A BIOMECHANICAL ANALYSIS OF THE POSTURE OF MUSCULAR DYSTROPHY

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BY

D.L. BURKE
Master of Science Thesis
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The results indicate that both lordosis and equinus stabilize the knee in extension. These compensatory mechanisms are progressively negated by progressive knee flexion contractures, resulting in inability to stand when the quadriceps muscles are severely weakened. An explanation is offered for the significant clinical observations of lordosis which disappears with knee bracing, requirement for knee bracing following heel cord lengthening, and of work hypertrophy of the calf muscles, which occur in muscular dystrophy.

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A thesis submitted to the Faculty of Graduate Studies and Research in partial fulfillment of the requirements for the degree of Master of Science.

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LIST OF ABBREVIATIONS

C.F.P.	–	centre of foot pressure
C of G	–	centre of gravity
N.S.M.	–	net stabilizing moment

ABSTRACT

This study reports on a biomechanical analysis of the vertical standing posture of normal human subjects and muscular dystrophy patients. The compensatory roles of lordosis and equinus in stabilizing the knee joint were studied using a force plate, cinephotographic and electromyographic methods.

The results indicate that both lordosis and equinus stabilize the knee in extension. These compensatory mechanisms are progressively negated by progressive knee flexion contractures, resulting in inability to stand when the quadriceps muscles are severely weakened. An explanation is offered for the significant clinical observations of lordosis which disappears with knee bracing, requirement for knee bracing following heel cord lengthening, and of work hypertrophy of the calf muscles, which occur in muscular dystrophy.

CHAPTER I

INTRODUCTION

The erect standing posture of man has attracted systematic study from a variety of viewpoints for almost a century. In 1887 Muybridge(45) and in 1889 Braun and Fischer(10) published their investigation of cine-photographic recorded body form and the centres of gravity of body segments. Since that time the mechanics of standing, measurement of postural deformities and neuromuscular functions have been investigated by several branches of the basic sciences, medicine, surgery, and, more recently, the biomedical engineer. The literature is extensive and includes the responses of various organ systems to postural variations.

Precision quantitative devices have been used comparatively little, however, by the orthopaedic specialist in the examination of postural disorders of the musculo-skeletal system. An understanding of the function of the locomotor apparatus in the upright or orthograde position is essential to research into dynamics of the body as it is the starting position in the transition to dynamic function.

Until the present time, most of the investigations have dealt primarily with static measurement of the centre of gravity of the body, measurement of the supportive forces of the body and the pressure distribution under the feet in standing and during walking.

There is growing interest not only in normal posture and gait, but also in how it may be altered by disease. The manner in which various diseases alter postural mechanics are of interest to the treating physician for several reasons. Such studies can lead to a more rational approach to selection of appropriate surgical and rehabilitative measures, assist in evaluating the results of surgery, and aid in establishing prognostic criteria.

This study was undertaken to investigate the characteristic posture of the childhood form of muscular dystrophy. The posture is characterized by lordosis, equinus and large calf muscles. Traditionally, these alterations have been explained empirically by attributing the lordosis to weak abdominal muscles and hip flexion contractures, and the equinus and calf hypertrophy to so-called "pseudohypertrophy". A unified explanation of these findings is proposed in the belief that they represent a complex compensatory substitution pattern, which provides stability to the lower limbs in the presence of muscle weakness. This study represents the first time that either normal subjects or subjects with pathological musculoskeletal conditions have been studied on a force plate to determine the influence of equinus and lordosis on the stabilizing moment at the knee joint.

CHAPTER II

MUSCULAR DYSTROPHY

2.1 DEFINITION

The term muscular dystrophy is reserved for those forms of genetically determined myopathies in which a degenerative process develops primarily in the muscle fibres themselves. Muscular dystrophy may therefore be defined as a genetically determined primary degenerative myopathy.

2.2 ETIOLOGY AND CLASSIFICATION

On the basis of classical clinical-anatomical description, pure muscular dystrophies have been divided into the following categories:

(i) Pseudohypertrophic (Duchenne 1868; Gowers 1879)

(ii) Pelvic girdle atrophic (Leydon 1876; Mobias 1879)

(iii) Fascio-Scapulo-Humero (Landouzy and Dejerine 1884)

(iv) Juvenile Scapulo-Humero (Erb 1884)

(v) Distal (Gowers 1902)

(vi) Late life (Nevan 1936)

(vii) Barnes type (Barnes 1932)

(viii) Ocular forms (Hutchinson 1879; Fuchs 1890)

This classification, however, has created a good deal of confusion concerning the mode of inheritance of the various forms of the disease. Examples of autosomal recessive, dominant and sex linked recessive inheritance were found in each of the clinical varieties by Milhorat & Wolf[46] and Bell[6].

According to Walton[60] a more acceptable classification is as follows:

1. Duchenne Type Muscular Dystrophy
   a) sex linked recessive variety
   b) autosomal recessive variety
2. Limb Girdle Muscular Dystrophy
   a) autosomal recessive
   b) sporadic
3. Fascio-Scapulo Humero Muscular Dystrophy
   (Autosomal dominant or rarely recessive variety)
4. Distal Variety
5. Ocular Myopathy
6. Congenital Muscular Dystrophy

2.3 PATHOLOGY

2.3.1 Histology

Clinically, cases of muscular dystrophy can be loosely divided into the categories previously outlined, but pathologically it is much more difficult to define these groups[7,49]. In general, lipomatosis is most likely to be found in the childhood (Duchenne) form which occurs predominantly in young boys in conjunction with pseudohypertrophy. Fibrosis is more common in the adult slowly progressive varieties. Once clinical weakness is evident, the changes are in general similar in all forms. The histological picture[49] is characterized by a random, haphazard involvement of individual muscle cells so that injured, dead and dying cells are mixed in with normal cells and with cells that have undergone compensatory hypertrophy.

In early cases described by Pearson[47,48] which were found by analyzing levels of various serum enzymes which are elevated through the preclinical and most of the clinical stages of the childhood form of the disease, some of the earlier events have been studied histologically. These studies have shown that myopathic lesions exist in the first few moments of life, though weakness may not appear until more than two years later. Moreover, it may be necessary for the dystrophic process to involve and affect to a significant degree about fifty percent of the fibres of a muscle before clinical weakness can be detected in the usual activities of daily living. Another feature of the pathology of early dystrophy is active regeneration of damaged muscle fibres. As the disease progresses, this feature becomes less evident. These studies also show that even in fully developed dystrophy, the muscle fibres retain the capacity to regenerate after induced injury.

The gross appearance of the muscles varies depending upon the type, duration and intensity of the disease process and the extent of replacement of the muscle fibres by fat and fibrous connective tissues. In the earliest stages, when clinical evidence is barely evident, only slight loss of the red-brown coloration is noted. Certain muscles, notably the calf, which undergo pseudohypertrophy are of normal coloration early, and later when the muscle is replaced with fat, the muscle resembles a yellow fatty tumor. Atrophic muscles in which condensation or overgrowth of fibrous connective tissue predominates are small in size, grayish white and tough in consistency.

The typical biopsy from a weakened proximal muscle in the average case of childhood dystrophy about one or two years after clinical recognition of weakness will usually reveal fairly typical histopathological findings.

These features are:

1) variability in diameter of individual fibres,
2) central nuclei,
3) splitting of parent fibres,
4) a variety of degenerative changes,
   (a) vacuolization
   (b) hyalinization
   (c) homogenization
5) atrophic fibres,
6) hypertrophied fibres scattered at random, some being hyalinized. These have been interpreted as true compensatory hypertrophy of sound fibres in an otherwise weakened muscle,
7) regenerating fibres,
8) fatty infiltration of an active and passive nature,
9) fibrosis which can be found as a late event in most varieties of dystrophy. In advanced childhood dystrophy it occurs as a partial replacement factor along with fat, but some of the increase may merely represent a condensation of the previous supporting connective tissue elements.

In early symptomatic dystrophy, at least one half of the muscle fibres must be involved, and at least partially functionally incompetent, before any strength is compromised for normal daily living activities[7].

In the advanced stages the histopathologic features are:

(1) variation in diameter of muscle fibres,

(2) reduction in number of recognizable muscle fibres,

(3) replacement by fat or fibrous connective tissue, and

(4) increased degenerative changes in the remaining fibres.

2.3.2 Pseudohypertrophy

The mechanism of enlargement of the calf muscles in the childhood form of the disease and its true nature is still controversial. For this reason the term "pseudohypertrophy" is widely used for descriptive purposes. It was postulated by Erb[17] that the fibre hypertrophy represented the initial and essential process in dystrophy, and that it was later followed by splitting, degeneration, atrophy, and fatty replacement. Pearson's[47,48] preclinical observations have made this hypothesis questionable. He states that the hypertrophy is not a true work enlargement of fibres, since it occurs randomly and often scantily throughout the muscle and an accompanying increase in the number of myofibrils is not consistently found. Other authorities, notably Shy[52] and Greenfield[20] accept the concept of true hypertrophy but frankly admit their inability to explain it. Undoubtedly the fatty infiltration makes up a percentage of the calf bulk, but there is strong histological evidence for true muscle fibre hypertrophy.

2.4 CLINICAL MANIFESTATIONS

The clinical manifestations of the various forms of muscular dystrophy depend upon the pattern of muscular weakness and wasting which occurs as the disease progresses.

It is generally accepted that weakness of the pelvic girdle muscles accounts for:

(1) inability of the quadriceps to stabilize the knee joint,

(2) difficulty in climbing stairs and in rising from low chairs or from the floor,

(3) accentuation of the lumbar lordosis, and

(4) a typical waddling gait.

The pelvic girdle weakness results in a typical "climbing up the legs" or Gower's Sign when the affected individual attempts to stand up from the floor. Weakness of the shoulder girdle muscles gives a characteristic sloping appearance to the shoulders with difficulty in raising the arms above the head. As the disease advances, patients utilize trick movements to overcome the weakness.

As a general principle, a joint with weakness of one group of muscles and not of its antagonist has a tendency for contractures of the antagonist to develop, and muscular contractures may in turn lead to secondary skeletal distortion. Muscular inactivity will lead to skeletal atrophy, a feature which is particularly seen in the Duchenne variety of the disease. The earliest manifestations of the Duchenne type muscular dystrophy may be detectable by only a closely associated family member who becomes aware of a very subtle decrease in motor skill.

Walton[60] characterized muscular dystrophy of the Duchenne type by the following:

1) Expression usually in the male but occasionally in the female.

2) Onset in the first three years of life or occasionally as late as the third decade.

3). Transmission usually as a sex linked recessive character with a high mutation rate but in under 10% of cases is an autosomal recessive.

4) Symmetrical involvement, first of the pelvic girdle musculature and later of the shoulder girdles.

5) Pseudohypertrophy particularly of the calf muscles but sometimes the quadriceps and deltoids occur in over 80% of cases.

6) Abortive or partially affected cases do not occur.

7) Steady and rapid progression which lead to inability to walk within 10 years of onset.

8) In progressive deformity with muscular contractures, skeletal distortion and atrophy occur.

9) Death from innination, respiratory infection, and cardiac failure occur usually in the second decade but sometimes not until middle life.

Miller[39,40] made particular note of the abnormal posture of these dystrophic children, characterized by lordosis, equinus and large calf muscles (Fig. 2.1). These observations had previously been explained empirically by attributing the lordosis to weak abdominal muscles and hip flexion contractures, and the equinus and calf hypertrophy to so-called "pseudohypertrophy", the mysterious infiltration of the muscle by fat.

He made the following clinical observations:

1) Children who walk fairly well with equinus contractures are totally disabled by heel cord lengthening. They promptly require application of long leg braces not only to restore ambulation but also

Fig. 2.1

Characteristic posture of muscular dystrophy to reduce the lordosis to a considerable degree. The effect of such surgery and subsequent bracings is illustrated in Fig. 2.2. These incidental observations raised doubt in his mind about the usual theories and suggested that the posture of pseudohypertrophic muscular dystrophy is, in fact, compensatory in nature.

The following additional observations and data were accumulated by Miller[40] in the Muscular Dystrophy Clinic, University of Illinois, and tend to support this theory.

2) Observed hip flexion contractures in the ambulatory patient are too small to explain the lordosis. They progress slowly if at all as long as the child is able to walk. The average hip flexion contractures of 58 children studied measured on the first visit to the clinic was less than 10^{o}. The increase over an average of 20 months was less than 5^{o}.

3) All patients had marked weakening of the quadriceps and hip extensor muscles - even children who walked fairly well. These muscles usually graded less than 4, that is not strong enough to extend the limb fully against gravity,

4) In contrast to the weakening hip and knee muscles, the gastrocnemius and soleus retain a relatively large proportion of their strength. They appear to be the most powerful muscles in the lower limb. Even very late in the disease when hardly a finger or a toe can be moved voluntarily, the calf contains histologically recognizable muscle and can produce active plantar flexion. The enlargement of the calf muscles appears to be the result of a true hypertrophy in response to a functional demand (not to pseudohypertrophy).

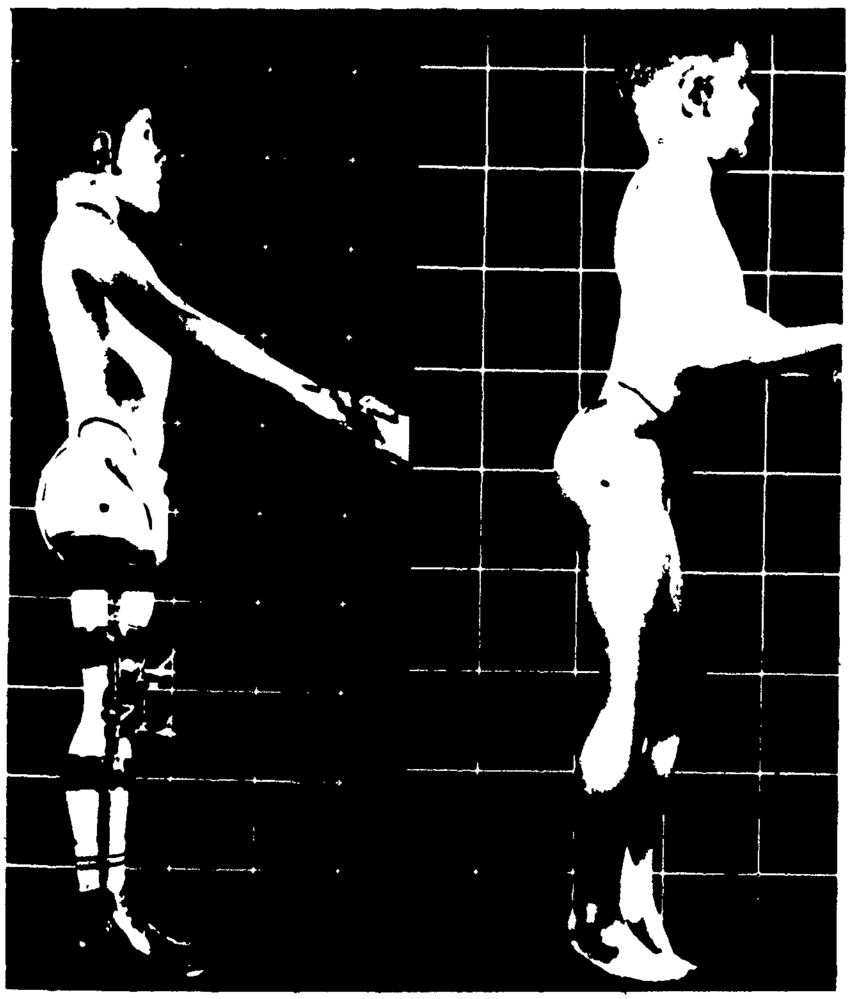


Fig. 2.2

Effect of knee bracing in muscular dystrophy

5) Equinus deformities are a consistent component of the late posture of these patients, but early in the disease it appears electively, that is the patient employs equinus only in moments of apprehension or uneven footing apparently to increase the stability of the lower limb.

6) The cessation of independent walking is preceeded by fairly rapid increase in equinus and development of small but obvious knee flexion contractures.

7) In the University of Illinois series, no children with knee flexion contractures of greater than 15° had independent ambulation without the benefit of bracing.

CHAPTER III

HUMAN STANDING POSTURE

3.1 INTRODUCTION

The human body can be considered to be a multisegmental structure consisting of body segments with several degrees of freedom at the articulations. The maintenance of the upright stance is achieved by maintaining the segmental centres of gravity in such relationship that the projected whole body centre of gravity lies within the base of support. Control and stabilization of the segments is provided by ligaments, muscles and gravitational forces acting across the joints. Movement about any of the joints allowing movement of the body segment in a sagittal plane will obviously result in a shift of the centre of gravity in that plane. The relationship of the projected line of gravity to a particular joint axis will change the stabilizing moment due to gravitational forces. In this study related to the stabilizing effect of lordosis and equinus on knee stability, the primary concern was the relationship of the centre of gravity of the body segments and their projected line of gravity with respect to the knee joint axis. Muscle forces which are acting across the knee joint have either a positive or negative effect on the stabilizing moment of the knee. The historical biomechanical and anatomic aspects of posture having relevancy to this study are discussed in the subsequent sections.

3.2 HISTORICAL REVIEW

3.2.1 Centre of Gravity Determinations

The mean position of the body centre of gravity is located at the approximate level of the first sacral vertebra and anterior to it when the stance is vertical. There is slight variation reported in various investigations ranging from the level of the second sacral vertebra to the fifth lumbar vertebra. The contribution of the effect of gravitational forces to knee stability is a function of the relationship of the projected line of gravity of the body mass to the transverse axis of the knee joint. In the child who is learning to stand, the angle between the leg and the thigh is considerably less than 180°. Smith[55] stated that it is apparent that the body weight tends to flex the knee joint. Thus, in the infant as in the experimental animal, the muscles which are potentially capable of affecting stability at the knee joint during standing are the extensor group. On the other hand, in the stance of the adolescent and adult, as is now generally accepted (Johnson & Willis[30] and Brash[9]), the centre of gravity of the body falls in front of the axis of the knee joints and the angle between the leg and the thigh exceeds 180°. Consequently, in these age groups, the quadriceps muscle cannot control the position of the knee joint as has been suggested by Denny Brown[16]. On the contrary, the ability to perform this function is necessarily transferred to a flexor muscle group. Conditions existing in the adult human knee joint appear to be peculiar to man, and there is considerable evidence to suggest that they are peculiar to modern man (Morton[42] and Hooton[27]). It has therefore been postulated that the developmental change in the posture of the knee joint during standing and consequently in the identity of the anti-gravitational muscles is a recapitulation of the philogenic change.

In a pathological state (such as muscular dystrophy) characterized by knee flexion contractures, the stabilizing force at the knee must then revert to the quadriceps muscles or to gravitational forces acting on the upper body mass.

3.2.2 Centre of Foot Pressure and Postural Sway

The stabilizing base provided by the feet during standing has been studied by Morton[43,44] and by Hellebrandt and co-workers[21,22,23]. The studies were largely concerned with the anatomy of the feet and measurements of the distribution of pressure over the contact area of the feet with the ground when an attempt was made to stand quite still. These studies were restricted to a standardized stance with the heels closely approximated. Morton[44] considered the effective foot base to extend from the posterior heel margin anteriorly to include the heads of the metatarsals, and that the centre of gravity of the body weight plumbs to a point midway between these margins during normal standing. Hellebrandt[23] found 40% of the "under prop diameter" to be posterior to the gravity line. Whitney[61] investigated the anteroposterior stability of the body during standing, observing the maximum displacement of the centre of foot pressure which is possible during three manoeuvers; those of heeling and toeing, forced repeated sways and sustained leaning forwards and backwards. The anteroposterior distance between the centre of foot pressure limits for a given manoeuver was termed by him the effective foot base for the manoeuver.

Normal standing, however, is not a static posture. Vierordt[58] in 1862 established experimentally that the body is in continuous motion, even when the attempt was made to stand quite still. Subsequent investigations of this postural sway, predominantly as a test of psychomotor function have assessed the degree of sway chiefly by recording movements of the head in the horizontal plane (Miles[37,38], Baron[3] and Morgan[41]. Hellebrandt[23] recorded movements of the centre of foot pressure on the ground with the implication that these movements were directly related to movements of the vertical projection of the centre of gravity of the whole body. Smith[55] recorded anteroposterior movements at approximately the hip level. The expression of variation between subjects in the extent of postural sway has commonly been restricted to recording of the distance between the extreme limits of sway during a specified standing period, of the horizontal area of the limits for anteroposterior and lateral sway combined, or the total distance traversed by a fixed point on the body (usually of the head) in the horizontal plane. This type of data is not generally amenable to further mechanical analysis. The available data is not geometrically related to the knee joint axis and hence it is impossible to further analyse the gravitational forces with respect to the extending moment exerted at the knee joint. The measure of postural sway provided has been frequently empirically dependent on the details of construction of the recording apparatus.

Thomas and Whitney[57] in 1959 attempted to describe some of the events of postural sway in a more objective and mechanical manner using a specially constructed force platform to obtain a continuous record of horizontal forces of reaction at the feet, and the coordinates of the centre of foot pressure on the horizontal surface of the platform. They concluded that all forms of postural activity investigated were cyclical in nature and included both a high and low frequency component. The frequency of components of movement of the centre of foot pressure and change of trunk inclination was always very irregular with respect both to duration and amplitude. Average frequency of both movements varied between subjects from 0.12 - 0.39 Hz. with a mean of 0.21 Hz. The amplitude of the low frequency movements varied from 0.56 to 1.13 cm between subjects. For dynamic reasons, movements of the centre of foot pressure must exaggerate the accompanying movements of the centre of gravity of the body mass, the degree of exaggeration increasing with the frequency of the movement. The frequency component of trunk displacement showed great irregularity both as regards cyclic duration and amplitude in the corresponding low frequency components. The frequency of the displacement varied between subjects from 9.2 to 13.4 cycles per sec. with an average amplitude of the displacement at these frequencies from 2.8 - 15 microns or about 1/1000 of the corresponding low frequency displacements of the trunk at the umbilical level. No simple relationship could be found between the variation of the two components for different subjects.

Qualitative agreement is found in the literature on the following points.

(i) Some sway is always present during quiet standing. The largest component of this sway is at a frequency of about 0.2 Hz[33,54,57] with a small tremor of approximately 10 Hz superimposed on it.

(ii) Sway in the anteroposterior (a-p) plane tends to be larger than in the coronal plane.

(iii) Sway tends to be larger with the feet together than with the feet apart.

(iv) Sway is significantly increased by closing the eyes[51] while blind people sway about as much as sighted people with their eyes closed[25]. Baron and Fillizot[3,25] showed that the content of the field of vision can affect the sway pattern.

(v) Sway is not constant for an individual subject.

(vi) Neurological disorders, fatigue, sleeplessness, alcohol, and certain drugs cause an increase in postural sway[41].

Although the sway is affected by many factors, there do not appear to be any patterns of sway characteristic of specific individual disorders.

The significance of these sway characteristics to a study of a static posture is that no single value of the position of the ground reaction force on the feet will be representative of the sway range. A mean of several positions and their range over a full cycle of sway is more representative of the postural state. The inertial effects of body sway cause a slight discrepancy of the position of the ground reaction force relative to the position of the whole body centre of gravity. Assuming symmetrical sway forward and backward, the mean value of position of the ground reaction force will be identical to the mean position of the whole body centre of gravity.

3.2.3 Electromyography

Electromyographic studies of postural control by muscular activity has supplanted the technique of palpation of muscles and tendons. The advent of electronic amplifiers made possible this technique which allows monitoring of electrical activity in muscles using various types of electrodes.

Although electromyographic techniques were applied to man for diagnostic and clinical reasons prior to the 1940's, it was not until then that they were used to unravel the functions of individual muscles and groups of muscles. In 1944 Inman et al[28] applied the technique to study the function of the shoulder joint. Since that time almost every muscle in the body has been studied during quiet standing. Initially, disagreements as to degree of activity presented themselves due to variation in technique and electronics.

Reviews of electromyogtaphic studies of the postural muscles by Basmajian[5] and Joseph[31] summarize currently accepted views.

(i) Hip Muscles - The activity in these muscles is suprisingly slight. The iliospoas appears to have slight constant activity[5] and hip stability is maintained to a large degree by ligamentous structures such as the iliofemoral, pubofemoral and ischiofemoral ligaments. Carlsoo[12] found the quadriceps to be completely inactive in loaded subjects. The hamstring muscles showed individual variation from very active to complete inactivity. Forward swaying of 5^{o} and backward swaying of 5^{o} produced alternate hamstring and quadriceps activity[31].

(ii) Leg Muscles - The greatest amount of postural activity occurs in the soleus, gastrocnemius and tibialis anterior muscles. Carlsoo[12] found activity regularly in the soleus in quiet standing but never in the tibialis anterior. Activity in the tibialis anterior was found to be periodic. Activity in the soleus muscle is almost a constant finding, while gastrocnemius and tibialis anterior activity is cyclic. The discrepancy of findings with respect to soleus and gastrocnemius activity may be explained by the fact that the soleus is tonic while the gastrocnemius is phasic.

(iii) Other Muscle Groups - Intermittent reflex activity has also been detected in posterior vertebral, thoracic, abdominal, peroneal and intrinsic muscles of the feet.

In summary, it appears that the calf muscles of the leg are primarily responsible for postural stability, and although other muscles are active, they appear to act in conjunction with other passive elements to resist gravitational forces.

Force-EMG Relationships

Basmajian[5] reviewed the relationship of EMG to force and tension. There is evidence that:

(1) There is no direct quantitative relationship between a muscle's inherent power and the EMG.

(2) Isometrically and isotonically contracting muscle shows a direct relationship between mechanical tension and integrated EMG.

(3) The integrated EMG potentials vary directly with a simple count of motor unit spikes.

(4) The integrated output of different muscles should not be compared.

(5) Only under restricted conditions can force, speed and work output be judged from EMG data either recorded as spikes or integrated.

3.3 ANATOMICAL AND BIOMECHANICAL ASPECTS OF KNEE AND ANKLE JOINTS

3.3.1 Knee Joint

The mechanisms involved in maintaining passive and active resistance to extension at the knee joint are[55]

(1) postural contraction of flexor muscles, and

(2) passive resistance of the tissues of the joint consisting of (a) articular resistance, and
(b) extra-articular resistance.

The muscles involved in the postural muscle contraction are the hamstrings, to a slight degree, and also the gastrocnemius by virtue of its origin on the femoral condyles behind the centre of rotation.

The nature of the articular resistance to extension was first described by Goodsir[19] in 1868, who showed in an osteoligamentous preparation of the knee joint that extension is limited by a mechanism which involves tightening of joint ligaments and simultaneous locking of paired articular surfaces with logarithmic spiral curves; that is, by tensile forces in joint ligaments, and by compressive forces in the tissues deep to the articular surfaces. This was interpreted by Walmsley[59] to be an abrupt limit and that the tissues involved are practically unchanged in their dimensions by the applied forces. In normal standing, however, the maximum extension is usually slightly short of full extension and the exact limit of extension at the knee joint varies with the magnitude of the extending force and the tissues are appreciably distorted by stress of normal magnitude[1,26,55].

Smith[55] studied the extra-articular and intra-articular resistance of the knee to extension using a simple balance platform and lateral photographs of a subject with a knee joint position marker applied to the knee at a point determined by a crude instant centre record from photographs. He calculated the extending torque on the knee joint in symmetrical standing to be 5.1 lb. ft. with the knee 6^{o} short of full extension for a body weight of 161 lbs. He determined the passive resistance to be 0.9 lb. ft. from the articular mechanism and 2.7 lb. ft. from the extra-articular mechanism making a total passive resistance to extension of 3.6 lb. ft. This required 1.5 lb. ft. of flexing torque from the postural activity of the flexor muscles. In other words, of the total flexing torque which is required to counteract the force of gravity and stabilize the knee joint in symmetrical standing, about 50% is derived from passive resistance of the extra-articular tissues, about 30% from the postural activity of the flexor muscles and about 20% from the passive resistance of the articular mechanism.

The transverse axis of rotation of the knee joint cannot be determined from surface anatomical landmarks alone. Kinematic principles which require location of the instant centre (by radiographic examination) of the joint in the range of flexion under study is an accepted technique[18]. The knee joint has a polycentric transverse axis which is described as circoid by Steindler[56].

3.3.2 Ankle Joint

As at the knee, it is generally accepted that the ankle joint is stabilized by two forces operating in harmony[13,54]. The forces are those of the posterior crural muscles and the passive resistance to dorsiflexion exerted by periarticular tissues and articular surfaces. A very large measure, if not all of the activity is in the triceps surae muscles[53]. Smith [54] determined that the passive resistance at the ankle operates only over the terminal 3 degrees of dorsiflexion. In a young adult of average physique, a passive torque of constant value of 2.5 lb. ft. was found, but several assumptions made appear to be unreasonable and the validity is questionable. The tension in the calf muscles in an adult of average physique was found to range between 60 and 180 lbs. with a variation of ±35 pounds over a period of one second. Joseph et al[32] found that in a man of 140 lbs. the tissue tension, both active and passive had a value of about 35 lbs. at the ankle.

The axis of the tibio-talar joint varies considerably both in location and inclination to the horizontal. Some investigators have stated that the joint has a changing axis as the foot proceeds from dorsiflexion to plantar flexion[2,24,34]. Others[11,36] infer a single axis concept. Isman and Inman[29] report a detailed study attempting to define easily identifiable skeletal landmarks and clarify the single axis concept. They concluded that the tibio-talår joint could be considered a single axis joint for purposes of bracing, that the use of certain skeletal landmarks to determine the axis seem feasible, but no accurate method was found for the living subject. In that study no correlative radiographs were utilized. A general description of the position of the axis is that the trochlea of the talus is actually a portion of a truncated cone with its base located medial to the ankle[14]. The lateral profile is almost always an arc of a true circle and in all positions of the talus the axis of rotation must pass through the centre of the circle[2]. The medial profile is compounded of the arcs of two circles of differing radii. The axis is concluded to be a changing one since the medial point related to the talus shifts, causing the axis to be pointed downward and laterally during dorsiflexion and downwards and medially during plantar flexion. On the basis of the foregoing information, correlation of a lateral surface marker with a lateral radiograph of the ankle joint to correspond with the geometric centre of the lateral aspect of the trochlea, would give an accurate surface mark for that point on the axis.

CHAPTER IV

LEG MODEL OF LOWER EXTREMITY FOR EVALUATION OF THE ROLE OF LORDOSIS AND EQUINUS IN KNEE STABILIZATION

4.1 INTRODUCTION

In this chapter the postulated stabilizing effect of lordosis and equinus is introduced. A leg model to evaluate their effect on the stabilizing moment at the knee is described.

4.2 ROLE OF LORDOSIS AND EQUINUS IN STABILIZATION OF THE KNEE

In review of the clinical observations outlined in Chapter II relating to the clinical observations of posture in muscular dystrophy, we have:

(1) small hip flexion contractures,

(2) marked lordosis which is decreased by bracing the knees in extension,

(3) equinus foot deformities which initially appear electively and later become fixed contractures,

(4) consistently weak quadriceps and knee extensor muscles,

(5) pseudohypertrophy of the calf muscles, and

(6) knee flexion contractures prior to cessation of ambulation.

No unified explanation of these findings has been proposed. Figure 4.1 illustrates the line of gravity passing in front of the transverse knee joint axis and the transverse ankle axis, just anterior to the lateral malleolus. The ground reaction force is illustrated as

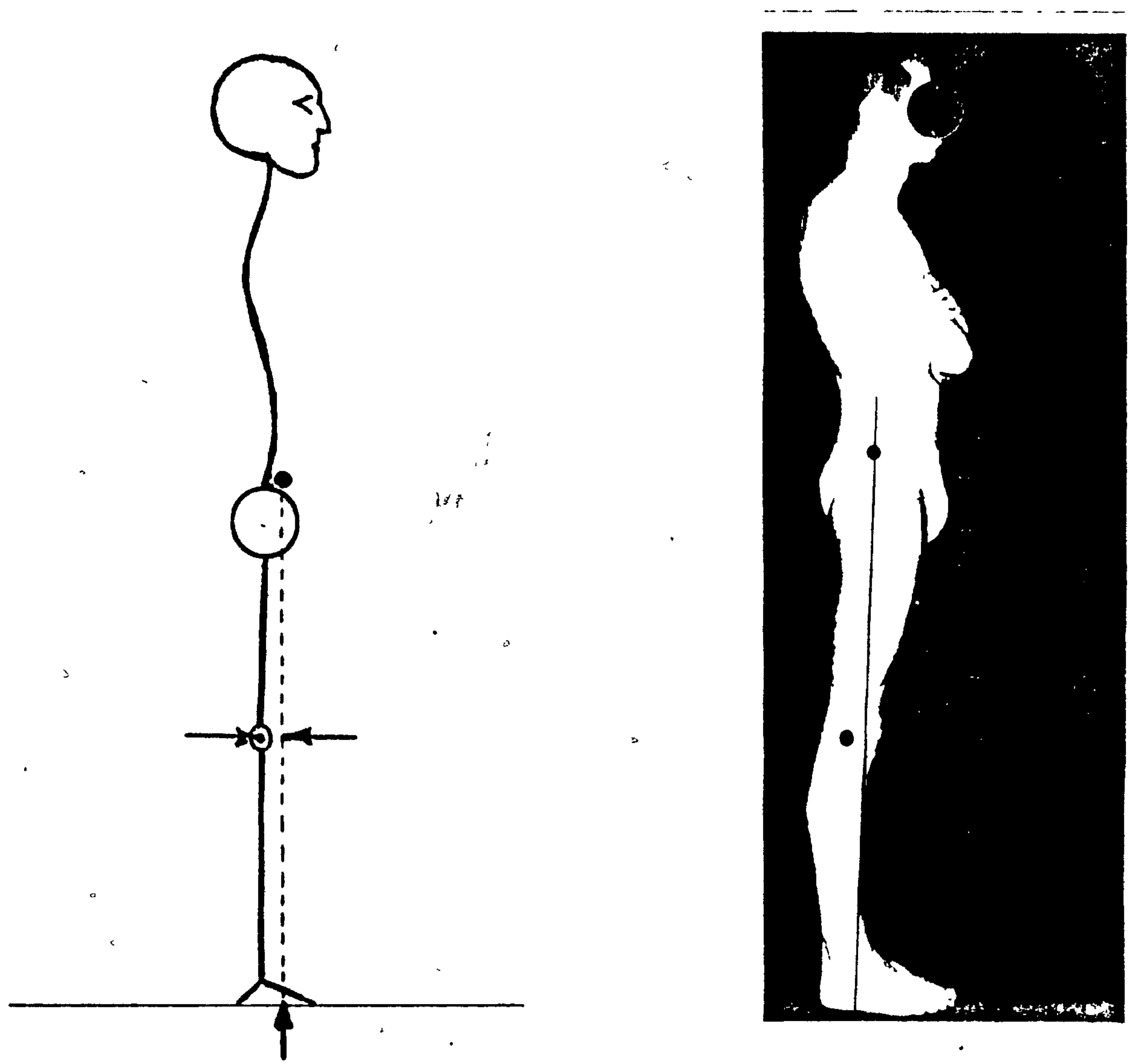


Fig. 4.1 Relationship of whole body centre of gravity to lower extremity joints

a vector acting vertically at the intersection of the downward projection of the line of gravity and the floor.

In the presence of knee flexion contractures (Fig. 4.2), the line of the projected whole body centre of gravity (C of G) now passes posterior to the knee joint axis. To prevent the knees from collapsing into flexion a strong extension force at the knee is required from quadriceps muscle activity. In the dystrophic child the quadriceps are, however, weakened and in moderately severe forms of the disease patients would be unable to prevent the knee from collapsing into flexion (Fig. 4.3). For a dystrophic child to maintain upright stance, knee stability would have to be accomplished by use of other muscle groups to realign the body segments such that the knee joint axis fell behind the line of gravity. How could this be accomplished?

The first method is by adopting equinus to move the base of support forward to the metatarsal heads, as shown in Fig. 4.4 and 4.5. The line of gravity must also shift forward to be aligned over the base of support and the knee joint axis is displaced posterior to the line of gravity.

Secondly, flexing the pelvis would again advance the line of gravity of the whole body C of G (Fig. 4.6). This maneuver also displaces the knee axis posterior to the line of gravity.

The combination of these two compensatory movements is illustrated in Fig. 4.7. The resulting posture is thus one of equinus and lordosis. A normal adult volunteer is shown in the composite photograph (Fig. 4.8),

