THE STEP TEST FOR BIOMECHANICAL ASSESSMENT OF HUMAN LOCOMOTION FUNCTION

by

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CONTENTS LIST

ABSTRACT

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Locomotion analysis and lower limb action exploration in general has reached remarkable levels of sophistication in recent years. Such sophisticated developments have been accompanied by an apparently unavoidable and increasing complexity of apparatus and equipment. This has made installation of such facilities for routine clinical use expensive and complex and in consequence there are relatively few centres which such assessments have become available for disability diagnosis and treatment monitoring.

Concurrently there has been increasing attention directed to the possibility of developing a simple technique useable in the restricted space normally available in routine clinics. Grieve et al(1978)highlighted in their exploration of movement patterns of the lower limb the potential applicability for this purpose of a "step" test. In such a test the subject raises himself from a standing position on to a step of pre-determined height leading with either the right or left leg. The full cycle consists of a step up and a step down.

The aim of the investigation undertaken has been a definitive exploration of the step test in which in addition to kinematic characteristics, dynamic assessment of the variations involved was also to be included. It was found as work progressed that the full kinetic analysis required the development of an increasingly complex computer program suitable for the generalised variability of displacements and of the force actions involved in the step specified. As things have now developed the program presented in the thesis is a format of analysis that is able to handle walking on the flat, walking up and down ramps, walking up and down stairs, jumping etc, in fact any action in which the lower limbs are involved. The development of these analyses took up a far greater proportion of the total project time than was initially anticipated. Nevertheless this being the first time that such an all embracing program was attempted, it was felt worthwhile to reallocate the effort available in favour of the program design and specification.

Inescapably the actual applied investigation involving normal subjects and patients had then to be reduced to a pilot investigation. Even this pilot programme covering 5 normal subjects and 5 patients involved the detailed analysis of some 25,000 frames of film.

The results of these tests highlight the fact that the step test in this simple form will not produce the definitive clinical data hoped for. One of the conclusions of the investigation therefore amounts to a recommendation not to continue exploration of the simple step test. On the other hand data and experience gained points clearly to the significant potential of a test consisting of the subject moving up a step by graded and varying step heights in which monitoring the kinetic changes from step to step is likely to produce data of value in diagnosis and therapy monitoring. There was no time to undertake experimental work on this step concept apart from mooting its feasibility.

The thesis consists of six chapters:-

Chapter 1 is an introduction giving an appreciation of the background presenting the clinical requirements and the clearly demonstrated need for a simple means of patient assessment.

Chapter 2 puts forward a critical review of the literature and explores in outline the classic studies of human locomotion, the clinical applications of gait analysis and the biomechanical assessment of the stepping function.

In Chapter 3 the experimental investigations are outlined in the conventional manner providing the definition and planning of the project, the development of the relevant methodology, devices and apparatus. The chapter culminates in putting forward the experimental results in sample form in the text and in full in the relevant appendices.

Chapter 4 concerns the analysis of the data collected. It is in this chapter that the formulation of a pioneer system of analysis is put forward that permits the handling of generalised human motion involving the lower limb.

Chapter 5 discusses the applicability of the step test as explored to clinical requirements as defined. It highlights the significance of the techniques evolved and suggests that the step test in its simplest form is unlikely to be capable of development into an effective clinical tool.

The conclusions in Chapter 6 summarise the findings in direct statements.

The thesis concludes with the appropriate bibliography and 2 appendices which give an outline of all the work undertaken and completed.

ACKNOWLEDGEMENTS

This thesis could not have been written without the assistance which I have received from many people. Firstly, I am grateful to Professor R. M. Kenedi without whom this work would have never been accomplished. He also deserves my gratitude for his friendly supervision and understanding throughout the course of this project.

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CHAPTER 1

INTRODUCTION

1. INTRODUCTION

The need to develop a simple technique for clinical assessment of the locomotor function of the lower limb has increased considerably in recent years. More recently there has been increased interest in the study of activities other than level walking, such as stair and ramp ascending and descending.

It has been suggested by D'Angelo and Grieve (1977) that stepping could be employed as a suitable test to be used in a clinical environment. In 1978 Grieve et al have provided data on the kinematics of non-pathological subjects stepping on and off a platform. By interpolating the experimental results predictions have been made for the movements in the form of angular displacement of the limb segments which would be expected on a step of rise equal to 10% of a persons height.

The present project is, in fact, an attempt to test this hypothesis viz that the step test could be used as a clinical tool. A more sophisticated technique has been used in order to obtain a complete biomechanical description of the task. It was the author's view that the forces and moments had to be included in the analysis and to give a better understanding of biomechanics involved in the proposed test. Additionally it was felt that the data from both limbs should be collected simultaneously.

The step can be negotiated forward or backwords, upwards or downwards, so that for each side of the subjects (patients) there were four manoeuvres to be analysed. In order to accomplish such analysis a comprehensive computer programme had to be developed. Priority had to be given to the development of such a programme which could form the basis for further work in this area. Considering the pioneer aspect of the research, the time available for the development of the techniques and experimental procedure it was possible to only test five normals and five patients. Nevertheless it was found that certain preliminary conclusions could be arrived at. Modifications and suggestions for further work are included.

All possible exploration of the step test as suggested were investigated within the limitations of project time and laboratory facilities.

CHAPTER 2

CRITICAL REVIEW OF THE LITERATURE

2.1 The Classical Studies of Human Locomotion
2.2 Clinical Applications of Gait
2.3 Biomechanical Assessment of Stepping

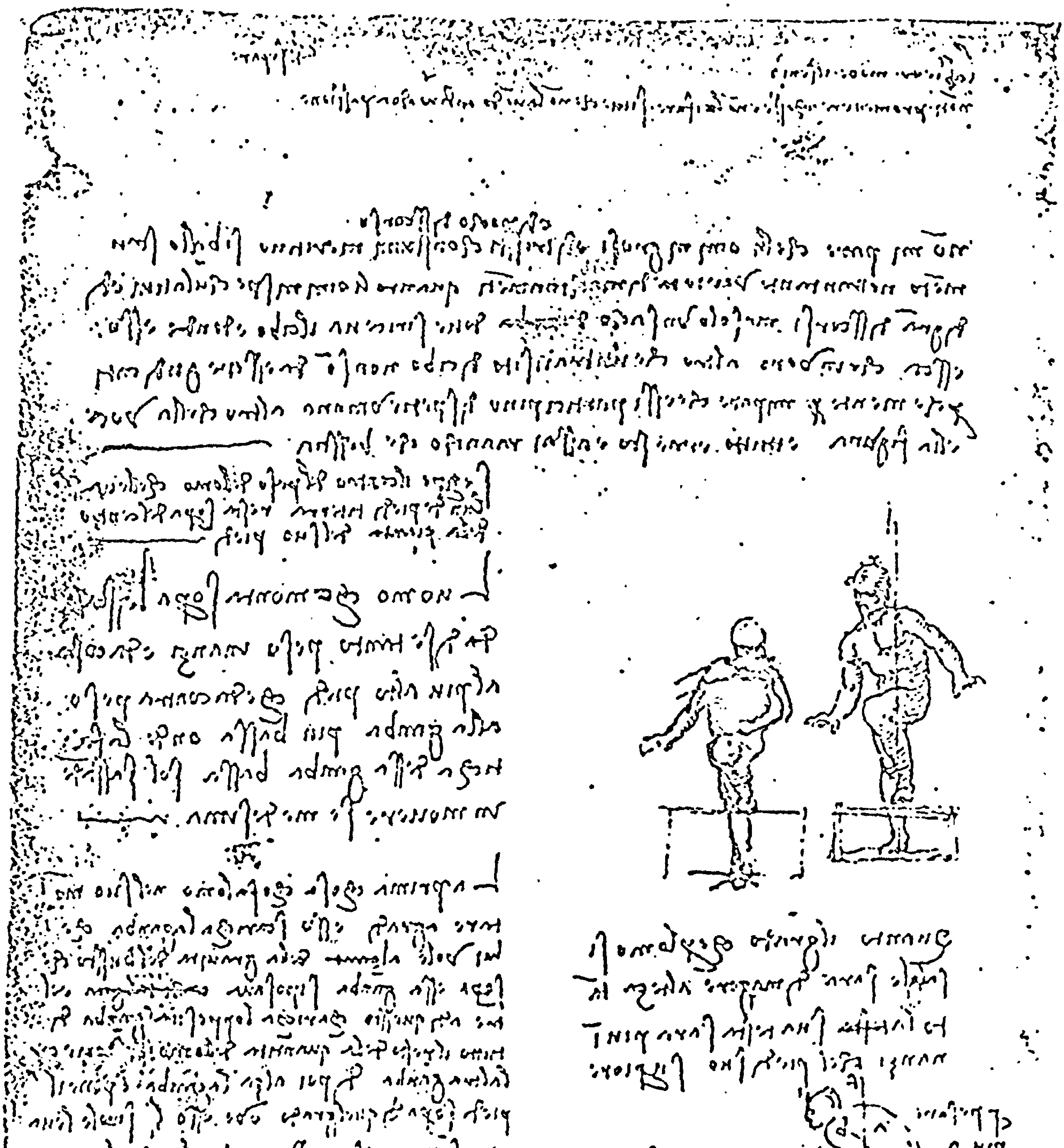


Fig 2.1

2. CRITICAL REVIEW OF THE LITERATURE

2.1 The Classical Studies of Human Locomotion

Locomotion is a phenomenon that has interested many investigators since the earliest days of our history. Walking is one of the few motor acts in which we all require a similar level of skill, since our working, domestic and social environments are designed to accommodate the walking man. Thus all possible modes of locomotion have attracted the interest of philosophers, mathematicians, anatomists, physiologists, surgeons, and recently bioengineers.

The motion of the human body in space has been investigated centuries before techniques were available for the accurate recording of the tasks. The title "Father of Kinesiology" is attributed to Aristotle (384 - 322 BC) whose treatise "Part of Animals, Movement of Animals, and Progression of Animals", has described for the first time the action of muscles and subjected them to geometrical analysis. He was the first to describe that in the process of walking rotatory motion is transformed into translatory motion.

Galen (131 - 201 AD) in his work "De Motu Musculorum" distinguished between motor and sensory nerves and between agonist and antagonist muscles groups.

Leonardo da Vinci (1452 - 1519) in his studies of anatomy was particularly interested in the structure and related performance of the human body. He has described the mechanics of the body in walking, stepping and jumping. (Fig. 2.1)

Galileo Galilei (1564 - 1643) who was a student of medicine before his searching for laws underlying certain physical phenomena, has also studied the motion of the human body. Alfonso Borelli (1608 - 1679) in his treatise "De Motu Animalium" among several things explained that bones serve as levers and that muscles function according to mathematical principles.

Direct experimentation on the movement of the body during locomotion has its foundations centuries later in the work of the Weber brothers (1836). They also initiated a series of experimental determinations of the whole body centre of gravity. The Webers observed the motions of the trunk through a telescope at a distance of 100 metres from the walkway, and in this way estimated the

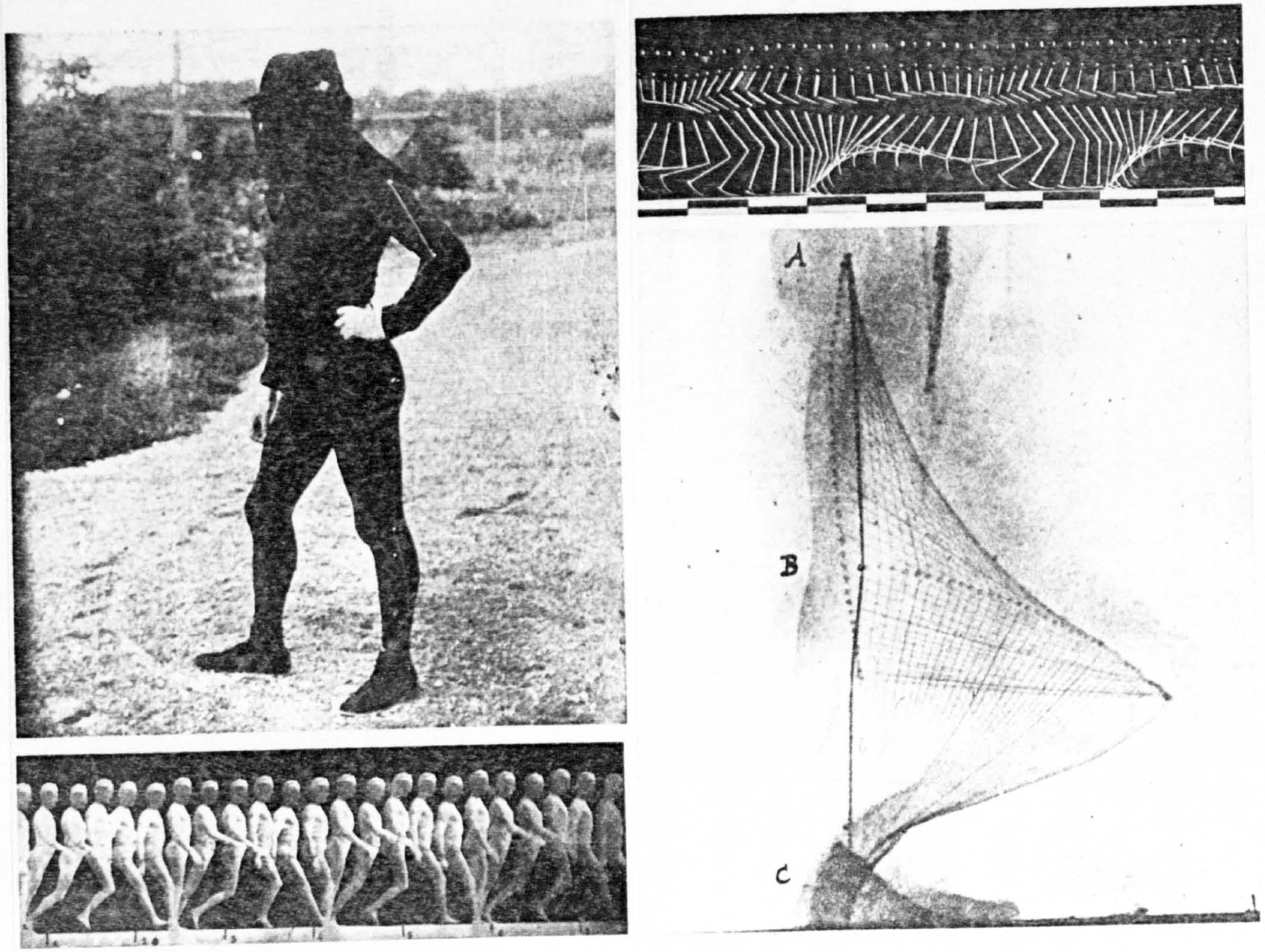


Fig 2.2

amplitude of the vertical oscillations and the inclination of the trunk to the vertical.

The first transducers attached to the body during locomotion were probably of the 'tabours' variety used by Marey (1885). His work is characterized by originality and inventiveness. He was quick to judge the importance of the work of Muybridge in 1882 which consisted of a series of photographs during the stepping of the trotting horse, by sequential exposures on 24 cameras mounted side by side. Marey however, devised a more elegant solution for field use in photographing birds and developed a photographic gun on which twelve exposures could be made in one second. The photographic plate was circular, and between each exposure (1/720th sec.) the plate was rotated 30 degrees. For the recording of human motion he invented an instrument called "chronocyclograph" which produced multiple exposures in a single photographic plate.(Fig. 2.2). A slotted disc rotated in front of the fixed plate making from 1/10th exposures to 1/5000th of a second. Experiments were carried out with the subjects dressed in many ways in order to produce better chronocyclographs. The precision offered by the new method allowed gait to be studied on a scientific basis.

Braune and Fisher (1890) used four chronocyclographs recording movements on the sagittal and coronal plane of walking. Incandescent tubes were attached to the limbs of a subject dressed in black. With this technique available these authors made laborious and detailed analysis of the human locomotion. From the kinematic descriptions of eleven points on the body Fisher (1898) by means of graphical differentiation, calculated the forces acting on the whole body centre of gravity. A notable aspect of the work of Browne and Fisher is the careful investigation in the area of anthropometry. Their investigation of the static and dynamic constants of human body segments provided data which was used by investigators for more than 50 years.

In 1916, Amar described an instrument that he had devised in order to evaluate artificial limbs. The apparatus which he called the "Trottoir Dynamographique" was the first force platform and consisted of two wooden beams, mounted on a cantilevered system of iron girders. In the region of each articulation a pneumatic chamber recorded pressure changes proportional to the applied force.

Amar reports the use of the force plate as an aid to the evaluation of pathological gait.

Elftman, in 1934 contributed to the study of gait with the design of a barograph which gave information on the distribution of pressure over the sole of the foot more accurately than had been previously possible. In 1939, he reported the design of a force plate which allowed him to calculate the instantaneous point of application of the force at the feet. Thus, by construction 'free body' diagrams for each segment of the lower limb and knowing the assumed centres of rotation of the joints Elftman calculates the net torque acting about the joints of the lower limbs, and from that an approximation for the net flexor and extensor muscles tensions throughout the walking cycle. In this classical paper, Elftman investigated the transfer of energy between the segments of the body in locomotion. An important concept introduced was that energy is being both supplied and absorbed by the muscles. These concepts had profound influence on future investigators in this area. Elftman, undertook further exploration on the principles of muscle action during locomotion (1941) with regard to the intrinsic property of the mechanics of muscle fibre.

Little advance was made until the work of Bresler and Frankel (1950) published, as an account of work done as part of the University of California programme. These studies basically repeated Elftman's own experiments using more sophisticated equipment. Bresler and Frankel used a platform instrumented with strain gauges to measure the vertical and horizontal components of applied forces, the torques, and to locate the instantaneous centre of pressure.

2.2 Clinical Applications of Gait

The majority of the work that has been done in the field of gait analysis has been undoubtedly oriented towards its possible applications in the clinical areas where locomotor assessment may be used either diagnostically or for noting progress as result of treatment. However, some of them are even more clinically oriented than the others, such as the work of Pauwells (1935). He calculated the magnitude and direction of the resultant force transmitted between the femoral head and the acetabulum for an individual standing on one leg. The value of this force he suggested was 2.92 times body weight. The object of this work was to improve a technique for osteotomy of the hip joint.

The College of Engineering in collaboration with the Medical School of the University of California (1947) carried out an extensive locomotion study in normal and amputated subjects. The purpose of the research was to achieve improvements in the design of artifical limbs. The most significant development of the California Group was the design and construction of an accurate force-platform, which measured the components of the resultant force in three dimensions at the centre of the top plate and the component moments about these axes. They have used two force-plates (Klopsteg and Wilson 1954) avoiding the assumption of absolute symmetry in the forces developed by the two lower limbs. As part of the same project, Bresler and Berry (1951) had expanded the classical work of Fenn's calculations of energy and power input-output relationships during normal and amputee gait (Bressler, Radcliffe and Berry, 1958). They characterized gait as a "push-pull" mechanism involving the expenditure of energy by the posterior limb and the absorption of energy by the anterior limb. They also emphasised the value of the "lock-unlock-lock" sequence of events at the normal knee joint in maintaining the energy level of the head, arms and trunk (HAT) relatively constant. The positive moment immediately following heel strike indicated the resultant force passing anteriorly with respect to the knee joint giving the stability that the authors called "locking". The reaction moves to a line of action which falls posterior to the knee joint, referred to by the authors as "unlocking".

Marks and Hirschberg (1958) attempted to use a force platform on the analysis of hemiplegic gait, and were able to show significant differences in the vertical force and knee moment curves obtained from normals and hemiplegic subjects. Drillis in 1958 suggested that measurement of the time period between the two peaks of the vertical force, in relation to the total stance force may be a useful indicator of pathological gait.

The work of the Californian group was extended by Paul (1965). The line of actions and moment arms of the ilio-psoas, rectus femoris, gluteus maximus, biceps femoris, gluteus medius and adductor magnus muscles were approximated to by measurements related to elastic threads appropriately attached to a skeleton. The period of activity of these muscles was detected by surface electromyography. With the use of photography and force-plate the net force and moment at the hip were calculated throughout the complete walking cycle. Furthermore by making certain assumptions Paul was able to estimate the three components of force between the head of the femur and the acetabulum. His results showed peak joint forces of approximately six times body weight to occur during the first 20% of the walking cycle.

Rydell (1966) made direct measurements of these forces in vivo, using a strain gauge instrumented head of an Austin-Moore hip prosthesis. The forces have been recorded during locomotion and other activities post operatively of a subject. The results showed peak forces of approximately two time body weight in one subject and over three times body weight in a second subject. Some dependance on the speed of walking was shown.

Most of the investigations concerned with pathological locomotion have been limited primarily to kinematic studies. As a typical example, Saunders (1952) postulated six determinants that may be used to assess gait patterns, they are: Pelvic rotation, pelvic tilt, knee flexion in stance phase, foot mechanisms, knee mechanisms and lateral displacements of the pelvis. All these determinants act to produce a sinusoidal displacement of the centre of gravity of the body of low magnitude, since this requires the minimal expenditure of energy.

Murray (1964) carried out a comprehensive study on the kinematics of human locomotion, obtained from photographic techniques producing "stick diagrams". This study was carried out in order to provide normal standards with which measurements of abnormal gait may be compared. The data was obtained by interrupted-light photography and the subjects were appropriately marked with reflective targets. Speed and timing of gait, stride dimensions, angular and linear displacements of the trunk and the limbs were measured and analysed.

While many workers have derived important conclusions from information concerning the linear and angular displacements of parts of the body in space as a function of time, others have tried to make use of the angular displacements of the lower limbs by producing means for the presentation of this basic information

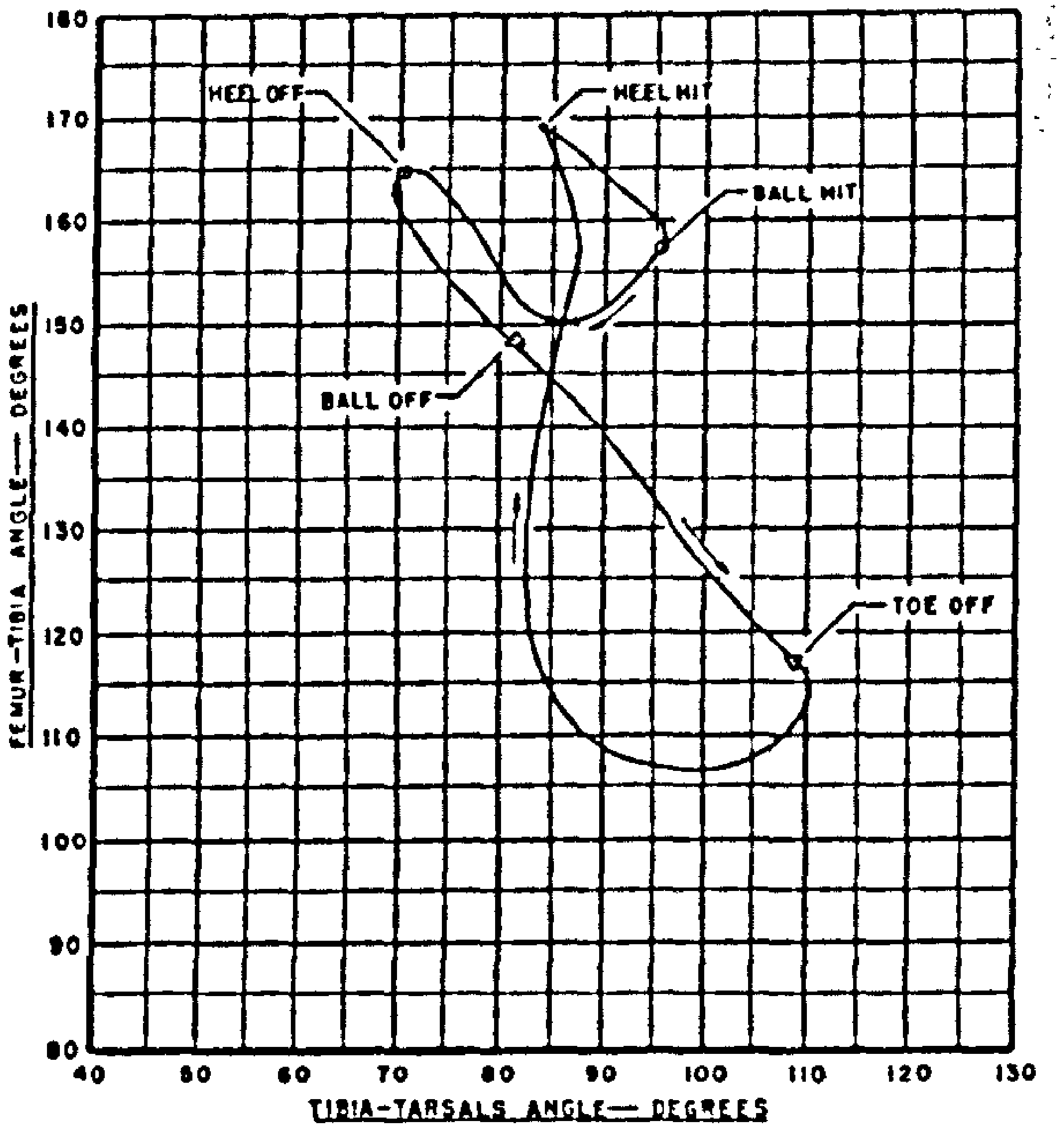


Fig 2.3

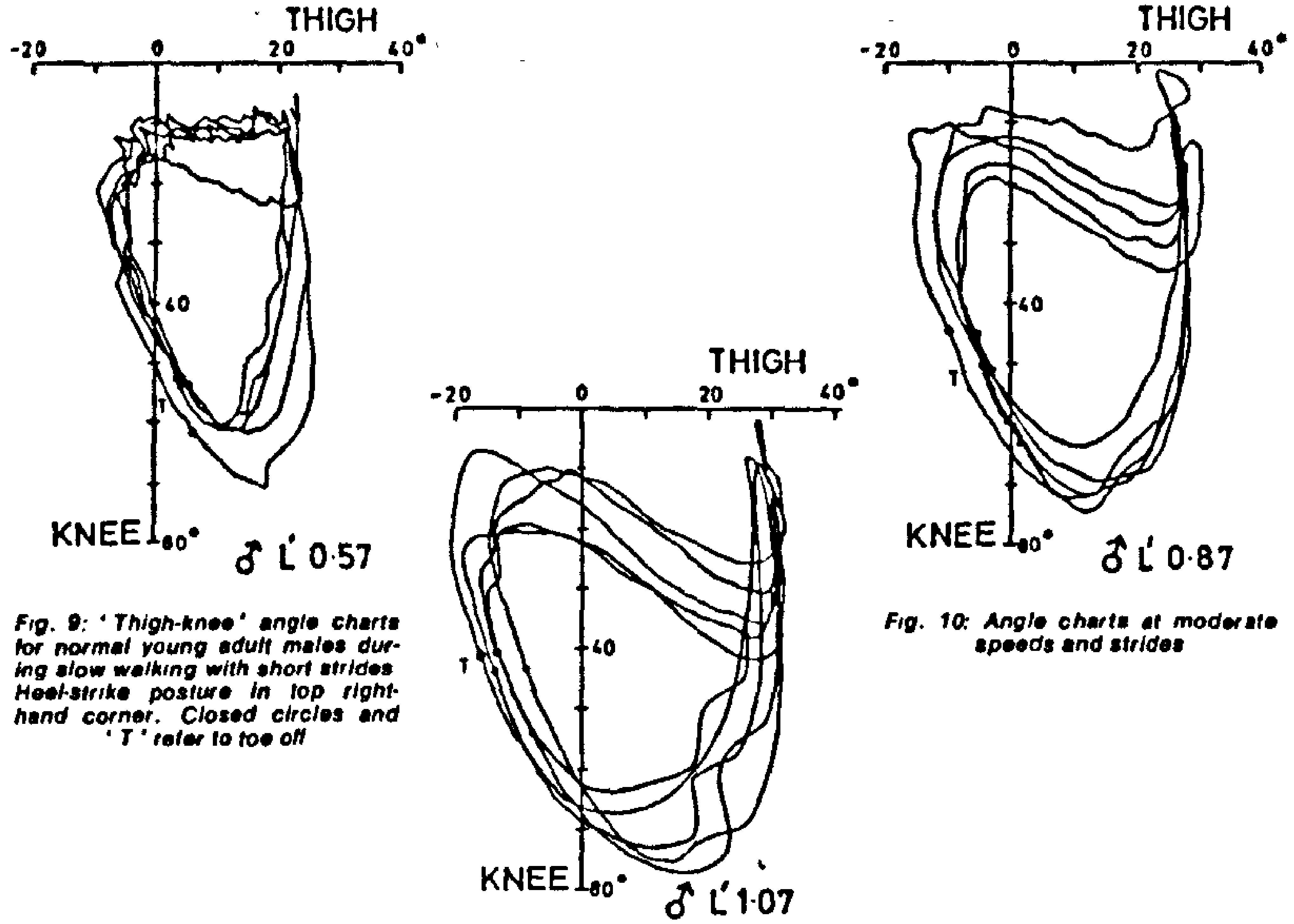


Fig. 9: 'Thigh-knee' angle charts for normal young adult males during slow walking with short strides Heel-strike posture in top right-hand corner. Closed circles and 'T' refer to toe off

Fig 11: Angle charts at fast speed and stride greater than stature

Fig. 10: Angle charts at moderate speeds and strides

Fig 2.4

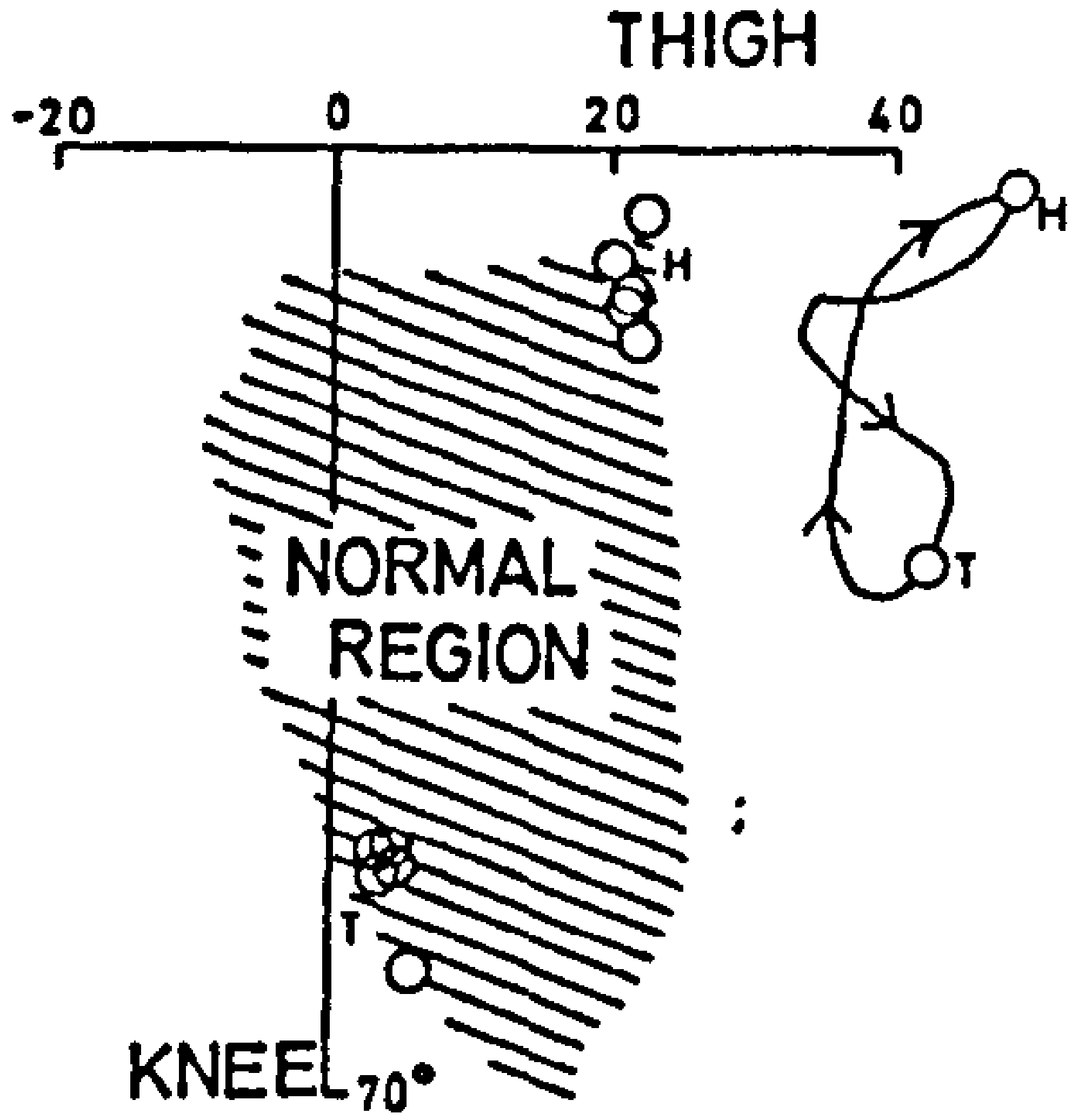


Fig. 12: Thigh-knee angle chart for patient with painful hip (on right) together with region of normal charts for slow walking 'H' and 'T' refer to heel-strike and toe-off respectively

Fig 2.5

in a meaningful way, enabling a pattern of movement to be characterized by a shape which is easily recognizable. This is achieved by producing a plot of one angle as a function of another angle. Wagner and Catranis (1954)(Fig.2.3) and Grieve (1968) (Fig. 2.4) . Grieve called these charts "angle-angle diagrams" and he explored the idea of studying families of similar shapes in order to identify pathological conditions. According to Grieve's philosophy these shapes would be easily recognizable by a mathematically untrained person (clinician, paramedic, etc) just by looking at the shapes of the diagrams (Fig.2.5).

2.3 Biomechanical Assessment of Stepping

Although there is literature of a substantial amount of research on the biomechanics of human locomotion in level walking, very little is to be found for other activities such as the 'step' action. (Refer to section 3.1).

Cappozzo and Leo (1974) have used Fourier series to obtain a mathematical description of the kinematics of normal subjects walking upstairs, and devised a mechanical model in order to calculate the muscular moments around the major points of the lower limbs. The object of the exercise was to produce a descriptive technique which would facilitate the collection of reliable data in order to detect the important features.of such manoeuvres so that the design of actual prostheses could be improved, and to be able to develop sophisticated walking machines. The authors described a characteristic pattern for all gait with a stride period from 1 to 1.50 seconds. No correlation could be made between the stride period and the anthropometric measurements, as the number of subjects tested was small. They suggested that when the stride period is outside of these above range some variations are evident, which could be correlated to a change of gait. The authors have presented an elegant technique to overcome the problem of handling kinematic data.

Grieve et al (1978) studied the kinematics of 21 normal subjects stepping at three different step heights. The sagittal plane rotations of the thigh and shank were recorded using a polarized light goniometer (Polgon). The purpose of this research was to attempt to establish a clinical test of the locomotor function of the lower limb. They have correlated the data between the heights of the step with the subjects stature and predicted norms for a step equal to 10% of the stature. Only one leg was monitored at a time, nc attempt having been made to measure both limbs simultaneously and only angular displacements were recorded. They expect that idiosyncratic differences could easily be detected by comparing the angle-angle diagram between subjects.

CHAPTER 3

EXPERIMENTAL INVESTIGATIONS

3.1 Definition and Planning of Project
3.2 Devices and Apparatus
3.3 Methodology and Data Collection
    3.3.1 General
    3.3.2 Laboratory Procedure
    3.3.3 The Tests
3.4 Experimental Results
    3.4.1 General
    3.4.2 Film Analysis

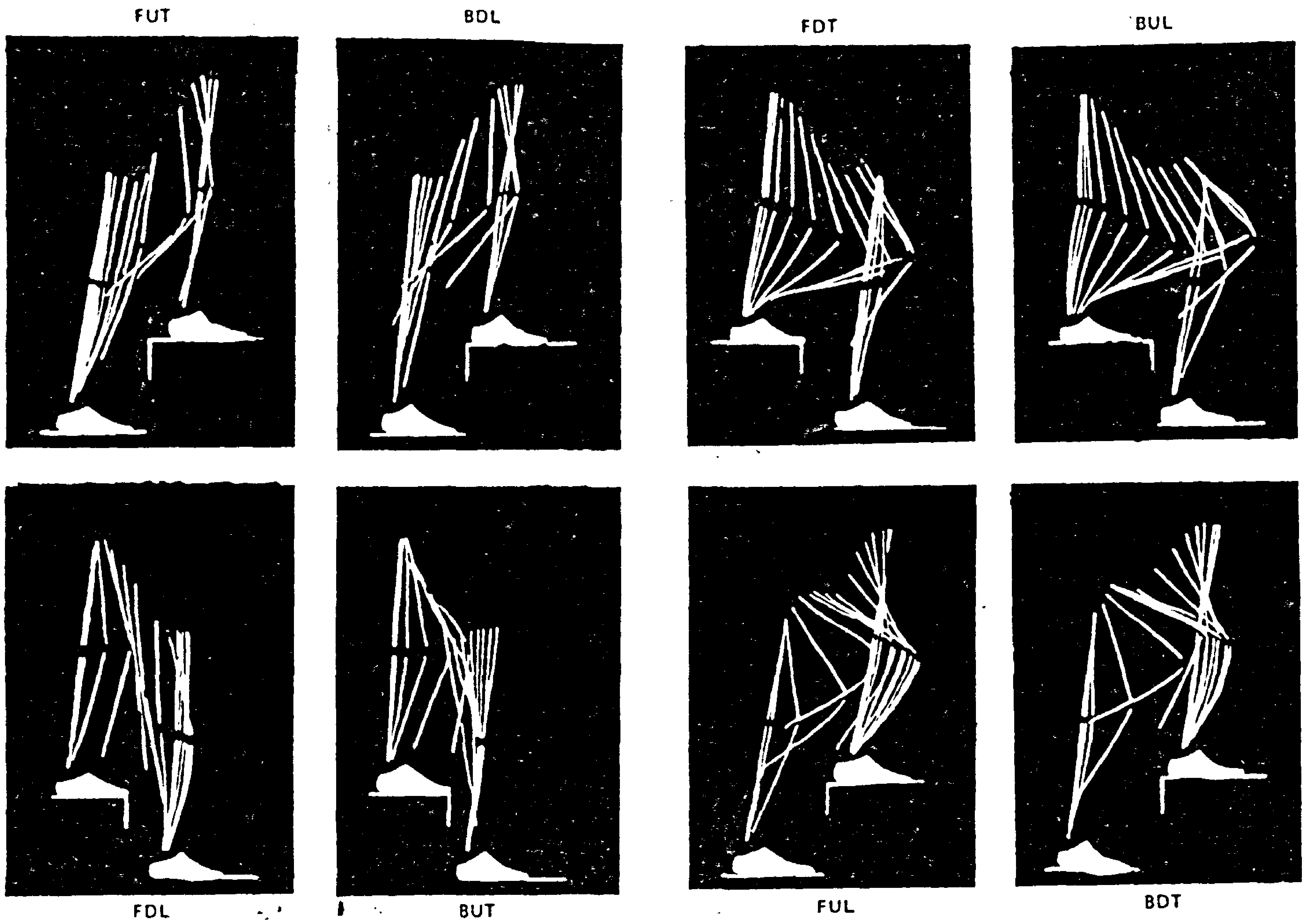


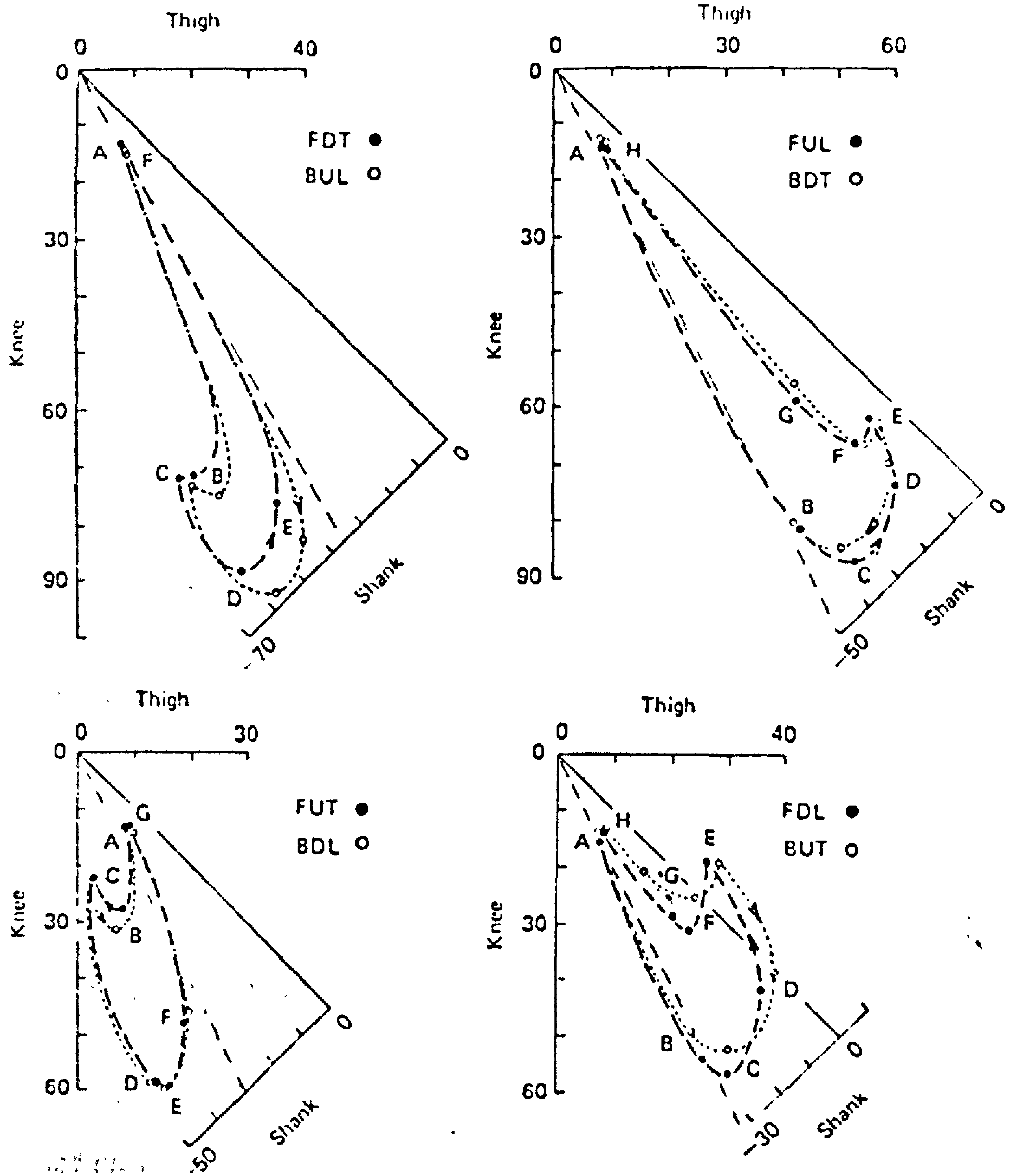
Fig 3.1 Strobe-flash photographs (re-touched) of marker tapes on the right limb of a normal adult male performing the four pairs of manoeuvres described on the text.

