar AnteriorInferiorNotchMT4Unscaledy = -0.0223;
   AnyVar AnteriorInferiorNotchMT4Unscaledz = -0.0191;
   AnyFloat AnteriorInferiorNotchMT4Unscaled =
      {AnteriorInferiorNotchMT4Unscaledx,AnteriorInferiorNotchMT4Unscaledy,AnteriorInferiorNotchMT4Unscaledz};
   AnyRefNode AnteriorInferiorNotchMT4 = {sRel =
      .Scale(.AnteriorInferiorNotchMT4Unscaled)};

// EDL 4
   AnyVar AnteriorSuperiorTuberosityMT4Unscaledx = 0.0204;
   AnyVar AnteriorSuperiorTuberosityMT4Unscaledy = -0.0193;
   AnyVar AnteriorSuperiorTuberosityMT4Unscaledz = -0.0021;
   AnyFloat AnteriorSuperiorTuberosityMT4Unscaled =
      {AnteriorSuperiorTuberosityMT4Unscaledx,AnteriorSuperiorTuberosityMT4Unscaledy,AnteriorSuperiorTuberosityMT4Unscaledz};
   AnyRefNode AnteriorSuperiorTuberosityMT4 = {sRel =
      .Scale(.AnteriorSuperiorTuberosityMT4Unscaled)};

// EDL 5
   AnyVar PosteriorSuperiorTuberosityMT4Unscaledx = -0.0381;
   AnyVar PosteriorSuperiorTuberosityMT4Unscaledy = -0.0227;
   AnyVar PosteriorSuperiorTuberosityMT4Unscaledz = -0.0156;
   AnyFloat PosteriorSuperiorTuberosityMT4Unscaled =
      {PosteriorSuperiorTuberosityMT4Unscaledx,PosteriorSuperiorTuberosityMT4Unscaledy,PosteriorSuperiorTuberosityMT4Unscaledz};
   AnyRefNode PosteriorSuperiorTuberosityMT4 = {sRel =
      .Scale(.PosteriorSuperiorTuberosityMT4Unscaled)};

// *** Ligaments (MT4) ***
// The fourth has one dorsal ligament from the third cuneiform and one from the cuboid
// Central band to cuboid, shares point with EDL 5 via point at Posterior Superior Tuberosity
// Medial band to 3rd cuneiform
AnyRefNode PosteriorMedialSuperiorTuberosityMT4 = {sRel = .Scale({-0.0334, -0.0192, -0.0114});};
// No true plantar ligaments

// *** Ligament Via Nodes ***
// Plantar Fascia shares Anterior Interior Notch
// *** Muscle Attachments (MT5) ***
// Peroneus Brevis Insertion: Tuberosity of base of 5th metatarsal
AnyVar PosteriorLateralSuperiorTuberosityMT5Unscaledx = -0.0473;
AnyVar PosteriorLateralSuperiorTuberosityMT5Unscaledy = -0.0390;
AnyVar PosteriorLateralSuperiorTuberosityMT5Unscaledz = -0.0395;
AnyFloat PosteriorLateralSuperiorTuberosityMT5Unscaled = {PosteriorLateralSuperiorTuberosityMT5Unscaledx, PosteriorLateralSuperiorTuberosityMT5Unscaledy, PosteriorLateralSuperiorTuberosityMT5Unscaledz};
AnyRefNode PosteriorLateralSuperiorTuberosityMT5 = {sRel = .Scale(.PosteriorLateralSuperiorTuberosityMT5Unscaled);};

// Peroneus Tertius Insertion: Dorsal surface of the base of the fifth metatarsal
AnyVar PosteriorSuperiorTuberosityMT5Unscaledx = -0.0479;
AnyVar PosteriorSuperiorTuberosityMT5Unscaledy = -0.0341;
AnyVar PosteriorSuperiorTuberosityMT5Unscaledz = -0.0286;
AnyFloat PosteriorSuperiorTuberosityMT5Unscaled = {PosteriorSuperiorTuberosityMT5Unscaledx, PosteriorSuperiorTuberosityMT5Unscaledy, PosteriorSuperiorTuberosityMT5Unscaledz};
AnyRefNode PosteriorSuperiorTuberosityMT5 = {sRel = .Scale(.PosteriorSuperiorTuberosityMT5Unscaled);};

// Flexor Digitori Minimi Brevis Origin: Base of 5th metatarsal and sheath of peroneus longus
AnyVar PosteriorInferiorTuberosityMT5Unscaledx = -0.0392;
AnyVar PosteriorInferiorTuberosityMT5Unscaledy = -0.0312;
AnyVar PosteriorInferiorTuberosityMT5Unscaledz = -0.0400;
AnyFloat PosteriorInferiorTuberosityMT5Unscaled = {PosteriorInferiorTuberosityMT5Unscaledx, PosteriorInferiorTuberosityMT5Unscaledy, PosteriorInferiorTuberosityMT5Unscaledz};
AnyRefNode PosteriorInferiorTuberosityMT5 = {sRel = .Scale(.PosteriorInferiorTuberosityMT5Unscaled);};

// *** Muscle Via Nodes ***
// Abductor Digiti Minimi routs via smooth facet on the under surface of the base of the fifth metatarsal
AnyVar PosteriorLateralTuberosityMT5Unscaledx = -0.0461;
AnyVar PosteriorLateralTuberosityMT5Unscaledy = -0.0380;
AnyVar PosteriorLateralTuberosityMT5Unscaledz = -0.0313;
AnyFloat PosteriorLateralTuberosityMT5Unscaled =
{PosteriorLateralTuberosityMT5Unscaledx,PosteriorLateralTuberosityMT5Unscaledy,PosteriorLateralTuberosityMT5Unscaledz};
AnyRefNode PosteriorLateralTuberosityMT5 = {sRel = .Scale(.PosteriorLateralTuberosityMT5Unscaled);};

// FDL 5
AnyVar FDLPathMT5Unscaledx = -0.0189;
AnyVar FDLPathMT5Unscaledy = -0.0340;
AnyVar FDLPathMT5Unscaledz = -0.0286;
AnyFloat FDLPathMT5Unscaled =
{FDLPathMT5Unscaledx,FDLPathMT5Unscaledy,FDLPathMT5Unscaledz};
AnyRefNode FDLPathMT5 = {sRel = .Scale(.FDLPathMT5Unscaled);};

// FDL 5 and FDB 5
AnyVar AnteriorInferiorNotchMT5Unscaledx = 0.0073;
AnyVar AnteriorInferiorNotchMT5Unscaledy = -0.0398;
AnyVar AnteriorInferiorNotchMT5Unscaledz = -0.0217;
AnyFloat AnteriorInferiorNotchMT5Unscaled =
{AnteriorInferiorNotchMT5Unscaledx,AnteriorInferiorNotchMT5Unscaledy,AnteriorInferiorNotchMT5Unscaledz};
AnyRefNode AnteriorInferiorNotchMT5 = {sRel = .Scale(.AnteriorInferiorNotchMT5Unscaled);};

// EDL 5
AnyVar AnteriorSuperiorTuberosityMT5Unscaledx = 0.0052;
AnyVar AnteriorSuperiorTuberosityMT5Unscaledy = -0.0362;
AnyVar AnteriorSuperiorTuberosityMT5Unscaledz = -0.0077;

AnyFloat AnteriorSuperiorTuberosityMT5Unscaled =
{AnteriorSuperiorTuberosityMT5Unscaledx,AnteriorSuperiorTuberosityMT5Unscaledy,AnteriorSuperiorTuberosityMT5Unscaledz};
AnyRefNode AnteriorSuperiorTuberosityMT5 = {sRel = .Scale(.AnteriorSuperiorTuberosityMT5Unscaled);};

// *** Ligaments ***
// The fifth MT has has one dorsal band from the cuboid
// Shared insertion with Peroneus Tertius at Posterior Superior Tuberosity
// No true plantar ligaments

// *** Ligament Via Nodes ***
// Plantar Fascia shares Anterior Interior Notch
AnyRefNode MT1STLNode = {
sRel = .Scale({-0.5067,0.1517,0.1917});
// MT1_R_G
ARel = {{0.381099,-0.283992,-0.879836},{0.856867,-0.248882,0.451484},{-0.347193,-0.925962,0.148494}};

AnyDrawSTL DrwSTL = {
    FileName = "STL\MT1.stl";
    ScaleXYZ = ..Scale({0.001, 0.001, 0.001});
    RGB = {0.5,0.5,0};
};

AnyRefNode MT2STLNode = {
    sRel = .Scale({-0.5067,0.1517,0.1917});
    // MT1_R_G
    ARel = {{0.381099,-0.283992,-0.879836},{0.856867,-0.248882,0.451484},{-0.347193,-0.925962,0.148494}};
    AnyDrawSTL DrwSTL = {
        FileName = "STL\MT2.stl";
        ScaleXYZ = ..Scale({0.001, 0.001, 0.001});
        RGB = {0.5,0.5,0};
    };
}

AnyRefNode MT3STLNode = {
    sRel = .Scale({-0.5067,0.1517,0.1917});
    // MT1_R_G
    ARel = {{0.381099,-0.283992,-0.879836},{0.856867,-0.248882,0.451484},{-0.347193,-0.925962,0.148494}};
    AnyDrawSTL DrwSTL = {
        FileName = "STL\MT3.stl";
        ScaleXYZ = ..Scale({0.001, 0.001, 0.001});
        RGB = {0.5,0.5,0};
    };
}

AnyRefNode MT4STLNode = {
    sRel = .Scale({-0.5067,0.1517,0.1917});
    // MT1_R_G
    ARel = {{0.381099,-0.283992,-0.879836},{0.856867,-0.248882,0.451484},{-0.347193,-0.925962,0.148494}};
    AnyDrawSTL DrwSTL = {
        FileName = "STL\MT4.stl";
        ScaleXYZ = ..Scale({0.001, 0.001, 0.001});
        RGB = {0.5,0.5,0};
    };
}

//AnyDrawSeg DrwSeg = {RGB = {0,0,0.5};}; //Dark Blue
AnyRefNode MT5STLNode = {
    sRel = .Scale({-0.5067,0.1517,0.1917});
// MT1_R_G
ARel = {{0.381099,-0.283992,-0.879836},{0.856867,-0.248882,0.451484},{-0.347193,-0.925962,0.148494}};

AnyDrawSTL DrwSTL = {
    FileName = "STL\MT5.stl";
    ScaleXYZ = ..Scale({0.001, 0.001, 0.001});
    RGB = {0.5,0.5,0};
};
}; // End of MidFoot

// Toes
// Hallux origin defined from proximal and distal points
AnySeg Toes = {
    AnyFunTransform3DLin &Scale = ..Scaling.GeometricalScaling.Toes.ScaleFunction;
    //r0 = {0.1796,0.050,-0.5825};
    r0 = {0.1428,0.0642,-0.5724};
    // G_R_Hallux
    Axes0 = {{0.0755,0.9219,-0.3799},{-0.5075,-0.2925,-0.8105},{-0.8584,0.2540,0.4458}};
    // Approximate Hallux as 30% of all toes
    AnyVar Mass_Hallux = 0.30*0.00070*..Scaling.AnthroData.BodyMass;
    // Geometry = Eliptical Cylinder
    AnyVar Length_Hallux = 0.0530;
    AnyVar Radiusy_Hallux = 0.0076;
    AnyVar Radiusz_Hallux = 0.0056;
    AnyVar Ixx_Hallux = Mass_Hallux*(Radiusy_Hallux*Radiusy_Hallux + Radiusz_Hallux*Radiusz_Hallux)/4;
    AnyVar Iyy_Hallux = Mass_Hallux*(Radiusz_Hallux*Radiusz_Hallux/4 + Length_Hallux*Length_Hallux*Length_Hallux/3);
    AnyVar Izz_Hallux = Mass_Hallux*(Radiusy_Hallux*Radiusy_Hallux/4 + Length_Hallux*Length_Hallux/3);
    //Jii = {Ixx,Iyy,Izz};

    // Approximate Toe2 as 25% of all toes
    AnyVar Mass_Toe2 = 0.25*0.00070*..Scaling.AnthroData.BodyMass;
    // Geometry = Eliptical Cylinder
    AnyVar Length_Toe2 = 0.0449;
    AnyVar Radiusy_Toe2 = 0.0060;
    AnyVar Radiusz_Toe2 = 0.0054;
    AnyVar Ixx_Toe2 = Mass_Toe2*(Radiusy_Toe2*Radiusy_Toe2 + Radiusz_Toe2*Radiusz_Toe2)/4;
    AnyVar Iyy_Toe2 = Mass_Toe2*(Radiusz_Toe2*Radiusz_Toe2/4 + Length_Toe2*Length_Toe2*Length_Toe2/3);
AnyVar Izz_Toe2 = Mass_Toe2*(Radiusy_Toe2*Radiusy_Toe2/4 + Length_Toe2*Length_Toe2/3);
//Jii = {Ixx,Iyy,Izz};
AnyVar d_Toe2X = -25.1/1000;
AnyVar d_Toe2Y = 5.2/1000;
AnyVar d_Toe2Z = -10.5/1000;

// Approximate Toe3 as 20% of all toes
AnyVar Mass_Toe3 = 0.20*0.00070*.Scaling.AnthroData.BodyMass;
// Geometry = Eiplitical Cylinder
AnyVar Length_Toe3 = 0.0398;
AnyVar Radiusy_Toe3 = 0.0058;
AnyVar Radiusz_Toe3 = 0.0050;
AnyVar Ixx_Toe3 = Mass_Toe3*(Radiusy_Toe3*Radiusy_Toe3/4 + Radiusz_Toe3*Radiusz_Toe3/4);
AnyVar Iyy_Toe3 = Mass_Toe3*(Radiusz_Toe3*Radiusz_Toe3/4 + Length_Toe3*Length_Toe3/3);
AnyVar Izz_Toe3 = Mass_Toe3*(Radiusy_Toe3*Radiusy_Toe3/4 + Length_Toe3*Length_Toe3/3);
//Jii = {Ixx,Iyy,Izz};
AnyVar d_Toe3X = -40.7/1000;
AnyVar d_Toe3Y = 5.2/1000;
AnyVar d_Toe3Z = -12.3/1000;

// Approximate Toe4 as 15% of all toes
AnyVar Mass_Toe4 = 0.15*0.00070*.Scaling.AnthroData.BodyMass;
// Geometry = Eiplitical Cylinder
AnyVar Length_Toe4 = 0.0363;
AnyVar Radiusy_Toe4 = 0.0054;
AnyVar Radiusz_Toe4 = 0.0035;
AnyVar Ixx_Toe4 = Mass_Toe4*(Radiusy_Toe4*Radiusy_Toe4/4 + Radiusz_Toe4*Radiusz_Toe4/4);
AnyVar Iyy_Toe4 = Mass_Toe4*(Radiusz_Toe4*Radiusz_Toe4/4 + Length_Toe4*Length_Toe4/3);
AnyVar Izz_Toe4 = Mass_Toe4*(Radiusy_Toe4*Radiusy_Toe4/4 + Length_Toe4*Length_Toe4/3);
//Jii = {Ixx,Iyy,Izz};
AnyVar d_Toe4X = -54.4/1000;
AnyVar d_Toe4Y = 12.1/1000;
AnyVar d_Toe4Z = -12.2/1000;