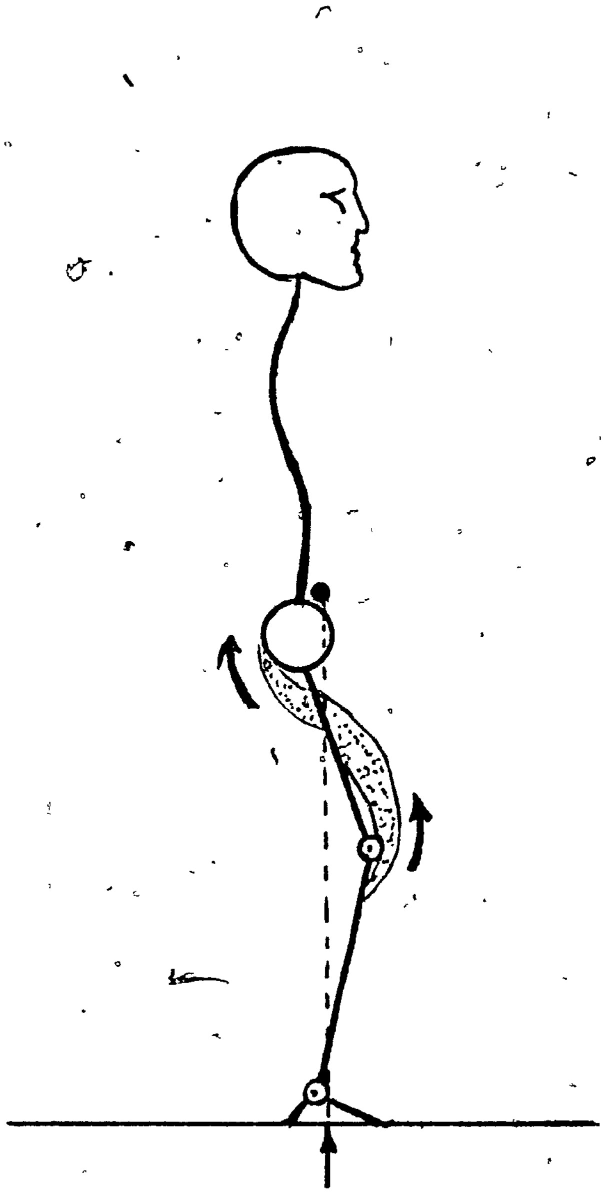


Fig. 4.2 Knee flexion contracture

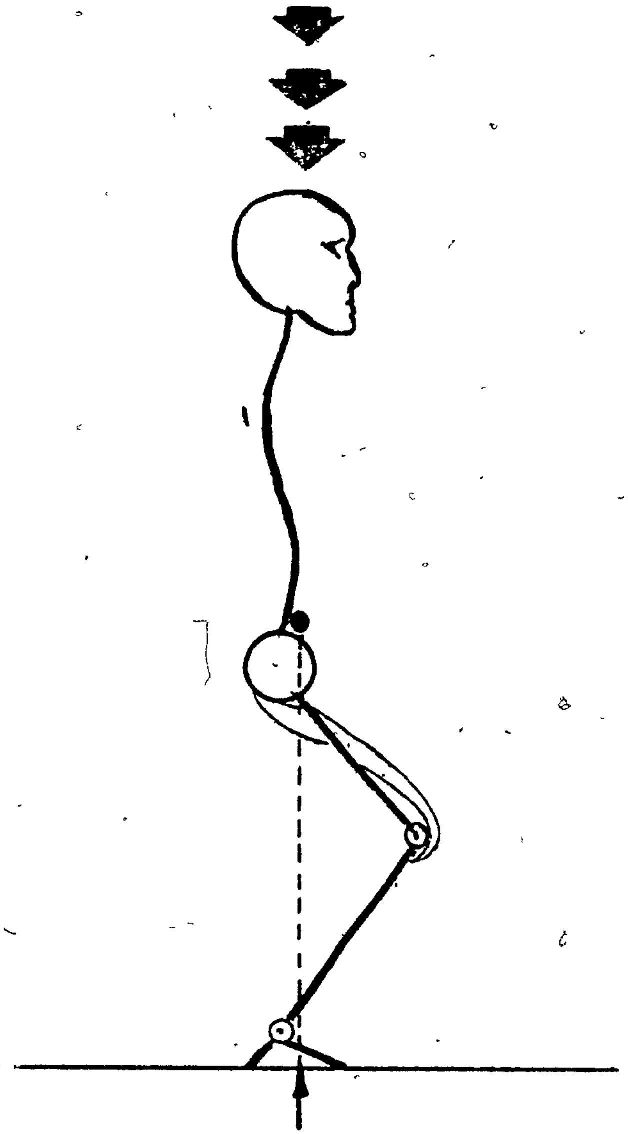


Fig. 4.3 Knee flexion contracture
with weak quadriceps

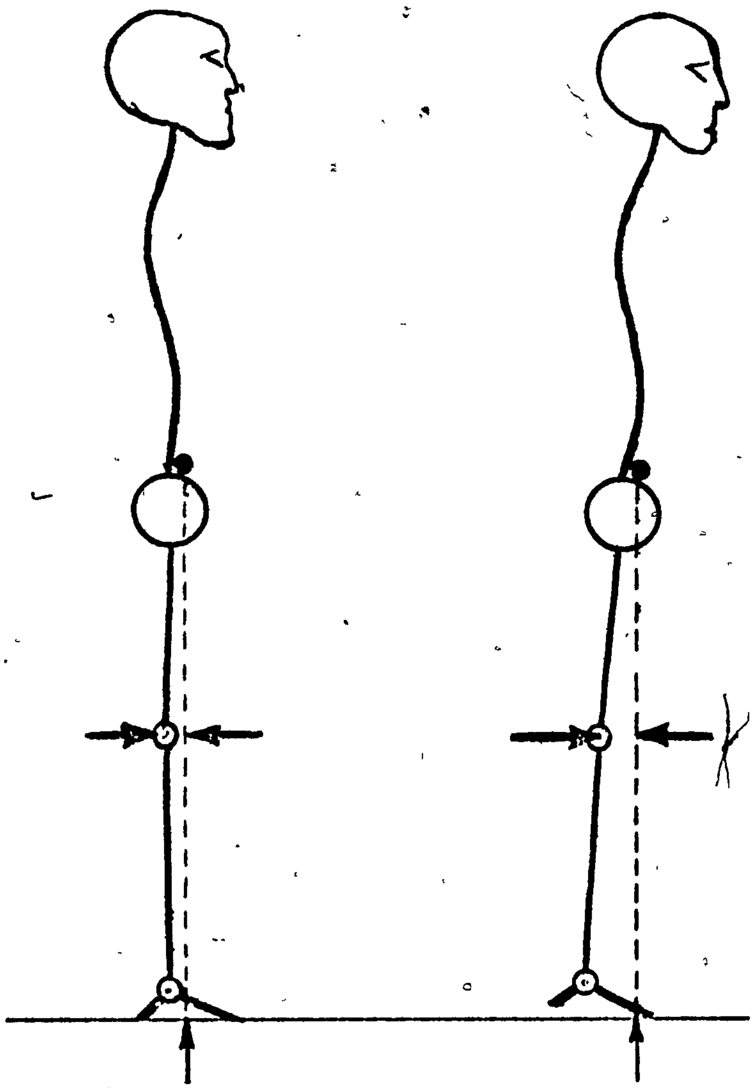


Fig. 4.4 Effect of equinus on knee stability

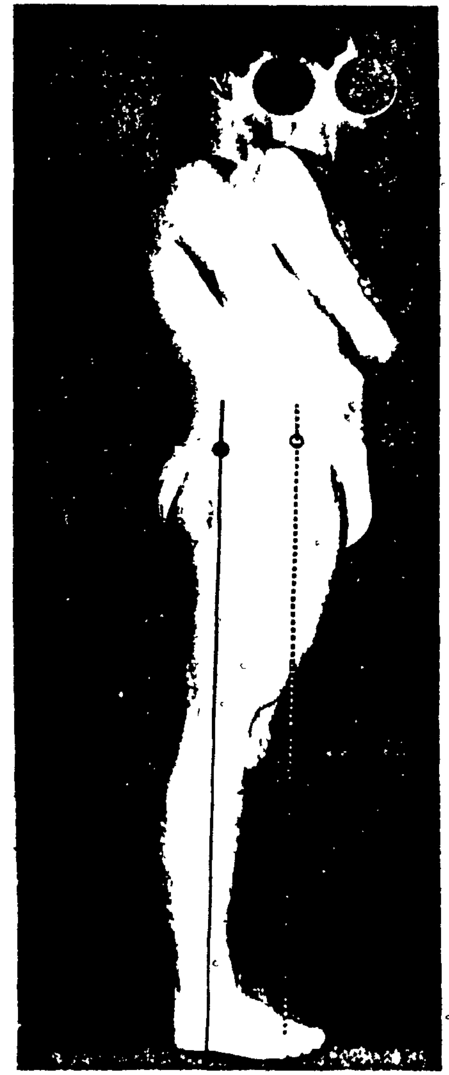


Fig. 4.5 Composite of equinus and "flat-foot" stance

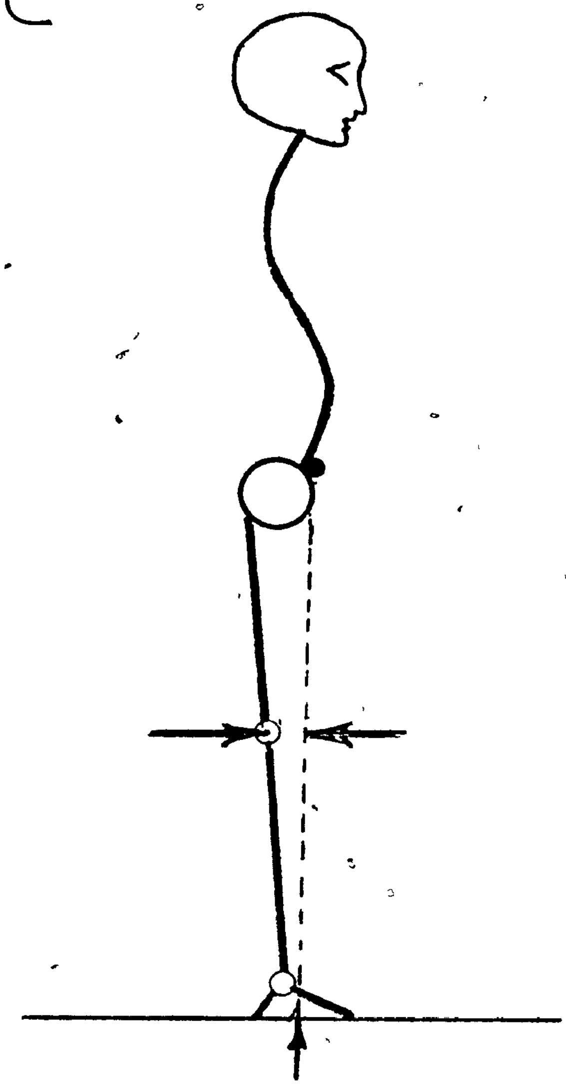


Fig. 4.6 Effect of lordosis on knee stability

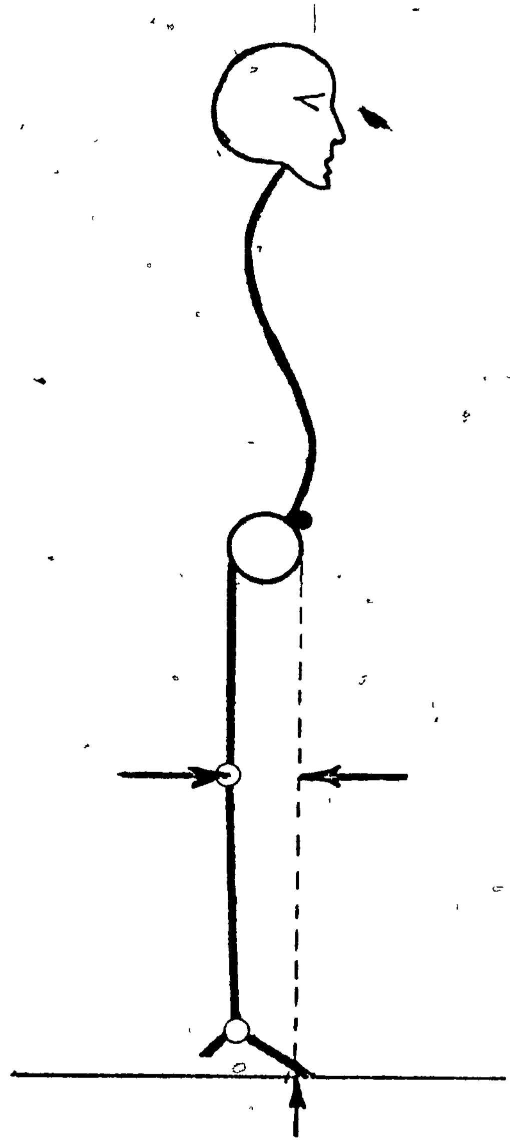


Fig. 4.7 Effect of equinus and lordosis on knee stability

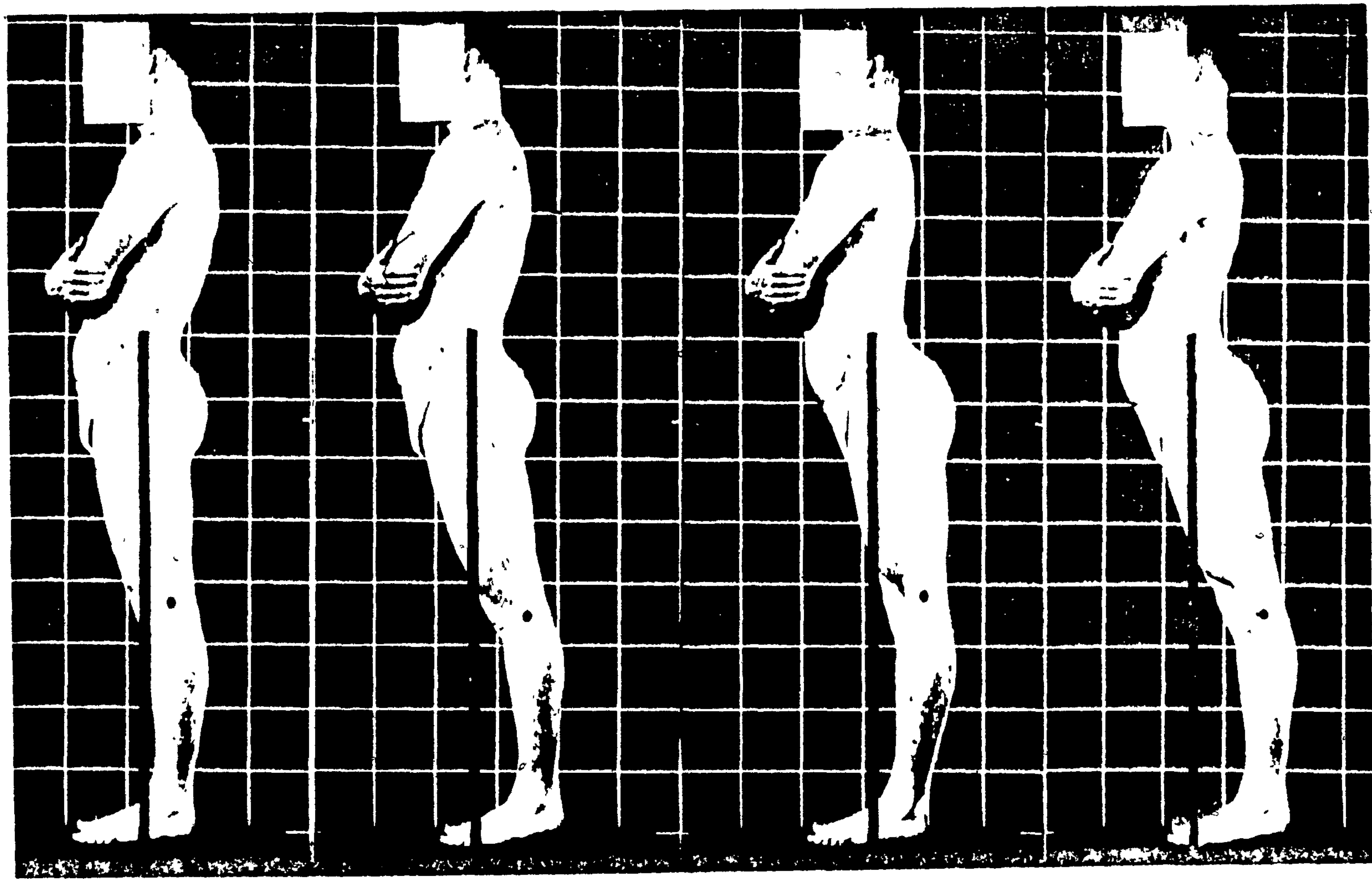


Fig. 4.8 Normal, equinus, lordosis, and equinus with lordosis stances (from left to right).

from left to right standing normally, in equinus, in lordosis, and in a combination of the two. It is evident that the knee is considerably further behind the line of gravity in the last stance than in the left hand posture.

It appears that the dystrophic child must compensate for weakening knee extensor muscles and progressive knee flexion contractures. In order to do so he assumes a lordotic posture and employs the relatively strong triceps surae muscles of the calf to adopt an equinus position. The progressive knee flexion contractures would eventually neutralize the advantage gained by moving the line of gravity forward, and the resulting stabilizing effect on the knee. The mechanism described would explain the major features of the dystrophic posture, response to heel cord lengthening, and possibly the mechanism responsible for hypertrophy of the calf muscles.

4.3 LEG MODEL

Consider the sagittal plane of a standing person with schematic representation of muscular, soft tissue and gravitational forces existing at the knee and ankle joints, and their relationship to the knee and ankle axes (Fig. 4.9). For static equilibrium at the knee joint, the summation of moments about the knee joint axis must equal zero (i.e. the flexing moments at the knee must equal the extending moments), or

$$M_B \text{ neg} = M_B \text{ pos} \qquad (4.1)$$

where M_B neg = flexing or clockwise moment

M_B pos = extending or counterclockwise moment

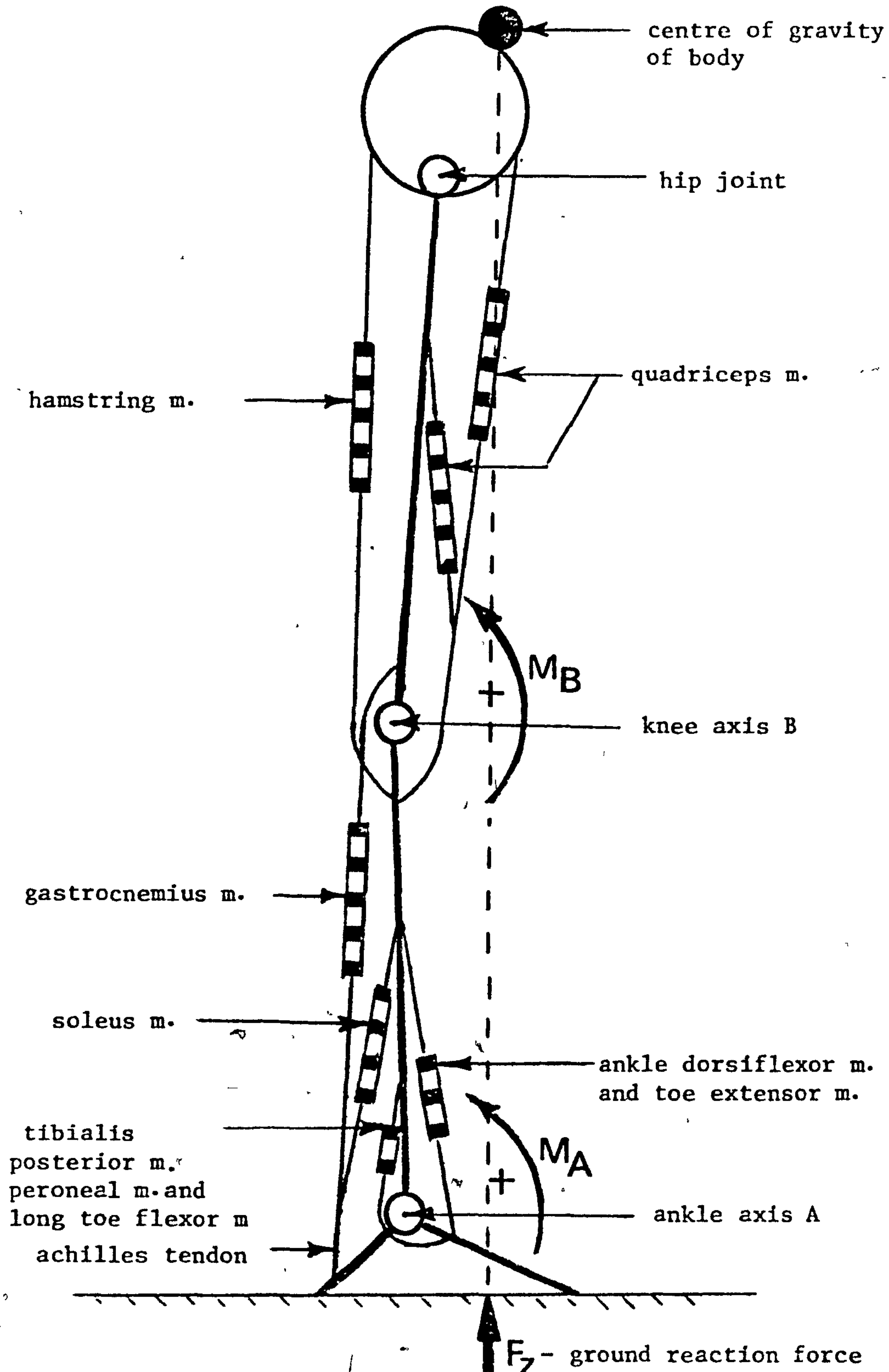


Fig. 4.9 Muscle relations in the sagittal leg plane

M_B neg = moment due to passive tissue elements limiting hyperextension of the joint + moment due to active knee flexor muscle contraction (a) gastrocnemius muscle
(b) hamstring muscles
(c) popliteus muscle

M_B pos = moment due to the extending moment of the force of gravity acting on the body mass above the knee joint axis + moment due to extensor muscle contraction
(a) quadriceps muscle

Consider these elements individually:

Moment due to passive tissue elements

The moment is exerted by passive tissue forces in the ligaments, capsule and intra-articular structures and is dependent on the degree of joint extension in relationship to their elastic properties and mechanical configuration of the knee joint. The magnitude is equal to the extending moment on the knee which is not restricted by activity in the flexor muscle groups.

Moment due to active knee flexor muscle contraction

Hamstring Muscle. The hamstring function at the knee in standing is to limit the forces which the passive elements must resist. On the basis of EMG data, the activity is on a cyclic basis related to forward and backward swaying. Smith[3] attributed 20% of total force at 6 degrees short of full extension to be due to flexor muscle activity.

Gastrocnemius Muscle. On the basis of EMG data most of the flexor muscle activity is in the triceps surae muscle, of which only the gastrocnemius muscle crosses the knee joint and produces flexing moments.

Popliteus Muscle. The popliteus muscle functions as a lateral rotator of the femur on the tibia and retractor of the lateral meniscus, and according to Last[35] is not even a weak flexor of the knee. We can therefore consider the active flexor moment to be due to gastrocnemius muscle forces and express the flexing moment by the equation,

$$M_B \text{ neg} = M_B \text{ passive} + M_B \text{ gas} \tag{4.2}$$

where

M_B passive = moment due to passive tissue elements resisting hyperextension of the knee and hamstring activity.

M_B gas = moment due to gastrocnemius muscle activity.

The extension moment due to quadriceps activity is considered negligible in normal standing posture in the absence of knee flexion contractures requiring augmentation of the normal gravitational forces to maintain knee stability. This is confirmed by EMG data which shows activity similar to hamstring activity of a cyclic nature related to backward sway. The extending moment is then expressed by the equation,

$$M_B \text{ pos} = M_B \text{ grav} \tag{4.3}$$

where

M_B grav = extending moment at the knee due to gravitational forces acting on the body mass above the knee joint.

By substitution:

$$M_B \text{ passive} + M_B \text{ gas} = M_B \text{ grav} \tag{4.4}$$

or

$$M_B \text{ passive} = M_B \text{ grav} - M_B \text{ gas} \tag{4.5}$$

If we define the net stabilizing moment (N.S.M.) as being equal to the magnitude of the extending moment due to gravity (M_B grav) minus the flexing torque due to gastrocnemius activity (M_B gas), then

$$N.S.M. = M_B \text{ grav} - M_B \text{ gas} \qquad (4.6)$$

In this derivation minimal activity specific to the hamstring activity is considered to be lumped with M passive. The value of M grav can be calculated by determining the lever arm from the axis of knee rotation to the effective line of action of the body mass above the knee joint and multiplying it by the net body weight W_n. The value of M_{gas} can be calculated by determining the lever arm from the axis of rotation of the knee to the line of action of the gastrocnemius muscle and multiplying it by the force exerted by the gastrocnemius. The force in the gastrocnemius must, however, be calculated indirectly by considering the forces acting at the ankle joint.

Referring again to the schematic representation in Fig. 4.9, for static equilibrium about the ankle, the summation of moments about the ankle axis must be equal to zero (i.e. the plantar flexing moments of the ankle must equal the dorsi flexing moments), or

$$M_A \text{neg} = M_A \text{pos} \qquad (4.7)$$

where

$M_A$neg = plantar flexing moment or clockwise moment at the ankle axis A.

$M_A$pos = dorsiflexing or counterclockwise moment at ankle axis A.

where $M_A neg$ = moment due to passive tissue elements limiting dorsiflexion at the ankle + moment due to active ankle flexor muscle contraction

(a) Triceps surae muscles
(b) Peroneus brevis and longus muscle
(c) Tibialis posterior muscle
(d) Flexor hallucis longus muscle
(e) Flexor digitorum longus muscle

and $M_A pos$ = moment due to the ground reaction force on the foot + moment due to passive tissue elements limiting plantar flexion of the ankle + moment due to active ankle dorsi flexor function of:

(a) tibialis anterior muscle
(b) extensor hallucis longus muscle
(c) extensor digitorum communis muscle.

Consider these moments individually:

Passive tissue elements limiting plantar and dorsiflexion. The passive tissue element forces are considered by Smith[54] to be significant only in the last few degrees of dorsiflexion. In the analysis in approximately neutral ankle positions and in plantar flexion, these forces can be considered negligible.

Moment due to active ankle flexor contraction. The peroneus brevis and longus, tibialis posterior, flexor hallucis longus and flexor digitorum communis muscles are all very weak plantar flexors of the ankle by virtue of their comparatively small bulk (compared to soleus and gastrocnemius muscles) and the close proximity to the transverse axis of the ankle joint. Their relative contribution to plantar flexion at the ankle has not been quantitatively determined, but the great majority of plantar flexion force is attributed to the tension exerted by the triceps surae muscles.

Moment due to active ankle dorsiflexor function. The muscles acting across the dorsum of the ankle have very minimal activity in normal stance except under conditions of perturbation such as repeated forced backward sway.

Moment due to ground reaction forces. The ground reaction force is normally located in front of the ankle axis and is the major force which is resisted by the triceps surae muscle. Thus, by attributing all plantar flexor activity to the triceps surae muscle and all dorsiflexing activity to the ground reaction force,

$M_A neg$ = moment due to triceps surae activity

and $M_A pos$ = moment due to ground reaction force.

Consider the free body diagram (Fig. 4.10) with the coordinate system as shown for the foot:

$$M_A neg = T\, L_2 \operatorname{Sin} \beta \tag{4.8}$$

$$M_A pos = \frac{F_z}{2} (X_A - X_F) \tag{4.9}$$

substituting in (4.7)

$$T\ \ L_2\ \ \operatorname{Sin} \beta = \frac{F_z}{2} (X_A - X_F) \tag{4.10}$$

and solving for T the tension in the tendoachilles

$$T = \frac{F_z\ \ (X_A - X_F)}{2\ L_2\ \ \operatorname{Sin} \beta} \tag{4.11}$$

In this analysis of the ankle joint the weight of the foot being 1.3% of total body weight is ignored in view of its close proximity to the ankle axis (Dempster[15]).

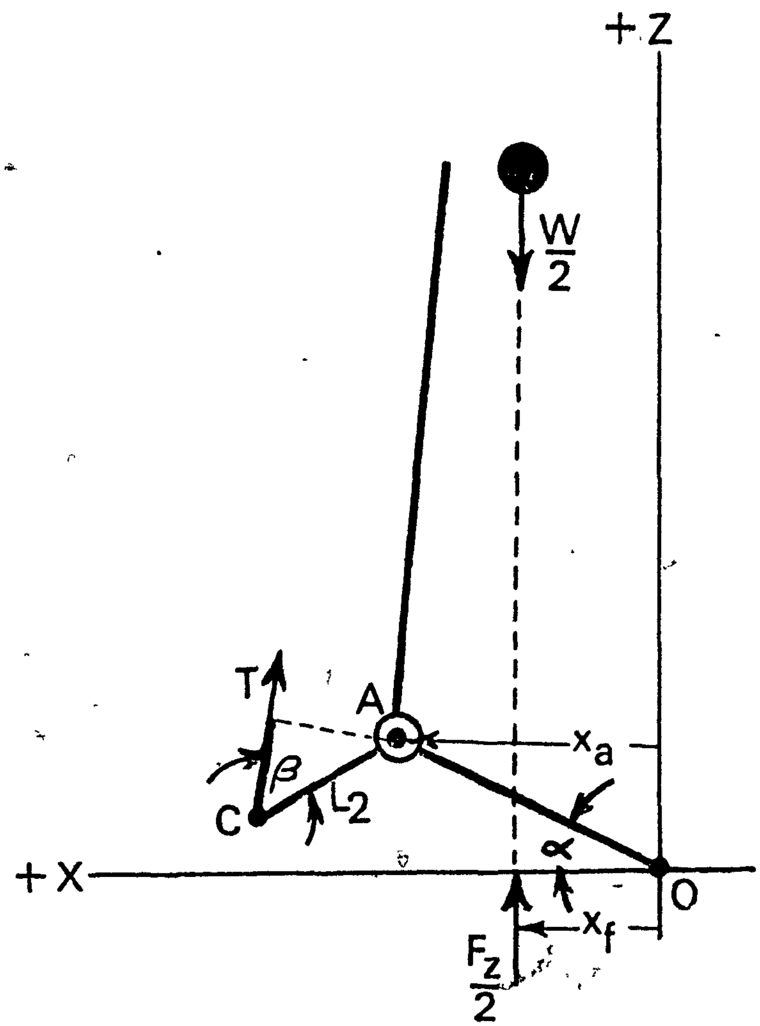


Fig. 4.10 Free body diagram of ankle

A - ankle axis

C - insertion of achilles tendon

L_2 - hindfoot link A-C

O - origin of coordinate system

$\frac{W}{2}$ - half body weight

α - angle formed by forefoot and base of support

β - angle formed by achilles tendon and hindfoot link A-C

T - tension in achilles tendon

$\frac{F_z}{2}$ - reactive ground force for each foot

Let the ratio of the tension in the gastrocnemius to the total tendoachilles tension T be defined by the term $(\frac{gas}{gas + sol})$. The tension in the gastrocnemius is then $(\frac{gas}{gas + sol})T$.

Consider now the free body diagram of the leg (Fig. 4.11). Using Dempster's tables[15], the position of the C. of G. of foot and shank is determined to be at a point 0.567 from the ankle to knee joint axis and W_s .059 W/2. The X coordinate of W/2 (one half of total body weight) equals the X coordinate of the reactive ground force $F_z/2$ and is denoted by X_F. To determine the coordinate of the line of action (X_{W_N}) of the body weight acting to stabilize the knee (W_N), the moment equation of the segmental body weights can be written about the coordinate X_F (Fig. 4.12).

$$W_S(X_{W_S} - X_F) = W_N(X_F - X_{W_N}) \tag{4.12}$$

but

$$X_{W_S} = X_A - 0.567\ (X_A - X_B) \tag{4.13}$$

substituting

$$W_S(X_A - 0.567(X_A - X_B) - X_F) = W_N(X_F - X_{W_N}) \tag{4.14}$$

simplifying to

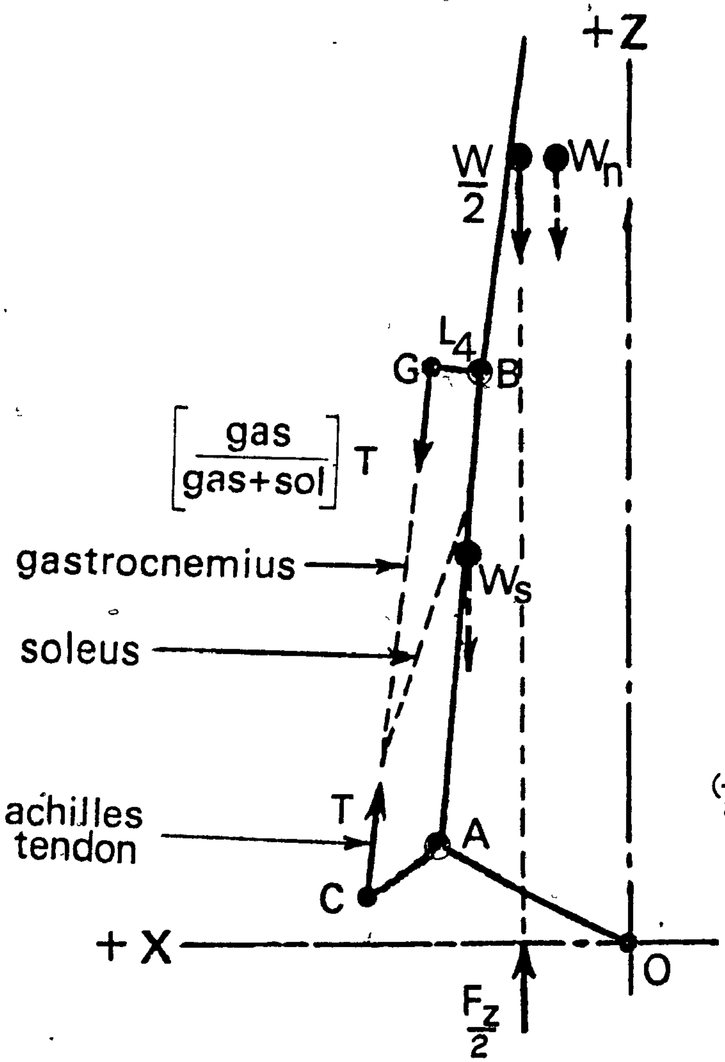
$$X_{W_N} = X_F - \left(\frac{W_S(X_A - 0.567(X_A - X_B) - X_F)}{W_N}\right) \tag{4.15}$$

Consider the free body diagram of the leg (Fig. 4.11). The moment due to M_{grav} is then

$$M_B grav = W_N\ (X_B - X_{W_N}) \tag{4.16}$$

and the flexing moment due to gastrocnemius activity is

$$M_B gas = (\frac{gas}{gas + sol})\ T\ \ L_4 \tag{4.17}$$



A - ankle axis

B - knee axis

C - insertion of achilles tendon

G - origin of gastrocnemius muscle

$\frac{W}{2}$ - half body weight

W_N - body weight acting across knee joint

W_S - weight of shank

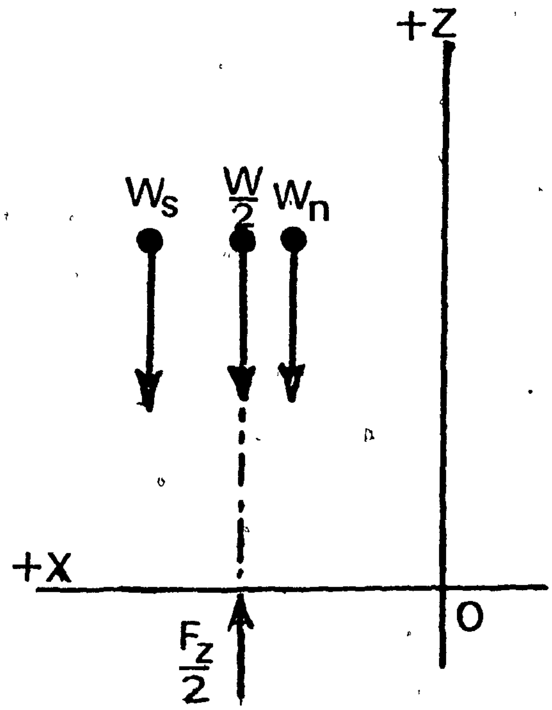
L_4 - distance from knee axis to line of action of gastrocnemius

T - tension in achilles tendon

$(\frac{gas}{gas+sol})T$ - tension in gastrocnemius

O - origin of coordinate system

Fig. 4.11 Free body diagram of leg



$\frac{W}{2}$ = half body weight

W_S = weight of shank

W_N = weight of body acting across knee joint

$\frac{F_z}{2}$ = ground reaction force on each foot

Fig. 4.12

Coordinate relationship for W_N (net body weight)

Substituting (4.16) and (4.17) into (4.6)

$$N.S.M. = W_N\ (X_B - X_{W_N}) - \left(\frac{gas}{gas + sol}\right) T \cdot L_4 \qquad (4.18)$$

But

$$W_N = F_z/2 - W_S \qquad (4.19)$$

and

$$W_S = 0.059\ F_z/2 \quad \text{(Dempster)} \qquad (4.20)$$

and

$$W_N = F_z/2 - .059\ F_z/2 \qquad (4.21)$$

and simplifying

$$W_N = 0.470\ F_z \qquad (4.22)$$

Therefore by substituting (4.22), (4.15), (4.11) and (4.20) into (4.18)

$$N.S.M. = 0.470F_z \left(X_B - \left(X_F - \frac{.059F_z}{2} \left(\frac{X_A - .0567(X_A - X_B) - X_F}{0.470F_z} \right) \right) \right) - \left(\frac{gas}{gas + sol}\right) \frac{F_z}{2} \frac{(X_A - X_F)}{L_2 \sin \beta} \qquad (4.23)$$

simplifying

$$N.S.M. = 0.470F_z\ (X_B - X_F) + .059F_z \left(\frac{X_A - 0.567(X_A - X_B) - X_F}{2} \right) - \left(\frac{gas}{gas + sol}\right) \frac{F_z\ (X_A - X_F)\ L_4}{2\ L_2 \sin \beta} \qquad (4.24)$$

factoring

$$N.S.M. = F_z \left(0.470(X_B - X_F) + .059 \left(\frac{X_A - 0.567\ (X_A - X_B) - X_F}{2} \right) - \left(\frac{gas}{gas + sol}\right) \frac{(X_A - X_F)\ L_4}{2\ L_2 \sin \beta} \right) \qquad (4.25)$$

This analysis applies to positions of equinus stance as well as to flat-footed stance. In equinus positions the angle β formed by the tendo-achilles and hind-foot segment is not a constant. The relationship of the angle β must therefore be determined as a function of the degree of equinus. The experimental determination of angle β and analysis are detailed in Sec. 6.5 and Sec. 7.3.

CHAPTER V

EXPERIMENTAL APPARATUS

5.1 INTRODUCTION

The schematic diagram in Fig. 5.1 indicates the experimental apparatus used to investigate the postural stability of the knee. The apparatus will be described in this chapter and consists of:

(1) A force plate to measure the coordinates of the center of foot pressure and ground reaction force.

(2) A 16 mm movie camera to record the surface markings of the ankle and knee joint axes and postural alterations.

(3) A background grid to determine the horizontal and vertical (X and Z) coordinates of the joints.

(4) Electromyographic apparatus for assessment of muscular activity in the triceps surae muscles.

(5) Radiological equipment.

(6) Data recording and processing equipment.

5.2 FORCE PLATE

5.2.1 Introduction

A general purpose force analysis platform was designed and built by the author in collaboration with Mr. R.E. Kearney. This force plate was envisioned as a general purpose biomechanical research tool and is therefore somewhat more sophisticated than necessary for the investigation described here.

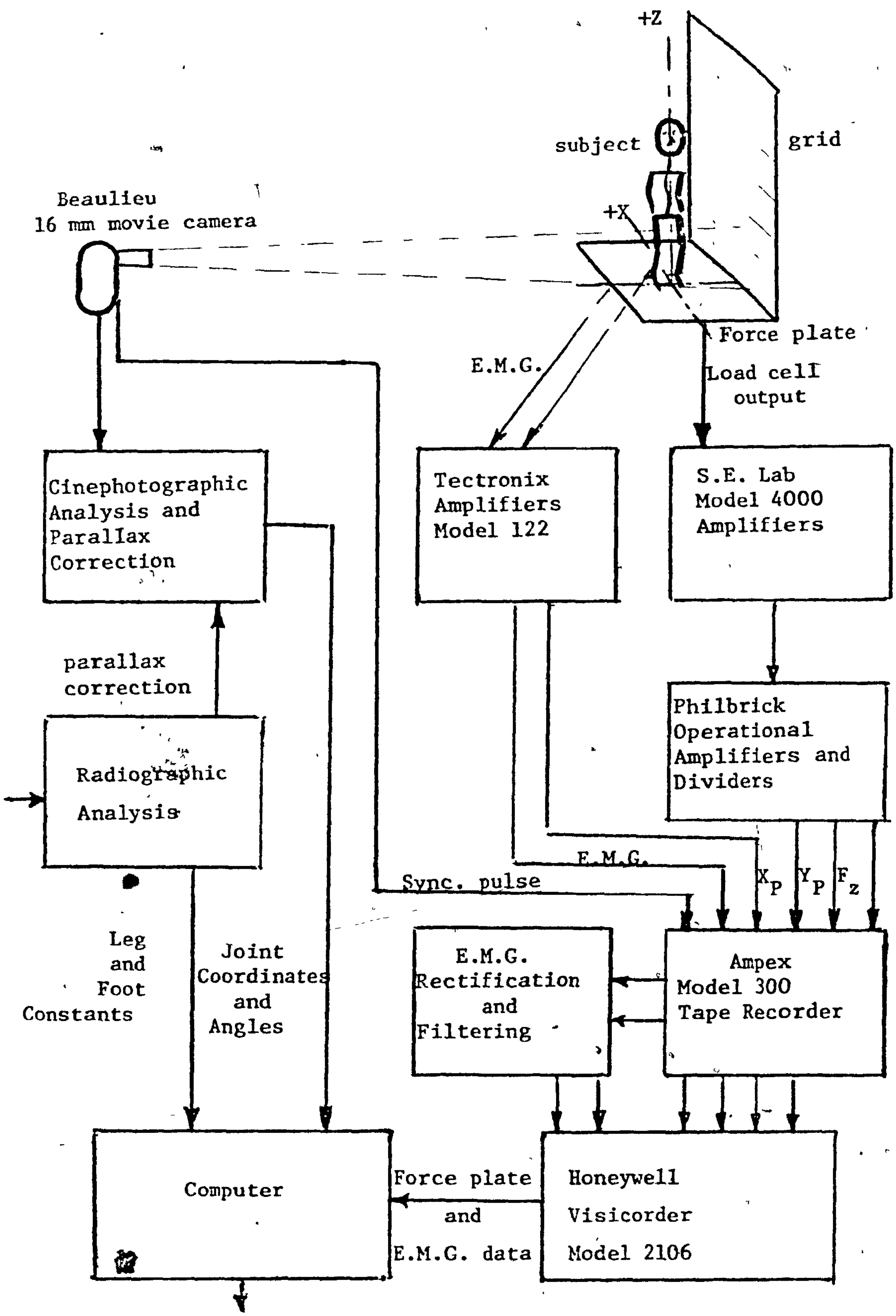


Fig. 5.1 Experimental apparatus and instrumentation

5.2.2 Design and Construction

The force plate (see Fig. 5.2) consists of a three-foot square plate supported by six load cells which are in turn mounted on another plate. Both plates are made of 3/4" thick magnesium to which a triangular frame of aluminium I beams has been bolted to provide added stiffness. Magnesium and aluminium were used in order to minimize the weight of the upper plate and hence keep the plate natural frequency as high as possible.

The load cells are arranged in a triangular array with the three vertical cells at the vertices and the three horizontal cells forming the sides of an equilateral triangle. The cells are all mounted on flexure rods, which are stiff axially but very flexible in bending. The flexures serve to eliminate cross coupling between the vertical and horizontal cells due to bending moments. The flexures were designed so that less than 1% of the force perpendicular to the flexure axis is taken up by bending of the flexures. Moments of this size will not alter the output from the cells used. Since the flexures are linear, the forces that they do absorb can easily be accounted for during calibration. BLH load cells were selected; 1000 lb. capacity for the vertical cells and 500 lb. capacity for the horizontal cells. The high capacity load cells were selected for the vertical measurement as a protection against shock overloads and to obtain a stiff support for the plate. The stiffness of the plate mounting combined with the mass of the upper plate determines its natural frequency. Note that while semi-conductor load cells are much stiffer, they were not used due to their non-linear output and temperature dependence.

More sensitive cells were used for the horizontal measurements

Fig. 5.2 The Force Plate

because the size of these forces was expected to be much smaller than that of the vertical forces.

5.2.3 Load Cell Electronics

The load cells are of the foil strain gauge type* and have a low output so that amplification is needed to give outputs suitable for further analog processing.

The S.E. Labs 4000 carrier amplifier system was selected for use. This system energizes the load cells with a 3 kHz carrier signal. The amplitude modulated load cell outputs are amplified by six A.C. amplifiers and this signal is then demodulated in a phase sensitive manner to give a D.C. output in the range 1.4 volts. The amplifiers are sensitive enough to give a full scale output for a 0.01% bridge unbalance and have infinite gain variability up to this level. The amplifiers also contain circuitry to allow both resistance and inductive unbalances to be removed.

The S.E. system also contains calibration and monitoring circuitry which allows the amplifiers to be balanced and their gains set easily.

The amplifiers have an optimum frequency response (flat from 0-1750 Hz) when feeding a 10k load. The amplifier outputs were therefore buffered from the variable impedance analog computation circuits by means of six operational amplifier followers with a fixed 10k input impedance.

The amplifiers in combination with the least sensitive load cells are capable of producing a full scale (1.4 volt) output for a

*in a full bridge circuit

load of less than 5 pounds and a noise level of less than 3 mv. This sensitivity is far in excess of anything required for these studies but could be of use in other studies - for example, balistocardiographic studies.

5.2.4 Analog Preprocessing

The amplified load cell outputs are not directly useful until they have been related to the plate geometry. The reference axis selected is shown in Fig. 5.3 where the origin (0) is near the centre of the plate. The variables of interest which must be calculated from the load cell outputs are:

(i) F_x = total force in x direction,

(ii) F_y = total force in y direction,

(iii) F_z = total force in z direction (total vertical force),

(iv) M_x = net moment about x axis,

(v) M_y = net moment about y axis,

(vi) M_z = net moment about z axis.

At times it may be useful to express M_y and M_x respectively in the slightly different form of

(vii) X_p = effective x coordinate of F_z,

(viii) Y_p = effective coordinate of F_z,

where X_p and Y_p are defined by the relations

$$X_p = \frac{M_y}{F_z} \tag{5.1}$$

$$Y_p = \frac{M_x}{F_z} \tag{5.2}$$

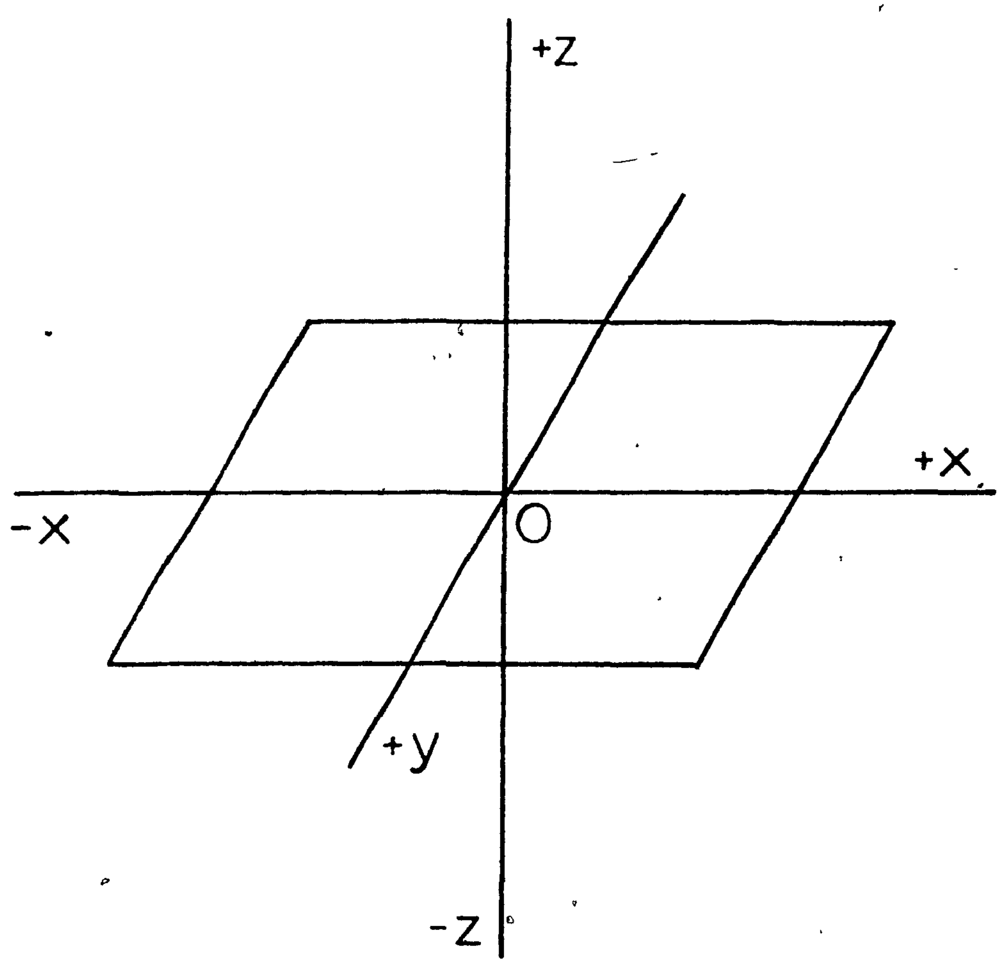


Fig. 5.3 Force plate reference axes

The detailed derivation of the equation relating these variables to the load cell outputs is found in Appendix A. These algebraic relations have been implemented by means of simple operational amplifier circuits which are patched together on Philbrick-Nexus operational manifolds, using Philbrick P85AU operational amplifiers. The divisions required to calculate X_p and Y_p are done by two Philbrick SPM1A multiplier-divider units.