3. EXPERIMENTAL INVESTIGATIONS

3.1 Definition and Planning of Project

Many aspects of gait have been widely studied both in experimental and clinical contexts. These include the assessment of the kinematics of the body segments as well as the ground to foot reactions and intersegmental loads transmitted by the major joints of the lower limbs. Although some different activities such as stair and ramp ascent and descent have been reported by and large the most widely studied activity has been the steady state walking on level surfaces. It has been suggested (D'Angelo and Grieve, 1977) and (Grieve et al 1978) that stepping could be employed as a test to be used for clinical assessment of the locomotor function in the lower limb from considerations of standardization, accuracy, convenience and minimal demand on space. The stepping movements can be performed in either a forward (F) or backwards (B) direction and in relation to the level surface, it can be either upwards (U) or downwards (D). When a limb leads (L) upwards and forwards in a stepping action, anti-gravity movements are performed which are in reverse time sequence of those it executes as a trailing (T) limb in the gravity-assisted movements backwards and downwards. Such conjugate pair of movement exhibit remarkable similarities in normal subjects (Fig. 3.1) although flexions in one case are extensions in the other, movements that are assisted by gravity in one are opposed by it in the other, and the muscle that is acting concentrically in one case will be acting eccentrically in the other.

Grieve et al (1978) provided data on the kinematics of non-pathological subjects stepping on and off a platform of various height. Predictions have been made of movements which would be expected on a step equal to 10% of a persons height. The biomechanical interpretation of such a task suggests that there would probably be less similarity in the conjugated manoeuvre in the presence of neuromuscular and articular disorders: thus it might be possible to assess performance by making within-subject comparisons. Considerations based on these studies show that more extreme positions of the joints are involved (using the letters above) in the FUL-BDT and FDT-BUL manoeuvres. This is due to the fact that the body passes through a position in which one limb is in contact with the step at the



Predicted forms of thigh-knee diagrams to be expected at a relative step height equal to 10% of stature.

Fig 3.2

same time as the contralateral one is acting as a support on the ground. This is a closely linked manoeuvre in which the position of the leading limb must closely reflect the difference of the height of the step and the ground (Fig. 3.2).

The present work reports a comprehensive three dimensional biomechanical analysis of "stepping" both for normals and for patients suffering from knee disorders. The activities analysed included taking a single step on level and on a step equal to 10% of the subjects height, both including their inverse manoeuvres. From all the possible combination of postures, the FUL-BDT has been chosen, because it represents the most natural task, i.e. the one that the subjects would have more confidence in performing as well as the one which is more likely to show variations.

3.2 Devices and Apparatus

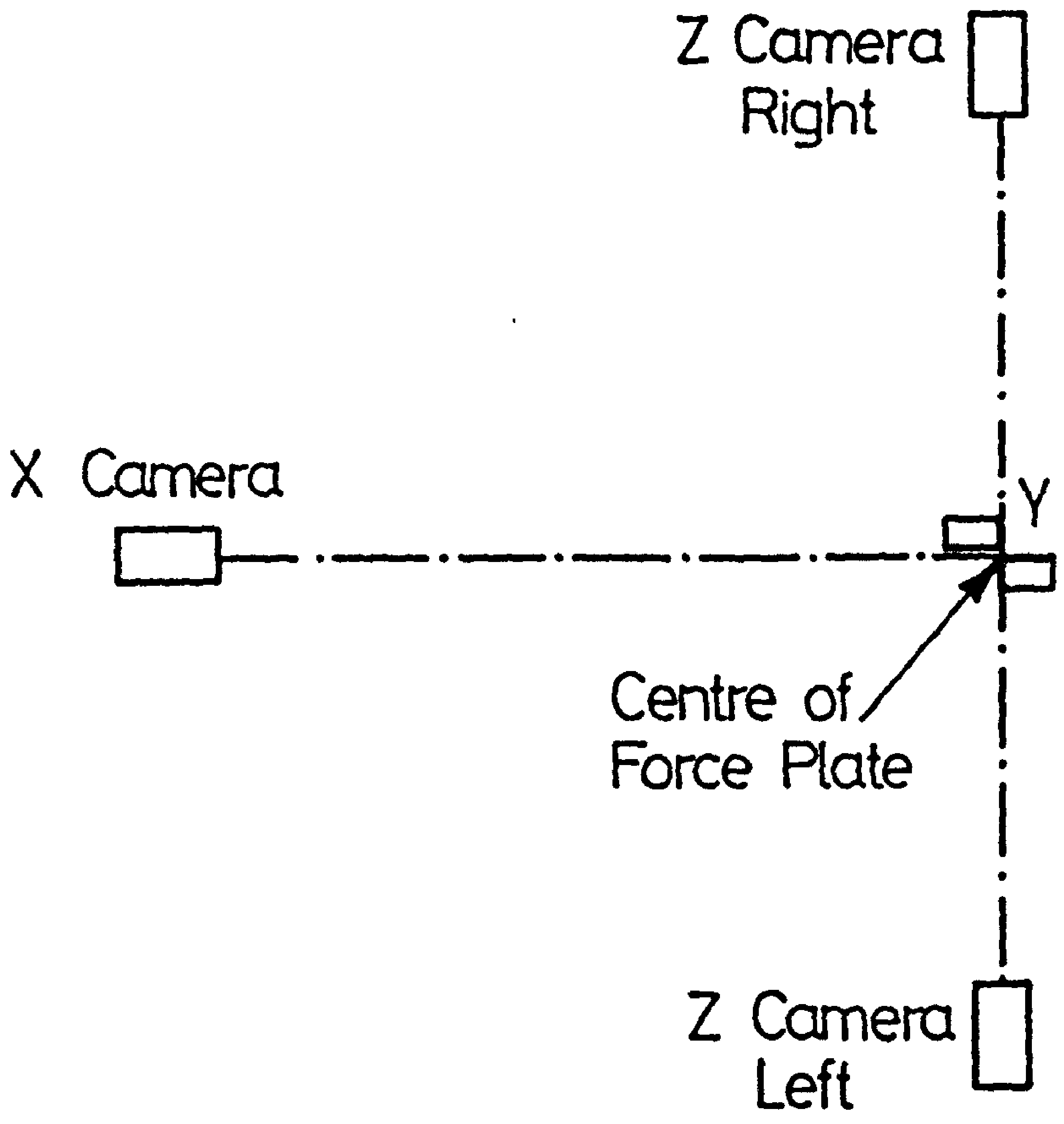
The tests were conducted using a walkpath incorporating two force sensitive platforms and three 16 mm cine-cameras. The forceplates are those supplied by the Kistler Instrument Company, and consist of two rigid steel plates supported on four transducers. The transducers which are of piezo-electric type, are mounted in such a way that it is possible to measure any force applied in terms of three orthogonal components (cartesian system) together with the three moments about the axes of the plate.

The platforms are mounted on concrete foundation blocks and are housed in a recess in the floor, so as the top of the plates are on the same level as the floor.

A set of nesting wooden platforms each of one cm thick were placed on top of the plate in order to create a step relative to 10% of the subject's height.

The twelve channels containing the force and the moment signals generated by the two force plates transducers are recorded and stored in magnetic tape at a sampling frequency of 50 Hz. This is achieved by means of a PDP-12 digital computer (Digital Equipment Co.). The analogue signals are later converted into digital form through a standard program (editor).

The kinematic data are obtained through photographic techniques and are recorded by three Paillard Bollex H. 16 (16 mm film) cine-cameras mounted



WALKPATH VIEWED FROM ABOVE

Fig. 3.3

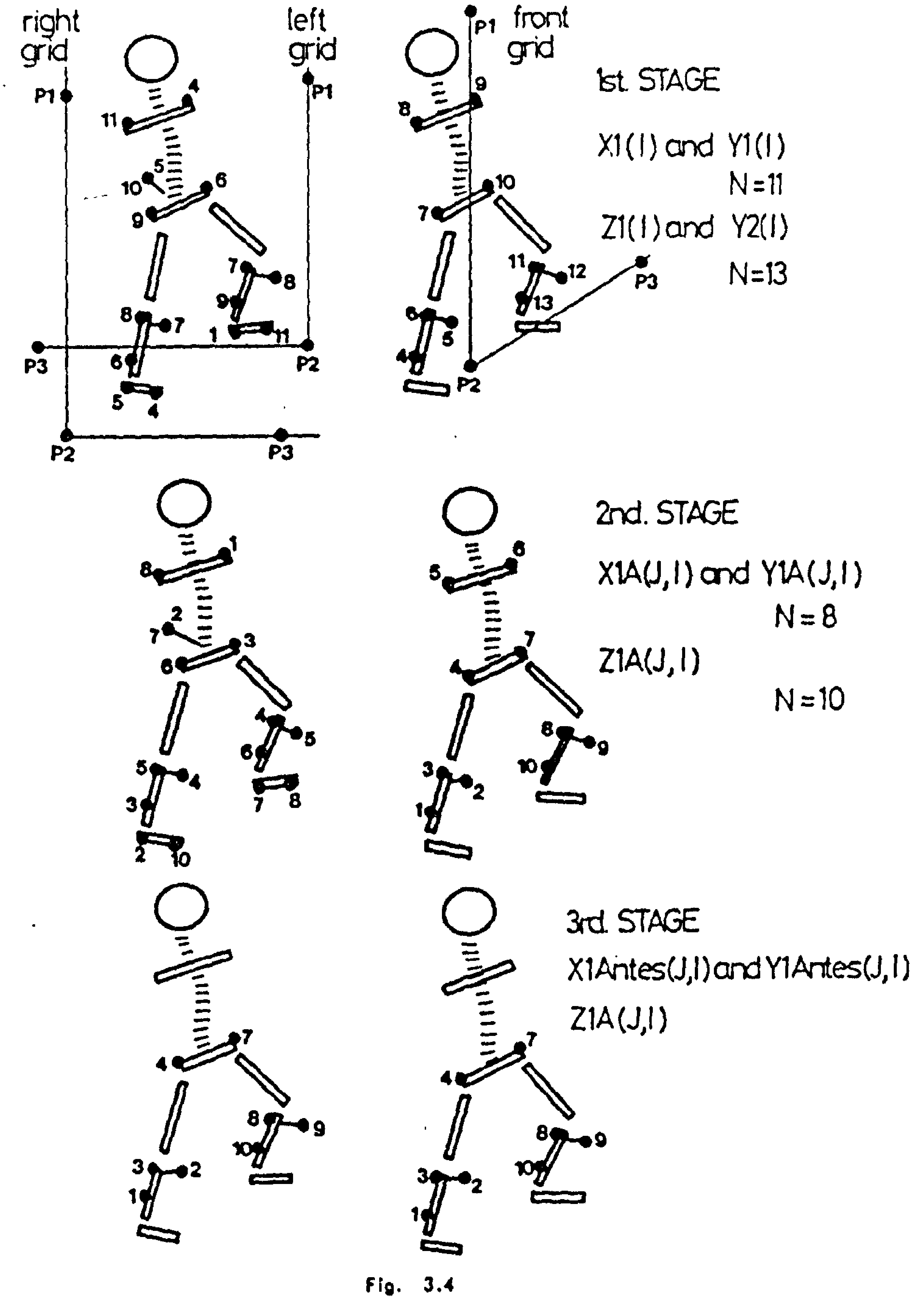

right grid
left grid
front grid
P1
P2
P3
1st. STAGE
X1(I) and Y1(I)
N=11
Z1(I) and Y2(I)
N=13
2nd. STAGE
X1A(J,I) and Y1A(J,I)
N=8
Z1A(J,I)
N=10
3rd. STAGE
X1Antes(J,I) and Y1Antes(J,I)
Z1A(J,I)

Fig. 3.4

in the X-Y and Z-Y grid planes (Fig.3.3). The shutter speed of the cameras is synchronized at 50 frames per second and colour film is used in each camera. Appropriate illumination is provided by overhead flood-lighting.

The force plate and cinematographic signals are related by firing a flash bulb in the fields of view of each camera. Additionally, firing of the flash bulb produces a transient voltage which triggers an event marker which is recorded on the magnetic tape containing the force plate data. Thus the film and the force data are related on line.

After each test the film is rewound in each camera and then re-exposed with the grid placed on the ground at the geometrical centre of the two force plates. The grid board consists of a black background with 5 inches (127 mm) square network of white lines.

3.3 Methodology and Data Collection

3.3.1 General

To obtain spatial co-ordinates from the limb displacements on the cine-films records, skin markers are required. The markers are constructed of wooden spheres of one cm diameter and painted a fluorescent yellow colour. The markers are attached to the subject's body by means of double-sided adhesive tape placed between the marker backing and the skin. The markers are placed on the surface of the following joints: achromio clavicular joint, anterior superior iliac spines (ASIS), a tail marker on the lombo sacral joint region, on the tibial tuberosity, on the fibula head region, on the lateral aspect of the shank, midway between the fibula head and the ankle lateral maleolus, and on the heel and head of the fifth metatarsal joint. All the markers have been given initial identification numbers which will then be changed according to the requirements at different stages on the main programme developed to calculate the co-ordinates of the joints centre (Fig. 3.4).

The pelvis has been considered as a rigid body, three markers (six quantities) are required to define its position in space. The same approach has been used for the shank. Once these segments are defined, the co-ordinates of the hip, knee and ankle joint centres are then derived. This procedure has been adopted to overcome a very common problem in defining the joint centres with markers placed on the skin surface of such joints; the difficulty due to the amount of movement of the skin around the joints during locomotion. The calculations are possible by stabilising the relating of patients anthropometric measurements with the marker system (this will be fully described in the chapter giving the mathematical analysis). To achieve this relationship it is necessary to take a static film shot (one frame of the film would be enough) of the subjects before the tests. This relates the joints' centre with the marker system relative to the grid for all the three cameras.

The hip joint centre is calculated relative to the position in space of the anterior superior iliac spines, this being based on a derived scaling factor for hip co-ordinate based in turn on the distance between the right and left iliac spines. These measurements were derived from skeletal and X-Ray measurements (in selected subjects) in order to obtain the scaling factor for each patients, where:
SCALING FACTOR = PATIENT MEASUREMENT / SKELETAL MEASUREMENT

The cine film recorded from the subject stepping on the sagittal (X,Y) plane is used to determine the X and Y co-ordinates of the joint centres, while the film recorded from the frontal (Z,Y) plane is used to measure the Z co-ordinate of the joint centred.

3.3.2 Laboratory procedure

Approximately one hour before the beginning of the test all the equipment is switched on and allowed to warm up. The cine cameras are loaded with 50 feet spools of Kodachrome 40 ASA 16 mm. film. This procedure is done with the cameras switched to "local mode" where they can be operated independently of each other. Illumination is provided by overhead floodlighting. The camera focus is adjusted and the lens apertures are set accordingly to readings of the photometer. It was found that best settings for the apertures were: f2.8 for the side cameras and f2 for the front one. The cameras are then switched to "remote mode" so that they can be operated synchronously from the control panel.

The charge amplifiers for the two force plates are divided into two sets for each plate: the top one which controls Fx, My, and Fz, is set to operate at 100 mechanical units per volt. While the lower one which controls Mx, Fy and

NAME	DATE
AGE	SEX
PATIENT	PATHOLOGY
TEST	
HEIGHT	
WEIGHT	

Distance between R and L ASIS	
Left ASIS to tail	Right ASIS to tail
ASIS to Gt. Troch. (Right)	ASIS to Gt.Troch. (Left)
Right thigh	Right shank
Left thigh	Left shank
Between shoulders	
Shoulder to ASIS(R)	Shoulder to ASIS (L)
Knee width (Right)	(Left)
Knee depth (Right)	(Left)
Ankle width (Right)	(Left)
Ankle depth (Right)	(Left)

COMMENTS

Fig. 3.5

Mz is set to operate at 20 mechanical units per volt. The buffer amplifiers for each channel is set to give the desired attenuation. At this stage the computer is already loaded with two tapes: one containing a standard programme called SAM12 (Jordan 1978) and the data tape. The programme has instructions for the total number of analogue and multiplexed channels to be used.

A flash bulb is positioned in the flash light tripod, which is mounted on the run number block. The tripod is then positioned so that it is visible to all cameras without obscuring the subject as the manoeuvres are performed. The flash switch is placed on the control planner to be operated together with the cameras and force plates switches.

The test subjects were subjected to a close medical examination and were asked to wear briefs. They were tested barefoot. Questions relating to the history of their locomotor disturbance were asked, anthropometric measurements were taken and the markers were placed on their anatomical landmarks. This procedure takes on average 25 minutes and all the measurements as well as the relevant clinical aspects were recorded in a standard form (Fig.3.5).

3.3.3 The Tests

The subject is asked to stand on the top of force-plate 1 (Fig. 3.6) and is allowed to perform as many manoeuvres as possible in order to feel confident with the test. These manoeuvres consisted of stepping forwards starting with the right leg on the top of force plate 2. Secondly stepping (Fig. 3.6) backwards on the top of force plate 1 this time starting with the left leg The manoeuvres were then repeated with a step equal to 10% of the patients height on the top of force plate 2.

The flash light was prepared, the computer reset and the force plates charge amplifiers inputs discharged. The cine cameras were started and then the subject was asked to perform the first manoeuvre. Each of the computer channels of stored load information was checked and if satisfactory and the spatial data appeared to be satisfactory (this includes the flash operation, cameras operation, and all markers being visible) the force plate data was written to the data tape. If the test was not satisfactory, then it was repeated, otherwise the same procedure was repeated for the next manoeuvres. On the test form all the details were noted, such as run number, block number on the computer tape etc. All the transducers

See Text for Details

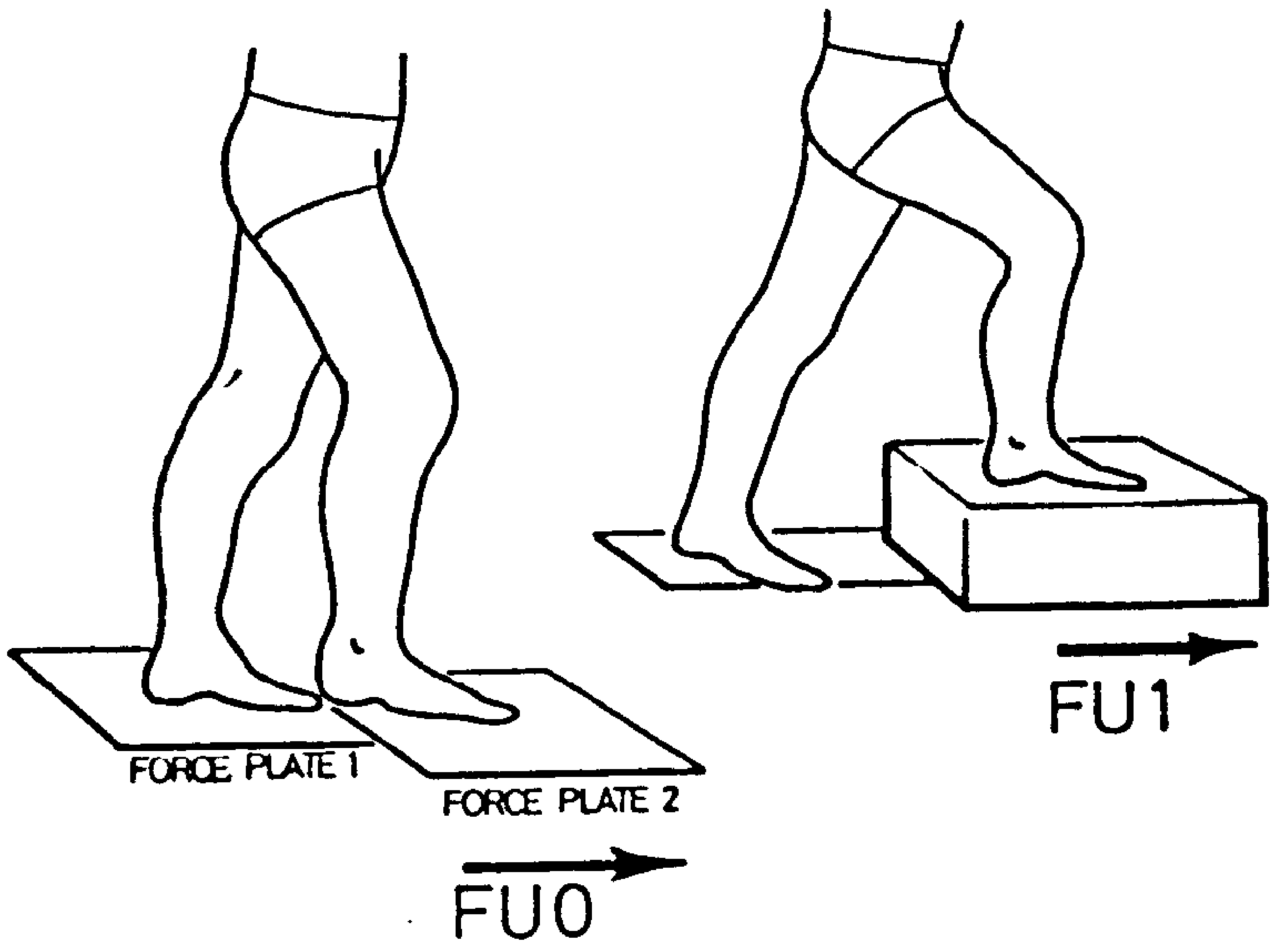


Fig. 3.6

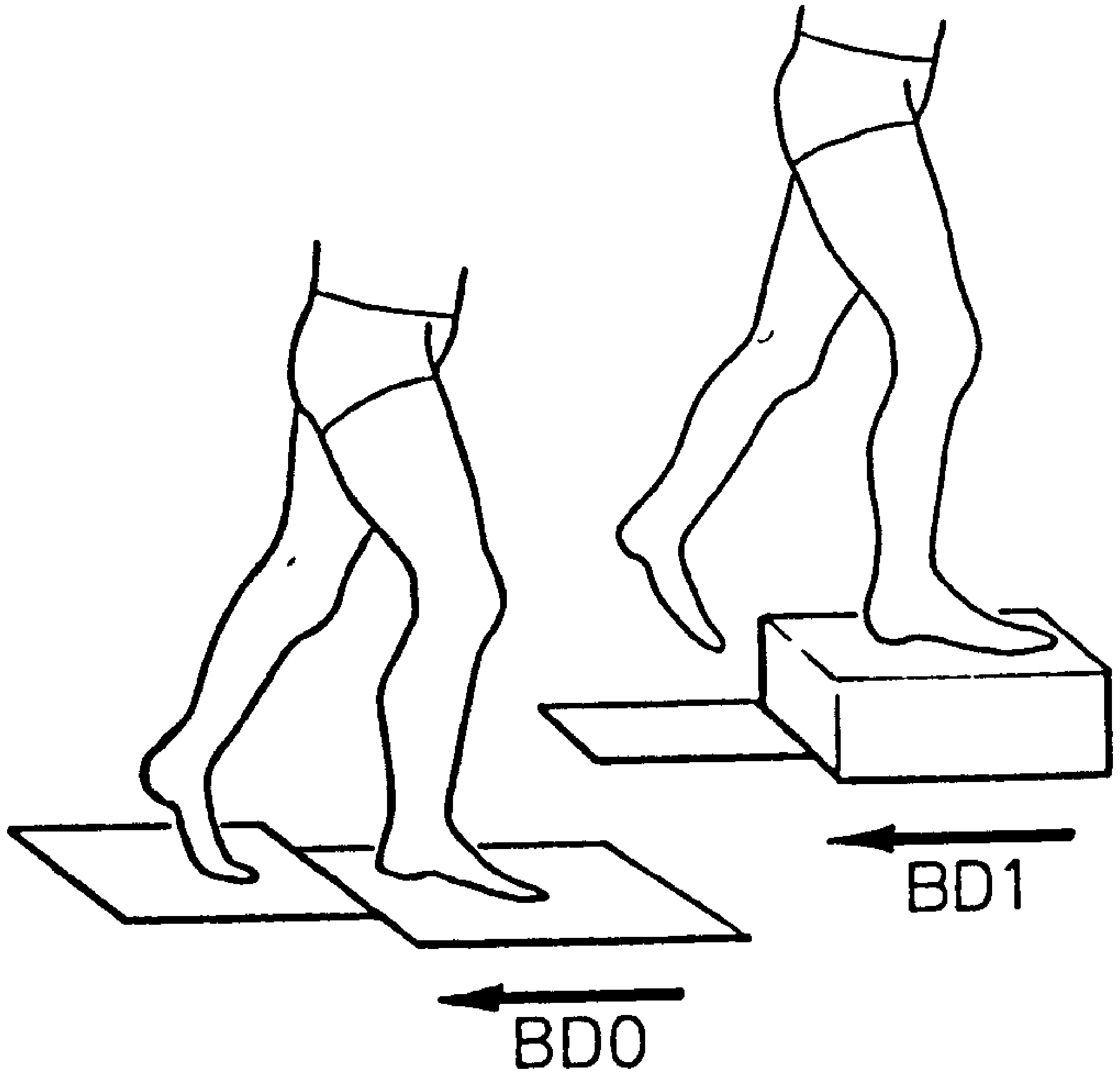


Fig. 3.7

and force plate amplifier gain settings were also recorded.

Once the tests were finished all the cameras were set to "local mode", lenses covered and the film rewound. A grid board consisting of a black background with 5 inches (127 cm) square network of white lines was placed on the ground at the geometrical optical axes of the three cine cameras. The lenses were uncovered and each camera was so re-exposed, superimposing the white square network on the film image.

3.4 Experimental Results

3.4.1 General

Force and moment data was stored on magnetic tape, while kinematic data was stored on cine film, both with sample intervals of 0.002 sec. and related on line through a flash bulb being fired in the field of view of the cameras and a transient voltage of the same event marking the force plate data. The method available to convey the data to CDC7600 computer to be processed is in the form of punched paper tape. (PPT)

Force and moment data was transferred from magnetic tape to PPT by means of the PDP12 computer, and this was achieved by means of a programme Editor (Jordan 1978). The data tape and the programme tape were loaded into the PDP12 and the desired block number selected. The events of the manoeuvres can be much more clearly seen using the Fy force plate data and with this channel displayed on the computer visual display unit (VDU) the first cursor was positioned on the beginning of the manoeuvre, while the second cursor was placed at the end of the event on the level of the base line. These positions were then checked for the other channels. All the values between and including the cursor values for each channel were then transferred to paper tape. The frame numbers of the cursors were recorded together with the frame where the flash event occurred.

3.4.2 Film analysis

The analysis of the cine-film records was performed in a semi-automated mode using a vanguard-PCD Spectro Digital Trace Reader. The film was projected by a Vanguard projector head onto a PCD reader glass screen. A gantry moved across the screen, carrying a cursor which could be moved vertically over the length of the gantry. Wire linkages on both gantry and cursor were connected to potentiometers, the output of which depend upon the X and Y co-ordinates of the cursors centre viewing sight. When a point on the body was located on the cursor sight, the depression of a switch caused the X and Y co-ordinates of the point to be punched onto paper tape.

Unfortunately, no printed output was available from the particular machine used, and human errors, eg. recording too few or too many co-ordinates per frame, were not detectable until a later stage of processing. As an aid to detecting errors of this nature, three fixed grid points were always recorded as the first data points in each frame enabling the co-ordinates at these points to be used as a basis for editing. Moreover, these three grid points are used to transfer the PCD reference system to the laboratory inertial frame system. The film is stepped through frame by frame until the frame in which the flash occurred is found, corresponding to the event marker on the force tape data. This event marker is related (as no. of points) to the point on the force data where the beginning of the movement occurs. This value was used on the film to identify the beginning of the manoeuvre. Both sides and front film were processed by following the same steps.

The paper tapes obtained by this procedure were read onto a magnetic tape in the CDC-7600 system at the University of London Computer Centre. Following editing subsequent processing of the co-ordinate data was carried out using FORTRAN IV programmes.

Control data such as subject and manoeuvre identification, camera specification etc, were typed directly onto paper tape in the correct sequence and spliced onto the beginning of each tape.

CHAPTER 4

ANALYSIS

4. ANALYSIS

4.1 Introduction

This chapter describes the theoretical analysis used to reduce the kinematics and force plate data recorded during the experimental sessions. The analysis converts the spatial data obtained from the cine films to real distance units and the force plate data into units of force, and thus loading information on the lower limb structures are obtained. A computer programme has been developed for this analysis (Appendix 1) and it is carried out in the following steps:

(a) Real distances and loads are obtained by applying parallax and scaling corrections to the spatial data and force calibration factors to the force plate data.

(b) From a kinematic static shot (the static test) recorded at the time of the experiment on the film, direction cosines are determined in order to define the co-ordinate system of the three markers mounted on the shank with respect to the ground reference system (GRS), and relate the shank system to the ankle and knee joints centre. The positional relationships between the shank markers and the joint centres remain the same during a test on a subject, but change from test to test and from subject to subject, thus requiring their positions to be redefined in the beginning of each test.

(c) During the dynamic test, the shank and pelvic co-ordinate systems of the structure is moving relative to the laboratory reference system for each frame of the film. At the instant of a particular frame, the moving structure and the reference system are fixed relative to one another, thereby permiting the direction cosines in the GRS of each of the co-ordinate system to be defined.

(d) Determinations of the loading between body segments at the anatomical joint centres, using both dynamic load and spatial data is obtained using Newtons' law.

(e) The direction cosines of the co-ordinate systems are relative to the GRS, thus a vector in any of the co-ordinate systems when multiplied by the direction cosine matrix, transfer the vector in the GRS.

The assumptions made for this analysis are as follows:

(i) Each structure, for which a co-ordinate system is defined is considered a rigid body; that is, the distance between the markers on the body is invariable.

The marker positions are chosen so that there is minimum skin movement relative to the respective bony prominences; therefore the marker is considered to be rigidly attached to the underlying skeletal structure.

4.2 Cine Film Analysis

The output data from the Vanguard-PCD film analyser is given with respect to the bottom left hand corner of the screen, and in order to refer all co-ordinates to the geometrical camera axes, which correspond to a centre line between the two force plates, calculations must be performed. For each frame analysed, three known fixed points of the grid were taken in order to account not only for the transfer of the origin of the co-ordinate system, but also to eliminate any small displacements of the film frame due to imperfections on the sprocket holes on the film. REF determines the laboratory reference axes system using the co-ordinate of the 3 auxiliary points marked on the grid. CHANGE transforms the co-ordinates of each marker on the frame from the vanguard system to the laboratory system.

The output is in arbitrary units representing voltages output from the Vanguard-PCD potentiometres. The values differ from the true physical co-ordinates, the difference depending on the magnification of the projected image. As all the calculations are performed using true co-ordinates, the image co-ordinate values have to be multiplied by a scaling factor (SCALING, in metres) derived from a known dimension on the film. For this particular analysis the scaling factor was calculated using 0.127 m.squares drawn on the grid as follows:

$$\text{SCALING} = \frac{0.127}{\text{The corresponding readings in Vanguard units}}$$

The force plate data on magnetic tape on the PDP 12 computer is in integer form between values of -512 to +512, where 512 represents an input voltage from the transducer amplifiers of 1 volt. To utilize this data in later calculations the stored information must be converted to the actual load units

Force= FP data x buffer const. x amplif. set. / 512 (in Newtons)

Moment= FP data x buffer const. x amplif. set.x 0.264 (in Newton meters)

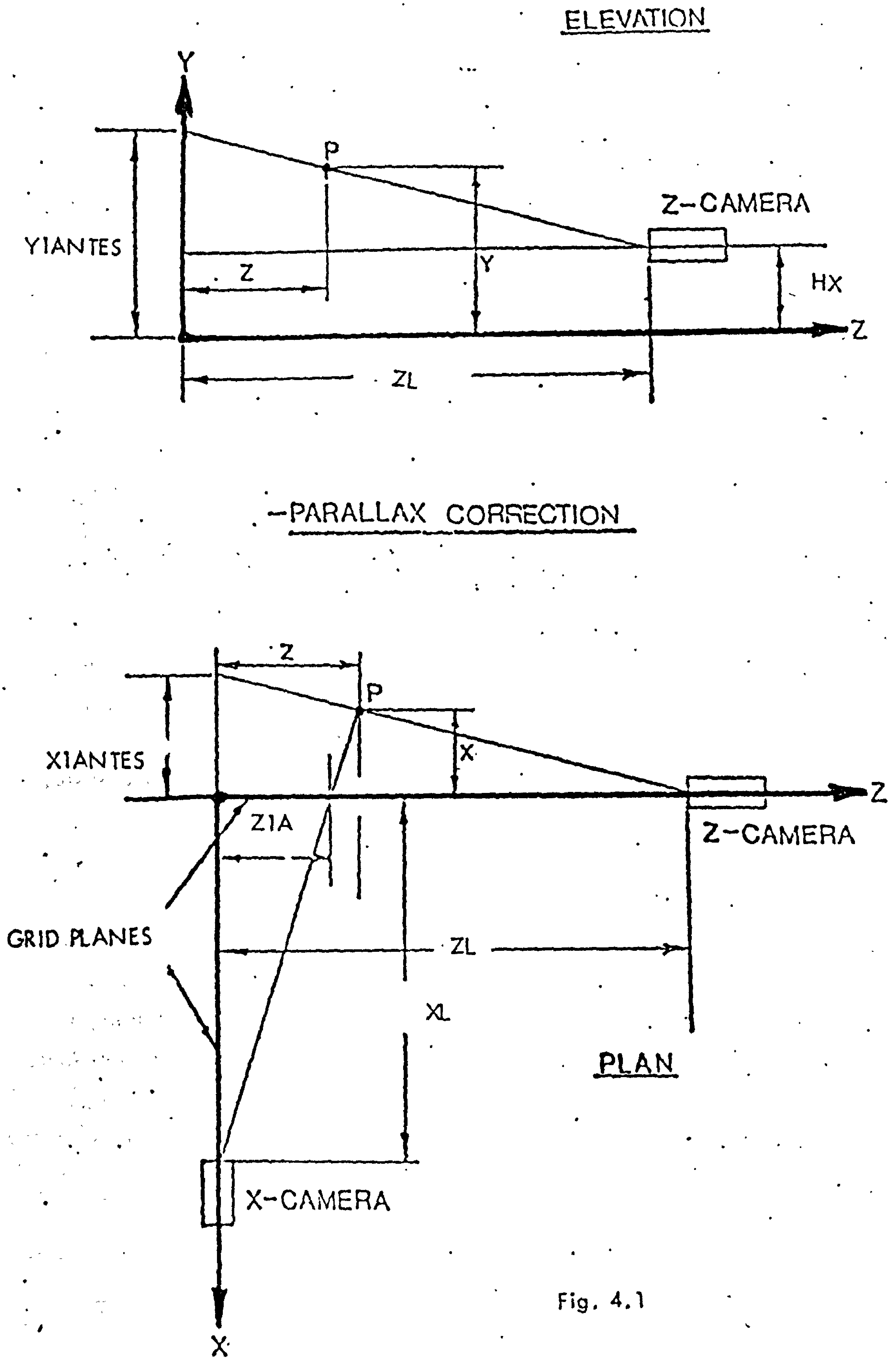

ELEVATION
Y
P
Z-CAMERA
YIANTES
Z
Y
HX
Z
ZL
-PARALLAX CORRECTION
Z
P
XIANTES
X
Z
Z1A
Z-CAMERA
GRID PLANES
ZL
XL
PLAN
X-CAMERA
X

Fig. 4.1

4.3 Parallax Corrections

The co-ordinates obtained by reading directly from the film grid are apparent and a parallax equation must be developed to determine the true X, Y and Z co-ordinates of the marker. This is achieved by simple geometrical analysis From (Fig. 4.1) it can be seen that (see Paul (1967) for full derivation of the equations):

$$Y = Y1ANTES - (Y1ANTES - HX)\ Z/XL \qquad (1)$$

$$X = X1ANTES - X1ANTES.Z/ZL \qquad (2)$$

$$Z = Z1A - Z1A.X/XL \qquad (3)$$

X1ANTES, Y1ANTES and Z1A are the apparent grid co-ordinates, and X, Y, and Z are the true co-ordinates. HX and HZ are the distances of the X and Z cameras from the origin of the system and HX is the height of the cameras above the floor.

From equations (2) and (3):

$$X = X1ANTES(1 - Z1A/ZL)/(1 - X1ANTES.Z1A/ZL.XL) \qquad (4)$$

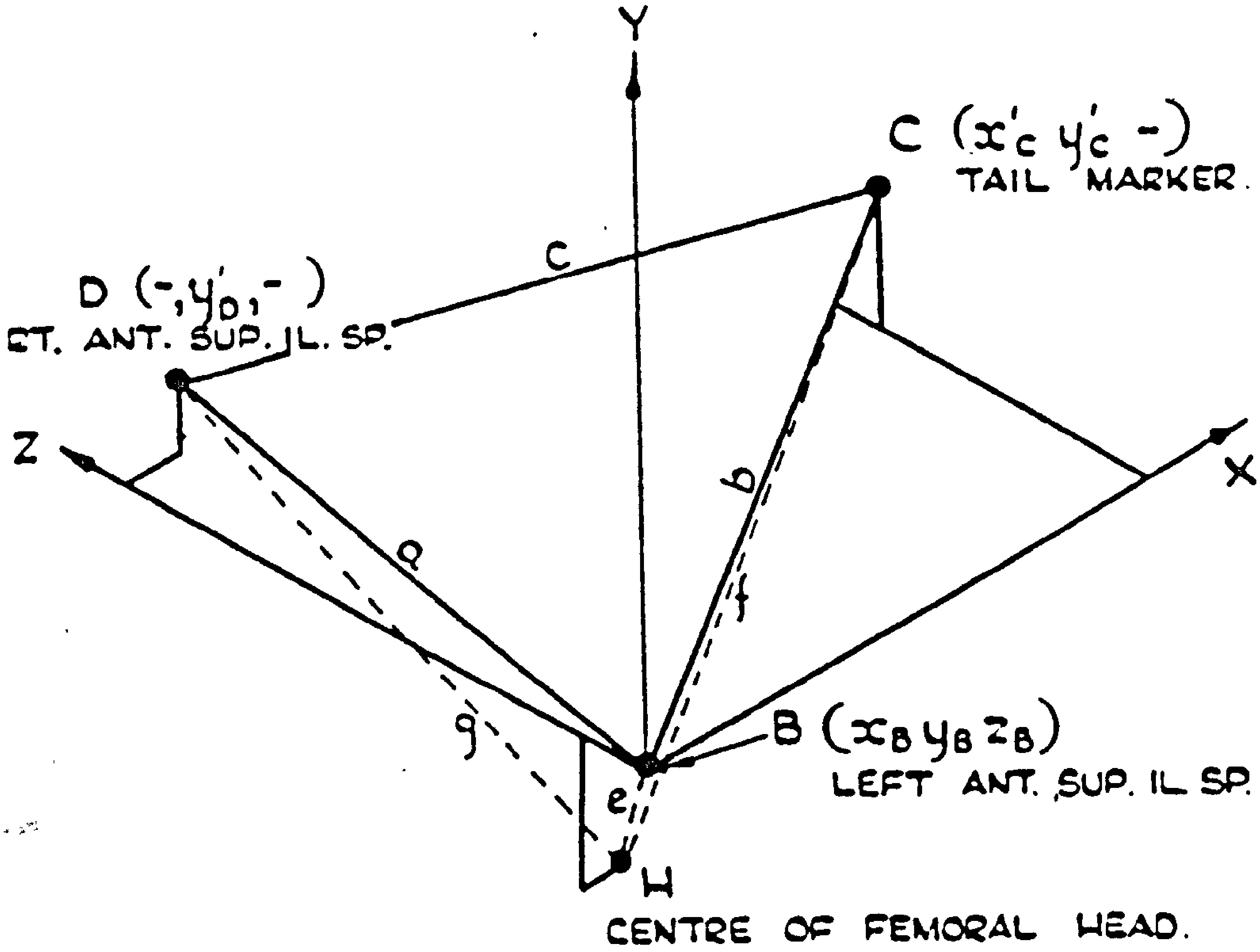
$$Z = Z1A(1 - X1ANTES/XL)/(1 - X1ANTES.Z1A/ZL.XL) \qquad (5)$$

The true X, Y and Z co-ordinates of the markers are derived and the Ankle, knee and hip joint centres are calculated.