// Approximate Toe5 as 10% of all toes
AnyVar Mass_Toe5 = 0.10*0.00070*.Scaling.AnthroData.BodyMass;
// Geometry = Eiplitical Cylinder
AnyVar Length_Toe5 = 0.0351;
AnyVar Radiusy_Toe5 = 0.0050;
\begin{verbatim}
AnyVar Radiusz_Toe5 = 0.0043;
AnyVar Ixx_Toe5 = Mass_Toe5*(Radiusy_Toe5*Radiusy_Toe5 +
Radiusz_Toe5*Radiusz_Toe5)/4;
AnyVar Iyy_Toe5 = Mass_Toe5*(Radiusz_Toe5*Radiusz_Toe5/4 +
Length_Toe5*Length_Toe5/3);
AnyVar Izz_Toe5 = Mass_Toe5*(Radiusy_Toe5*Radiusy_Toe5/4 +
Length_Toe5*Length_Toe5/3);
//Jii = [Ixx, Iyy, Izz];
AnyVar d_Toe5X = -72.0/1000;
AnyVar d_Toe5Y = 23.5/1000;
AnyVar d_Toe5Z = -3.6/1000;
Mass = Mass_Hallux + Mass_Toe2 + Mass_Toe3 + Mass_Toe4 + Mass_Toe5;
AnyVar Ixx = Ixx_Hallux + Ixx_Toe2 + Ixx_Toe3 + Ixx_Toe4 + Ixx_Toe5 +
Mass_Toe2*d_Toe2Y*d_Toe2Y + Mass_Toe2*d_Toe2Z*d_Toe2Z +
Mass_Toe3*d_Toe3Y*d_Toe3Y + Mass_Toe3*d_Toe3Z*d_Toe3Z +
Mass_Toe4*d_Toe4Y*d_Toe4Y + Mass_Toe4*d_Toe4Z*d_Toe4Z +
Mass_Toe5*d_Toe5Y*d_Toe5Y + Mass_Toe5*d_Toe5Z*d_Toe5Z;
AnyVar Iyy = Iyy_Hallux + Iyy_Toe2 + Iyy_Toe3 + Iyy_Toe4 + Iyy_Toe5 +
Mass_Toe2*d_Toe2X*d_Toe2X + Mass_Toe2*d_Toe2Z*d_Toe2Z +
Mass_Toe3*d_Toe3X*d_Toe3X + Mass_Toe3*d_Toe3Z*d_Toe3Z +
Mass_Toe4*d_Toe4X*d_Toe4X + Mass_Toe4*d_Toe4Z*d_Toe4Z +
Mass_Toe5*d_Toe5X*d_Toe5X + Mass_Toe5*d_Toe5Z*d_Toe5Z;
AnyVar Izz = Izz_Hallux + Izz_Toe2 + Izz_Toe3 + Izz_Toe4 + Izz_Toe5 +
Mass_Toe2*d_Toe2Y*d_Toe2Y + Mass_Toe2*d_Toe2X*d_Toe2X +
Mass_Toe3*d_Toe3Y*d_Toe3Y + Mass_Toe3*d_Toe3X*d_Toe3X +
Mass_Toe4*d_Toe4Y*d_Toe4Y + Mass_Toe4*d_Toe4X*d_Toe4X +
Mass_Toe5*d_Toe5Y*d_Toe5Y + Mass_Toe5*d_Toe5X*d_Toe5X;
Jii = [Ixx, Iyy, Izz];
\end{verbatim}
// *** Muscle attachments ***

// Extensor Hallucis Brevis Insertion: proximal phalanx of big toe
AnyVar ProximalPosteriorSuperiorTuberosityUnscaledx = 0.0011;
AnyVar ProximalPosteriorSuperiorTuberosityUnscaledy = 0.0359;
AnyVar ProximalPosteriorSuperiorTuberosityUnscaledz = -0.0049;
AnyFloat ProximalPosteriorSuperiorTuberosityUnscaled =
    {ProximalPosteriorSuperiorTuberosityUnscaledx, ProximalPosteriorSuperiorTuberosityUnscaledy,
    ProximalPosteriorSuperiorTuberosityUnscaledz};
AnyRefNode ProximalPosteriorSuperiorTuberosity = {sRel =
    .Scale(.ProximalPosteriorSuperiorTuberosityUnscaled);};

// Extensor Hallucis Longus Insertion: Base of distal phalanx of great toe
AnyVar DistalPosteriorSuperiorTuberosityUnscaledx = 0.0277;
AnyVar DistalPosteriorSuperiorTuberosityUnscaledy = 0.0351;
AnyVar DistalPosteriorSuperiorTuberosityUnscaledz = -0.0067;
AnyFloat DistalPosteriorSuperiorTuberosityUnscaled =
    {DistalPosteriorSuperiorTuberosityUnscaledx, DistalPosteriorSuperiorTuberosityUnscaledy,
    DistalPosteriorSuperiorTuberosityUnscaledz};
AnyRefNode DistalPosteriorSuperiorTuberosity = {sRel =
    .Scale(.DistalPosteriorSuperiorTuberosityUnscaled);};

// Flexor Hallucis Brevis Insertion: Medial tendon to medial side of base of proximal
// phalanx of big toe. Lateral tendon to lateral side of same, both via sesamoids
AnyVar ProximalPosteriorInferiorTuberosityUnscaledx = -0.0009;
AnyVar ProximalPosteriorInferiorTuberosityUnscaledy = 0.0273;
AnyVar ProximalPosteriorInferiorTuberosityUnscaledz = -0.0200;
AnyFloat ProximalPosteriorInferiorTuberosityUnscaled =
    {ProximalPosteriorInferiorTuberosityUnscaledx, ProximalPosteriorInferiorTuberosityUnscaledy,
    ProximalPosteriorInferiorTuberosityUnscaledz};
AnyRefNode ProximalPosteriorInferiorTuberosity = {sRel =
    .Scale(.ProximalPosteriorInferiorTuberosityUnscaled);};

// Flexor Hallucis Longus Insertion: Base of distal phalanx of big toe and slips to
// medial two tendons of flexor digitorum longus
AnyVar DistalPosteriorInferiorTuberosityUnscaledx = 0.0235;
AnyVar DistalPosteriorInferiorTuberosityUnscaledy = 0.0329;
AnyVar DistalPosteriorInferiorTuberosityUnscaledz = -0.0171;
AnyFloat DistalPosteriorInferiorTuberosityUnscaled =
    {DistalPosteriorInferiorTuberosityUnscaledx, DistalPosteriorInferiorTuberosityUnscaledy,
    DistalPosteriorInferiorTuberosityUnscaledz};
AnyRefNode DistalPosteriorInferiorTuberosity = {sRel =
    .Scale(.DistalPosteriorInferiorTuberosityUnscaled);};
// Abductor Hallucis Insertion: Medial aspect of base of proximal phalanx of big toe
// via medial sesamoid
AnyRefNode ProximalMedialTuberosity = {sRel = .Scale({-0.0067,0.0389,-0.0192});};

// *** Muscle Via Nodes ***
// FHL follows FHB at Proximal Posterior Inferior Tuberosity
// *** Ligament Attachments ***
// PlantarFascia shares insertion with FHB at ProximalPosterior Inferior Tuberosity
AnyRefNode HalluxSTLNode = {
sRel = .Scale({-0.4695,0.0325,0.3615});
// Hallux_R_G
ARel = {{0.0755,-0.5075,-0.8584},{0.9219,-0.2925,0.2540},{-0.3799,-0.8105,0.4458}};
AnyDrawSTL DrwSTL = {
  FileName = "STL\Hallux.stl";
  ScaleXYZ = .Scale({0.001, 0.001, 0.001});
  RGB = {0,0.5,0};
};
}; // End of Hallux

// Toe2
// ----
// Toe2 origin defined from proximal and distal points
AnySeg Toe2 = {
  AnyFunTransform3DLin &Scale = ..Scaling.GeometricalScaling.Toes.ScaleFunction;
  r0 = {0.1546,0.0552,-0.5930};
// G_R_Toe2
  Axes0 = {{0.2427,0.9144,-0.3240},{-0.8179,0.0133,-0.5752},{-0.5217,0.4046,0.7511}};
  Mass=0;
  Jii={0,0,0};

// *** Joints ***
AnyRefNode MP2Joint = {sRel = {-0.0203,0.0044,0.0085};
};

AnyVec3 UnscaledCylCenter = {-0.0203,0.0144,0.0085};
AnyRefNode CylCenter=
  sRel=.Scale(UnscaledCylCenter);
ARel = RotMat(80*pi/180,x);

AnySurfCylinder WrapSurf = {
    AnyVec3 Rad=..Scale({0.008,0,0});
    Radius = Rad[0];
    Length = 0.03;
};

// *** Muscle Attachments ***
AnyVar ProximalPosteriorSuperiorTuberosityUnscaledx = -0.0123;
AnyVar ProximalPosteriorSuperiorTuberosityUnscaledy = 0.0079;
AnyVar ProximalPosteriorSuperiorTuberosityUnscaledz = 0.0154;
AnyFloat ProximalPosteriorSuperiorTuberosityUnscaled =
{ProximalPosteriorSuperiorTuberosityUnscaledx,ProximalPosteriorSuperiorTuberosityUnscaledy,ProximalPosteriorSuperiorTuberosityUnscaledz};
AnyRefNode ProximalPosteriorSuperiorTuberosity = {sRel = .Scale(.ProximalPosteriorSuperiorTuberosityUnscaled);};

// EDL 2
AnyVar DistalPosteriorSuperiorTuberosityUnscaledx = 0.0114;
AnyVar DistalPosteriorSuperiorTuberosityUnscaledy = 0.0044;
AnyVar DistalPosteriorSuperiorTuberosityUnscaledz = 0.0098;
AnyFloat DistalPosteriorSuperiorTuberosityUnscaled =
{DistalPosteriorSuperiorTuberosityUnscaledx,DistalPosteriorSuperiorTuberosityUnscaledy,DistalPosteriorSuperiorTuberosityUnscaledz};
AnyRefNode DistalPosteriorSuperiorTuberosity = {sRel = .Scale(.DistalPosteriorSuperiorTuberosityUnscaled);};

// FDB 2
AnyVar ProximalPosteriorInferiorTuberosityUnscaledx = -0.0134;
AnyVar ProximalPosteriorInferiorTuberosityUnscaledy = 0.0061;
AnyVar ProximalPosteriorInferiorTuberosityUnscaledz = 0.0050;
AnyFloat ProximalPosteriorInferiorTuberosityUnscaled =
{ProximalPosteriorInferiorTuberosityUnscaledx,ProximalPosteriorInferiorTuberosityUnscaledy,ProximalPosteriorInferiorTuberosityUnscaledz};
AnyRefNode ProximalPosteriorInferiorTuberosity = {sRel = .Scale(.ProximalPosteriorInferiorTuberosityUnscaled);};

// FDL 2
AnyVar DistalPosteriorInferiorTuberosityUnscaledx = -0.0026;
AnyVar DistalPosteriorInferiorTuberosityUnscaledy = 0.0039;
AnyVar DistalPosteriorInferiorTuberosityUnscaledz = -0.0023;
AnyFloat DistalPosteriorInferiorTuberosityUnscaled =
{DistalPosteriorInferiorTuberosityUnscaledx,DistalPosteriorInferiorTuberosityUnscaledy,DistalPosteriorInferiorTuberosityUnscaledz};
AnyRefNode DistalPosteriorInferiorTuberosity = {sRel = .Scale(.DistalPosteriorInferiorTuberosityUnscaled);};

// *** Muscle Via Nodes ***
// FDL 2 follows FDB 2 at Proximal Posterior Inferior Tuberosity
// EDL 2 follows EDB 2 at Proximal Posterior Superior Tuberosity

// *** Ligament Attachments ***
// PlantarFascia (same as FDB 2)

// *** Draw ***
//AnyDrawSeg DrwSeg = {RGB = {0,0.5,0};}; //Dark Green
AnyRefNode Toe2STLNode = {
    sRel = {-0.3018,0.0979,0.5272};
    // Toe2_R_G
    ARel = {{0.2427,-0.8179,-0.5217}, {0.9144,0.0133,0.4046}, {-0.3240, -0.5752, 0.7511}};
    AnyDrawSTL DrwSTL = {
        FileName = "STL\Toe2.stl";
        ScaleXYZ = {0.001, 0.001, 0.001};
        RGB = {0,0.5,0};
    }
}; // End of Toe2

// Toe3
// ----
// Toe3 origin defined from proximal and distal points
AnySeg Toe3 = {
    AnyFunTransform3DLin &Scale = ..Scaling.GeometricalScaling.Toes.ScaleFunction;
    r0 = {0.1390,0.0552,-0.5948};
    // G_R_Toe3
    Axes0 = {{0.2427,0.9144,-0.3240}, {-0.8179,0.0133,-0.5752}, {-0.5217,0.4046,0.7511}};
    Mass=0;
    Jii={0,0,0};

    // *** Joints ***
    //AnyRefNode HalluxGRFNode = {sRel = {0.015,0,-0.0075};};
    AnyRefNode MP3Joint = {sRel = {-0.0182,0.0055,0.0057};
    //AnyDrawRefFrame drw = {RGB={0,1,0};};
    }
    AnyVec3 UnscaledCylCenter = {-0.0182,0.0155,0.0057};
    AnyRefNode CylCenter = {
        sRel=.Scale(.UnscaledCylCenter);
        ARel = RotMat(80*pi/180,x);
AnySurfCylinder WrapSurf = {
    AnyVec3 Rad=..Scale({0.006,0,0});
    Radius = Rad[0];
    Length = 0.03;
};

// *** Muscle Attachments ***
// EDB 3
AnyVar ProximalPosteriorSuperiorTuberosityUnscaledx = -0.0127;
AnyVar ProximalPosteriorSuperiorTuberosityUnscaledy = 0.0075;
AnyVar ProximalPosteriorSuperiorTuberosityUnscaledz = 0.0110;
AnyFloat ProximalPosteriorSuperiorTuberosityUnscaled =
{ProximalPosteriorSuperiorTuberosityUnscaledx,ProximalPosteriorSuperiorTuberosityUnscaledy,ProximalPosteriorSuperiorTuberosityUnscaledz};
AnyRefNode ProximalPosteriorSuperiorTuberosity = {sRel = .Scale(.ProximalPosteriorSuperiorTuberosityUnscaled)};

// EDL 3
AnyVar DistalPosteriorSuperiorTuberosityUnscaledx = 0.0099;
AnyVar DistalPosteriorSuperiorTuberosityUnscaledy = 0.0008;
AnyVar DistalPosteriorSuperiorTuberosityUnscaledz = 0.0090;
AnyFloat DistalPosteriorSuperiorTuberosityUnscaled =
{DistalPosteriorSuperiorTuberosityUnscaledx,DistalPosteriorSuperiorTuberosityUnscaledy,DistalPosteriorSuperiorTuberosityUnscaledz};
AnyRefNode DistalPosteriorSuperiorTuberosity = {sRel = .Scale(.DistalPosteriorSuperiorTuberosityUnscaled)};