5.2.5 Calibration

Static calibration of the system was necessary to account for any forces absorbed by flexures and to ensure that the system is both linear and repeatable. This was done by first setting the amplifier gains at about the correct level, calibrating the plate and the resetting the amplifier gains to give a convenient output scale.

Calibration loads were first applied in gradual steps and then removed in the same steps to provide a check on both the linearity and the repeatability of the system.

The vertical calibration loads were easily applied by using dead weights since only positive loads were of interest. The horizontal loads were applied in both directions through a lever arrangement.

While the plate was being calibrated in one direction, the other two force outputs were monitored to check for cross coupling effects. In all cases these effects were completely negligible.

Calibration curves for F_x, F_y, F_z are shown in Figures 5.4, 5.5 and 5.6.

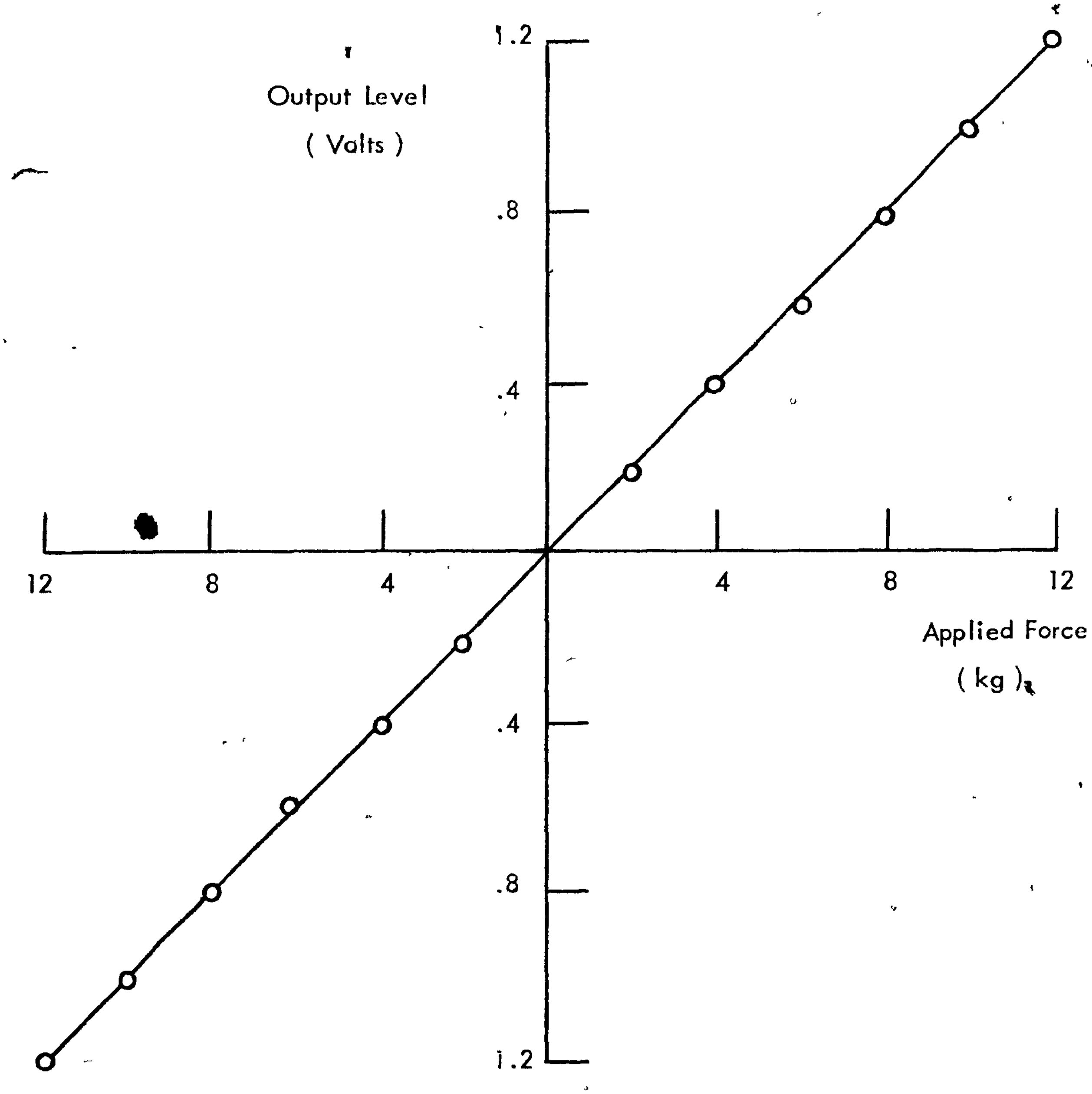


Fig. 5.4 F_x calibration curve

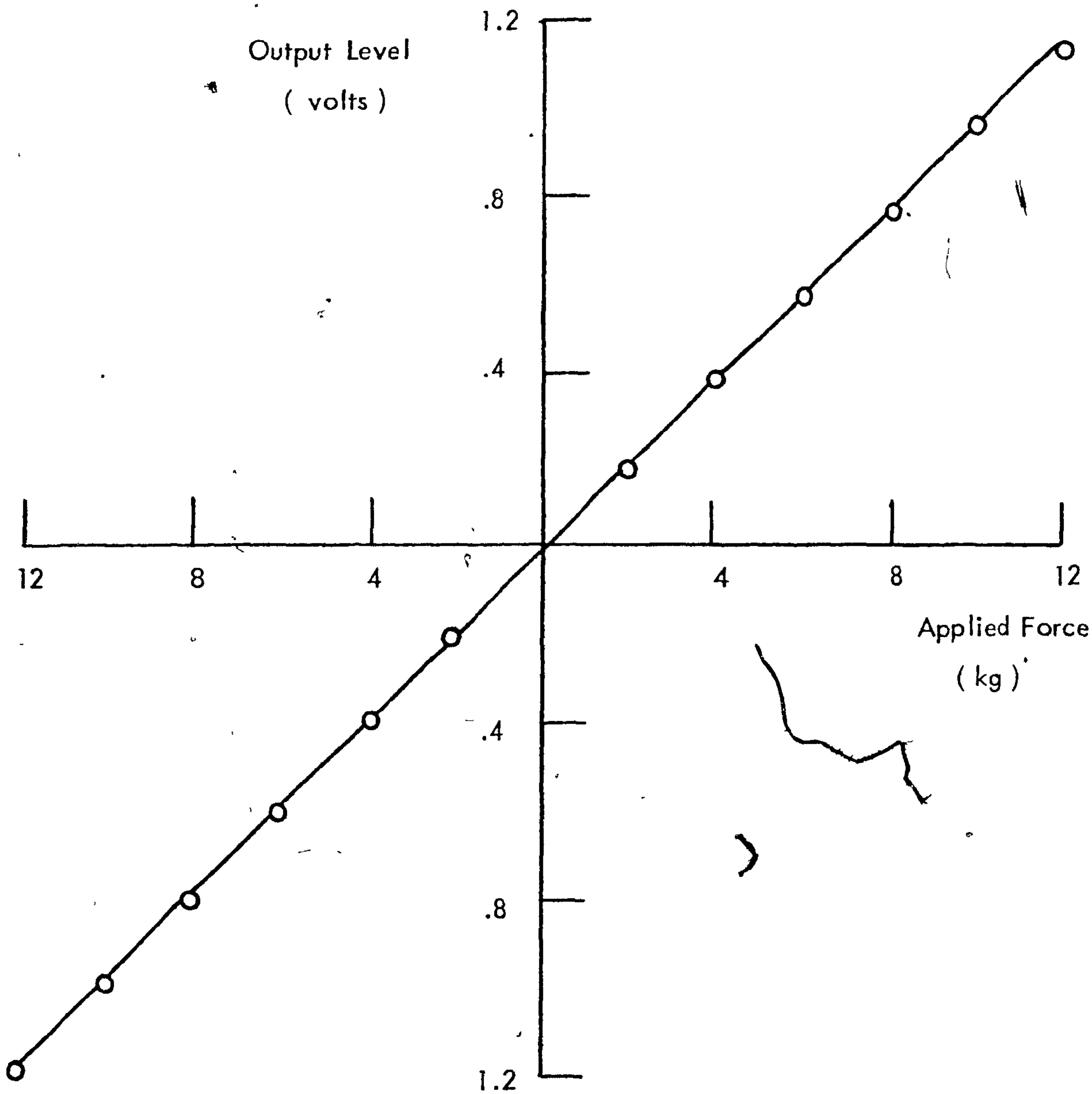


Fig. 5.5 F_y calibration curve

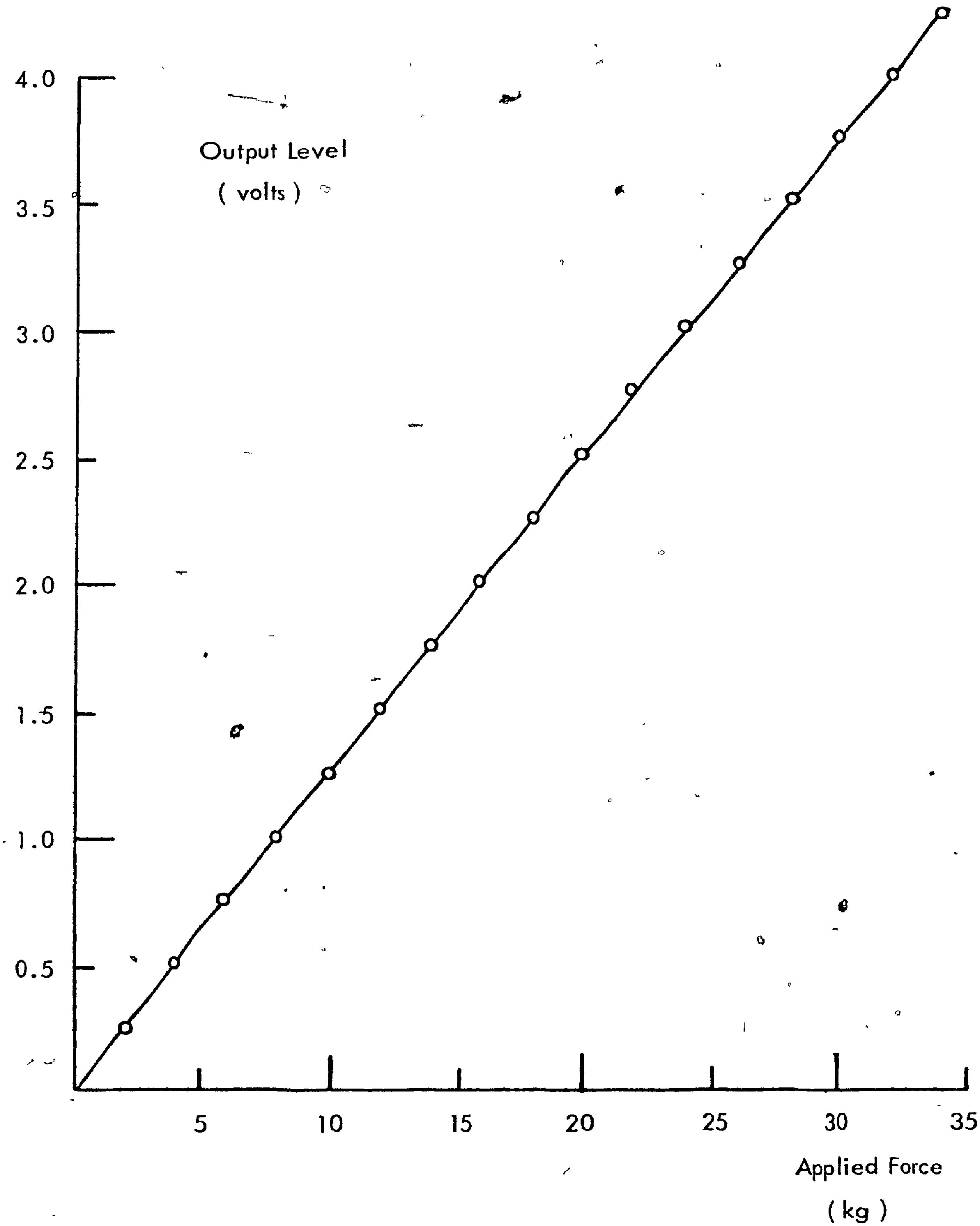


Fig. 5.6 F_z calibration curve

No attempt was made to calibrate the other outputs since they are derived from the same variables which were calibrated through F_x, F_y, F_x, and so do not need direct calibration.

The moment outputs were, of course, checked in an approximate manner to ensure that there were no wiring errors.

Dynamic calibration of the plate was attempted by applying an impulsive load and observing the response. Typical response curves are shown in Fig. 5.7, 5.8 and 5.9 for shocks applied in the x, y, z directions. These complex responses were treated as damped second order responses to provide approximate values for natural frequency and damping ratios. The values obtained were:

Direction	Natural Frequency (W_n)	Damping Ratio (δ)
x	168 Hz	.20
y	105 Hz	.60
z	200 Hz	.19

These figures apply for the plate supporting a 200 lb. man but the differences between the loaded and unloaded plates were small probably as a result of the loose coupling between the man and plate. These natural frequencies are well above any expected postural frequencies required for accurate measurements. However they do imply that some caution is necessary in studying impulsive type of loading as in fast walking or running.

The force plate electronics were set up to have the following output scales for work described in the thesis.

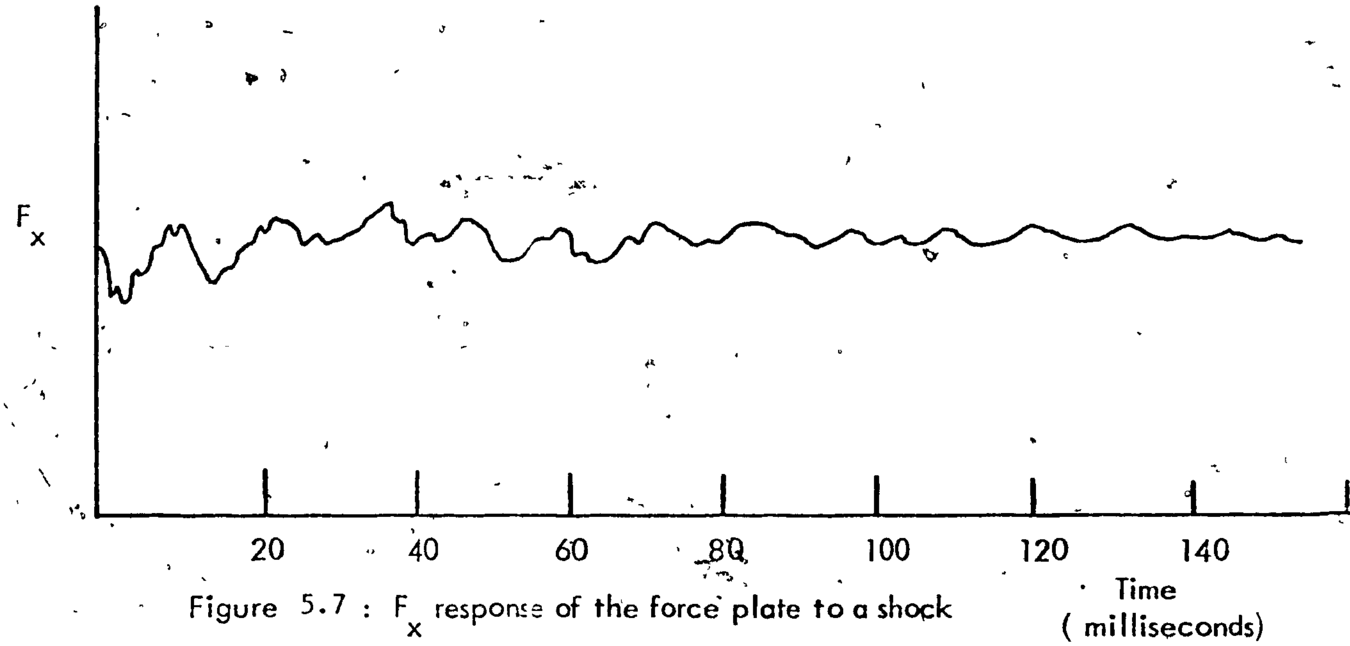


Figure 5.7 : F_x response of the force plate to a shock load applied in the X direction.

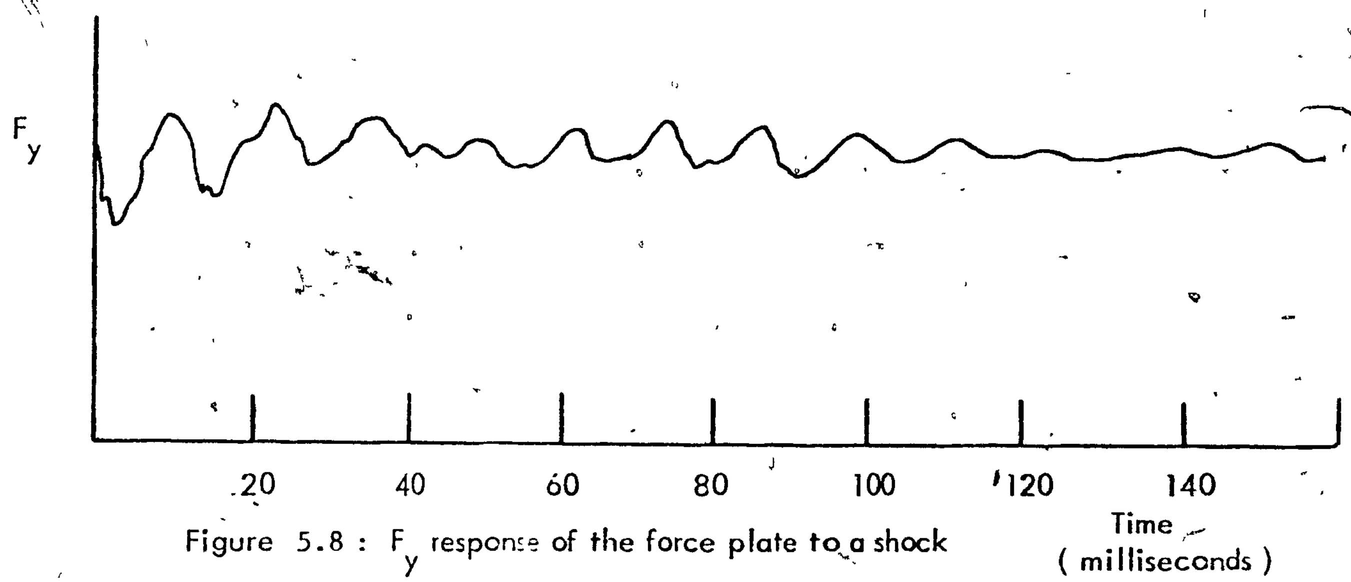


Figure 5.8 : F_y response of the force plate to a shock load applied in the Y direction.

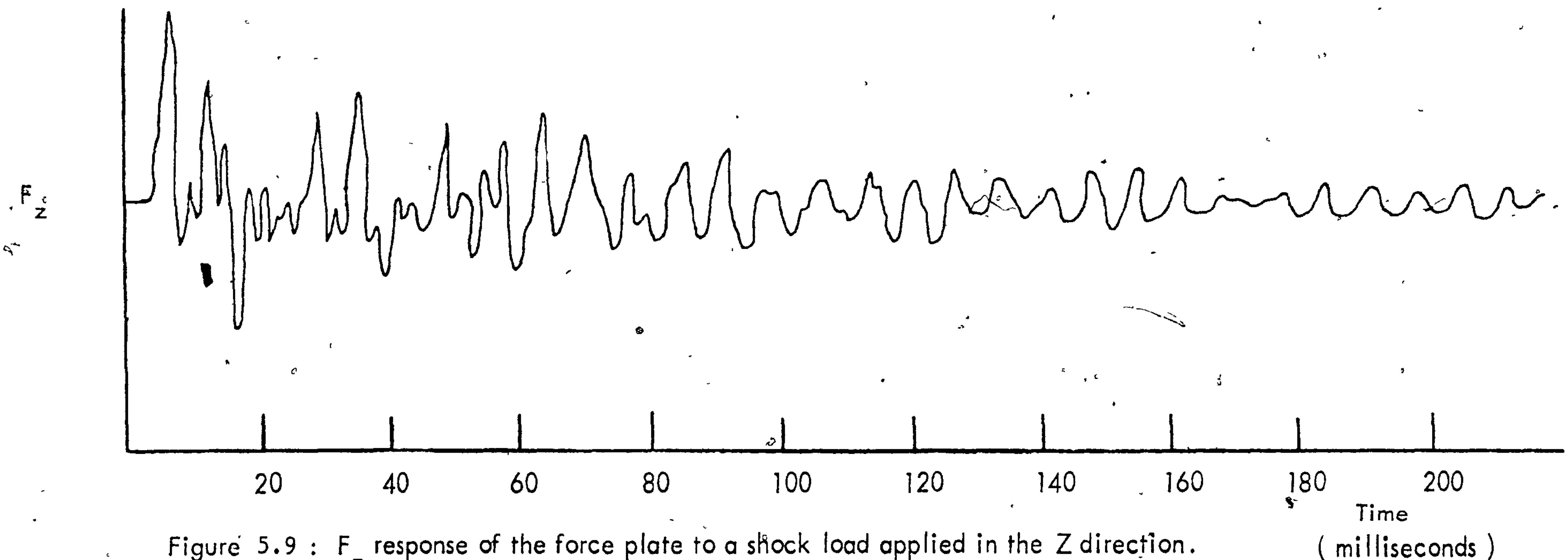


Figure 5.9 : F_z response of the force plate to a shock load applied in the Z direction.

Variable	*Scale*	*Noise Level*	*Accuracy*
F_x	10mv/N	5mv	±1/2N
F_y	10mv/N	5mv	±1/2N
F_z	10mv/N	5mv	±1/2N
X_p	1v/cm	50mv	±.5mm
Y_p	1v/cm	50mv	±.5mm
M_z	10v/N-m	50mv	15N-cm

The noise levels quoted were observed experimentally.

5.3 CINEPHOTOGRAPHY AND BACKGROUND GRID

5.3.1 Camera and Grid

The camera selected was a Beaulieu RIG "Sync" 16 mm electric cine-camera. The variable speed capability was from 1 to 64 frames per second. The camera was mounted 25 feet from the plane of the subject and 26.5 feet from the background grid. Using a 75 mm lens, a view of a standing subject's lower extremity was obtainable. The cine-film was projected using a Bell & Howell 16 mm projector with manual frame advance against a background grid matching the photographic grid to an accuracy of ±1 mm. Parallax error was reduced by maintaining the ratio of the distances, $\frac{\text{lens to subject}}{\text{subject to grid}}$, as high as possible in the available working space . The parallax error is calculated in Appendix B and is determined for horizontal displacements to be 6 mm for object placed 10 cm from the lens axis. Camera speed used in this study was 16 frames per second.

5.3.2 Synchronization Pulse

The camera was equipped with an alternator attached to the film transport mechanism. It generated 2½ cycles of a sinusoidal wave for each frame taken. A counting circuit was designed to emit a pulse for each 2½ cycles of the camera generator pulse. By correct phasing of the counting circuit it was possible to have this pulse emitted at the time the shutter opening occurred. The circuit therefore produced a pulse which would allow the cinephotographic information on each frame to be correlated with other variables.

5.4 ELECTROMYOGRAPHY (E.M.G.)

5.4 1 Electrodes

Beckman surface electrodes were used to record the electrical activity in the gastrocnemius and soleus muscles. Two sets of electrodes were utilized on the same leg in an attempt to evaluate the relative activity. Surface electrodes were used to enable signals to be recorded from a larger muscle bulk than possible with wire electrodes and since these muscles are superficial, they could easily be identified.

Application technique involved shaving and washing the skin with alcohol and applying the electrodes with conducting electrode jelly and Beckman adhesive.

5.4.2 Amplifiers

The surface electrodes were connected to Tektronix Type 122 differential preamplifiers through shielded cables. A gain of 1000 was adequate to raise the EMG signal level for further analog processing.

The Tektronix Type 122 amplifiers were equipped with variable first order high and low pass filters for reduction of noise level. The best results were obtained with a high-pass filter break point set at 10 Hz and low pass filter break point set at 1 kHz.

5.4.3 Rectification and Filtering

The amplified EMG's were then processed through an analog network patched into the Philbrick operational manifolds. The network was developed at the BioMedical Engineering Unit by H.H. Kwee. A circuit diagram of the network is shown in Fig. 5.10.

The circuit first high pass filters the input to reduce any noise resulting from low frequency motions of the body. The wave is then full-wave rectified and smoothed by a low pass filter. Both the high pass and low pass filters are simple first order filters with variable break points. A low pass break point of 24 Hz and a high pass break point of 100 Hz were found to give the best results.

5.4.4 Electrode Placement

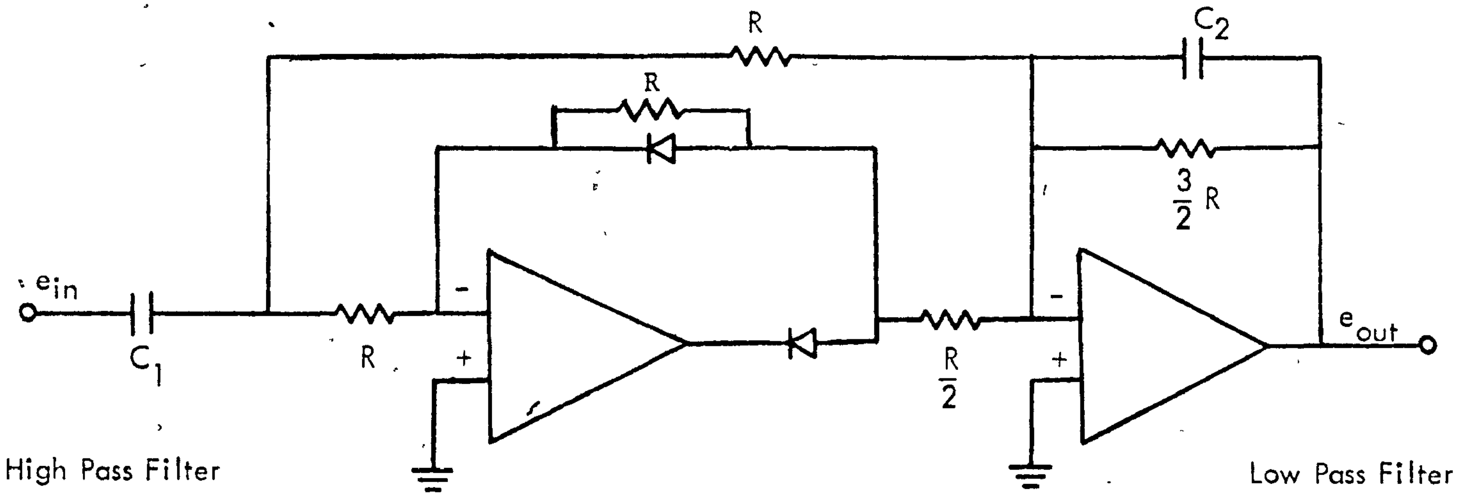
Two electrodes spaced several centimeters apart were placed over the muscle belly of the gastrocnemius and soleus muscles on the same leg. It was found possible to establish separation of the electrical activity in these muscles by checking the activity of the soleus in a neutral ankle position and the gastrocnemius with greater plantar flexion, to ensure that there was minimal cross-coupling between them.

A common ground electrode was used for both sets of electrodes and was separated from them.

5.5 DATA RECORDING

5.5.1 FM Tape Recorder

A 7-channel Ampex SP-300 was utilized to record force plate and EMG variables and the synchronization pulse from the sine wave generator



Capacitor C_1 determines the high pass break point

Capacitor C_2 determines the low pass break point

Fig. 5.10: Circuit Diagram of the EMG Processing Card.

on the 16 mm movie camera. A simple manual switch in the output of the counting circuit enabled the initial recorded frame of the photographic record to be correlated with the other variables. By storing the data on magnetic tape, subsequent processing of EMG records and conversion to strip chart form for visual analysis was possible.

5.5.2 Visicorder

A 7 channel Honeywell Visicorder Oscillograph Model 2106, equipped with a Honeywell Accudata Model 117, multi-channel DC amplifier was used to transform the variables recorded on the Ampex tape recorder into strip chart form. The gains were adjusted on the input to the visicorder to give the following scales.

X_p - 1 cm displacement on force plate equal to 1/2 inch on strip chart.

Y_p - 1 cm displacement on force plate equal to 1/2 inch on strip chart.

F_z - 100 newtons = 1 inch

Synchronization pulse = full sweep of strip chart

5.5.3 IBM 360 Computer

The IBM 360 Computer facilities at the McGill Computing Centre were utilized for data processing. The variables from force plate, EMG, cinephotography and radiological measurements were combined on punch cards with one data set correlating to a single 16 millimeter cine exposure. A computer program in FORTRAN language was written to do the calculations.

5.6 RADIOLOGY EQUIPMENT

Standard radiology equipment was utilized at the Radiology Departments of the Montreal General Hospital and the Montreal Children's Hospital to take the full length radiographs of the leg in subjects tested. Coning techniques were utilized to limit the exposure fields and restrict the X-ray dosages. The full-length films were taken at a source to plate distance of 20 feet with the plates located immediately adjacent to the part examined. Radio-opaque markers were applied to the skin and centered over the skin marks utilized for photography.

CHAPTER VI

EXPERIMENTAL METHOD AND PROTOCOL

6.1 INTRODUCTION

The experiments consisted of the study of one normal adult, two normal children, and two children with the Duchenne form of muscular dystrophy. The experimental methods and protocol used are described.

6.2 EXPERIMENTAL METHOD

Subjects were dressed in shorts only, providing complete exposure of the lower extremities to the mid-thigh level and wore no footwear. Physical examinations of the muscular dystrophy subjects' lower extremities were performed and the active and passive range of motion of the knee and ankle joints documented. Height and weight measurements were recorded for each subject. Prior to application of EMG electrodes, the subjects were instructed in the manoeuvers which were to be performed during the experiment. They were instructed to stand with the knees fully extended, with the feet together and symmetrically placed with the intermalleolar distance equal to one cm. and the medial borders of the feet oriented along the anteroposterior axis. The manoeuver of lordosis was demonstrated and adopted under supervision instructing the subject to allow the abdomen to protrude and to extend the shoulders such that a lordotic posture was adopted. The adoption of a slow continuous progression of the degree of equinus and return to a plantigrade position was practiced until the subjects could confidently carry out the manoeuvers with ease over a period of approximately 45 seconds. Normal subjects were instructed in both manoeuvers. The muscular dystrophy children were instructed in only the equinus manoeuver, since they were unable to decrease the degree of lumbar lordosis in a standing position. They were, however, capable of adopting a flat foot stance with heel contact.

The EMG electrodes were then applied to the calf of the right leg over the soleus muscle and one of the heads of the gastrocnemius muscle. A check of function was then made to ensure that a good quality signal was obtained. Surface marks were then applied to the lateral aspect of the lateral femoral condyle, to the tip of the lateral malleolus and to the head of the fifth metatarsal using black tape and marker pencil. The surface landmarks were determined at this stage by palpation. The marks were applied with the knees fully extended and the ankle in a neutral position to minimize skin movement error during the manoeuvers.

The subject was then positioned on the force plate such that he faced to the right when viewed from the camera position with the right side exposed to the camera. The feet were positioned with the medial aspect of the foot aligned parallel to the a-p or X axis of the force plate and the 5th metatarsal marker on each foot centered on the Y transverse axis. The foot positions and X and Y force plate axis were recorded on semi-transparent grid paper applied to the force plate prior to positioning of the subject. The background grid was positioned such that the vertical Z-Y plane formed a right angle with the vertical grid. The EMG connections were then made and recording of the force plate variables and EMG records started. Prior to the onset of each phase of the experiment, a call card denoting the phase of the experiment was placed in the field of view of the camera to document the succeeding record. At the time the subjects began each phase of the experiment, the movie camera was started and the synchronization pulse switch opened.

During the manoeuvers, the subjects' arms were immobilized by having them grasp their shorts with arms fully extended.

Following the experiment on the force plate, the subjects were transported to the Radiology Departments of the Montreal Children's Hospital or the Montreal General Hospital where lateral radio opaque markers were applied to the knee, ankle and fifth metatarsal head markers. Two lateral radiographs of the knee were taken in positions of full extension and approximately ten degrees of flexion of the knee for determination of the instant centres of rotation. A lateral radiograph of the ankle was also taken. The distance of X ray source to subject was 20 feet to minimize parallax.

6.3 EXPERIMENTAL SUBJECTS

The subjects studied with their pertinent body weight, height and significant pathology related to their disease is noted in Table 6.1. Fig. 6.1, 6.2, 6.3, 6.4 and 6.5 show photographs of the subjects. The foot positions shown in the photographs were not those described and used in the experiments. The muscular dystrophy subjects MD1 and MD2

TABLE 6.1

CLINICAL DATA ON EXPERIMENTAL SUBJECTS

Subject	Age	Height cm	Weight cm	Remarks
Adult JM	40	179.0	79.9	normal adult
N_3 (child)	11 yr. 8 mo.	148.6	44.3	History of fracture of right tibia and fibula six months prior to study. Ambulatory out of cast for two and a half months. No limp. No flexion deformity of knee.
N_4 (child)	9 yr. 6 mo.	131.2	31.8	normal child
M.D.1 (late dystrophy)	11 yr. 10 mo.	134.5	31.9	gait - equinus stance - just capable of heel contact during stance, lordotic. knee - fixed flexion contracture of 10 degrees. ankle - active and passive dorsiflexion to 5 degrees. Positive Gower's sign.
M.D.2 (early dystrophy)	8 yr. 5 mo.	116.5	24.2	gait - heel-toe. stance - heel contact, but adopts equinus in moments of apprehension - lordosis present. knee - flexion contracture of 5 degrees. ankle - active and passive dorsiflexion to 10 degrees. Positive Gower's sign.

Fig. 6.1 Subject Adult (JM)

Fig. 6.2 Subject N_3 (Normal child)

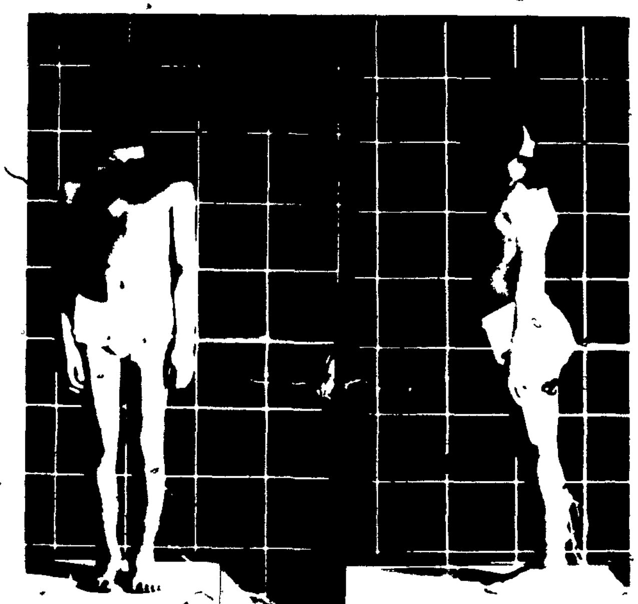


Fig. 6.3. Subject N_4 (Normal child)

Fig. 6.4 Subject M.D.1 (Advanced dystrophy)

Fig. 6.5 Subject M.D.2 (early dystrophy)

were brothers. The severity of the disease process in the older of the two was more advanced. The age related clinical course of the disease process in these two children was similar with respect to age of onset of detectable weakness, functional disability and progression of contractures, as well as calf pseudohypertrophy. The younger child (M.D.2) walked with a heel toe gait, but adopted equinus in moments of apprehension. M.D.1 walked with equinus but could stand with feet symmetrically placed and heel contact. The two normal children were selected on the basis of weight and height to match as closely as possible the characteristics of the dystrophic children studied. Subject N_3 had sustained a fracture of his right tibia and fibula approximately six months prior to the study and had been ambulatory for two and a half months. He had no clinical deformity or shortening and did not walk with an obvious limp nor did he appear to "favour" that extremity.

6.4 EXPERIMENTAL PROTOCOL

The sequence of study for each of the subjects is detailed below.

	No. of Photographic Frames	Data Points
Subject (Adult J.M.)		
Phase I - plantigrade	246	50
Phase II - continuous slow rise into full equinus and return to plantigrade.	336	68
Phase III - equinus in steps.	316	64
Phase IV - lordosis	136	28
Phase V - lordosis and continuous slow rise into full equinus and return to plantigrade.	281	57
Phase VI - lordosis and equinus in steps.	281	57
Subject N_3 (Normal child)		
Phase I - plantigrade	111	23
Phase II - equinus-slow rise and descent.	151	31
Phase III - lordosis	106	22
Phase IV - lordosis and equinus with slow rise and descent.	206	42

	No. of Photographic Frames	Data Points
Subject N_4 (Normal child)		
Phase I - plantigrade	86	18
Phase II - equinus-slow rise and descent.	206	42
Phase III - lordosis	71	15
Phase IV - lordosis and equinus with slow rise and descent.	226	46
Subject M.D.1 (advanced muscular dystrophy)		
Phase I - plantigrade	331	83
Phase II - equinus-slow rise and descent.	821	67
Subject M.D.2 (early muscular dystrophy)		
Phase I - plantigrade	316	64
Phase II - equinus-slow rise and descent.	341	69

6.5 RELATIONSHIP OF ACHILLES TENDON TO HINDFOOT SEGMENT

To determine the relationship of the angle β of the tendo-achilles to the hindfoot segment in various degrees of equinus during standing, a set of serial radiographs of the ankle were made at intervals of 10^o of equinus with the central axis of the X-ray source aligned parallel to the ankle axis. The relationship of the angular change of β to α (the degree of equinus) was determined to be linear. This analysis is detailed in Section 7.3.

6.6 GASTROCNEMIUS AND SOLEUS MUSCLE CROSS-SECTIONAL AREAS AND WEIGHTS

Cadaver dissections of calf muscles was done on four legs. The muscles were incised transversely at the maximum cross-section of the muscle belly and the area measured using a planimeter. The entire muscle bellies were then dissected from the legs and the weights measured. The relative cross-sectional areas were then used to calculate a constant for the $\left(\frac{\text{gas}}{\text{gas + sol}}\right)$ strength relationship. The data and calculations are detailed in Appendix C.

CHAPTER VII

DATA PROCESSING AND RESULTS

7.1 INTRODUCTION

Data processing of recorded variables and constants was done following compilation of the following:

Variables:

Single frame analysis of cine records:

- X_A - X coordinate of ankle axis (cm)
- Z_A - Z coordinate of ankle axis (cm)
- X_B - X coordinate of knee axis (cm)
- Z_B - Z coordinate of knee axis (cm)
- α - angle defined by forefoot link A-O and force plate surface (degrees)

Strip chart record of magnetic tape data:

- F_z - total vertical force
- Y_p - transverse coordinate of C.F.P. (cm)
- X_p - anteroposterior coordinate of C.F.P. (cm)
- EMG_{gas} - EMG activity in gastrocnemius muscle
- EMG_{sol} - EMG activity in soleus muscle

Constants:

- $(\frac{gas}{gas+sol})$ - ratio on basis of EMG activity or muscle cross-sectional area of gastrocnemius and soleus muscles

β_0 - plantigrade angle of tendoachilles relative to hindfoot link A-C (degrees)

α_0 - plantigrade angle of A-0 axis relative to force plate surface (degrees)

Body weight - in Kg

L_2 - hindfoot length (cm)

L_4 - gastrocnemius lever arm (cm)

Following application of correction factors for cinephotograph parallax and the error of skin joint markers relative to true axis determined radiologically, and scaling of gastrocnemius and soleus EMG activity, sets of data cards were prepared for each subject corresponding to each photographic frame analyzed. Calculations were then performed utilizing a Fortran program and IBM-360 computer. The calculated N.S.M.'s were then sorted for degree of equinus at 2 to 4 degree intervals, and means calculated. Details of the data processing follow.

7.2 CINEPHOTOGRAPH ANALYSIS

The 400 ASA TRX black and white reversal film was developed by a commercial firm. The developed film was then projected on a Bell & Howell projector and surveyed at normal and slow motion speeds prior to analysis. Any abnormal deviations in hand positions or asymmetry of knee positions which could account for abnormal or erratic C.F.P. shifts were noted and these studies were rejected. Subject N_3 was the only subject to demonstrate gross deviation of knee and stance symmetry (Fig. 7.1). The subject tended to allow his right knee to flex and to maintain his left knee extended, indicative of him taking

Fig. 7.1 Stance assymetry (Subject N_3)

a disproportionate amount of weight on the left leg. This was confirmed by the strip chart record of Y_p coordinate of foot pressure. Having surveyed records of each phase of the experiment, single frame analysis of the film was carried out. The film was projected onto a paper grid with millimeter gradations and the distance from projector to projection surface adjusted such that the photographed grid exactly matched the paper grid on the projection surface. Using the coordinate system shown in Fig. 7.2, the coordinates X_A, Z_A, X_B, and angle α were then recorded to the nearest 0.5 mm and to the nearest $\frac{1}{2}$ degree for every 5th or 10th frame for the phase, depending on length of each run. The photographic coordinates were then adjusted for parallax with corrections as given in Table B-1, Appendix B. The correction factors for the true position of joint axis A and B were determined from radiographs and added to the parallax adjusted values (see Sec. 7.3).