4.4 Calculation of the Unknown Co-ordinate

All the markers used in this analysis could be seen at least by two of the three cine-cameras so that the requirements for parallax correction were obtained. However, one exception was the tail marker placed on the Lombo-sacral region, this marker could only be seen by both side cameras. Thus the Z grid co-ordinate of this marker had to be calculated based upon the distances between the anterior superior iliac spine (ASIS) marker and the tail marker, (see fig.4.2) from the following equation:

$$(Xc - Xb)^2 + (Yc - Yb)^2 + (Zc - Zb)^2 = B^2 \qquad (6)$$



REFERENCE POINTS ON PELVIS.

Fig. 4.2 (From Paul 1967)

$$\begin{aligned} & Zc^2\left[(X1ANTESc / ZL)^2 + (Y1ANTESc - HX)^2 / ZL^2 + 1\right] + \\ & (2Zc / ZL)\left[X1ANTES\,(Xb - X1ANTESc) + (Y1ANTESc - HX)\right. \\ & \left.(Yb - Y1ANTESc) - Zb\,ZL\right] + (X1ANTESc - Xb)^2 + (Y1ANTESc - Yb)^2 + \\ & Zb^2 - B^2 = 0 \end{aligned} \tag{7}$$

In this quadratic equation only the smaller root is the solution required. See Paul (1967) for full derivaton of the method.

4.5 Defining the Static Co-ordinate Systems

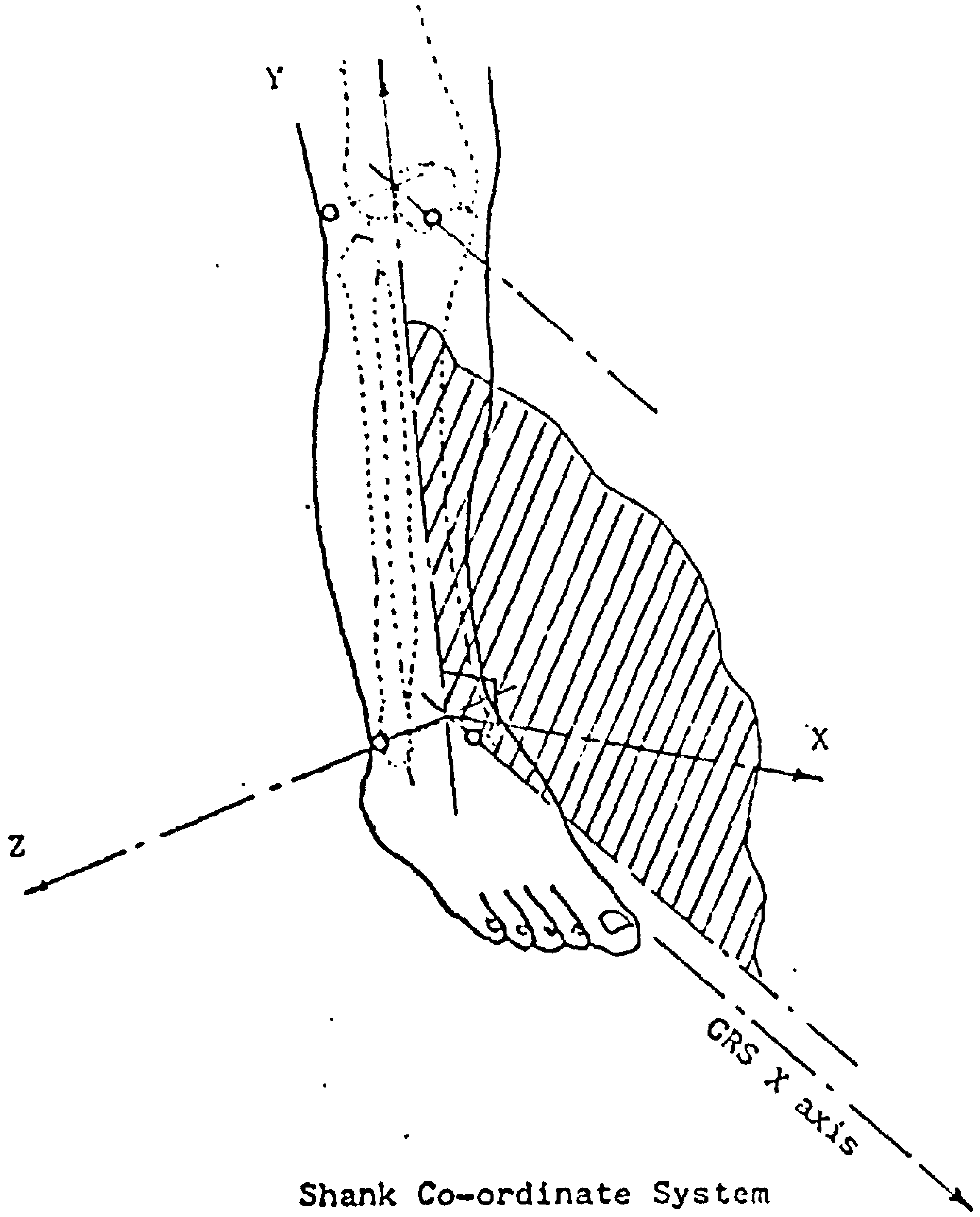
Static analysis employs a cine film frame from both the side and front cameras, with images of the patient's shank only, such that all calibration markers shown in Fig. 4.3 can be seen by both cameras. Three markers arranged in a triangle have been used to define a co-ordinate system. These markers are positioned such that a line joining two selected markers A and B in Fig. 4.3 lies on the Y axis. The Z axis is normal to the plane in which all the three markers lie and the X axis is perpendicular to both the Y and Z axes.

The shank co-ordinate system (see Fig.4.3) makes use of markers placed anterior and lateral to the knee and ankle joint centres such that the side camera will obtain from the lateral markers the X and Y co-ordinates, while the front camera obtains the Z co-ordinates from the joint front markers. A line joining the joint centres lies along the Y axis of the shank co-ordinate system. The normal to the plane in which the Y axis of this system and the X axis of the GRS lie, defines the Z axis and a line perpendicular to the Z and Y axis of this system defines the X axis.

Also from the static test, the direction cosines of the vector between the medial and the lateral knee markers and the medial and the lateral ankle markers are found. These direction cosines are applied in determining the medial knee and ankle marker co-ordinates in the dynamic tests.

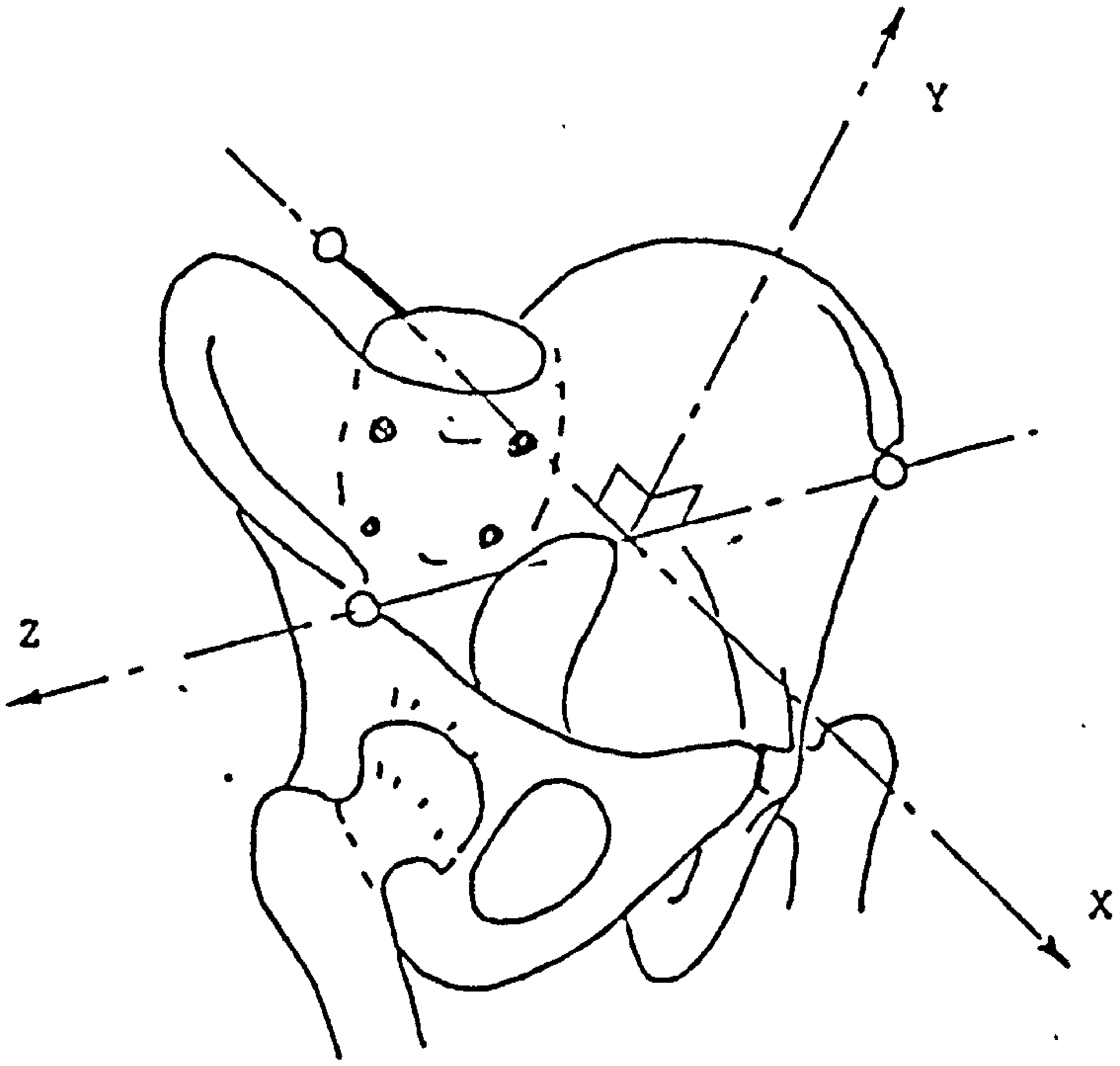
4.6 Defining the Dynamic Co-ordinate System

Using the markers shown in Fig 4.3 , the shank segment, the pelvis and the



Shank Co-ordinate System

Fig. 4.3



Pelvis Co-ordinate System

Fig. 4.4

thigh are obtained for successive frames of cine film. Once the marker co-ordinates have been found, the method used for obtaining the co-ordinate system in the dynamic situation is the same as that for the static situation.

The pelvis marker triangle co-ordinates (Fig.4.4) are obtained after parallax corrections. The Y axis is normal to the plane in which the three markers lie, while the Z axis is defined by the line between the two anterior superior iliac spines. The X axis is perpendicular to both Z and Y axes.

The sense of these axes are:

Y is positive from inferior to superior

X is positive from posterior to anterior

Z is positive from medial to right lateral.

From measurements performed on a skeleton and a number of normal subjects, the vector from the anterior superior iliac spine to the hip joint centre (HJC) of the same side in the pelvis co-ordinate system has the following components:

x = 0.183* D86

y = 0.305* D86

z = 0.122* D86

Where D86 is the distance between the two ASIS. (Harrington 1974).

The thigh co-ordinate system takes the line between the hip and the knee joint centres to define its Y axis, as neither the hip nor the knee centres is defined by markers, position is obtained by taking a known vector from one marker (on the shank for the knee and ankle and on the ASIS for the hip) to the respective joint centre. From the static shot a vector is defined from the marker 1 (if left side marker 10) to both the knee and the ankle joint centre. This vector is then transferred to the GRS and added to the position vector of the respective camera to the marker.

4.7 Intersegmental Force Actions

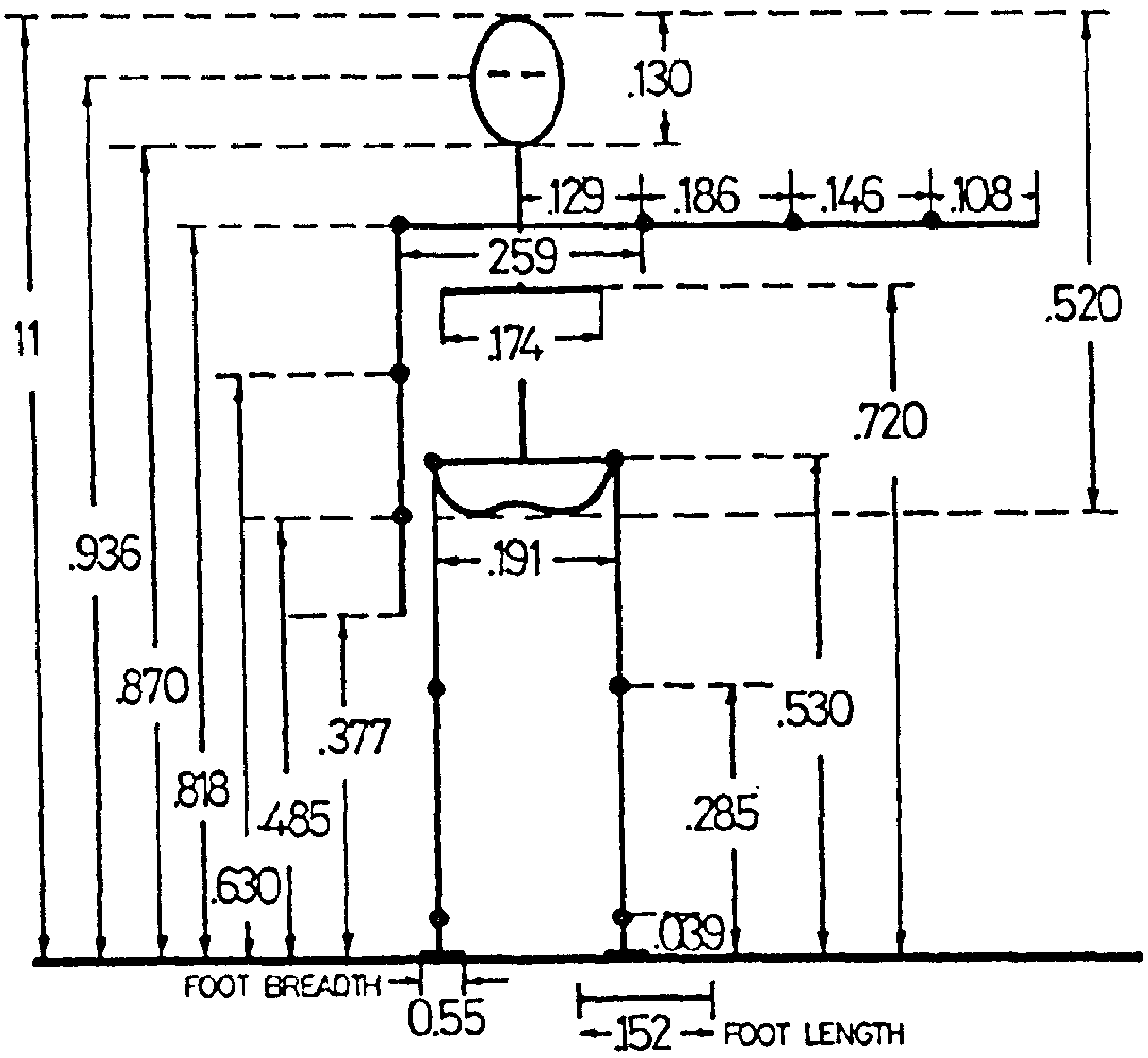
4.7.1 Mass and centre of mass

To calculate the force and moments acting on a joint during locomotion it is necessary to know the mass and the positions of the centre of mass of the limb segments. This is achieved by means of tables, for this particular work the information published by Drillis and Contini (1966) has been used (Fig. 4.5).

Fig. 4.5

BODY SEGMENT MASS PROPERTIES

(as reported by Contine and Drillis (1966) - Technical Report No. 1166.03 of New York University)



SEGMENT LENGTH EXPRESSED AS RATIO OF BODY HEIGHT

Segment Mass in Percent of the Total Body Mass (Mean Values)

Investigator:	Harless	Meeh	Braune and Fischer	Bernstein	Dempster	N.Y.U
Segment						
Head, Neck and trunk	53.42	59.08	49.68	52.98	56.50	58.04
Upper Arms	6.48	6.19	6.72	5.31	5.30	7.14
Forearms	3.62	3.38	4.56	3.64	3.10	3.60
Hands	1.68	1.48	1.68	1.41	1.20	1.20
Thighs	22.36	17.36	23.16	24.43	19.30	18.92
Shanks	8.78	9.35	10.54	9.31	9.00	8.40

TABLE XIII: Location of Mass Centres from Proximal Joint in Percent of Segment Length

	Investigators				
Segments	Harless	Braune and Fischer	Bernstein	Dempster	N.Y.U
Entire Arm	-	42.6	-	43.6	43.1
Upper Arm	48.5	47.0	46.6	43.6	44.2
Forearm and Hand	-	45.8	-	67.7*	38.2
Forearm	44.0	42.1	41.2	43.0	42.3
Hand	47.4	-	-	-	39.2
Entire leg	-	41.5	-	43.4	39.7
Thigh	46.7	44.0	38.6	43.3	41.0
Shank and foot	-	51.9	-	43.3	45.0
Shank	36.0	42.0	41.3	43.3	39.3
Foot (from heel)	46.0	43.4	-	43.3	44.5

*Distance from elbow to ulnar styloid is assumed to be 100 percent.

TABLE XVIII: Ratio (C_3) of Radius of Gyration (p) to Segment Length (l)

	Braune and Fischer				N.Y.U and Live	Weighted
Segment	I Cadaver I Test		I Cadaver II Test		Subjects	Average
	R	L	R	L		
Entire Upper Extremity	-		0.30	0.31	0.24	0.252
Upper Arm	0.27	0.27	0.29	0.31	0.26	0.268
Forearm and Hand	0.26	0.28	0.29	0.32	0.25	0.263
Entire Lower Extremity	-		0.32	0.32	0.24	0.256
Thigh	0.26	0.27	0.31	0.31	0.23	0.250
Shank and foot	0.32	0.32	0.33	0.35	0.29	0.303
Shank	0.25	0.26	0.24	0.26	0.27	0.264
Average	0.27	0.28	0.30	0.31	0.25	0.265

It is assumed that these tests based on eight subjects provide better coefficients for the different segments.

For the purpose of determining the centre of mass, the foot and the shank are considered as one body.

4.7.2 Moment of inertia

As in the case of mass and centre of mass the moment of inertia was also estimated using the information given by tables. (Fig. 4.5) Drillis and Contini.

The analysis ignores the torques due to moments of inertia about the long axis of the limb segments.

4.7.3 Accelerations of limb segments.

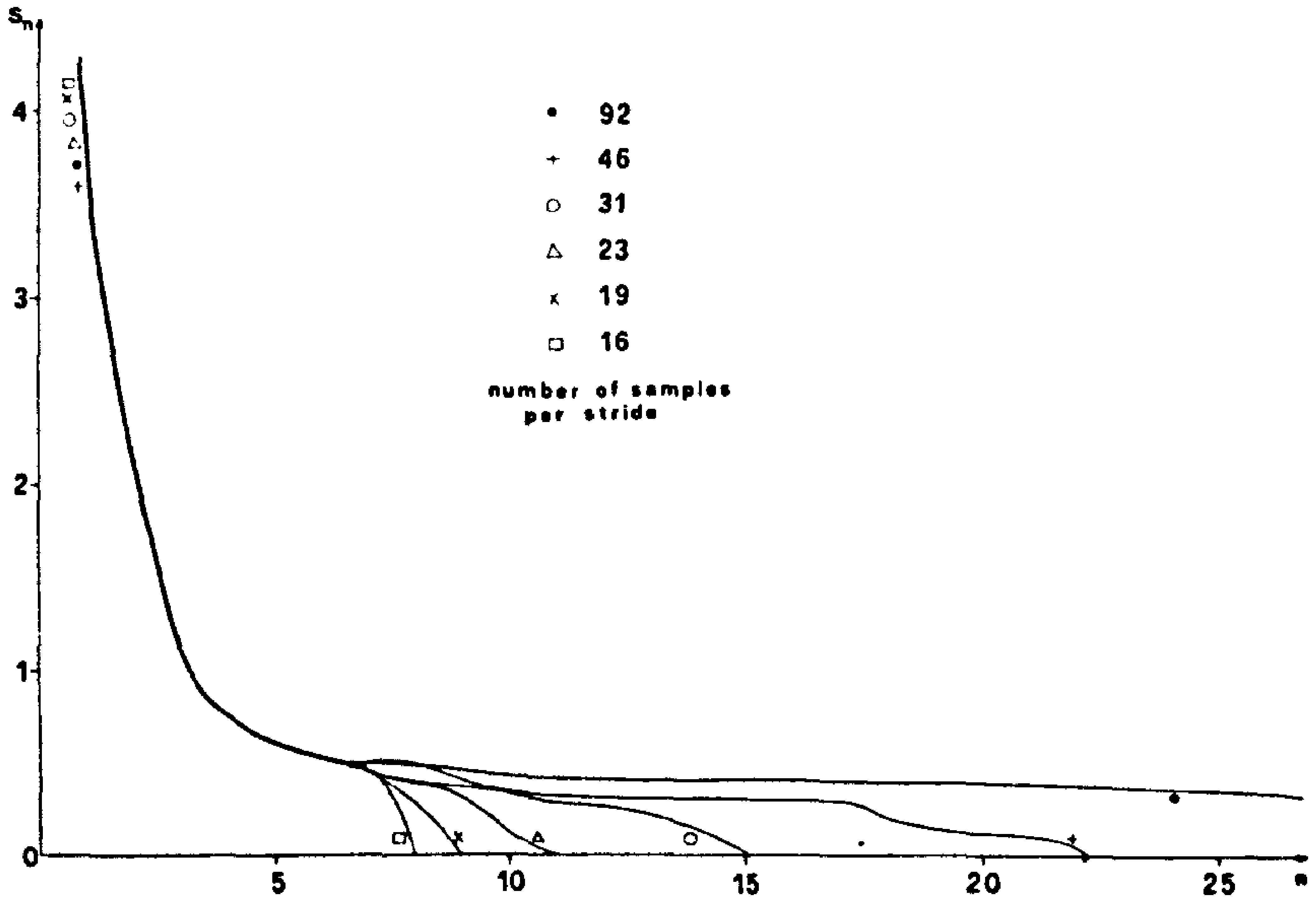
Velocity and accerlations are obtained by differentiation of the displacement data.

To reduce error due to noise in the signal some authors (see Winter et al 1974) have passed the displacement data through a low pass digital filter in order to reduce noise. Thus to achieve this the cut off frequency should be stated ad priori (usually up to 8 or 10 H.Z).

For the present analysis, the algorithm used has been described by Cappozzo et al (1975) which has been designed to obtain the time functions of the variables in an analytical form. Since all biomechanical functions can be represented as periodic functions, and have the properties of "well behaved" functions, they can be represented by trigonometric functions:

$$R\bar{n} = R\bar{n}(t) = Ao + \sum_{i}^{\bar{n}}{}_{i} (A_i \sin\omega_i t + B_i \cos\omega_i t) \qquad (8)$$

The technique comprises two steps: First, the determination of a function which fits the data accurately. Assuming that the sampled data are subject to a random error whose statistical characteristics do not change with time, each sample can be seen as an observation from a normal population having a mean value and variance. Under this assumption a method of least square is used for the estimation of the parameters Ao, Aj, Bj, and of the variance (for details see



Example of plot of the square root of the variance estimate [$s(n)$], vs order n of the regression curve R_n for different sampling rates.

Best fitting parameters

GAIT	HARMONICS ORDER	η_1 Mod [°]	η_1 Phase [rad]	η_1 E[σ] [°]	η_2 Mod [°]	η_2 Phase [rad]	η_2 E[σ] [°]	η_3 Mod [°]	η_3 Phase [rad]	η_3 E[σ] [°]	$\bar{X}_H$ Mod [mm]	$\bar{X}_H$ Phase [rad]	$\bar{X}_H$ E[σ] [mm]	Z_H Mod [mm]	Z_H Phase [rad]	Z_H E[σ] [mm]
WALKING UPSTAIRS	0	17.6	—	—	133.5	—	—	85.7	—	—	20.8	—	—	817.7	—	—
	1	26.7	0.00	3.0	36.2	0.00	6.2	9.1	0.00	4.9	11.8	0.00	10.6	19.7	0.00	16.6
	2	3.8	1.16	1.0	7.8	2.08	2.8	3.8	1.04	4.1	11.8	-0.96	6.3	21.9	-3.03	4.1
	3	0.6	0.43	0.9	3.0	-3.06	1.7	3.1	-2.73	3.5	4.0	-1.26	5.6	4.5	-1.68	2.4
	4	0.8	0.28	0.6	0.9	-2.68	1.6	2.6	-0.87	2.9	4.2	-1.28	4.7	1.7	2.71	2.1
	5	0.3	1.19	0.8	1.2	3.14	1.3	1.4	1.73	2.8	2.3	-1.34	4.4	0.7	0.60	2.0
	6	0.6	0.14	0.4	0.7	-1.82	1.2	1.9	-1.96	2.4	3.3	-2.14	3.6	0.8	2.49	2.0
	7	0.4	0.74	0.3	0.4	-2.02	1.2	1.3	0.00	2.2	1.6	-2.32	3.4	0.6	2.76	1.9
	8	0.2	0.84	0.3	0.7	-1.23	1.1	1.2	2.63	2.0	1.8	-2.96	3.2	1.6	3.09	1.4
	9	0.1	0.48	0.3	0.7	-1.78	1.0	1.0	-0.96	1.8	0.7	-2.65	3.3	0.9	-0.03	1.2
	10	0.2	2.70	0.3	0.8	-1.47	0.8	1.0	0.90	1.6	0.3	-2.11	3.3	0.5	2.33	1.2
	11	0.2	2.40	0.2	0.3	-0.42	0.8	1.0	-3.07	1.4	2.1	-3.04	2.8	0.5	-2.43	1.1
	12	0.1	1.06	0.2	0.4	-0.89	0.8	0.6	-0.37	1.4	1.8	2.98	2.4	0.9	0.63	0.8
	13	0.2	2.31	0.1	0.6	0.03	0.4	1.3	1.71	0.8	2.1	1.88	1.3	0.5	1.82	0.4
	14	0.0	0.01	0.0	0.6	0.24	0.0	0.7	-2.00	0.0	1.8	1.46	0.0	0.4	0.83	0.0
LEVEL WALKING	0	11.7	—	—	151.1	—	—	100.6	—	—	-494.4	—	—	870.4	—	—
	1	26.1	0.00	4.66	21.5	0.00	15.7	6.3	0.00	6.2	8.9	0.00	14.8	11.7	0.00	24.9
	2	8.7	0.68	2.14	20.8	-0.35	3.7	7.6	0.89	2.9	19.1	1.09	4.9	32.6	2.14	6.3
	3	2.3	-0.36	1.29	3.7	4.66	2.4	2.1	0.32	2.8	3.2	1.29	4.4	6.3	1.67	4.2
	4	1.2	1.17	0.9	1.9	1.11	1.9	2.9	1.56	1.2	2.4	-2.53	4.0	3.3	5.06	3.8
	5	0.3	-2.10	0.9	1.6	2.81	1.8	0.5	1.11	1.1	1.6	0.30	3.9	2.2	-2.30	3.2
	6	0.4	-0.37	0.9	0.8	-2.18	1.4	0.3	1.62	1.1	0.7	-2.82	4.0	1.6	-1.89	3.0
	7	0.5	0.74	0.8	0.7	-1.96	1.3	0.6	2.90	1.0	1.9	-1.20	3.8	1.4	-2.14	2.8
	8	0.2	0.58	0.8	0.3	-1.66	1.3	0.2	1.70	1.0	1.2	-2.89	3.7	1.2	-0.76	2.7
	9	0.1	0.88	0.8	0.3	-1.52	1.3	0.5	2.64	1.0	1.9	-2.43	3.4	0.5	1.87	2.7
	10	0.1	0.13	0.5	0.6	-1.44	1.3	0.7	3.11	0.8	0.6	-1.04	3.4	1.7	-0.32	3.4
	11	0.4	0.19	0.8	0.7	-1.36	1.1	0.2	2.11	0.8	2.6	-1.96	2.8	1.6	1.90	1.9

Fig 4.6

Carnahan et al 1969). Secondly, a minimization of the mean square error with respect to the parameters Ao, Aj, Bj is performed once the optimal parameters of the functions have been estimated, the problem of determining the more convenient number of harmonics, can be done by inspection of the plot of the square root of the variance versus the number of samples (Fig.4.6) from Cappozzo et al 1975). Once the analytical form of the displacement curve is known the velocities and accelerations can be found by analytical differentiation.

4.8 Calculation of the Intersegmental Moments

The externally applied moments relative to the grid axis, acting at the centre of the joints are calculated from the ground to foot force actions and the joints spatial co-ordinates.

The sign convention adopted in this programme is in accordance with the proposed international standard (C.P.R.D.1975). This can be seen on Fig.4.7 which shows the positive directions for forces and moments.

For the calculation of the instantaneous centre of pressure at the foot allowance have to be made for the height of the step, placed on force plate two.

The general form of the moment equation is as follows: (see fig. 4.8 for orientation).

$$MzK = MzA - mg\,\bar{r}_1 \sin\theta_1 - I\ddot{\theta} - IFx\,\bar{r}_1 \cos\theta_1 - IFy\,\bar{r}_1 \sin\theta_1 + FxA\,\bar{r}_2 \cos\theta_2 + FyA\,\bar{r}_2 \sin\theta_2 \qquad (8)$$

FxA = Fx component at the ankle joint.
FyA = Fy " " " " "
IFx = x component of Inertia force acting at the CG
IFy = y " " " " " " "
$I\ddot{\theta}$ = Inertia torque at the CG
mg = Weight of the limb
MzA = Moment at the ankle

A computer programme has been developed to accept the force plate and kinematic film. A block diagram showing the operational sequence of the computer programme is given in Fig. 4.9

CO-ORDINATE SYSTEM ADOPTED

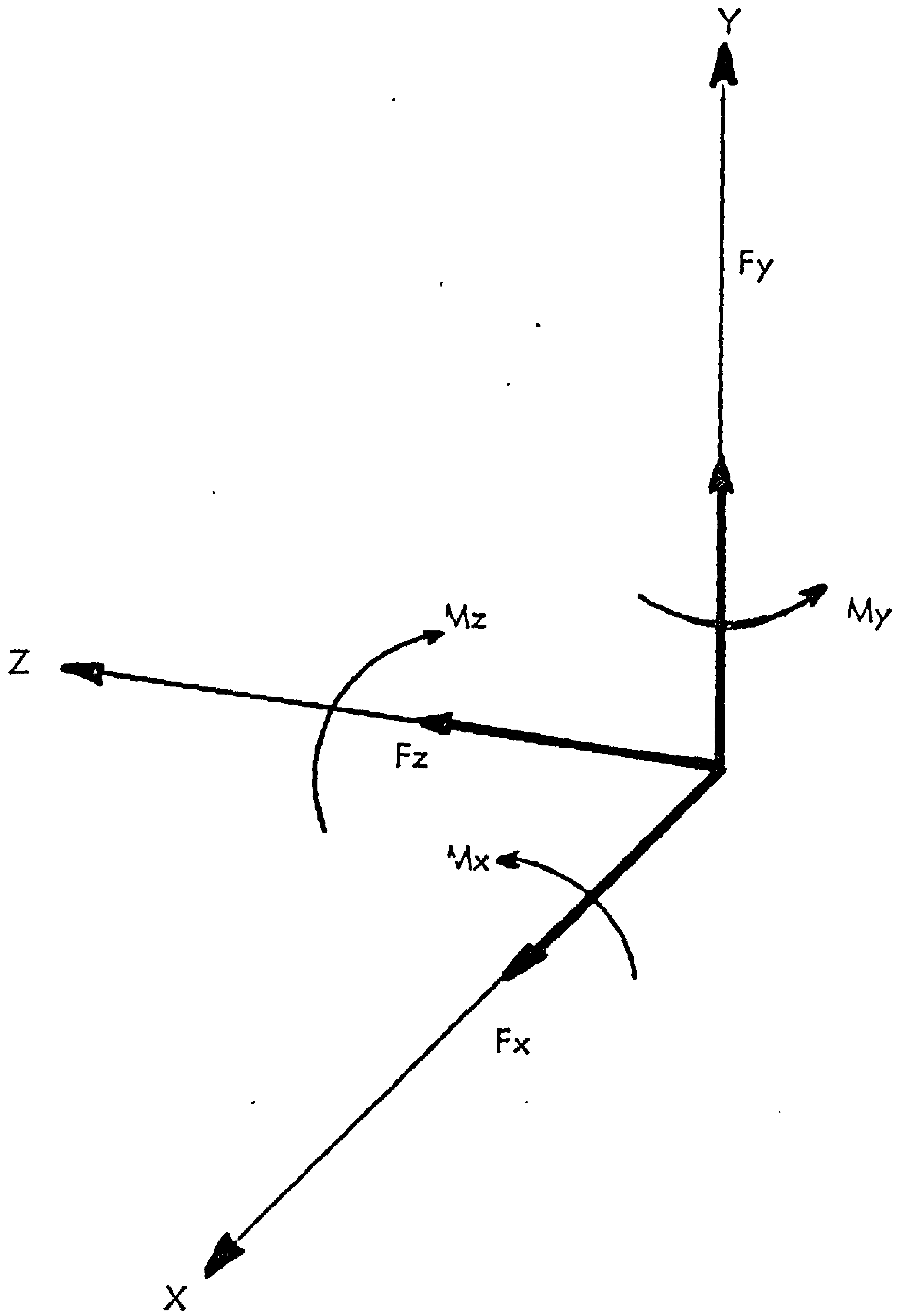


Fig. 4.7

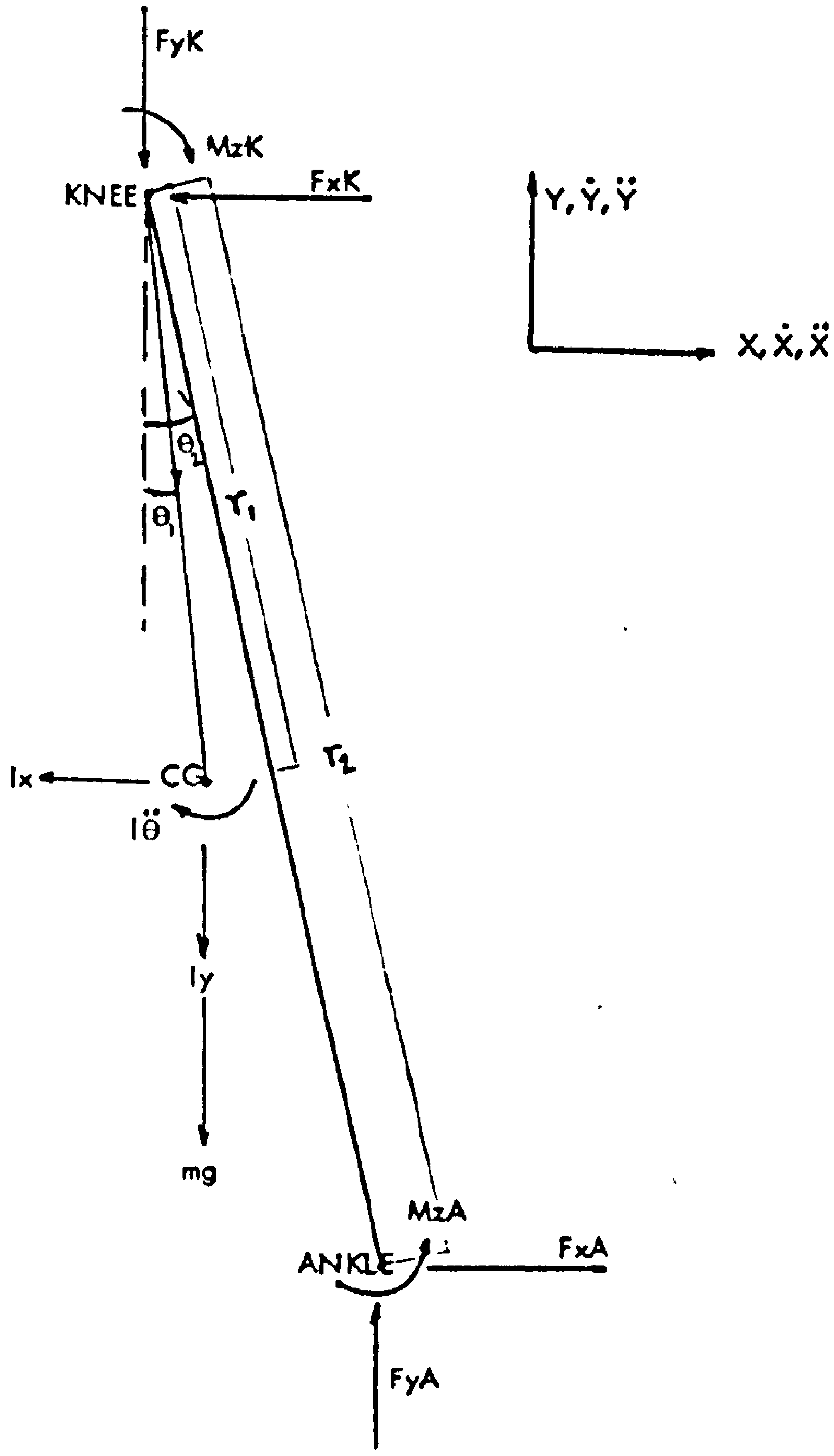

FyK
MzK
KNEE
FxK
Y, Ẏ, Ÿ
X, Ẋ, Ẍ
θ2
θ1
r1
r2
Ix
CG
Iθ̈
Iy
mg
MzA
ANKLE
FxA
FyA

Fig. 4.8

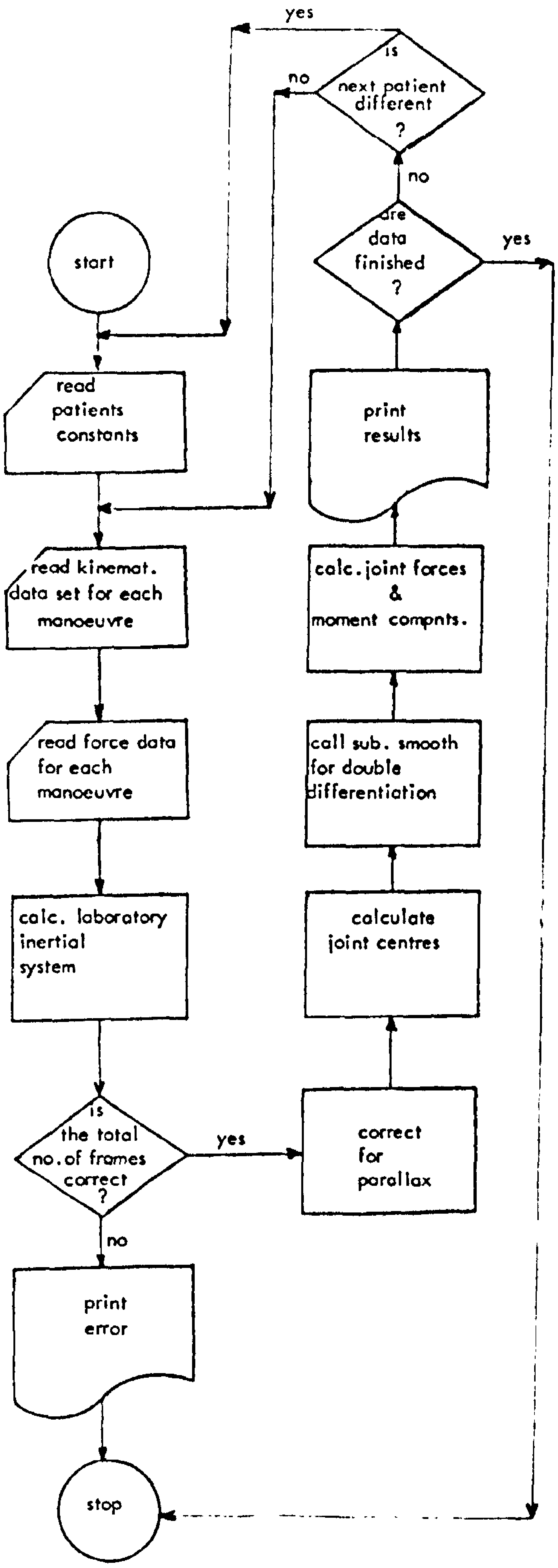

yes
is next patient different ?
no
no
are data finished ?
yes
start
read patients constants
print results
read kinemat. data set for each manoeuvre
calc. joint forces & moment compnts.
read force data for each manoeuvre
call sub. smooth for double differentiation
calc. laboratory inertial system
calculate joint centres
is the total no. of frames correct ?
yes
correct for parallax
no
print error
stop

Fig. 4.9

CHAPTER 5

RESULTS AND DISCUSSION

CHAPTER 5 DISCUSSION OF RESULTS

5.1 Introduction

The step test described by Grieve et al (1978) included four basic pairs of manoeuvres (FUL-BDT, FDT-BUL, FDL-BUT and FUT-BDL). However, as outlined in the methodology only one pair of the four has been investigated in this project. This is the first of the manoeuvres referred to as FUL-BDT. Grieve's nomenclature was designed to describe the manoeuvre and to correspond to the location of the Polgon sensors on the subjects leg. Thus, FUL means forward (F) upwards (U) with polgon sensors mounted on the leading (L) leg. FUT describes the same manoeuvre but this time with the polgon sensors mounted on the trailing (T) leg.