// FDB 3
AnyVar ProximalPosteriorInferiorTuberosityUnscaledx = -0.0149;
AnyVar ProximalPosteriorInferiorTuberosityUnscaledy = 0.0036;
AnyVar ProximalPosteriorInferiorTuberosityUnscaledz = -0.0017;
AnyFloat ProximalPosteriorInferiorTuberosityUnscaled =
{ProximalPosteriorInferiorTuberosityUnscaledx,ProximalPosteriorInferiorTuberosityUnscaledy,ProximalPosteriorInferiorTuberosityUnscaledz};
AnyRefNode ProximalPosteriorInferiorTuberosity = {sRel = .Scale(.ProximalPosteriorInferiorTuberosityUnscaled)};

// FDL 3
AnyVar DistalPosteriorInferiorTuberosityUnscaledx = 0.0038;
AnyVar DistalPosteriorInferiorTuberosityUnscaledy = 0.0014;
AnyVar DistalPosteriorInferiorTuberosityUnscaledz = 0.0018;
AnyFloat DistalPosteriorInferiorTuberosityUnscaled =
{DistalPosteriorInferiorTuberosityUnscaledx,DistalPosteriorInferiorTuberosityUnscaledy,DistalPosteriorInferiorTuberosityUnscaledz};
AnyRefNode DistalPosteriorInferiorTuberosity = {sRel = Scale(DistalPosteriorInferiorTuberosityUnscaled);};

// *** Muscle Via Nodes ***
// FDL 3 follows FDB 3 at Proximal Posterior Inferior Tuberosity

// *** Ligament Attachments ***
// PlantarFascia (same as FDB 3)
AnyRefNode Toe3STLNode = {
    sRel = {-0.2988,0.1128,0.5235};
    ARel = {{0.2427,-0.8179,-0.5217},{0.9144,0.0133,0.4046},{-0.3240,-0.5752,0.7511}};
    AnyDrawSTL DrwSTL = {
        FileName = "STL\Toe3.stl";
        ScaleXYZ = {0.001, 0.001, 0.001};
        RGB = {0,0.5,0};
    }
}; // End of Toe3

// Toe4
// ----
// Toe4 origin defined from proximal and distal points
AnySeg Toe4 = {
    r0 = {0.1253,0.0621,-0.5947};
    ARel = RotMat(80*pi/180,x);
    Axes0 = {{0.0035,0.9999,0.0127},{-0.9656,0.0067,-0.2599},{-0.2600,-0.0113,0.9655}};
    Mass=0;
    Jii={0,0,0};
}

// *** Joints ***
AnyRefNode MP4Joint = {sRel = {-0.0141,-0.0037,0.0108};
};

AnyVec3 UnscaledCylCenter = {-0.0141,-0.0037+.01,0.0108};
AnyRefNode CylCenter={
    sRel=.Scale(UnscaledCylCenter);
    ARel = RotMat(80*pi/180,x);
    AnySurfCylinder WrapSurf = {
        AnyVec3 Rad=.Scale(0.007,0,0);;
        Radius = Rad[0];
        Length = 0.03;
    };
}
// *** Muscle Attachments ***
// EDB 4
AnyVar ProximalPosteriorSuperiorTuberosityUnscaledx = -0.0073;
AnyVar ProximalPosteriorSuperiorTuberosityUnscaledy = -0.0023;
AnyVar ProximalPosteriorSuperiorTuberosityUnscaledz = 0.0144;
AnyFloat ProximalPosteriorSuperiorTuberosityUnscaled =
{ProximalPosteriorSuperiorTuberosityUnscaledx,ProximalPosteriorSuperiorTuberosityUnscaledy,ProximalPosteriorSuperiorTuberosityUnscaledz};
AnyRefNode ProximalPosteriorSuperiorTuberosity = {sRel =
.Scale(.ProximalPosteriorSuperiorTuberosityUnscaled);};

// EDL 4
AnyVar DistalPosteriorSuperiorTuberosityUnscaledx = 0.00103;
AnyVar DistalPosteriorSuperiorTuberosityUnscaledy = -0.0037;
AnyVar DistalPosteriorSuperiorTuberosityUnscaledz = 0.0026;
AnyFloat DistalPosteriorSuperiorTuberosityUnscaled =
{DistalPosteriorSuperiorTuberosityUnscaledx,DistalPosteriorSuperiorTuberosityUnscaledy,DistalPosteriorSuperiorTuberosityUnscaledz};
AnyRefNode DistalPosteriorSuperiorTuberosity = {sRel =
.Scale(.DistalPosteriorSuperiorTuberosityUnscaled);};

// FDB 4
AnyVar ProximalPosteriorInferiorTuberosityUnscaledx = -0.0124;
AnyVar ProximalPosteriorInferiorTuberosityUnscaledy = -0.0004;
AnyVar ProximalPosteriorInferiorTuberosityUnscaledz = 0.0048;
AnyFloat ProximalPosteriorInferiorTuberosityUnscaled =
{ProximalPosteriorInferiorTuberosityUnscaledx,ProximalPosteriorInferiorTuberosityUnscaledy,ProximalPosteriorInferiorTuberosityUnscaledz};
AnyRefNode ProximalPosteriorInferiorTuberosity = {sRel =
.Scale(.ProximalPosteriorInferiorTuberosityUnscaled);};

// FDL 4
AnyVar DistalPosteriorInferiorTuberosityUnscaledx = 0.0051;
AnyVar DistalPosteriorInferiorTuberosityUnscaledy = -0.0007;
AnyVar DistalPosteriorInferiorTuberosityUnscaledz = -0.0037;
AnyFloat DistalPosteriorInferiorTuberosityUnscaled =
{DistalPosteriorInferiorTuberosityUnscaledx,DistalPosteriorInferiorTuberosityUnscaledy,DistalPosteriorInferiorTuberosityUnscaledz};
AnyRefNode DistalPosteriorInferiorTuberosity = {sRel =
.Scale(.DistalPosteriorInferiorTuberosityUnscaled);};}
// *** Muscle Via Nodes ***
// FDL 4 follows FDB 4 at Proximal Posterior Inferior Tuberosity
// *** Ligament Attachments ***
// PlantarFascia (same as FDB 4)
AnyRefNode Toe4STLNode = {
    sRel = {-0.0951,-0.1324,0.5887};
    // Toe4_R_G
    ARel = {{0.0035,-0.9656,-0.2600},{0.9999,0.0067,-0.0113},{0.0127,-0.2599,0.9655}};
    AnyDrawSTL DrwSTL = {
        FileName = "STL\Toe4.stl";
        ScaleXYZ = {0.001, 0.001, 0.001};
        RGB = {0,0.5,0};
    }
}; // End of Toe4

// Toe5
// ----
// Toe5 origin defined from proximal and distal points
AnySeg Toe5 = {
    AnyFunTransform3DLin &Scale = ..Scaling.GeometricalScaling.Toes.ScaleFunction;
    r0 = {0.1077,0.0735,-0.5862};
    // G_R_Toe5
    Axes0 = {{0.0035,0.9999,0.0127},{-0.9656,0.0067,-0.2599},{-0.2600,-0.0113,0.9655}};
    Mass=0;
    Jii={0,0,0};

    // *** Joints ***
    AnyRefNode MP5Joint = {sRel = {-0.0139,-0.0052,0.0093};
    }

    AnyVec3 UnscaledCylCenter = {-0.0139,-0.0052+0.01,0.0093};
    AnyRefNode CylCenter=
        sRel=.Scale(UnscaledCylCenter);
        ARel = RotMat(80*pi/180,x);
        AnySurfCylinder WrapSurf = {
            AnyVec3 Rad=.Scale({0.007,0,0});
            Radius = Rad[0];
            Length = 0.03;
        }
};

// *** Muscle Attachments ***
// EDB 5
AnyVar ProximalPosteriorSuperiorTuberosityUnscaledx = -0.0069;
AnyVar ProximalPosteriorSuperiorTuberosityUnscaledy = -0.0011;
AnyVar ProximalPosteriorSuperiorTuberosityUnscaledz = 0.0120;
AnyFloat ProximalPosteriorSuperiorTuberosityUnscaled =
{ProximalPosteriorSuperiorTuberosityUnscaledx,ProximalPosteriorSuperiorTuberosityUnscaledy,ProximalPosteriorSuperiorTuberosityUnscaledz};
AnyRefNode ProximalPosteriorSuperiorTuberosity = {sRel = .Scale(.ProximalPosteriorSuperiorTuberosityUnscaled);};

// EDL 5
AnyVar DistalPosteriorSuperiorTuberosityUnscaledx = 0.0095;
AnyVar DistalPosteriorSuperiorTuberosityUnscaledy = 0.0036;
AnyVar DistalPosteriorSuperiorTuberosityUnscaledz = 0.0019;
AnyFloat DistalPosteriorSuperiorTuberosityUnscaled =
{DistalPosteriorSuperiorTuberosityUnscaledx,DistalPosteriorSuperiorTuberosityUnscaledy,DistalPosteriorSuperiorTuberosityUnscaledz};
AnyRefNode DistalPosteriorSuperiorTuberosity = {sRel = .Scale(.DistalPosteriorSuperiorTuberosityUnscaled);};

// FDB 5
AnyVar ProximalPosteriorInferiorTuberosityUnscaledx = -0.0129;
AnyVar ProximalPosteriorInferiorTuberosityUnscaledy = -0.0036;
AnyVar ProximalPosteriorInferiorTuberosityUnscaledz = -0.0002;
AnyFloat ProximalPosteriorInferiorTuberosityUnscaled =
{ProximalPosteriorInferiorTuberosityUnscaledx,ProximalPosteriorInferiorTuberosityUnscaledy,ProximalPosteriorInferiorTuberosityUnscaledz};
AnyRefNode ProximalPosteriorInferiorTuberosity = {sRel = .Scale(.ProximalPosteriorInferiorTuberosityUnscaled);};

// FDL 5
AnyVar DistalPosteriorInferiorTuberosityUnscaledx = 0.0025;
AnyVar DistalPosteriorInferiorTuberosityUnscaledy = 0.0008;
AnyVar DistalPosteriorInferiorTuberosityUnscaledz = -0.0041;
AnyFloat DistalPosteriorInferiorTuberosityUnscaled =
{DistalPosteriorInferiorTuberosityUnscaledx,DistalPosteriorInferiorTuberosityUnscaledy,DistalPosteriorInferiorTuberosityUnscaledz};
AnyRefNode DistalPosteriorInferiorTuberosity = {sRel = .Scale(.DistalPosteriorInferiorTuberosityUnscaled);};

// Flexor Digiti Minimi Brevis
AnyRefNode ProximalLateralTuberosity = {sRel = .Scale({-0.0126,-0.0094,0.0041});};
// Abductor Digiti Minimi
AnyRefNode DistalLateralTuberosity = {sRel = .Scale({0.0051,-0.0042,0.0006});};
// *** Muscle Via Nodes ***
// FDL 5 follows FDB 5 at Proximal Posterior Inferior Tuberosity

// *** Ligament Attachments ***
// PlantarFascia (same as FDB 5)
AnyRefNode Toe5STLNode = {
sRel = {-0.0818,-0.1148,0.5837};
// Toe5_R_G
ARel = {{0.0035,-0.9656,-0.2600},{0.9999,0.0067,-0.0113},{0.0127,-0.2599,0.9655}};
AnyDrawSTL DrwSTL = {
    FileName = "STL\Toe5.stl";
    ScaleXYZ = {0.001, 0.001, 0.001};
    RGB = {0,0.5,0};
};
}; // End of Toe5

// FootJointsRight.any

AnyFolder FootJointsRight = {
    // Knee
    AnySphericalJoint KneeJoint = {
        AnyRefNode &FemurNode = ..FootSegmentsRight.Femur.KneeJointNode;
        AnyRefNode &ShankNode = ..FootSegmentsRight.Shank.KneeJoint;
    }; //End of Knee Joint

    AnySphericalJoint AnkleJoint = {
        AnyRefNode &ShankNode = ..FootSegmentsRight.Shank.AnkleJoint;
        AnyRefNode &HindFootNode = ..FootSegmentsRight.HindFoot.AnkleJoint;
    }; //End of Ankle Joint

    AnySphericalJoint MidFootJoint = {
        AnyRefNode &HindFootNode = ..FootSegmentsRight.HindFoot.MidFootJoint;
        AnyRefNode &MidFootNode = ..FootSegmentsRight.MidFoot.MidFootJoint;
    }; //End of MidFoot Joint

    AnyRevoluteJoint ToeJoint = {
        Axis = y;
        AnyRefNode &MidFootNode = ..FootSegmentsRight.MidFoot.ToeJoint;
        AnyRefNode &HalluxNode = ..FootSegmentsRight.Toes.ToeJoint;
    }; //End of Toe Joint
AnyRevoluteJoint MP2Joint = {
    Axis = y;
    AnyRefNode &MidFootNode = ..FootSegmentsRight.MidFoot.MP2Joint;
    AnyRefNode &HalluxNode = ..FootSegmentsRight.Toe2.MP2Joint;
}; //End of Toe2 Joint

AnyRevoluteJoint MP3Joint = {
    Axis = y;
    AnyRefNode &MidFootNode = ..FootSegmentsRight.MidFoot.MP3Joint;
    AnyRefNode &HalluxNode = ..FootSegmentsRight.Toe3.MP3Joint;
}; //End of Toe3 Joint

AnyRevoluteJoint MP4Joint = {
    Axis = y;
    AnyRefNode &MidFootNode = ..FootSegmentsRight.MidFoot.MP4Joint;
    AnyRefNode &HalluxNode = ..FootSegmentsRight.Toe4.MP4Joint;
}; //End of Toe4 Joint

AnyRevoluteJoint MP5Joint = {
    Axis = y;
    AnyRefNode &MidFootNode = ..FootSegmentsRight.MidFoot.MP5Joint;
    AnyRefNode &HalluxNode = ..FootSegmentsRight.Toe5.MP5Joint;
}; //End of Toe5 Joint

}; //End of Joints

***********************************************************************
===============================================================
//ScalingUniform_MF_TS_together.any

AnyFolder Scaling ={
    AnyFolder GeometricalScaling = {
        AnyFolder Toes = {
            AnyVar GeomScale = (..AnthroSegmentLengths.MidFootLength / ..StandardParameters.MidFootLength);
            AnyFunTransform3DLin ScaleFunction = {
                ScaleMat ={{GeomScale,0,0},{0,GeomScale,0},{0,0,GeomScale}};
                Offset = {0,0,0};
            };
        };
        AnyFolder MidFoot = {
            AnyVar GeomScale = (..AnthroSegmentLengths.MidFootLength / ..StandardParameters.MidFootLength);
            AnyFunTransform3DLin ScaleFunction = {
                ScaleMat ={{GeomScale,0,0},{0,GeomScale,0},{0,0,GeomScale}};
                Offset = {0,0,0};
AnyFolder HindFoot = {
    AnyVar GeomScale = (..AnthroSegmentLengths.HindFootLength / ..StandardParameters.HindFootLength);
    AnyFunTransform3DLin ScaleFunction = {
        ScaleMat = {{.GeomScale,0,0},{0,.GeomScale,0},{0,0,.GeomScale}};
        Offset = {0,0,0};
    };
};

AnyFolder Shank = {
    AnyVar GeomScale = (..AnthroSegmentLengths.ShankLength / ..StandardParameters.ShankLength);
    AnyFunTransform3DLin ScaleFunction = {
        ScaleMat = {{.GeomScale,0,0},{0,.GeomScale,0},{0,0,.GeomScale}};
        Offset = {0,0,0};
    };
};