7.3 RADIOGRAPHIC ANALYSIS

7.3.1 Axis of Knee and Angle

The knee axes were determined by the method of instant centres, utilizing two lateral X-rays of the knee in a range of 10^{o} flexion to hyperextension (Fig. 7.3). Having located the instant centre on the

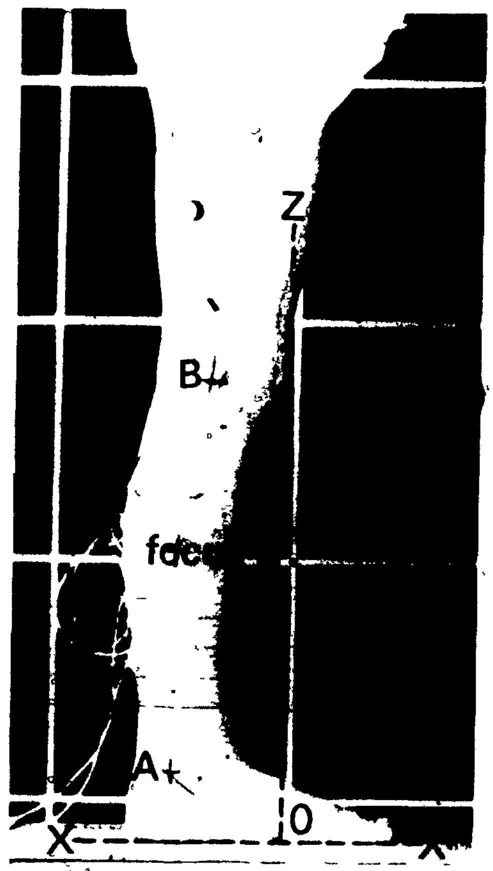


Fig. 7.2 Coordinate measurements on cinephotograph.

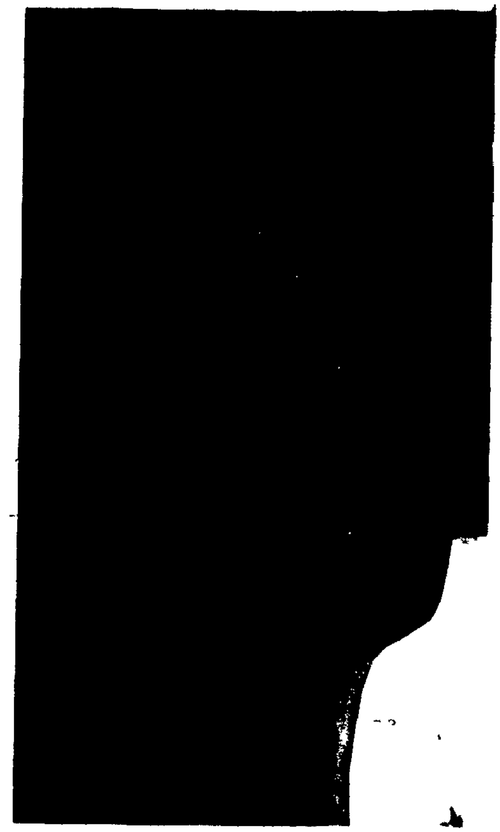


Fig. 7.3 Knee axis determination

lateral femoral condyle, the correction constant for the skin marker positions were measured and are shown in Table 7.1. The line of action of the lateral head of the gastrocnemius muscle origin on the posterolateral aspect of the femoral condyle was located and the distance L_4 (the lever arm of the gastrocnemius) was measured as the perpendicular distance from the line of action of the gastrocnemius to the axis of rotation of the knee as shown in Fig. 7.4.

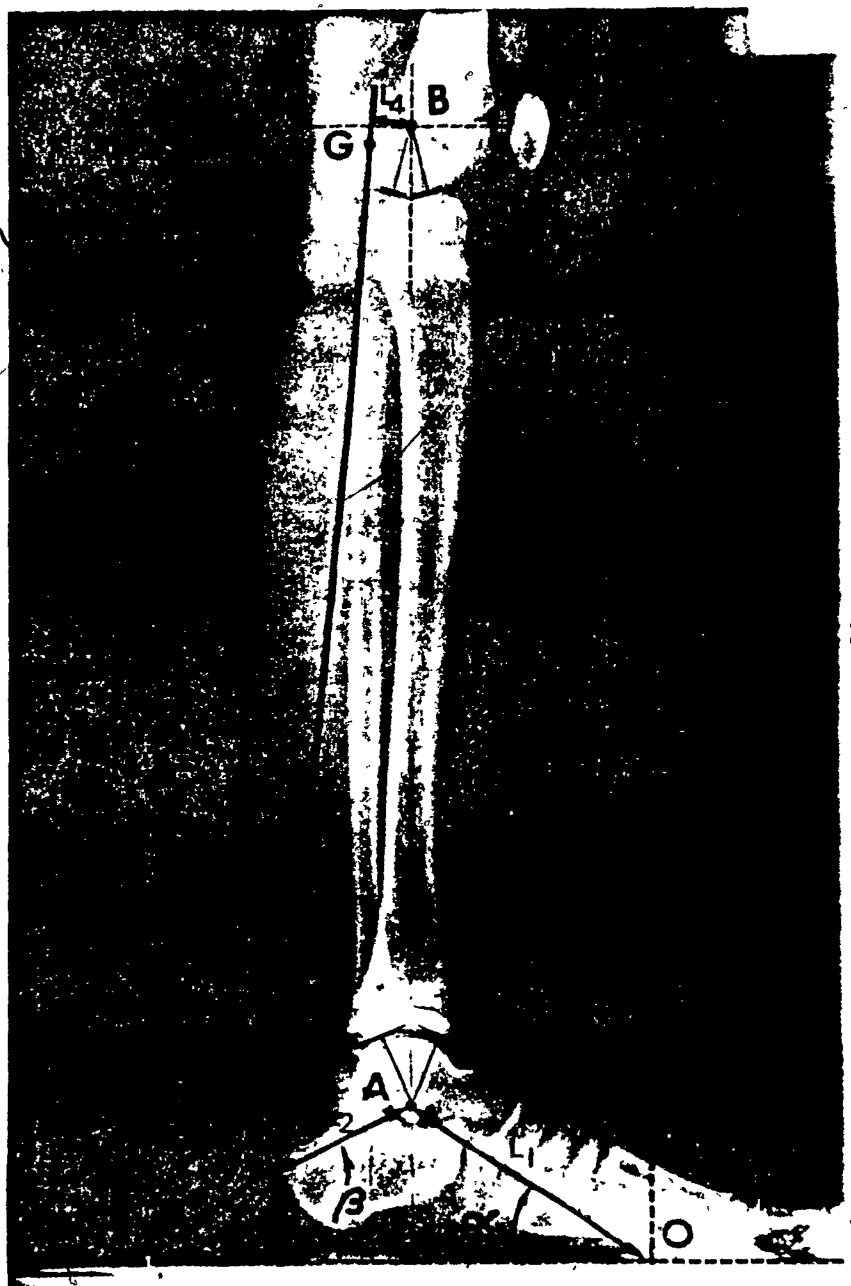


Fig. 7.4

Lateral Radiograph of leg and foot

TABLE 7.1

Foot and Leg Constants and Correction Constants for Knee and Ankle Coordinates

Subject	Plantigrade foot angles (degrees)		Foot measurements (cm)		Correction constants (mm)			
	α_0	β_0	L_2	L_4	X_A	X_B	Z_A	Z_B
Adult	35.0	58.0	6.7	2.2	−3	+4	0	0
N_3	36.0	58.0	5.9	1.6	−10	+6	0	−2
N_4	32.5	58.0	5.1	1.4	−7	+3	−5	+7
MD1	32.0	58.0	4.8	1.5	−7	+8	−2	0
MD2	29.0	60.0	3.8	1.3	−9	−4	0	−10

The ankle joint axis was located on the lateral radiograph of the foot and ankle at the lateral aspect of the talar dome by constructing perpendiculars to the tangent of the articular surface of the talus (Fig. 7.5). The correction constant was measured on a coordinate basis to allow skin marker position to coincide with the radiologically determined axis. The correction factors for the joint positions are tabulated in Table 7.1.

Analysis of the serial set of X-rays (Fig. 7.6) of the foot and ankle of subject Adult J.M. in a range of equinus showed a linear variation of the angle β (angle formed by the achilles tendon with the hindfoot segment L_2) as a function of the degree of equinus as measured by angle α (angle formed by the forefoot segment AO with the

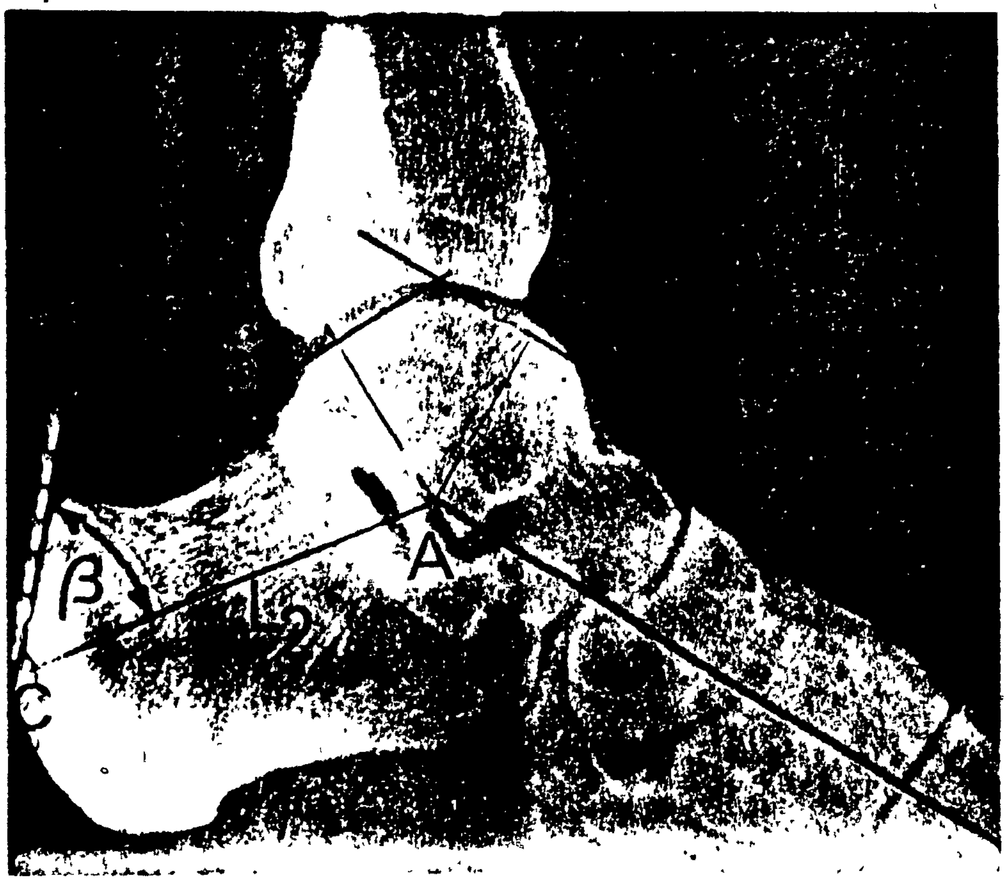


Fig. 7.6 Achilles tendon relationship to hindfoot segment

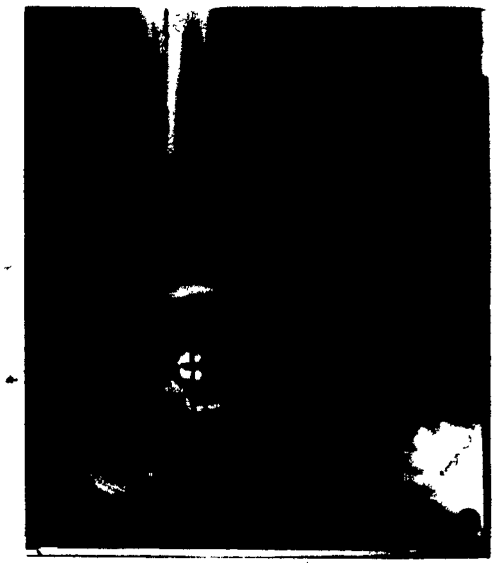


Fig. 7.5 Ankle axis determination

floor). The measurement of the angles is tabulated in Table 7.2.

Position	α	β	Δα	Δβ	Δα/Δβ
1. plantigrade	35	58	0	0	--
2.	41	61	+6	+3	0.50
3.	53	67	+18	+11	0.61
4.	61	71	+26	+13	0.50
5. equinus	74	79	+39	+21	0.53

TABLE 7.2

Variation of Angle β as a function of Angle α

The relationship of angle α to β is linear as evident in Fig. 7.7.

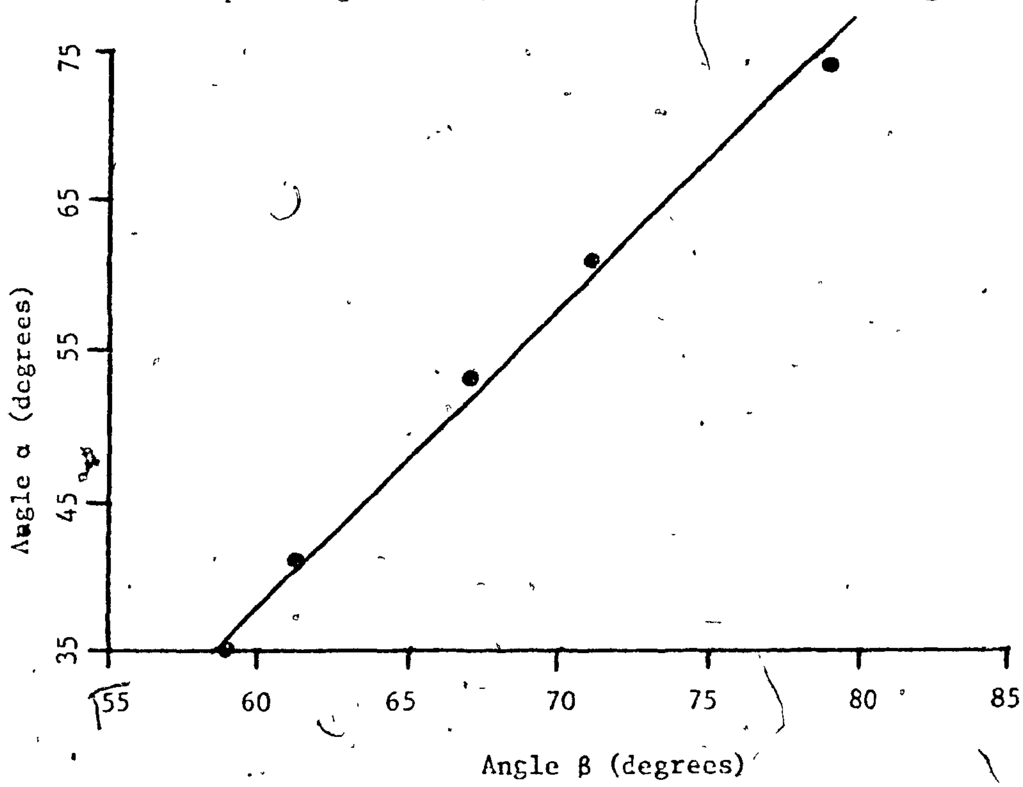


Fig. 7.7 Achilles tendon angle β as a function of the angle α

The correction constant, to express the angle β as a function of angle α can be expressed as

$$\beta = \beta_0 + CF\,(\Delta\alpha) \qquad (7.1)$$

where CF = a constant

$\Delta\alpha$ = degree of equinus

β_0 = plantigrade angle of achilles tendon to hindfoot segment AO

but if

$$CF = \frac{\Sigma\Delta\beta}{\Sigma\Delta\alpha} \qquad (7.2)$$

$$CF = \frac{3 + 11 + 13 + 21}{6 + 18 + 26 + 39} = \frac{48}{89} = 0.54 \qquad (7.3)$$

$$\beta = \beta_0 + 0.54(\Delta\alpha) \qquad (7.4)$$

This constant was determined for only one subject, as the multiple radiation exposures would have been too high for the children utilized in the study. The same constant was therefore applied to all subjects. The hindfoot segment L_2(AC) was measured for each subject and tabulated in Table 7.1. The value of α_0 and β_0, the plantigrade angle α and β are also included in Table 7.1. The lateral radiograph shown in Fig. 7.4 illustrates these measurements.

7.4 MAGNETIC TAPE RECORD CONVERSION TO STRIP CHART AND ANALYSIS

7.4.1 Magnetic Tape to Strip Chart Conversion

The magnetic tape recorder channel allocation and attenuation used is shown in Table 7.3. The conversion of the tape record to strip chart form was then accomplished by inverting the sign of the flutter compensation channel 2 and adding it to the output of channels 1, 3, 4

Tape Recorder Channel	Variable	Attenuation
1	voice and synchronization pulse	0
2	ground for flutter and wow compensation	0
3	EMG - Soleus	2.5:1
4	F_z total vertical force	1:2.5
5	X	1:2.5
6	Y	1:5
7	EMG - Gastrocnemius	2.5:1

TABLE 7.3 Channel allocations and attenuation

5, 6 and 7, using analogue techniques on a Philbrick operational amplifier manifold. The output signals were then connected to the input amplifiers of ~~the visicorder~~ with channel correlations (as shown in Table 7.3). Attenuations were then adjusted for each output channel to give the output scales as shown in the same table.

TABLE 7.4 Channel Correlation Magnetic Tape-Visicorder, and Strip Chart Scale

Variable	Tape Recorder Channel	Visicorder Channel	Strip Chart Scale
voice and synchronization pulse	1	6	----
ground	2	3	zero reference for X & Y
EMG soleus	3	2	
F_z	4	7	100 Newton= 1" visicorder
X	5	4	1 cm plate= ½" visicorder
Y	6	5	1 cm plate= ½" visicorder
EMG - gastrocnemius	7	1	

7.4.2 Strip Chart Analysis

Strip chart records were run at a paper speed of 8 inches per second. The variable F_z and Y_p were scrutinized for each run performed. The variation of Y_p (lateral or transverse coordinate of the centre of foot pressure) was scrutinized for a variation of greater than ±0.5 cm from the midline. Portions of the records with a greater deviation from the midline were rejected as being unacceptable. This occurred only in subject N_3 and correlated with a tendency to flex his right knee and distribute weight unevenly on his two feet, as evident in the photographic records.

The magnitude of F_z was scrutinized for variation of the greater than ±10 newtons. Deviation of greater than this value was not noted during the course of the experiments indicating well controlled adoption of equinus with minimal dynamic effect of ascent or descent during equinus manoeuvers or due to postural sway. The value for F_z utilized in all calculations was the body weight recorded on the force plate prior to starting the individual experiments.

The value of X_p was scaled and recorded with the coordinate data from photographic analysis.

EMG records were inspected for conditions of quiet standing and during adoption of lordotic and equinus manoeuvers. Using an arbitrary scale of 0 to 5 with 5 representing the maximum voltage envelope of the filtered EMG, the activity in soleus and gastrocnemius muscles was scaled. These values were recorded for the subjects on a frame by frame analysis of the strip charts.

The input variables are shown in the computer printout sheets in Appendix E.

7.5 COMPUTER ANALYSIS

Four programs were utilized in the analysis of the data and are shown in Appendix D. Program number 1 was used for phases of the experiments which were plantigrade and had no equinus introduced with EMG activity scaled. Program number 2 was used for phases of the experiment which were plantigrade and had no equinus introduced with no EMG activity scaled. Program number 3 was used for phases of the experiment which had equinus introduced with EMG activity scaled. Program number 4 was used for phases of the experiment which had equinus introduced without EMG activity recorded. The program with EMG scaled had a computer output designated PNEMG, and utilized a $(\frac{gas}{gas+sol})$ constant based on EMG activity. Additional computer outputs for $(\frac{gas}{gas+sol})$ value of 0.25, 0.50, 0.75 and 1.0 designated respectively as PN25, PN50, PN75 and PN100 were programmed. The output for these programs are compiled in Appendix E for each of the subjects and phases.

7.6 DATA PRESENTATION AND AVERAGING

The individual data points for the N.S.M. computer output for a $(\frac{gas}{gas+sol})$ value of 0.50 were plotted from the data in Appendix E. The EMG data for relative muscle activity indicated approximately equal activity in the soleus and gastrocnemius muscles. The N.S.M. values were grouped in intervals of 2 to 4 degrees of equinus and the arithmetic means calculated. The compilation and averaging is tabulated in Appendix F. The graphical presentation is shown in Sec. 7.7.

The centre of foot pressures (C.F.P.) for the various stance modes are indicated planimetrically on the foot silouettes.

7.7 RESULTS

7.7.1 N.S.M. (Net Stabilizing Moment)

Subject Adult J.M.

The mean value of the N.S.M. in normal plantigrade stance was 143 kg. cm. With the adoption of equinus the value of the N.S.M. reached a maximum of 220 kg.cm. in the range of 8 to 10 degrees of equinus, and gradually declined in a linear fashion to 160 kg. cm. at 36 degrees of equinus (Fig. 7.8).

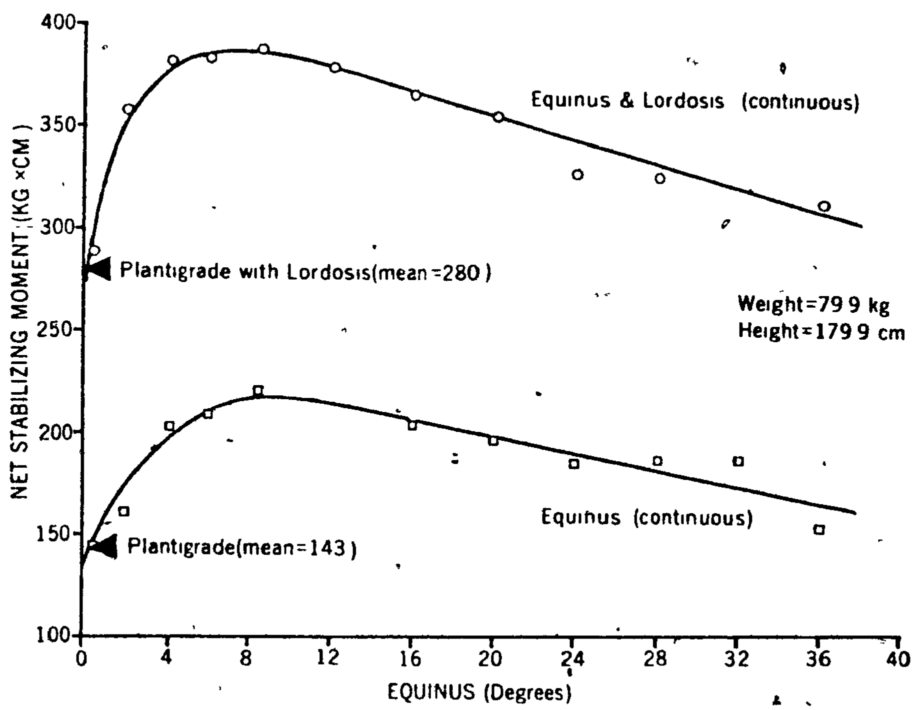


Fig. 7.8

Stabilizing moment at the knee joint of Subject Adult J.M. simulation of dystrophic posture (continuous)

Adoption of lordosis alone resulted in a mean N.S.M. of 280 kg. cm. The addition of equinus again resulted in a maximum N.S.M. at approximately 10 degrees of equinus of 380 kg. cm. Further increase in equinus resulted in a linear decrease in N.S.M. to a value of 320 kg. cm. at 36 degrees of equinus.

When these same phases of the experiment were carried out in step-wise adoption of equinus, almost identical mean values for the curves were produced (Fig. 7.9):

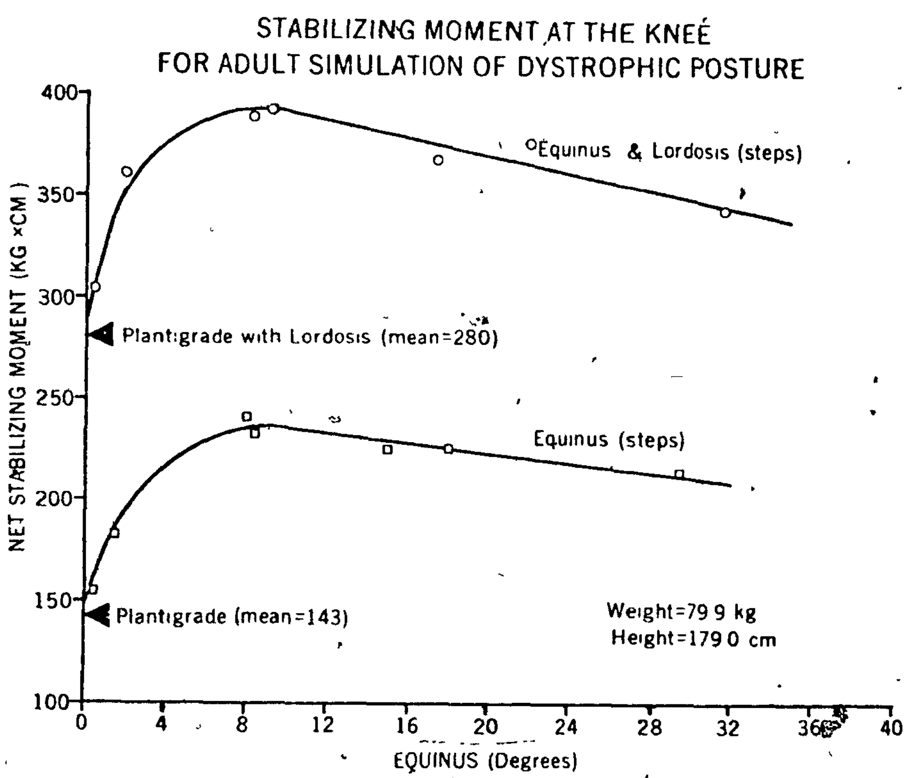


Fig. 7.9

Stabilizing moment at the knee joint of Subject Adult J.M. simulation of dystrophic posture (steps)

Subject N_3 - normal child

The results of the analysis of the experiments performed on this subject were very erratic and were attributed to a tendency to stand assymetrically. This involuntary shift of body weight to his left leg was probably an attempt to favour his right leg because of slight residual weakness resulting from recent fracture of that extremity from habit. The N.S.M. data was found to be inconsistent.

Subject N_4

The mean value of the N.S.M. in plantigrade stance was 41.6 kg. cm. With the adoption of equinus the value of the N.S.M. reached a maximum of 90 kg. cm. in the range of 8 to 10 degrees of equinus and gradually declined in a linear fashion to 82 kg. cm. at 40 degrees of equinus (Fig. 7.10).

Adoption of lordosis alone resulted in a mean N.S.M. of 106.9 kg. cm. The addition of equinus again resulted in a maximum N.S.M. at approximately 10 degrees of equinus of 158 kg. cm. Further increase on equinus resulted in a progressive decrease in N.S.M. to 124 kg. cm. at 40 degrees.

Subject MD1

The N.S.M. in plantigrade position for this child with his natural lordosis was found to be 24.0 kg. cm. Further increase in equinus resulted in a maximum N.S.M. of 30 to 35 kg. cm. at about 6 degrees of equinus (Fig. 7.11); further increase in equinus resulted in no improvement in the stabilizing moment. The limits of the range of the N.S.M. in various degrees of equinus were quite narrow relative to those for the normal subject of similar weight.

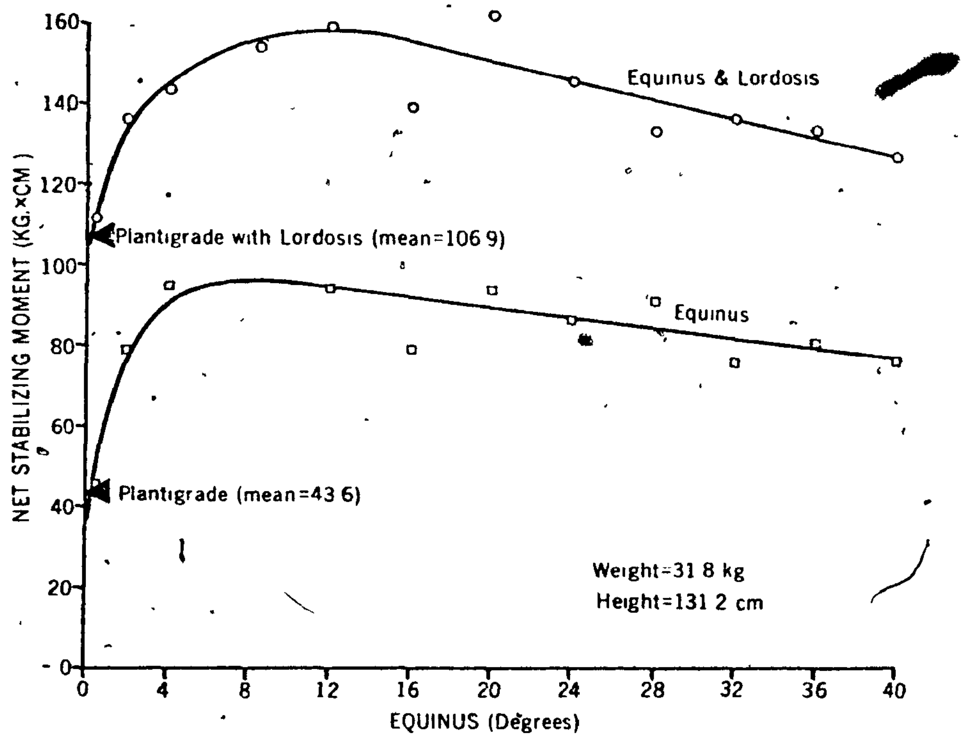


Fig. 7.10 Stabilizing moment at the knee joint for Subject Child N_4 simulation of dystrophic posture

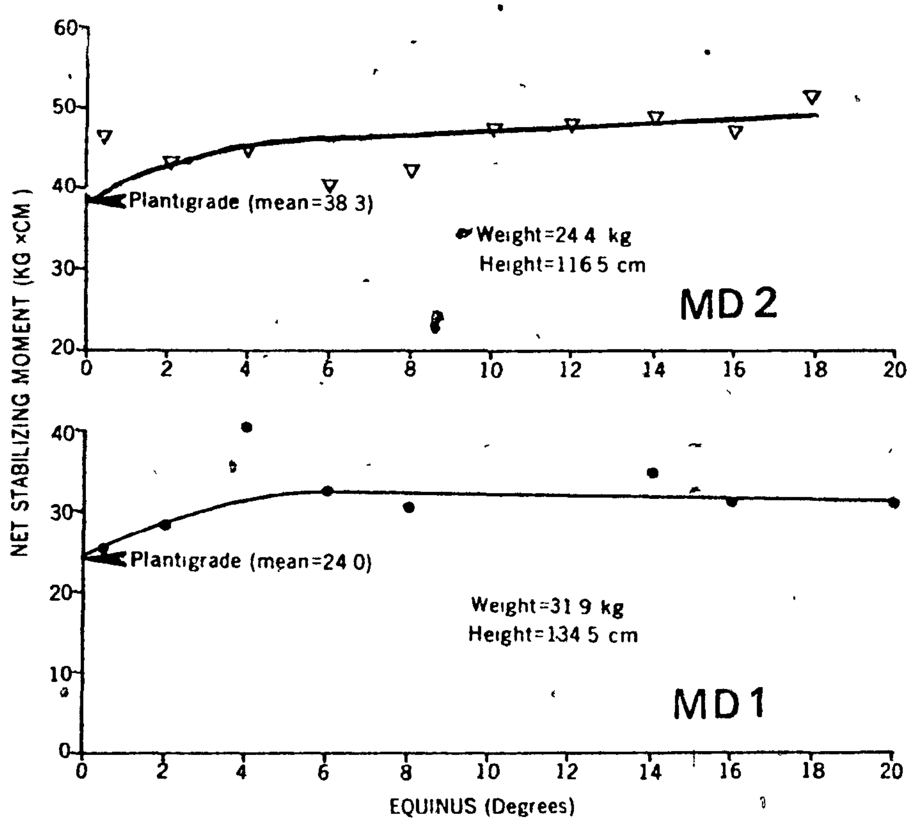


Fig. 7.11 Stabilizing moment at the knee joint for Subjects MD1 and MD2

Subject MD2

The younger of the two muscular dystrophy children had a mean N.S.M. of 38.3 kg. cm. in plantigrade position with natural lordosis (Fig. 7.11). The N.S.M. did not reach a distinct maximum over the range of zero to 18 degrees of equinus. A comparative plot of the results for subjects N_4, MD1 and MD2 is shown in Fig. 7.12.

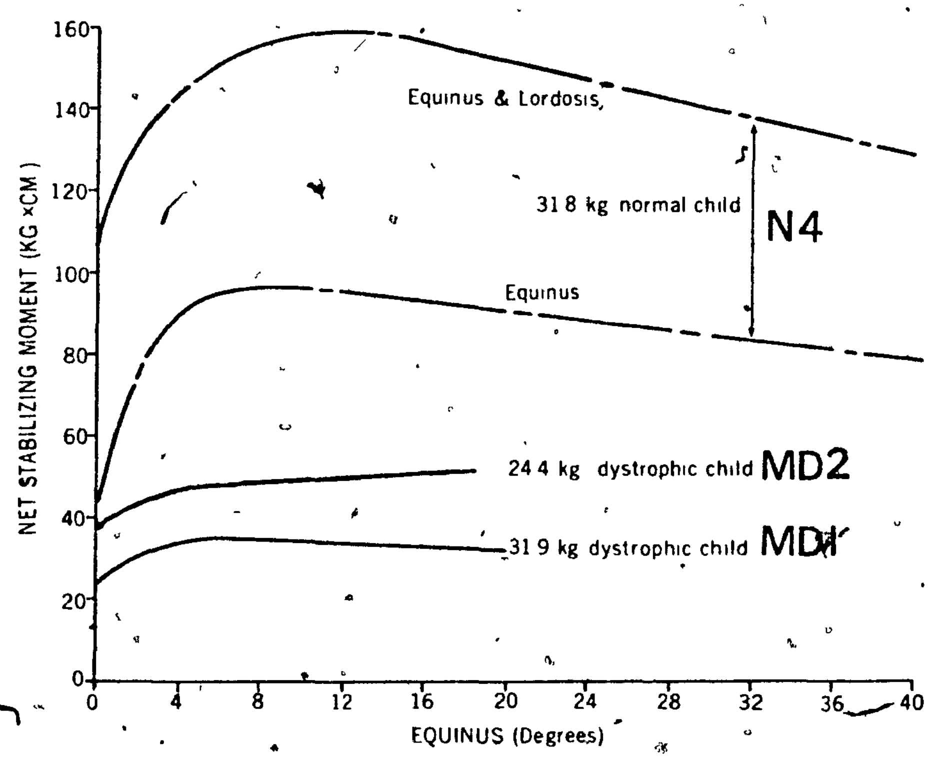


Fig. 7.12

Comparison of knee stabilizing effect of equinus in normal and dystrophic children

If the plantigrade with lordosis N.S.M. of subject N_4 is normalized for a body weight of 31.9 kg. cm. and compared to MD1 and MD2 normalized for the same weight and height, the comparative N.S.M.'s are illustrated in Fig. 7.13.

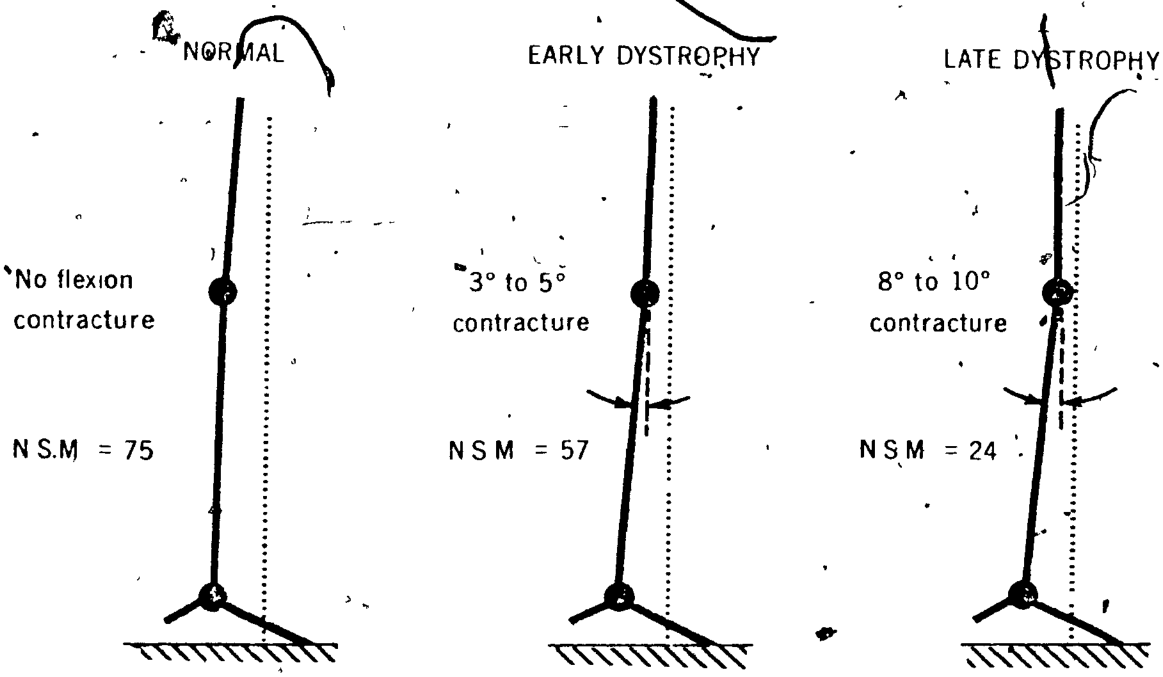


Fig. 7.13
Effect of knee flexion contracture on N.S.M. in plantigrade stance (normalized for body weight of 31.9 kg.)

Considering the lordotic posture of the early and late dystrophy patients and that in the subject N_4, lordosis accounted for an increase of N.S.M. of 63.6 kg. cm. Neither of the dystrophic subjects would have been able to stabilize the knee without this lordotic component.

7.7.2 Centre of Foot Pressure (C.F.P.)

The range of centre of foot pressures for the various stance modes of the normal subjects J.M. and N_4, and the dystrophic children MD1 and MD2 are indicated planimetrically in Fig. 7.14.

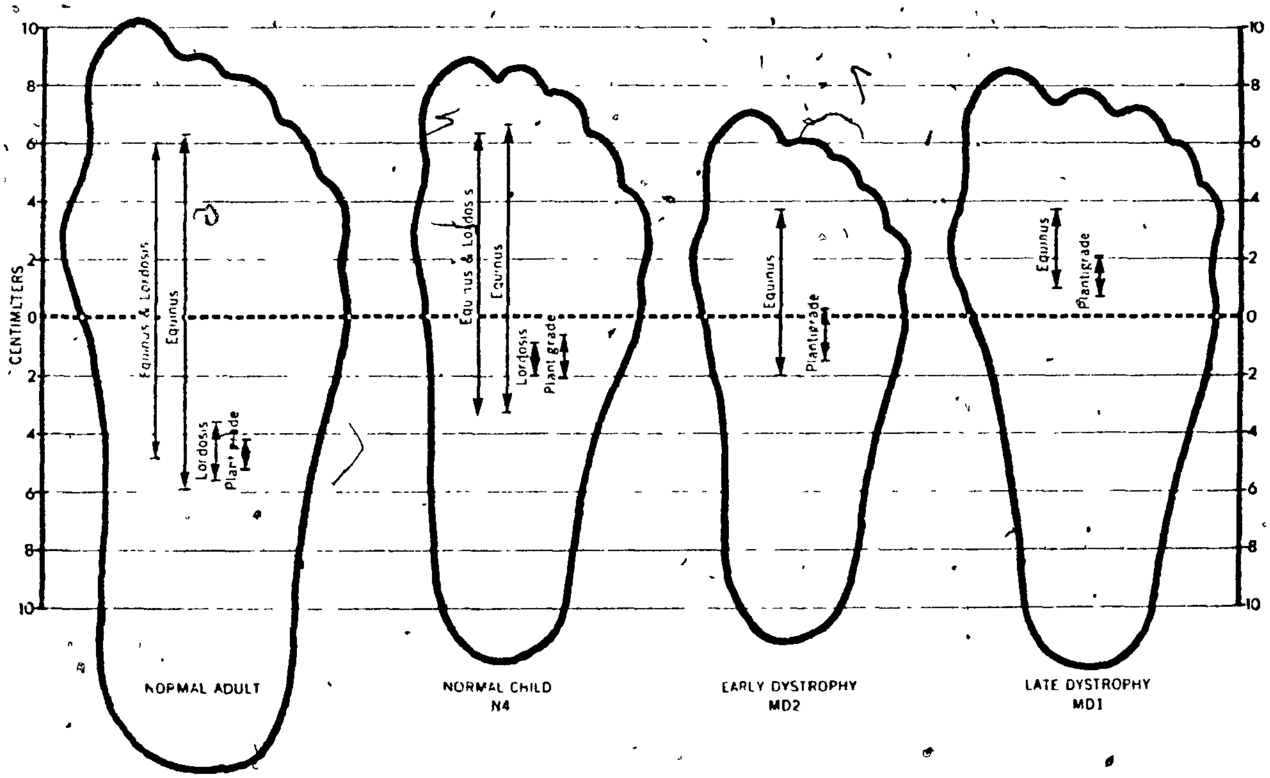


Fig. 7.14

Centre of foot pressure

7.7.3 Tendoachilles Tension

The mean tendoachilles tension in plantigrade stance is tabulated for each of the five subjects in Table 7.5.

Subject	Body wt. (kg.)	Mean achilles tendon tension	Achilles tendon tension as a % of body wt.	
J.M.	79.9	39.9	50.0	Mean Normal
N_3	44.3	21.2	49.5	62.3%
N_4	31.8	27.8	87.4	
MD1	31.9	30.9	96.9	Mean Dystrophic
MD2	24.4	21.0	85.9	91.4%

TABLE 7.5 Achilles Tendon Tension in Plantigrade Stance

The mean value for the three normal subjects was 62.3% of body weight and for the dystrophic children was 91.4% of body weight.

CHAPTER VIII

DISCUSSION, CONCLUSIONS AND RECOMMENDATIONS

8.1 DISCUSSION

The adult and child simulation experiments revealed an increase in N.S.M. of 96% for Subject Adult J.M. and 145% for Subject N_4 due to lordosis alone. A maximum increase in N.S.M. of 161% for Subject Adult J.M. and 260% for Subject N_4, due to the effect of both lordosis and equinus, occurred at approximately 8 to 10^o of equinus. The mean values for N.S.M. in plantigrade stance for the normals and dystrophic children when normalized for a body weight of 31.9 Kg revealed a decrease in N.S.M. as a function of the severity of the disease in spite of the lordotic posture. The fixed flexion deformities of the knees cause an anterior displacement of the knee joint axis negating the effect of the forward shift of the centre of gravity of the body to a greater degree as the deformity increases. Since the normalized effect of lordosis in subject N_4 accounted for an increase of the N.S.M. of 63.3 Kg cm, neither of the two dystrophic children would be able to stabilize their knees by the gravitational moment alone without adopting lordosis. Their net stabilizing moment would be (-63.3 + 57) = -6.3 Kg cm for subject M.D.2 and (-63.3 + 24.0)= -39.7 kg cm for subject M.D.1. The sudden loss of lordosis in muscular dystrophy patients who have been fitted with long leg braces is thereby explained.