In this study the two manoeuvres carried out were described as follows:

(i) with the subject (S) or patient (P) stepping forward (F) and upwards (U) always with the right leg leading. This manoeuvre is then referred to simply as FU O (or FU 1); zero to indicate zero height step and one to indicate 10% height step respectively. The results for the right leg are then referred to as R/FU O (or R/FU 1) and for the left leg as L/FU O (or L/FU 1).

(ii) with the subject (S) or patient (P) stepping backwards (B) downwards (D) always with the left leg leading. This manoeuvre is referred to simply as BD O (or BD 1) zero to indicate zero height step and one to indicate 10% height step respectively. The results for the right leg are then referred to as R/BD O (or R/BD 1) and for the left leg as L/BD O (or L/BD 1).

It should be emphasised that, considerable amount of work was necessary in order to reduce the cine-film data using a Vanguard-PCD film analyser. Each manoeuvre was seen by three cameras (both limbs analysed simultaneously) for zero stepping height and 10% stepping height for each patient and subject. The number of frames analysed for each manoeuvre was about 300 (100 for each camera giving a total for all subjects and patients of the order of 25,000). On average, the film analysis for a patient (subject) carrying out all the manoeuvres was 12 hours. Furthermore, additional time had to be spent in editing the film data so as to ensure elimination of human errors.

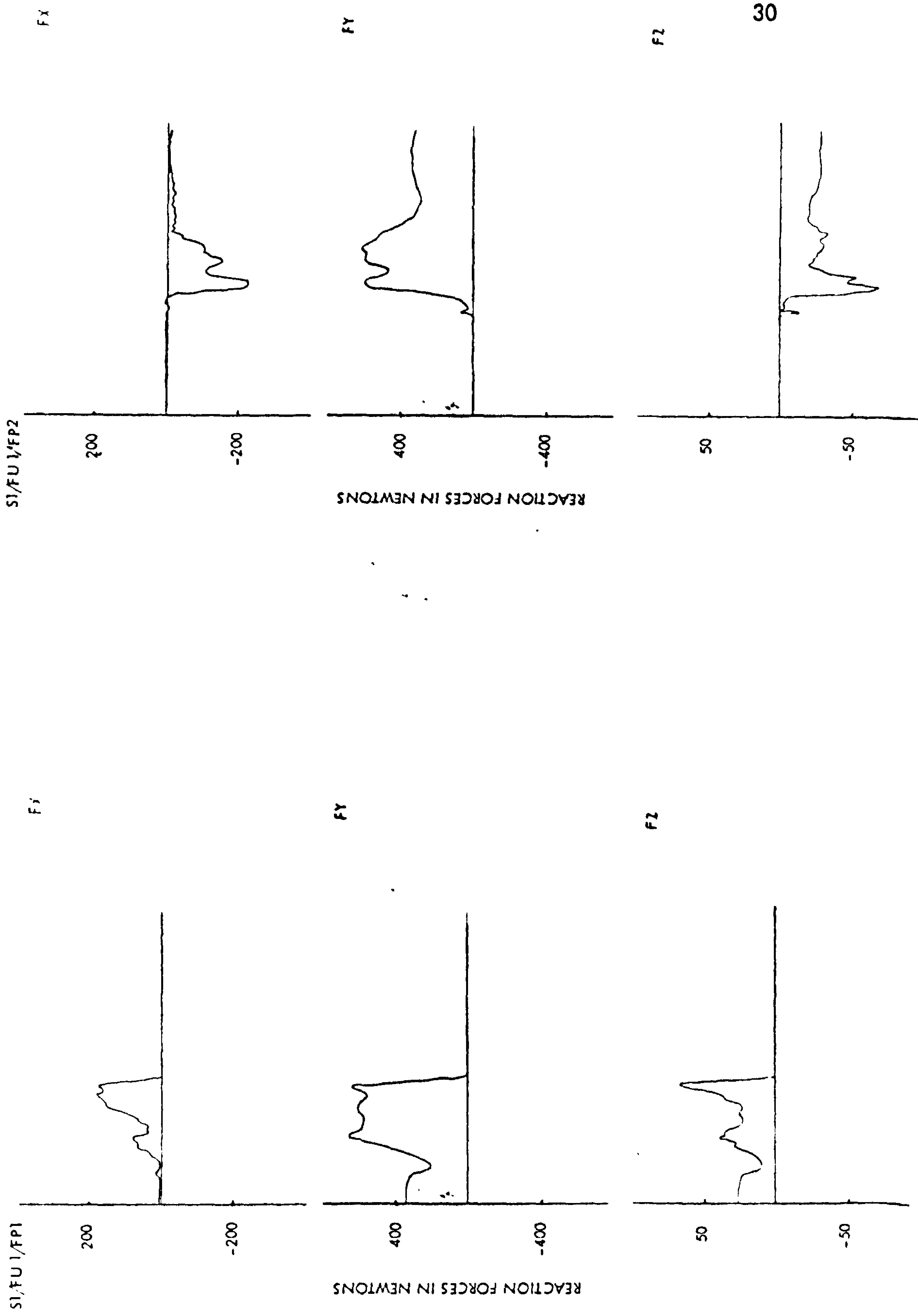

S1/FU1/FP2
FX
FY
FZ
200
-200
400
-400
50
-50
REACTION FORCES IN NEWTONS
S1/FU1/FP1
FX
FY
FZ
200
-200
400
-400
50
-50
REACTION FORCES IN NEWTONS

Fig. 5.1

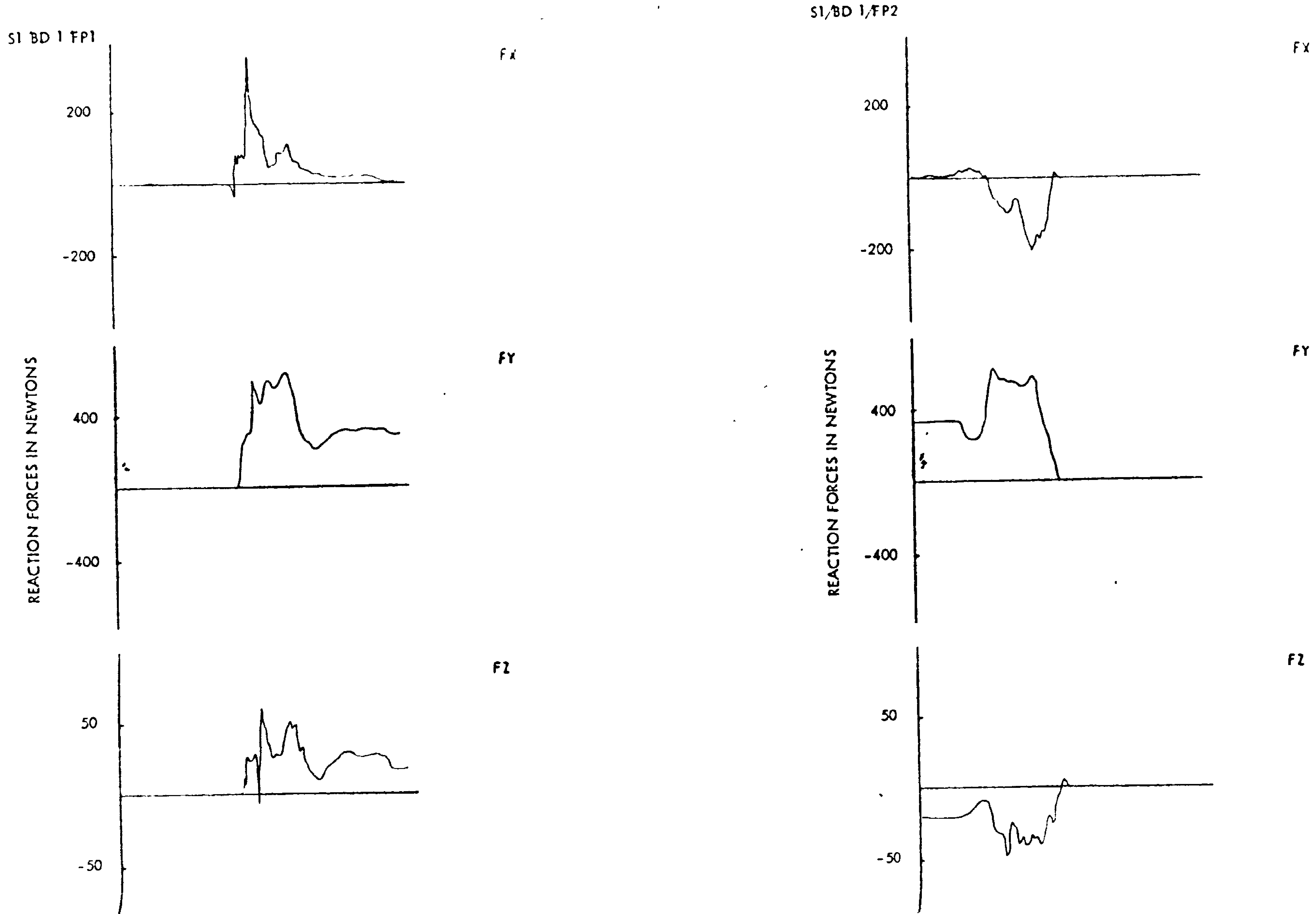

S1 BD 1 FP1
200
-200
FX
REACTION FORCES IN NEWTONS
400
-400
FY
50
-50
FZ
S1/BD 1/FP2
200
-200
FX
REACTION FORCES IN NEWTONS
400
-400
FY
50
-50
FZ

Fig.5.2

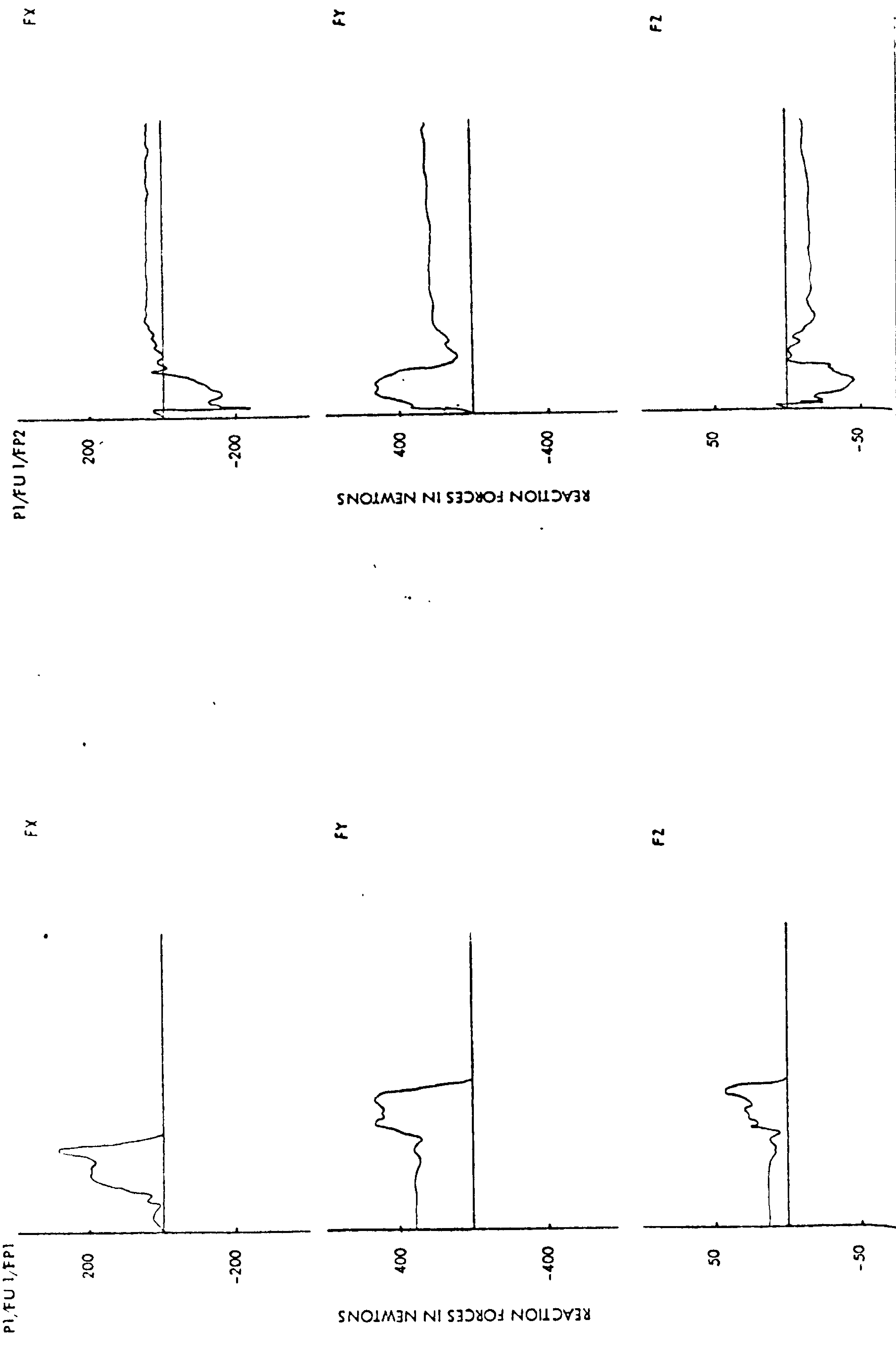

P1/FU1/FP2
FX
FY
FZ
200
-200
400
-400
50
-50
REACTION FORCES IN NEWTONS
P1/FU1/FP1
FX
FY
FZ
200
-200
400
-400
50
-50
REACTION FORCES IN NEWTONS

Fig.5.3

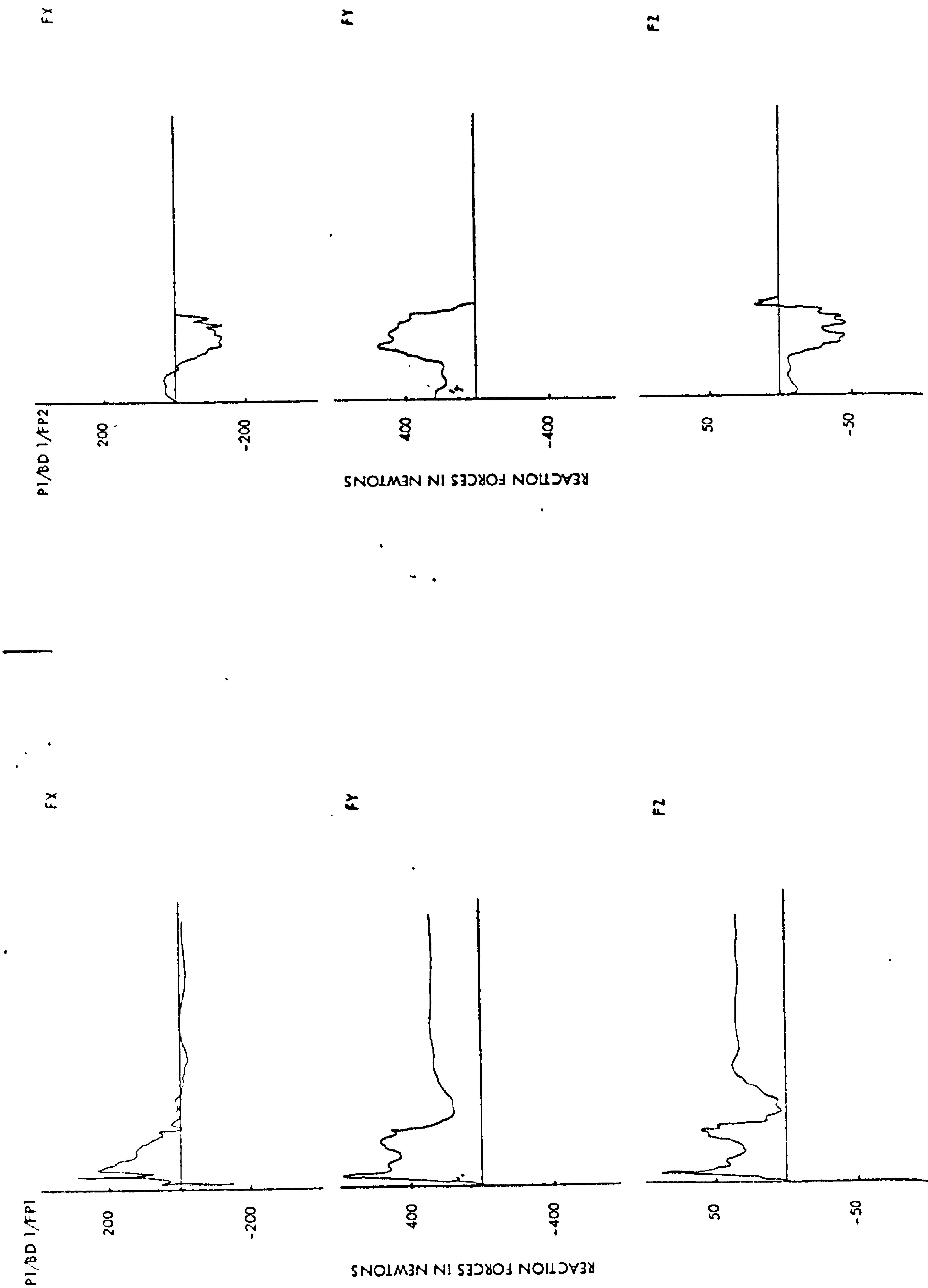

P1/BD 1/FP2
FX
200
-200
FY
400
-400
FZ
50
-50
REACTION FORCES IN NEWTONS
P1/BD 1/FP1
FX
200
-200
FY
400
-400
FZ
50
-50
REACTION FORCES IN NEWTONS

Fig.5.4

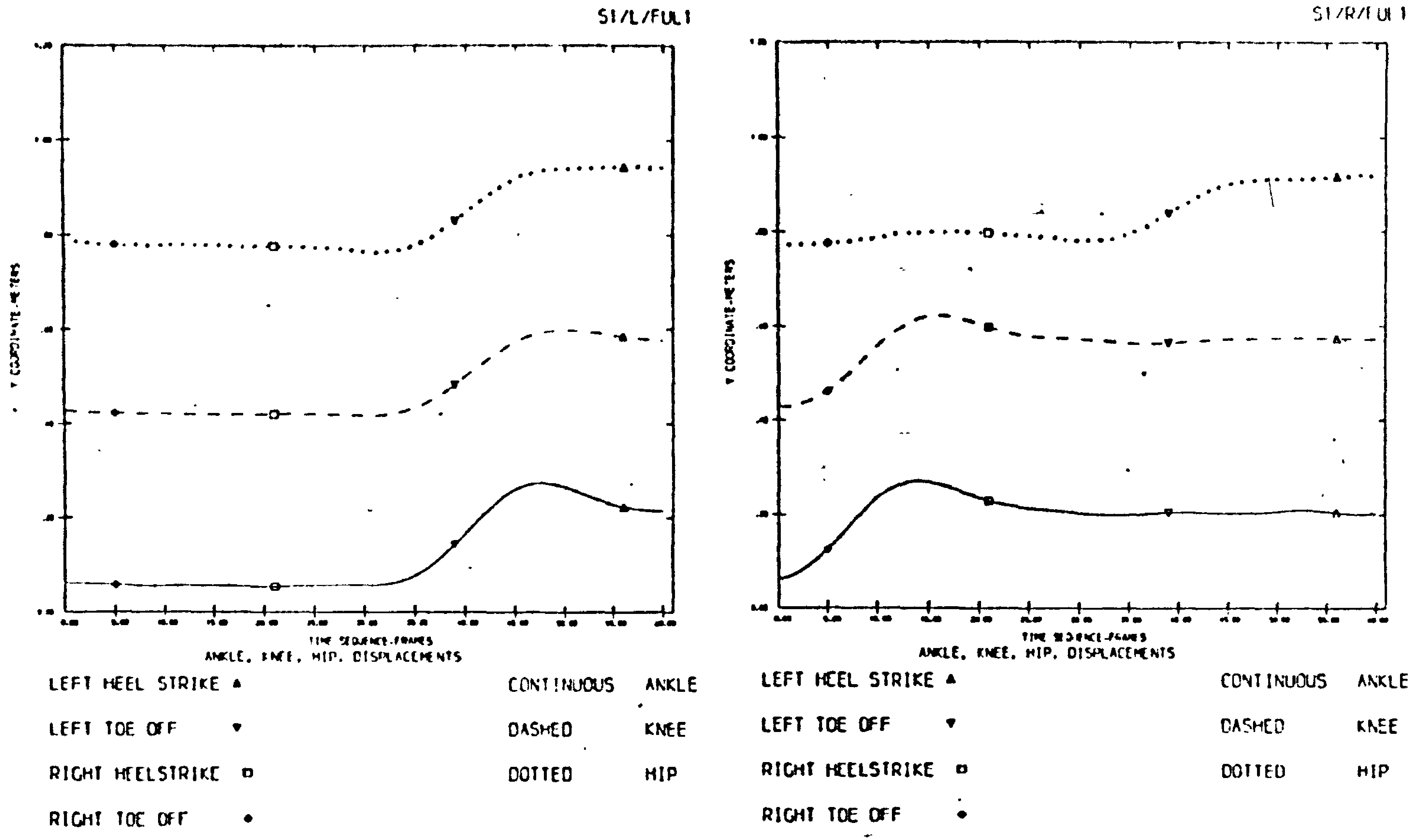

S1/L/FUL1
Y COORDINATE-METRES
TIME SEQUENCE-FRAMES
ANKLE, KNEE, HIP, DISPLACEMENTS
LEFT HEEL STRIKE ▲
LEFT TOE OFF ▼
RIGHT HEELSTRIKE □
RIGHT TOE OFF ◆
CONTINUOUS ANKLE
DASHED KNEE
DOTTED HIP
S1/R/FUL1
Y COORDINATE-METRES
TIME SEQUENCE-FRAMES
ANKLE, KNEE, HIP, DISPLACEMENTS
LEFT HEEL STRIKE ▲
LEFT TOE OFF ▼
RIGHT HEELSTRIKE □
RIGHT TOE OFF ◆
CONTINUOUS ANKLE
DASHED KNEE
DOTTED HIP

Fig 5.5

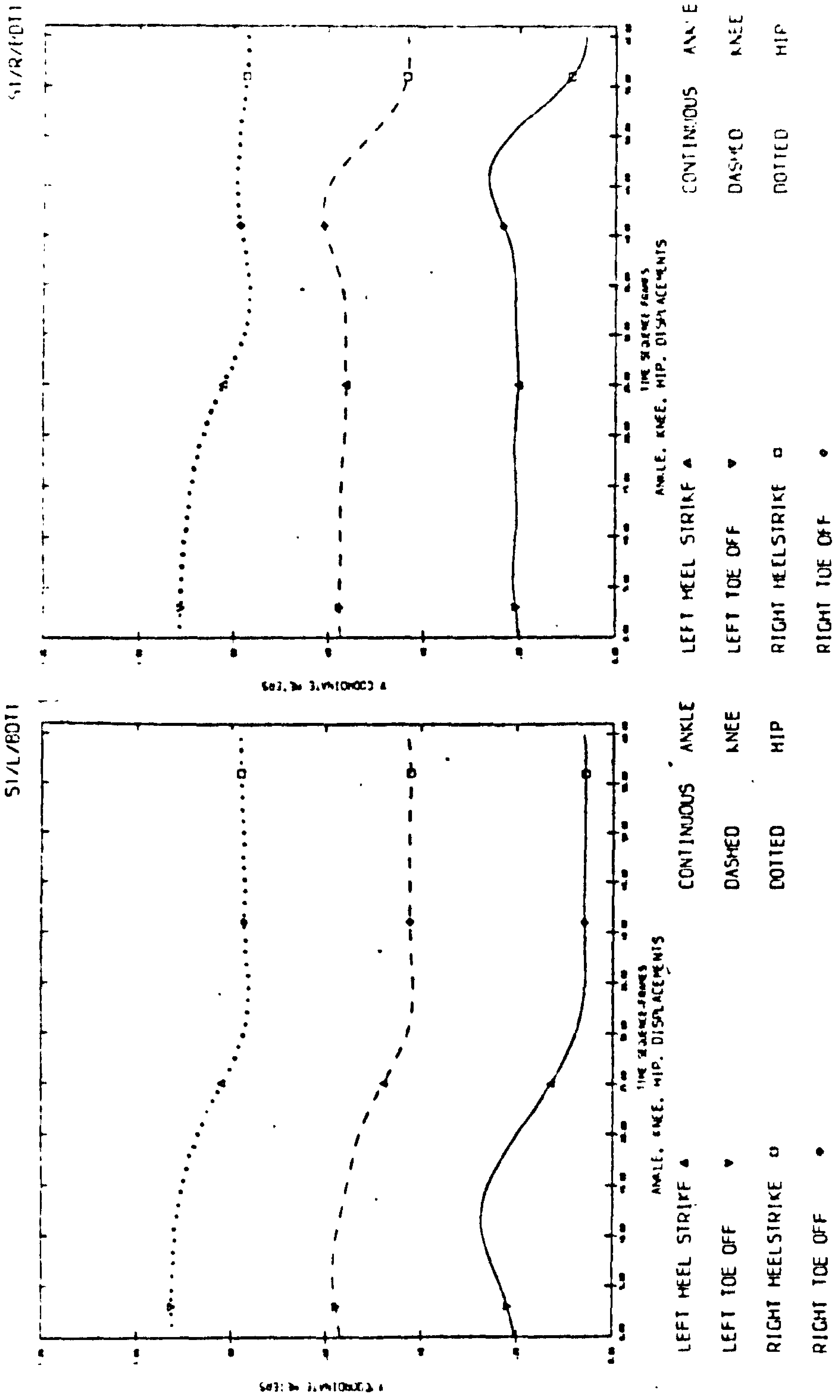

S1/L/BOT1
S1/R/BOT1
Y COORDINATE IN CMS
TIME SEQUENCE-FRAMES
ANKLE, KNEE, HIP, DISPLACEMENTS
LEFT HEEL STRIKE ▲
LEFT TOE OFF ▼
RIGHT HEELSTRIKE ◻
RIGHT TOE OFF ◆
CONTINUOUS ANKLE
DASHED KNEE
DOTTED HIP

Fig 5.6

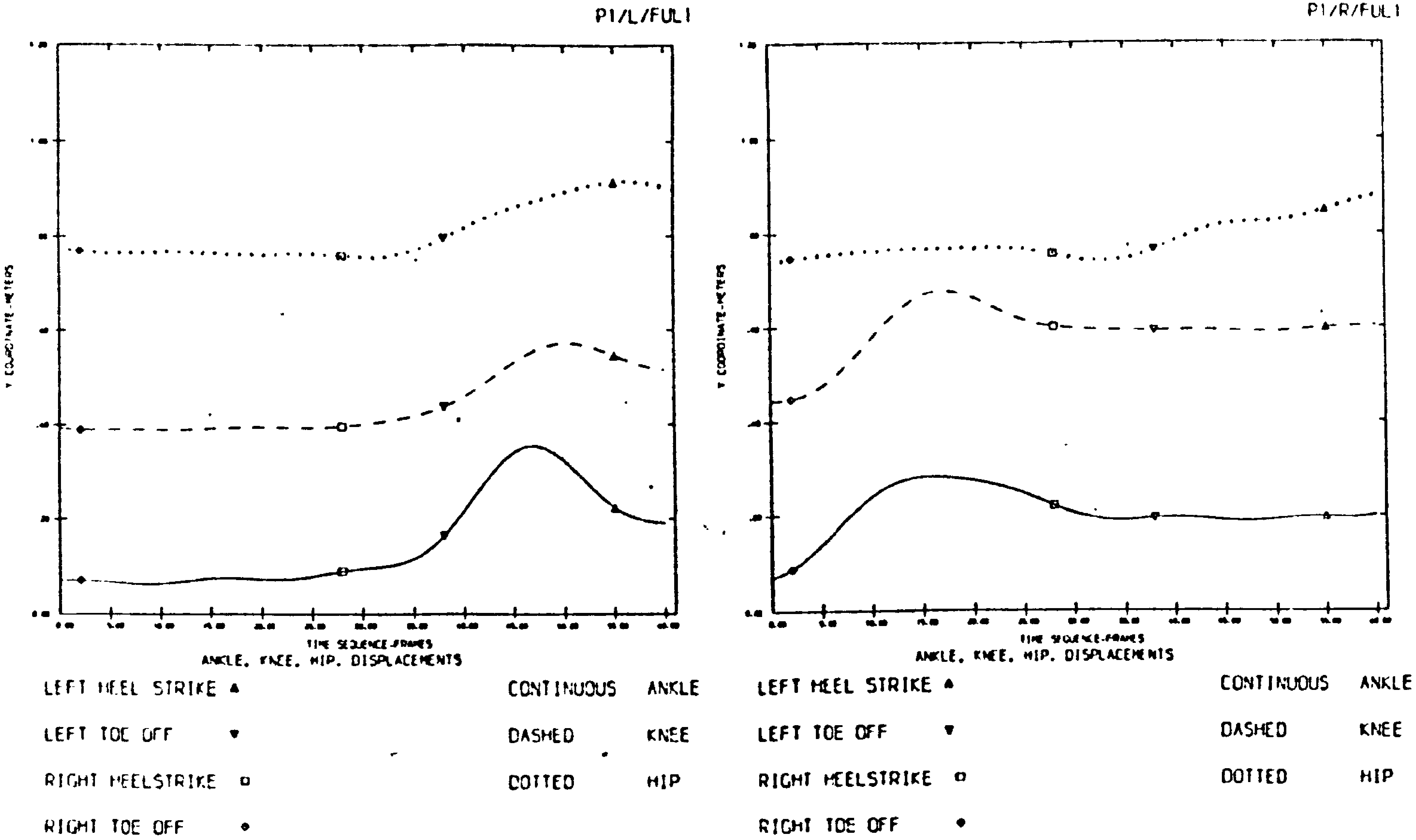

P1/L/FUL1
Y COORDINATE-METERS
TIME SEQUENCE-FRAMES
ANKLE, KNEE, HIP, DISPLACEMENTS
LEFT HEEL STRIKE ▲
LEFT TOE OFF ▼
RIGHT HEELSTRIKE ◻
RIGHT TOE OFF ◆
CONTINUOUS ANKLE
DASHED KNEE
DOTTED HIP
P1/R/FUL1
Y COORDINATE-METERS
TIME SEQUENCE-FRAMES
ANKLE, KNEE, HIP, DISPLACEMENTS
LEFT HEEL STRIKE ▲
LEFT TOE OFF ▼
RIGHT HEELSTRIKE ◻
RIGHT TOE OFF ◆
CONTINUOUS ANKLE
DASHED KNEE
DOTTED HIP

Fig 5.7

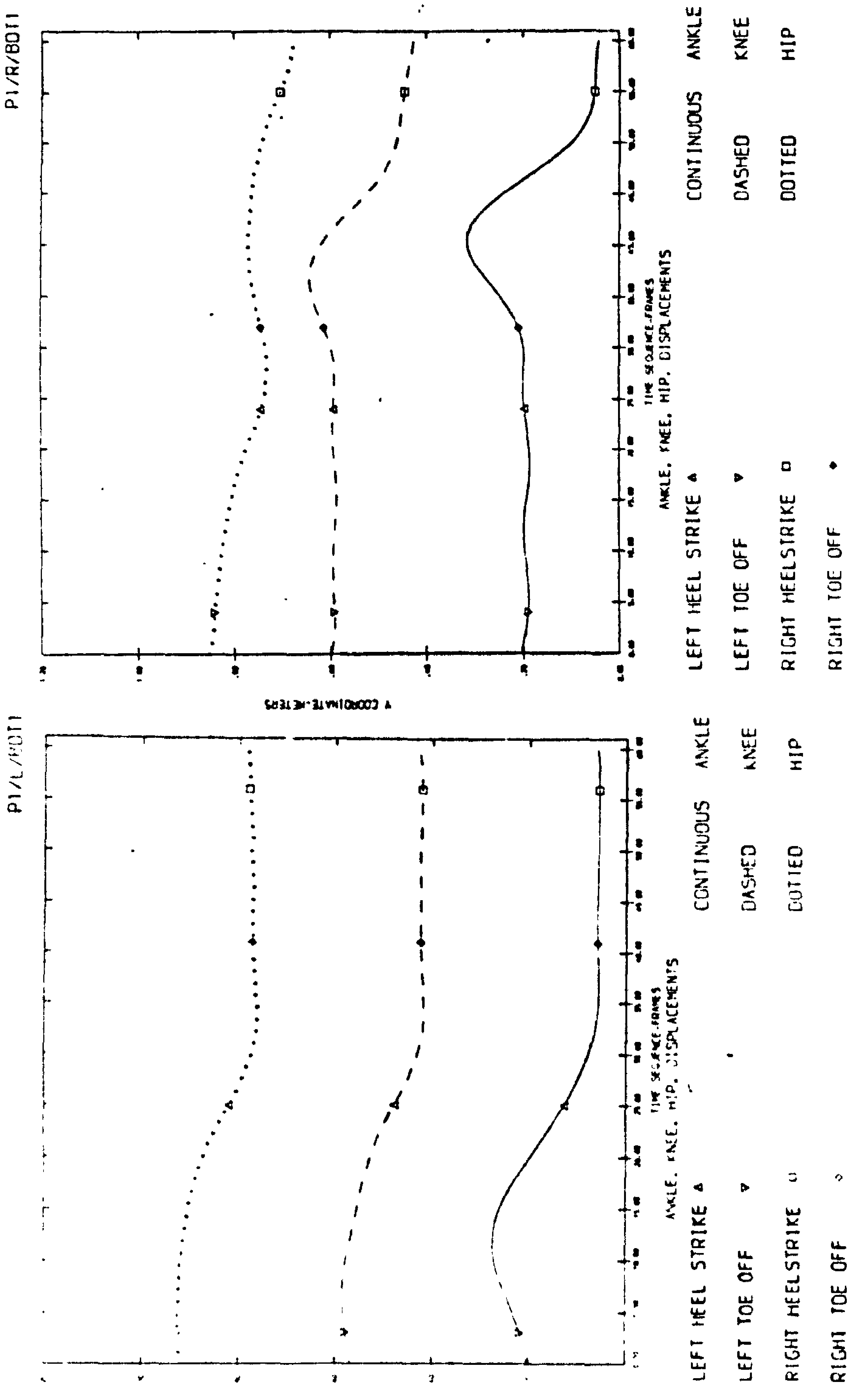

P1/R/BOT1
Y COORDINATE-METERS
TIME SEQUENCE-FRAMES
ANKLE, KNEE, HIP, DISPLACEMENTS
LEFT HEEL STRIKE △
LEFT TOE OFF ▽
RIGHT HEELSTRIKE □
RIGHT TOE OFF ◆
CONTINUOUS ANKLE
DASHED KNEE
DOTTED HIP
P1/L/BOT1
Y COORDINATE METERS
TIME SEQUENCE-FRAMES
ANKLE, KNEE, HIP, DISPLACEMENTS
LEFT HEEL STRIKE △
LEFT TOE OFF ▽
RIGHT HEELSTRIKE □
RIGHT TOE OFF ◇
CONTINUOUS ANKLE
DASHED KNEE
DOTTED HIP

Fig 5. 8

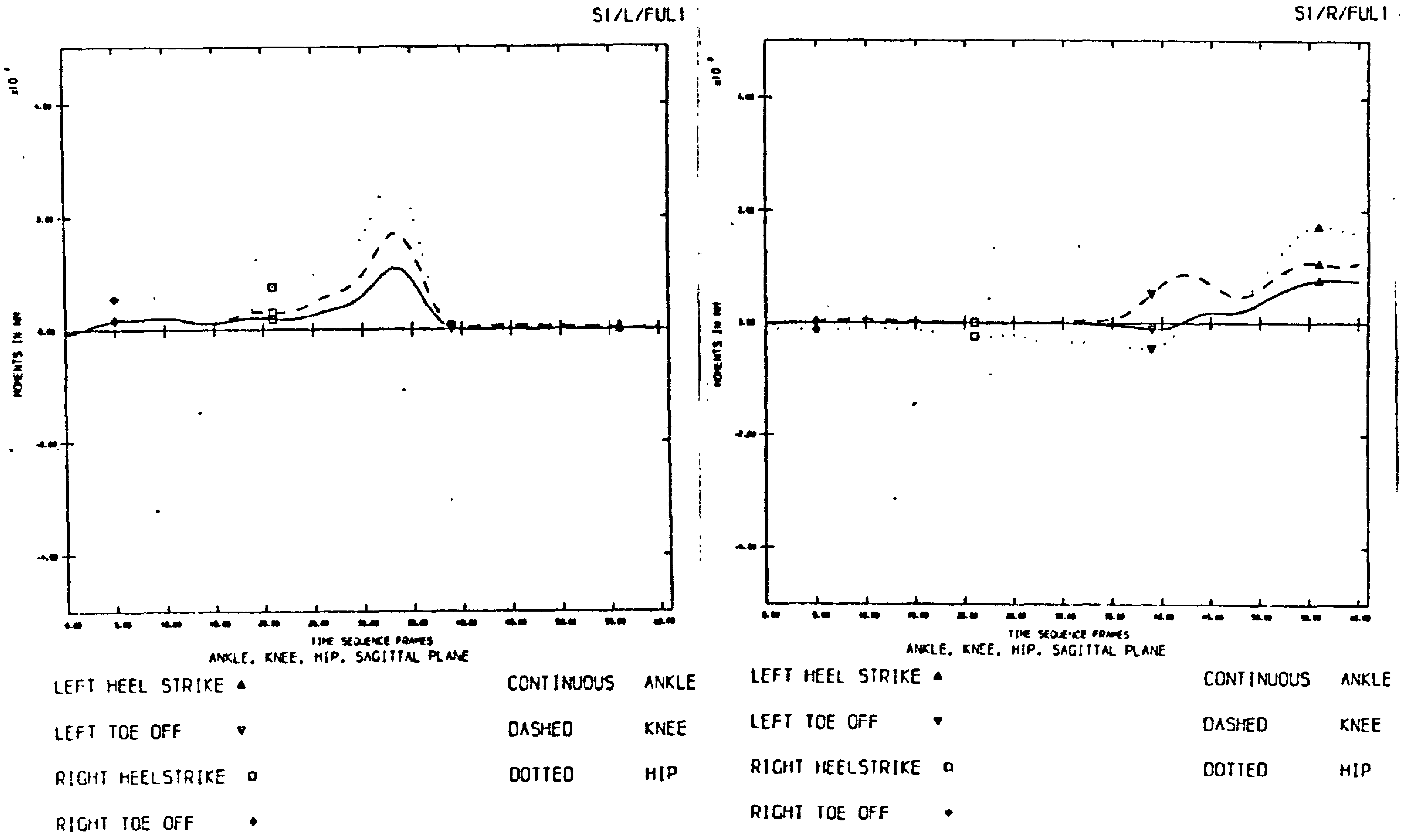

SI/L/FUL1
SI/R/FUL1
MOMENTS IN NM
x10
4.00
2.00
0.00
-2.00
-4.00
TIME SEQUENCE FRAMES
ANKLE, KNEE, HIP, SAGITTAL PLANE
LEFT HEEL STRIKE ▲
LEFT TOE OFF ▼
RIGHT HEELSTRIKE □
RIGHT TOE OFF ◆
CONTINUOUS ANKLE
DASHED KNEE
DOTTED HIP