AnyFolder Thigh = {
    AnyVar GeomScale = (..AnthroSegmentLengths.ThighLength / ..StandardParameters.ThighLength);
    AnyFunTransform3DLin ScaleFunction = {
        ScaleMat = {{.GeomScale,0,0},{0,.GeomScale,0},{0,0,.GeomScale}};
        Offset = {0,0,0};
    };
};

};

.GetInstance(FunTransform3DLin, Shank.ScaleFunction);

StandardParameters.any
AnyFolder StandardParameters = {
    AnyVar bodymass = 75; // kg
    AnyVar stature = 1.88; // m
    AnyVar ThighLength = 0.2124*stature;
    AnyVar ShankLength = 0.2491*stature;
    AnyVar HindFootLength = 0.0648*stature;
    AnyVar MidFootLength = 0.0382*stature;
    AnyVar ToesLength = 0.0287*stature;
    AnyVar FootLength = HindFootLength+MidFootLength+ToesLength;
};
AnyVar ThighMass = 0.1478*bodymass;
AnyVar ShankMass = 0.0465*bodymass;
AnyVar HindFootMass = 0.00929*bodymass;
AnyVar MidFootMass = 0.003*bodymass;
AnyVar ToesMass = 0.007*bodymass;
AnyVar FootMass = HindFootMass+MidFootMass+ToesMass;
};

//LocalMarkerCoordinateAndSize.any

//this files contains the initial guess on the marker position it is all in local coordinates of the segment

AnyFolder LocalMarkerCoordinates = {
    // Femur Seg M:1-2
    AnyVec3 RFEP = {0.0025,0.0039,0.1528};
    AnyVec3 RKNE = {0.0,-0.0559,-0.3068};
    AnyVec3 RTHI = {.0598,-0.0077,-0.3042};
    //Shank Seg M:3-4
    //AnyVec3 RTIB = {-0.0109,-0.0984,-0.0755};
    AnyVec3 RTIB = {-0.0109,-0.0984,-0.1455};
    AnyVec3 RTIBU = {0.0332,-0.0048,-0.0484};
    AnyVec3 RTIBL = {0.0211,-0.0038,-0.1483};
    AnyVec3 RANK = {-0.0217,-0.0278,-0.2892};
    //HindFoot Seg M:5-8
    //AnyVec3 RHEE = {-0.0465,0,0};
    AnyVec3 RHEE = {-0.0493,-0.0015,0.0052}; //Altered
    AnyVec3 RCALTB = {0.0203,-0.018,-0.0079};
    AnyVec3 RLCAL = {-0.0219,-0.0225,-0.0167};
    AnyVec3 RMCAL = {-0.0219,0.0225,0.0067};
    //MidFootSeg M:9-12
    AnyVec3 RMT23B = {-0.0307,0,0};
    AnyVec3 RMT23H = {0.0307,0,0};
    AnyVec3 RMT1BM = {-0.0212,0.0350,-0.0145};
    AnyVec3 RMT1HM = {0.0272,0.0400,-0.0206};
    //Toes Seg M: 13-15
    AnyVec3 RTOE1 = {0.0219,0.0406,-0.0043};
    AnyVec3 RTOE2 = {0.0369,0.0365,-0.0061};
    AnyVec3 RTOE3 = {0.0219,0.0293,-0.0014};
};

AnyFolder ScalingParameters = {
    AnyVar THIGH = 0.2124*stature;
}
AnyVar SHANK = 0.2491*stature;
AnyVar HINDFOOT = 0.0648*stature;
AnyVar MIDFOOT = 0.0382*stature;
AnyVar TOES = 0.0287*stature;
}
***********************************************************************
//AnyMan.any
AnyFolder AnthroData = {
    AnyVar BodyMass = 39;
    AnyVar BodyHeight = 1.35;
    AnyVar Density = 1000;
    AnyVar LegLength = 0.920;
    AnyVar FootLength = 0.260;
    AnyVar FootWidth = 0.105;
    AnyVar bodymass = BodyMass;
    AnyVar ThighMass = 0.1478*bodymass;
    AnyVar ShankMass = 0.0465*bodymass;
    AnyVar HindFootMass = 0.00929*bodymass;
    AnyVar MidFootMass = 0.003*bodymass;
    AnyVar ToesMass = 0.007*bodymass;
    AnyVar FootMass = HindFootMass+MidFootMass+ToesMass;
}; // Whole Body Parameters

//Only the lengths for the leg are used for this model, but the a full dataset
//needs to be present in order to load the model
AnyFolder AnthroSegmentLengths = {
    AnyVar ThighLength = .ScalingParameters.THIGH;
    AnyVar ShankLength = .ScalingParameters.SHANK;
    AnyVar HindFootLength = .ScalingParameters.HINDFOOT;
    AnyVar MidFootLength = .ScalingParameters.MIDFOOT;
    AnyVar ToesLength = .ScalingParameters.TOES;
    AnyVar FootLength = HindFootLength+MidFootLength+ToesLength;
};

//MarkerTopology.any

//This file contains the marker topology of the data set it links free floating markers with the
markers on the human
// it also calculates a guess on the sRel value of the marker, the validity of this guess
depends strongly on how accurate the
// posture has been adjusted to comply with the free floating markers.
// The SegNr refers to the segment numbers used by the gaitapplication2.exe file
// This is a list of the segments and the corresponding SegNr

// Right Femur = 0
// Right Shank = 1
// Right HindFoot = 2
// Right MidFoot = 3
// Right Toes = 4

AnyFolder MarkerTopology = {
    AnyFolder &MarkerFolder = ..Markers;
    AnyFolder &lm = ..HumanModel.Scaling.LocalMarkerCoordinates;
    AnyFolder M1 = {
        AnyInt MarkerNo = 0;
        AnyString Name = "RFEP"; // name of the marker
        AnySeg &Seg = ..HumanModel.FootSegmentsRight.Femur; // reference to the segment
        Seg = {
            AnyRefNode RFEP = {sRel = .Scale(....lm.RFEP); #include "DrawMarker.any"};
        }; // add the marker to the segment it will read the sRel values from
        AnyString SegNr = "0"; // segment nr according to the numbering system in the
        GaitApplication2 file
        AnyRefNode &Node = Seg.RFEP; // reference to the node on the human model
        AnySeg &FreeMarker = .MarkerFolder.RFEP.Seg; // reference to free floating marker
        segment
        AnyVec3 NodePos = ..lm.RFEP;
        AnyString ScaleType = "0"; // 0 means scale with the segment and 1 means do not
        scale.
    },

    AnyFolder M2 = {
        AnyInt MarkerNo = 1;
        AnyString Name = "RKNE"; // name of the marker
        AnySeg &Seg = ..HumanModel.FootSegmentsRight.Femur; // reference to the segment
        Seg = {
            AnyRefNode RKNE = {sRel = .Scale(....lm.RKNE); #include "DrawMarker.any"};
        }; // add the marker to the segment it will read the sRel values from
        AnyString SegNr = "0"; // segment nr according to the numbering system in the
        GaitApplication2 file
        AnyRefNode &Node = Seg.RKNE; // reference to the node on the human model
        AnySeg &FreeMarker = .MarkerFolder.RKNE.Seg; // reference to free floating marker
        segment
    },
AnyVec3 NodePos = .lm.RKNE;
AnyString ScaleType = " 0 ";
};

AnyFolder M3 = {
AnyInt MarkerNo = 2;
AnyString Name = "RTHI"; // name of the marker
AnySeg &Seg = HumanModel.FootSegmentsRight.Femur; // reference to the segment
where the marker is located on the human model
Seg = {AnyRefNode RTHI = {sRel = .Scale(....lm.RTHI); #include
"DrawMarker.any"};}; // add the marker to the segment it will read the sRel values from
the file outputpar.any
AnyString SegNr = " 0 "; // segment nr according to the numbering system in the
GaitApplication2 file
AnyRefNode &Node = Seg.RTHI; // reference to the node on the human model
AnySeg &FreeMarker = MarkerFolder.RTHI.Seg; // reference to free floating marker
segment
AnyVec3 NodePos = .lm.RTHI;
AnyString ScaleType = " 0 ";
};

AnyFolder M4 = {
AnyInt MarkerNo = 3;
AnyString Name = "RTIB"; // name of the marker
AnySeg &Seg = HumanModel.FootSegmentsRight.Shank; // reference to the segment
where the marker is located on the human model
Seg = {AnyRefNode RTIB = {sRel = .Scale(....lm.RTIB); #include
"DrawMarker.any"};}; // add the marker to the segment it will read the sRel values from
the file outputpar.any
AnyString SegNr = " 1 "; // segment nr according to the numbering system in the
GaitApplication2 file
AnyRefNode &Node = Seg.RTIB; // reference to the node on the human model
AnySeg &FreeMarker = MarkerFolder.RTIB.Seg; // reference to free floating marker
segment
AnyVec3 NodePos = .lm.RTIB;
AnyString ScaleType = " 0 ";
};

AnyFolder M5 = {
AnyInt MarkerNo = 4;
AnyString Name = "RTIBU"; // name of the marker
AnySeg &Seg = HumanModel.FootSegmentsRight.Shank; // reference to the segment
where the marker is located on the human model
Seg = {AnyRefNode RTIBU = {sRel = .Scale(....lm.RTIBU); #include
"DrawMarker.any"};}; // add the marker to the segment it will read the sRel values from
the file outputpar.any
AnyString SegNr =" 1 "; //segment nr according to the numbering system in the GaitApplication2 file
AnyRefNode &Node=Seg.RTIBU; //reference to the node on the human model
AnySeg &FreeMarker=.MarkerFolder.RTIBU.Seg; //reference to free floating marker segment
AnyVec3 NodePos =.lm.RTIBU;
AnyString ScaleType = " 0 ";

};

AnyFolder M6={
  AnyInt MarkerNo=5;
  AnyString Name = "RTIBL"; //name of the marker
  AnySeg &Seg=...HumanModel.FootSegmentsRight.Shank; //reference to the segment where the marker is located on the human model
  Seg={AnyRefNode RTIBL={sRel= .Scale(....lm.RTIBL); #include "DrawMarker.any"};}; //add the marker to the segment it will read the sRel values from the file outputpar.any
  AnyString SegNr =" 1 "; //segment nr according to the numbering system in the GaitApplication2 file
  AnyRefNode &Node=Seg.RTIBL; //reference to the node on the human model
  AnySeg &FreeMarker=.MarkerFolder.RTIBL.Seg; //reference to free floating marker segment
  AnyVec3 NodePos =.lm.RTIBL;
  AnyString ScaleType = " 0 ";
};

AnyFolder M7={
  AnyInt MarkerNo=6;
  AnyString Name = "RANK"; //name of the marker
  AnySeg &Seg=...HumanModel.FootSegmentsRight.Shank; //reference to the segment where the marker is located on the human model
  Seg={AnyRefNode RANK={sRel= .Scale(....lm.RANK); #include "DrawMarker.any"};}; //add the marker to the segment it will read the sRel values from the file outputpar.any
  AnyString SegNr =" 1 "; //segment nr according to the numbering system in the GaitApplication2 file
  AnyRefNode &Node=Seg.RANK; //reference to the node on the human model
  AnySeg &FreeMarker=.MarkerFolder.RANK.Seg; //reference to free floating marker segment
  AnyVec3 NodePos =.lm.RANK;
  AnyString ScaleType = " 0 ";
};

AnyFolder M8={
  AnyInt MarkerNo=7;
}
AnyString Name = "RHEE"; //name of the marker
AnySeg &Seg =...HumanModel.FootSegmentsRight.HindFoot; //reference to the segment where the marker is located on the human model
Seg={AnyRefNode RHEE = {sRel = .Scale(....Im.RHEE); #include "DrawMarker.any"};}; //add the marker to the segment it will read the sRel values from the file outputpar.any
AnyString SegNr = "2 "; //segment nr according to the numbering system in the GaitApplication2 file
AnyRefNode &Node = Seg.RHEE; //reference to the node on the human model
AnySeg &FreeMarker = .MarkerFolder.RHEE.Seg; //reference to free floating marker segment
AnyVec3 NodePos = .Im.RHEE;
AnyString ScaleType = "0 ";
}

AnyFolder M9 = {
    AnyInt MarkerNo = 8;
    AnyString Name = "RCALTB"; //name of the marker
    AnySeg &Seg =...HumanModel.FootSegmentsRight.HindFoot; //reference to the segment where the marker is located on the human model
    Seg={AnyRefNode RCalTB = {sRel = .Scale(....Im.RCalTB); #include "DrawMarker.any"};}; //add the marker to the segment it will read the sRel values from the file outputpar.any
    AnyString SegNr = "2 "; //segment nr according to the numbering system in the GaitApplication2 file
    AnyRefNode &Node = Seg.RCalTB; //reference to the node on the human model
    AnySeg &FreeMarker = .MarkerFolder.RCalTB.Seg; //reference to free floating marker segment
    AnyVec3 NodePos = .Im.RCalTB;
    AnyString ScaleType = "0 ";
}

AnyFolder M10 = {
    AnyInt MarkerNo = 9;
    AnyString Name = "RLCAL"; //name of the marker
    AnySeg &Seg =...HumanModel.FootSegmentsRight.HindFoot; //reference to the segment where the marker is located on the human model
    Seg={AnyRefNode RLCAL = {sRel = .Scale(....Im.RLCAL); #include "DrawMarker.any"};}; //add the marker to the segment it will read the sRel values from the file outputpar.any
    AnyString SegNr = "2 "; //segment nr according to the numbering system in the GaitApplication2 file
    AnyRefNode &Node = Seg.RLCAL; //reference to the node on the human model
    AnySeg &FreeMarker = .MarkerFolder.RLCAL.Seg; //reference to free floating marker segment
    AnyVec3 NodePos = .Im.RLCAL;
AnyString ScaleType = "0 ";
};

AnyFolder M11={
  AnyInt MarkerNo=10;
  AnyString Name = "RMCAL"; //name of the marker
  AnySeg &Seg=...HumanModel.FootSegmentsRight.HindFoot; //reference to the
  Seg={AnyRefNode RMCAL={sRel= .Scale(....lm.RMCAL); #include
    "DrawMarker.any"};}; //add the marker to the segment it will read the sRel values from
  AnyString SegNr ="2 "; //segment nr according to the numbering system in the
  GaitApplication2 file
  AnyRefNode &Node=Seg.RMCAL; //reference to the node on the human model
  AnySeg &FreeMarker=.MarkerFolder.RMCAL.Seg; //reference to free floating marker
  AnyVec3 NodePos =..lm.RMCAL;
  AnyString ScaleType = "0 ";
};

AnyFolder M12={
  AnyInt MarkerNo=11;
  AnyString Name = "RMT23B"; //name of the marker
  AnySeg &Seg=...HumanModel.FootSegmentsRight.MidFoot; //reference to the
  Seg={AnyRefNode RMT23B={sRel= .Scale(....lm.RMT23B); #include
    "DrawMarker.any"};}; //add the marker to the segment it will read the sRel values from
  AnyString SegNr ="3 "; //segment nr according to the numbering system in the
  GaitApplication2 file
  AnyRefNode &Node=Seg.RMT23B; //reference to the node on the human model
  AnySeg &FreeMarker=.MarkerFolder.RMT23B.Seg; //reference to free floating
  marker segment
  AnyVec3 NodePos =..lm.RMT23B;
  AnyString ScaleType = "0 ";
};