The maximum N.S.M. of the knee through a range of equinus occurred at 8 to 10 degrees for the normal subjects and at about 4 degrees in the dystrophic children and then decreased in linear fashion. This can be attributed to two mechanisms. Firstly, adoption of further equinus results in an increase of the perpendicular distance from the line of action of achilles tendon to ankle axis A defined by the distance $L_2 \sin \beta$. Since the angle β increases approximately 0.5 degrees for each 1.0 degree increase in equinus the tension in the tendon achilles should in fact decrease with increase in equinus and the negative moment at the knee M_{gas} also decrease with equinus if the dorsiflexing moment remained constant. However, through the first few degrees of equinus there is a rapid shift of the ground reactive force toward the metatarsal heads increasing the dorsiflexing moment $F_z(X_A - X_F)$. Since the value $\sin \beta\ L_2$ does not increase as rapidly, the value of T must increase rapidly to maintain the balance of moments about ankle axis A. In doing so, the value $T(\frac{gas}{gas + sol})L_4$ causes a decrease in N.S.M. Although the moment arm $(X_A - X_F)$ initially increases on heel lift off, further equinus causes a progressive decrease in the moment arm. The net effect of this is to decrease tendoachilles tension and the flexing moment at the knee.

Secondly, if we consider the leg and reactive ground force and C of G location as shown in Fig. 8.1 in which A represents plantigrade stance, B slight equinus and C extreme equinus, it is evident from the coordinate data for all subject runs and demonstrated in the

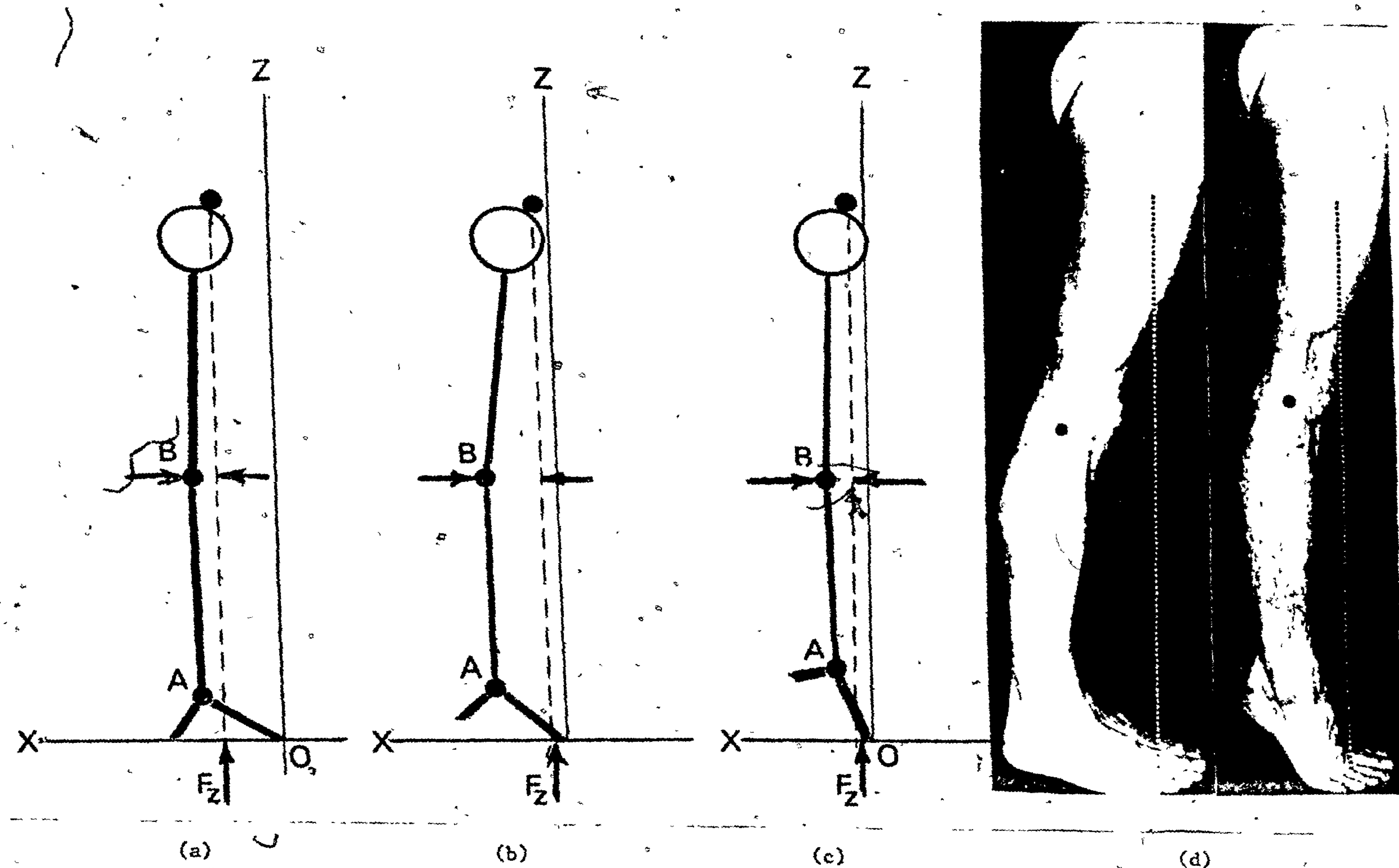


Fig. 8.1 Relationship of knee and ankle axis to line of gravity in (a) plantigrade stance (b) moderate equinus (c) extreme equinus (d) photographic composite.

diagrams that in the initial slight equinus that a marked shift of the CFP occurs forward. The moment arm ($X_B - X_{W_N}$) similarly increases rapidly. With further equinus both ankle axis A and knee axis B shift forward relative to the restricted stance base of the metatarsal heads resulting in gradual decrease in the moment arm ($X_B - X_{W_N}$) and in the M_{grav}. Thus, the combination of (a) early marked increase in ($X_B - X_{W_N}$) and (b) early increase in T, gives an early marked increase in N.S.M.

Further equinus causes (1) progressive decrease in ($X_B - X_{W_N}$) when maximal shift of F_z has occurred and (2) progressive decrease in T. The net result is a progressive net decrease in the N.S.M. after the maximum is reached at about 8 to 10 degrees of equinus.

Although both subject MD1 and MD2 both stood with contact along the plantar aspect of the foot, including the heel surface, it is evident that in plantigrade stance (Fig. 7.14) that their CFP was further advanced toward the metatarsal heads than for the normal subjects, indicating slight equinus. By shifting the comparative curves of Fig. 7.12 for MD; and MD2 by 4^o to the right, as shown in Fig. 8.2, a similar maximal point of N.S.M. at 8^o of equinus occurs and the curve configuration (Fig. 7.15), though having a lesser relative maximum, is more similar in pattern. The majority of the compensatory effect of early equinus for MD2 (and to a greater amount for MD1) is therefore not represented in the curves of Fig. 7.12. In other words, they were not standing in a normal plantigrade fashion, but had already shifted their CFP slightly forward toward the metatarsal heads, and utilized a portion of the compensatory effect of equinus.

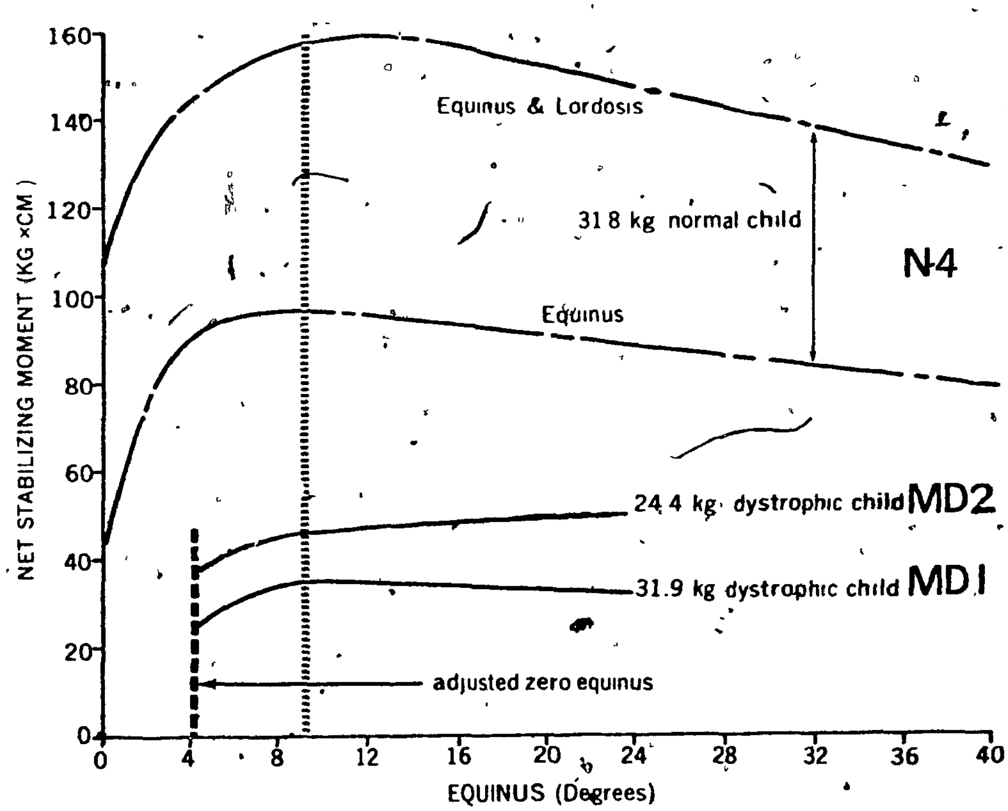


Fig. 8.2 Comparison of knee stabilizing effect of equinus in normal and dystrophic children.

8.2 CONCLUSIONS

Knee stability in normal subjects is greatly enhanced by adoption of equinus and lordosis. The knee stability in muscular dystrophic children is less than that of normal subjects, by virtue of the knee flexion contractures. Lordosis and equinus play a very significant role in maintenance of knee stability in upright stance in these dystrophic children. These studies explain on a mechanical basis the significant clinical observations of lordosis which disappear with knee bracing, requirement for knee bracing following heel cord lengthening, and an explanation for the calf muscle hypertrophy. Insight is added to their orthopaedic management.

8.3 RECOMMENDATIONS

(1) The approach used to study these patients entailed accurate determination of axis of rotation of joints and to do so involved laborious photographic analysis and correlation with many other variables. A more automated system of analysis, with integrated television and electronic scanning techniques for joint coordinates and on-line data processing, would make such analysis of musculoskeletal conditions of the lower extremities more feasible. Dynamic studies of gait would thus be more practical as a clinical tool.

(2) Development of techniques for in ~~vivo~~ human evaluation of force output of several muscle groups by EMG techniques should be developed for better quantitative evaluation of muscle activity.

(3) The methods employed in this study would be useful in studying other disease entities involving the lower extremity, where knee stability is a major determinant of the subjects ability to stand.

Derivation of the Force Plate Equations

The force plate variables defined in Chapter IV were obtained by algebraic manipulation of the load cell outputs. The relations defining these manipulations are derived in this appendix.

Referring to Fig. A.1 which shows the layout of the load cells in the force plate -

sum the forces in the X direction to get

$$F_x - F_4 + F_5 \cos 60 + F_6 \cos 60 = 0 \qquad \text{(A.1)}$$

rearranging and evaluating of constants gives

$$F_x = F_4 - 0.5\,(F_5 + F_6) \qquad \text{(A.2)}$$

Similarly summing forces in the Y direction gives

$$F_y - F_5 \sin 60 + F_6 \sin 60 = 0 \qquad \text{(A.3)}$$

and

$$F_y = 0.866\,(F_5 - F_6) \qquad \text{(A.4)}$$

The vertical force is simply

$$F_z = F_1 + F_2 + F_3 \qquad \text{(A.5)}$$

Now sum the moments about the X axis to get

$$M_x + L_1F_1 - L_2F_2 + L_1F_3 = 0 \qquad \text{(A.6)}$$

which gives

$$M_x = -20F_1 + 45.9F_2 - 20F_3 \qquad \text{(A.7)}$$

Similarly summing moments about the Y axis gives

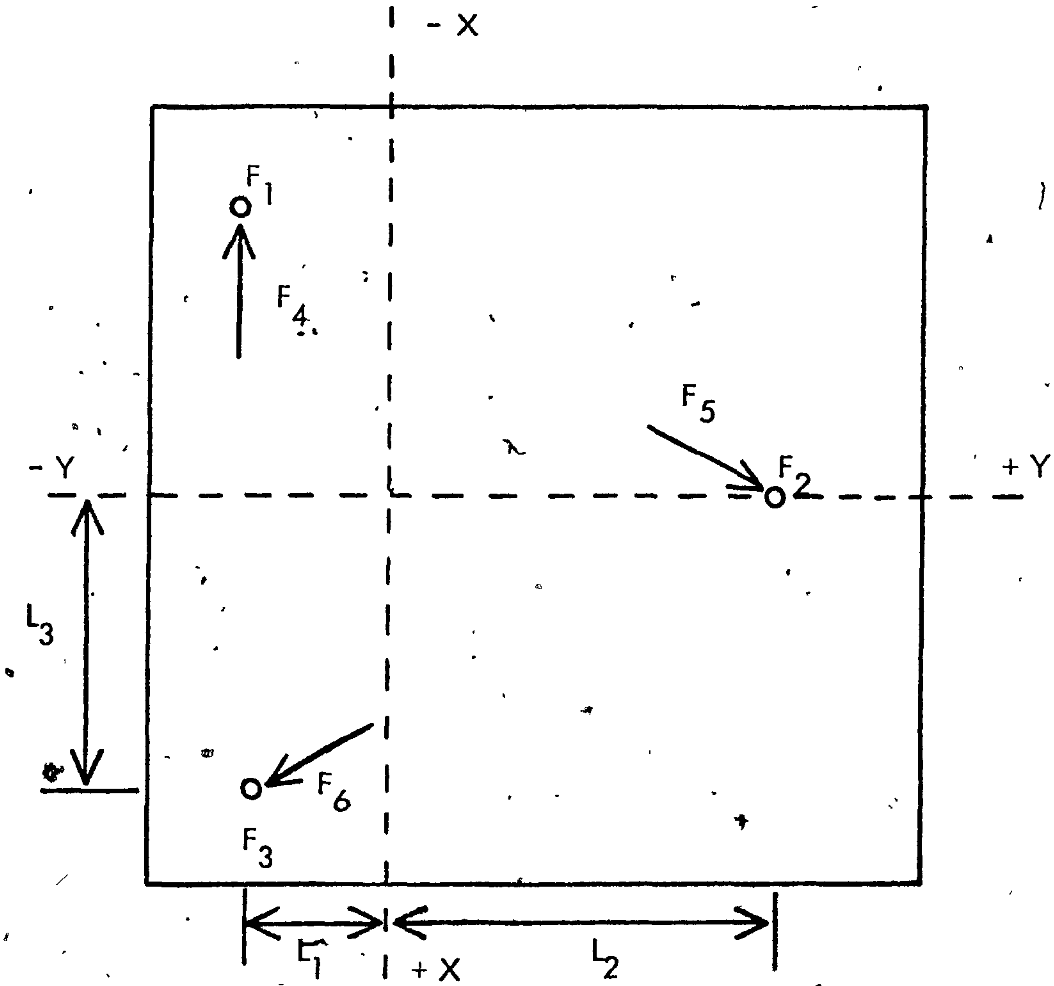
$$M_y - L_3F_3 + L_3F_1 = 0 \qquad \text{(A.8)}$$

and

$$M_y = 38.1\,(F_3 - F_1) \qquad \text{(A.9)}$$

sum moments about the vertical axis

$$M_z - L_1F_4 - L_2F_5 \cos 60 + L_1F_6 \sin 30 + L_3F_6 \cos 30 = 0 \qquad \text{(A.10)}$$



The three vertical load cells F_1, F_2, F_3 form the vertices of an equilateral triangle.

$L_1 = 20$ cm .; $L_2 = 45.9$ cm.; $L_3 = 38.1$ cm.;

Figure A.1 : Layout of the load cells on the force plate.

giving

$$M_z = 20F_4 + 22.95F_5 + 23F_6 \quad (A.11)$$

The position of the effective centre of pressure is defined by the relations

$$F_z X_p = M_y \quad (A.12)$$

or

$$X_p = \frac{M_y}{F_z} \quad (A.13)$$

Using Eq. (A.9) and (A.5), we get

$$X_p = \frac{38.1\,(F_3 - F_1)}{F_1 + F_2 + F_3} \quad (A.14)$$

Similarly,

$$F_z Y_p = M_x \quad (A.15)$$

and

$$Y_p = \frac{M_x}{F_z} \quad (A.16)$$

and using Eq. (A.7) and (A.5)

$$Y_p = \frac{-20F_1 + 45.9F_2 - 20F_3}{F_1 + F_2 + F_3} \quad (A.17)$$

summarizing

$$F_x = F_4 - 0.5\,(F_5 + F_6) \quad (A.18)$$

$$F_y = 0.866\,(F_6 - F_5) \quad (A.19)$$

$$F_z = F_1 + F_2 + F_3 \quad (A.20)$$

$$M_x = -20F_1 + 45.9F_2 - 20F_3 \quad (A.21)$$

$$M_y = 38.1\,(F_3 - F_1) \quad (A.22)$$

$$M_z = 20F_4 + 22.95F_5 + 23F_6 \quad (A.23)$$

$$X_p = \frac{38.1\,(F_3 - F_1)}{F_1 + F_2 + F_3} \quad (A.24)$$

$$Y_p = \frac{-20F_1 + 45.9F_2 - 20F_3}{F_1 + F_2 + F_3} \quad (A.25)$$

APPENDIX B

Derivation of Parallax Correction for Cinephotographic Data

Consider the relationship of the camera, grid and object shown in Fig. B.1.

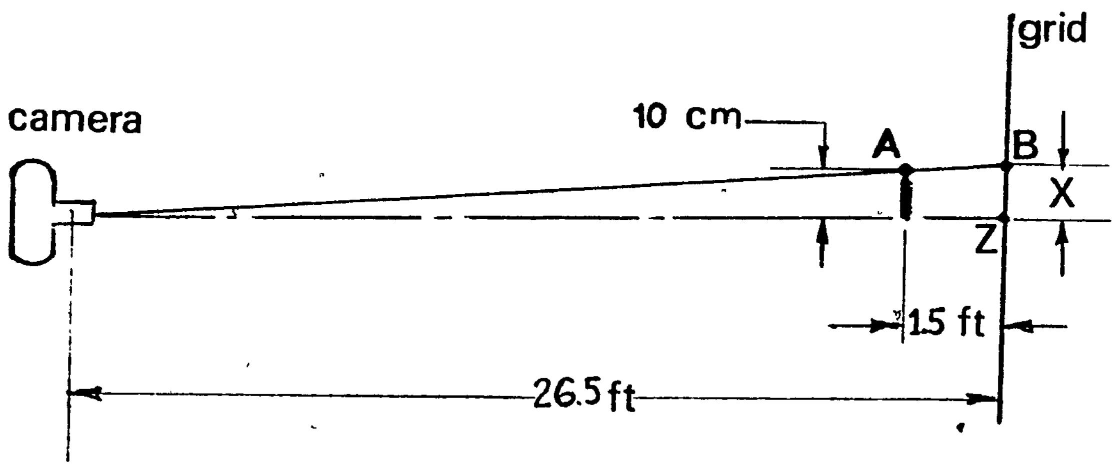


Figure B.1 Relationship of camera, object and grid

The camera was focused on the Z axis at a point 20 cm from the stance base or X-Y plane. Corrections for parallax had therefore to be applied to joint coordinates which did not coincide with the focal point. If we let X cm equal the magnified dimension of an object A located 10 cm from the focal point, then:

$$\frac{X}{26.5} = \frac{10 \text{ cm}}{25}$$

$$X = 10 \times \frac{26.5}{25} \quad 10.6 \text{ cm}$$

$$\text{Parallax} = 10.6 - 10 \quad 0.6 \text{ cm or } 6\%$$

A 6% correction was therefore applied to the coordinate data.

APPENDIX C

Results of Cadaveric Leg Dissection

Leg No.	Cross sectional Area. (cm^2)		Weight (gm)		Ratio ($\frac{gas}{gas+sol}$)	
	gastrocnemius	soleus	gastrocnemius	soleus	by area	by weight
1	17.1	19.0	140	168	0.47	0.46
2	20.3	18.5	179	185	0.52	0.46
3	17.0	16.1	128	158	0.51	0.45
4	19.9	18.0	153	170	0.47	0.52
				MEAN	0.49	0.47

The mean ($\frac{gas}{gas + sol}$) ratio by weight is 0.47 and by cross sectional area is 0.49.

APPENDIX D

COMPUTER PROGRAMS

```
FORTRAN IV G LEVEL 1, MOD 4          MAIN          DATE = 70176          08/40/41          PAGE 0001

      C      PROGRAM NO.1--EMG WITH ACTIVITY
             DO 6 I=1,12
             READ(5,10) A1,A2,A3,A4,A5,A6,A7,A8,A9,A10,A11,A12,A13,A14,A15,A16
          10 FORMAT(16A4)
             WRITE(6,20) A1,A2,A3,A4,A5,A6,A7,A8,A9,A10,A11,A12,A13,A14,A15,A16
          20 FORMAT('1',15X,'NAME=',4A4,'PHASE=',2A4,'STANCE=',2A4,'CONDITION='
            1,9A4)
             READ(5,30) NF,ALPHAO,BETAO,D2,D3,D4,F
          30 FORMAT(I10,6F10.1)
             WRITE(6,40)
          40 FORMAT('0',7X,2HNF,5X,6HALPHAO,5X,5HBETAO,7X,2HD2,8X,2HD3,8X,2HD4,
            29X,1HF)
             WRITE(6,50) NF,ALPHAO,BETAO,D2,D3,D4,F
          50 FORMAT(' ',1I10,6F10.1)
             N=0
           5 WRITE(6,70)
          70 FORMAT('0',3X,5HFRAME,6X,2HXF,5X,3HSOL,5X,3HGAS,6X,2HXA,6X,2HXB,
            36X,2HYA,3X,5HTHETA,2X,6HALDELT,3X,5HPNEMG,4X,4HPPOS,4X,4HPN25,
            44X,4HPN50,4X,4HPN75,3X,5HPN100)
           1 READ(5,60) IFRAM,XF,SOL,GAS,XA,XB,YA,YB,THETA
          60 FORMAT(I15,1F5.1,2F5.0,5F5.1)
             ALPHA=(ATAN2(YA,XA))*57.3
             ALDELT=ALPHA-ALPHAO
             ARG=(BETAO+(0.54*ALDELT))/57.3
             T=F*(XA-XF)/(2.0*D2*SIN(ARG))
             WN=0.470*F
             WS=0.755*F
             XWN=XF-(WS*(XA-0.567*(XA-XB)-XF))/WN
             PPOS=WN*(XB-XWN)
             PN100=PPOS-1.00*T*D4
             PN75=PPOS-0.75*T*D4
             PN50=PPOS-0.50*T*D4
             PN25=PPOS-0.25*T*D4
             IF(GAS) 4,2,3
           2 PNEMG=PPOS
             GO TO 8
           3 PNEMG=PPOS-(GAS/(GAS+SOL))*T*D4
           4 GO TO 8
           8 WRITE(6,80) IFRAM,XF,SOL,GAS,XA,XB,YA,THETA,ALDELT,PNEMG,PPOS,
            5PN25,PN50,PN75,PN100
          80 FORMAT(' ',1I8,1F8.1,2F8.0,11F8.1)
             N=N+1
             IF(NF-N) 6,6,1
           6 CONTINUE
             STOP
             END

TOTAL MEMORY REQUIREMENTS 0007D2 BYTES
```

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```
C       PROGRAM NO.2-EMG WITHOUT ACTIVITY
        DO 7 I=1,15
        READ(5,10) A1,A2,A3,A4,A5,A6,A7,A8,A9,A10,A11,A12,A13,A14,A15,A16
     10 FORMAT(16A4)
        WRITE(6,20) A1,A2,A3,A4,A5,A6,A7,A8,A9,A10,A11,A12,A13,A14,A15,A16
     20 FORMAT('1',15X,'NAME=',4A4,'PHASE=',2A4,'STANCE=',2A4,'CONDITION='
       1,8A4)
        READ(5,30) NF,ALPHAO,BETAO,D2,D3,D4,F
     30 FORMAT(I10,6F10.1)
        WRITE(6,40)
     40 FORMAT('0',7X,2HNF,5X,6HALPHAO,5X,5HBETAO,7X,2HD2,8X,2HD3,8X,2HD4,
       29X,1HF)
        WRITE(6,50) NF,ALPHAO,BETAO,D2,D3,D4,F
     50 FORMAT(' ',1I10,6F10.1)
        N=0
        SPPOS=0
        SPNEMG=0
        SPN100=0
        SPN75=0
        SPN50=0
        SPN25=0
        ST=0
        STHETA=0
      5 WRITE(6,70)
     70 FORMAT('0',3X,5HFRAME,6X,2HXF,5X,3HSOL,5X,3HGAS,6X,2HXA,6X,2HXB,
       36X,2HYA,3X,5HTHETA,2X,6HALDELT,3X,5HPNEMG,4X,4HPPOS,4X,4HPN25,
       44X,4HPN50,4X,4HPN75,3X,5HPN100)
      1 READ(5,60) IFRAM,XF,SOL,GAS,XA,XB,YA,YB,THETA
     60 FORMAT(I5,1F5.1,2F5.0,5F5.1)
        ALPHA=(ATAN2(YA,XA))*57.3
        ALDELT=ALPHA-ALPHAO
        ARG=(BETAO+(0.54*ALDELT))/57.3
        T=F*(XA-XF)/(2.0*D2*SIN(ARG))
        WN=0.470*F
        WS=0.050*F
        XWN=XF-(WS*(XA-0.567*(XA-XB)-XF))/WN
        PPOS=WN*(XB-XWN)
        PN100=PPOS-1.0*T*D4
        PN75=PPOS-0.75*T*D4
        PN50=PPOS-0.50*T*D4
        PN25=PPOS-0.25*T*D4
        IF(GAS) 4,2,3
      2 PNEMG=PPOS
        GO TO 8
      3 PNEMG=PPOS-(GAS/(GAS+SOL))*T*D4
      4 GO TO 8
      8 WRITE(6,80) IFRAM,XF,SOL,GAS,XA,XB,YA,THETA,ALDELT,PNEMG,PPOS,
       *PN25,PN50,PN75,PN100
     80 FORMAT(' ',1I8,1F9.1,2F8.0,11F8.1)
        N=N+1
        SPPOS=SPPOS+PPOS
        SPNEMG=SPNEMG+PNEMG
        SPN100=SPN100+PN100
        SPN75=SPN75+PN75
```

```
      SPN50=SPN50+PN50
      SPN25=SPN25+PN25
      ST=ST+T
      STHETA=STHETA+THETA
      IF(NE-N) 6,6,1
    6 FNE=NE
      PPOSM=SPPOS/FNE
      PNEMGM=SPNEMG/FNE
      PN100M=SPN100/FNE
      PN75M=SPN75/FNE
      PN50M=SPN50/FNE
      PN25M=SPN25/FNE
      TM=ST/FNE
      THETAM=STHETA/FNE
      WRITE(6,90) THETAM,PNEMGM,PPOSM,PN25M,PN50M,PN75M,PN100M
   90 FORMAT('0',51X,'MEAN=',1F8.1,1F16.1,5F8.1)
      WRITE(6,100) TM
  100 FORMAT('0',10X,'ACHILLES TENSION(MEAN)=',1F8.1)
    7 CONTINUE
      STOP
      END
```

TOTAL MEMORY REQUIREMENTS 0009E2 BYTES

```
FORTRAN IV G LEVEL 1, MOD 4              MAIN              DATE = 70176          12/00/28              PAGE 0001
      C       PROGRAM NO.3 NO ACTIVITY-NO END
              DO 7 I=1,4
              READ(5,10) A1,A2,A3,A4,A5,A6,A7,A8,A9,A10,A11,A12,A13,A14,A15,A16
           10 FORMAT(16A4)
              WRITE(6,20) A1,A2,A3,A4,A5,A6,A7,A8,A9,A10,A11,A12,A13,A14,A15,A16
           20 FORMAT('1',15X,'FRAME=',4A4,'PHASE=',2A4,'STANCE=',2A4,'CONDITION='
             18A4)
              READ(5,30) NF,ALPHAD,BETAD,D2,D3,D4,F
           30 FORMAT(I10,6F10.1)
              WRITE(6,40)
           40 FORMAT('0',7X,2HNF,5X,6HALPHAD,5X,5HBETAD,7X,2HD2,8X,2HD3,8X,2HD4,
             29X,1HF)
              WRITE(6,50) NF,ALPHAD,BETAD,D2,D3,D4,F
           50 FORMAT(' ',I10,6F10.1)
              N=0
              SPPOS=0
              SPN100=0
              SPN75=0
              SPN50=0
              SPN25=0
              ST=0
              STHETA=0
              WRITE(6,70)
           70 FORMAT('0',3X,5HFRAME,6X,2HXF,6X,2HXA,6X,2HXB,6X,2HYA,3X,5HTHETA,
             32X,6HALDELT,4X,4HPPOS,4X,4HPN25,4X,4HPN50,4X,4HPN25,3X,5HPN100)
            1 READ(5,60) IFRAM,XF,XA,XB,YA,YB,THETA
           60 FORMAT(I15,1F5.1,1F15.1,5F5.1)
              ALPHA=(ATAN2(YA,XA))*57.3
              ALDELT=ALPHA-ALPHAD
              ARG=(BETAD+(0.54*ALDELT))/57.3
              T=F*(XA-XF)/(2.0*D2*SIN(ARG))
              WN=0.470*F
              WS=0.750*F
              XWN=XF-(WS*(XA-0.567*(XA-XB)-XF))/WN
              PPOS=WN*(XB-XWN)
              PN100=PPOS-1.0*T*D4
              PN75=PPOS-0.75*T*D4
              PN50=PPOS-0.50*T*D4
              PN25=PPOS-0.25*T*D4
              WRITE(6,80) IFRAM,XF,XA,XB,YA,THETA,ALDELT,PPOS,PN25,PN50,PN75,
             4PN100
           80 FORMAT(' ',I19,11F8.1)
              N=N+1
              SPPOS=SPPOS+PPOS
              SPN100=SPN100+PN100
              SPN75=SPN75+PN75
              SPN50=SPN50+PN50
              SPN25=SPN25+PN25
              ST=ST+T
              STHETA=STHETA+THETA
              IF(NF-N) 6,6,1
            6 FNF=NF
              PPOSM=SPPOS/FNF
              PN100M=SPN100/FNF
```

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```
              PN75M=SPN75/FNF
              PN50M=SPN50/FNF
              PN25M=SPN25/FNF
              TM=ST/FNF
              THETAM=STHETA/FNF
              WRITE(6,90) THETAM,PPOSM,PN25M,PN50M,PN75M,PN100M
           90 FORMAT('0',35X,'MEAN=',1F8.1,1F16.1,4F8.1)
              WRITE(6,100) TM
          100 FORMAT('0',10X,'ACHILLES TENSION(MEAN)=',1F8.1)
            7 CONTINUE
              STOP
              END

 TOTAL MEMORY REQUIREMENTS C009E6 BYTES
```

```
C       PROGRAM NO.4     ACTIVITY - NO EMG
        DO 6 I=1,4
        READ(5,10) A1,A2,A3,A4,A5,A6,A7,A8,A9,A10,A11,A12,A13,A14,A15,A16
     10 FORMAT(16A4)
        WRITE(6,20) A1,A2,A3,A4,A5,A6,A7,A8,A9,A10,A11,A12,A13,A14,A15,A16
     20 FORMAT('1',15X,'NAME=',4A4,'PHASE=',2A4,'STANCE=',2A4,'CONDITION='
       1,2A4)
        READ(5,30) NF,ALPHAO,BETAO,D2,D3,D4,F
     30 FORMAT(I10,6F10.1)
        WRITE(6,40)
     40 FORMAT('0',7X,2HNF,5X,6HALPHAO,5X,5HBETAO,7X,2HD2,8X,2HD3,8X,2HD4,
       29X,1HF)
        WRITE(6,50) NF,ALPHAO,BETAO,D2,D3,D4,F
     50 FORMAT(' ',1I10,6F10.1)
        N=0
        WRITE(6,70)
     70 FORMAT('0',3X,5HFRAME,6X,2HXF,6X,2HXA,6X,2HXB,6X,2HYA,3X,5HTHETA,
       *32X,6HALDELT,4X,4HPPOS,4X,4HPN25,4X,4HPN50,4X,4HPN75,3X,5HPN100)
      1 READ(5,60) IFRAM,XF,XA,XB,YA,YB,THETA
     60 FORMAT(I15,1F5.1,1F15.1,5F5.1)
        ALPHA=(ATAN2(YA,XA))*57.3
        ALDELT=ALPHA-ALPHAO
        ARG=(BETAO+(0.54*ALDELT))/57.3
        T=F*(XA-XF)/(2.0*D2*SIN(ARG))
        WN=0.475*F
        WS=0.550*F
        XWN=XF-(WS*(XA-0.567*(XA-XB)-XF))/WN
        PPOS=WS*(XB-XWN)
        PN100=PPOS-1.0*T*D4
        PN75=PPOS-0.75*T*D4
        PN50=PPOS-0.50*T*D4
        PN25=PPOS-0.25*T*D4
        WRITE(6,80) IFRAM,XF,XA,XB,YA,THETA,ALDELT,PPOS,PN25,PN50,PN75,
       4PN100
     80 FORMAT(' ',1I9,11F8.1)
        N=N+1
        IF(NF-N) 6,6,1
      6 CONTINUE
        STOP
        END
```

TOTAL MEMORY REQUIREMENTS 000716 BYTES -

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NAME=ADULT(J.M.)   PHASE=ONE   STANCE=TWO   CONDITION=PLANTIGRADE-

NF	ALPHAO	BETAO	D2	D3	D4	E
15	35.0	56.0	6.7	44.0	2.2	79.0

FRAME	XF	SOL	GAS	XA	XB	YA	THETA	ALDEL	PNEMG	PPOS	PN25	PN50	PN75	PN100
1	6.0	1.	0.	11.6	10.5	6.9	63.5	-4.3	190.3	190.3	168.3	146.3	124.3	102.4
6	5.9	0.	0.	11.6	10.4	6.9	64.0	-4.3	190.5	190.5	168.1	145.7	123.4	101.0
11	5.5	0.	0.	11.6	10.5	6.8	63.0	-4.6	194.5	194.5	172.0	149.6	127.2	104.8
16	5.3	0.	0.	11.6	10.6	6.9	63.0	-4.3	198.4	198.4	176.1	153.7	131.3	108.9
21	5.5	0.	0.	11.6	10.7	6.9	63.0	-4.3	202.4	202.4	180.0	157.7	135.3	112.9
26	5.9	0.	0.	11.6	10.7	6.8	62.5	-4.6	202.4	202.4	180.0	157.6	135.1	112.7
31	5.9	0.	0.	11.7	10.6	6.8	63.0	-4.8	198.6	198.6	175.8	152.9	130.1	107.2
36	6.0	0.	0.	11.9	10.8	6.8	62.5	-4.8	202.4	202.4	180.0	157.5	135.0	112.6
41	6.0	1.	0.	11.6	10.5	6.8	62.0	-4.6	190.3	190.3	168.2	146.2	124.2	102.1
46	6.0	1.	0.	11.5	10.5	6.9	63.5	-4.0	190.1	190.1	168.5	147.0	125.4	103.8
51	6.0	1.	0.	11.4	10.4	6.8	64.5	-4.2	185.9	185.9	164.7	143.5	122.3	101.2
56	6.1	1.	0.	11.6	10.4	6.8	64.0	-4.6	182.1	182.1	160.5	138.8	117.2	95.6
61	6.2	1.	0.	11.5	10.4	6.8	64.0	-4.4	177.7	177.7	156.9	136.1	115.3	94.4
66	6.0	1.	0.	11.5	10.5	6.8	63.0	-4.4	190.1	190.1	168.5	146.9	125.3	103.6
71	6.1	1.	0.	11.5	10.4	6.8	63.5	-4.4	181.9	181.9	160.7	139.5	118.3	97.1
						MEAN=	63.3		191.8	191.8	169.9	147.9	126.0	104.0

ACHILLES TENSION(MEAN)= 39.9

NAME=ADULT(J.M.) PHASE=TWO / STANCE=TWO CONDITION=EQUINUS-CONTINUOUS

WE	ALPHA0	BETA0	D2	D3	D4	E
69	35.0	66.0	6.7	44.0	2.2	79.9

FRAME	XF	SOL	GAS	XA	XB	YA	THETA	ALDELT	PNEMC	PPOS	PN25	PN50	PN75	PN100
1	3.7	1.	0.	11.7	8.4	6.1	67.5	-7.5	205.4	205.4	172.9	140.5	108.1	75.6
6	3.4	1.	0.	11.6	7.8	6.6	69.0	-5.4	193.7	193.7	160.9	128.2	95.4	62.6
11	1.4	1.	0.	11.5	6.9	6.6	69.0	-5.1	233.4	233.4	193.9	154.3	114.8	75.3
16	1.4	1.	0.	11.5	6.5	6.6	69.0	-5.1	225.8	225.8	185.4	145.1	104.8	64.5
21	0.3	1.	0.	11.5	6.1	6.7	69.0	-4.9	260.4	260.4	215.4	170.4	125.4	80.4
26	-1.5	1.	0.	11.5	5.5	6.7	70.0	-4.8	308.1	308.1	256.3	204.6	152.8	101.0
31	-1.9	1.	0.	11.5	5.4	6.8	70.0	-4.4	316.8	316.8	263.9	211.1	158.2	105.4
36	-1.7	1.	1.	11.5	4.8	6.9	70.0	-4.0	183.9	288.4	236.1	183.8	131.4	79.1
41	-2.2	2.	1.	11.5	4.3	7.1	70.0	-3.3	210.0	281.0	227.7	174.4	121.2	67.9
46	-1.[illegible]	2.	1.	11.2	4.1	7.3	69.5	[illegible]	247.5	323.2	266.4	209.6	152.8	96.0
51	-1.9	2.	1.	11.3	4.2	7.7	66.5	-0.7	204.0	272.3	221.1	169.8	118.5	67.2
56	-2.[illegible]	2.	1.	11.2	3.8	8.2	65.0	1.2	229.8	302.5	248.0	193.5	138.9	84.4
61	-2.1	2.	1.	11.0	3.5	8.5	64.0	2.7	186.9	294.3	240.6	186.9	133.2	79.5
66	-2.6	2.	1.	10.9	3.3	8.9	62.5	3.9	136.8	264.9	213.8	162.8	111.7	69.6
71	-3.1	2.	1.	10.6	2.9	9.2	61.5	6.0	201.0	269.3	218.1	166.9	115.5	64.3
76	-3.1	2.	2.	10.5	3.2	9.5	59.5	7.1	190.0	281.2	230.6	180.0	129.4	78.8
81	-2.5	3.	2.	10.4	3.0	9.8	58.5	8.3	171.2	247.6	199.9	152.2	104.5	56.8
86	-3.4	3.	2.	10.0	2.5	10.3	56.0	10.5	186.4	264.7	215.7	166.8	117.8	68.9
91	-3.6	4.	2.	9.7	2.3	10.8	53.5	13.1	200.3	264.5	216.4	168.3	120.2	72.1
96	-4.0	3.	2.	9.3	2.5	11.5	50.5	16.0	212.6	288.6	241.1	193.6	146.1	98.6
101	-2.7	3.	2.	9.3	3.2	11.6	48.5	16.3	193.3	261.8	219.0	176.2	133.4	90.5
106	-3.5	3.	2.	9.1	2.8	11.9	47.5	17.6	171.0	236.9	195.7	154.5	113.3	72.2
111	-3.5	3.	2.	8.9	2.3	12.1	46.5	19.0	188.4	258.4	215.0	171.6	128.1	84.7
116	-3.2	3.	2.	8.6	2.2	12.3	45.5	20.0	174.9	241.3	199.8	159.3	116.8	75.3
121	-3.6	3.	3.	8.4	2.3	12.5	43.5	21.1	177.7	261.8	219.8	177.7	135.7	93.6
126	-3.6	3.	3.	8.0	2.3	12.9	42.0	23.2	190.3	261.0	220.7	180.3	140.0	99.6
131	-6.3	4.	4.	7.3	1.5	13.2	41.0	26.1	247.8	341.5	294.6	247.8	200.9	154.0
136	-5.[illegible]	3.	3.	7.6	1.5	12.6	42.0	23.9	210.8	299.7	255.2	210.8	166.4	122.0
141	-4.4	3.	3.	7.8	2.2	12.7	41.5	23.4	205.6	290.4	248.0	205.6	163.2	120.8
146	-3.6	3.	3.	7.6	1.8	12.9	40.0	24.5	162.5	240.1	201.3	162.5	123.7	84.9
151	-4.[illegible]	4.	3.	7.3	1.3	13.1	39.5	25.9	176.7	244.7	205.1	165.4	125.7	86.1
156	-5.2	3.	2.	7.2	1.0	13.3	39.5	26.6	206.4	274.7	232.0	189.4	146.7	104.0
161	-4.5	2.	2.	7.2	1.2	13.2	38.5	26.4	172.6	253.2	212.9	172.6	132.3	92.0
166	-5.[illegible]	3.	2.	6.6	0.7	13.7	37.0	29.7	194.6	253.0	213.4	173.7	134.1	94.5
171	-4.5	2.	1.	6.6	0.7	13.7	36.5	29.3	181.3	231.8	193.9	156.0	118.1	80.2
176	-3.9	2.	1.	6.7	0.7	13.6	37.0	28.8	158.3	206.7	170.4	134.2	97.9	61.7
181	-5.4	2.	1.	6.5	0.6	13.7	36.0	29.6	211.5	265.6	225.0	184.4	143.8	103.2
186	-3.7	2.	2.	7.0	1.1	13.5	37.0	27.6	141.5	214.9	178.2	141.5	104.8	68.1
191	-4.7	2.	1.	6.8	0.7	13.5	37.5	28.3	188.2	240.7	201.3	161.9	122.5	83.2
196	-4.1	1.	1.	6.8	0.8	13.6	37.5	28.4	144.7	219.4	182.0	144.7	107.4	70.1
201	-3.4	1.	1.	6.8	0.9	13.7	37.5	28.6	120.0	189.8	154.9	120.0	85.1	50.2
206	-4.7	1.	1.	6.5	0.8	13.9	36.0	29.5	167.7	244.1	205.9	167.7	129.6	91.4
211	-3.5	1.	1.	6.6	0.8	13.8	36.0	29.4	124.6	193.6	159.1	124.6	90.2	55.7
216	-4.[illegible]	1.	1.	6.4	0.7	13.9	35.5	30.3	146.5	218.7	182.6	146.5	110.4	74.3
221	-4.[illegible]	1.	1.	6.6	0.8	13.7	36.5	29.3	142.3	214.7	178.5	142.3	106.1	69.9
226	-4.[illegible]	1.	1.	6.8	1.0	13.5	37.5	28.3	156.3	231.6	194.0	156.3	118.6	80.9
231	-4.[illegible]	2.	2.	7.3	1.1	12.9	41.5	25.5	167.9	249.4	208.[illegible]	167.9	127.1	86.4
236	-3.4	2.	2.	7.9	2.3	12.4	41.5	22.5	173.6	252.4	213.0	173.6	134.2	94.8
241	-3.9	1.	1.	8.1	2.5	12.3	44.0	21.6	198.0	281.9	240.0	198.0	156.0	114.1
246	-3.5	2.	1.	8.5	2.8	12.0	46.0	19.7	221.6	277.9	235.7	193.4	151.1	108.9
251	-4.4	2.	2.	8.7	2.8	11.8	46.5	18.6	223.7	316.4	270.0	223.7	177.4	131.1
256	-3.9	2.	1.	9.2	3.2	11.1	50.0	15.4	249.8	312.3	265.4	218.5	171.6	124.6
261	-3.[illegible]	2.	1.	9.8	3.7	10.5	51.5	13.0	233.6	295.6	249.1	202.6	156.1	109.6
266	-2.[illegible]	1.	1.	9.7	3.8	10.4	54.0	12.0	249.1	350.2	299.7	249.1	198.6	14[illegible].1
271	-2.7	1.	1.	10.3	4.[illegible]	9.9	56.0	9.9	200.2	296.0	248.1	200.2	152.3	104.3
276	-2.9	2.	1.	10.4	4.2	9.5	57.5	7.4	284.2	355.0	301.[illegible]	[illegible]	[illegible]	14[illegible]
281	-3.2	2.	0.	10.8	4.7	9.8	59.5	7.2	346.4	346.4	294.3	242.3	190.2	138.2