Fig.5.9

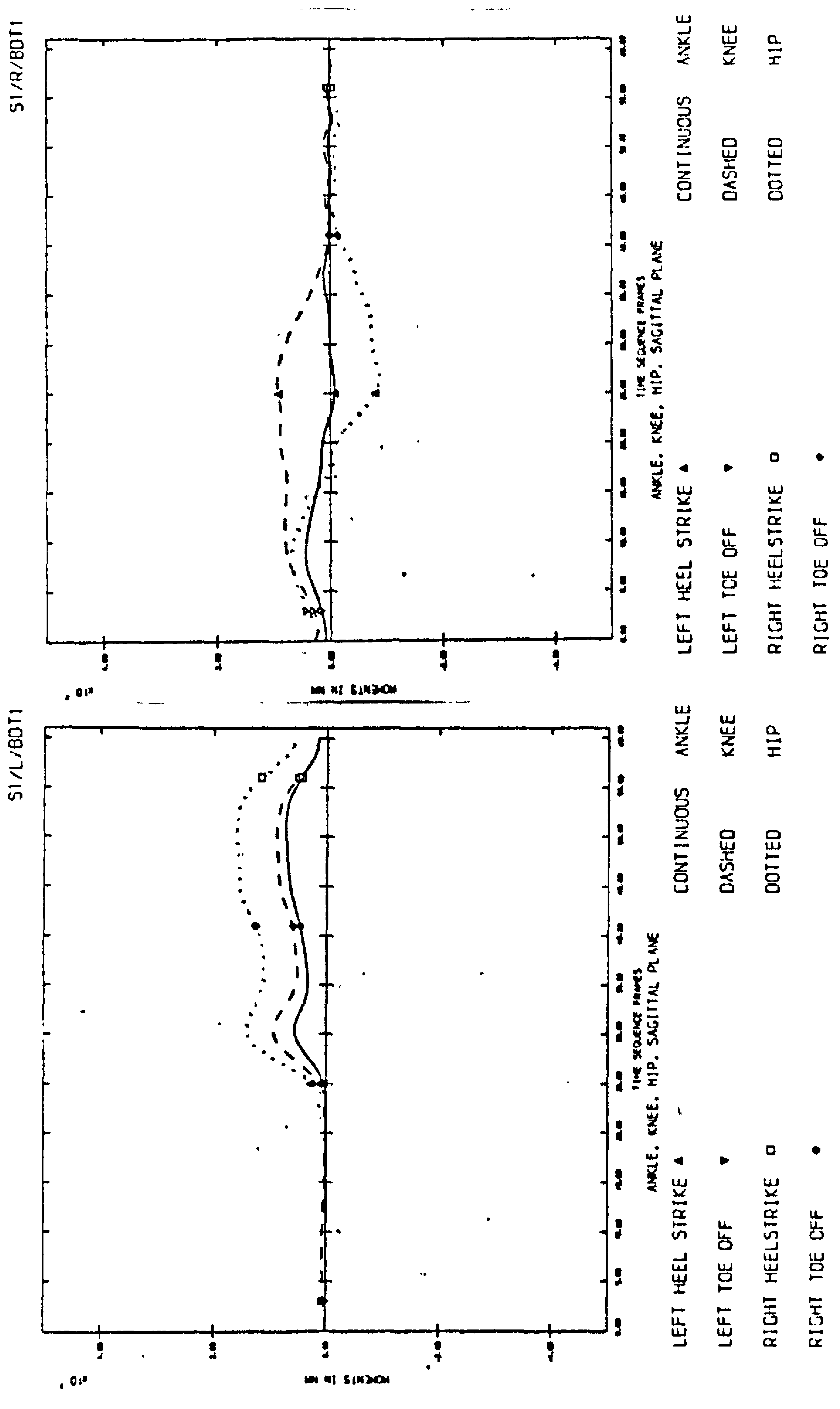

S1/R/BDT1
MOMENTS IN NM
x10¹
TIME SEQUENCE FRAMES
ANKLE, KNEE, HIP, SAGITTAL PLANE
LEFT HEEL STRIKE ▲
LEFT TOE OFF ▼
RIGHT HEELSTRIKE □
RIGHT TOE OFF ◆
CONTINUOUS ANKLE
DASHED KNEE
DOTTED HIP
S1/L/BDT1
MOMENTS IN NM
x10¹
TIME SEQUENCE FRAMES
ANKLE, KNEE, HIP, SAGITTAL PLANE
LEFT HEEL STRIKE ▲
LEFT TOE OFF ▼
RIGHT HEELSTRIKE □
RIGHT TOE OFF ◆
CONTINUOUS ANKLE
DASHED KNEE
DOTTED HIP

Fig.5.10

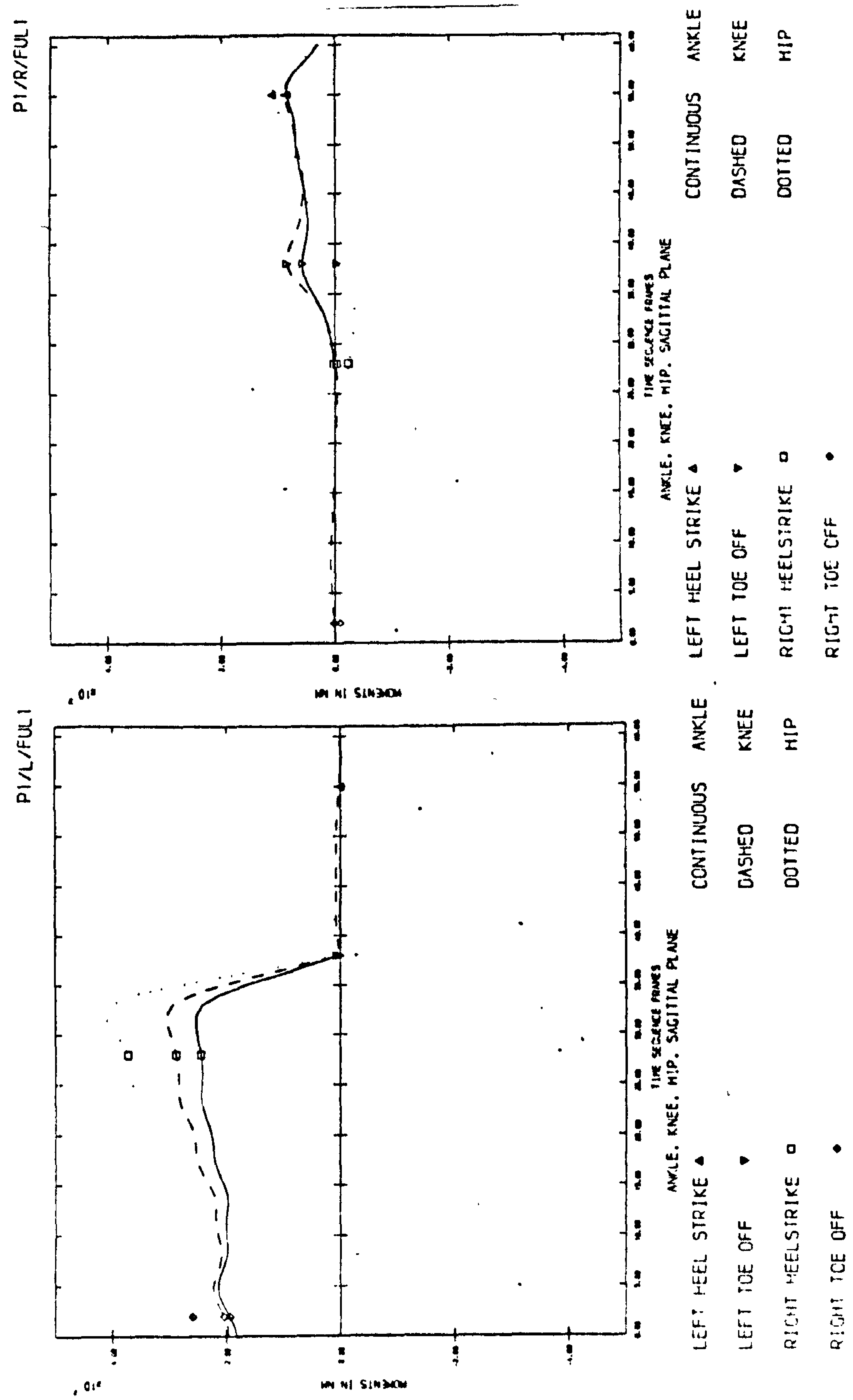

P1/R/FUL1
P1/L/FUL1
MOMENTS IN NM
x10^1
TIME SEQUENCE FRAMES
ANKLE, KNEE, HIP, SAGITTAL PLANE
LEFT HEEL STRIKE ▲
LEFT TOE OFF ▼
RIGHT HEELSTRIKE □
RIGHT TOE OFF ◆
CONTINUOUS ANKLE
DASHED KNEE
DOTTED HIP

Fig.5.11

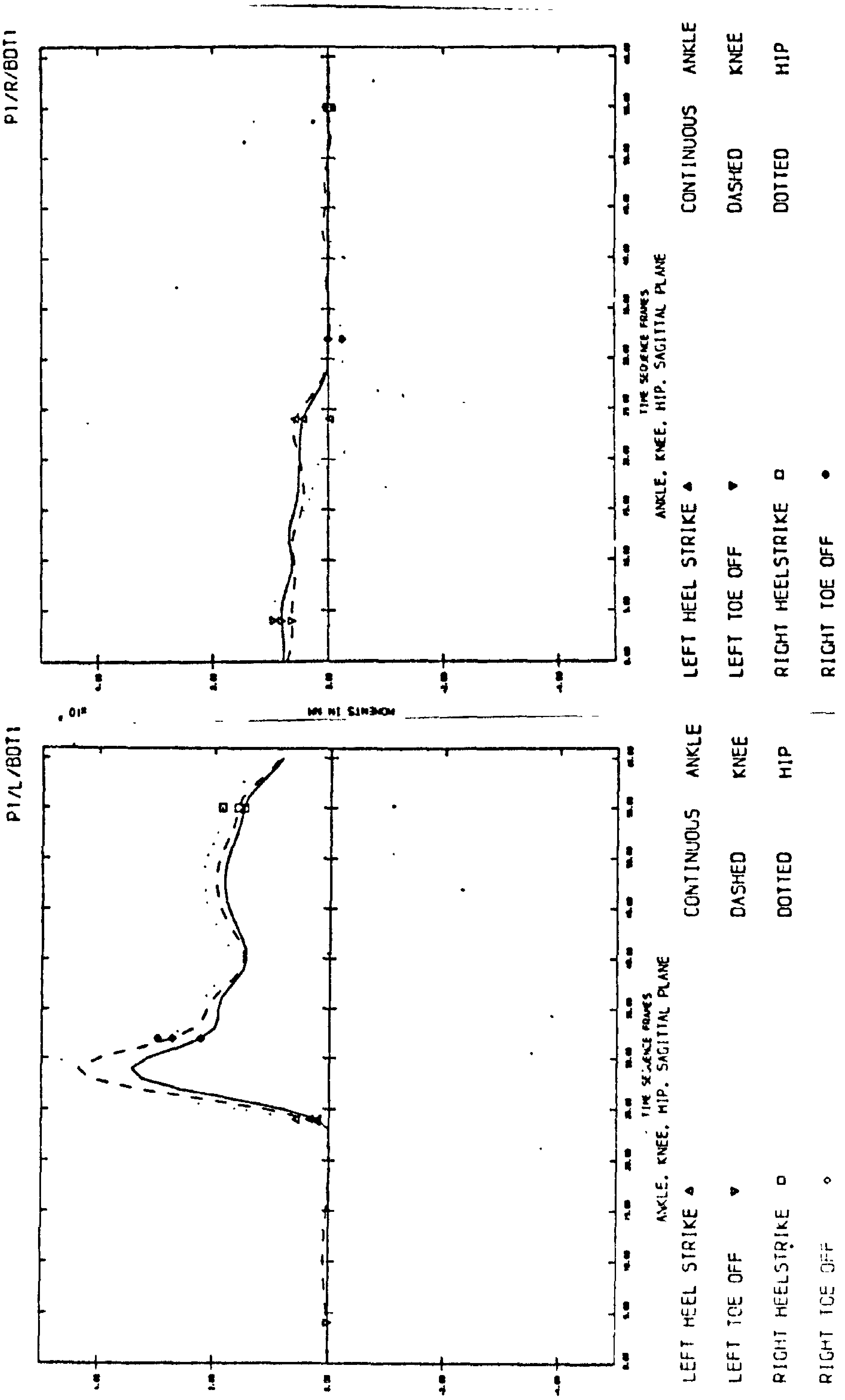

P1/R/BDT1
P1/L/BDT1
MOMENTS IN NM
*10²
TIME SEQUENCE FRAMES
ANKLE, KNEE, HIP, SAGITTAL PLANE
LEFT HEEL STRIKE ▲
LEFT TOE OFF ▼
RIGHT HEELSTRIKE □
RIGHT TOE OFF ●
RIGHT TOE OFF ◇
CONTINUOUS ANKLE
DASHED KNEE
DOTTED HIP

Fig.5.12

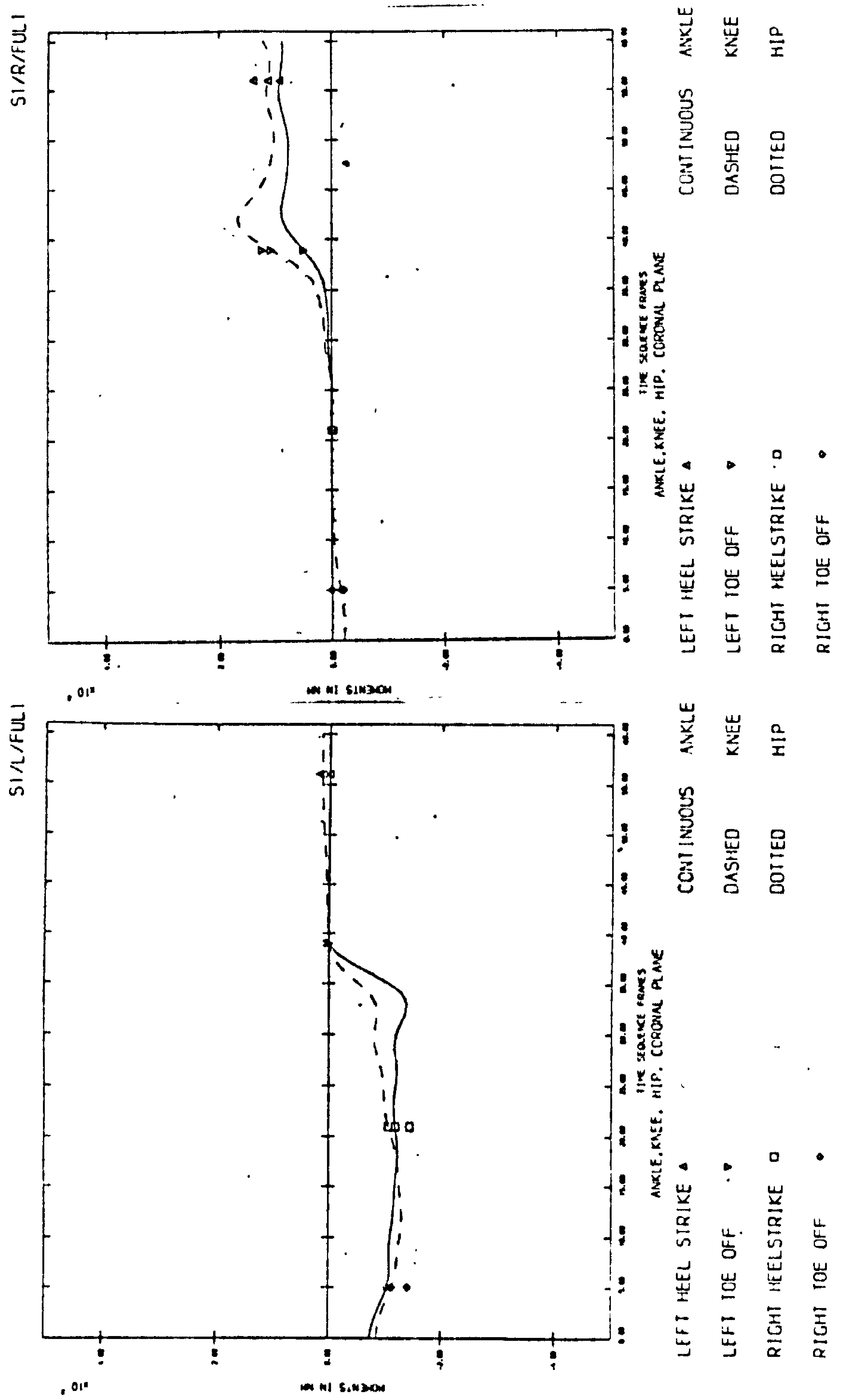

S1/R/FUL1
S1/L/FUL1
×10¹
MOMENTS IN NM
TIME SEQUENCE FRAMES
ANKLE, KNEE, HIP, CORONAL PLANE
LEFT HEEL STRIKE ▲
LEFT TOE OFF ▼
RIGHT HEELSTRIKE □
RIGHT TOE OFF ◆
CONTINUOUS ANKLE
DASHED KNEE
DOTTED HIP

Fig.5.13

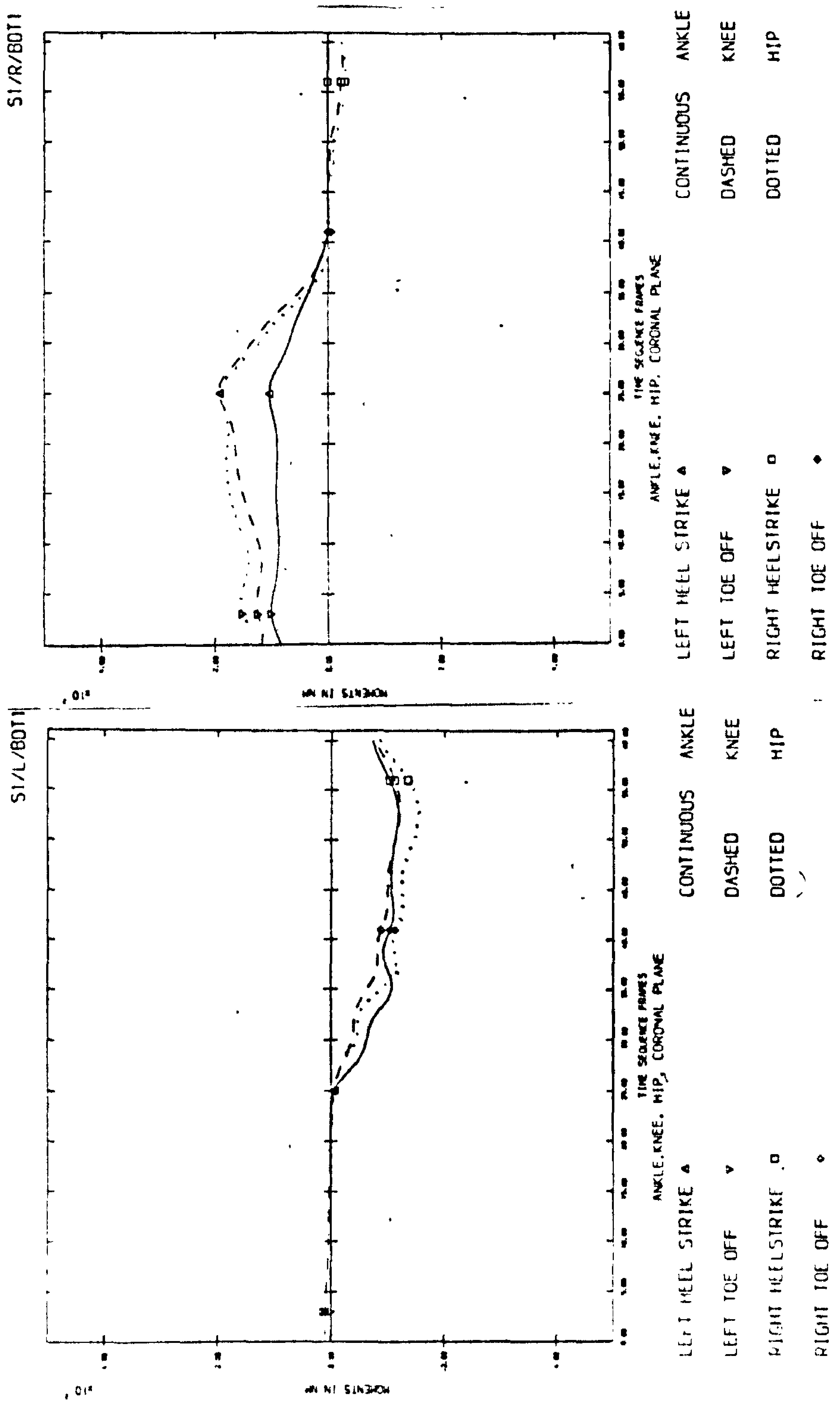

S1/R/BDT1
MOMENTS IN NM
TIME SEQUENCE FRAMES
ANKLE, KNEE, HIP, CORONAL PLANE
LEFT HEEL STRIKE ▲
LEFT TOE OFF ▼
RIGHT HEELSTRIKE □
RIGHT TOE OFF ◆
CONTINUOUS ANKLE
DASHED KNEE
DOTTED HIP
S1/L/BDT1
MOMENTS IN NM
TIME SEQUENCE FRAMES
ANKLE, KNEE, HIP, CORONAL PLANE
LEFT HEEL STRIKE ▲
LEFT TOE OFF ▼
RIGHT HEELSTRIKE □
RIGHT TOE OFF ◇
CONTINUOUS ANKLE
DASHED KNEE
DOTTED HIP

Fig.5.14

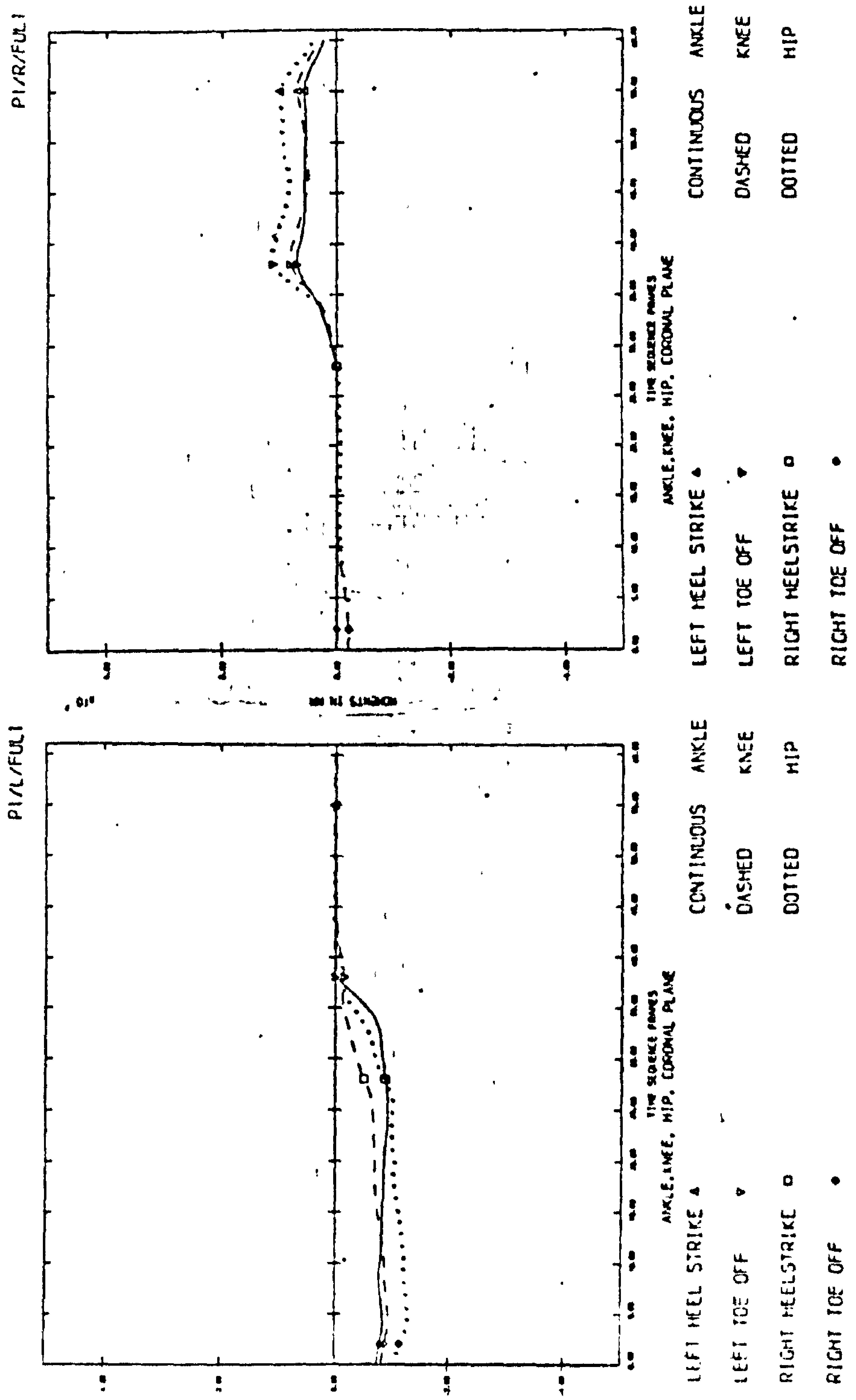

P1/R/FUL1
MOMENTS IN NM
TIME SEQUENCE FRAMES
ANKLE,KNEE, HIP, CORONAL PLANE
LEFT HEEL STRIKE ▲
LEFT TOE OFF ▼
RIGHT HEELSTRIKE □
RIGHT TOE OFF ●
CONTINUOUS ANKLE
DASHED KNEE
DOTTED HIP
P1/L/FUL1
MOMENTS IN NM
TIME SEQUENCE FRAMES
ANKLE,KNEE, HIP, CORONAL PLANE
LEFT HEEL STRIKE ▲
LEFT TOE OFF ▼
RIGHT HEELSTRIKE □
RIGHT TOE OFF ●
CONTINUOUS ANKLE
DASHED KNEE
DOTTED HIP

Fig 5.15

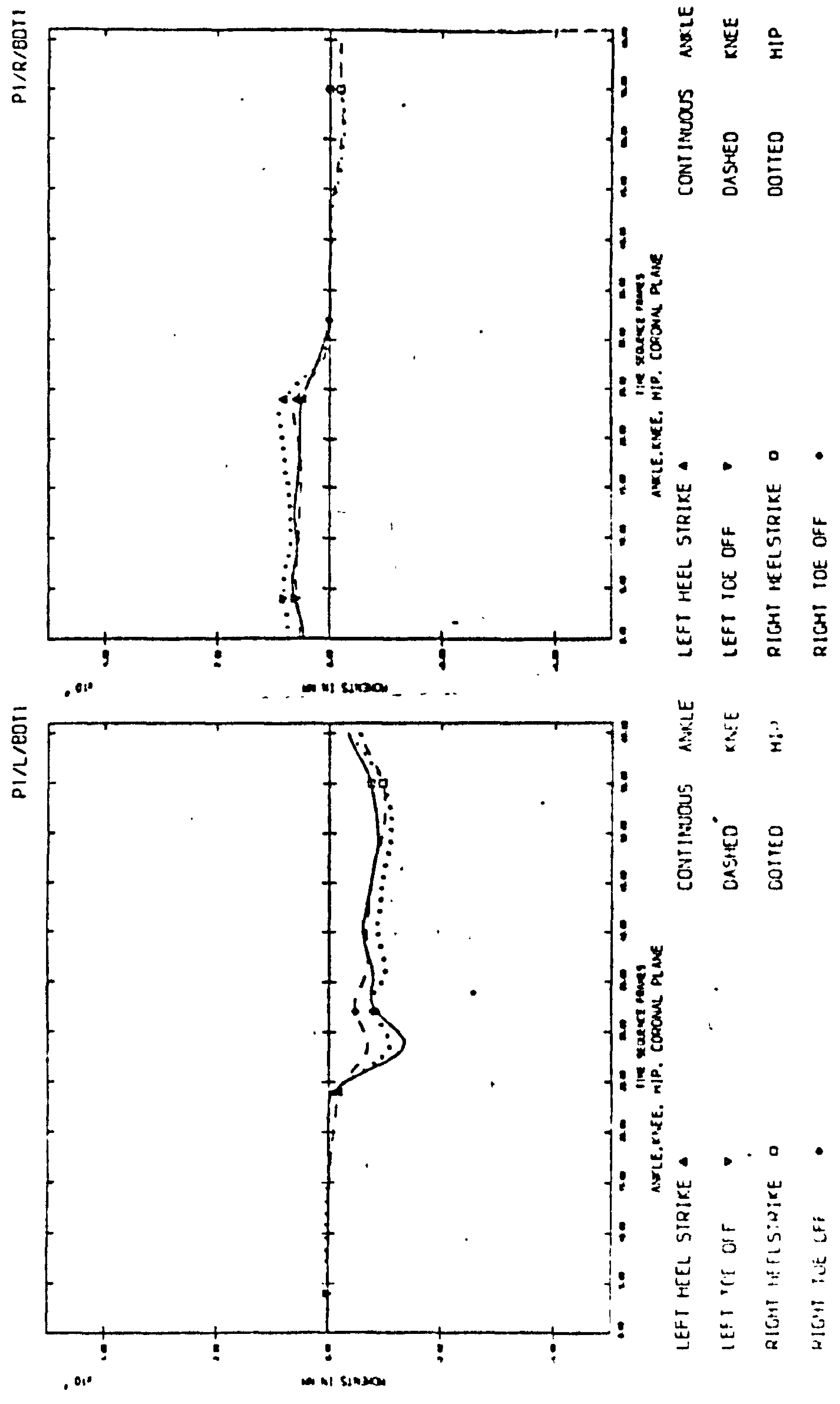

P1/R/BDT1
P1/L/BDT1
MOMENTS IN NM
×10¹
TIME SEQUENCE FRAMES
ANKLE,KNEE, HIP, CORONAL PLANE
LEFT HEEL STRIKE ▲
LEFT TOE OFF ▼
RIGHT HEELSTRIKE □
RIGHT TOE OFF ●
CONTINUOUS ANKLE
DASHED KNEE
DOTTED HIP

Fig 5.16

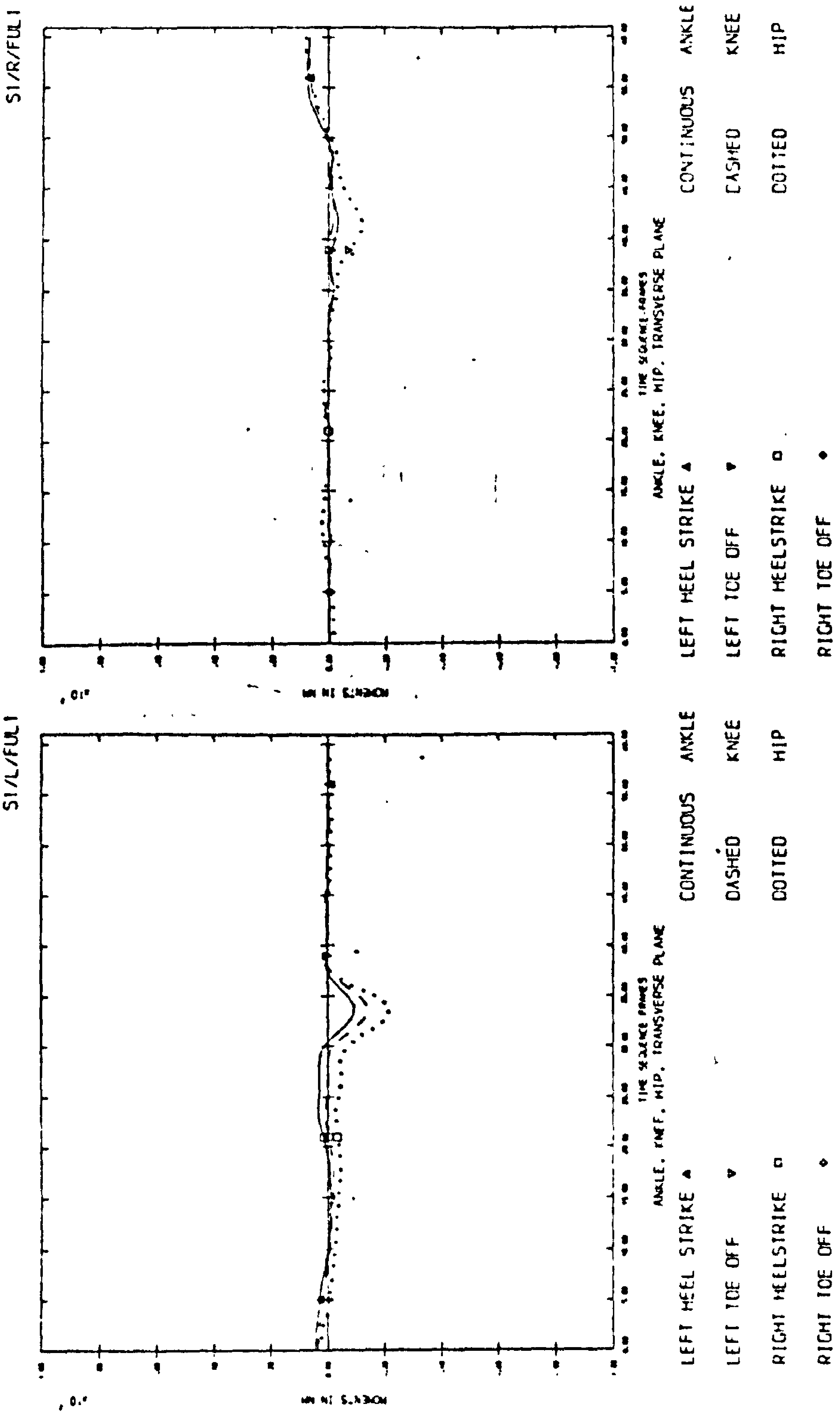

S1/L/FUL1
S1/R/FUL1
MOMENTS IN NM
TIME SEQUENCE FRAMES
ANKLE, KNEE, HIP, TRANSVERSE PLANE
LEFT HEEL STRIKE ▲
LEFT TOE OFF ▼
RIGHT HEELSTRIKE □
RIGHT TOE OFF ◆
CONTINUOUS ANKLE
DASHED KNEE
DOTTED HIP

Fig 5.17

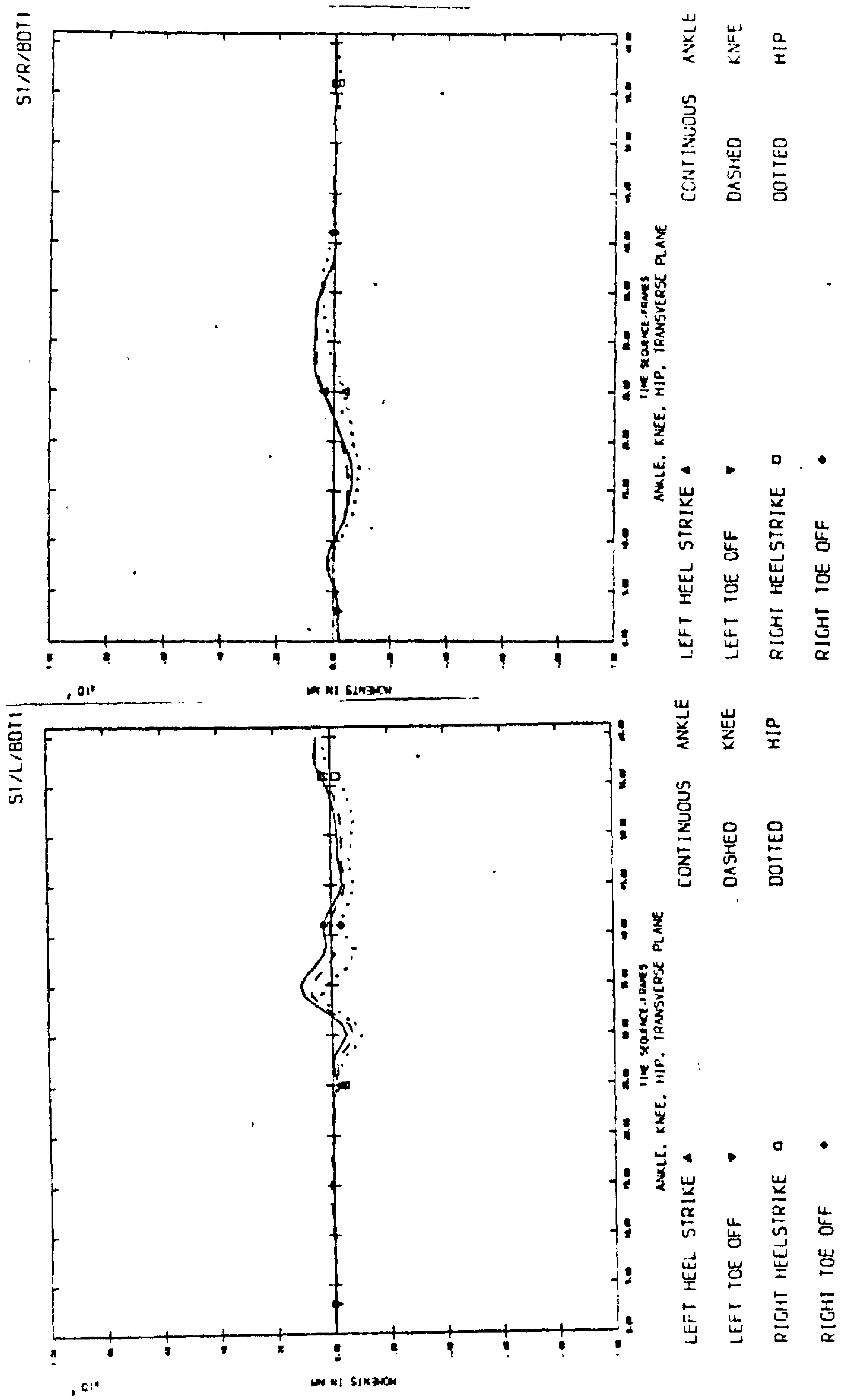

S1/R/BOT1
S1/L/BOT1
x10²
MOMENTS IN NM
TIME SEQUENCE-FRAMES
ANKLE, KNEE, HIP, TRANSVERSE PLANE
LEFT HEEL STRIKE ▲
LEFT TOE OFF ▼
RIGHT HEELSTRIKE □
RIGHT TOE OFF ◆
CONTINUOUS ANKLE
DASHED KNEE
DOTTED HIP

Fig.5.18

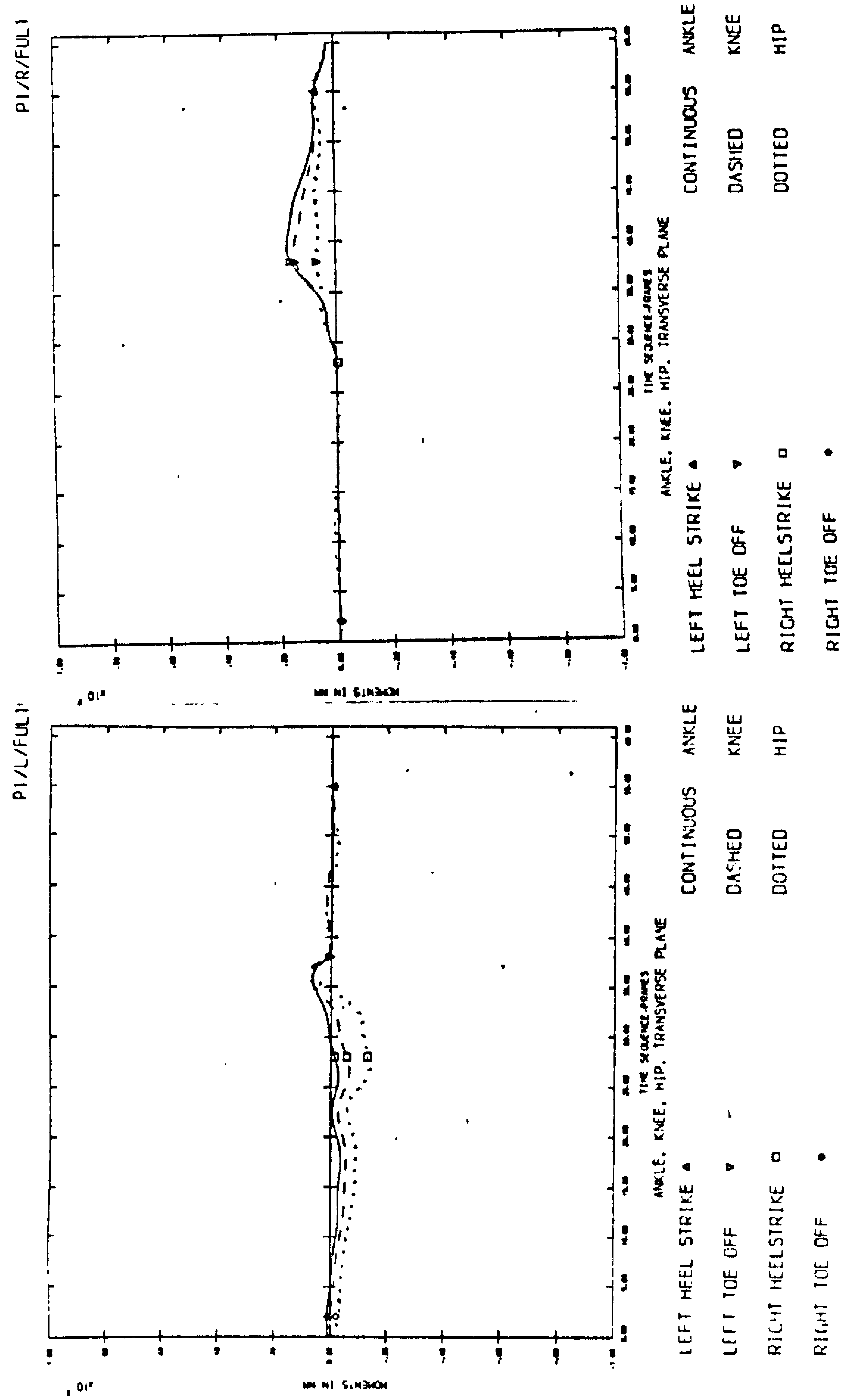

P1/R/FUL1
MOMENTS IN NM
x10
TIME SEQUENCE-FRAMES
ANKLE, KNEE, HIP, TRANSVERSE PLANE
LEFT HEEL STRIKE ▲
LEFT TOE OFF ▼
RIGHT HEELSTRIKE □
RIGHT TOE OFF ●
CONTINUOUS ANKLE
DASHED KNEE
DOTTED HIP
P1/L/FUL1
MOMENTS IN NM
x10
TIME SEQUENCE-FRAMES
ANKLE, KNEE, HIP, TRANSVERSE PLANE
LEFT HEEL STRIKE ▲
LEFT TOE OFF ▼
RIGHT HEELSTRIKE □
RIGHT TOE OFF ●
CONTINUOUS ANKLE
DASHED KNEE
DOTTED HIP