AnyFolder M13={
  AnyInt MarkerNo=12;
  AnyString Name = "RMT23H"; //name of the marker
  AnySeg &Seg=...HumanModel.FootSegmentsRight.MidFoot; //reference to the
  Seg={AnyRefNode RMT23H={sRel= .Scale(....lm.RMT23H); #include
    "DrawMarker.any"};}; //add the marker to the segment it will read the sRel values from
  AnyString SegNr ="4 "; //segment nr according to the numbering system in the
  GaitApplication2 file
  AnyRefNode &Node=Seg.RMT23H; //reference to the node on the human model
  AnySeg &FreeMarker=.MarkerFolder.RMT23H.Seg; //reference to free floating
  marker segment
  AnyVec3 NodePos =..lm.RMT23H;
  AnyString ScaleType = "0 ";
};
AnyString SegNr =" 3 "; //segment nr according to the numbering system in the GaitApplication2 file
AnyRefNode &Node=Seg.RMT23H; //reference to the node on the human model
AnySeg &FreeMarker=.MarkerFolder.RMT23H.Seg; //reference to free floating marker segment
AnyVec3 NodePos =.lm.RMT23H;
AnyString ScaleType = " 0 ";
}

AnyFolder M14 ={
AnyInt MarkerNo=13;
AnyString Name = "RMT1BM"; //name of the marker
AnySeg &Seg=...HumanModel.FootSegmentsRight.MidFoot; //reference to the segment where the marker is located on the human model
Seg={AnyRefNode RMT1BM={sRel= .Scale(.lm.RMT1BM); #include "DrawMarker.any"});}; //add the marker to the segment it will read the sRel values from the file outputpar.any
AnyString SegNr =" 3 "; //segment nr according to the numbering system in the GaitApplication2 file
AnyRefNode &Node=Seg.RMT1BM; //reference to the node on the human model
AnySeg &FreeMarker=.MarkerFolder.RMT1BM.Seg; //reference to free floating marker segment
AnyVec3 NodePos =.lm.RMT1BM;
AnyString ScaleType = " 0 ";
}

AnyFolder M15 ={
AnyInt MarkerNo=14;
AnyString Name = "RMT1HM"; //name of the marker
AnySeg &Seg=...HumanModel.FootSegmentsRight.MidFoot; //reference to the segment where the marker is located on the human model
Seg={AnyRefNode RMT1HM={sRel= .Scale(.lm.RMT1HM); #include "DrawMarker.any"});}; //add the marker to the segment it will read the sRel values from the file outputpar.any
AnyString SegNr =" 3 "; //segment nr according to the numbering system in the GaitApplication2 file
AnyRefNode &Node=Seg.RMT1HM; //reference to the node on the human model
AnySeg &FreeMarker=.MarkerFolder.RMT1HM.Seg; //reference to free floating marker segment
AnyVec3 NodePos =.lm.RMT1HM;
AnyString ScaleType = " 0 ";
}

AnyFolder M16 ={
AnyInt MarkerNo=15;
AnyString Name = "RTOE1"; //name of the marker
AnySeg &Seg=...HumanModel.FootSegmentsRight.Toes; //reference to the segment where the marker is located on the human model
Seg={AnyRefNode RTOE1={sRel=.Scale(...lm.RTOE1); #include "DrawMarker.any"};}; //add the marker to the segment it will read the sRel values from the file outputpar.any
AnyString SegNr = "4 "; //segment nr according to the numbering system in the GaitApplication2 file
AnyRefNode &Node=Seg.RTOE1; //reference to the node on the human model
AnySeg &FreeMarker=.MarkerFolder.RTOE1.Seg; //reference to free floating marker segment
AnyVec3 NodePos =..lm.RTOE1;
AnyString ScaleType = " 0 ";
};

AnyFolder M17 ={  
   AnyInt MarkerNo=16;  
   AnyString Name = "RTOE2";  //name of the marker  
   AnySeg &Seg=...HumanModel.FootSegmentsRight.Toes; //reference to the segment where the marker is located on the human model  
Seg={AnyRefNode RTOE2={sRel=.Scale(...lm.RTOE2); #include "DrawMarker.any"};}; //add the marker to the segment it will read the sRel values from the file outputpar.any  
AnyString SegNr = "4 "; //segment nr according to the numbering system in the GaitApplication2 file  
AnyRefNode &Node=Seg.RTOE2; //reference to the node on the human model  
AnySeg &FreeMarker=.MarkerFolder.RTOE2.Seg; //reference to free floating marker segment  
AnyVec3 NodePos =..lm.RTOE2;
AnyString ScaleType = " 0 ";
};

AnyFolder M18 ={  
   AnyInt MarkerNo=17;  
   AnyString Name = "RTOE3";  //name of the marker  
   AnySeg &Seg=...HumanModel.FootSegmentsRight.Toes; //reference to the segment where the marker is located on the human model  
Seg={AnyRefNode RTOE3={sRel=.Scale(...lm.RTOE3); #include "DrawMarker.any"};}; //add the marker to the segment it will read the sRel values from the file outputpar.any  
AnyString SegNr = "4 "; //segment nr according to the numbering system in the GaitApplication2 file  
AnyRefNode &Node=Seg.RTOE3; //reference to the node on the human model  
AnySeg &FreeMarker=.MarkerFolder.RTOE3.Seg; //reference to free floating marker segment  
AnyVec3 NodePos =..lm.RTOE3;
AnyString ScaleType = " 0 ";
AnyMat33 RightLegToesJoint_MidFoot =
Main.MarkerPlacementStudy.HumanModel.FootSegmentsRight.MidFoot.ToeJoint.ARel;
AnyMat33 RightLegToesJoint_Toes =
Main.MarkerPlacementStudy.HumanModel.FootSegmentsRight.Toes.ToeJoint.ARel;

AnyString String = {
  "INITPOS" + " 
  + strval(.ThighRightLin.Pos[0]) + " 
  + strval(.ThighRightLin.Pos[1]) + " 
  + strval(.ThighRightLin.Pos[2]) + " 
  + strval(.ThighRightRot.Pos[0]) + " 
  + strval(.ThighRightRot.Pos[1]) + " 
  + strval(.ThighRightRot.Pos[2]) + " 
  + strval(.ThighRightRot.Pos[3]) + " 
  + strval(.ShankRightLin.Pos[0]) + " 
  + strval(.ShankRightLin.Pos[1]) + " 
  + strval(.ShankRightLin.Pos[2]) + " 
  + strval(.ShankRightRot.Pos[0]) + " 
  + strval(.ShankRightRot.Pos[1]) + " 
  + strval(.ShankRightRot.Pos[2]) + " 
  + strval(.ShankRightRot.Pos[3]) + " 
  + strval(.HindFootRightLin.Pos[0]) + " 
  + strval(.HindFootRightLin.Pos[1]) + " 
  + strval(.HindFootRightLin.Pos[2]) + " 
  + strval(.HindFootRightRot.Pos[0]) + " 
  + strval(.HindFootRightRot.Pos[1]) + " 
  + strval(.HindFootRightRot.Pos[2]) + " 
  + strval(.HindFootRightRot.Pos[3]) + " 
  + strval(.MidFootRightLin.Pos[0]) + " 
  + strval(.MidFootRightLin.Pos[1]) + " 

+ strval(.MidFootRightLin.Pos[2]) + " "
+ strval(.MidFootRightRot.Pos[0]) + " "
+ strval(.MidFootRightRot.Pos[1]) + " "
+ strval(.MidFootRightRot.Pos[2]) + " "
+ strval(.MidFootRightRot.Pos[3]) + " "

+ strval(.ToesRightLin.Pos[0]) + " "
+ strval(.ToesRightLin.Pos[1]) + " "
+ strval(.ToesRightLin.Pos[2]) + " "
+ strval(.ToesRightRot.Pos[0]) + " "
+ strval(.ToesRightRot.Pos[1]) + " "
+ strval(.ToesRightRot.Pos[2]) + " "
+ strval(.ToesRightRot.Pos[3]) + " ",

"EULERANGLE" +" "
+ strval(.Mannequin.Posture.Right.ThighRotZ/180*pi) + " "
+ strval(.Mannequin.Posture.Right.ThighRotY/180*pi) + " "
+ strval(.Mannequin.Posture.Right.ThighRotX/180*pi) + " "
+ strval(.Mannequin.Posture.Right.KneeInternalExternal/180*pi) + " "
+ strval(.Mannequin.Posture.Right.KneeFlexion/180*pi) + " "
+ strval(.Mannequin.Posture.Right.KneeAbduction/180*pi) + " "
+ strval(.Mannequin.Posture.Right.AkleInternalExternal/180*pi) + " "
+ strval(.Mannequin.Posture.Right.AklePlantarFlexion/180*pi) + " "
+ strval(.Mannequin.Posture.Right.AkleEversion/180*pi) + " "
+ strval(.Mannequin.Posture.Right.MidFootJointInternalExternal/180*pi) + " "
+ strval(.Mannequin.Posture.Right.MidFootJointPlantarFlexion/180*pi) + " "
+ strval(.Mannequin.Posture.Right.MidFootJointEversion/180*pi) + " "
+ strval(.Mannequin.Posture.Right.ToesJointPlantarFlexion/180*pi),

// Specify the scaling law
// "SCALINGLAW ZSCALING ",
// "SCALINGLAW UNIFORMSCALING ",
"SCALINGLAW UNIFORMSCALING _TOESMIDFOOTTOGETHER",
// "SCALINGLAW LENGTHMASSSSCALING",

/// Include the standard parameters
"STANDARDTHIGHLENGTH " +
strval(...HumanModel.Scaling.StandardParameters.ThighLength) ,
"STANDARDSHANKLENGTH " +
strval(...HumanModel.Scaling.StandardParameters.ShankLength) ,
"STANDARDHINDFOOTLENGTH " +
strval(...HumanModel.Scaling.StandardParameters.HindFootLength) ,
"STANDARDMIDFOOTLENGTH " +
strval(...HumanModel.Scaling.StandardParameters.MidFootLength) ,
"STANDARDTOESLENGTH " +
strval(...HumanModel.Scaling.StandardParameters.ToesLength) ,
"STANDARDTHIGHMASS " + strval(...HumanModel.Scaling.StandardParameters.ThighMass),
"STANDARDHINDFOOTMASS " + strval(...HumanModel.Scaling.StandardParameters.HindFootMass),
"STANDARDMIDFOOTMASS " + strval(...HumanModel.Scaling.StandardParameters.MidFootMass),
"STANDARDTOESMASS " + strval(...HumanModel.Scaling.StandardParameters.ToesMass),

// // Include the current mass parameters. These parameters are only used when a
MASSLENGTH scaling is performed.
"ANTROTHIGH " + strval(...HumanModel.Scaling.AnthroData.ThighMass),
"ANTROSHANK " + strval(...HumanModel.Scaling.AnthroData.ShankMass),
"ANTROHINDFOOT " + strval(...HumanModel.Scaling.AnthroData.HindFootMass),
"ANTROMIDFOOT " + strval(...HumanModel.Scaling.AnthroData.MidFootMass),
"ANTROTOES " + strval(...HumanModel.Scaling.AnthroData.ToesMass),

//Unscaled coordinates for joints these numbers should only change if there are
modifications in the Body
// right knee thigh
"RIGHTKNEETHIGH " +
strval(...HumanModel.FootSegmentsRight.Femur.UnscaledKneeJointNode[0]) + " " +
strval(...HumanModel.FootSegmentsRight.Femur.UnscaledKneeJointNode[1]) + " " +
strval(...HumanModel.FootSegmentsRight.Femur.UnscaledKneeJointNode[2]),

// right knee shank
"RIGHTKNEESHANK " +
strval(...HumanModel.FootSegmentsRight.Shank.UnscaledKneeJointNode[0]) + " " +
strval(...HumanModel.FootSegmentsRight.Shank.UnscaledKneeJointNode[1])+ " " +
strval(...HumanModel.FootSegmentsRight.Shank.UnscaledKneeJointNode[2]),

// right ankle shank
"RIGHTANKLESHANK " +
strval(...HumanModel.FootSegmentsRight.Shank.UnscaledAnkleJointNode[0]) + " " +
strval(...HumanModel.FootSegmentsRight.Shank.UnscaledAnkleJointNode[1])+ " " +
strval(...HumanModel.FootSegmentsRight.Shank.UnscaledAnkleJointNode[2]),

// right ankle foot
"RIGHTANKLEHINDFOOT " +
strval(...HumanModel.FootSegmentsRight.HindFoot.UnscaledAnkleJointNode[0])+ " " +
strval(...HumanModel.FootSegmentsRight.HindFoot.UnscaledAnkleJointNode[1])+ " " +
strval(...HumanModel.FootSegmentsRight.HindFoot.UnscaledAnkleJointNode[2])+ " ",

// right midfoot joint in hindfoot
"RIGHTMIDFOOTJOINTHINDFOOT" +
strval(...HumanModel.FootSegmentsRight.HindFoot.UnscaledMidFootJointNode[0]) + " "+
strval(...HumanModel.FootSegmentsRight.HindFoot.UnscaledMidFootJointNode[1]) + " "+
strval(...HumanModel.FootSegmentsRight.HindFoot.UnscaledMidFootJointNode[2]),

"RIGHTMIDFOOTJOINTMIDFOOT" +
strval(...HumanModel.FootSegmentsRight.MidFoot.UnscaledMidFootJointNode[0]) + " "+
strval(...HumanModel.FootSegmentsRight.MidFoot.UnscaledMidFootJointNode[1]) + " "+
strval(...HumanModel.FootSegmentsRight.MidFoot.UnscaledMidFootJointNode[2]),

"RIGHTTOEJOINTMIDFOOT" +
strval(...HumanModel.FootSegmentsRight.MidFoot.UnscaledToeJointNode[0]) + " "+
strval(...HumanModel.FootSegmentsRight.MidFoot.UnscaledToeJointNode[1]) + " "+
strval(...HumanModel.FootSegmentsRight.MidFoot.UnscaledToeJointNode[2]),

"AREL_RIGHTTOESJOINT_MIDFOOT" +
strval(RightLegToesJoint_MidFoot[0][0]) + " "+
strval(RightLegToesJoint_MidFoot[0][1]) + " "+
strval(RightLegToesJoint_MidFoot[0][2]) + " "+
strval(RightLegToesJoint_MidFoot[1][0]) + " "+
strval(RightLegToesJoint_MidFoot[1][1]) + " "+
strval(RightLegToesJoint_MidFoot[1][2]) + " "+
strval(RightLegToesJoint_MidFoot[2][0]) + " "+
strval(RightLegToesJoint_MidFoot[2][1]) + " "+
strval(RightLegToesJoint_MidFoot[2][2]),