[illegible]	-2.3	1.	1.	11.1	5.0	8.5	61.5	2.4	218.8	321.0	269.9	218.8 ✓	167.7	116.6
201	-3.0	1.	0.	11.2	5.2	8.3	63.0	1.5	358.8	358.8	304.4	250.0	195.6	141.1
[illegible]	-3.5	1.	0.	11.4	5.3	7.8	65.0	-0.6	342.1	342.1	288.2	234.2	180.3	126.3
[illegible]	-2.0	1.	0.	11.5	5.5	7.5	65.5	-1.0	329.3	329.3	276.4	223.6	170.8	118.0
[illegible]	-1.9	1.	0.	11.7	5.7	7.2	67.5	-3.4	329.3	329.3	276.0	222.7	169.4	116.1
[illegible]	-1.2	1.	1.	11.7	6.3	6.0	68.5	-4.5	275.5	328.0	276.7	225.5	174.2	122.9
[illegible]	-0.7	0.	0.	11.9	7.3	6.6	67.5	-6.0	376.4	376.4	277.9	229.2	180.6	132.1
[illegible]	2.4	1.	0.	11.9	8.7	6.5	67.0	-6.4	264.4	264.4	226.9	189.5	152.1	114.6
[illegible]	5.7	0.	0.	12.1	9.7	6.3	66.5	-7.5	195.1	195.1	167.1	139.1	111.1	83.1
[illegible]	5.5	0.	0.	11.8	10.3	6.5	64.0	-6.1	189.0	189.0	165.3	141.6	117.9	94.2
[illegible]	5.5	0.	0.	12.0	10.7	6.5	65.5	-6.[illegible]	205.5	205.5	180.9	156.4	131.8	107.2

NAME=ADULT(J.M.)   PHASE=THREE   STANCE=TWO   CONDITION=EQUINUS IN STEPS

NO	ALPHAO	BETAO	D2	D3	D4	F
44	35.0	55.0	6.7	44.0	2.2	79.9

FRAME	XF	SOL	CAS	XA	XB	YA	THETA	ALDELT	PNEMG	PPOS	PN25	PN50	PN75	PN100
1	5.5	0.	0.	11.9	10.5	6.3	65.0	-7.1	214.2	214.2	188.3	162.4	135.5	110.6
6	5.5	0.	0.	11.9	10.5	6.4	65.0	-6.7	214.2	214.2	188.4	162.5	136.7	110.9
11	5.5	0.	0.	11.9	10.5	6.5	65.0	-5.7	214.2	214.2	188.4	162.7	136.9	111.2
16	5.5	0.	0.	11.9	10.5	6.4	64.5	-6.7	214.2	214.2	188.4	162.5	136.7	110.9
21	5.5	0.	0.	12.0	10.5	6.5	65.0	-6.6	214.4	214.4	188.2	162.0	135.8	109.6
26	5.5	0.	0.	11.9	10.6	6.5	65.0	-6.4	218.2	218.2	192.5	166.7	140.9	115.2
31	5.5	0.	0.	12.0	10.6	6.4	64.0	-6.9	218.4	218.4	192.2	165.9	139.6	113.4
36	5.5	0.	0.	12.0	10.5	6.4	64.5	-6.9	214.4	214.4	188.1	161.9	135.6	109.3
41	5.5	0.	0.	12.0	10.2	6.5	65.5	-6.6	202.3	202.3	176.1	149.9	123.7	97.5
46	5.6	1.	0.	12.0	9.8	6.4	65.5	-6.9	182.0	182.0	156.2	130.3	104.4	78.6
51	5.0	1.	0.	12.1	8.9	6.6	65.5	-6.4	171.4	171.4	142.8	114.2	85.6	57.0
56	3.6	1.	0.	11.8	8.0	6.5	67.5	-6.1	236.0	236.0	199.0	162.0	125.1	88.1
61	3.2	1.	0.	11.8	7.8	6.6	67.5	-5.8	329.4	329.4	282.9	236.4	189.9	143.3
66	1.7	1.	0.	11.9	8.2	6.5	66.5	-5.4	282.3	282.3	241.2	200.2	159.1	118.1
71	2.8	1.	0.	11.8	7.7	6.6	67.5	-5.8	215.5	215.5	179.4	143.3	107.2	71.1
76	2.0	1.	0.	11.9	7.3	6.6	67.5	-6.0	233.4	233.4	193.7	153.9	114.2	74.4
81	0.0	1.	1.	11.7	6.4	6.7	67.5	-5.2	197.9	281.3	234.6	187.9	141.1	94.4
86	-1.0	1.	1.	11.6	5.7	6.8	67.5	-4.6	195.0	295.2	245.1	195.0	144.8	94.7
91	-1.7	2.	1.	11.4	5.0	7.4	66.5	-2.0	227.9	[illegible]	245.0	193.7	142.4	91.1
96	-2.9	2.	1.	10.3	4.9	7.8	65.0	2.1	273.5	340.7	290.3	239.9	189.4	139.0
101	-3.3	2.	1.	11.1	4.5	8.1	64.0	1.1	258.2	330.5	276.3	222.1	168.0	113.8
106	-3.8	1.	0.	11.1	4.6	8.0	64.0	0.8	368.3	368.3	311.0	253.6	196.2	139.9
111	-3.6	1.	0.	11.2	4.1	8.1	64.0	0.9	339.9	339.9	283.0	226.1	169.1	112.2
116	-3.4	2.	1.	11.1	3.9	8.0	64.5	0.8	248.8	323.2	267.4	211.6	155.8	100.0
121	-4.2	2.	1.	11.2	4.3	8.0	64.5	0.5	294.2	373.4	314.0	254.6	195.3	135.9
126	-3.3	2.	1.	11.1	3.0	8.6	63.0	2.8	245.9	319.0	264.2	209.4	154.6	99.8
131	-3.6	3.	2.	10.5	3.6	9.3	58.5	6.5	234.2	318.4	[illegible]	213.2	160.6	108.0
136	-4.2	4.	3.	10.0	2.9	10.5	55.0	11.4	225.9	314.6	262.8	211.1	159.4	107.6
141	-4.4	3.	2.	10.0	2.9	10.4	55.0	11.1	235.0	319.0	266.5	213.9	161.4	108.9
146	-4.6	3.	2.	10.1	2.8	10.3	55.5	10.6	241.6	327.7	273.9	220.1	166.4	112.6
151	-4.9	2.	2.	10.2	3.1	10.2	55.5	10.0	238.4	348.4	293.4	238.4	183.4	128.3
156	-4.3	2.	1.	10.1	3.2	10.2	55.5	10.3	257.0	326.0	274.5	222.1	169.7	117.3
161	-4.6	2.	1.	9.7	2.6	10.3	55.0	11.7	249.4	318.8	266.8	214.7	162.7	110.7
166	-4.5	2.	1.	10.0	3.9	10.4	55.0	11.1	297.0	367.5	314.6	261.7	208.8	155.9
171	-4.5	3.	2.	8.5	1.6	12.2	47.0	20.1	198.8	271.9	226.2	180.5	134.8	89.1
176	-5.5	5.	3.	7.5	1.2	13.3	43.0	25.6	228.7	296.0	251.2	206.3	161.4	116.5
181	-5.9	5.	2.	7.4	1.6	13.3	40.0	25.9	276.4	328.8	283.0	237.1	191.2	145.4
186	-6.3	5.	3.	8.1	2.5	12.8	42.0	22.7	297.0	370.7	321.6	272.4	223.3	174.2
191	-6.0	3.	3.	8.1	2.4	12.6	42.0	22.2	197.7	282.1	239.9	197.7	155.5	113.3
196	-4.7	3.	2.	8.1	2.4	12.4	42.0	21.9	240.2	311.7	267.0	222.3	177.5	132.8
201	-4.4	3.	2.	8.1	2.1	12.6	42.5	22.2	217.2	287.0	243.4	199.7	156.1	112.5
206	-3.5	3.	2.	9.1	2.4	12.6	42.5	22.2	199.9	265.2	224.4	183.6	142.8	101.9
211	-4.5	3.	2.	8.3	2.5	12.4	43.5	21.2	236.0	307.7	262.9	218.0	173.2	128.4
216	-4.5	3.	2.	8.9	2.8	11.7	47.5	17.7	244.9	321.0	273.5	225.9	178.4	130.8
221	-4.1	2.	1.	[illegible]	3.3	10.0	56.0	[illegible]	[illegible]	326.7	274.5	222.4	170.2	118.0
226	-3.6	2.	1.	10.4	3.7	9.6	57.5	7.7	253.0	322.2	270.3	218.4	166.5	114.5
231	-4.3	2.	1.	10.4	3.4	9.7	57.5	8.0	256.0	327.1	273.7	220.4	167.1	113.8
236	-3.3	2.	1.	10.3	3.5	9.7	56.5	9.3	241.7	309.7	258.7	207.7	156.6	105.6
241	-4.0	2.	1.	10.6	3.9	9.5	58.5	6.9	275.1	347.6	293.2	238.8	184.5	130.1
246	-3.9	2.	1.	10.6	4.2	9.3	58.5	6.2	279.5	351.2	297.4	243.6	189.8	136.0
251	-2.9	1.	1.	11.2	4.9	8.7	61.0	2.8	235.2	342.5	288.9	235.2	181.6	127.9
256	-2.3	1.	1.	11.5	5.5	8.0	63.5	-0.2	252.3	363.1	307.7	252.3	197.0	141.6
261	-2.1	1.	1.	10.5	5.3	7.9	63.5	2.0	227.0	323.4	275.2	227.0	178.9	130.7
266	-2.0	1.	1.	11.3	4.0	8.1	65.6	0.6	202.2	304.7	253.5	202.2	151.0	99.7
271	-2.3	1.	1.	11.3	5.3	8.2	63.0	1.8	229.0	333.5	281.2	229.0	176.6	124.3
276	-2.1	1.	0.	11.3	5.0	8.7	62.5	1.0	262.3	363.3	307.9	252.5	197.1	141.9
281	-2.4	2.	1.	11.3	5.6	8.2	62.5	1.0	297.0	358.2	304.8	251.3	197.9	144.4

115.

[illegible]	-2.8	2.	1.	11.5	6.5	7.7	64.0	-1.2	317.9	300.6	336.1	291.6	227.0	172.5
[illegible]	-3.3	[illegible]	0.	11.9	8.0	6.6	67.0	-6.0	485.5	485.6	424.5	353.5	302.5	241.5
304	-3.0	0.	0.	12.7	9.7	6.6	64.0	-6.0	537.7	537.7	476.6	415.6	354.6	293.6
301	0.0	0.	0.	12.1	10.5	6.4	65.0	-7.1	447.1	447.1	398.1	349.2	300.2	251.2
[illegible]	5.9	0.	0.	12.1	10.5	6.4	65.0	-7.1	201.9	201.9	176.4	150.9	125.5	100.0
311	5.5	0.	0.	12.1	10.5	6.4	66.0	-7.1	214.6	214.6	187.9	161.2	134.5	107.8
314	5.5	0.	0.	12.2	10.5	6.4	65.0	-7.3	214.8	214.8	187.7	160.5	133.4	106.2

NAME=ADULT(J.M.) PHASE=FCUP STANCE=TWO CONDITION=LORDOSIS

NF.	ALPHAO	BETAO	D2	D3	D4	F
28	35.0	58.0	6.7	44.0	2.2	79.0

FRAME	XF	SOL	GAS	XA	XB	YA	THETA	ALDELT	PNEMG	PPOS	PN25	PN50	PN75	PN100
1	5.4	0.	0.	11.5	11.1	6.3	64.0	-6.3	239.0	239.0	214.8	190.5	166.2	142.0
6	5.5	0.	0.	11.5	11.0	6.4	64.0	-5.9	230.9	230.9	207.1	183.2	159.4	135.6
11	5.5	0.	0.	11.5	10.7	6.5	64.0	-5.5	218.9	218.9	195.2	171.4	147.7	123.9
16	5.5	0.	0.	11.4	10.7	6.4	64.0	-5.7	218.7	218.7	195.3	172.0	148.6	125.2
21	5.5	0.	0.	11.6	11.2	6.5	64.0	-5.7	239.0	239.0	214.8	190.7	166.5	142.3
26	5.6	1.	1.	11.5	11.4	6.5	63.5	-5.5	195.9	242.6	219.2	195.9	172.5	149.2
31	5.9	1.	1.	11.5	11.5	6.5	63.5	-5.5	213.4	263.3	238.3	213.4	188.5	163.5
36	4.7	1.	1.	11.5	12.1	6.5	62.5	-5.5	271.2	328.9	300.0	271.2	242.3	213.4
41	5.0	1.	1.	11.7	13.0	6.5	62.0	-5.9	278.5	331.7	305.1	278.5	251.9	225.3
46	4.5	1.	1.	11.6	13.2	6.5	62.0	-5.7	304.1	360.4	332.2	304.1	275.9	247.8
51	5.3	1.	1.	11.6	13.6	6.4	60.5	-6.1	292.8	342.8	317.8	292.8	267.7	242.7
56	5.9	1.	1.	11.6	13.6	6.4	61.0	-6.1	275.8	321.9	298.9	275.8	252.8	229.8
61	5.3	1.	1.	11.6	13.6	6.4	61.0	-6.1	292.8	342.8	317.8	292.8	267.7	242.7
66	3.6	1.	1.	11.6	13.3	6.5	62.0	-5.7	338.5	401.9	370.2	338.5	306.8	275.1
71	3.7	1.	1.	11.7	13.4	6.5	60.5	-5.9	338.4	401.9	370.2	338.4	306.7	274.9
76	5.2	1.	1.	11.7	13.6	6.5	61.0	-5.9	295.6	347.2	321.4	295.6	269.8	244.0
81	4.7	1.	1.	11.6	13.2	6.5	62.0	-5.7	297.3	352.0	324.6	297.3	270.0	242.6
86	4.2	1.	1.	11.6	13.3	6.5	61.5	-5.7	318.2	376.9	347.5	318.2	288.9	259.6
91	4.7	1.	1.	11.6	13.3	6.5	61.5	-5.7	301.3	356.0	328.6	301.3	273.9	245.6
96	4.0	1.	1.	11.6	13.4	6.5	61.5	-5.7	329.0	389.2	359.1	329.0	298.8	268.7
101	4.1	1.	1.	11.6	13.2	6.5	61.5	-5.7	317.6	377.1	347.3	317.6	287.9	258.2
106	4.1	1.	1.	11.9	13.4	6.5	62.0	-6.1	324.2	385.4	354.8	324.2	293.6	263.0
111	3.8	1.	1.	11.7	13.2	6.5	61.5	-5.9	327.1	389.8	358.5	327.1	295.7	264.4
116	3.9	1.	1.	11.7	13.2	6.5	61.5	-5.9	323.7	385.6	354.7	323.7	292.8	261.8
121	3.9	1.	1.	11.7	13.3	6.5	61.5	-5.9	327.7	389.6	358.6	327.7	296.7	265.8
126	4.1	1.	1.	11.6	13.2	6.5	61.0	-5.7	317.6	377.1	347.3	317.6	287.9	258.2
131	3.7	1.	1.	11.6	13.4	6.5	61.0	-5.7	339.1	401.7	370.4	339.1	307.8	276.5
136	4.2	1.	1.	11.6	13.5	6.5	61.0	-5.7	326.2	384.8	355.5	326.2	296.8	267.5
						MEAN=	62.0		289.0	335.6	308.1	280.5	252.9	225.4

ACHILLES TENSION(MEAN)= 50.1

NAME=ADULT(J.M.) PHASE=FIVE STANCE=TWO CONDITION=LORDOSIS AND EQUINUS-CONTINUOUS

NF	ALPHA0	BETA0	D2	D3	D4	F
57	35.0	66.0	6.7	44.0	2.2	79.9

FRAME	XF	SOL	GAS	XA	XB	YA	THETA	ALDELT	PNEMG	PPOS	PN25	PN50	PN75	PN100
1	5.8	0.	0.	11.7	10.8	6.3	65.0	-6.7	213.2	213.2	189.4	165.6	141.8	118.0
6	5.8	0.	0.	11.6	10.8	6.3	64.5	-6.9	213.0	213.0	190.5	166.1	142.7	119.3
11	5.8	0.	0.	11.7	10.7	6.3	64.5	-6.7	209.1	209.1	185.3	161.5	137.7	113.9
16	5.9	0.	0.	11.8	11.1	6.3	64.5	-6.9	225.4	225.4	201.2	177.0	152.7	128.5
21	5.8	0.	0.	11.6	11.1	6.3	63.5	-6.6	225.0	225.0	201.7	178.3	154.9	131.6
26	5.9	0.	0.	11.7	11.6	6.3	63.0	-6.7	245.4	245.4	221.6	197.7	173.9	150.1
31	5.6	0.	0.	11.7	11.9	6.3	62.5	-6.7	261.9	261.9	237.2	212.6	188.0	163.4
36	5.5	0.	0.	11.7	12.2	6.3	63.0	-6.7	277.9	277.9	253.3	228.7	204.1	179.5
41	5.5	0.	0.	11.8	13.5	6.3	61.0	-6.9	338.7	338.7	313.2	287.8	262.3	236.9
46	5.4	0.	0.	11.7	14.2	6.3	61.0	-6.7	366.8	366.8	341.4	316.0	290.6	265.2
51	6.0	0.	0.	11.8	14.3	6.4	60.0	-6.5	345.7	345.7	322.3	299.0	275.6	252.2
56	6.0	0.	0.	11.8	14.3	6.3	60.5	-6.9	345.7	345.7	322.3	298.9	275.4	252.0
61	5.8	0.	0.	11.8	13.8	6.4	61.0	-6.5	334.1	334.1	309.9	285.7	261.5	237.3
66	4.6	1.	1.	11.7	13.0	6.4	61.5	-6.3	295.2	352.4	323.8	295.2	266.7	238.1
71	3.3	1.	1.	11.8	12.5	6.3	62.5	-6.9	318.8	387.4	353.1	318.8	284.4	250.1
76	1.2	1.	1.	11.7	11.2	6.4	63.0	-6.3	339.2	423.7	381.4	339.2	296.9	254.7
81	0.5	1.	0.	11.7	10.7	6.4	64.0	-6.3	433.2	433.2	388.1	343.0	298.0	252.9
86	-0.3	2.	1.	11.7	10.4	6.5	63.5	-5.9	390.7	454.9	406.7	358.6	310.4	262.2
91	-0.6	2.	1.	11.7	9.8	6.7	64.0	-5.2	377.9	443.5	394.3	345.2	296.1	246.9
96	-2.5	1.	1.	11.6	9.0	6.8	64.0	-4.6	379.2	491.4	435.3	379.2	323.1	266.9
101	-3.5	2.	1.	11.4	8.6	7.3	63.5	-2.4	439.2	517.1	458.7	400.2	341.8	283.3
106	-3.6	2.	1.	11.2	8.2	7.9	60.5	0.2	428.7	504.9	447.7	390.5	333.4	276.2
111	-4.6	1.	0.	11.0	7.8	9.0	60.0	1.0	530.6	530.6	470.7	410.7	350.7	290.8
116	-3.5	1.	1.	11.0	7.8	9.0	60.5	1.0	372.7	484.1	428.4	372.7	316.9	261.2
121	-4.0	2.	1.	10.8	7.5	8.3	60.0	2.5	417.6	492.8	436.4	380.0	323.6	267.2
126	-4.4	3.	1.	10.8	7.5	8.8	57.5	4.7	433.2	509.7	452.3	394.9	337.5	280.1
131	-4.2	3.	1.	10.7	7.3	9.0	57.0	5.1	433.0	489.0	433.0	377.0	320.9	264.9
136	-5.0	3.	2.	10.5	7.3	9.3	55.5	6.5	433.9	526.4	468.6	410.8	352.9	295.1
141	-3.2	3.	1.	10.4	7.5	9.7	54.0	8.0	407.8	458.2	407.8	357.4	307.1	256.7
146	-4.7	3.	1.	9.9	6.5	10.2	52.5	10.9	427.0	480.3	427.0	373.7	320.3	267.0
151	-5.0	3.	1.	9.3	5.7	11.1	49.5	15.0	408.3	459.6	408.3	357.0	305.7	254.5
156	-6.0	3.	1.	8.6	5.0	11.8	45.5	18.9	420.7	472.3	420.7	369.2	317.6	266.0
161	-5.7	3.	1.	8.4	4.9	12.2	43.5	20.5	401.6	451.2	401.6	352.1	302.6	253.1
166	-5.3	4.	3.	8.2	5.3	12.4	41.5	21.5	373.0	454.0	406.7	359.5	312.3	265.0
171	-3.1	5.	3.	7.0	5.3	12.7	38.0	23.1	302.9	360.4	322.1	283.8	245.5	207.3
176	-6.0	5.	4.	6.9	4.5	13.4	35.5	27.8	370.1	448.7	404.5	360.2	316.0	271.7
181	-4.8	3.	2.	6.7	3.9	13.4	34.0	28.4	310.5	373.4	334.1	294.7	255.3	216.0
186	-6.5	3.	2.	6.0	3.5	13.8	33.0	31.5	359.0	427.8	385.3	342.9	300.5	258.0
191	-6.8	2.	1.	6.0	3.5	14.0	35.0	31.8	382.6	440.5	397.0	353.6	310.2	266.8
196	-4.9	3.	2.	7.1	3.3	13.3	38.0	26.0	264.7	350.1	309.2	268.3	227.4	186.5
201	-6.8	2.	1.	6.8	3.2	13.4	39.5	28.1	367.9	430.0	383.4	336.8	290.2	243.6
206	-4.6	1.	1.	8.4	4.6	12.2	43.5	[illegible]	315.3	396.6	351.0	305.3	259.7	214.0
211	-5.0	1.	1.	8.0	4.7	11.4	48.0	[illegible]	310.7	418.6	369.1	319.7	270.2	220.8
216	-4.7	2.	1.	9.8	6.0	11.4	51.0	11.7	389.7	460.0	407.2	354.5	301.7	249.0
221	-3.4	2.	1.	10.5	7.4	9.3	53.5	6.5	393.7	462.8	411.0	359.1	307.2	255.4
226	-2.6	1.	1.	11.0	8.1	8.7	57.0	3.3	355.0	458.2	406.6	355.0	303.4	251.8
231	-3.2	1.	1.	11.3	9.2	7.9	60.0	-0.5	376.0	488.2	432.1	376.0	319.9	263.8
236	-2.5	1.	0.	11.4	8.5	7.5	62.0	-1.7	470.9	470.9	416.6	362.3	308.0	253.7
241	-2.0	1.	0.	11.6	8.6	7.0	64.0	-3.9	454.2	454.2	400.5	346.4	292.6	238.7
246	-1.3	1.	1.	11.7	9.5	6.8	64.0	-4.8	353.9	456.7	405.3	353.9	302.5	251.1
251	-0.6	1.	0.	11.6	10.3	6.7	61.0	-5.0	463.4	463.4	414.7	366.0	317.4	268.7
256	2.7	[illegible]	[illegible]	11.7	10.9	6.5	63.0	-5.9	432.8	432.8	388.6	344.4	300.3	256.1
261	3.5	[illegible]	[illegible]	11.9	11.4	6.5	63.0	-6.1	393.9	393.9	354.9	315.9	276.9	237.9
266	5.6	[illegible]	0.	11.0	12.1	6.4	62.5	-5.7	274.3	274.3	248.9	223.5	198.1	172.6
271	5.8	[illegible]	[illegible]	11.9	12.3	6.3	62.5	-6.9	273.7	273.7	249.5	225.2	201.0	176.8
276	5.8	0.	0.	11.8	12.0	6.4	63.0	-6.5	261.6	261.6	237.5	[illegible]	[illegible]	164.9
281	5.9	0.	0.	11.8	11.7	6.4	62.5	-6.5	249.6	249.6	225.4	201.2	177.0	152.9

NAME=ADULT(J.M.)   PHASE=SIX   STANCE=TWO   CONDITION=LORDOSIS AND EQUINUS-STEPS

NF	ALPHAO	BETAO	D2	D3	D4	F
57	35.0	58.0	6.7	44.0	2.2	79.0

FRAME	XF	SOL	GAS	XA	XB	YA	THETA	ALDELT	PNEMG	PPOS	PN25	PN50	PN75	PN100
1	4.1	0.	0.	11.7	10.5	5.5	64.5	-5.9	269.9	269.9	239.7	209.6	179.4	149.2
6	4.3	0.	0.	12.0	10.4	6.5	64.5	-6.6	258.2	258.2	227.5	196.8	166.1	135.4
11	4.6	0.	0.	11.9	10.7	6.4	64.5	-6.7	257.3	257.3	228.2	199.1	170.0	140.8
16	4.5	0.	0.	12.2	11.9	6.4	64.5	-7.5	310.1	310.1	278.8	247.5	216.2	184.9
21	3.5	0.	0.	11.9	11.8	6.6	62.0	-6.0	347.1	347.1	313.7	280.4	247.0	213.7
26	3.4	1.	0.	11.9	12.5	6.5	62.5	-6.4	379.1	379.1	345.3	311.4	277.6	243.8
31	3.7	2.	1.	11.9	13.1	6.5	61.5	-6.4	393.4	432.2	395.6	359.0	322.4	285.8
36	3.7	1.	1.	11.9	12.6	6.6	62.5	-6.0	339.3	412.3	375.8	339.3	302.7	266.2
41	4.4	0.	0.	12.0	12.9	6.6	61.5	-5.2	353.4	353.4	323.2	293.0	262.8	232.6
46	4.9	2.	1.	11.9	12.7	6.6	62.0	-6.0	291.0	328.5	300.3	272.2	244.0	215.8
51	3.6	1.	0.	11.8	13.3	6.6	63.0	-5.8	446.2	446.2	405.7	365.1	324.8	284.4
56	3.3	1.	1.	11.8	12.7	6.6	63.5	-5.8	333.6	391.0	357.3	323.6	289.9	256.2
61	3.0	0.	0.	11.8	12.3	6.5	63.5	-6.1	391.8	391.8	356.5	321.1	285.7	250.3
66	1.5	1.	1.	11.7	11.0	6.6	63.0	-5.6	317.7	394.4	358.0	317.7	277.3	236.9
71	-3.4	1.	1.	11.6	10.3	6.8	63.0	-4.6	457.1	575.2	516.1	457.1	398.1	339.1
76	-1.1	0.	0.	11.8	10.7	6.7	64.0	-5.4	495.4	495.4	444.3	393.3	342.3	291.3
81	1.4	1.	1.	11.7	10.6	6.7	63.5	-5.2	305.3	396.7	346.0	305.3	264.7	224.0
86	-0.3	2.	1.	11.7	9.8	7.0	64.0	-4.1	363.2	425.9	378.9	331.8	284.8	237.7
91	-2.7	2.	1.	11.1	8.4	9.2	59.5	1.5	399.6	469.3	417.0	364.7	312.4	260.0
96	-4.1	2.	1.	10.8	9.2	8.5	57.5	3.7	444.7	519.3	463.3	407.4	351.4	295.5
101	-4.3	2.	1.	10.9	7.8	8.4	58.5	2.6	471.9	507.7	450.9	394.0	337.1	280.2
106	-5.3	1.	0.	10.8	7.5	8.4	58.5	2.0	509.0	529.0	469.6	410.2	350.8	291.3
111	-5.3	3.	1.	10.9	7.5	8.6	60.0	3.3	449.7	529.2	469.6	409.9	350.2	290.6
116	-3.5	3.	1.	10.9	7.7	8.5	59.0	3.0	424.2	478.7	424.2	369.7	315.1	260.6
121	-5.1	3.	1.	10.5	7.2	9.2	54.5	6.2	463.1	520.7	463.1	405.4	347.8	290.1
126	-4.7	3.	2.	9.5	6.4	10.8	44.5	13.7	399.1	470.1	419.5	368.9	318.2	267.5
131	-5.2	2.	1.	9.4	5.8	11.0	48.0	14.5	397.8	467.0	415.1	363.2	311.3	259.4
136	-5.9	3.	1.	9.2	5.4	11.1	48.0	15.4	426.4	479.9	426.4	373.0	319.5	266.0
141	-5.9	2.	1.	9.4	5.7	11.0	48.0	14.5	419.7	492.2	437.9	383.5	329.1	274.7
146	-5.4	2.	1.	9.6	6.3	10.5	49.0	12.6	423.9	495.6	441.9	388.1	334.3	280.6
151	-4.4	3.	1.	9.6	6.7	10.6	49.0	12.8	419.6	469.7	419.6	369.5	319.4	269.3
156	-5.1	3.	3.	9.5	6.5	11.0	47.5	14.2	386.9	490.8	438.9	386.9	334.9	283.0
161	-6.3	5.	3.	7.5	4.7	13.2	36.5	25.4	393.7	452.8	406.1	360.6	314.5	268.4
166	-5.7	3.	3.	7.0	4.4	13.3	34.5	27.2	323.6	406.4	365.0	323.6	282.1	240.7
171	-5.4	2.	1.	7.3	4.8	13.1	36.0	25.9	373.6	431.3	388.0	344.7	301.4	258.1
176	-5.2	2.	1.	7.5	5.0	12.9	37.5	24.8	373.4	431.3	387.9	344.4	301.0	257.5
181	-5.9	3.	2.	7.5	5.2	12.8	37.5	24.6	301.5	464.3	418.8	373.3	327.8	282.2
186	-5.2	3.	1.	7.6	5.0	12.9	38.0	24.3	387.7	431.5	387.7	343.8	299.9	256.1
191	-5.9	2.	1.	7.6	4.7	12.9	39.0	24.3	397.2	448.8	402.6	356.3	310.0	263.8
196	-6.0	3.	1.	8.0	4.9	12.4	42.0	22.2	397.4	461.9	413.5	365.1	316.8	268.5
201	-3.9	3.	1.	10.1	7.3	10.0	50.0	9.7	308.3	465.6	415.1	364.6	314.1	263.6
206	-4.2	2.	1.	10.2	7.2	10.1	51.0	9.7	412.8	482.5	430.2	377.9	325.6	273.3
211	-4.5	2.	1.	9.9	6.6	10.3	51.0	11.1	401.3	470.5	418.6	366.6	314.7	262.8
216	-4.6	1.	0.	9.8	6.3	10.3	51.0	11.4	462.6	462.6	410.7	358.8	307.0	255.1
221	-4.9	1.	1.	9.8	6.3	10.3	51.0	11.4	370.2	475.1	422.2	369.2	316.2	263.3
226	-4.6	1.	0.	10.0	6.7	10.0	52.0	10.0	478.9	478.9	426.0	373.0	320.1	267.1
231	-3.1	1.	1.	11.0	8.0	8.5	58.0	2.7	363.8	469.9	416.8	363.8	310.7	257.6
236	-3.2	1.	1.	11.1	8.3	8.3	58.5	1.8	379.0	486.2	432.1	379.0	323.9	269.8
241	-3.3	1.	0.	11.1	8.3	8.3	59.0	1.8	478.5	478.5	424.0	369.5	315.0	260.5
246	-3.0	1.	1.	10.9	7.6	8.5	59.0	3.0	376.0	487.3	431.6	376.0	320.3	264.7
251	-3.0	1.	1.	11.0	7.9	8.4	58.5	2.4	383.6	495.2	439.4	383.6	327.7	271.9
256	-3.8	1.	1.	11.0	9.4	9.4	59.0	2.4	403.4	515.1	459.3	403.4	347.6	291.8
261	-3.3	1.	1.	11.3	9.5	8.3	58.5	0.2	447.6	563.6	505.6	447.6	389.6	331.6
266	1.7	1.	1.	11.0	11.2	6.6	63.5	-6.0	324.2	406.8	365.5	324.2	283.0	241.6
271	2.8	2.	1.	12.0	12.1	6.6	62.0	-6.2	330.7	398.5	351.0	315.3	278.7	242.2
276	1.7	0.	0.	11.0	12.3	6.6	63.5	-6.0	442.2	442.2	401.7	[illegible]	[illegible]	358.2
281	2.6	1.	1.	11.9	12.8	6.4	61.5	-6.7	350.2	424.5	387.3	350.2	313.1	276.0

NAME=CHILD(M.D.1)   PHASE=TWO   STANCE=TWO   CONDITION=PLANTIGRADE

NF	ALPHAO	BETAO	D2	D3	D4	F
83	32.0	60.0	4.8	35.0	1.5	31.9

FRAME	XF	XA	XB	YA	THETA	ALDECT	PPOS	PN25	PN50	PN75	PN100
1	-0.8	7.9	1.5	6.1	67.0	6.0	43.0	31.9	19.9	7.9	-4.1
11	-0.9	7.5	1.5	6.1	66.5	6.8	45.8	33.7	21.8	10.0	-1.8
21	-1.0	7.5	1.4	6.0	66.0	6.3	45.6	33.6	21.6	9.6	-2.4
31	-0.9	7.5	1.4	6.0	66.5	6.3	42.2	30.5	18.8	7.1	-4.6
41	-0.4	7.5	1.5	6.0	66.5	6.7	37.0	25.0	15.0	4.0	-7.0
51	-0.7	7.6	1.6	6.0	67.0	6.3	43.7	32.1	20.6	9.0	-2.6
61	-0.9	7.6	1.8	6.0	67.0	6.3	45.4	33.7	22.0	10.3	-1.4
71	-0.6	7.6	1.7	6.0	66.5	6.3	43.6	32.2	20.9	9.3	-2.1
81	-0.5	7.6	1.7	6.0	67.0	6.3	41.9	30.6	19.4	8.1	-3.2
91	-0.6	7.7	1.7	6.0	67.0	5.9	43.7	32.1	20.5	8.9	-2.6
101	-0.6	7.7	1.6	6.0	67.0	5.9	42.1	30.5	18.9	7.3	-4.3
111	-0.8	7.6	1.5	6.0	66.0	6.3	43.9	32.1	20.4	8.7	-3.0
121	-0.7	7.6	1.5	6.0	67.0	6.3	42.1	30.5	19.0	7.4	-4.2
131	-0.7	7.6	1.5	6.0	67.5	6.3	42.1	30.5	19.0	7.4	-4.2
141	-0.7	7.7	1.5	6.0	67.5	5.9	42.2	30.5	18.7	7.0	-4.7
151	-0.6	7.7	1.5	6.0	67.5	5.9	40.5	28.9	17.3	5.7	-5.9
161	0.1	7.6	1.7	6.0	67.0	6.3	31.8	21.4	10.9	0.5	-10.0
171	-0.6	7.7	1.5	6.0	67.0	5.9	40.5	28.9	17.3	5.7	-5.9
181	-0.9	7.7	1.5	6.0	67.5	5.9	45.6	33.5	21.5	9.5	-2.5
191	-0.9	7.6	1.4	6.0	67.0	6.3	43.9	32.0	20.2	8.3	-3.5
201	-1.1	7.5	1.4	6.0	67.0	6.7	47.2	35.0	23.2	11.3	-0.7
211	-0.8	7.7	1.5	6.0	67.5	5.9	43.9	32.0	20.1	8.3	-3.6
221	-0.6	7.5	1.4	6.0	67.5	6.7	38.7	27.5	16.2	4.9	-6.4
231	-0.5	7.9	1.3	6.0	67.0	5.6	42.1	30.5	18.9	7.3	-4.3
241	-0.6	7.7	1.6	6.0	67.5	5.9	42.1	30.5	18.9	7.3	-4.3
251	-0.7	7.5	1.4	6.0	67.0	6.7	40.4	29.0	17.6	6.2	-5.2
261	-0.6	7.7	1.5	6.0	66.5	5.9	40.5	28.9	17.3	5.7	-5.9
271	-0.9	7.6	1.5	6.0	67.5	6.3	43.8	32.1	20.4	8.7	-3.0
281	-1.0	7.6	1.5	6.0	67.0	6.3	47.2	35.2	23.2	11.2	-0.8
291	-0.7	7.6	1.6	6.0	67.0	6.3	43.7	32.1	20.6	9.0	-2.6
301	-0.1	7.7	1.7	6.0	67.0	5.9	35.3	24.4	13.5	2.6	-8.3
311	-0.2	7.6	1.7	6.0	66.5	6.3	36.0	25.0	15.1	4.3	-6.6
321	-0.6	7.6	1.6	6.0	67.0	6.3	42.0	30.6	19.2	7.7	-3.7
331	-0.5	7.6	1.5	6.0	66.5	6.3	38.7	27.6	16.1	4.9	-6.4
341	-0.5	7.6	1.4	6.0	66.5	6.3	37.1	25.8	14.5	3.2	-8.0
351	-0.6	7.6	1.4	6.0	67.5	6.3	38.8	27.4	15.9	4.5	-6.9
361	-0.6	7.6	1.2	6.0	67.5	6.3	40.7	28.8	17.0	5.1	-6.7
371	-0.9	7.6	1.3	6.0	67.0	6.3	42.3	30.4	18.6	6.7	-5.1
381	-0.9	7.9	1.4	6.0	67.5	5.6	44.0	31.9	19.7	7.5	-4.6
391	-0.9	7.8	1.5	6.0	67.0	5.6	45.6	33.5	21.3	9.1	-3.0
401	-0.2	7.7	1.5	6.0	66.5	5.9	37.1	25.8	14.5	3.2	-8.1
411	-0.4	7.6	1.6	6.0	66.5	6.3	38.6	27.5	16.3	5.2	-6.0
421	-1.0	7.6	1.4	6.0	67.5	6.3	45.6	33.6	21.6	9.6	-2.4
431	-1.2	7.6	1.2	6.0	66.5	6.3	45.7	33.5	21.2	8.9	-3.3
441	-0.8	7.5	1.5	6.0	67.5	6.7	43.7	32.2	20.6	9.1	-2.5
451	-0.6	7.6	1.5	6.0	66.0	6.3	40.4	29.0	17.6	6.1	-5.3
461	-0.6	7.6	1.5	6.0	66.5	6.3	40.4	29.0	17.6	6.1	-5.3
471	-1.0	7.6	1.3	6.0	67.0	6.3	43.9	32.0	20.0	8.0	-4.0
481	-0.6	7.6	1.5	6.0	67.0	6.3	40.4	29.0	17.6	6.1	-5.3
491	-0.6	7.6	1.5	6.0	67.0	6.3	40.4	29.0	17.6	6.1	-5.3
501	-0.6	7.7	1.5	6.0	68.0	5.9	40.5	28.9	17.3	5.7	-5.9
511	-0.4	7.6	1.7	6.0	66.5	6.3	40.2	29.1	17.9	6.8	-6.4
521	-0.7	7.7	2.0	5.9	67.5	5.5	50.2	38.5	25.7	14.9	3.2
531	-0.9	7.7	1.7	5.8	69.5	5.0	47.1	35.2	23.2	11.3	-0.6
541	-0.5	7.6	1.5	5.9	67.0	5.8	33.7	27.4	16.1	4.8	-6.5
551	-0.8	7.5	1.4	5.8	68.0	5.4	42.7	30.6	18.7	6.9	-6.0
561	-0.9	7.6	1.2	5.9	68.0	5.8	40.7	29.8	16.9	5.0	-6.8