Fig.5.19

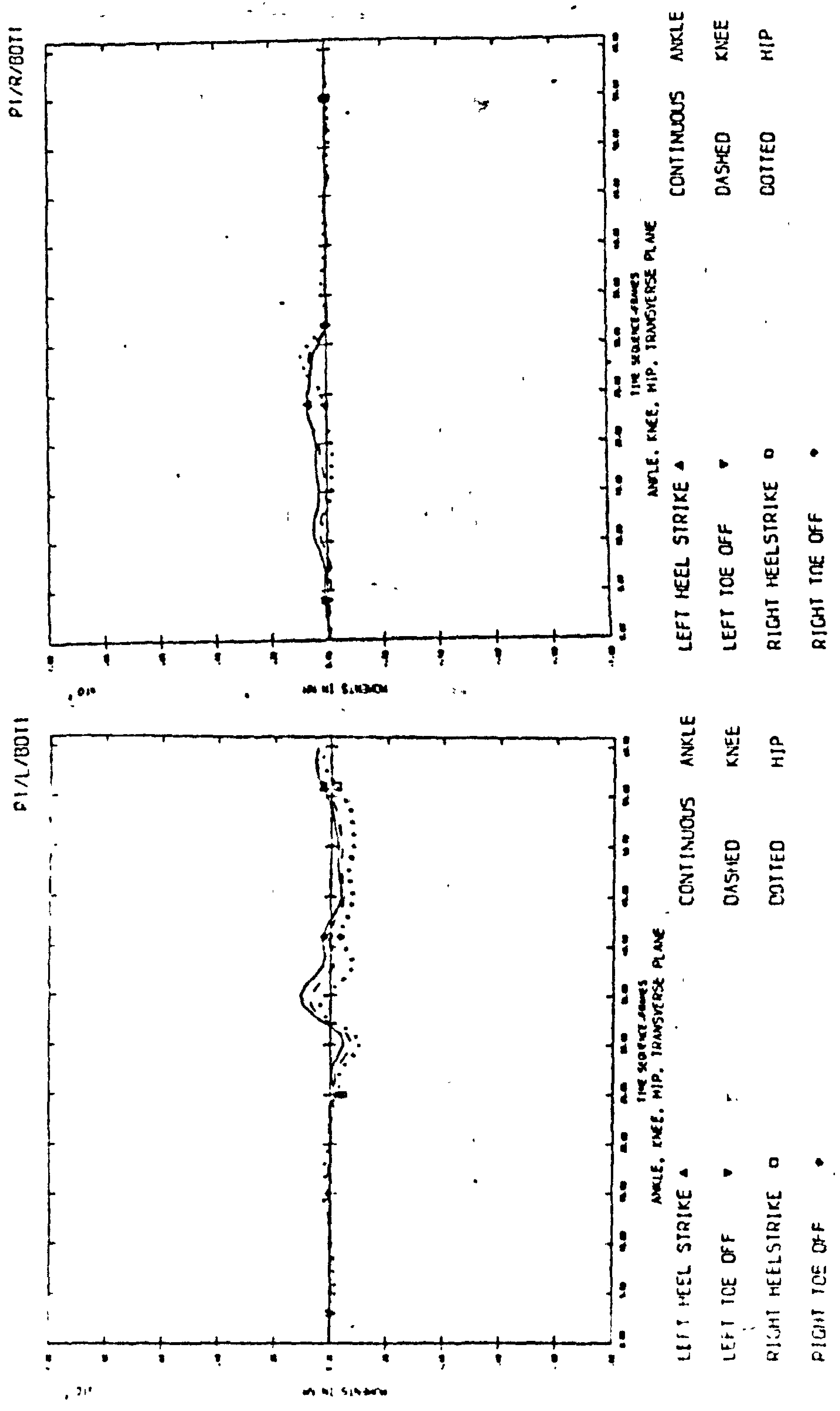

P1/R/BOT1
MOMENTS IN NM
TIME SEQUENCE-FRAMES
ANKLE, KNEE, HIP, TRANSVERSE PLANE
LEFT HEEL STRIKE ▲
LEFT TOE OFF ▼
RIGHT HEELSTRIKE ◻
RIGHT TOE OFF ◆
CONTINUOUS ANKLE
DASHED KNEE
DOTTED HIP
P1/L/BOT1
MOMENTS IN NM
TIME SEQUENCE-FRAMES
ANKLE, KNEE, HIP, TRANSVERSE PLANE
LEFT HEEL STRIKE ▲
LEFT TOE OFF ▼
RIGHT HEELSTRIKE ◻
RIGHT TOE OFF ◆
CONTINUOUS ANKLE
DASHED KNEE
DOTTED HIP

Fig 5.20

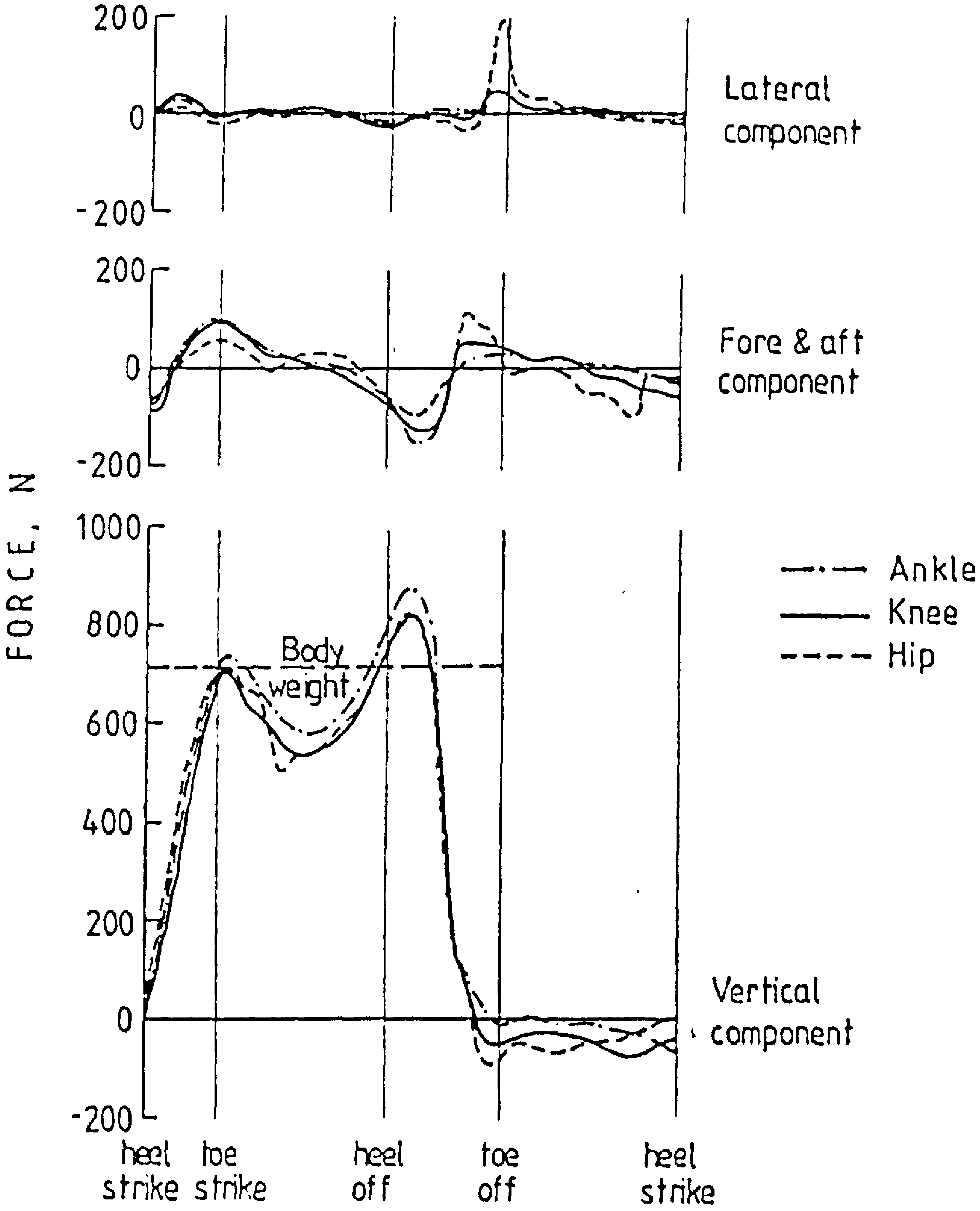


Fig 5.21 Intersegment forces in level walking.

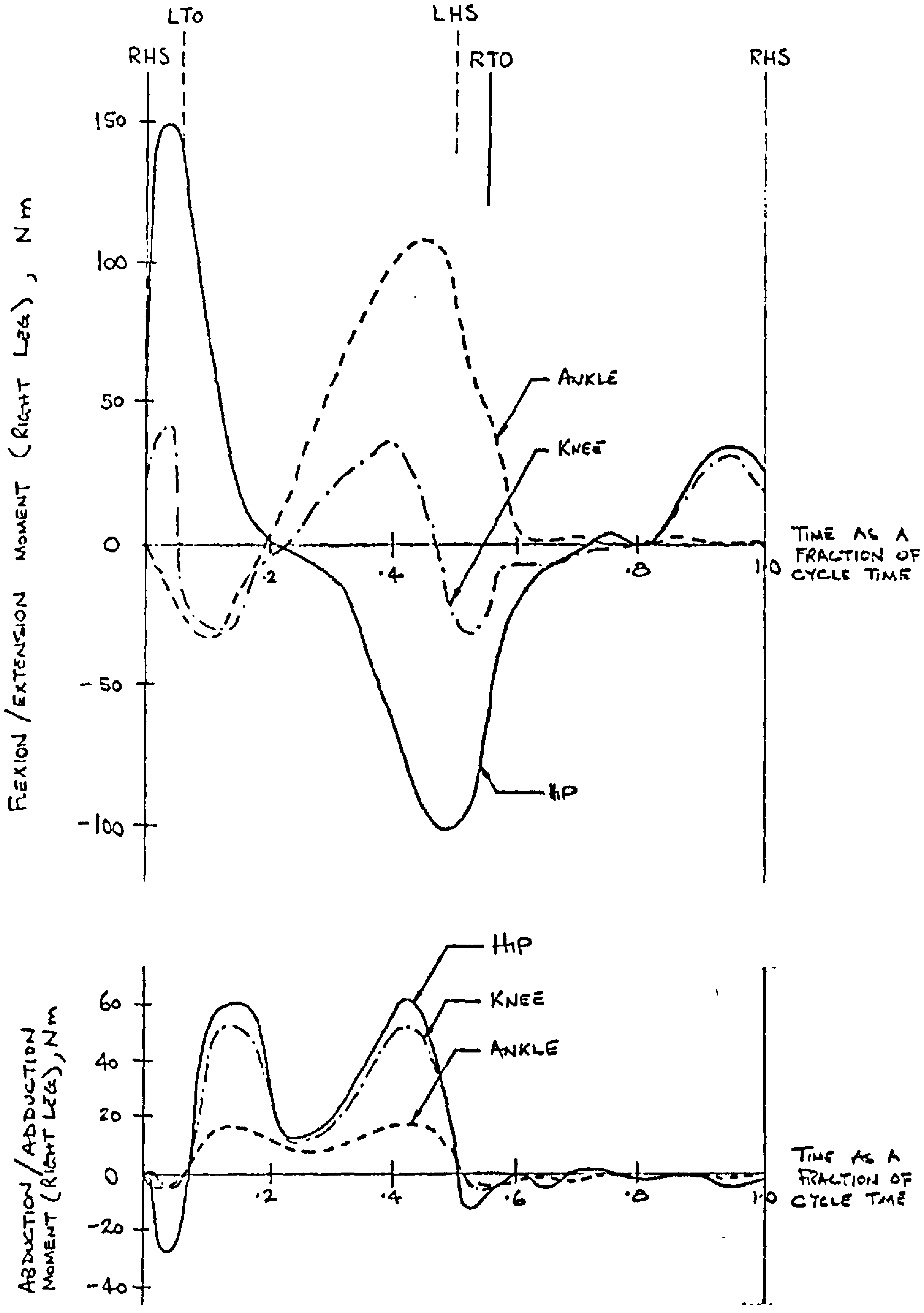
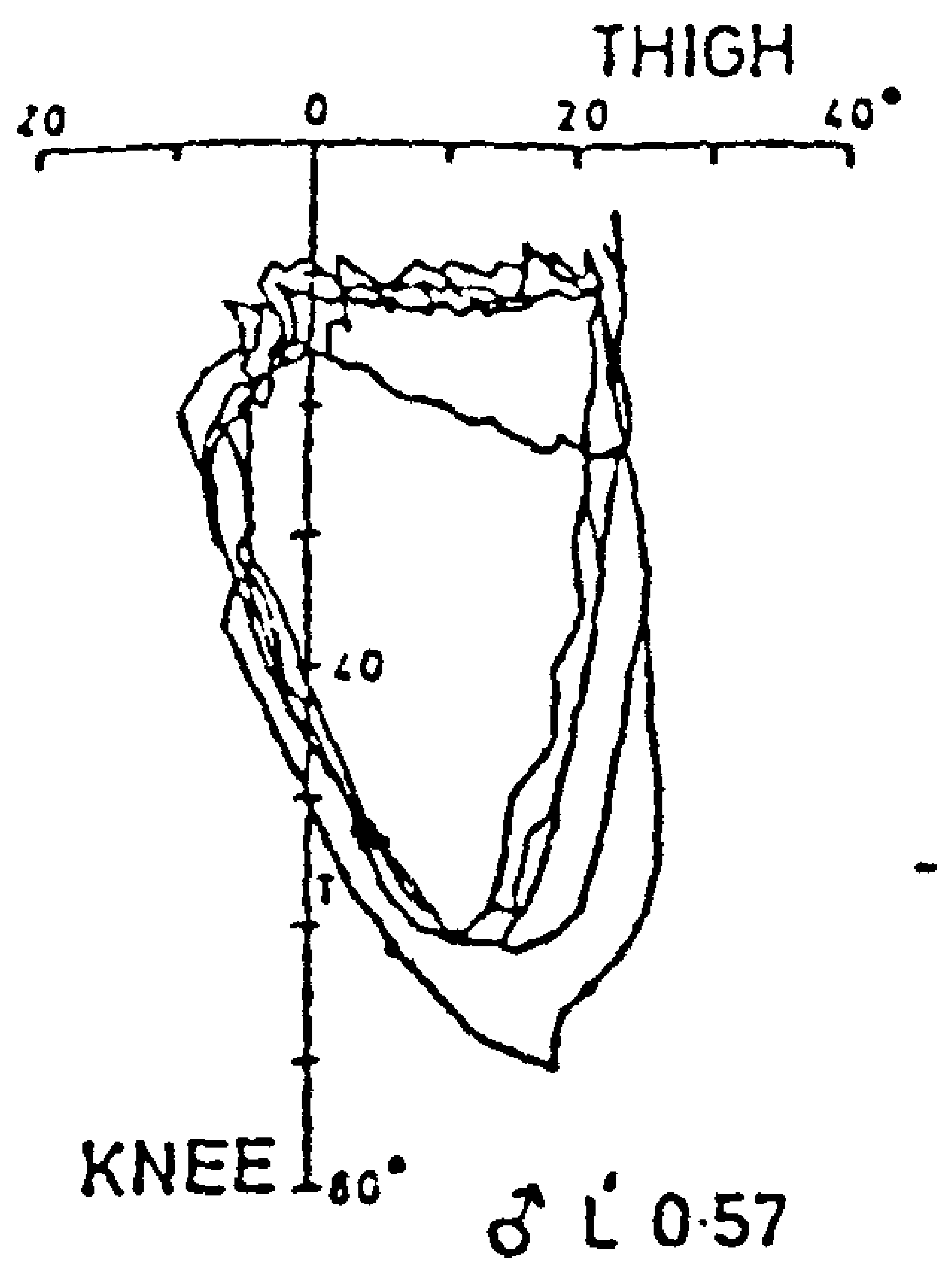
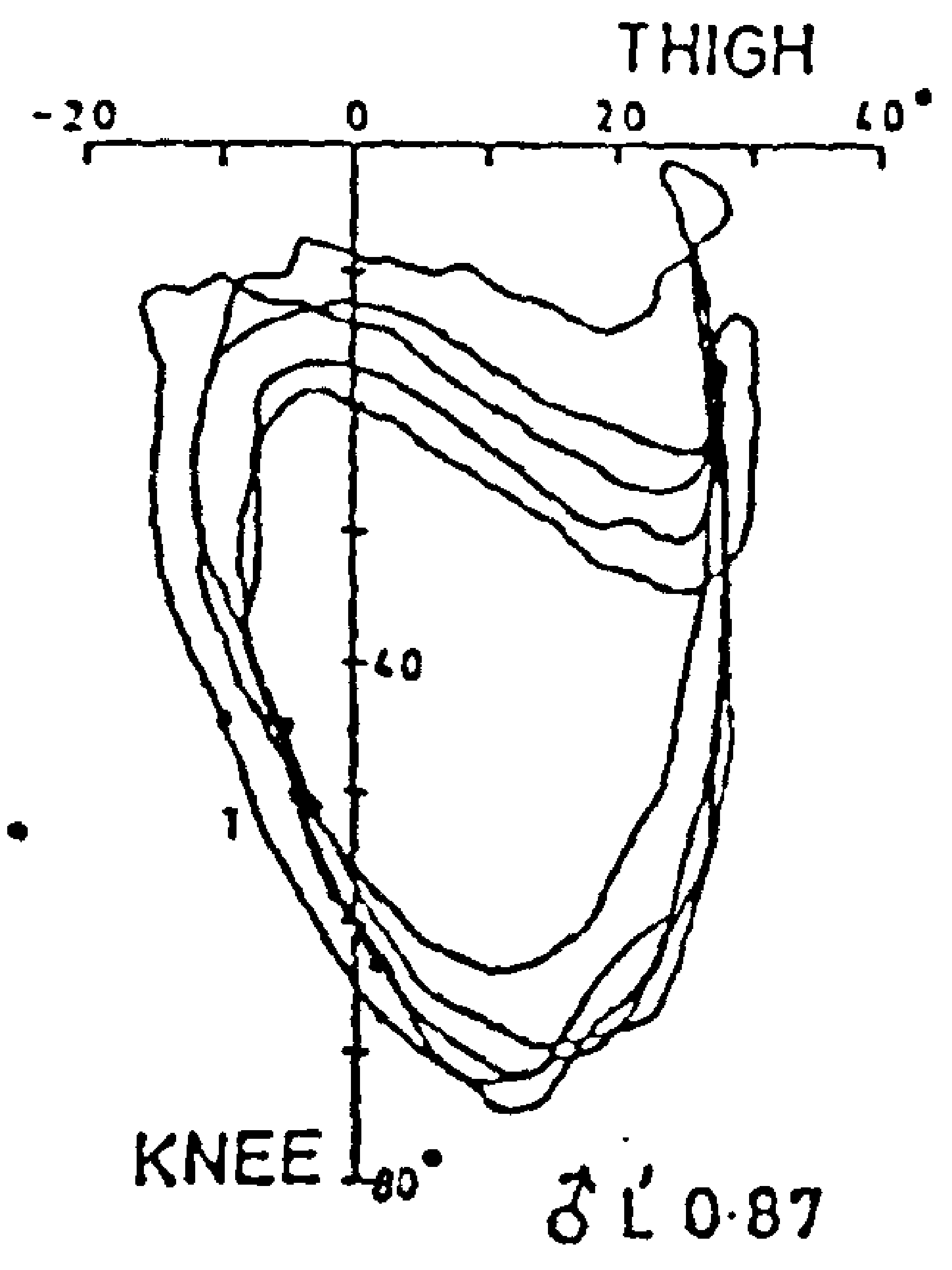

LTo
RHS
LHS
RTO
RHS
150
100
50
0
-50
-100
Flexion / Extension Moment (Right Leg), Nm
Ankle
Knee
Hip
·2
·4
·6
·8
1·0
Time as a fraction of cycle time
Hip
Knee
Ankle
60
40
20
0
-20
-40
Abduction / Adduction Moment (Right Leg), Nm
·2
·4
·6
·8
1·0
Time as a fraction of cycle time

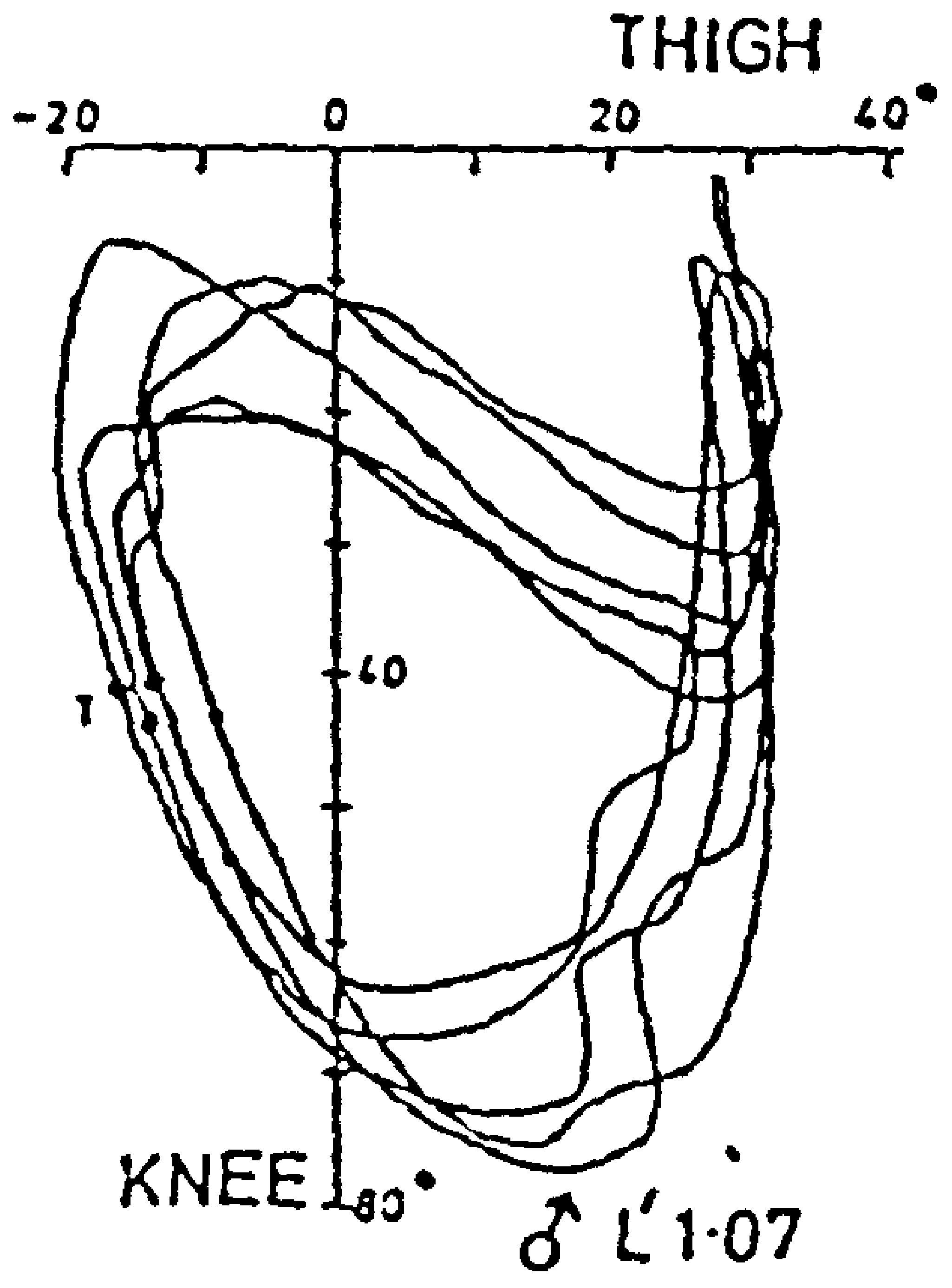
Fig. 5.22



. ' Thigh-knee ' angle charts for normal young adult males during slow walking with short strides. Heel-strike posture in top right-hand corner. Closed circles and ' T ' refer to toe off

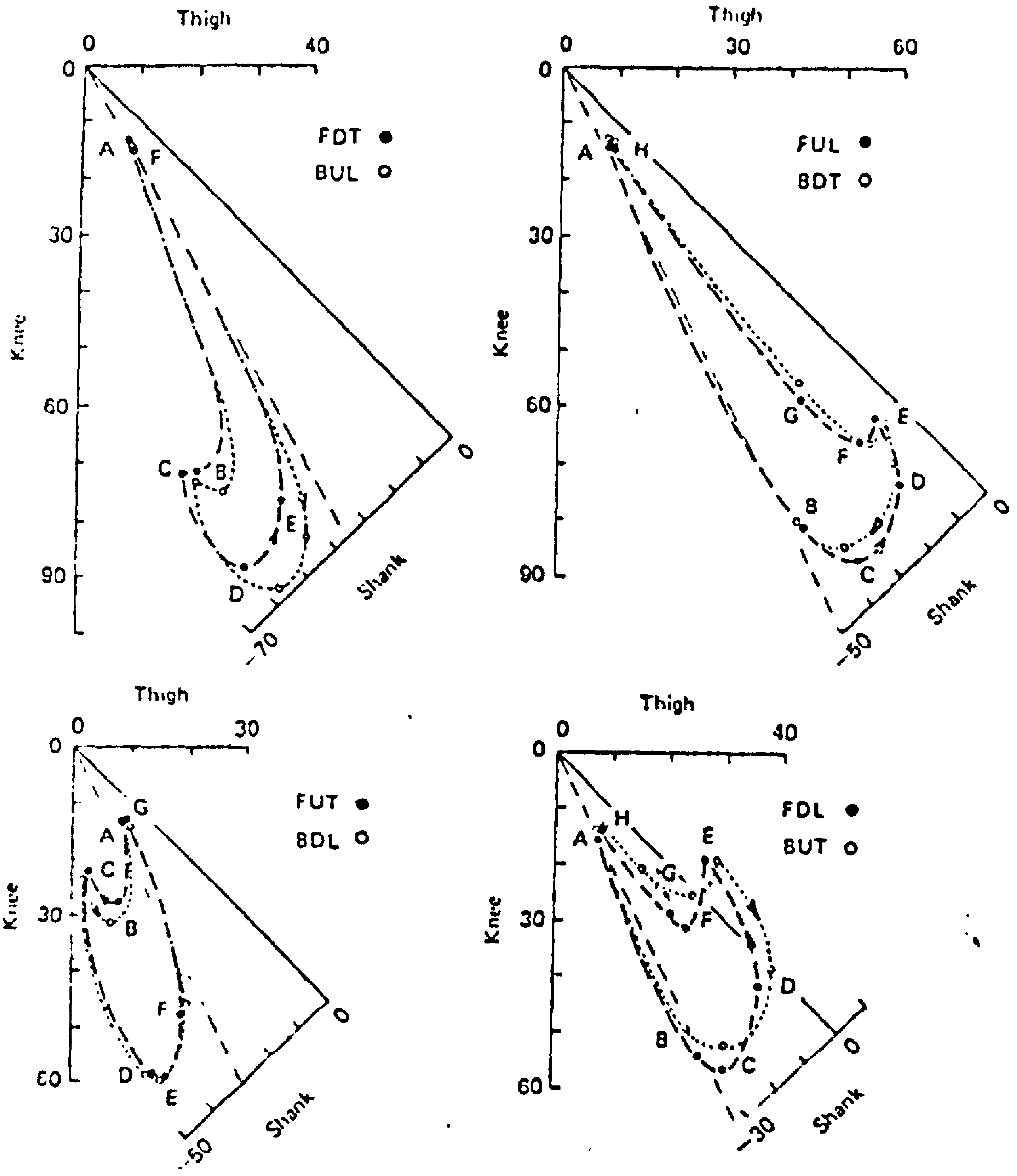


Angle charts at moderate speeds and strides



Angle charts at fast speed and stride greater than stature

Fig.5.23



Predicted forms of thigh-knee diagrams to be expected at a relative step height equal to 10% of stature.

Fig 5.24

5.2 Raw Data and Calculation of Moment

Sample for some of the raw data from the tests of one normal subject and one patient are presented in Fig. 5.1 to 5.8.

In comparing the forceplate (FP) data for the normals with those for the pathologicals it will be noticed that the forces for the patients showed considerable instability (made apparent by the fluctuations on the force signals) particularly on the y component of force 'Fy' see Fig. 5.1 to 5.4)

Referring to the Fy force trace Fig. 5.1 to 5.4 the initial force value is about 300 N which is about half of the body weight (this value varies, sometimes more and sometimes less than half body weight). It depends on the way the test subject is standing prior to commencement of the experiment.

The pattern of the Fy force has the characteristic double peak shape observed on tests for normal level walking (see Fig. 5.21). The peak value however, is only about 10% above body weight, whereas on walking values between 20% to 40% above body weight have been reported. This of course is due to the fact that only one step is performed and the inertia effects are much smaller than in walking.

It was considered that the Y displacements were the most relevant in the raw data and these are shown in Fig. 5.5 to 5.8. For the FU I manoeuvre (Fig. 5.5) it is noted that the hip rises smoothly as the subject walks on the step, whereas the knee and the ankle displacements show peaks which indicate that the subject attempts to clear the step during the swing phase. The same applies for the BD' I manoeuvre. Symmetries for the left and right leg for the two manoeuvres are evident. There are no significant differences between the normals (Fig. 5.5 and 5.6) and the patients tested (Fig. 5.7 and 5.8) in the displacements curves.

From the raw data, the moments in the sagittal, coronal and transverse planes have been calculated and sample graphs for the results for the same subject and patient are presented in Fig. 5.9 to 5.20.

It will be appreciated that a large number of graphs have been obtained, one set for each of the five normal subjects and for each of the five patients tested. In order to allow comparisons between subjects, between patients, between patients and subjects, between various types of manoeuvres to be made easily, the curves for the same manoeuvres for normals and patients have been superimposed on the same diagram.

During swing phase very small load actions have been noted. These are practically zero at the ankle and very slight at the knee and hip due to inertia effects. Load actions during the swing phase have been reported to be of low magnitude when compared to those obtained during the stance phase of locomotion by several investigators (Paul, 1967 and Frankel and Bressler, 1952).

5.3 Moments in the Sagittal Plane

5.3.1 Moments at the ankle joint. The results for the ankle are as follows:

Fig. 5.25 FU O (left and right) for patients and subjects
Fig. 5.26 BD O (left and right) for patients and subjects
Fig. 5.27 FU 1 (left and right) for patients and subjects
Fig. 5.28 BD 1 (left and right) for patients and subjects

Examination of Fig. 5.25 and 5.26 shows that the shapes of the graphs for the zero height step are similar to those obtained using a 10% step height (Fig. 5.27 and 5.28). The patient P1, however showed higher moment values than the other patients in all cases. The following discussion is based on the results of the 10% step test but applies equally well to the zero height step.

Referring to Fig. 5.26 and 5.28, BD O and BD I are similar to those for FU O and FU 1 but the graphs are in the reverse order with respect to time; due to the backwards direction of the BD manoeuvre.

On examination of Fig. 5.25 and 5.27, it is evident that the initial negative (plantar flexing moment) that is observed in normal level walking (see Fig. 5.22) is absent. This is because proper heel strike does not obtain in any of the manoeuvres examined in this study. The dorsiflexion moment was in the range of 50 - 100 Nm which is somewhat less than the reported average of 100 to 150 Nm to normal level walking (see Fig. 5.22).

It is evident from Fig. 5.25 to 5.28 for normal subjects that the loading on the two ankles (right and left) is not symmetrical - the loading on the left ankle tends