"AREL_RIGHTTOESJOINT_TOES" +
strval(RightLegToesJoint_Toes[0][0]) + " "+
strval(RightLegToesJoint_Toes[0][1]) + " "+
strval(RightLegToesJoint_Toes[0][2]) + " "+
strval(RightLegToesJoint_Toes[1][0]) + " "+
strval(RightLegToesJoint_Toes[1][1]) + " "+
strval(RightLegToesJoint_Toes[1][2]) + " "+
strval(RightLegToesJoint_Toes[2][0]) + " "+
strval(RightLegToesJoint_Toes[2][1]) + " "+
strval(RightLegToesJoint_Toes[2][2]),

strval(.MarkerTopology.M1.NodePos[1]) + " "+
strval(.MarkerTopology.M1.NodePos[2]) + " weightdummy.txt " +
.MarkerTopology.M1.Name + " .txt dummy.txt dummy.txt " + "off off off", 
.MarkerTopology.M2.ScaleType + strval(.MarkerTopology.M2.NodePos[0]) + " "+
strval(.MarkerTopology.M2.NodePos[1]) + " "+
strval(.MarkerTopology.M2.NodePos[2])+ " weightdummy.txt " +
.MarkerTopology.M2.Name+ ".txt dummy.txt dummy.txt " + "on off off",
strval(.MarkerTopology.M3.NodePos[1]) + ""
strval(.MarkerTopology.M3.NodePos[2]) + " weightdummy.txt " +
.MarkerTopology.M3.Name+ ".txt dummy.txt dummy.txt " + "on on on",
strval(.MarkerTopology.M4.NodePos[1]) + ""
strval(.MarkerTopology.M4.NodePos[2]) + " weightdummy.txt " +
.MarkerTopology.M4.Name+ ".txt dummy.txt dummy.txt " + "on on on",
strval(.MarkerTopology.M5.NodePos[1]) + ""
strval(.MarkerTopology.M5.NodePos[2]) + " weightdummy.txt " +
.MarkerTopology.M5.Name+ ".txt dummy.txt dummy.txt " + "on on on",
strval(.MarkerTopology.M6.NodePos[1]) + ""
strval(.MarkerTopology.M6.NodePos[2]) + " weightdummy.txt " +
.MarkerTopology.M6.Name+ ".txt dummy.txt dummy.txt " + "on on on",
strval(.MarkerTopology.M7.NodePos[1]) + ""
strval(.MarkerTopology.M7.NodePos[2]) + " weightdummy.txt " +
.MarkerTopology.M7.Name+ ".txt dummy.txt dummy.txt " + "off off off",
strval(.MarkerTopology.M8.NodePos[1]) + ""
strval(.MarkerTopology.M8.NodePos[2]) + " weightdummy.txt " +
.MarkerTopology.M8.Name+ ".txt dummy.txt dummy.txt " + "off off off",
.MarkerTopology.M9.Name+ ".txt dummy.txt dummy.txt " + "on off off",
strval(.MarkerTopology.M10.NodePos[1]) + ""
strval(.MarkerTopology.M10.NodePos[2]) + " weightdummy.txt " +
.MarkerTopology.M10.Name+ ".txt dummy.txt dummy.txt " + "on on on",
strval(.MarkerTopology.M11.NodePos[1]) + ""
strval(.MarkerTopology.M11.NodePos[2]) + " weightdummy.txt " +
.MarkerTopology.M11.Name + ".txt dummy.txt dummy.txt " + "on on on",
strval(.MarkerTopology.M12.NodePos[1]) + " +
strval(.MarkerTopology.M12.NodePos[2]) + " weightdummy.txt " +
.MarkerTopology.M12.Name + ".txt dummy.txt dummy.txt " + "off off off",
strval(.MarkerTopology.M13.NodePos[1]) + " +
.MarkerTopology.M13.Name + ".txt dummy.txt dummy.txt " + "off off off",
strval(.MarkerTopology.M14.NodePos[1]) + " +
strval(.MarkerTopology.M15.NodePos[1]) + " +
strval(.MarkerTopology.M15.NodePos[2]) + " weightdummy.txt " +
.MarkerTopology.M15.Name + ".txt dummy.txt dummy.txt " + "off off on",
strval(.MarkerTopology.M16.NodePos[1]) + " +
.MarkerTopology.M16.Name + ".txt dummy.txt dummy.txt " + "on on off",
.MarkerTopology.M17.ScaleType + strval(.MarkerTopology.M17.NodePos[0]) + " +
strval(.MarkerTopology.M17.NodePos[1]) + " +
strval(.MarkerTopology.M17.NodePos[2]) + " weightdummy.txt " +
.MarkerTopology.M17.Name + ".txt dummy.txt dummy.txt " + "on on off",
strval(.MarkerTopology.M18.NodePos[1]) + " +
strval(.MarkerTopology.M18.NodePos[2]) + " weightdummy.txt " +
.MarkerTopology.M18.Name + ".txt dummy.txt dummy.txt " + "on on off",
"SCALEMAN THIGH" + " +strval(.sp.THIGH) + " on",
"SCALEMAN SHANK" + " +strval(.sp.SHANK) + " on",
"SCALEMAN HINDFOOT" + " +strval(.sp.HINDFOOT) + " on",
"SCALEMAN MIDFOOT" + " +strval(.sp.MIDFOOT) + " on",
"SCALEMAN TOES" + " +strval(.sp.MIDFOOT) + " on"};
***********************************************************************
//Mannequin.any

AnyFolder Mannequin = {
    AnyFolder Posture = {
        AnyFolder Right = {
            AnyVar ThighX = -1.616720915000814e+000;
            AnyVar ThighY = -9.265578908062610e-001;
            AnyVar ThighZ = 0.70;
            AnyVar ThighRotX = -5.0;
            AnyVar ThighRotY = -25.0;
            AnyVar ThighRotZ = 0.0;
            AnyVar KneeInternalExternal = 0.0;
            AnyVar KneeFlexion = 30.0;
            AnyVar KneeAbduction = 0.0;
            AnyVar AnkleInternalExternal = 0.0;
            AnyVar AnklePlantarFlexion = 0.0;
            AnyVar AnkleEversion = 0.0;
            AnyVar MidFootJointInternalExternal = 0.0;
            AnyVar MidFootJointPlantarFlexion = 0.0;
            AnyVar MidFootJointEversion = 0.0;
            AnyVar ToesJointInternalExternal = 0.0;
            AnyVar ToesJointPlantarFlexion = 0.0;
            AnyVar ToesJointEversion = 0.0;
        }
    }
}

AnyFolder PostureVel = {
    //This controls the position of the pelvi wrt. to the global reference frame
    AnyFolder Right = {
        AnyVar ThighX = 0.0;
        AnyVar ThighY = 0.0;
        AnyVar ThighZ = 0.0;
        AnyVar ThighRotX = 0.0;
        AnyVar ThighRotY = 0.0;
        AnyVar ThighRotZ = 0.0;
        AnyVar KneeInternalExternal = 0.0;
        AnyVar KneeFlexion = 0.0;
        AnyVar KneeAbduction = 0.0;
        AnyVar AnkleInternalExternal = 0.0;
        AnyVar AnklePlantarFlexion = 0.0;
        AnyVar AnkleEversion = 0.0;
        AnyVar MidFootJointInternalExternal = 0.0;
        AnyVar MidFootJointPlantarFlexion = 0.0;
        AnyVar MidFootJointEversion = 0.0;
        AnyVar ToesJointInternalExternal = 0.0;
        AnyVar ToesJointPlantarFlexion = 0.0;
        AnyVar ToesJointEversion = 0.0;
    }
}
AnyVar MidFootJointPlantarFlexion = 0.0;
AnyVar MidFootJointEversion = 0.0;
AnyVar ToesJointInternalExternal = 0.0;
AnyVar ToesJointPlantarFlexion = 0.0;
AnyVar ToesJointEversion = 0.0;

};
};
};
***********************************************************************
=====================================================================
/JointAnglesAndDrivers.any

AnyFolder Drivers = {
// Aliases for convenient referencing
AnyFolder &JntPos=..Mannequin.Posture;
AnyFolder &JntVel=..Mannequin.PostureVel;

// ************************************
// Drivers for attaching the right thigh to the global reference system
// ************************************

AnyKinEqSimpleDriver RightThighGroundDriver = {
AnyKinLinear lin ={
  AnyFixedRefFrame &ref1 =....EnvironmentModel.GlobalRef;
  AnySeg &ref2 =....HumanModel.FootSegmentsRight.Femur;
};
AnyKinRotational rot ={
  AnyFixedRefFrame &ref1 =....EnvironmentModel.GlobalRef;
  AnySeg &ref2 =....HumanModel.FootSegmentsRight.Femur;
  Type=RotAxesAngles;
};
DriverPos=
  .JntPos.Right.ThighX,
  .JntPos.Right.ThighY,
  .JntPos.Right.ThighZ,
  pi/180*.JntPos.Right.ThighRotZ,
  pi/180*.JntPos.Right.ThighRotY,
  pi/180*.JntPos.Right.ThighRotX
};
DriverVel=
  .JntVel.Right.ThighX,
  .JntVel.Right.ThighY,
  .JntVel.Right.ThighZ,
  pi/180*.JntVel.Right.ThighRotZ,
pi/180*.JntVel.Right.ThighRotY,  
pi/180*.JntVel.Right.ThighRotX  
};  
Reaction.Type={On,On,On,On,On,On};  
};  

// Drivers for the right leg  

//Knee driver  
AnyKinEqSimpleDriver KneeDriverRight= {  
AnyKinRotational rot = {  
Type=RotAxesAngles;  
AnySeg &ref1 = ....HumanModel.FootSegmentsRight.Femur;  
AnySeg &ref2 = ....HumanModel.FootSegmentsRight.Shank;  
};  
DriverPos= {  
pi/180*.JntPos.Right.KneeInternalExternal,  
pi/180*.JntPos.Right.KneeFlexion,  
pi/180*.JntPos.Right.KneeAbduction  
};  
DriverVel= {  
pi/180*.JntVel.Right.KneeInternalExternal,  
pi/180*.JntVel.Right.KneeFlexion,  
pi/180*.JntVel.Right.KneeAbduction  
};  
Reaction.Type= {On,On,On};  
};  

//Ankle driver  
AnyKinEqSimpleDriver AnkleDriverRight= {  
AnyKinRotational rot = {  
Type=RotAxesAngles;  
AnySeg &ref1 = ....HumanModel.FootSegmentsRight.Shank;  
AnySeg &ref2 = ....HumanModel.FootSegmentsRight.HindFoot;  
};  
DriverPos= {  
pi/180*.JntPos.Right.AnkleInternalExternal,  
pi/180*.JntPos.Right.AnklePlantarFlexion,  
pi/180*.JntPos.Right.AnkleEversion  
};  
DriverVel= {  
pi/180*.JntVel.Right.AnkleInternalExternal,  
pi/180*.JntVel.Right.AnklePlantarFlexion,  
pi/180*.JntVel.Right.AnkleEversion  
};
Reaction.Type={On,On,On};

// midfoot joint driver
AnyKinEqSimpleDriver MidFootJointDriverRight={
    AnyKinRotational rot ={
        Type=RotAxesAngles;
        AnySeg &ref1 = ....HumanModel.FootSegmentsRight.HindFoot;
        AnySeg &ref2 = ....HumanModel.FootSegmentsRight.MidFoot;
    };
    DriverPos={
        pi/180*.JntPos.Right.MidFootJointInternalExternal,
        pi/180*.JntPos.Right.MidFootJointPlantarFlexion,
        pi/180*.JntPos.Right.MidFootJointEversion
    };
    DriverVel={
        pi/180*.JntVel.Right.MidFootJointInternalExternal,
        pi/180*.JntVel.Right.MidFootJointPlantarFlexion,
        pi/180*.JntVel.Right.MidFootJointEversion
    };
    Reaction.Type={On,On,On};
};

// toe joint driver
AnyKinEqSimpleDriver ToeJointDriverRight={
    AnyKinMeasureOrg Org ={
        AnyKinRotational rot ={
            Type=RotAxesAngles;
            Axis1=y;
            Axis2=x;
            Axis3=z;
            AnyRefFrame &ref1 = .....HumanModel.FootSegmentsRight.MidFoot.ToeJoint;
            AnyRefFrame &ref2 = .....HumanModel.FootSegmentsRight.Toes.ToeJoint;
        };
        MeasureOrganizer={0};
    };
    DriverPos={
        pi/180*.JntPos.Right.ToesJointPlantarFlexion
    };
    DriverVel={
        pi/180*.JntVel.Right.ToesJointPlantarFlexion
    };
    Reaction.Type={On};
};

AnyFolder Toe2Driver = {


AnyVar ToesCoef = 1.0;
AnySwitchVar OnOff = On;
AnyRefFrame &ToeOneRef = ...HumanModel.FootSegmentsRight.MidFoot.ToeJoint;
AnyRefFrame &ToeOne = ...HumanModel.FootSegmentsRight.Toes.ToeJoint;
AnyRefFrame &ToeTwoRef = ...HumanModel.FootSegmentsRight.MidFoot.MP2Joint;
AnyRefFrame &ToeTwo = ...HumanModel.FootSegmentsRight.Toe2.MP2Joint;
#include "ToeDriver.any"
};

AnyFolder Toe3Driver = {
AnyVar ToesCoef = 1.0;
AnySwitchVar OnOff = On;
AnyRefFrame &ToeOneRef = ...HumanModel.FootSegmentsRight.MidFoot.ToeJoint;
AnyRefFrame &ToeOne = ...HumanModel.FootSegmentsRight.Toes.ToeJoint;
AnyRefFrame &ToeTwoRef = ...HumanModel.FootSegmentsRight.MidFoot.MP3Joint;
AnyRefFrame &ToeTwo = ...HumanModel.FootSegmentsRight.Toe3.MP3Joint;
#include "ToeDriver.any"
};

AnyFolder Toe4Driver = {
AnyVar ToesCoef = 1;
AnySwitchVar OnOff = On;
AnyRefFrame &ToeOneRef = ...HumanModel.FootSegmentsRight.MidFoot.ToeJoint;
AnyRefFrame &ToeOne = ...HumanModel.FootSegmentsRight.Toes.ToeJoint;
AnyRefFrame &ToeTwoRef = ...HumanModel.FootSegmentsRight.MidFoot.MP4Joint;
AnyRefFrame &ToeTwo = ...HumanModel.FootSegmentsRight.Toe4.MP4Joint;
#include "ToeDriver.any"
};

AnyFolder Toe5Driver = {
AnyVar ToesCoef = 1;
AnySwitchVar OnOff = On;
AnyRefFrame &ToeOneRef = ...HumanModel.FootSegmentsRight.MidFoot.ToeJoint;
AnyRefFrame &ToeOne = ...HumanModel.FootSegmentsRight.Toes.ToeJoint;
AnyRefFrame &ToeTwoRef = ...HumanModel.FootSegmentsRight.MidFoot.MP5Joint;
AnyRefFrame &ToeTwo = ...HumanModel.FootSegmentsRight.Toe5.MP5Joint;
#include "ToeDriver.any"
};

}; //Drivers

ulumi

//OptModel.any

AnyFolder OptModel = {
AnyFolder &HumanModel = ..HumanModel;
//Create segments for each of the markers and drive them according to data
/include "MarkerListMoverInclude.any"
#include "Mannequin.any"

AnyFolder OptimizedMarkers = {
    AnyFolder &lm=...HumanModel.Scaling.LocalMarkerCoordinates;
    AnyFolder &sp=...HumanModel.Scaling.ScalingParameters;
    AnyVec3 RGB={0,1,0};  //color of optimized markers
    #include "MarkerTopology.any"
};

//Environment around the human
AnyFolder EnvironmentModel = {
    //Model of the floor and force plates
    #include "Environment.any"
};