NAME=CHIPD(M.O.1) PHASE=TWO STANCE=TWO CONDITION=PLANTIGRADE

NF	ALPHAO	BETAO	D2	D3	D4	F
83	32.0	60.0	4.8	35.0	1.5	31.0

FRAME	XF	XA	XB	YA	THETA	ALPELT	PPCS	PN25	PN50	PN75	PN100
1	-0.8	7.8	1.5	6.1	67.0	6.0	43.9	31.9	19.9	7.9	-4.1
11	-0.9	7.5	1.5	6.1	66.5	6.8	45.5	33.7	21.8	10.0	-1.8
21	-1.0	7.6	1.4	6.0	66.0	6.3	45.6	33.6	21.6	9.6	-2.4
31	-0.8	7.6	1.4	6.0	66.5	6.3	42.2	30.5	18.8	7.1	-4.6
41	-0.4	7.5	1.5	6.0	66.5	6.7	37.0	26.0	15.0	4.0	-7.0
51	-0.7	7.6	1.6	6.0	67.0	6.3	42.7	32.1	20.6	9.0	-2.6
61	-0.8	7.6	1.6	6.0	67.0	6.3	45.4	33.7	22.0	10.3	-1.4
71	-0.6	7.6	1.7	6.0	66.5	6.3	43.6	32.2	20.8	9.3	-2.1
81	-0.5	7.6	1.7	6.0	67.0	6.3	41.9	30.6	19.4	8.1	-3.2
91	-0.6	7.7	1.7	6.0	67.0	5.9	43.7	32.1	20.5	8.9	-2.6
101	-0.6	7.7	1.6	6.0	67.0	5.9	42.1	30.5	18.9	7.3	-4.3
111	-0.8	7.6	1.5	6.0	66.0	6.3	43.8	32.1	20.4	8.7	-3.0
121	-0.7	7.6	1.5	6.0	67.0	6.3	42.1	30.5	19.0	7.4	-4.2
131	-0.7	7.6	1.5	6.0	67.5	6.3	42.1	30.5	19.0	7.4	-4.2
141	-0.7	7.7	1.5	6.0	67.5	5.9	42.2	30.5	18.7	7.0	-4.7
151	-0.6	7.7	1.5	6.0	67.5	5.9	40.5	28.9	17.3	5.7	-5.9
161	0.1	7.6	1.7	6.0	67.0	6.3	31.8	21.4	10.9	0.5	-10.0
171	-0.6	7.7	1.5	6.0	67.0	5.9	40.5	28.9	17.3	5.7	-5.9
181	-0.9	7.7	1.5	6.0	67.5	5.9	45.6	33.5	21.5	9.5	-2.5
191	-0.9	7.6	1.4	6.0	67.0	6.3	41.9	32.0	20.2	8.3	-3.5
201	-1.1	7.5	1.4	6.0	67.0	6.7	47.2	35.2	23.2	11.3	-0.7
211	-0.8	7.7	1.5	6.0	67.5	5.9	43.9	32.0	20.1	8.3	-3.6
221	-0.6	7.5	1.4	6.0	67.5	6.7	38.7	27.5	16.2	4.9	-6.4
231	-0.5	7.8	1.7	6.0	67.0	5.6	42.1	30.5	18.9	7.3	-4.3
241	-0.6	7.7	1.6	6.0	67.5	5.9	42.1	30.5	18.9	7.3	-4.3
251	-0.7	7.5	1.4	6.0	67.0	6.7	40.4	29.0	17.6	6.2	-5.2
261	-0.6	7.7	1.5	6.0	66.5	5.9	40.5	28.9	17.3	5.7	-5.9
271	-0.8	7.6	1.5	6.0	67.5	6.3	43.8	32.1	20.4	8.7	-3.0
281	-1.0	7.6	1.5	6.0	67.0	6.3	47.2	35.2	23.2	11.2	-0.8
291	-0.7	7.6	1.6	6.0	67.0	6.3	43.7	32.1	20.6	9.0	-2.6
301	-0.1	7.7	1.7	6.0	67.0	5.9	35.3	24.4	13.5	2.6	-8.3
311	-0.2	7.6	1.7	6.0	66.5	6.3	36.9	26.0	15.1	4.3	-6.6
321	-0.6	7.6	1.6	6.0	67.0	6.3	42.0	30.6	19.2	7.7	-3.7
331	-0.5	7.6	1.5	6.0	66.5	6.3	38.7	27.4	16.1	4.9	-6.4
341	-0.5	7.6	1.4	6.0	66.5	6.3	37.1	25.8	14.5	3.2	-8.0
351	-0.6	7.6	1.4	6.0	67.5	6.3	38.8	27.4	15.9	4.5	-6.9
361	-0.5	7.6	1.2	6.0	67.5	6.3	40.7	28.8	17.0	5.1	-6.7
371	-0.9	7.6	1.3	6.0	67.0	6.3	42.3	30.4	18.6	6.7	-5.1
381	-0.9	7.9	1.4	6.0	67.5	5.6	44.0	31.9	19.7	7.5	-4.6
391	-0.9	7.8	1.5	6.0	67.0	5.6	45.6	33.5	21.3	9.1	-3.0
401	-0.4	7.7	1.5	6.0	66.5	5.9	37.1	25.8	14.5	3.2	-8.1
411	-0.4	7.6	1.6	6.0	66.5	6.3	38.6	27.5	16.3	5.2	-6.0
421	-1.0	7.6	1.4	6.0	67.5	6.3	45.6	33.6	21.6	9.6	-2.4
431	-1.2	7.6	1.2	6.0	66.5	6.3	45.7	33.5	21.2	8.9	-3.3
441	-0.8	7.5	1.5	6.0	67.5	6.7	43.7	32.2	20.6	9.1	-2.5
451	-0.6	7.5	1.5	6.0	66.0	6.3	40.4	29.0	17.6	6.1	-5.3
461	-0.6	7.6	1.5	6.0	66.5	6.3	40.4	29.0	17.6	6.1	-5.3
471	-1.0	7.6	1.3	6.0	67.0	6.3	43.9	32.0	20.0	8.0	-4.0
481	-0.6	7.6	1.5	6.0	67.0	6.3	40.4	29.0	17.6	6.1	-5.3
491	-0.6	7.6	1.5	6.0	67.0	6.3	40.4	29.0	17.6	6.1	-5.3
501	-0.6	7.7	1.5	6.0	68.0	5.9	40.5	28.9	17.3	5.7	-5.9
511	-0.4	7.6	1.7	6.0	66.5	6.3	40.2	29.1	17.9	6.8	-4.4
521	-0.7	7.7	2.0	5.9	67.5	5.5	50.2	38.5	26.7	14.9	3.2
531	-0.9	7.7	1.7	5.8	66.5	5.0	47.1	35.2	23.2	11.3	-0.6
541	-0.5	7.6	1.5	5.9	67.0	5.8	38.7	27.4	16.1	4.8	-6.5
551	-0.8	7.5	1.4	5.8	68.0	5.4	42.2	30.6	18.7	6.9	-4.0
561	-0.5	7.6	1.2	5.9	68.0	5.8	40.7	28.8	16.9	5.0	-6.8

571	-0.8	7.5	1.1	5.9	67.5	5.8	37.4	25.6	13.9	2.2	-9.6
581	-0.6	7.6	1.2	5.9	68.5	5.9	35.6	24.1	12.7	1.2	-10.2
591	-0.9	7.6	1.0	5.9	68.0	5.8	35.8	24.0	12.3	0.6	-11.2
601	-0.5	7.7	1.2	5.9	69.0	5.5	34.0	22.5	11.0	-0.4	-11.9
611	-0.7	7.7	1.2	5.9	68.5	5.5	37.4	25.6	13.9	2.1	-9.7
621	-0.7	7.7	1.3	6.0	67.5	5.9	39.0	27.2	15.5	3.8	-7.9
631	-0.3	7.6	1.3	6.0	67.0	6.3	32.1	21.1	10.1	-0.9	-11.9
641	-0.3	7.7	1.4	5.9	69.5	5.5	33.8	22.6	11.4	0.2	-11.0
651	-0.3	7.7	1.4	5.9	68.0	5.5	33.8	22.6	11.4	0.2	-11.0
661	-0.5	7.7	1.2	5.9	68.0	5.5	34.0	22.5	11.0	-0.4	-11.9
671	-0.5	7.7	1.3	5.9	67.5	5.5	35.6	24.1	12.6	1.2	-10.3
681	-0.6	7.8	1.2	5.9	68.0	5.1	35.8	24.0	12.7	0.4	-11.3
691	-0.9	7.7	1.2	5.9	67.5	5.5	39.0	27.2	15.3	3.4	-8.5
701	-0.7	7.7	1.2	5.9	69.0	5.5	37.4	25.6	13.9	2.1	-9.7
711	-0.7	7.6	1.2	5.9	68.0	5.8	37.3	25.7	14.1	2.5	-9.1
721	-0.5	7.7	1.2	5.9	69.0	5.5	35.7	24.1	12.4	0.8	-10.8
731	-0.6	7.7	1.2	5.9	67.5	5.5	35.7	24.1	12.4	0.8	-10.8
741	-1.0	7.6	1.0	6.0	68.0	6.3	39.1	27.1	15.2	3.2	-8.8
751	-0.8	7.6	1.1	5.9	68.0	5.8	37.4	25.6	13.9	2.2	-9.6
761	-0.9	7.6	1.0	5.9	68.0	5.8	35.8	24.0	12.3	0.6	-11.2
771	-1.2	7.6	1.0	5.9	68.0	5.8	42.5	30.2	17.9	5.6	-6.7
781	-0.9	7.6	1.0	5.9	67.0	5.8	37.4	25.6	13.7	1.8	-10.0
791	-0.9	7.5	0.9	5.9	68.0	6.2	34.1	22.5	10.9	-0.7	-12.2
801	-0.9	7.6	1.0	5.9	68.0	5.8	35.8	24.0	12.3	0.6	-11.2
811	-0.6	7.7	1.2	5.9	68.0	5.5	35.7	24.1	12.4	0.8	-10.8
821	-0.6	7.6	1.2	6.0	68.5	6.3	35.6	24.2	12.7	1.3	-10.1
				MEAN=	67.3		40.2	28.6	17.0	5.4	-6.2

ACHILLES TENSION(MEAN)= 30.9

NAME=CHILD(M.D.?) PHASE=TWO STANCE=TWO CONDITION=EQUINUS

NO	ALPHA0	BETA0	D2	D3	D4	F
57	32.0	60.0	4.8	35.0	1.5	31.9

FRAME	XF	XA	XB	YA	THETA	ALPELT	PPOS	PN25	PN50	PN75	PN100
1	-0.6	7.6	1.5	6.0	67.0	6.3	40.4	29.0	17.6	6.1	-5.3
6	-0.5	7.6	1.5	6.6	66.5	9.0	38.7	27.6	16.4	5.3	-5.9
11	-0.9	7.6	1.5	6.5	67.0	8.5	43.0	32.2	20.6	9.0	-2.6
16	-1.0	7.6	1.4	6.1	66.5	6.0	45.6	33.6	21.6	9.7	-2.3
21	-1.0	7.9	1.5	6.0	67.5	5.6	47.3	35.0	22.7	10.4	-1.9
26	-0.9	7.5	1.4	6.1	66.5	6.8	43.9	32.0	20.2	8.4	-3.4
31	-0.7	7.6	1.5	6.0	67.5	6.3	42.1	30.5	19.0	7.4	-4.2
36	-0.4	7.6	1.6	6.0	66.0	6.[illegible]	38.6	27.5	16.3	5.2	-6.0
41	-0.4	7.6	1.6	6.0	66.5	6.3	39.6	27.5	16.3	5.2	-6.0
46	-0.6	7.6	1.5	6.0	67.5	6.3	40.4	29.0	17.6	6.1	-5.3
51	-0.7	7.6	1.5	6.0	66.5	6.3	42.1	30.5	19.0	7.4	-4.2
56	-1.0	7.6	1.4	6.5	66.5	8.5	45.6	33.7	21.8	10.0	-1.9
61	-1.0	7.7	1.5	6.0	67.0	5.9	47.2	35.1	22.9	10.8	-1.3
66	-0.9	7.[illegible]	1.7	6.0	66.5	5.9	47.1	35.2	23.3	11.5	-0.4
71	-0.9	7.7	1.5	6.0	66.5	5.9	43.0	32.0	20.1	8.3	-3.6
76	-0.3	7.6	1.3	6.0	67.0	6.3	32.1	21.1	10.1	-0.9	-11.9
81	-1.7	7.5	0.7	6.3	66.5	9.0	46.0	33.3	20.6	7.9	-4.8
86	-2.4	7.3	0.3	7.0	63.5	11.8	51.3	39.1	24.0	11.7	-1.5
91	-2.7	7.1	0.4	7.6	60.0	15.0	57.0	44.6	31.4	18.3	5.1
96	-2.4	7.0	0.7	8.0	57.5	16.8	57.4	44.9	32.4	19.8	7.3
101	-2.5	6.6	0.7	8.5	57.0	20.2	58.8	46.8	34.8	22.8	10.8
106	-3.0	6.3	0.8	9.0	50.0	23.0	68.6	56.5	44.3	32.1	20.0
111	-2.3	6.6	1.5	8.6	52.0	20.5	68.3	56.6	44.8	33.1	21.4
116	-2.0	7.1	2.2	8.0	55.5	16.4	74.0	62.7	50.6	38.4	26.2
121	-1.4	7.3	2.3	7.7	56.5	14.5	66.5	54.8	43.1	31.4	19.7
126	-2.0	7.1	2.[illegible]	7.9	56.5	16.1	71.7	59.5	47.3	35.1	23.0
131	-2.0	7.2	1.7	8.4	54.5	17.4	66.9	54.7	42.4	30.2	17.9
136	-2.5	6.8	1.3	8.7	53.0	20.0	68.6	56.3	44.1	31.8	19.5
141	-2.3	6.9	1.4	8.8	52.5	19.9	66.9	54.8	42.6	30.5	18.3
146	-2.9	6.9	0.8	8.7	53.0	20.0	67.3	54.5	41.7	28.9	16.1
151	-2.6	6.9	1.2	8.6	53.0	19.3	68.8	56.2	43.6	31.1	18.5
156	-2.6	6.9	1.3	8.5	52.5	19.3	70.3	57.0	45.2	33.0	20.6
161	-2.5	6.9	1.5	8.5	53.5	18.9	71.5	59.5	47.0	34.6	22.1
166	-2.2	7.0	1.6	8.5	53.5	18.5	68.5	56.3	44.1	31.9	19.7
171	-2.4	7.1	1.5	8.4	54.0	17.8	75.2	62.6	49.9	37.3	24.7
176	-2.2	7.3	2.1	8.2	55.0	16.3	76.8	64.1	51.4	38.7	26.0
181	-2.0	7.3	2.2	8.1	55.0	16.9	75.0	62.6	50.1	37.7	25.3
186	-2.0	7.1	2.1	8.1	54.5	16.8	73.3	61.1	49.0	36.8	24.7
191	-2.0	7.3	2.6	8.1	55.5	16.0	81.5	69.0	56.6	44.1	31.7
196	-1.5	7.6	2.8	7.6	57.5	13.0	76.5	64.2	51.8	39.5	27.2
201	-1.1	7.9	2.9	7.3	60.0	11.1	69.9	57.7	45.6	33.5	21.3
206	-1.4	7.9	2.5	7.1	61.5	10.3	70.1	57.5	44.9	32.4	19.8
211	-1.7	7.6	2.0	7.0	61.0	10.6	67.0	54.3	41.6	28.9	16.2
216	-1.6	7.2	2.1	6.8	63.0	9.1	67.1	54.1	41.2	28.3	15.3
221	-1.5	7.9	2.4	6.5	64.5	7.4	70.3	57.2	44.2	31.2	18.2
226	-1.2	7.9	2.5	6.4	64.5	7.0	66.8	54.2	41.6	28.9	16.3
231	-1.3	8.0	2.9	6.1	65.5	5.3	75.0	62.0	49.0	36.0	22.9
236	0.1	8.1	3.1	6.1	65.5	5.0	54.7	43.5	32.3	21.0	9.8
241	-0.6	8.0	3.1	6.1	65.5	5.3	66.4	54.4	42.3	30.3	18.3
246	-0.5	8.0	3.2	6.1	64.5	5.3	66.3	54.4	42.5	30.6	18.7
251	-0.3	9.0	3.3	6.1	65.0	5.3	64.6	53.0	41.3	29.7	18.1
256	0.0	8.[illegible]	3.3	6.1	64.5	5.3	60.5	49.3	37.1	25.9	14.7
261	[illegible]	[illegible]	3.[illegible]	6.1	64.5	5.3	60.6	48.[illegible]	36.9	25.6	14.2
266	-0.[illegible]	7.[illegible]	3.[illegible]	5.9	65.5	5.1	61.1	49.5	38.7	27.5	16.3
271	-0.3	7.[illegible]	3.2	5.9	66.0	5.[illegible]	62.9	51.5	40.1	28.8	17.4
276	-0.1	7.3	4.1	5.9	66.0	5.1	57.8	46.5	35.7	24.6	13.5
281	-0.3	7.0	3.3	5.8	66.5	4.2	64.5	53.0	41.4	29.0	18.3

[illegible]	-0.2	7.9	3.1	5.8	66.0	4.6	59.5	48.3	37.0	25.8	14.6
301	-0.2	7.9	3.1	5.8	66.0	4.6	59.5	49.3	37.0	25.8	14.6
[illegible]	[illegible]	7.8	3.2	5.8	65.5	4.6	60.4	48.3	37.2	24.1	15.0
[illegible]	-0.1	7.9	3.2	5.9	65.0	4.6	59.4	48.3	37.2	26.1	15.0
[illegible]	0.0	7.9	3.2	5.9	66.0	4.6	57.7	46.8	35.8	24.9	13.9
311	0.0	7.9	3.2	5.9	66.0	5.1	57.7	46.8	35.9	25.0	14.0
316	0.0	7.9	3.2	5.9	65.5	4.8	57.8	46.7	35.6	24.6	13.5
321	-0.2	7.9	3.0	5.9	66.0	5.1	57.9	46.7	35.5	24.3	13.1
326	-0.3	7.4	3.0	5.9	65.5	5.1	59.6	48.2	36.9	25.5	14.2
331	-0.3	7.9	3.0	5.9	65.5	5.1	59.6	48.2	36.9	25.5	14.2

McGILL UNIVERSITY COMPUTING CENTRE

NAME=CHILD(M.D.2) PHASE=TWO STANCE=TWO CONDITION=PLANTIGRADE

NF	ALPHA0	BETA0	D2	D3	D4	F
64	25.0	58.0	3.8	28.6	1.3	24.4

FRAME	XF	XA	XB	YA	THETA	ALDELT	PPPS	PN25	PN50	PN75	PN100
1	1.6	7.4	5.3	4.5	66.5	2.3	49.1	42.0	35.0	27.9	20.9
6	1.6	7.3	5.2	4.6	66.0	3.2	47.8	40.9	34.0	27.1	20.2
11	1.5	7.2	5.1	4.7	65.5	4.1	47.8	40.9	34.1	27.2	20.4
16	1.4	7.4	5.1	4.7	66.5	3.4	49.2	42.0	34.7	27.5	20.2
21	1.5	7.3	4.9	4.6	67.0	3.2	45.4	39.4	31.4	24.4	17.4
26	1.0	7.3	4.9	4.6	67.5	3.2	50.6	43.0	35.4	27.8	20.2
31	0.7	7.3	4.7	4.7	66.5	3.9	53.3	45.3	37.4	29.4	21.5
36	0.9	7.1	4.6	4.7	65.5	4.5	49.3	41.9	34.4	27.0	19.6
41	1.0	7.2	4.7	4.5	67.0	3.0	49.3	41.8	34.3	26.8	19.3
46	1.1	7.3	4.7	4.6	67.0	3.2	48.1	40.6	33.1	25.6	18.1
51	0.9	7.2	4.6	4.7	65.5	4.1	49.4	41.8	34.2	26.7	19.1
56	0.6	7.2	4.5	4.7	65.0	4.1	52.0	44.1	36.2	28.2	20.3
61	0.9	7.2	4.7	4.7	65.5	3.8	50.7	43.0	35.3	27.5	19.8
66	0.9	7.2	4.6	4.6	65.0	3.6	49.4	41.9	34.2	26.6	19.0
71	[illegible]	7.3	4.5	4.5	65.5	2.7	52.1	44.0	35.8	27.7	19.6
76	0.9	7.2	4.6	4.7	65.0	4.1	50.7	43.0	35.3	27.6	19.9
81	0.8	7.2	4.7	4.6	66.5	3.6	51.9	44.2	36.5	28.7	21.0
86	1.1	7.2	4.8	4.6	66.0	3.6	49.3	41.9	34.5	27.2	19.8
91	1.1	7.2	5.0	4.6	66.5	3.6	51.7	44.4	37.0	29.6	22.3
96	1.2	7.2	5.1	4.8	65.5	4.7	51.6	44.5	37.3	30.1	22.9
101	1.8	7.3	5.4	4.9	64.5	4.3	47.7	41.0	34.4	27.8	21.2
106	2.0	7.3	5.5	4.5	65.0	2.7	46.3	39.9	33.5	27.0	20.6
111	2.1	7.4	5.6	4.4	65.5	1.7	46.3	39.8	33.4	26.9	20.5
116	1.9	7.3	5.6	4.7	63.5	3.8	48.8	42.3	35.8	29.3	22.9
121	1.9	7.3	5.5	4.6	65.0	3.2	47.6	41.1	34.5	28.0	21.5
126	1.9	7.2	5.5	4.4	64.5	2.4	47.5	41.1	34.7	28.2	21.8
131	1.5	7.3	5.2	4.4	64.5	2.1	49.1	42.0	35.0	27.9	20.9
136	1.1	7.2	5.2	4.8	65.5	4.7	54.2	46.9	39.5	32.2	24.9
141	1.3	7.3	5.3	4.6	65.5	3.2	52.9	45.6	38.4	31.1	23.9
146	1.6	7.3	5.4	4.4	65.5	2.1	50.2	43.3	36.4	29.4	22.5
151	2.0	7.3	5.6	4.6	65.0	3.2	47.5	41.1	34.7	28.3	21.9
156	2.1	7.2	5.6	4.6	64.5	3.6	46.2	40.0	33.9	27.7	21.6
161	2.2	7.3	5.5	4.7	64.0	3.9	43.7	37.6	31.4	25.3	19.1
166	2.4	7.3	5.8	4.4	65.0	2.1	44.8	38.9	32.9	26.9	21.0
171	2.5	7.3	5.9	4.4	64.5	2.1	44.8	39.0	33.1	27.3	21.4
176	2.4	7.4	6.0	4.6	63.5	2.9	47.3	41.3	35.2	29.2	23.1
181	2.1	7.3	5.9	4.6	63.5	3.7	49.9	43.6	37.4	31.1	24.8
186	1.9	7.3	5.8	4.6	64.5	3.2	51.3	44.8	38.2	31.7	25.2
191	1.7	7.3	5.7	4.3	66.5	1.5	52.6	45.8	39.0	32.1	25.3
196	1.9	7.3	5.9	4.4	65.0	2.1	52.5	45.9	39.4	32.8	26.2
201	1.7	7.1	5.6	4.4	65.5	2.9	51.3	44.7	38.2	31.7	25.1
206	1.6	7.2	5.6	4.4	65.0	2.4	52.6	45.8	39.0	32.2	25.4
211	1.6	7.3	5.6	4.5	64.5	2.7	52.7	45.8	38.9	32.0	25.1
216	1.5	7.2	5.5	4.6	65.0	3.6	52.7	45.8	38.9	32.1	25.2
221	1.6	7.4	5.6	4.6	66.0	2.9	52.8	45.7	38.7	31.7	24.7
226	1.9	7.2	5.6	4.4	65.0	2.4	50.0	43.5	36.9	30.4	23.8
231	2.0	7.2	5.7	4.5	65.0	3.0	48.7	42.4	36.1	29.8	23.5
236	1.9	7.3	5.6	4.7	65.0	3.8	50.1	43.5	36.9	30.2	23.6
241	1.5	7.3	5.7	4.5	65.0	2.7	55.2	48.2	41.2	34.1	27.1
246	1.6	7.3	5.5	4.4	65.5	2.1	51.5	44.5	37.6	30.7	23.7
251	1.7	7.4	5.7	4.8	65.0	4.0	52.7	45.8	39.0	32.1	25.3
256	1.6	7.3	5.6	4.7	65.5	3.9	52.7	45.8	39.0	32.1	25.2
261	1.6	7.2	5.5	4.4	66.0	2.4	51.4	44.6	37.8	31.0	24.2
266	1.6	7.3	5.6	4.5	65.0	2.7	52.7	45.8	38.9	32.0	25.1
271	2.1	7.3	5.7	4.6	65.0	3.2	47.5	41.2	34.9	28.6	22.3
276	[illegible]	7.2	5.7	4.7	64.0	4.1	49.7	42.4	36.2	29.9	23.[illegible]
281	1.9	7.3	5.7	4.6	65.0	3.2	51.3	44.7	38.0	31.4	24.8

[illegible]	[illegible]	7.3	5.8	4.4	66.5	2.1	51.3	44.7	38.1	31.6	25.0
221	[illegible]	7.2	5.9	6.5	65.0	2.7	46.1	40.1	34.0	27.9	21.9
[illegible]	2.?	7.4	5.8	4.7	6?.5	3.4	47.5	41.2	34.9	28.6	22.4
[illegible]	2.4	7.3	5.0	4.4	65.5	2.1	44.0	40.1	34.1	28.2	22.[illegible]
[illegible]	2.?	7.3	6.0	4.4	65.5	2.1	49.9	43.7	37.5	31.3	25.1
311	2.5	7.4	6.1	4.4	65.5	1.7	47.2	41.2	35.3	29.4	23.4
316	2.?	7.2	6.9	4.7	64.5	4.1	60.9	54.8	48.8	42.8	36.8
				MEAN=	65.3		49.9	43.1	36.2	29.4	22.6

ACHILLES TENSION(MEAN)= 21.0

NAME=CHILD(M,D,2)   PHASE=ONE   STANCE=ONE   CONDITION=EQUINUS

NF	ALPHAO	BETAO	D2	D3	D4	F
59	29.0	58.0	3.8	29.6	1.3	24.4

FRAME	XF	XA	XB	YA	THETA	ALDELT	PPOS	PN25	PN50	PN75	PN100
1	2.0	7.9	5.9	4.4	67.0	0.4	51.5	44.6	37.3	30.2	23.0
6	2.1	7.8	5.0	4.3	69.0	-0.1	50.2	43.2	36.2	29.2	22.2
11	2.3	7.9	6.1	4.3	68.5	-0.4	50.2	43.3	36.4	29.4	22.5
16	2.4	7.9	6.1	4.5	68.5	1.0	49.8	42.7	35.6	29.0	22.4
21	2.4	7.4	5.9	4.3	68.5	-0.1	44.4	39.7	33.1	26.4	19.8
26	1.7	7.9	6.3	4.4	69.0	0.1	60.4	52.7	45.1	37.5	29.9
31	1.4	7.7	5.5	4.3	69.5	0.2	54.2	46.5	38.8	31.1	23.3
36	1.5	7.9	5.6	4.3	68.5	-0.1	54.3	46.5	38.8	31.0	23.3
41	1.3	7.0	5.4	4.3	70.0	-0.4	54.5	46.3	38.2	30.1	21.9
46	1.7	7.8	5.4	4.3	69.0	-0.1	49.3	41.7	34.2	26.7	19.2
51	2.0	7.9	5.1	4.4	69.5	0.4	41.7	34.6	27.5	20.3	13.2
56	0.4	7.7	4.5	4.4	70.5	0.7	54.0	46.0	37.9	28.1	19.1
61	0.1	7.3	4.2	4.4	71.5	0.4	55.2	45.7	36.3	26.9	17.4
66	-1.1	7.6	3.4	4.9	70.0	3.9	60.7	50.2	39.7	29.3	18.8
71	-1.7	6.3	2.6	6.3	71.5	13.4	58.2	48.3	38.4	28.5	18.7
76	-1.4	7.1	2.1	6.0	64.5	11.2	48.3	38.4	28.6	18.7	8.8
81	-1.9	7.2	2.6	5.4	67.0	7.9	49.3	39.7	30.0	20.3	10.7
86	-0.6	7.9	2.3	4.5	73.5	0.7	53.2	42.8	32.4	22.0	11.5
91	0.3	7.7	3.1	4.5	73.0	1.9	39.0	30.0	21.0	12.0	3.0
96	-0.7	7.4	2.6	5.0	70.0	5.0	45.6	35.9	26.2	16.5	6.8
101	-0.9	7.4	2.2	5.3	68.5	6.6	43.3	33.4	23.6	13.7	3.9
106	-1.0	6.9	2.0	6.4	61.0	14.3	53.3	43.4	33.4	23.5	13.5
111	-1.9	6.9	2.4	6.3	65.5	13.9	57.0	47.1	37.2	27.4	17.5
116	-1.8	6.6	2.2	6.8	58.5	16.9	54.4	44.9	35.3	25.8	16.3
121	-2.1	6.7	2.4	6.9	57.0	16.8	60.8	50.8	40.9	30.9	20.9
126	-2.0	6.9	2.6	6.8	58.5	16.0	62.0	52.0	42.0	32.0	22.0
131	-1.3	7.3	3.3	6.0	62.5	10.4	61.9	51.9	41.8	31.8	21.8
136	-0.7	7.5	3.1	5.3	66.5	6.3	51.8	42.0	32.3	22.5	12.8
141	-0.4	7.9	3.5	4.7	71.0	1.9	54.3	44.2	34.1	24.0	13.9
146	1.1	7.9	3.4	4.5	72.0	0.7	32.5	24.2	15.8	7.5	-0.9
151	1.6	7.7	4.1	4.5	71.0	1.3	34.5	27.1	19.6	12.2	4.7
156	-0.5	7.5	3.9	5.3	55.5	[illegible]	59.0	49.5	40.0	30.5	21.0
161	0.4	7.7	4.3	4.8	67.5	2.9	52.5	43.6	34.8	26.0	17.1
166	-0.3	7.6	3.6	4.9	69.0	3.9	52.9	43.3	33.8	24.3	14.8
171	-0.4	7.9	3.8	4.7	70.0	2.1	56.7	46.7	36.8	26.8	16.8
176	-0.3	7.6	3.1	4.9	69.5	3.8	46.7	37.2	27.7	18.2	8.6
181	-1.0	7.5	3.1	5.4	66.5	6.8	55.7	45.6	35.5	25.4	15.4
186	-1.0	7.5	3.6	5.2	67.5	5.4	61.0	51.6	41.3	31.1	20.8
191	-1.9	7.5	3.4	5.6	65.0	7.8	59.3	49.3	39.3	29.3	19.2
196	-1.1	7.3	3.5	5.7	63.0	9.0	63.0	53.1	43.3	33.4	23.6
201	-1.1	7.5	4.1	5.7	62.5	8.2	69.2	59.1	49.0	38.9	28.8
206	-0.4	7.9	4.9	4.7	69.0	1.8	70.3	60.2	50.1	40.0	29.8
211	1.3	7.9	4.0	4.4	71.5	0.1	37.3	29.2	21.1	12.9	4.8
216	-0.2	7.8	3.6	4.5	72.5	1.0	49.2	39.4	29.6	19.8	10.1
221	0.1	7.7	3.4	4.4	72.5	0.7	45.3	36.0	26.7	17.3	8.0
226	-0.5	7.7	3.3	4.9	69.5	3.5	53.1	43.1	33.1	23.0	13.0
231	-1.7	6.9	2.3	6.4	62.0	13.9	54.5	44.6	34.8	24.9	15.0
236	-2.7	5.9	1.9	7.8	50.5	23.9	61.9	52.4	42.9	33.4	23.9
241	-2.0	6.5	3.2	7.4	53.5	19.7	69.2	59.7	50.1	40.6	31.1
246	-1.5	6.5	3.3	7.0	55.0	17.7	65.3	56.0	46.8	37.5	28.3
251	-0.8	7.3	3.5	6.0	63.5	10.4	57.9	49.4	39.0	29.6	20.1
256	0.6	8.2	3.0	4.3	75.0	-1.3	45.3	35.8	26.4	17.0	7.6
261	1.4	7.9	2.8	4.2	74.5	-1.0	33.5	25.5	17.4	9.4	1.4
266	1.3	7.0	3.7	4.3	72.5	-0.4	40.1	31.3	22.5	13.9	5.0
271	0.2	7.9	3.6	4.4	72.5	0.1	46.6	37.1	27.6	18.2	8.7
276	-0.5	7.9	4.1	4.6	70.5	1.2	61.7	51.5	41.2	31.0	20.7
281	-0.3	7.3	5.0	4.2	71.5	-1.0	70.2	60.1	49.9	39.8	29.6

286	1.7	8.3	6.3	4.0	69.0	-2.4	60.4	52.6	44.7	36.8	29.0
291	2.1	9.1	5.6	4.0	70.0	-2.7	56.6	49.1	41.6	34.0	26.5
296	2.5	7.0	6.9	4.1	65.5	-1.6	47.6	40.0	34.2	27.5	20.8
301	2.3	7.9	5.9	4.2	69.0	-0.7	46.4	39.6	32.8	26.0	19.2
305	2.5	7.9	6.1	4.4	64.5	0.4	47.5	41.0	34.5	28.0	21.5
311	2.6	8.3	6.0	4.3	67.0	-0.7	43.3	37.8	32.4	27.0	21.5
315	2.3	7.3	6.6	4.3	67.5	-0.4	56.3	49.4	42.5	35.6	28.7
321	2.1	7.9	6.7	4.2	66.2	-1.0	60.1	52.9	45.8	38.6	31.4
326	2.5	8.0	6.5	3.9	69.5	-3.0	52.6	45.7	38.8	31.9	25.0
331	2.6	8.3	6.3	4.0	69.5	-2.4	48.8	42.1	35.3	28.6	21.8
336	1.5	7.9	5.9	4.2	68.0	-1.3	58.0	50.1	42.2	34.3	26.4
341	1.4	7.3	6.1	4.1	69.5	-1.6	61.8	53.7	45.6	37.6	29.5

NAME=CHILD(N3) PHASE=ONE STANCE=ONE CONDITION=PLANTIGRADE

NF	ALPHAO	BETAO	D2	D3	D4	F
23	36.0	58.0	5.9	37.4	1.6	44.3

FRAME	XF	SOL	GAS	XA	XB	YA	THETA	ALDELT	PNEMG	PPOS	PN25	PN50	PN75	PN100
1	3.7	1.	0.	8.1	6.0	6.1	63.5	1.0	56.3	56.3	48.5	40.8	33.0	25.3
6	3.3	1.	0.	8.0	5.9	6.1	64.0	1.3	63.3	63.3	55.0	46.8	38.5	30.3
11	3.9	1.	0.	7.9	5.9	6.1	63.5	1.7	51.5	51.5	44.3	37.1	29.9	22.7
16	3.9	1.	0.	9.1	5.9	5.9	64.0	0.1	51.7	51.7	44.1	36.5	28.9	21.3
21	3.7	1.	0.	8.1	5.9	6.0	63.5	0.5	54.0	54.0	46.3	38.5	30.7	23.0
26	3.7	1.	0.	8.1	5.9	6.0	64.0	0.5	54.0	54.0	46.3	38.5	30.7	23.0
31	3.4	1.	0.	8.0	5.9	5.9	64.5	0.4	56.3	56.3	48.5	40.7	33.0	25.2
36	3.4	1.	0.	8.1	5.9	6.0	64.0	0.5	61.1	61.1	52.8	44.5	36.2	27.9
41	3.4	1.	0.	8.1	5.9	6.0	64.5	0.5	61.1	61.1	52.9	44.5	36.2	27.9
46	3.0	1.	0.	8.1	5.9	6.0	64.5	0.5	70.5	70.5	61.4	52.4	43.4	34.4
51	2.9	1.	0.	8.1	5.8	6.0	64.5	0.5	72.9	72.9	63.6	54.2	44.8	35.5
56	2.7	1.	0.	8.1	5.8	6.0	64.5	0.5	75.3	75.3	65.7	56.2	46.7	37.1
61	2.6	1.	0.	8.1	5.8	6.0	64.5	0.5	77.6	77.6	67.9	58.2	48.5	38.8
66	2.7	1.	0.	8.1	5.6	6.0	64.5	0.5	70.8	70.8	61.3	51.7	42.2	32.7
71	2.8	1.	0.	8.1	5.6	6.0	64.5	0.5	68.4	68.4	59.1	49.7	40.4	31.0
76	3.2	1.	0.	8.1	5.7	6.0	64.5	0.5	61.3	61.3	52.7	44.0	35.4	26.7
81	3.3	1.	0.	8.1	5.7	6.0	64.5	0.5	59.0	59.0	50.5	42.0	33.5	25.1
86	3.4	1.	0.	8.1	5.7	6.0	64.5	0.5	56.6	56.6	48.3	40.0	31.7	23.4
91	3.4	1.	0.	8.1	5.6	6.0	64.0	0.5	54.4	54.4	46.1	37.8	29.5	21.2
96	3.4	1.	0.	8.1	5.6	6.0	64.0	0.5	54.4	54.4	46.1	37.8	29.5	21.2
101	3.3	1.	0.	8.1	5.5	6.0	65.0	0.5	54.5	54.5	46.0	37.6	29.1	20.6
106	3.2	1.	0.	8.1	5.4	6.0	65.0	0.5	54.6	54.6	46.0	37.3	28.7	20.0
111	3.3	1.	0.	8.1	5.6	6.0	64.0	0.5	56.7	56.7	48.3	39.8	31.3	22.8
						MEAN=	64.3		60.7	60.7	52.2	43.8	35.3	26.8

ACHILLES TENSION(MEAN)= 21.2

NAME=CHILD(N3) PHASE=ONE STANCE=ONE CONDITION=EQUINUS

NE	ALPHAD	BETAD	D2	D3	D4	F
31	36.0	56.0	5.9	37.4	1.6	44.3

FRAME	XF	SOL	GAS	XA	XB	YA	THETA	ALDFLT	PNEMG	PPOS	PN25	PN50	PN75	PN100
1	3.4	1.	0.	8.1	5.3	6.0	63.5	0.5	47.7	47.7	39.4	31.1	22.8	14.5
6	3.2	1.	0.	8.1	5.3	6.0	64.5	0.5	52.4	52.4	43.7	35.1	26.4	17.8
11	2.6	1.	0.	8.0	5.2	6.1	64.5	1.3	64.1	64.1	54.6	45.1	35.6	26.1
16	2.8	1.	0.	8.0	5.1	6.3	65.0	0.9	57.2	57.2	48.0	38.9	29.7	20.5
21	3.4	1.	0.	8.0	5.0	6.1	65.0	1.3	40.9	40.9	32.8	24.7	16.6	8.6
26	0.4	2.	1.	8.0	4.1	6.2	66.0	1.8	73.4	91.1	77.8	64.5	51.2	37.8
31	-3.1	2.	1.	8.0	3.4	6.3	65.5	2.2	131.7	157.5	138.1	118.7	99.3	79.9
36	-4.8	3.	1.	8.0	3.0	6.5	66.5	3.1	158.8	188.4	166.2	143.9	121.6	99.4
41	-3.6	2.	1.	7.7	2.5	7.1	64.0	6.7	123.1	148.8	129.5	110.3	91.0	71.7
46	-4.4	3.	1.	7.6	1.9	7.7	61.5	9.4	133.9	154.1	133.9	113.7	93.4	73.2
51	-5.5	3.	1.	7.5	2.0	8.1	60.0	11.2	160.3	182.0	160.3	138.6	116.8	95.1
56	-5.1	3.	1.	7.4	1.8	8.5	59.5	13.0	147.3	168.0	147.3	126.6	105.9	85.2
61	-5.0	3.	2.	7.1	1.1	9.1	56.5	16.0	118.1	149.7	130.0	110.2	90.4	70.6
66	-5.1	4.	2.	6.6	-0.1	9.9	52.0	20.3	99.7	124.8	105.9	87.1	68.3	49.5
71	-5.5	3.	2.	5.9	-1.6	10.8	48.5	25.4	71.0	99.9	81.9	63.8	45.8	27.8
76	-5.5	3.	3.	4.8	-2.6	12.0	42.5	32.2	44.4	76.3	60.4	44.4	28.4	12.4
81	-5.4	3.	4.	3.6	-3.4	12.9	35.5	38.4	23.3	54.8	41.0	27.2	13.4	-0.3
86	-5.5	2.	4.	4.0	-2.9	13.1	36.5	37.0	37.6	78.1	62.9	47.7	32.5	17.3
91	-6.0	2.	2.	4.1	-2.9	13.1	37.5	36.6	49.5	80.6	65.1	49.5	34.0	18.5
96	-4.6	2.	2.	5.1	-2.6	12.1	43.5	31.2	25.4	55.6	40.5	25.4	10.3	-4.8
101	-5.3	2.	2.	4.9	-2.9	12.0	44.0	31.8	27.3	58.0	42.7	27.3	11.9	-3.5
106	-5.7	2.	3.	5.0	-2.8	11.9	44.5	31.2	43.5	76.8	60.1	43.5	26.8	10.2
111	-5.7	2.	1.	5.5	-2.4	11.5	47.0	28.4	62.9	86.3	68.7	51.2	33.6	16.1
116	-3.4	2.	1.	6.8	-1.6	9.2	58.0	17.5	29.6	51.7	35.1	18.5	1.9	-14.6
121	-2.9	3.	1.	7.5	-1.0	9.0	63.0	14.2	37.0	54.1	37.0	19.9	2.7	-14.4
126	-3.5	2.	1.	7.5	-0.9	7.6	65.5	9.4	45.7	70.4	51.9	33.4	14.8	-3.7
131	-3.6	1.	1.	7.7	-0.4	7.1	68.0	6.7	45.6	84.2	64.9	45.6	26.3	7.0
136	-2.7	2.	1.	7.9	0.6	6.6	69.0	3.9	61.1	85.6	67.2	48.9	30.5	12.1
141	-0.6	2.	1.	8.0	1.4	6.2	69.0	1.8	34.2	54.3	39.3	24.2	9.1	-6.0
146	-1.3	2.	1.	8.0	1.3	6.3	69.0	2.2	40.5	61.5	45.7	30.0	14.3	-1.5
151	-1.0	1.	0.	8.0	3.1	6.1	67.0	1.3	101.6	101.6	85.8	70.0	54.2	38.4

NAME=CHILD(N3)   PHASE=ONE   STANCE=ONE   CONDITION=LORDOSIS

NF	ALPHAO	BETAO	D2	D3	D4	E
22.	36.0	56.0	5.9	37.4	1.6	44.3

FRAME	XF	SOL	CAS	XA	XB	YA	THETA	ALDELT	PNEMG	PPOS	PN25	PN50	PN75	PN100
1	1.7	1.	0.	9.1	4.2	6.0	66.0	-2.6	64.1	64.1	50.8	37.5	24.2	10.9
6	1.8	1.	0.	9.1	4.1	5.9	66.5	-3.0	59.6	59.6	46.4	33.2	20.1	6.9
11	1.5	1.	0.	9.1	4.2	6.0	66.5	-2.6	68.8	68.8	55.1	41.5	27.8	14.1
16	1.2	1.	0.	9.0	4.2	6.0	66.5	-2.3	75.7	75.7	61.7	47.7	33.7	19.7
21	1.1	1.	0.	9.0	4.0	6.0	67.0	-2.3	73.6	73.6	59.4	45.2	31.1	16.9
26	1.2	1.	0.	9.0	4.0	6.0	67.0	-2.3	71.3	71.3	57.3	43.3	29.3	15.3
31	1.3	1.	0.	9.0	4.0	6.0	67.0	-2.3	68.9	68.9	55.1	41.3	27.5	13.6
36	1.3	1.	0.	9.0	4.0	6.0	67.0	-2.3	68.9	68.9	55.1	41.3	27.5	13.6
41	1.3	1.	0.	9.0	4.0	6.0	67.0	-2.3	68.9	68.9	55.1	41.3	27.5	13.6
46	1.2	1.	0.	9.1	4.0	6.0	65.5	-2.6	71.4	71.4	57.2	43.0	28.8	14.5
51	1.1	1.	0.	9.0	3.9	6.0	66.5	-2.3	71.4	71.4	57.2	43.0	28.8	14.6
56	1.0	1.	0.	9.1	3.9	6.0	67.5	-2.6	73.8	73.8	59.3	44.7	30.1	15.6
61	1.1	2.	0.	9.1	3.9	6.0	66.0	-2.6	71.5	71.5	57.1	42.7	28.3	13.9
66	1.2	2.	0.	9.1	3.9	6.1	66.0	-2.2	69.2	69.2	55.0	40.8	26.6	12.5
71	0.9	2.	0.	9.1	3.8	6.1	66.0	-2.2	76.3	76.3	61.4	46.5	31.6	16.7
76	0.6	2.	0.	9.1	3.9	6.0	67.0	-2.6	81.0	81.0	65.7	50.4	35.1	19.8
81	0.7	2.	0.	9.1	3.7	6.0	67.5	-2.6	76.4	76.4	61.3	46.2	31.1	16.0
86	1.0	2.	0.	9.1	3.7	6.0	67.5	-2.6	69.4	69.4	54.8	40.2	25.7	11.1
91	1.0	2.	0.	9.1	3.7	6.0	67.5	-2.6	69.4	69.4	54.9	40.2	25.7	11.1
96	1.3	2.	0.	9.1	3.7	6.0	67.5	-2.6	62.4	62.4	48.3	34.3	20.3	6.2
101	1.5	1.	0.	9.1	3.7	6.0	67.5	-2.6	57.7	57.7	44.0	30.3	16.7	3.0
106	1.3	1.	0.	9.1	3.7	6.0	67.5	-2.6	62.4	62.4	48.3	34.3	20.3	6.2
						MEAN=	66.8		69.6	69.6	55.5	41.3	27.2	13.0