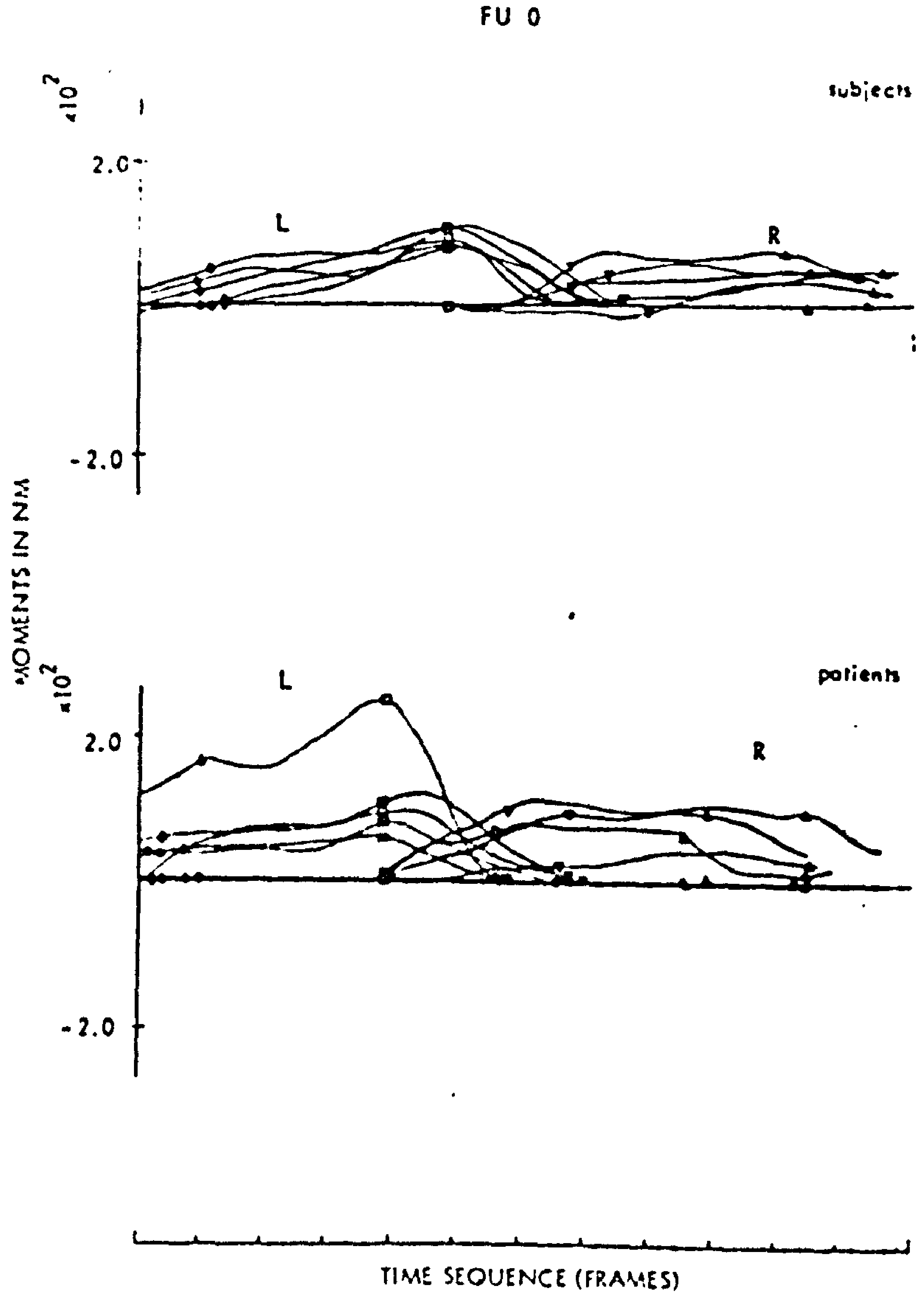


Fig. 5.25 ankle moments sagittal plane

LEFT HEEL STRIKE △

LEFT TOE OFF ▽

RIGHT HEELSTRIKE □

RIGHT TOE OFF ◇

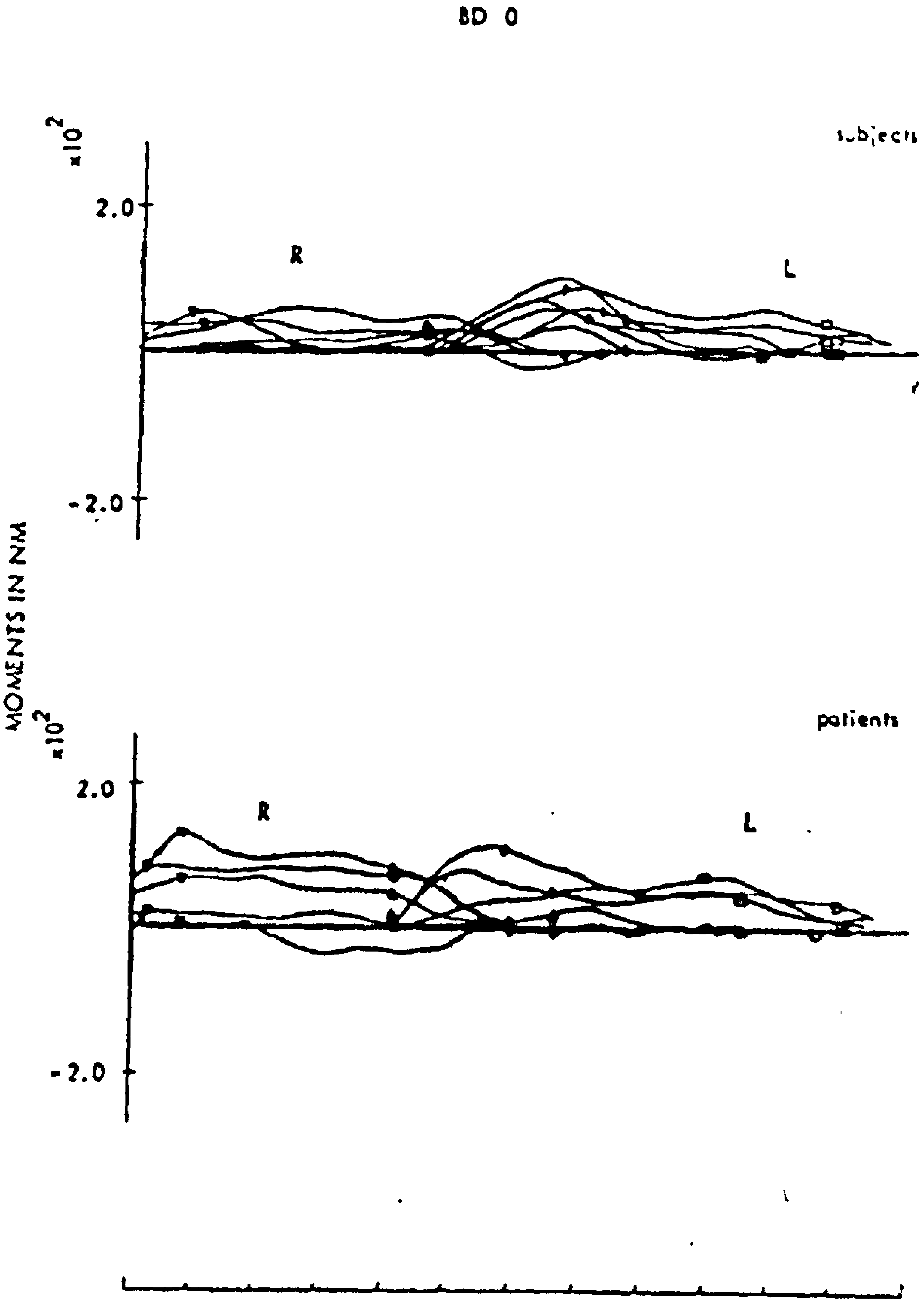


Fig. 5.26 ankle moments sagittal plane

LEFT HEEL STRIKE △

LEFT TOE OFF ▽

RIGHT HEELSTRIKE □

RIGHT TOE OFF ◇

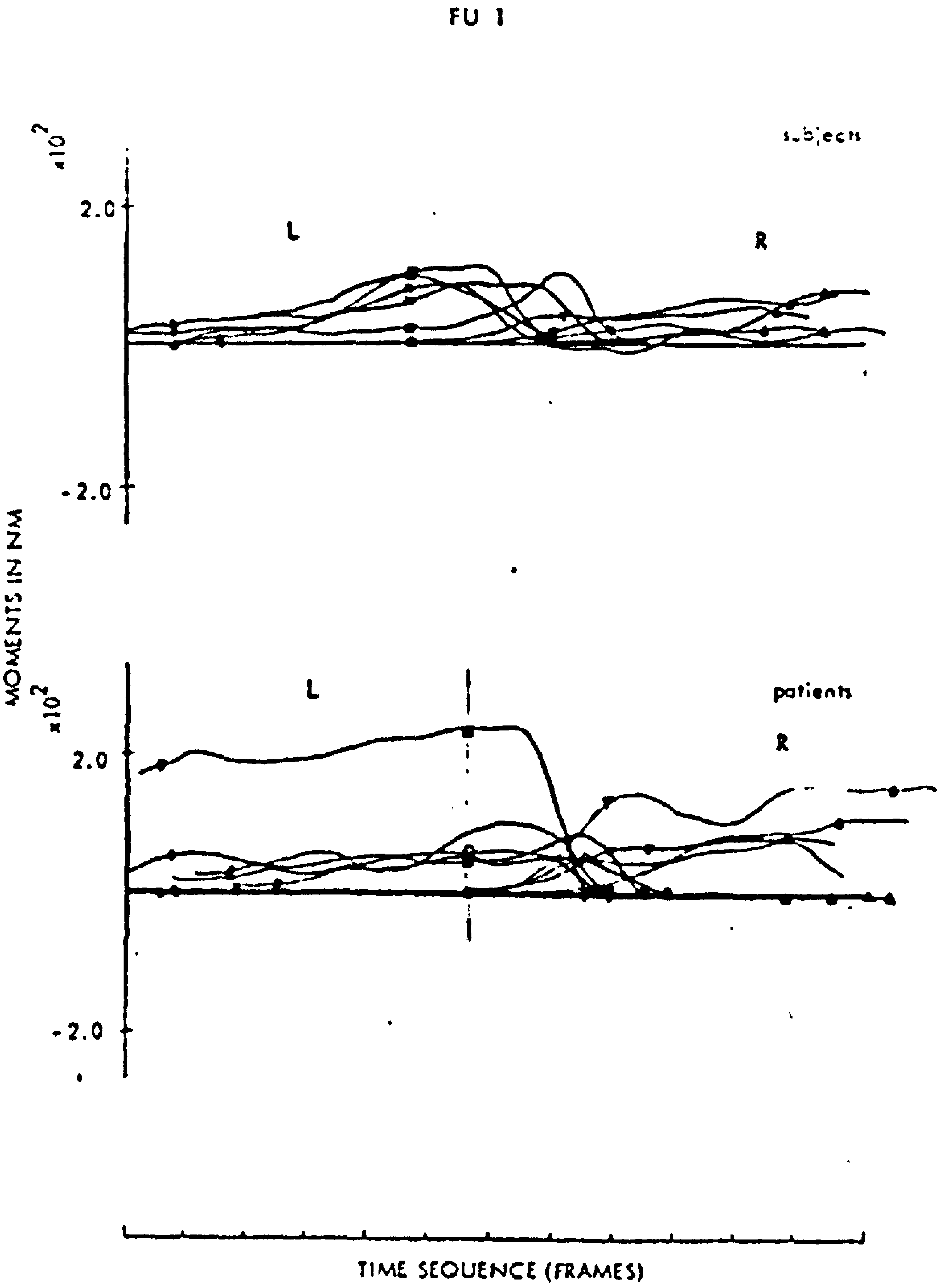


Fig. 5.27 ankle moments sagittal plane

LEFT HEEL STRIKE △

LEFT TOE OFF ▽

RIGHT HEELSTRIKE □

RIGHT TOE OFF ◇

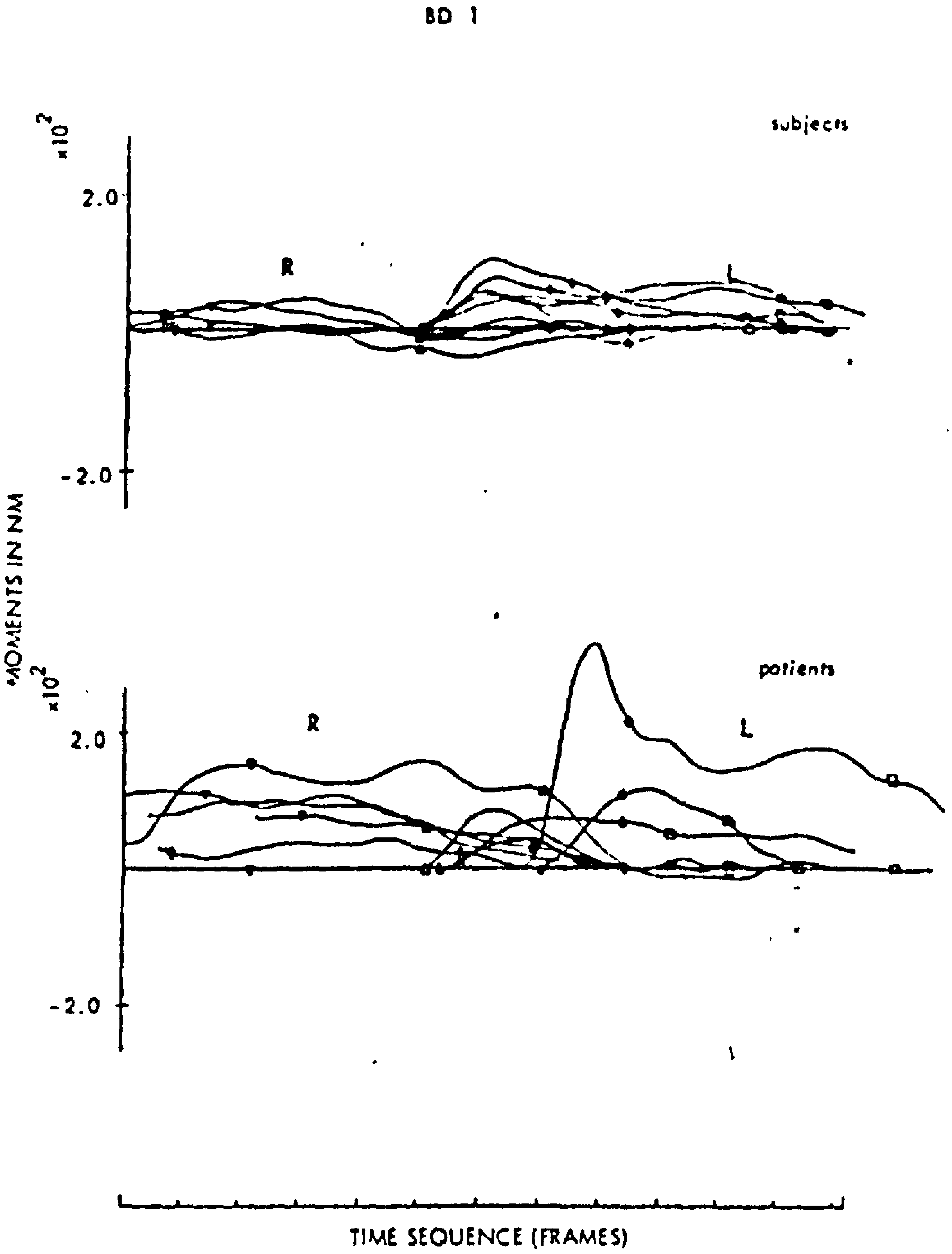


Fig. 5:28 ankle moments sagittal plane

LEFT HEEL STRIKE △

LEFT TOE OFF ▽

RIGHT HEELSTRIKE □

RIGHT TOE OFF ◇

to be higher than that on the right. This may be explained as follows: on a FU manoeuvre (zero or 10% height) the left leg being posterior to the body, applies the push off power, and on the BD manoeuvre the left leg is again posterior to the body and decelerates the body on the backwards movement.

In both cases this has the effect of increasing the ground reaction force and hence increasing the ankle moment. In the case of the patients the scatter was so large that trends cannot readily be seen for most patients. However, one patient (P1) displayed high ankle moments with the left ankle moment being higher than the right as in the case of the normals.

This tends to indicate that the ankle joint plays an active part during stepping and therefore one would expect this joint to compensate for knee deficiencies of the contralateral leg.

The temporal parameters of gait, for all patients showed considerably larger scatter than those for the normal subjects.

5.3.2 Moments at the knee joint

Fig. 5.29 FU.O (left and right) for patients and subjects
Fig. 5.30 BD O " " " " " " "
Fig. 5.31 FU 1 " " " " " " "
Fig. 5.32 BD 1 " " " " " " "

On examination of the diagrams 5.29 and 5.31 the moments obtained with zero height step are generally of the same order as those for the 10% step. At first sight this would appear to be rather surprising as one would expect the quadriceps to be more active during a 10% stepping action, resulting in higher moments. However, the ankle results suggest that active plantar flexion by means of gastrocnemius action on the contralateral side (trailing limb) assist the ascending leg and thus reducing the load required by the quadriceps.

The results for the knee moments for the patients (Fig. 5.31 and 5.32) showed considerable scatter when compared to those for the normals. This applies to both zero and 10% height step test. Again patient (P1) showed higher values than the rest of the patients.

On comparing Fig. 5.29 with the graphs obtained from normal subjects during level walking (Fig. 5.20) it is noted that the usual moment curve

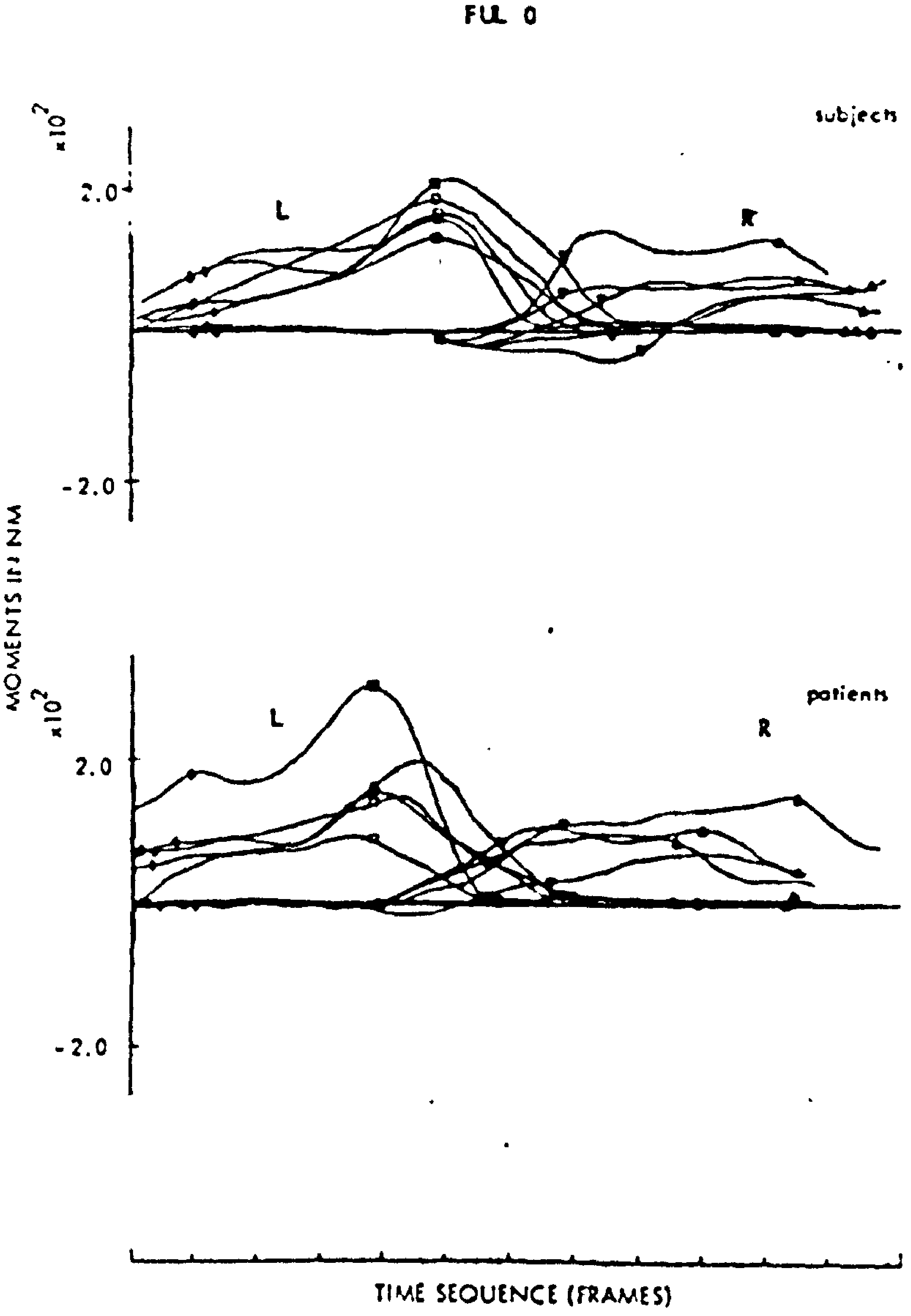


Fig. 5.29 knee moments sagittal plane

LEFT HEEL STRIKE △

LEFT TOE OFF ▽

RIGHT HEELSTRIKE □

RIGHT TOE OFF ◇

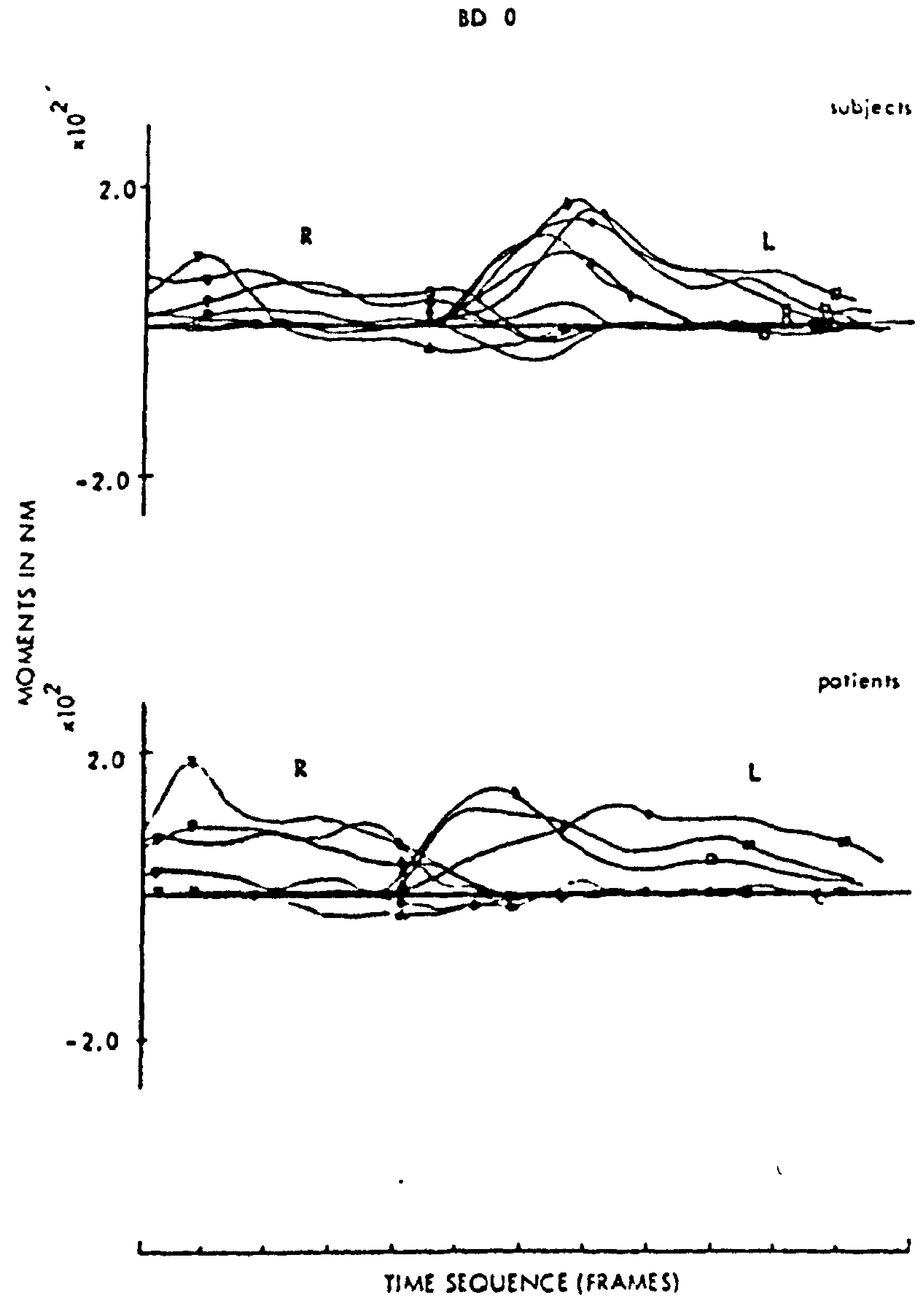


Fig. 5.30 knee moments sagittal plane

LEFT HEEL STRIKE ^

LEFT TOE OFF ▽

RIGHT HEELSTRIKE □

RIGHT TOE OFF ◇

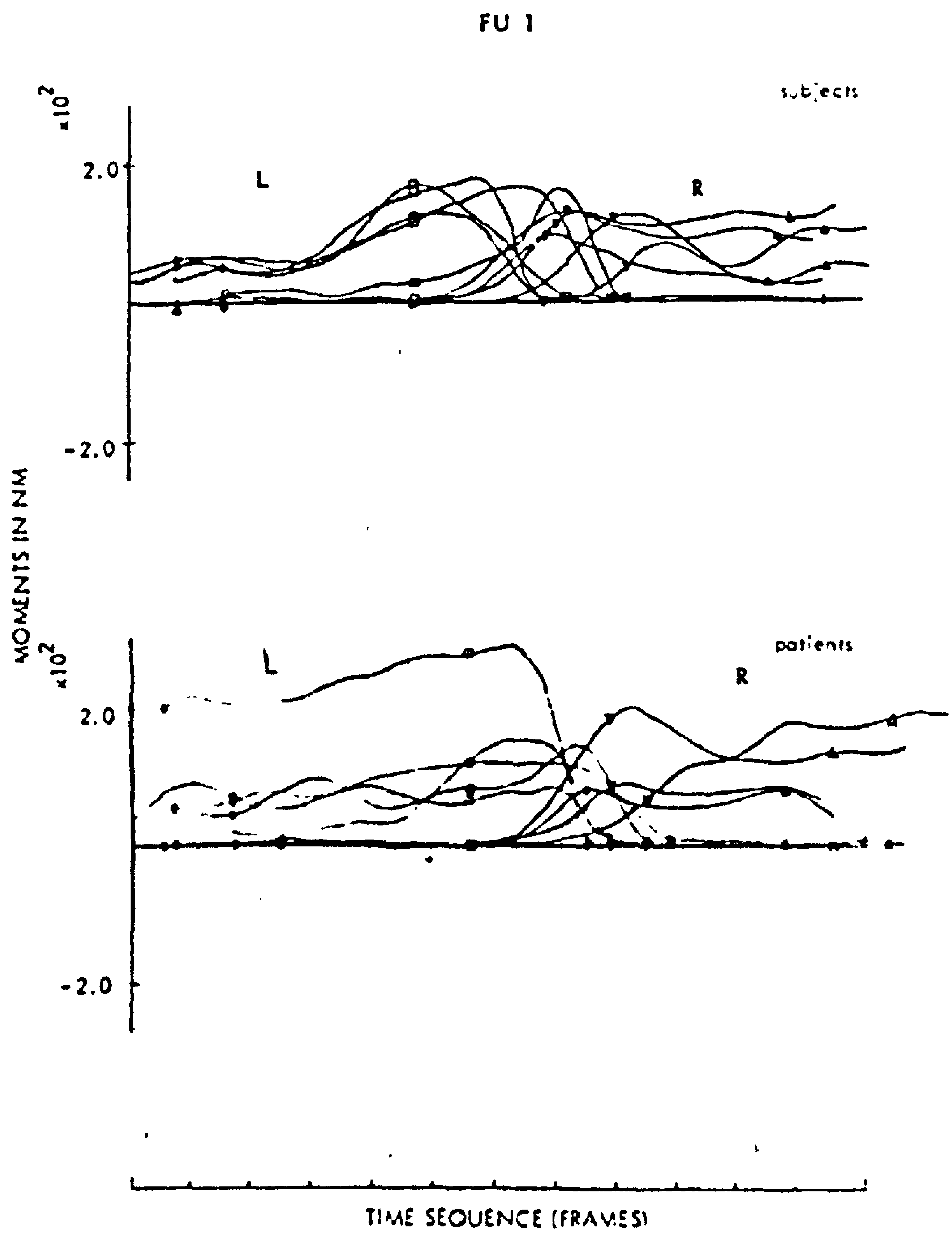


Fig. 5.31 knee moments sagittal plane

LEFT HEEL STRIKE △

LEFT TOE OFF ▽

RIGHT HEELSTRIKE □

RIGHT TOE OFF ◇

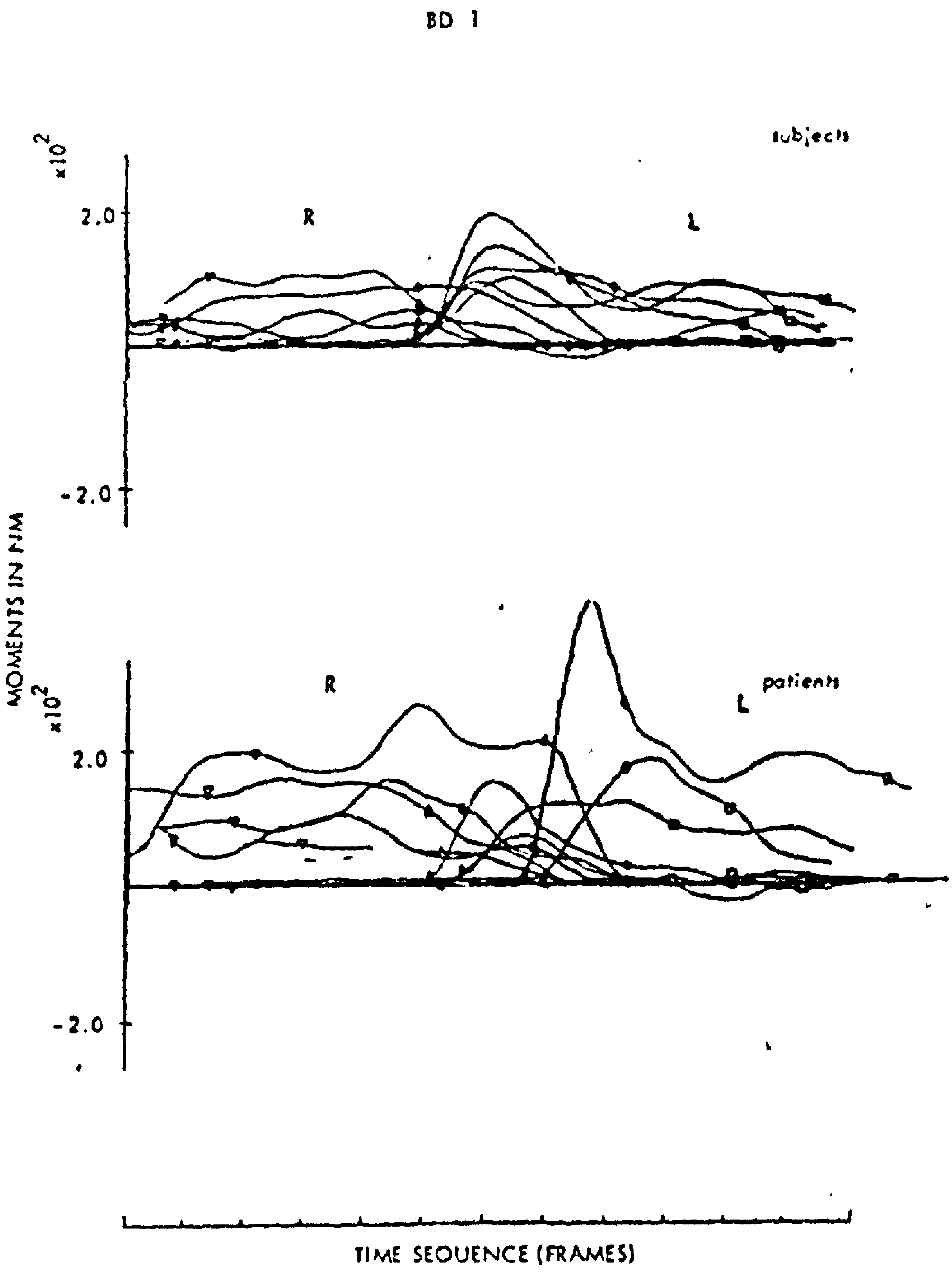


Fig. 5.32 knee moments sagittal plane

LEFT HEEL STRIKE △

LEFT TOE OFF ▽

RIGHT HEELSTRIKE □

RIGHT TOE OFF ◇

reversal (locking and unlocking of the knee) is only present on the leading leg and at the zero step. The maximum knee extension moment recorded during the test was on the range of 120 to 200 Nm for both zero high and 10% step height. This is much higher than for normal level walking which is of the order of 40 Nm (see Fig. 5.20). It is reckoned that this is due to the fact that in the stepping manoeuvres the knee assumes a hyperextended posture throughout most of the stance phase.

As was pointed out in the case of the ankle, the knee moments are also higher on the left leg than those on the right leg.

Again here, patient Pl has displayed significant differences from the others. At this stage it is not possible to provide an explanation for this.

5.3.3 Moments at the hip joint

Fig. 5.33 FL O (left and right) for patients and subjects
Fig. 5.34 BD O " " " " " " "
Fig. 5.35 FU 1 " " " " " " "
Fig. 5.36 BD 1 " " " " " " "

As in the case of the moments at the knee there were no apparent differences between the results obtained using zero height step and the 10% step height.

From Fig. 5.35 and 5.36 it is noted that the left leg has larger moments than the right during the stance phase. This is due to rigorous extensor activity which is required to stabilize the trunk.

Apart from patient P1 who displayed outstandingly large moments, there was very little difference to be seen between normals and pathologicals.

The graphs are similar to those obtained for normal level walking if it is remembered that they only constitute part of the cycle of level walking. The maximum value has a range of 200 to 250 Nm, which is also (as in the case of the knee) higher than for normal level walking which was about 150 Nm (see Fig. 5.20).

5.4 Moments in the Coronal Plane

5.4.1 Moments at the ankle joint

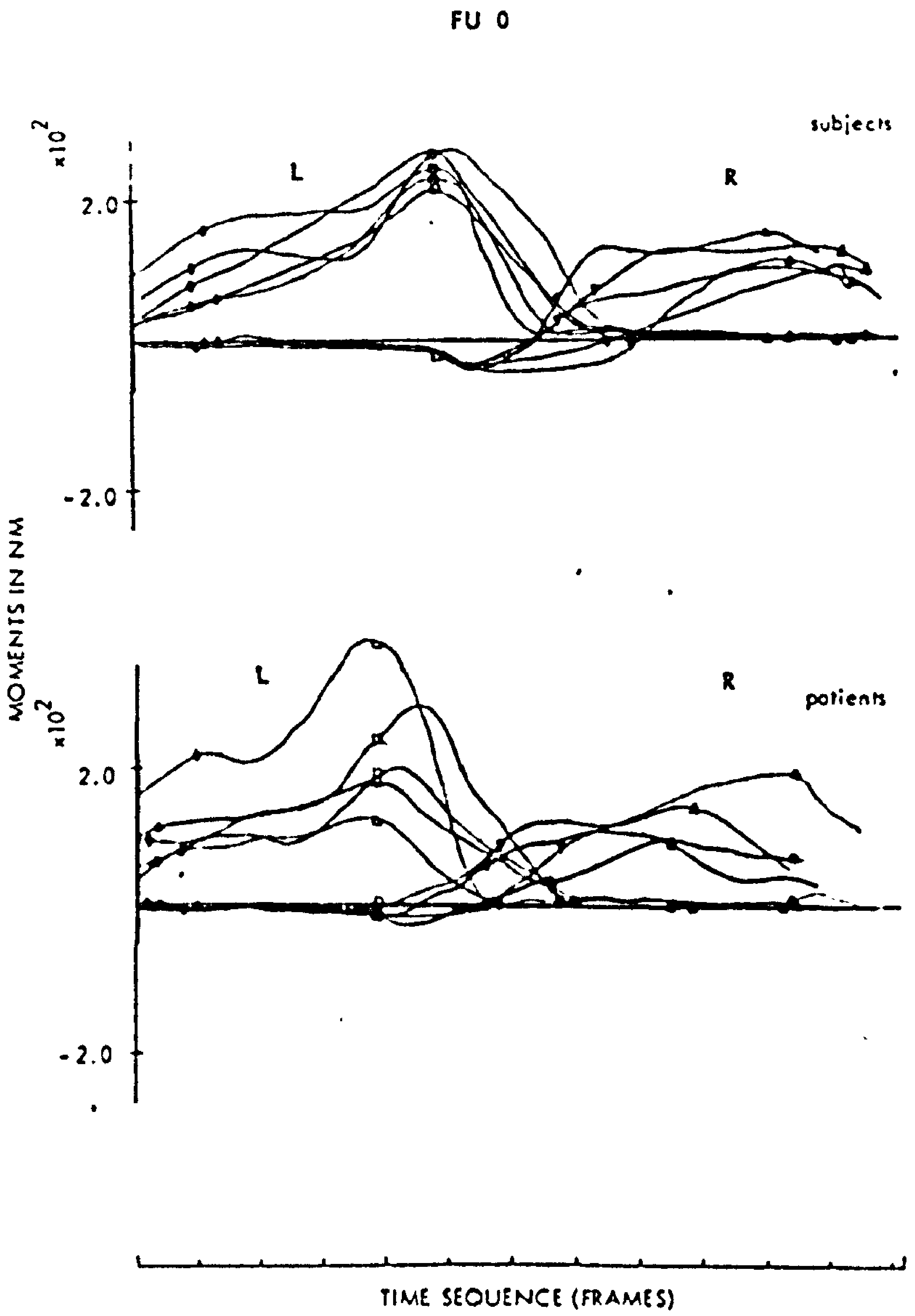


Fig. 5.33 hip moments sagittal plane

LEFT HEEL STRIKE △

LEFT TOE OFF ▽

RIGHT HEELSTRIKE □

RIGHT TOE OFF ◇

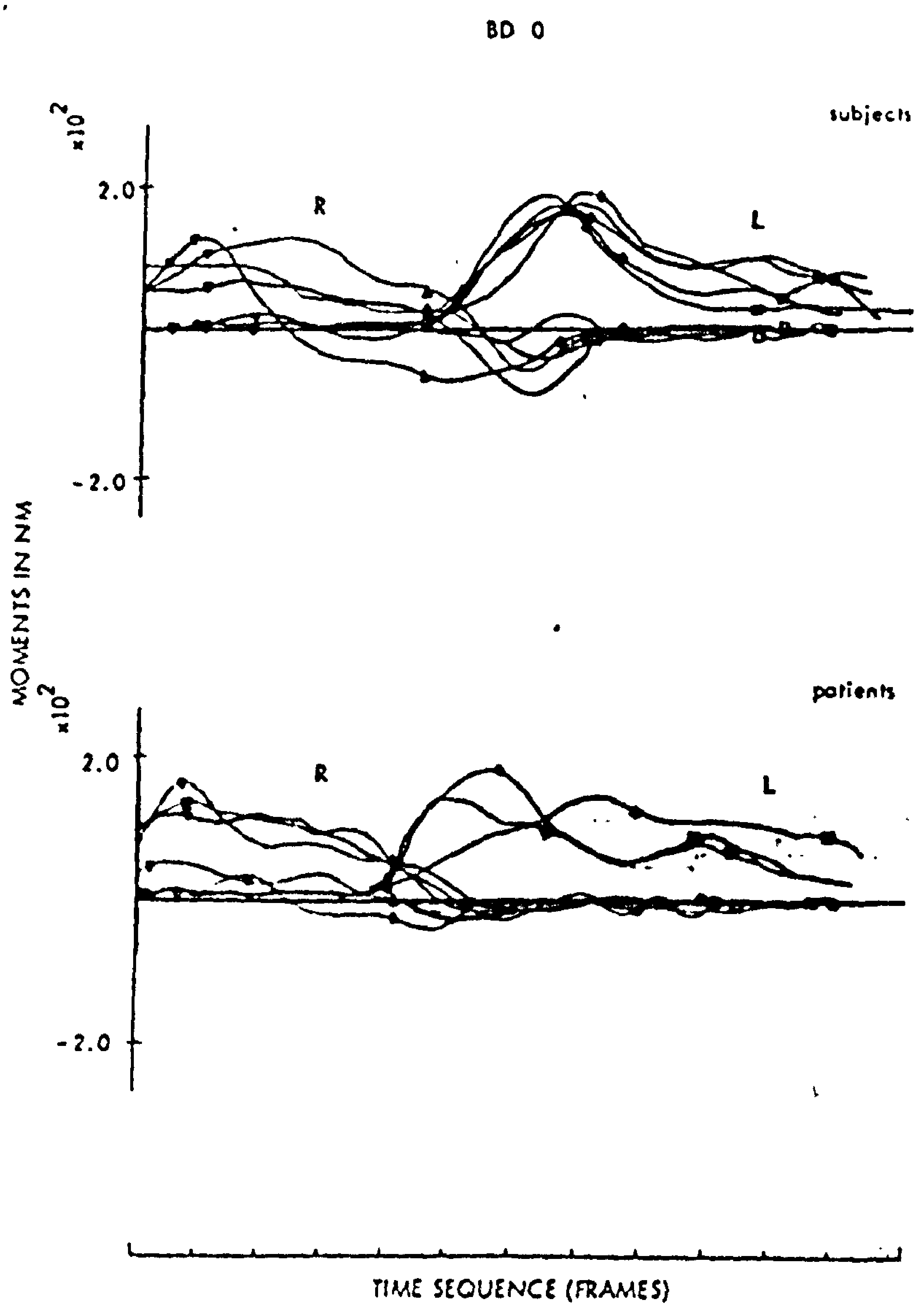


Fig. 5.34 hip moments sagittal plane

LEFT HEEL STRIKE △

LEFT TOE OFF ▽

RIGHT HEELSTRIKE □

RIGHT TOE OFF ◇

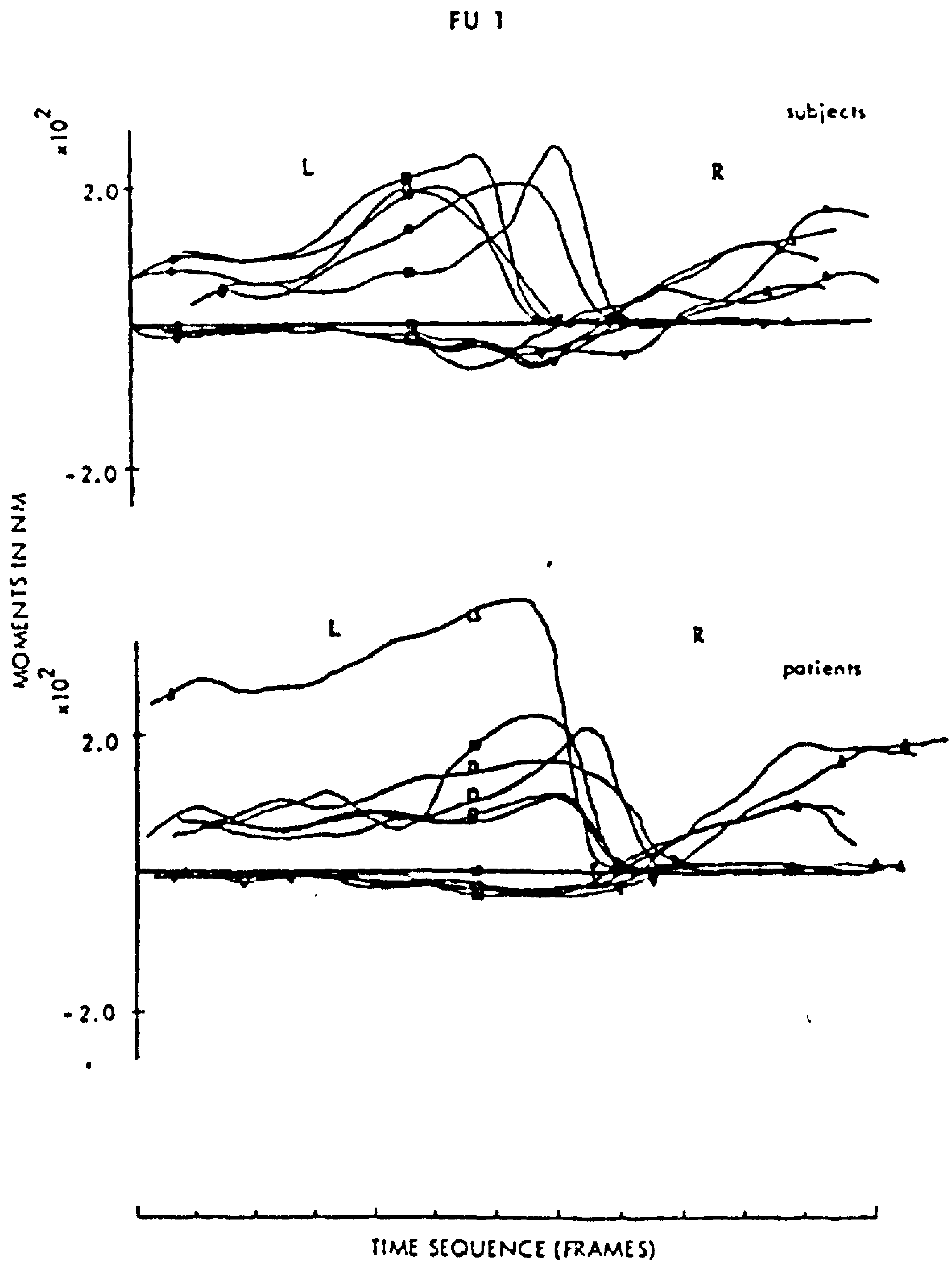


Fig. 5.35 hip moments sagittal plane

LEFT HEEL STRIKE △

LEFT TOE OFF ▽

RIGHT HEELSTRIKE □

RIGHT TOE OFF ◇

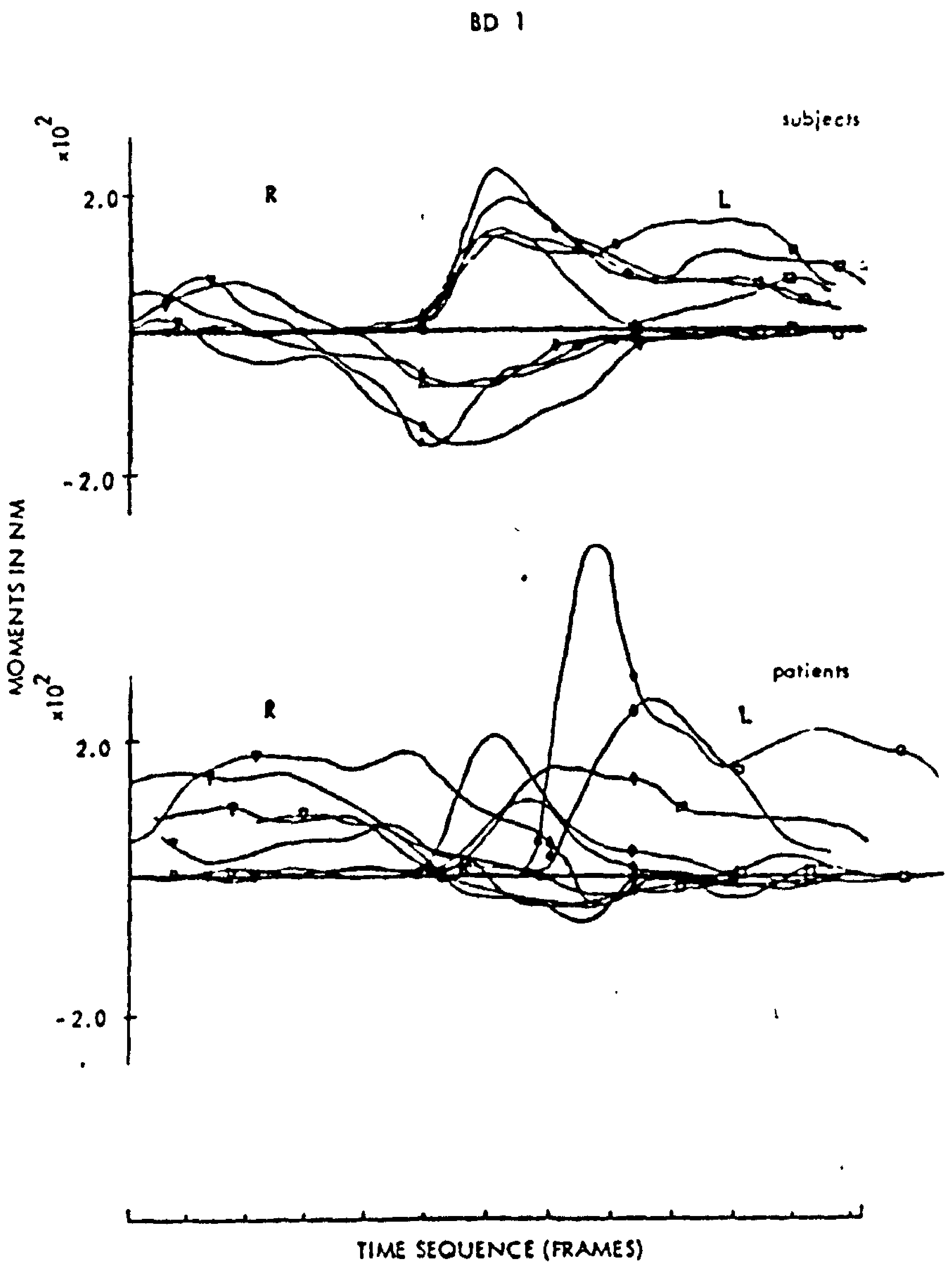


Fig. 5.36 hip moments sagittal plane

LEFT HEEL STRIKE △

LEFT TOE OFF ▽

RIGHT HEELSTRIKE □

RIGHT TOE OFF ◇

Fig. 5.37 FU O (left and right) for patients and subjects
Fig. 5.38 BD O " " " " " " "
Fig. 5.39 FU 1 " " " " " " "
Fig . 5.40 BD 1 " " " " " " "

All the graphs are very similar, and have the shape that one would expect. Fig. 5.39 the normals for instance have shown that the left ankle the moments are negative during the stance phase, which means that the external force actions tend to invert the ankle. The right leg has positive moments which indicate that the right ankle is also tended to be inverted.