//Connection between environment and the human
AnyFolder ModelEnvironmentConnection = {
    //Drivers for the model
    #include "JointsAndDriversOptimized.any"
};

***********************************************************************

/Environment.any

AnyFixedRefFrame GlobalRefRot={
    Axes = Main.Orientation;
    Origin={0,0,0};
};

AnyVar ScaleFactor = 0.001000;

AnySeg CenterOfPressureHindFoot={
    Mass=0;
    Jii={0,0,0,0,0,0};
    AnyRefNode node={
        //sRel={0.1131,0.154,-0.4847};
        sRel={0,0,0};
        AnyDrawNode drw={ScaleXYZ={0.005,.005,.005}; RGB={1,0,0};};
    };
};

AnySeg CenterOfPressureMidFoot={
    Mass=0;
Jii={0.0,0.0,0.0};

AnyRefNode node=
    //sRel={0.11796,0.0808,-0.5158};
    sRel={0,0,0};
    AnyDrawNode drw={ScaleXYZ={0.005,.005,.005}; RGB={1,0,0};};
};

AnySeg CenterOfPressureToes={
    Mass=0;
    Jii={0.0,0.0,0.0};
    AnyRefNode node=
        //sRel={0.1757,0.0549,-0.5849};
        sRel={0,0,0};
        AnyDrawNode drw={ScaleXYZ={0.005,.005,.005}; RGB={1,0,0};};
    };

// HindFoot
AnyKinLinear LinHindFoot={
    Ref = 0;
    AnyRefFrame &ref1=.GlobalRefRot;
    AnyRefFrame &ref2=.CenterOfPressureHindFoot;
};

AnyKinRotational RotHindFoot={
    AnyRefFrame &ref1=.GlobalRefRot;
    AnyRefFrame &ref2=.CenterOfPressureHindFoot;
    Type=RotVector;
};

AnyKinEqInterPolDriver LinDrvHindFoot={
    AnyKinLinear &ref1 = .LinHindFoot;
    Type=PiecewiseLinear;
    Data=.ScaleFactor*Main.C3DFileData.ProcessedData.COPHFR.Pos';
    Reaction.Type={0,0,0};
};

AnyKinEqSimpleDriver RotDrvHindFoot={
    AnyKinRotational &ref1 = .RotHindFoot;
    DriverPos={0,0,0};
    DriverVel={0,0,0};
    Reaction.Type={0,0,0};
};
AnyReacForce ForcePlateHindFootRContactForce={
    AnyKinLinear LinH={
        //very very important this ensurs that the reaction is between artifical segment and the foot
        //and not between foot and globalref if Ref had been equal -1 which is default
        Ref=0;
        AnySeg &ref1=..CenterOfPressureHindFoot;
        AnySeg &ref2=..HumanModel.FootSegmentsRight.HindFoot;
    };
    AnyKinRotational RotH={
        AnySeg &ref1=..CenterOfPressureHindFoot;
        AnySeg &ref2=..HumanModel.FootSegmentsRight.HindFoot;
        Type=RotVector;
    };
}
AnyForce3D ForceOnForcePlateHindFoot={
    AnyFunInterpol forceH={
        Type=PiecewiseLinear;
        //Type=Bspline;
        //BsplineOrder = 4.000000;
        //#include "time.any"
        Data=Main.C3DFileData.ProcessedData.GRFHFR.Pos';
        //#include "ForcePlate_HindFoot3.any"
    };
    AnySeg &ref1=..CenterOfPressureHindFoot;
    F=forceH(t);
};

AnyDrawVector DrawSupportHindFoot={
    AnyRefFrame &ref=..CenterOfPressureHindFoot;
    Vec = 0.001*.ForceOnForcePlateHindFoot.F;
    PointAway = Off;
    DrawCoord = Off;
    Line.RGB = {1,0,0};
    Line.Thickness =0.0075;
    Line.End.Thickness = 4*0.0075;
    Line.End.Length = 4*0.0075;
    Line.End.Style=Line3DCapStyleArrow;
};
// End of HindFoot
// MidFoot
AnyKinLinear LinMidFoot=
   Ref = 0;
   AnyRefFrame &ref1=.GlobalRefRot;
   AnyRefFrame &ref2=.CenterOfPressureMidFoot;
};

AnyKinRotational RotMidFoot=
   AnyRefFrame &ref1=.GlobalRefRot;
   AnyRefFrame &ref2=.CenterOfPressureMidFoot;
   Type=RotVector;
};

AnyKinEqInterPolDriver LinDrvMidFoot=
   AnyKinLinear &ref1= .LinMidFoot;
   Type=PiecewiseLinear;
   Data=.ScaleFactor*Main.C3DFileData.ProcessedData.COPMFR.Pos';
   Reaction.Type={0,0,0};
};

AnyKinEqSimpleDriver RotDrvMidFoot=
   AnyKinRotational &ref1= .RotMidFoot;
   DriverPos={0,0,0};
   DriverVel={0,0,0};
   Reaction.Type={0,0,0};
};

AnyReacForce ForcePlateMidFootFootRContactForce=
   AnyKinLinear LinM=
      //very very important this ensurs that the reaction is between artifical segment and the
      //and not between foot and globalref if Ref had been equal -1 which is default
      Ref=0;
      AnySeg &ref1=..CenterOfPressureMidFoot;
      AnySeg &ref2=...HumanModel.FootSegmentsRight.MidFoot;
    };;
   AnyKinRotational RotM= {
      AnySeg &ref1=..CenterOfPressureMidFoot;
      AnySeg &ref2=...HumanModel.FootSegmentsRight.MidFoot;
      Type=RotVector;
    };
  
};

AnyForce3D ForceOnForcePlateMidFoot ={
   AnyFunInterpol forceM ={
Type=PiecewiseLinear;
   Data=-Main.C3DFileData.ProcessedData.GRFMFR.Pos';
};
AnySeg &ref1=.CenterOfPressureMidFoot;
F=forceM(t);
};

AnyDrawVector DrawSupportMidFoot = {
   AnyRefFrame &ref = .CenterOfPressureMidFoot;
   Vec = 0.001*.ForceOnForcePlateMidFoot.F;

   PointAway = Off;
   DrawCoord = Off;

   Line.RGB = {0,1,0};
   Line.Thickness =0.0075;
   Line.End.Thickness = 4*0.0075;
   Line.End.Length = 4*0.0075;
   Line.End.Style=Line3DCapStyleArrow;
};
// End of MidFoot

// Toes
AnyKinLinear LinToes={
   Ref = 0;
   AnyRefFrame &ref1=.GlobalRefRot;
   AnyRefFrame &ref2=.CenterOfPressureToes;
};

AnyKinRotational RotToes={
   AnyRefFrame &ref1=.GlobalRefRot;
   AnyRefFrame &ref2=.CenterOfPressureToes;
   Type=RotVector;
};

AnyKinEqInterPolDriver LinDrvToes={
   AnyKinLinear &ref1 = .LinToes;
   Type=PiecewiseLinear;
   Data=.ScaleFactor*Main.C3DFileData.ProcessedData.COPTSR.Pos';
   Reaction.Type={0,0,0};
};
AnyKinEqSimpleDriver RotDrvToes={
  AnyKinRotational &ref1=.RotToes;
  DriverPos={0,0,0};
  DriverVel={0,0,0};
  Reaction.Type={0,0,0};
};

AnyReacForce ForcePlateToesFootRContactForce={
  AnyKinRotational RotT=
    AnyRefFrame &ref1=..GlobalRefRot;
    AnyRefFrame &ref2=..CenterOfPressureToes;
    Type=RotAxesAngles;
  );
};

AnyFolder ConditionalContactToe1={
  //BaseObject ={AnyDrawRefFrame drw={ScaleXYZ={1,1,1}*0.5;}};
  AnyRefFrame &BaseObject=.CenterOfPressureToes; //Object which delivers the forces
  AnyRefFrame &TargetObject= ..HumanModel.FootSegmentsRight.Toes; //Location where the force is applied
  AnyRefFrame &StrengthObject=TargetObject; //Node used for strength measurement, occasionally this is different from the target object
  AnyFolder &DrawRef=Main.DrawSettings; //reference to the folder which contains drawsettings
  //low limit for the strength measure function, if the distance measured along Direction[0] is below this val. the strength will be zero (negative)
  AnyVar UserDefinedLimitLow=-2.0;
  //high limit for the strength measure function, if the distance measured along Direction[0] is above this val. the strength will be zero
  AnyVar UserDefinedLimitHigh=2.0;
  //high limit for the strength measure function, if the radius measured along the plane with Direction[0] as normal is above this val. the strength will be zero
  AnyVar UserDefinedRadiusLimit=5.0;
  AnyVar Strength =1000; //strength of muscles
  AnyVar StaticFrictionCoefficient=1; //Friction coefficient
  AnyVar ScaleFactor =1; //scale factor for draw vectors it can be set differently than by the drawsettings
  AnyIntArray Direction={1,0,0}; //first element gives normal direction
#include  "G:\Research\Foot Model\My Folder\Anybody Model\Repository7.1\Body\AAUHuman\ToolBox\FrictionContactMuscles\ContactSurfaceLinPush.any"
AnyFolder ConditionalContactToe2 = {
    AnyRefFrame &BaseObject=.CenterOfPressureToes; //Object which delivers the forces
    AnyRefFrame &TargetObject=..HumanModel.FootSegmentsRight.Toe2;//Location where the force is applied
    AnyRefFrame &StrengthObject=TargetObject; //Node used for strength measurement, occasionally this is different from the target object

    AnyFolder &DrawRef=Main.DrawSettings; //reference to the folder which contains drawsettings
        //low limit for the strength measure function, if the distance measured along Direction[0] is below this val. the strength will be zero (negative)
        AnyVar UserDefinedLimitLow=-2.0;
        //high limit for the strength measure function, if the distance measured along Direction[0] is above this val. the strength will be zero
        AnyVar UserDefinedLimitHigh=2.0;
        //high limit for the strength measure function, if the radius measured along the plane with Direction[0] as normal is above this val. the strength will be zero
        AnyVar UserDefinedRadiusLimit=5.0;
    AnyVar Strength =1000; //strength of muscles
    AnyVar StaticFrictionCoefficient=1; //Friction coefficient
    AnyVar ScaleFactor =1; //scale factor for draw vectors it can be set differently than by the drawsettings
    AnyIntArray Direction={2,0,1}; //first element gives normal direction
        //include "c:\test4\Repository7\Body\AAUHuman\ToolBox\FrictionContactMuscles\ContactSurfaceLinPush.any"
        //include "G:\Research\Foot Model\My Folder\Anybody Model\Repository7.1\Body\AAUHuman\ToolBox\FrictionContactMuscles\ContactSurfaceLinPush.any"
    }
    AnyFolder ConditionalContactToe3 = {

    AnyRefFrame &BaseObject=.CenterOfPressureToes; //Object which delivers the forces
    AnyRefFrame &TargetObject=..HumanModel.FootSegmentsRight.Toe3;//Location where the force is applied
    AnyRefFrame &StrengthObject=TargetObject; //Node used for strength measurement, occasionally this is different from the target object
    AnyRefFrame &StrengthObject=TargetObject; //Node used for strength measurement, occasionally this is different from the target object

    AnyFolder &DrawRef=Main.DrawSettings; //reference to the folder which contains drawsettings
        //low limit for the strength measure function, if the distance measured along Direction[0] is below this val. the strength will be zero (negative)
        AnyVar UserDefinedLimitLow=-2.0;
//high limit for the strength measure function, if the distance measured along Direction[0] is above this val. the strength will be zero
AnyVar UserDefinedLimitHigh=2.0;

//high limit for the strength measure function, if the radius measured along the plane with Direction[0] as normal is above this val. the strength will be zero
AnyVar UserDefinedRadiusLimit=5.0;

AnyVar Strength =1000; //strength of muscles
AnyVar StaticFrictionCoefficient=1; //Friction coefficient
AnyVar ScaleFactor =1; //scale factor for draw vectors it can be set differently than by the drawsettings

AnyIntArray Direction={2,0,1}; //first element gives normal direction
#include "c:\test4\Repository7\Body\AAUHuman\ToolBox\FrictionContactMuscles\ContactSurfaceLinPush.any"
#include "G:\Research\Foot Model\My Folder\Anybody Model\Repository7.1\Body\AAUHuman\ToolBox\FrictionContactMuscles\ContactSurfaceLinPush.any"

AnyFolder ConditionalContactToe4 = {

AnyRefFrame &BaseObject=.CenterOfPressureToes; //Object which delivers the forces
AnyRefFrame &TargetObject=..HumanModel.FootSegmentsRight Toe4; //Location where the force is applied
AnyRefFrame &StrengthObject=TargetObject; //Node used for strength measurement, occasionally this is different from the target object

AnyFolder &DrawRef=Main.DrawSettings; //reference to the folder which contains drawsettings
//low limit for the strength measure function, if the distance measured along Direction[0] is below this val. the strength will be zero (negative)
AnyVar UserDefinedLimitLow=-2.0;
//high limit for the strength measure function, if the distance measured along Direction[0] is above this val. the strength will be zero
AnyVar UserDefinedLimitHigh=2.0;

//high limit for the strength measure function, if the radius measured along the plane with Direction[0] as normal is above this val. the strength will be zero
AnyVar UserDefinedRadiusLimit=5.0;

AnyVar Strength =1000; //strength of muscles
AnyVar StaticFrictionCoefficient=1; //Friction coefficient
AnyVar ScaleFactor =1; //scale factor for draw vectors it can be set differently than by the drawsettings

AnyIntArray Direction={2,0,1}; //first element gives normal direction
#include "c:\test\4\Repository7\Body\AAUHuman\ToolBox\FrictionContactMuscles\ContactSurfaceLinPush.any"
#include "G:\Research\Foot Model\My Folder\Anybody Model\Repository7.1\Body\AAUHuman\ToolBox\FrictionContactMuscles\ContactSurfaceLinPush.any"
}

AnyFolder ConditionalContactToe5 = {

AnyRefFrame &BaseObject=.CenterOfPressureToes; //Object which delivers the forces
AnyRefFrame &TargetObject= ..HumanModel.FootSegmentsRight.Toe5;//Location where the force is applied
AnyRefFrame &StrengthObject=TargetObject; //Node used for strength measurement, occasionally this is different from the target object

AnyFolder &DrawRef=Main.DrawSettings; //reference to the folder which contains drawsettings
//low limit for the strength measure function, if the distance measured along Direction[0] is below this val. the strength will be zero (negative)
AnyVar UserDefinedLimitLow=-2.0;
//high limit for the strength measure function, if the distance measured along Direction[0] is above this val. the strength will be zero
AnyVar UserDefinedLimitHigh=2.0;

//high limit for the strength measure function, if the radius measured along the plane with Direction[0] as normal is above this val. the strength will be zero
AnyVar UserDefinedRadiusLimit=5.0;
AnyVar Strength =1000; //strength of muscles
AnyVar StaticFrictionCoefficient=1; //Friction coefficient
AnyVar ScaleFactor =1; //scale factor for draw vectors it can be set differently than by the drawsettings

AnyIntArray Direction={2,0,1}; //first element gives normal direction
#include "c:\test\4\Repository7\Body\AAUHuman\ToolBox\FrictionContactMuscles\ContactSurfaceLinPush.any"
#include "G:\Research\Foot Model\My Folder\Anybody Model\Repository7.1\Body\AAUHuman\ToolBox\FrictionContactMuscles\ContactSurfaceLinPush.any"