ACHILLES TENSION(MEAN)= 35.4

NAME=CHILD(M 3) PHASE=ONE STANCE=ONE CONDITION=EQUINUS AND LORDOSIS

NF	ALPHA0	BETA0	D2	D3	D4	F
42	36.0	58.0	5.9	37.4	1.6	44.3

FRAME	XF	SOL	GAS	XA	XB	YA	THETA	ALDELT	PNEMG	PPOS	PN25	PN50	PN75	PN100
1	1.3	1.	0.	8.0	3.4	6.1	68.0	1.3	54.4	54.4	42.6	30.9	19.1	7.3
6	1.3	1.	0.	8.0	3.4	6.2	67.0	1.8	54.4	54.4	42.7	30.9	19.2	7.4
11	0.9	1.	0.	8.0	3.3	6.2	67.0	1.8	63.9	63.9	51.3	38.7	26.0	13.4
16	1.1	1.	0.	8.0	3.0	6.2	67.5	1.8	50.2	50.2	38.1	26.0	13.9	1.8
21	0.7	1.	0.	8.0	2.4	6.2	68.0	1.8	46.2	46.2	33.4	20.6	7.8	-5.0
26	-2.7	2.	1.	7.9	1.5	6.3	68.5	2.6	83.2	107.9	89.4	70.9	52.4	33.9
31	-4.6	2.	0.	7.9	1.0	6.6	69.0	3.9	139.0	139.0	117.4	95.7	74.1	52.4
36	-4.9	2.	1.	7.7	0.4	6.9	66.0	5.9	103.7	132.5	110.9	89.3	67.7	46.1
41	-5.5	3.	1.	7.4	0.0	7.4	64.0	9.0	108.2	137.3	115.5	93.7	72.0	50.2
46	-5.9	3.	1.	7.5	0.0	7.7	64.0	9.8	122.0	144.4	122.0	99.7	77.3	55.0
51	-5.0	3.	1.	7.5	0.0	7.9	63.0	10.5	104.7	125.7	104.7	83.8	62.8	41.9
56	-5.4	3.	1.	7.4	-0.4	8.2	61.5	11.5	104.7	126.0	104.7	83.4	62.1	40.8
61	-5.5	2.	1.	7.5	-0.2	8.3	61.0	11.9	104.1	132.9	111.3	89.6	68.0	46.3
66	-6.0	3.	1.	7.1	-0.9	8.7	60.0	14.8	107.0	128.6	107.0	85.5	64.0	42.4
71	-5.6	3.	1.	7.0	-0.9	9.9	58.0	15.9	100.7	121.3	100.7	80.1	59.4	38.8
76	-5.2	3.	1.	6.8	-0.9	9.1	57.0	17.2	90.0	109.5	90.0	70.4	50.9	31.4
81	-4.9	4.	1.	6.8	-1.0	9.6	55.0	18.7	85.1	100.2	81.3	62.3	43.4	24.5
86	-5.0	4.	2.	6.5	-0.5	10.3	52.0	20.6	88.6	113.5	94.8	76.2	57.6	38.9
91	-5.5	4.	2.	6.2	-0.8	10.7	48.5	23.9	93.3	118.1	99.5	80.9	62.3	43.7
96	-5.8	5.	2.	5.6	-1.5	11.4	45.0	27.8	88.3	109.8	90.9	73.0	55.1	37.2
101	-4.6	5.	2.	5.3	-1.9	11.7	43.5	29.6	97.0	118.3	99.7	81.1	62.5	43.9
106	-5.4	5.	3.	5.4	-1.6	11.7	43.5	29.2	95.9	125.1	106.3	87.6	68.8	50.0
111	-4.8	4.	2.	6.1	-1.4	11.1	49.0	25.2	65.2	88.2	70.9	53.7	36.4	19.2
116	-4.9	3.	2.	6.5	-0.9	10.4	51.0	22.0	70.9	99.8	81.7	63.6	45.6	27.5
121	-5.5	3.	1.	7.0	-0.2	9.6	51.0	17.9	105.3	132.4	112.1	91.8	71.5	51.2
126	-4.2	2.	1.	7.2	0.1	8.8	58.0	14.7	83.8	108.8	90.1	71.3	52.6	33.8
131	-4.4	2.	1.	7.3	0.1	8.7	58.0	14.0	87.9	113.6	94.3	75.0	55.7	36.4
136	-5.0	1.	1.	7.4	-0.1	8.3	61.0	12.7	82.1	123.3	102.7	82.1	61.5	40.9
141	-4.7	1.	1.	7.4	-0.2	8.0	62.0	11.2	73.6	114.1	93.9	73.6	53.4	33.2
146	-5.3	2.	1.	7.5	-0.2	7.7	64.0	9.8	99.5	128.2	106.7	85.2	63.7	42.1
151	-4.6	2.	1.	7.7	0.1	7.3	66.5	7.5	90.9	118.7	97.8	76.9	56.0	35.1
156	-3.1	2.	1.	7.7	0.0	7.0	67.0	6.3	56.7	81.4	62.9	44.4	25.9	7.5
161	-4.6	2.	1.	7.8	-0.1	6.8	68.5	5.1	95.9	114.4	93.1	71.7	50.4	29.0
166	-4.3	1.	0.	7.8	0.1	6.9	68.5	5.1	111.8	111.8	91.0	70.2	49.3	28.5
171	-3.9	1.	0.	7.8	0.2	6.5	70.0	3.8	104.7	104.7	84.4	64.1	43.9	23.6
176	-4.4	1.	0.	7.9	0.6	6.4	69.5	3.0	130.1	130.1	108.4	86.6	64.8	43.1
181	-1.4	1.	0.	8.0	1.2	6.1	70.0	1.3	68.6	68.6	52.1	35.6	19.1	2.6
186	-1.9	1.	0.	8.0	1.1	6.3	70.0	2.2	75.8	75.8	58.6	41.5	24.4	7.2
191	-1.6	1.	0.	8.0	1.4	6.1	70.0	1.3	77.8	77.8	60.9	44.0	27.2	10.3
196	-1.1	1.	0.	8.0	1.4	6.1	70.5	1.3	66.1	66.1	50.1	34.1	18.1	2.1
201	-1.0	1.	0.	8.0	1.5	6.1	69.5	1.7	65.9	65.9	50.1	34.3	18.5	2.7
206	-0.7	1.	0.	8.0	1.3	6.2	70.0	1.8	54.5	54.5	39.2	24.0	8.7	-6.5

NAME=CHILD(M4) PHASE=ONE STANCE=ONE CONDITION=PLANTIGRADE

NF	ALPHAO	BETAO	D2	D3	D4	F
19	32.5	56.0	5.1	32.1	1.4	31.8

FRAME	XF	SOL	GAS	XA	XB	YA	THETA	ALDELT	PNFMG	PPOS	PN25	PN50	PN75	PN100
1	0.0	1.	0.	8.0	4.7	5.3	67.5	1.0	58.6	58.6	49.5	40.4	31.4	72.3
6	1.1	1.	0.	8.0	4.3	5.3	69.0	1.0	56.8	56.9	48.0	39.2	30.4	21.5
11	1.2	1.	0.	7.9	4.0	5.3	67.0	1.4	53.6	53.6	44.8	36.0	27.2	18.4
16	0.4	1.	0.	7.8	3.8	5.3	67.5	1.7	60.4	60.4	51.0	41.6	32.2	22.7
21	0.4	1.	0.	7.8	3.8	5.3	67.0	1.7	60.4	60.4	51.0	41.6	32.2	22.7
26	0.2	1.	0.	7.8	4.0	5.3	67.0	1.7	67.0	67.0	57.3	47.6	38.0	28.3
31	0.0	1.	0.	8.0	3.9	5.3	68.0	1.0	68.9	68.9	58.7	48.5	38.2	28.0
36	0.7	1.	0.	8.0	3.8	5.3	68.0	1.0	55.6	55.6	46.2	36.9	27.5	18.2
41	0.0	1.	0.	8.0	3.7	5.3	69.0	1.0	65.7	65.7	55.5	45.3	35.0	24.8
46	0.6	1.	0.	7.9	3.7	5.3	68.5	1.4	55.6	55.6	46.2	36.9	27.6	18.3
51	0.4	1.	0.	7.9	3.7	5.3	67.5	1.7	59.8	58.8	49.4	40.0	30.6	21.1
56	-0.4	1.	0.	7.9	3.7	5.3	68.5	1.4	72.4	72.4	61.8	51.2	40.6	30.0
61	-0.2	1.	0.	7.9	3.7	5.3	68.0	1.4	69.0	69.0	58.7	48.3	38.0	27.7
66	0.4	1.	0.	7.9	3.7	5.3	68.0	1.4	58.9	58.9	49.4	39.8	30.2	20.6
71	-0.2	1.	0.	8.0	3.8	5.3	69.0	1.0	70.7	70.7	60.2	49.7	39.2	28.7
76	0.2	1.	0.	8.0	3.9	5.3	68.0	1.0	65.6	65.6	55.6	45.6	35.6	25.7
81	0.2	1.	0.	8.1	4.0	5.3	69.0	0.7	67.3	67.3	57.1	47.0	36.9	26.8
86	0.0	1.	0.	8.0	3.9	5.3	68.0	1.0	68.9	68.9	58.7	48.5	38.2	28.0
						MEAN=	67.9		63.0	63.0	53.3	43.6	33.8	24.1

ACHILLES TENSION(MEAN)= 27.8

NAME=CHILD(N4) PHASE=ONE STANCE=ONE CONDITION=EQUINUS

NF	ALPHAO	BETAO	D2	D3	D4	F
42	32.5	55.0	5.1	22.1	1.4	31.8

FRAME	XF	SOL	GAS	XA	XB	YA	THETA	ALDELT	PNEMG	PPOS	PN25	PN50	PN75	PN100
1	2.4	2.	0.	8.0	5.3	5.3	65.0	1.0	51.0	51.0	43.9	36.7	29.5	22.3
6	2.5	1.	0.	8.0	5.3	5.3	66.0	1.0	47.6	47.6	40.7	33.8	26.9	20.0
11	2.4	2.	0.	8.0	5.3	5.2	66.0	0.5	51.0	51.0	43.8	36.6	29.4	22.2
16	3.3	2.	0.	8.1	5.4	5.2	67.0	0.2	37.5	37.5	31.4	25.2	19.0	12.8
21	-0.2	2.	0.	8.0	5.3	5.3	65.5	1.0	94.7	94.7	84.2	73.7	63.3	52.8
26	2.0	2.	0.	8.0	5.3	5.2	66.0	0.5	57.7	57.7	50.0	42.3	34.6	26.9
31	1.3	3.	1.	8.1	4.8	5.3	65.5	0.7	56.0	64.9	56.0	47.0	38.0	29.0
36	-2.2	3.	1.	8.0	4.3	5.5	65.0	2.0	93.4	112.4	99.4	86.4	73.4	60.5
41	-1.8	3.	1.	7.9	3.9	5.7	67.0	3.2	85.3	97.5	85.3	73.0	60.8	49.5
46	-5.4	5.	2.	7.7	3.5	6.9	62.0	9.4	134.8	153.1	137.1	121.1	105.0	89.0
51	-3.4	5.	2.	6.9	2.8	7.2	60.0	13.7	93.5	107.6	95.3	82.9	70.5	58.2
56	-3.7	5.	2.	7.3	2.5	8.0	55.5	16.[illegible]	93.4	108.0	95.3	82.5	69.8	57.1
61	-3.[illegible]	5.	2.	6.9	2.1	8.5	53.0	18.8	76.4	89.6	78.1	66.6	55.1	43.5
66	-4.1	5.	2.	6.1	1.5	9.6	47.5	25.1	84.5	97.9	86.2	74.5	62.7	51.0
71	-5.2	5.	2.	5.8	1.3	10.0	45.0	27.4	98.6	113.0	100.4	87.9	75.3	62.7
76	-4.9	5.	2.	5.1	0.7	10.6	42.0	31.8	84.9	97.8	86.5	75.2	63.9	52.6
81	-5.4	5.	2.	4.9	0.3	10.8	39.0	3[illegible].1	86.4	99.6	88.0	76.4	64.9	53.3
86	-5.8	5.	2.	4.3	-0.1	11.5	36.0	37.0	86.6	99.5	88.2	76.9	65.7	54.4
91	-6.6	5.	2.	3.3	-0.8	12.0	31.0	42.1	84.5	100.9	90.0	79.0	68.1	57.1
96	-6.9	5.	2.	2.[illegible]	-0.7	12.0	30.0	41.7	61.7	75.7	66.4	57.1	47.8	38.5
101	-7.6	5.	2.	3.5	-0.7	11.8	32.5	41.0	105.4	119.5	107.2	94.8	82.6	70.3
106	-4.8	4.	2.	3.9	-0.7	11.5	34.0	39.2	59.9	72.6	63.1	53.5	44.0	34.4
111	-6.8	3.	1.	3.7	-0.7	11.8	32.5	40.1	94.5	106.2	94.5	82.9	71.2	59.6
116	-7.2	3.	1.	3.9	-0.5	11.7	34.0	39.1	103.9	116.3	103.9	91.6	79.3	66.9
121	-6.4	3.	1.	4.1	-0.3	11.5	35.0	37.9	94.5	106.2	94.5	82.8	71.1	59.4
126	-6.2	2.	1.	4.3	-0.1	11.2	36.0	36.5	92.1	107.9	96.0	84.2	72.4	60.5
131	-6.5	2.	1.	4.6	0.1	11.1	39.0	35.0	98.1	114.7	102.2	89.8	77.4	64.9
136	-4.5	1.	0.	5.0	0.3	10.9	40.0	32.7	84.6	84.6	73.9	63.2	52.5	41.8
141	-5.9	2.	1.	5.7	0.3	10.8	41.0	29.7	91.1	108.7	95.5	82.4	69.2	56.0
146	-6.2	2.	0.	5.6	0.8	10.3	43.5	29.0	121.7	121.7	108.2	94.8	81.4	68.0
151	-5.7	2.	1.	5.7	1.0	10.1	44.5	29.1	99.2	116.5	103.5	90.5	77.5	64.5
156	-6.4	2.	1.	5.8	0.9	9.9	46.0	27.1	108.2	126.8	112.8	99.9	84.9	71.0
161	-5.7	2.	1.	6.3	1.5	9.2	50.0	23.[illegible]	106.[illegible]	125.0	111.1	97.2	83.3	69.4
166	-4.9	2.	1.	6.8	1.9	8.9	53.0	19.8	100.1	118.4	104.7	91.0	77.3	63.6
171	-4.4	2.	1.	7.0	2.2	8.2	55.0	17.0	96.9	114.9	101.[illegible]	87.9	74.4	60.9
176	-4.9	2.	1.	7.4	3.0	7.6	58.0	13.3	115.2	134.8	120.1	105.4	90.8	76.1
181	-3.6	2.	1.	8.7	3.5	6.8	61.0	5.[illegible]	103.2	123.[illegible]	108.3	93.0	77.6	62.3
186	-2.6	2.	1.	8.0	4.6	6.0	63.0	4.4	106.1	123.9	110.6	97.3	84.0	70.6
191	-0.2	1.	1.	7.8	5.5	5.4	66.0	2.2	87.6	97.8	87.6	77.4	67.3	57.1
196	2.6	2.	1.	8.1	5.8	5.3	66.0	0.7	46.3	55.7	48.7	41.6	34.6	27.5
201	1.4	2.	0.	8.3	6.1	5.3	66.0	0.1	80.9	80.9	72.0	63.1	54.2	45.4
206	1.4	2.	0.	8.2	5.9	5.2	66.0	-0.1	76.0	76.0	67.2	58.5	49.7	40.9

McGILL UNIVERSITY COMPUTING CENTRE

NAME=CHILD(N4)   PHASE=ONE   STANCE=ONE   CONDITION=LORDOSIS

NF	ALPHIO	BETAO	D2	D3	D4	F
15	32.5	56.0	5.1	32.1	1.4	31.8

FRAME	XE	SOL	GAS	XA	XB	YA	THETA	ALDELT	PNEMG	PPOS	PN25	PN50	PN75	PN100
1	0.4	3.	0.	8.3	8.2	5.2	62.5	-0.4	127.9	127.9	118.0	108.1	98.1	88.2
6	1.0	3.	0.	8.3	8.1	5.2	63.0	-0.4	119.6	119.6	110.2	100.8	91.3	81.9
11	0.5	3.	0.	8.2	8.1	5.2	62.0	-0.1	127.9	127.9	118.0	108.1	99.2	88.3
16	0.7	3.	0.	8.4	8.5	5.1	63.5	-1.2	131.1	131.1	121.2	111.2	101.2	91.2
21	0.7	3.	0.	8.3	8.1	5.2	61.5	-0.4	124.6	124.6	114.8	105.0	95.2	85.4
26	0.6	3.	0.	8.3	8.1	5.2	62.0	-0.4	126.3	126.3	116.4	106.5	96.5	86.6
31	0.8	3.	0.	8.3	8.1	5.2	62.0	-0.4	123.0	123.0	113.3	103.6	93.9	84.3
36	0.9	3.	0.	8.3	8.2	5.2	62.0	-0.4	122.9	122.9	113.3	103.8	94.2	84.7
41	0.7	3.	0.	8.3	8.2	5.1	62.0	-0.9	126.2	126.2	116.4	106.6	96.7	86.9
46	0.3	3.	0.	8.4	8.2	5.1	62.5	-1.7	133.1	133.1	122.6	112.1	101.6	91.1
51	0.7	3.	0.	8.2	8.1	5.1	62.0	-0.6	124.6	124.6	114.9	105.2	95.5	85.8
56	0.4	3.	0.	8.4	8.1	5.2	62.0	-0.7	129.8	129.8	119.4	109.1	98.8	88.4
61	0.6	3.	0.	8.3	8.1	5.2	64.0	-0.4	126.3	126.3	116.4	106.5	96.5	86.6
66	0.1	3.	0.	8.2	7.8	5.2	64.0	-0.1	129.9	129.9	119.4	109.0	98.6	88.1
71	0.2	3.	0.	8.2	7.8	5.2	64.0	-0.1	128.2	128.2	117.9	107.6	97.3	87.0
						MEAN=	62.6		126.8	126.8	116.8	106.9	96.9	87.0

ACHILLES TENSION(MEAN)=   28.4

NAME=CHILD(14) PHASE=ONE STANCE=ONE CONDITION=EQUINUS AND LORDOSIS

NF	ALPHAO	BETAO	D2	D3	D4	F
45	32.5	56.0	5.1	22.1	1.4	31.8

FRAME	XF	SOL	GAS	XA	XB	YA	THETA	ALDELT	PNEMG	PPOS	PN25	PN50	PN75	PN100
1	-1.0	1.	1.	8.4	7.6	5.3	63.0	-0.2	121.1	145.3	133.2	121.1	109.0	96.9
6	-0.7	2.	1.	8.4	7.6	5.3	64.0	-0.2	124.6	140.3	128.5	116.8	105.1	93.4
11	-0.2	2.	1.	8.4	7.7	5.3	64.0	-0.2	118.7	133.5	122.4	111.3	100.2	89.1
16	-0.2	2.	1.	8.3	7.6	5.3	65.0	0.1	111.2	125.1	114.6	104.2	93.8	83.4
21	-0.5	2.	1.	8.2	7.5	5.3	63.0	0.4	122.3	135.1	124.0	112.9	101.6	90.5
26	-0.4	2.	1.	8.2	7.5	5.3	63.0	0.4	118.7	133.5	122.4	111.4	100.3	89.3
31	-0.2	2.	1.	8.3	7.5	5.3	63.0	0.1	115.6	130.2	119.2	108.3	97.4	86.4
36	-0.8	3.	1.	8.2	7.1	5.3	63.5	0.4	122.2	133.8	122.2	110.7	99.1	87.6
41	-2.5	4.	1.	8.2	6.3	5.5	65.0	1.4	140.2	151.3	137.5	123.7	109.9	96.1
46	-5.4	4.	2.	7.8	5.6	6.5	59.5	7.4	165.1	186.8	170.5	154.2	137.9	121.5
51	-3.4	4.	2.	7.8	5.3	6.8	59.0	8.6	130.0	148.4	134.6	120.9	107.1	93.3
56	-5.1	5.	2.	7.4	5.0	7.6	55.0	13.3	154.7	171.9	156.8	141.8	126.8	111.7
61	-5.0	5.	3.	7.1	4.8	8.3	50.5	17.0	145.2	166.0	152.4	138.1	123.7	109.4
66	-7.0	5.	3.	6.8	4.5	8.5	49.0	18.8	171.0	195.3	179.1	162.9	146.7	130.4
71	-6.5	5.	3.	6.9	4.9	8.7	49.0	19.1	159.8	193.4	177.7	161.9	146.2	130.5
76	-6.3	5.	2.	6.4	4.5	9.3	45.0	23.0	155.7	174.8	160.7	146.5	132.4	118.3
81	-6.5	5.	4.	5.6	3.9	10.2	39.5	28.7	151.7	176.4	162.5	148.6	134.8	120.9
86	-7.2	5.	5.	4.9	2.9	11.0	35.0	[illegible]	142.7	169.9	156.1	142.7	129.1	115.5
91	-7.2	5.	4.	5.1	2.5	10.6	38.0	31.8	140.6	165.3	151.4	137.5	123.6	109.8
96	-5.4	5.	5.	5.4	2.7	10.3	40.0	29.8	116.9	141.8	129.3	116.9	104.4	91.9
101	-5.8	3.	3.	5.4	2.7	10.3	40.0	29.8	119.8	145.2	132.5	119.8	107.1	94.4
106	-7.0	3.	3.	5.2	2.9	10.5	38.0	31.2	140.8	168.4	154.6	140.8	127.0	113.2
111	-7.3	2.	2.	5.1	2.9	10.7	36.5	33.0	143.8	171.8	157.8	143.8	129.8	115.8
116	-5.6	2.	2.	5.6	3.3	10.2	41.0	28.7	126.1	151.6	138.8	126.1	113.4	100.6
121	-6.0	3.	3.	5.4	3.4	10.3	38.5	29.8	133.9	159.8	146.8	133.9	121.0	108.0
126	-5.3	3.	3.	3.9	2.5	11.5	29.0	38.8	111.9	132.4	122.1	111.9	101.7	91.4
131	-7.3	2.	2.	4.0	2.6	11.7	32.0	38.6	142.5	167.7	155.1	142.5	130.0	117.4
136	-5.6	2.	3.	4.2	3.1	11.3	29.5	37.1	121.0	147.2	136.3	125.4	114.5	103.5
141	-5.5	2.	3.	4.3	3.3	11.2	30.0	36.7	122.6	148.8	137.9	127.0	116.0	105.1
146	-6.5	2.	3.	4.2	3.4	11.3	30.0	37.1	138.5	167.2	155.3	143.3	131.4	119.5
151	-5.7	2.	3.	4.7	4.0	10.9	33.0	34.2	135.7	163.7	152.1	140.4	128.7	117.1
156	-4.4	2.	2.	5.1	4.4	10.7	34.5	32.0	127.2	148.6	137.9	127.2	116.5	105.7
161	-4.6	2.	4.	5.3	4.4	10.5	35.0	30.7	125.2	152.1	140.9	129.7	118.5	107.3
166	-5.7	2.	5.	5.4	4.5	10.3	37.0	29.8	136.3	172.3	159.7	147.1	134.5	121.9
171	-5.4	2.	3.	5.6	4.6	10.2	37.5	28.7	139.0	169.0	156.5	144.0	131.5	119.0
176	-5.0	2.	2.	6.1	4.9	9.6	42.0	25.1	147.0	167.5	154.7	142.0	129.2	116.4
181	-5.0	1.	2.	6.5	5.3	9.1	45.0	22.0	138.6	174.2	160.9	147.5	134.1	120.8
186	-4.4	1.	1.	7.1	5.8	8.2	49.5	16.6	145.4	172.6	159.0	145.4	131.7	118.1
191	-3.1	1.	1.	7.3	6.3	8.0	50.0	15.1	134.1	158.9	146.5	134.1	121.7	109.3
196	-4.3	1.	1.	7.3	6.7	7.5	51.5	13.3	157.6	185.5	171.6	157.6	143.7	129.7
201	-5.0	1.	1.	7.5	7.3	7.1	53.5	10.9	176.7	207.1	191.9	176.7	161.5	146.3
206	-2.3	1.	1.	8.3	7.9	6.0	60.0	4.4	143.5	170.3	156.9	143.5	130.2	116.8
211	-1.7	1.	2.	8.5	9.7	5.7	61.0	1.3	157.4	174.8	161.8	148.7	135.7	122.7
216	0.7	1.	1.	8.6	9.5	5.3	67.0	-0.9	139.1	147.3	137.1	126.9	116.7	106.4
221	2.1	2.	0.	8.7	10.1	5.1	62.0	-2.1	116.6	116.6	109.3	102.0	94.7	87.4
226	3.4	2.	0.	8.6	10.3	5.2	62.0	-1.3	114.7	114.7	107.9	101.2	94.5	87.7

APPENDIX F

COMPILATION AND AVERAGING OF DATA

SUBJECT ADULT J.M.

	Equinus (degrees)		0.5	2.0	4.0	6.0	8.5	12.0	16.[illegible]
	Interval (degrees)		0-1	1-3	3-5	5-7	7-10	10-14	14-[illegible]
	No. of values		3	7	5	4	3	3	5
Equinus Continu-ous	Range of N.S.M. (kg.cm.)	min.	128.2	183.8	174.4	169.8	143.5	162.8	152.[illegible]
		max.	204.6	225.5	225.5	234.2	250.0	186.9	248.[illegible]
	Mean N.S.M.(kg.cm.)		145.3	161.9	203.5	209.3	220.7	172.1	204.[illegible]
Equinus & Lordosis Continuous	No. of values		17	5	2	2	3	5	2
	Range of N.S.M. (kg.cm.)	min.	210.2	345.3	362.3	376.0	372.7	355.0	357.[illegible]
		max.	358.6	379.2	400.2	390.5	380.0	410.8	373[illegible]
	Mean N.S.M.(kg.cm.)		288.2	358.1	381.2	383.2	381.8	379.3	365

SUBJECT ADULT J.M.

	Equinus (degrees)		0.5	1.6	8.4	8.0	14.9	18[illegible]
	Interval (degrees)		0-1	1.3-2.5	7.6-9.2	5.9-9.9	13.4-16.8	17[illegible]
	No. of values		12	5	7	8	7	7
Equinus Steps	Range N.S.M. (kg.cm.)	min.	114.2	143.4	209.4	202.2	207.7	21[illegible]
		max.	166.7	236.4	254.6	281.6	243.6	2[illegible]
	Mean N.S.M. (kg.cm.)		155.2	183.5	232.5	241.4	225.2	22[illegible]

SUBJECT ADULT J.M.

	Equinus (degrees)		0.5	2	8.2	9.1	17.2	2[illegible]
	Interval (degrees)		0.0-1.0	1.0-3.0	7-9.4	8.2-10.0	16.4-18.1	1[illegible]
	No. of values		17	5	7	6	6	7
Equinus & Lordosis Steps	Range N.S.M.	min.	196.8	317.7	363.8	364.7	358.8	3[illegible]
		max.	393.0	457.1	447.6	410.2	377.9	3[illegible]
	Mean N.S.M.		304.0	361.0	388.8	392.6	376.1	3[illegible]

1 of

APPENDIX F

COMPILATION AND AVERAGING OF DATA

SUBJECT ADULT J.M.

	2.0	4.0	6.0	8.5	12.0	16.0	20.0	24.0	28.0	32.0	36.0
	1-3	3-5	5-7	7-10	10-14	14-18	18-22	22-26	26-30	30-34	34-38
	7	5	4	3	3	5	4	4	6	9	14
.2	183.8	174.4	169.8	143.5	162.8	152.2	166.8	154.5	158.3	162.5	124.6
.6	225.5	225.5	234.2	250.0	186.9	248.8	249.1	218.5	223.7	247.8	189.4
.3	161.9	203.5	209.3	220.7	172.1	204.7	196.7	185.7	187.0	187.4	153.1
	5	2	2	3	5	2	2	3	4	--	5
.2	345.3	362.3	376.0	372.7	355.0	357.4	354.5	294.7	283.8	--	268.3
.6	379.2	400.2	390.5	380.0	410.8	373.7	357.0	369.2	359.5	--	353.6
.2	358.1	381.2	383.2	381.8	379.3	365.5	355.3	327.8	325.2	--	332.3

SUBJECT ADULT J.M.

5	1.6	8.4	8.0	14.9	18.0	29.3
	1.3-2.5	7.6-9.2	5.9-9.9	13.4-16.8	17.1-18.9	24.8-33.0
	5	7	8	7	7	10
4.2	143.4	209.4	202.2	207.7	211.1	180.5
6.7	236.4	254.6	281.6	243.6	261.7	272.4
5.2	183.5	232.5	241.4	225.2	226.0	214.3

SUBJECT ADULT J.M.

5	2	8.2	9.1	17.2	20.8	31
0-1.0	1.0-3.0	7-9.4	8.2-10.0	16.4-18.1	19.3-22.2	29.0-34.0
7	5	7	6	6	7	8
96.8	317.7	363.8	364.7	358.8	363.2	323.6
93.0	457.1	447.6	410.2	377.9	386.9	373.3
04.0	361.0	388.8	392.6	376.1	368.3	351.5

SUBJECT N_3

	Equinus (degrees)		0.5	2.0	4.0	8.5	12.0	16.0	20.0	24.0
	Interval (degrees)		0-1	1-3	3-5	7-10	10-14	14-18	18-22	22-26
Equinus No Lordosis	No. of values		10	3	2	--	2	3	2	3
	Range of N.S.M. (kg.cm.)	min.	25.2	73.0	93.0	--	82.9	66.6	91.0	74.5
		max.	73.7	86.4	97.3	--	105.4	87.9	97.2	97.2
	Mean N.S.M. (kg.cm.)		45.8	79.0	95.1	--	94.1	79.0	94.1	86.5
Equinus & Lordosis	No. of values		11	2	1	3	3	3	2	3
	Range of N.S.M. (kg.cm.)	min.	104.2	123.7	143.5	137.9	141.8	134.1	161.9	142.0
		max.	121.1	148.7		168.5	176.7	145.4	162.9	147.5
	Mean N.S.M. (kg.cm.)		111.5	136.2	143.5	154.2	158.7	139.2	162.4	145.3

SUBJECT MD1

Equinus (degrees)		0.5	2.0	4.0	6.0	8.0	10.0	12.0	14.0
Interval (degrees)		0-1	1-3	3-5	5-7	7-9	9-11	11-13	13-15
No. of values		9	14	2	8	16	0	0	1
Range of N.S.M. (kg.cm.)	min.	18.7	11.2	39.8	27.3	24.3			34.8
	max.	37.7	41.8	40.9	44.7	35.1			
Mean N.S.M. (kg.cm.)		25.2	28.2	40.3	32.7				34.8

SUBJECT MD2

Equinus (degrees)		0.5	2.0	4.0	6.0	8.0	10.0	12.0	14.0
Interval (degrees)		0-1	1-3	3-5	5-7	7-9	9-11	11-13	13-15
No. of values		26	12	1	5	2	8	6	3
Range of N.S.M. (kg.cm.)	min.	33.9	22.9	43.7	31.3	41.5	37.5	34.8	34.7
	max.	60.9	50.5		45.9	43.5	71.0	60.0	66.0
Mean N.S.M. (kg.cm.)		45.1	41.9	43.7	39.4	42.3	46.1	46.6	47.8

SUBJECT N_3

2.0	4.0	8.5	12.0	16.0	20.0	24.0	28.0	32.0	36.0	40.0
1-3	3-5	7-10	10-14	14-18	18-22	22-26	26-30	30-34	34-38	38-42
3	2	--	2	3	2	3	4	4	3	5
73.0	93.0	--	82.9	66.6	91.0	74.5	82.4	63.2	76.9	53.5
86.4	97.3	--	105.4	87.9	97.2	97.2	98.9	89.8	84.2	91.6
79.0	95.1	--	94.1	79.0	94.1	86.5	91.65	76.2	81.3	76.5
2	1	3	3	3	2	3	7	6	4	2
123.7	143.5	137.9	141.8	134.1	161.9	142.0	116.9	127.2	125.4	111.9
148.7		168.5	176.7	145.4	162.9	147.5	148.6	143.8	143.3	142.5
136.2	143.5	154.2	158.7	139.2	162.4	145.3	133.8	136.9	134.0	127.2

SUBJECT MD1

2.0	4.0	6.0	8.0	10.0	12.0	14.0	16	20.8
1-3	3-5	5-7	7-9	9-11	11-13	13-15	15-17	20.3-21.3
14	2	8	16	0	0	1	2	6
11.2	39.8	27.8	24.3			34.8	23.9	24.9
41.8	40.9	44.7	35.1				38.3	38.8
28.2	40.3	32.7				34.8	31.1	31.0

SUBJECT MD2

2.0	4.0	6.0	8.0	10.0	12.0	14.0	16.0	18.0
1-3	3-5	5-7	7-9	9-11	11-13	13-15	15-17	17-19
12	1	5	2	8	6	3	3	2
22.9	43.7	31.3	41.5	37.5	34.8	34.7	43.6	51.2
50.5		45.9	43.5	71.0	60.0	66.0	46.2	53.2
41.9	43.7	39.4	42.3	46.1	46.6	47.8	45.3	52.1

BIBLIOGRAPHY

1. Bar, E.: Elasticatsprunfungen der Gelenknorpel. Arch. Entw. Mech. Org. 108:739, 1927.
2. Barnett, C.H., Napier, J.R.: The axis of rotation of the ankle joint in man. J. Anat., London, 86:1, 1952.
3. Baron, J.B.: Presentation d'un appareil pour mettre en evidence les deplacements du centre de gravité du corps dans le polygone de sustenation. Arch. Mal. Prof. 25:41, 1964.
4. Baron, J.B., Filliozot, R.: Syndromes subjectives post-commotionnels ameliores par correction occulo-mortice. Arch. Mal. Prof. 25:328, 1964.
5. Basmajian, J.V.: Muscles Alive. The Williams and Wilkins Co., Baltimore, 1967.
6. Bell, J.: Treasury of Human Inheritance. Cambridge University Press, London, 1947.
7. Bourne, G.H. and Ma. Nelly Golorz: Muscular Dystrophy in Man and Animals. Hafner Publishing Co., New York, 1963.
8. Brantigan, O.C., Voshell, A.F.: The mechanics of the ligaments and menisci of the knee joint. J. Bone and Joint Surg. 25: 121, 1943.
9. Brash, J.C.: Cunningham's Textbook of Anatomy, 9th ed. Oxford University Press, London, 1951.
10. Braune, W., Fisher, O.: Ub den scherpankt des menschlichen Korpos mit ruchsicht auf die austrustung des deutschen infantenstem. Abh. d.K. Sachs Ges d Wiss. 15:2, 1889.
11. Braus, H.: Anatomie des Menschen. Springer, Berlin, 1921.
12. Carlsoo, S.: Influence of frontal and dorsal loads on muscle activity and on the weight bearing capacity of the feet. Acta. Orthop. Scand. 34:299, 1964.
13. Clemenson, S.: Some studies on muscle tone. Proc. R. Soc. Med. 44:637, 1951.
14. Close, J.R.: Motor function in the lower extremity. Charles C. Thomas, Springfield, Illinois, 1964.

15. Dempster, W.: Space Requirements of the Seated Operator. W.A.D.C. Technical Report 55-159, 1955. Report released to the Office of Technical Services, U.S. Dept. of Commerce, Washington, D.C.

16. Denny Brown, D.: The interpretation of the electromyogram. Arch. Neurol. Psychiat. 61:99, 1949.

17. Erb, W.: Veber die "juvenile form" der progressiven musleatrophie. Deutsch. Arch. Klin. Med. 34:467, 1884.

18. Frankel, V.H., Burstein, A.H.: Orthopaedic Biomechanics. Lee and Febinger, Philadelphia, 1970.

19. Goodsir, J.: The Anatomical Memoirs of John Goodsir. Black, Edinburgh, 1868.

20. Greenfield, J.G.: Personal communication to Miller, J.E.

21. Hellebrandt, F.A.G., Braun, G., Tepper, R.H.: The eccentricity of the mean vertical projection of the centre of gravity during standing. Physioth. Rev. 22:186, 1942.

22. Hellebrandt, F.A.G., Braun, G., Tepper, R.H.: The relation of the centre of gravity to base of support in stance. Amer. J. Physiol. 119:331, 1937.

23. Hellebrandt, F.A.G., Tepper, R.H., Braun, G.L., Elliot, M.C.: The location of the cardinal anatomical orientation planes passing through the centre of weight in young adult women. Amer. J. Physiol. 121:465, 1938.

24. Hicks, J.H.: The mechanics of the foot. J. Anat., Lond. 87:345, 1933.

25. Hinsdale, G.: The station of man considered physiologically and clinically. Amer. J. med. Sci. N.S. 93:478, 1887.

26. Hirsch, C.: A contribution to the pathogenesis of chondromalacia of the patella. Acta chir. Scand. 90(Supp. 83):1, 1944.

27. Hooton, E.A.: Up from the Ape. Macmillan, New York, 1947.

28. Inman, V.T., Saunders, J.B. de C.M., Abbott, L.C.: Observations on the function of the shoulder joint. J. Bone and Joint Surg. 26:1, 1944.

29. Isman, R.E., Inman, V.T.: Anthropometric studies of the human foot and ankle. Bull. Prosthetic Res., Washington, D.C. BR10-11, 97, 1969.

30. Johnston, T.B., Whillis, J. (editors): Gray's Anatomy, 31st ed. Longmans, London, 1954.

31. Joseph, J.: Posture and electromyography; Chapter XI in The Scientific Basis of Medicine Annual Reviews. Athlone Press, Univ. of London, 1963.

32. Joseph, J., Nightingale, A.: Electromyography of muscles of posture: leg muscles in males. J. Physiol. 117:484, 1952.

33. Kelton, I.W., Wright, R.D.: The mechanism of easy standing in man. Aust. J. exp. Biol. med. Sci. 27:505, 1949.

34. Krause, W.: Handbuch der Anatomie des Menschen. Leipzig. S. Hirzel, 1903.

35. Last, R.J.: Anatomy, Regional and Applied. Churchill, London, 1966.

36. Manter, J.T.: Movements of the subtalar and transverse tarsal joints. Anat. Rec. 80:397, 1941.

37. Miles, W.R.: Static equilibrium as a useful test of motor control. J. Indust. Hyg. 3:316, 1922.

38. Miles, W.R.: Static equilibrium; in Methods in Medical Research, Vol. 3, YearBook Pub. Inc., Chicago, 1950.

39. Miller, J.E.: Management of muscular dystrophy. J. Bone and Joint. Surg. 49:1205, 1967.

40. Miller, J.E.: Unpublished data.

41. Morgan, P.C., Watkins, R.: Centre of gravity movements in the standing human body. Nature 215:324, 1967.

42. Morton, D.J.: The Human Foot. Columbia Univ. Press, New York, 1935.

43. Morton, D.J.: Foot biomechanics: functional disorders and deformities. In Medical Physics (Glasser, O., editor), Year Book Publishers, Inc. 1:457, 1950.

44. Morton, D.J.: Human Locomotion and Body Form. Williams and Wilkins Co., Baltimore, 1952.

45. Muybridge, E.: The Human Figure in Motion. Dover Pub. Inc., New York, 1955.

46. Milhorat, A.T., Wolff, H.G.: Studies in disease of muscle. Heredity of progressive muscular dystrophy: relationship between age of onset of symptoms and clinical course. Arch. Neurol. Psychiat. 49:641, 1943.

47. Pearson, C.M.: Serum enzymes in muscular dystrophy and certain other neuromuscular diseases. New Eng. J. Med. 256, 1069, 1957.

48. Pearson, C.M., Choudhurys, R., Favler, W.M., Jones, M.H., Griffith, W.H.: Studies of enzymes in serum in muscular dystrophy. Paediatrics 28:962, 1961.

49. Robbins, S.L.: Textbook of Pathology with Clinical Application. W.B. Saunders, London, 1962.

50. Rose, G.K.: Correction of the pronated foot. J. Bone and Joint Surg. 44-B:462, 1962.

51. Scogland, J.E.: A quantitative study of normal and pathological station in human subjects. Med. Rec. 155:15, 1942.

52. Shy, G.M.: Personal communication to Miller, J.E.

53. Smith, J.W.: Muscular control of the arches of the foot in standing; an electromyographic assessment. J. Anat., Lond. 90:236, 1954.

54. Smith, J.W.: The forces acting at the human ankle joint during standing. J. Anat., Lond. 91:545, 1957.

55. Smith, J.W.: Observations on the postural mechanism of the human knee joint during standing. J. Anat., Lond. 90:236, 1956.

56. Steindler, A.: Mechanics of Normal and Pathological Motion in Man. Charles C. Thomas, Springfield, 211, 1935.

57. Thomas, D.P., Whitney, R.J.: Postural movements during normal standing in man. J. Anat., Lond. 93:524, 1959.

58. Vierordt, K.: Grundiss der Physiologie des Menschen. Tubingen, H. Lauppschen, 1862.

59. Walmsley, T.: The articular mechanism of diarthrosis. J. Bone and Joint Surg. 10:40, 1928.

60. Walton, J.N.: Clinical aspects of human muscular dystrophy. In Muscular Dystrophy in Man and Animals. Bourne, G.H., Ma. N. Galorz (editors), Hafner Publishing Co., New York, 1963.

61. Whitney, R.J.: The stability provided by the feet during maneuvers whilst standing. J. of Anat. Lond. 96:103, 1962.