AnyForce3D ForceOnForcePlateToes = {
    AnyFunInterpol forceT = {
        Type=PiecewiseLinear;
        //Type=Bspline;
        //BsplineOrder = 4.000000;
        //#include "time.any"
        Data=-Main.C3DFileData.ProcessedData.GRFTSR.Pos';
        //#include "ForcePlate_Toes3.any"
    }
    AnySeg &ref1=.CenterOfPressureToes;
    F=forceT(t);
};

AnyDrawVector DrawSupportToes = {
    AnyRefFrame &ref = .CenterOfPressureToes;
    Vec = 0.001*.ForceOnForcePlateToes.F;
    PointAway = Off;
    DrawCoord = Off;
    Line.RGB = {0,0,1};
    Line.Thickness =0.0075;
    Line.End.Thickness = 4*0.0075;
    Line.End.Length = 4*0.0075;
    Line.End.Style=Line3DCapStyleArrow;
};

// End of Toes

//=====================================================================================================

//JointsAndDriversOptimized.any

AnyFolder JointsAndDrivers = {
    AnyFixedRefFrame GlobalRef = {
        Origin={0,0,0};
    }
    AnyKinMeasureOrg JointMeasures = {
        AnyKinLinear ThighLin = {
            
        };
    }


//Ref = -1;
AnyRefFrame &ref1 = ..GlobalRef;
AnySeg &ref2 = ....HumanModel.FootSegmentsRight.Femur;
};

AnyKinRotational ThighRot = {
    Type = RotAxesAngles;
    AnyRefFrame &ref1 = ..GlobalRef;
    AnySeg &ref2 = ....HumanModel.FootSegmentsRight.Femur;
};

AnyKinRotational RightKnee = {
    Type = RotAxesAngles;
    AnyRefFrame &ref1 = ....HumanModel.FootSegmentsRight.Femur;
    AnyRefFrame &ref2 = ....HumanModel.FootSegmentsRight.Shank;
};

AnyKinRotational RightAnkle = {
    Type = RotAxesAngles;
    AnyRefFrame &ref1 = ....HumanModel.FootSegmentsRight.Shank;
    AnyRefFrame &ref2 = ....HumanModel.FootSegmentsRight.HindFoot;
};

AnyKinRotational RightMidFootJoint = {
    Type = RotAxesAngles;
    AnyRefFrame &ref1 = ....HumanModel.FootSegmentsRight.HindFoot;
    AnyRefFrame &ref2 = ....HumanModel.FootSegmentsRight.MidFoot;
};

AnyKinMeasureOrg RightToeJoint ={
    AnyKinRotational rot = {
        Type = RotAxesAngles;
        Axis1 = y;
        Axis2 = z;
        Axis3 = x;
        AnyRefFrame &ref1 = .....HumanModel.FootSegmentsRight.MidFoot.ToeJoint;
        AnyRefFrame &ref2 = .....HumanModel.FootSegmentsRight.Toes.ToeJoint;
    }; 
    MeasureOrganizer = {0};
};

AnyKinEqInterPolDriver Jntdriver =
{
    FileErrorContinueOnOff = On;
    Type = Bspline;
}
B splineOrder = 4;
FileName = "output-euler.txt";
AnyKinMeasureOrg &meas = .JointMeasures;
Reaction.Type={
  On,On,On,
  On,On,On,
  On,On,On,
  Off,Off,Off,
  On,Off,On,
  Off};
};
AnyReacForce RightAnkleReaction = {
  AnyKinMeasureOrg org = {
    AnyKinRotational RightAnkleReaction = {
      Type = RotVector;
      AnyRefFrame &ref1 = .....HumanModel.FootSegmentsRight.Shank;
      AnyRefFrame &ref2 = .....HumanModel.FootSegmentsRight.HindFoot;
    };  
    MeasureOrganizer = {1,0,0};  // carry the moment around x and z not y
  };}
};

AnyFolder Toe2Driver = {
  AnyVar ToesCoef = 1.0;
  AnySwitchVar OnOff = On;
  AnyRefFrame &ToeOneRef = ...HumanModel.FootSegmentsRight.MidFoot.ToeJoint;
  AnyRefFrame &ToeOne = ...HumanModel.FootSegmentsRight.Toes.ToeJoint;
  AnyRefFrame &ToeTwoRef = ...HumanModel.FootSegmentsRight.MidFoot.MP2Joint;
  AnyRefFrame &ToeTwo = ...HumanModel.FootSegmentsRight.Toe2.MP2Joint;
  #include "ToeDriver.any"
};

AnyFolder Toe3Driver = {
  AnyVar ToesCoef = 1.0;
  AnySwitchVar OnOff = On;
  AnyRefFrame &ToeOneRef = ...HumanModel.FootSegmentsRight.MidFoot.ToeJoint;
  AnyRefFrame &ToeOne = ...HumanModel.FootSegmentsRight.Toes.ToeJoint;
  AnyRefFrame &ToeTwoRef = ...HumanModel.FootSegmentsRight.MidFoot.MP3Joint;
  AnyRefFrame &ToeTwo = ...HumanModel.FootSegmentsRight.Toe3.MP3Joint;
  #include "ToeDriver.any"
};

AnyFolder Toe4Driver = {
  AnyVar ToesCoef = 1.0;
  AnySwitchVar OnOff = On;
AnyRefFrame &ToeOneRef = ...HumanModel.FootSegmentsRight.MidFoot.ToeJoint;
AnyRefFrame &ToeOne = ...HumanModel.FootSegmentsRight.Toes.ToeJoint;
AnyRefFrame &ToeTwoRef = ...HumanModel.FootSegmentsRight.MidFoot.MP4Joint;
AnyRefFrame &ToeTwo = ...HumanModel.FootSegmentsRight.Toe4.MP4Joint;

#include "ToeDriver.any"

AnyFolder Toe5Driver = {
    AnyVar ToesCoef = 1.0;
    AnySwitchVar OnOff = On;
    AnyRefFrame &ToeOneRef = ...HumanModel.FootSegmentsRight.MidFoot.ToeJoint;
    AnyRefFrame &ToeOne = ...HumanModel.FootSegmentsRight.Toes.ToeJoint;
    AnyRefFrame &ToeTwoRef = ...HumanModel.FootSegmentsRight.MidFoot.MP5Joint;
    AnyRefFrame &ToeTwo = ...HumanModel.FootSegmentsRight.Toe5.MP5Joint;
    #include "ToeDriver.any"
};

}

******************************************************************************

============================================================================
/CalibModel.any
AnyFolder CalibModel = {
    AnyFolder &HumanModel = ..HumanModel;

    //Connection between environment and the human
    AnyFolder ModelEnvironmentConnection = {
        //Drivers for the model
        #include "JointsAndDriversOptimized.any"
    };
};

******************************************************************************

============================================================================
/AngleMA.any

AnyVar default = 1e-20;

//Ankle Plantarflexors
AnyOutputFun MA_MedGastroc = {
    #include "MA_MedGastroc.any"
Val = .MomentArm_MedGastroc-Data[round(Main.MAStudy.t)];

AnyOutputFun MaxAct = {
  Val = Main.MAStudy.MaxMuscleActivity;
};

AnyVar MomentArm_LatGastroc = -

AnyVar MomentArm_Soleus = -

AnyVar MomentArm_PeroneusBrevis = -

AnyVar MomentArm_PeroneusLongus = -

AnyVar MomentArm_TibPost = -

// Ankle Dorsiflexors

AnyVar MomentArm_TibAnt = -

AnyVar MomentArm_PeroneusTertius = -

// Toe Extensors

AnyVar MomentArm_EHB = -
Main.HumanModel.FootMusclesRight.EHB.LmDot/(Main.HumanModel.FootJointsRight.AnkleJoint.Vel[1]+0.000001);

AnyVar MomentArm_EDB2 = -
Main.HumanModel.FootMusclesRight.EDB2.LmDot/(Main.HumanModel.FootJointsRight.AnkleJoint.Vel[1]+0.000001);

AnyVar MomentArm_EDB3 = -
Main.HumanModel.FootMusclesRight.EDB3.LmDot/(Main.HumanModel.FootJointsRight.AnkleJoint.Vel[1]+0.000001);

AnyVar MomentArm_EDB4 = -
\textbf{AnyVar MomentArm\textunderscore\textit{EDB5}} = - \text{Main.HumanModel.FootMusclesRight.EDB5.LmDot}/(\text{Main.HumanModel.FootJointsRight.AnkleJoint.Vel}[1]+0.000001);
\textbf{AnyVar MomentArm\textunderscore\textit{EHL}} = - \text{Main.HumanModel.FootMusclesRight.EHL.LmDot}/(\text{Main.HumanModel.FootJointsRight.AnkleJoint.Vel}[1]+0.000001);
\textbf{AnyVar MomentArm\textunderscore\textit{EDL2}} = - \text{Main.HumanModel.FootMusclesRight.EDL2.LmDot}/(\text{Main.HumanModel.FootJointsRight.AnkleJoint.Vel}[1]+0.000001);
\textbf{AnyVar MomentArm\textunderscore\textit{EDL3}} = - \text{Main.HumanModel.FootMusclesRight.EDL3.LmDot}/(\text{Main.HumanModel.FootJointsRight.AnkleJoint.Vel}[1]+0.000001);
\textbf{AnyVar MomentArm\textunderscore\textit{EDL4}} = - \text{Main.HumanModel.FootMusclesRight.EDL4.LmDot}/(\text{Main.HumanModel.FootJointsRight.AnkleJoint.Vel}[1]+0.000001);
\textbf{AnyVar MomentArm\textunderscore\textit{EDL5}} = - \text{Main.HumanModel.FootMusclesRight.EDL5.LmDot}/(\text{Main.HumanModel.FootJointsRight.AnkleJoint.Vel}[1]+0.000001);

\textcolor{red}{// Toe Flexors}
\textbf{AnyVar MomentArm\textunderscore\textit{FHB}} = - \text{Main.HumanModel.FootMusclesRight.FHB.LmDot}/(\text{Main.HumanModel.FootJointsRight.AnkleJoint.Vel}[1]+0.000001);
\textbf{AnyVar MomentArm\textunderscore\textit{FDB2}} = - \text{Main.HumanModel.FootMusclesRight.FDB2.LmDot}/(\text{Main.HumanModel.FootJointsRight.AnkleJoint.Vel}[1]+0.000001);
\textbf{AnyVar MomentArm\textunderscore\textit{FDB3}} = - \text{Main.HumanModel.FootMusclesRight.FDB3.LmDot}/(\text{Main.HumanModel.FootJointsRight.AnkleJoint.Vel}[1]+0.000001);
\textbf{AnyVar MomentArm\textunderscore\textit{FDB4}} = - \text{Main.HumanModel.FootMusclesRight.FDB4.LmDot}/(\text{Main.HumanModel.FootJointsRight.AnkleJoint.Vel}[1]+0.000001);
\textbf{AnyVar MomentArm\textunderscore\textit{FDB5}} = - \text{Main.HumanModel.FootMusclesRight.FDB5.LmDot}/(\text{Main.HumanModel.FootJointsRight.AnkleJoint.Vel}[1]+0.000001);
\textbf{AnyVar MomentArm\textunderscore\textit{FHL}} = - \text{Main.HumanModel.FootMusclesRight.FHL.LmDot}/(\text{Main.HumanModel.FootJointsRight.AnkleJoint.Vel}[1]+0.000001);

\textbf{AnyVar MomentArm\textunderscore\textit{FDL2}} = - \text{Main.HumanModel.FootMusclesRight.FDL2.LmDot}/(\text{Main.HumanModel.FootJointsRight.AnkleJoint.Vel}[1]+0.000001);
AnyVar MomentArm_FDL3 = -

AnyVar MomentArm_FDL4 = -

AnyVar MomentArm_FDL5 = -
Main.HumanModel.FootMusclesRight.FDL5.LmDot/(Main.HumanModel.FootJointsRight.AnkleJoint.Vel[1]+0.000001);

*******************************************************************************

AnyFolder MADrivers = {
//Driver for HJC motion
AnyKinLinear LinHJC={
 AnyRefFrame &ref1=Main.GlobalRef;
 AnyRefFrame &ref2=Main.HumanModel.FootSegmentsRight.Femur.HipJointNode;
};

AnyKinRotational RotHJC={
 AnyRefFrame &ref1=Main.GlobalRef;
 AnyRefFrame &ref2=Main.HumanModel.FootSegmentsRight.Femur.HipJointNode;
 Type=RotVector;
};

AnyKinEqSimpleDriver LinDrvHJC={
 AnyKinLinear &ref1= LinHJC;
 DriverPos={0,0,0};
 DriverVel={0,0,0};
 Reaction.Type={On,On,On};
};

AnyKinEqSimpleDriver RotDrvHJC={
 AnyKinRotational &ref1= RotHJC;
 DriverPos={0,0,0};
 DriverVel={0,0,0};
 Reaction.Type={On,On,On};
};

// End of HJC driver

AnyKinEqSimpleDriver KneeDriver = {
 DriverPos={0,8*pi/180,0};
 DriverVel={0,0,0};
Reaction.Type = {On,On,On};

//Ankle Joint
AnyKinEqSimpleDriver AnkleDriver = {
    AnySphericalJoint &AnkleJoint = Main.HumanModel.FootJointsRight.AnkleJoint;
    DriverVel={0,0,0};
    DriverPos={0, -75* pi/180,-10*pi/180};
    Reaction.Type = {On,On,On};
};

//MidFoot Joint
AnyKinEqSimpleDriver MidFootDriver = {
    AnySphericalJoint &MidFootJoint = Main.HumanModel.FootJointsRight.MidFootJoint;
    DriverPos={0,0 * pi/180,0};
    DriverVel={0,-0.02,0};
    Reaction.Type = {On,On,On};
};

//Toe Joint
AnyKinEqSimpleDriver ToeDriver = {
    AnyRevoluteJoint &ToeJoint = Main.HumanModel.FootJointsRight.ToeJoint;
    DriverPos={0};
    DriverVel={0};
    Reaction.Type = {On};
};

AnyKinEqSimpleDriver Toe2Driver = {
    AnyRevoluteJoint &ToeJoint = Main.HumanModel.FootJointsRight.MP2Joint;
    DriverPos={0};
    DriverVel={0};
    Reaction.Type = {On};
};

AnyKinEqSimpleDriver Toe3Driver = {
    AnyRevoluteJoint &ToeJoint = Main.HumanModel.FootJointsRight.MP3Joint;
    DriverPos={0};
    DriverVel={0};
    Reaction.Type = {On};
};

AnyKinEqSimpleDriver Toe4Driver = {
    AnyRevoluteJoint &ToeJoint = Main.HumanModel.FootJointsRight.MP4Joint;
    DriverPos={0};
    DriverVel={0};
    //DriverPos={20 * pi/180};
//DriverVel={-0.02};
Reaction.Type = {On};
};

AnyKinEqSimpleDriver Toe5Driver = {
    AnyRevoluteJoint &ToeJoint = Main.HumanModel.FootJointsRight.MP5Joint;
    DriverPos={0};
    DriverVel={0};
    Reaction.Type = {On};
};
// End of Moment Arm Driver

***********************************************************************
***********************************************************************
***********************************************************************