All graphs display a double peak characteristic similarly displayed by the Fy ground reaction force, which is also to be expected. The Fy ground force is the force mainly responsible for the production of this moment.

Loading on the left leg is higher than on the right leg, this was noted also on the sagittal moments.

In comparing normals and pathologicals the graphs are very similar, except perhaps that the patients showed lower values. The shape of the curves are similar to those obtained to normal level walking but the maximum value is much higher (120 vs 20 Nm). It is thought that the reason for this is the very wide walking base adopted in stepping.

5.4.2 Moments at the knee joint

Fig. 5.41 FU O (left and right) for patients and subjects
Fig. 5.42 BD O " " " " " " "
Fig. 5.43 FU 1 " " " " " " "
Fig. 5.44 BD 1 " " " " " " "

The graphs for the knee are similar in shape to those of the ankle; which is to be expected. There is more scatter in the results for the knee than the ankle.

5.4.3 Moments at the hip joint

Fig. 4.45 FU O (left and right) for patients and subjects
Fig. 5.46 BD O " " " " " " "
Fig. 5.47 FU 1 " " " " " " "
Fig. 5.48 BD 1 " " " " " " "

FU 0

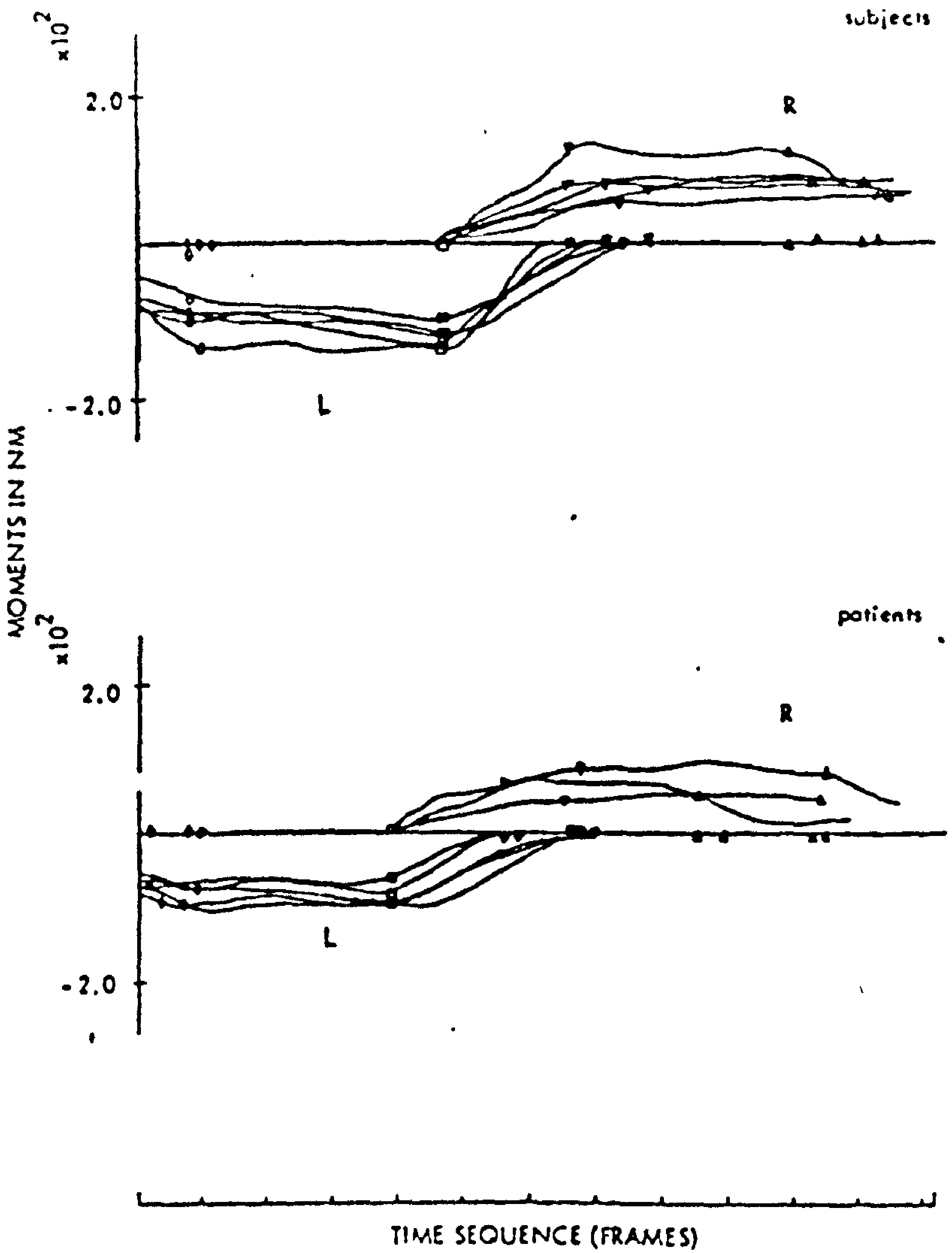


Fig. 5.37 ankle moments coronal plane

LEFT HEEL STRIKE △

LEFT TOE OFF ▽

RIGHT HEELSTRIKE □

RIGHT TOE OFF ◇

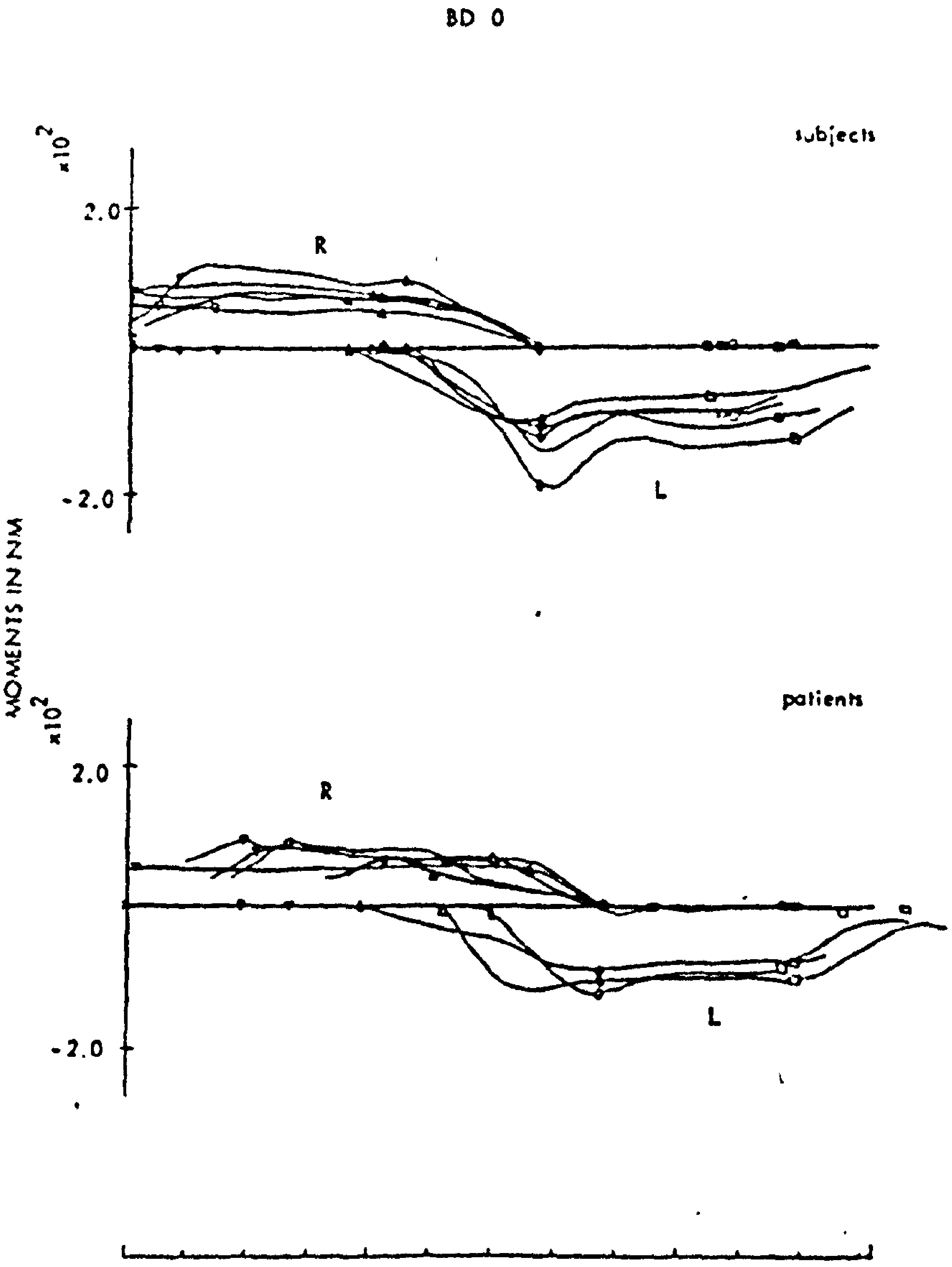


Fig. 5.38 ankle moments coronal plane

LEFT HEEL STRIKE △

LEFT TOE OFF ▽

RIGHT HEELSTRIKE □

RIGHT TOE OFF ○

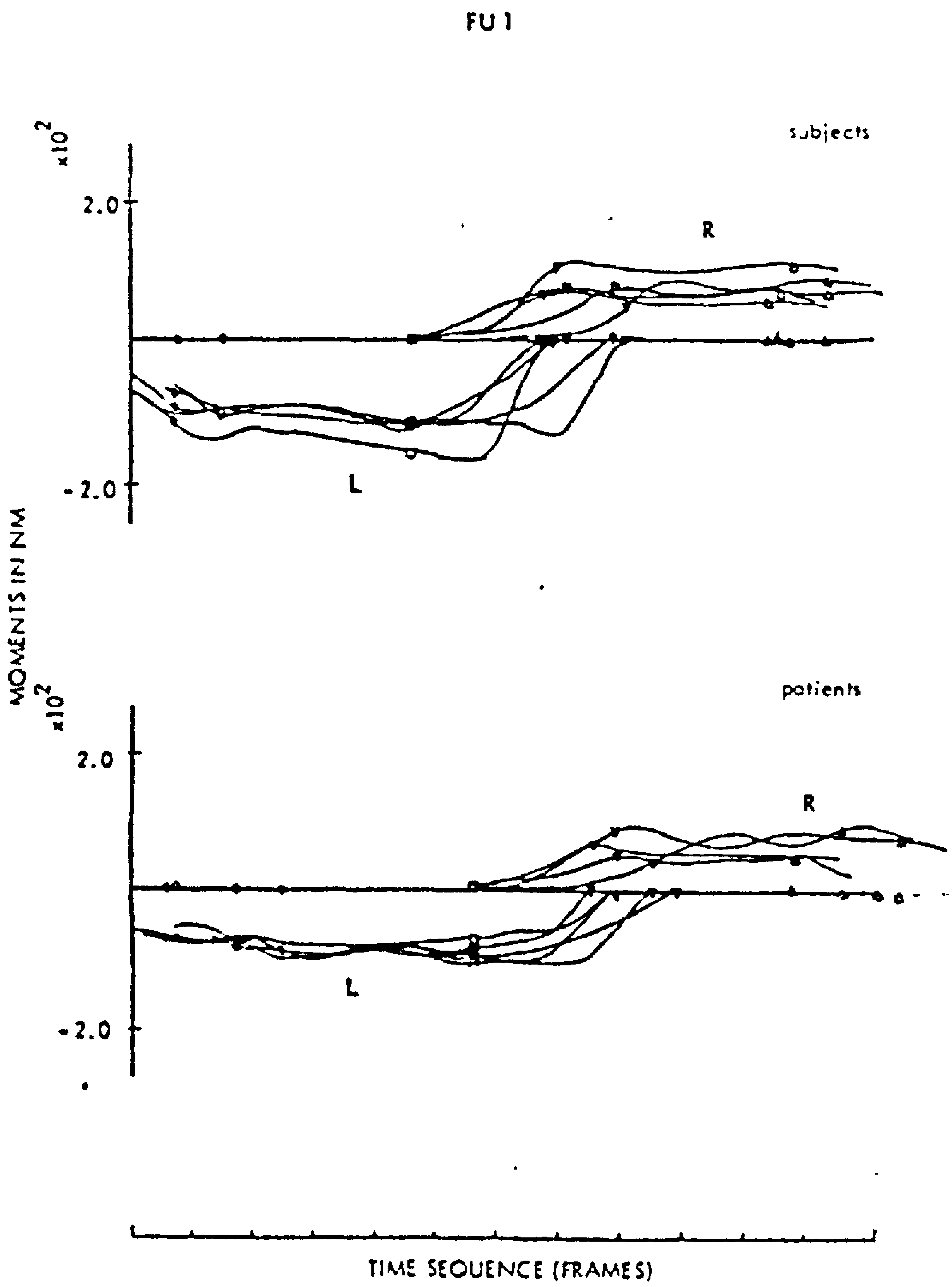


Fig. 5.39 ankle moments coronal plane

LEFT HEEL STRIKE △

LEFT TOE OFF ▽

RIGHT HEELSTRIKE □

RIGHT TOE OFF ◇

BD 1

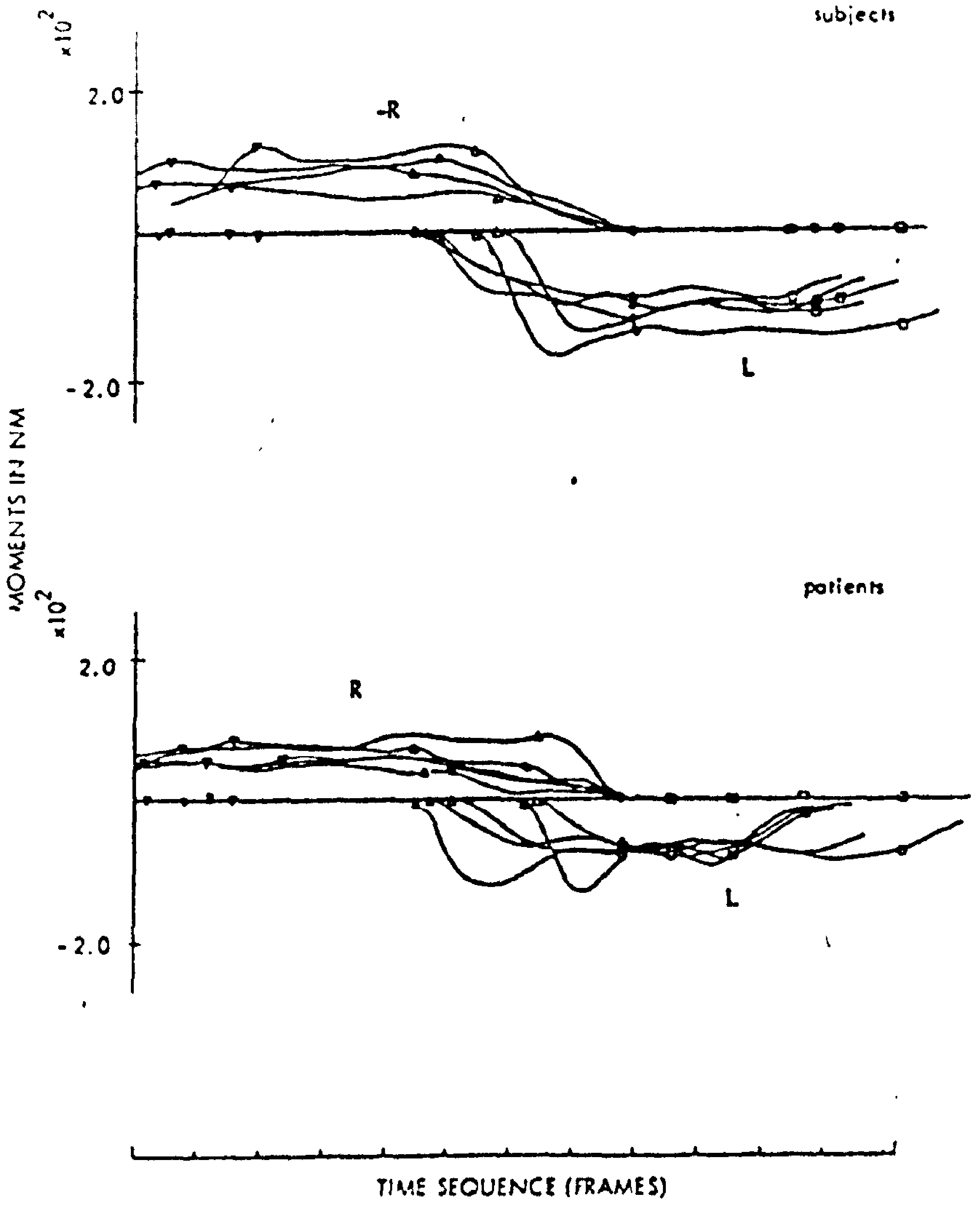


Fig. 5.40 ankle moments coronal plane

LEFT HEEL STRIKE △

LEFT TOE OFF ▽

RIGHT HEELSTRIKE □

RIGHT TOE OFF ◇

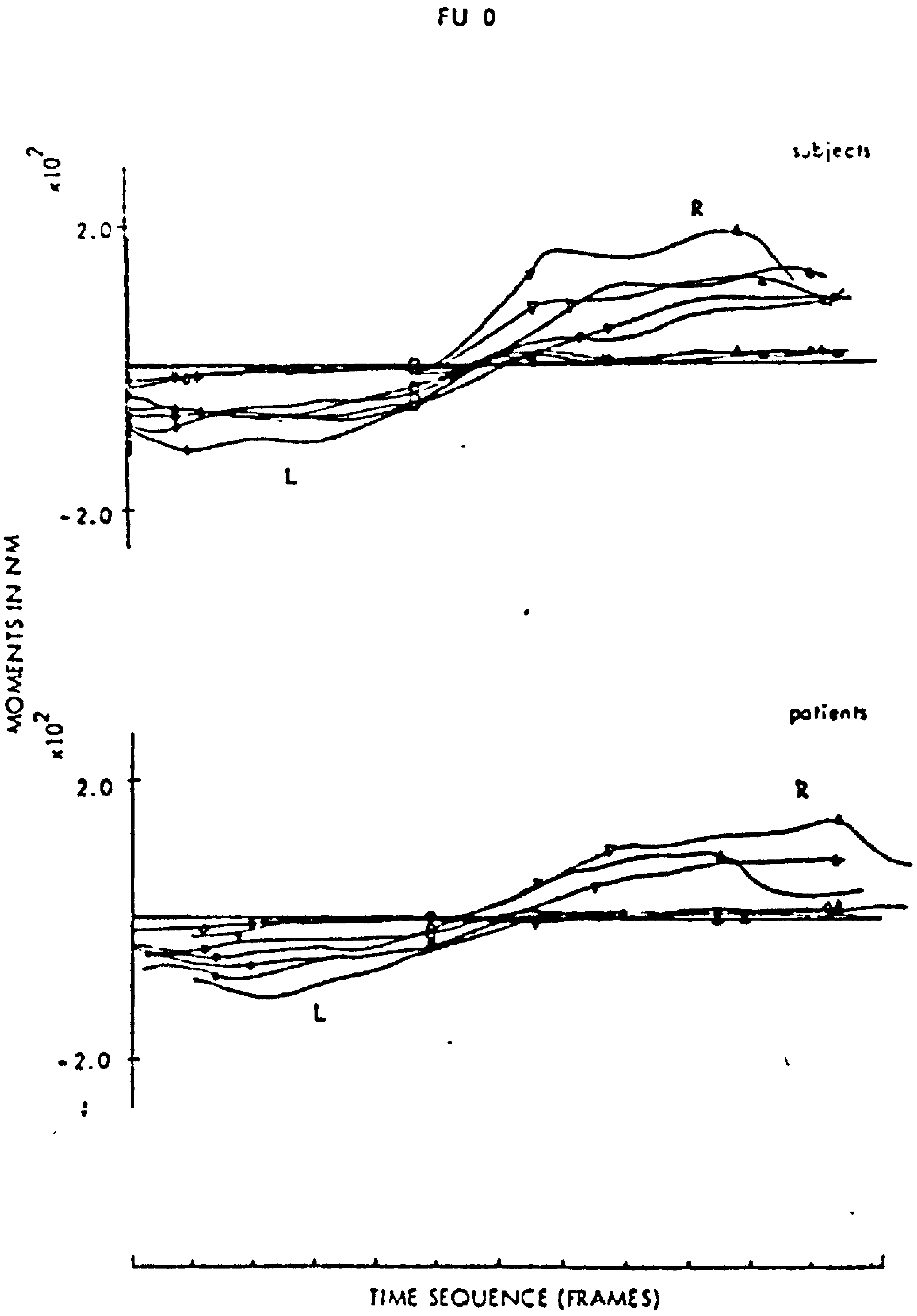


Fig. 5.41 knee moments coronal plane

LEFT HEEL STRIKE △

LEFT TOE OFF ▽

RIGHT HEELSTRIKE □

RIGHT TOE OFF ◇

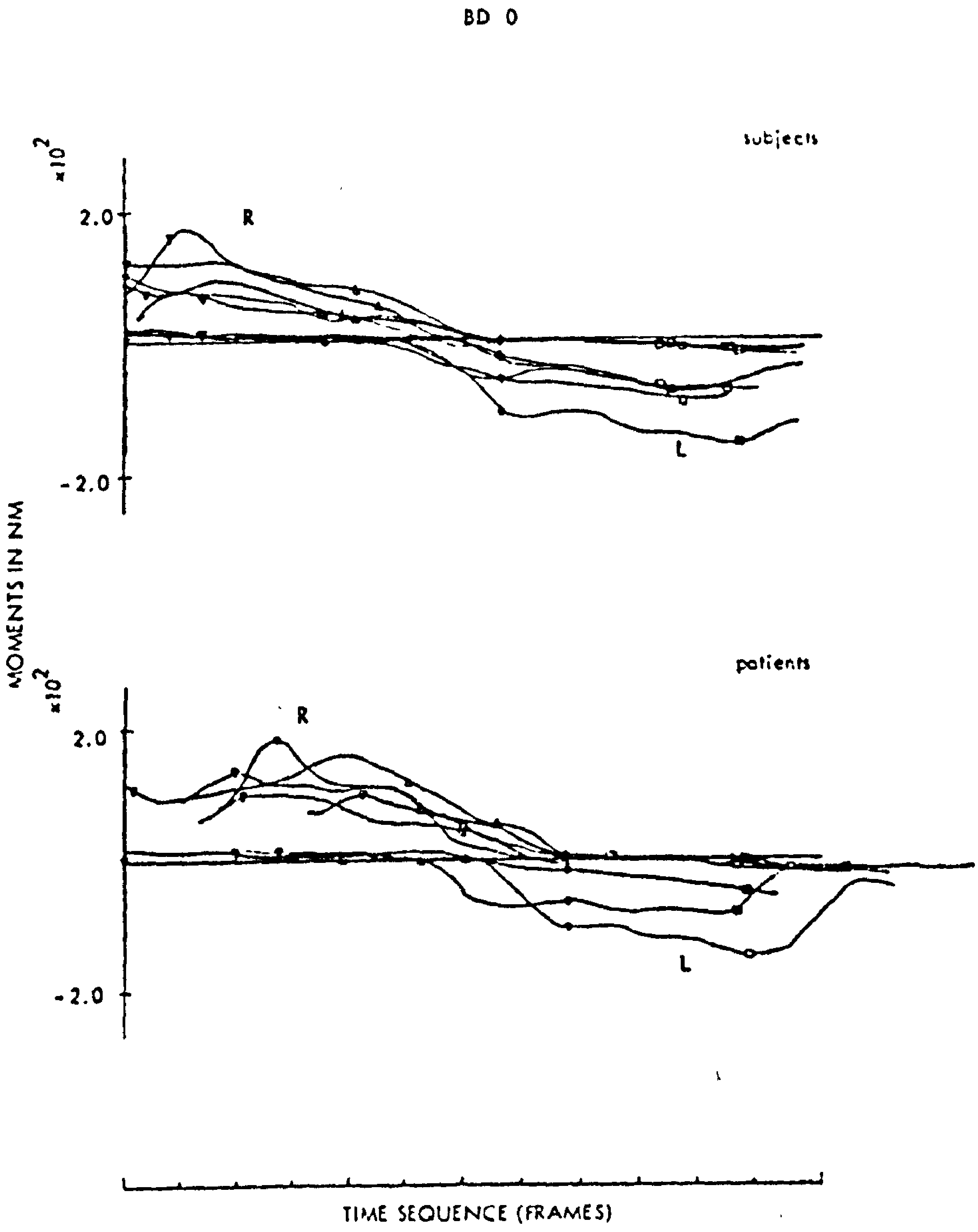


Fig. 5.42 knee moments coronal plane

LEFT HEEL STRIKE ^

LEFT TOE OFF ▽

RIGHT HEELSTRIKE □

RIGHT TOE OFF ◇

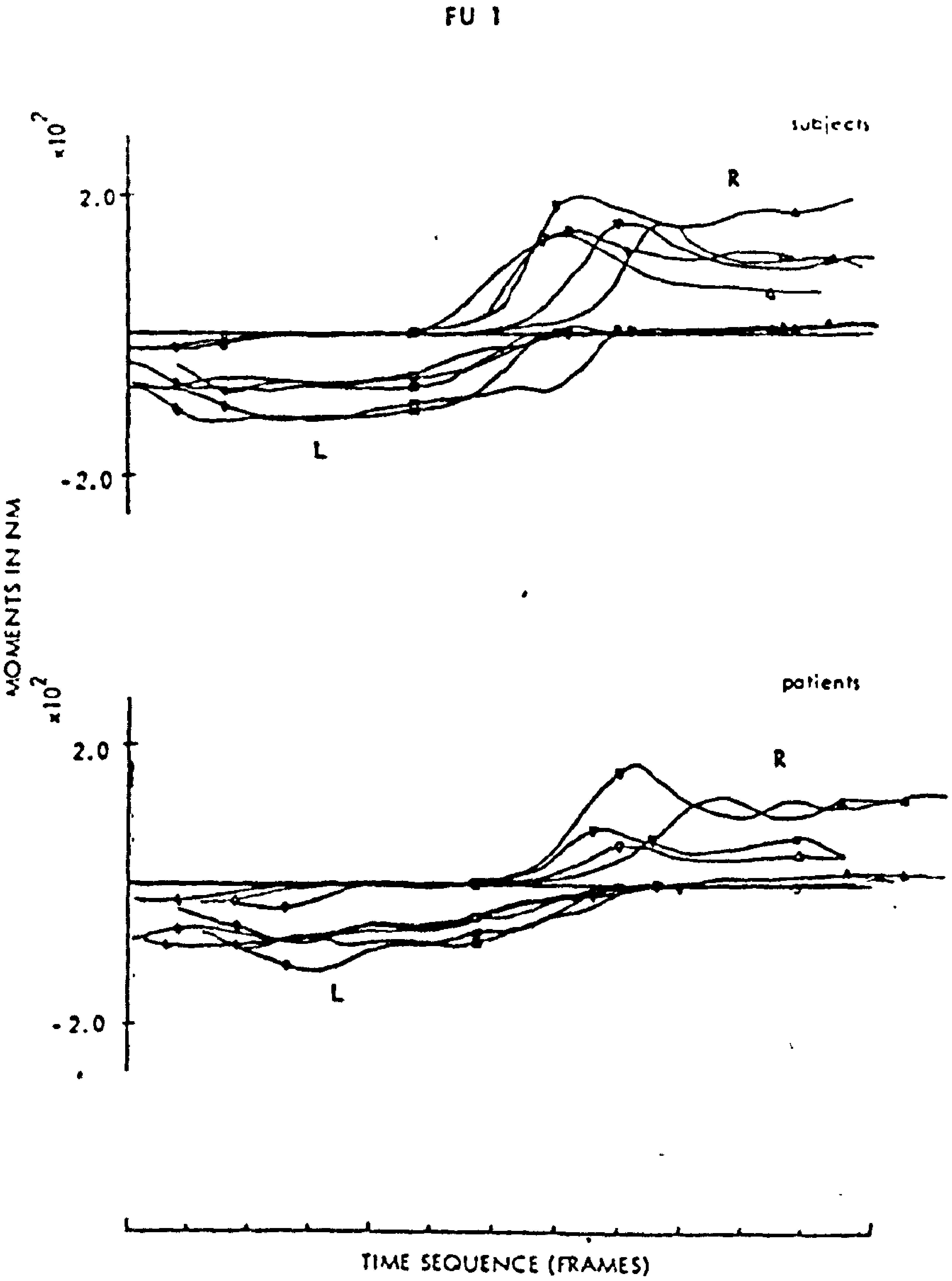


Fig. 5.43 knee moments coronal plane

LEFT HEEL STRIKE △

LEFT TOE OFF ▽

RIGHT HEELSTRIKE □

RIGHT TOE OFF ○

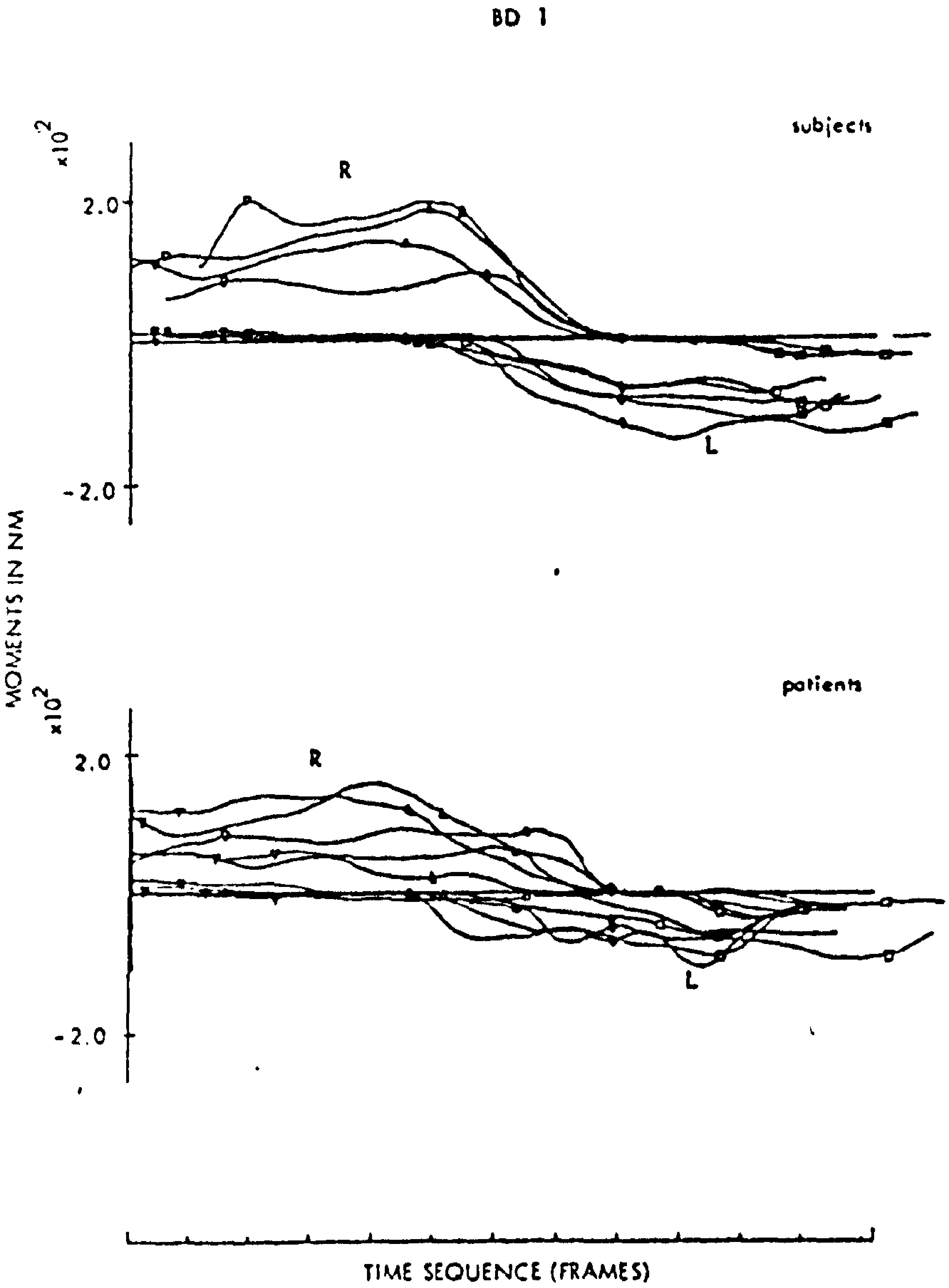


Fig. 5.44 knee moments coronal plane

LEFT HEEL STRIKE △
LEFT TOE OFF ▽
RIGHT HEELSTRIKE □
RIGHT TOE OFF ◇

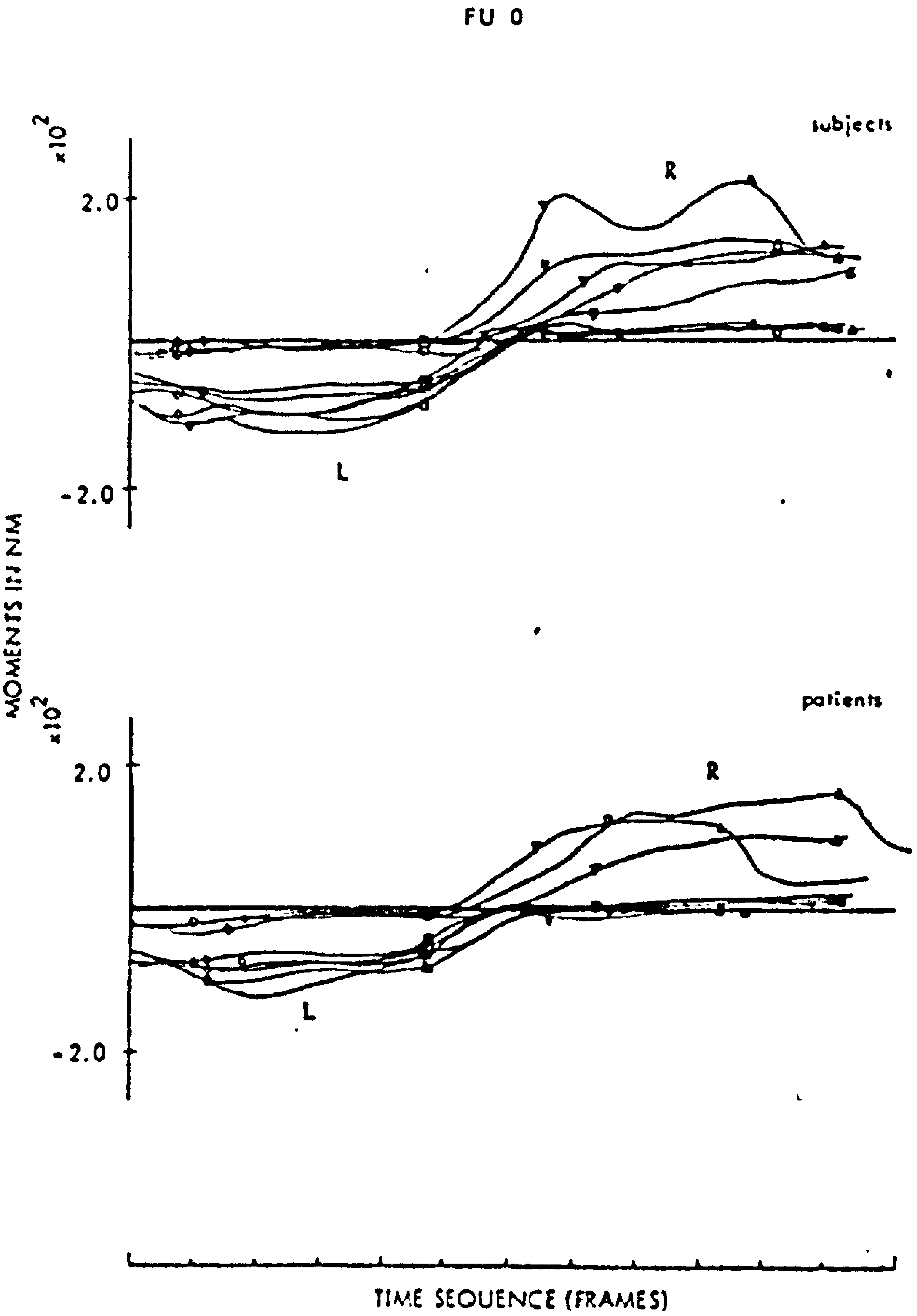


Fig. 5.45 hip moments coronal plane

LEFT HEEL STRIKE △

LEFT TOE OFF ▽

RIGHT HEELSTRIKE □

RIGHT TOE OFF ◇

8D 0

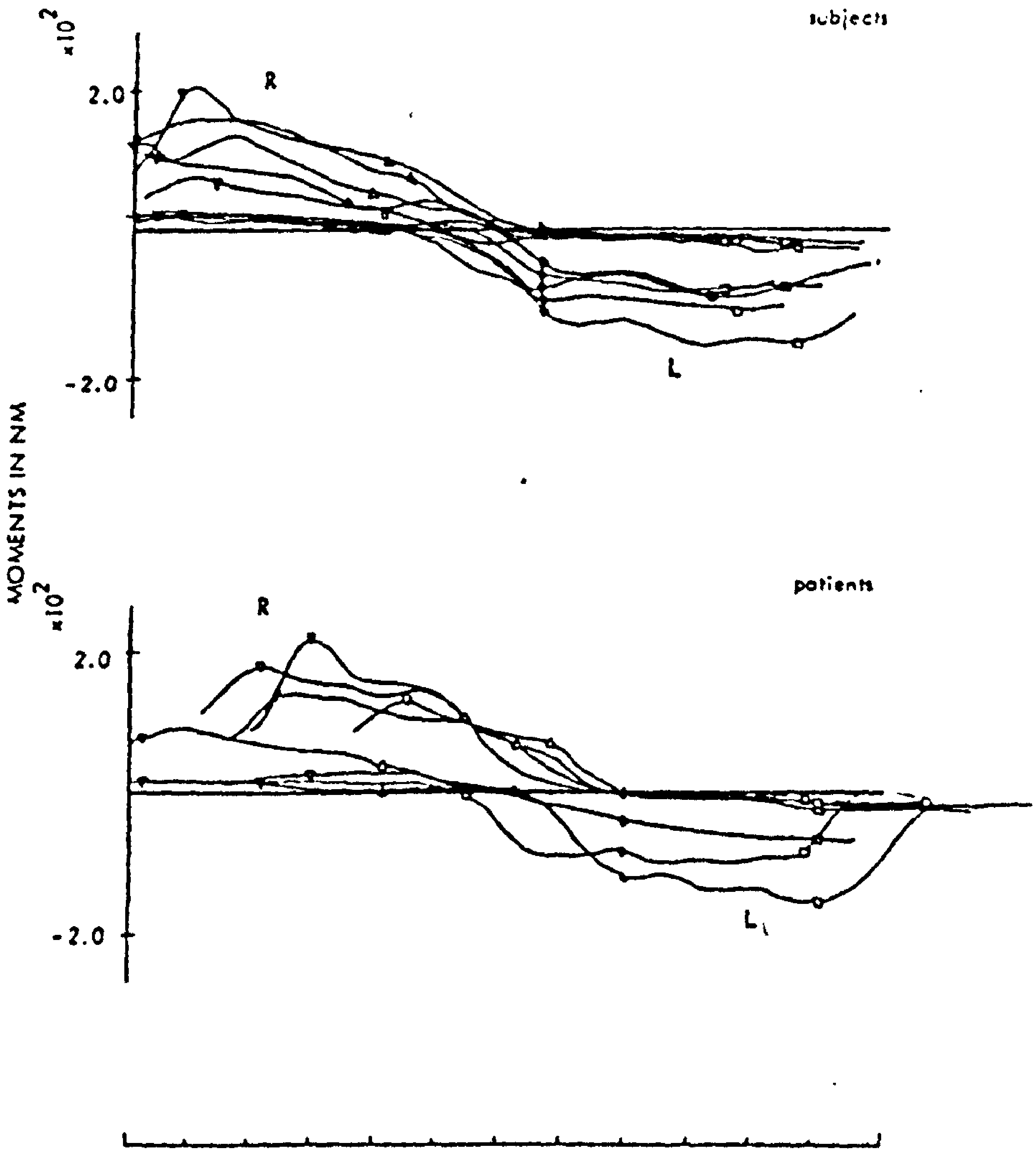


Fig. 5.46 hip moments coronal plane

LEFT HEEL STRIKE △

LEFT TOE OFF ▽

RIGHT HEELSTRIKE □

RIGHT TOE OFF ◇

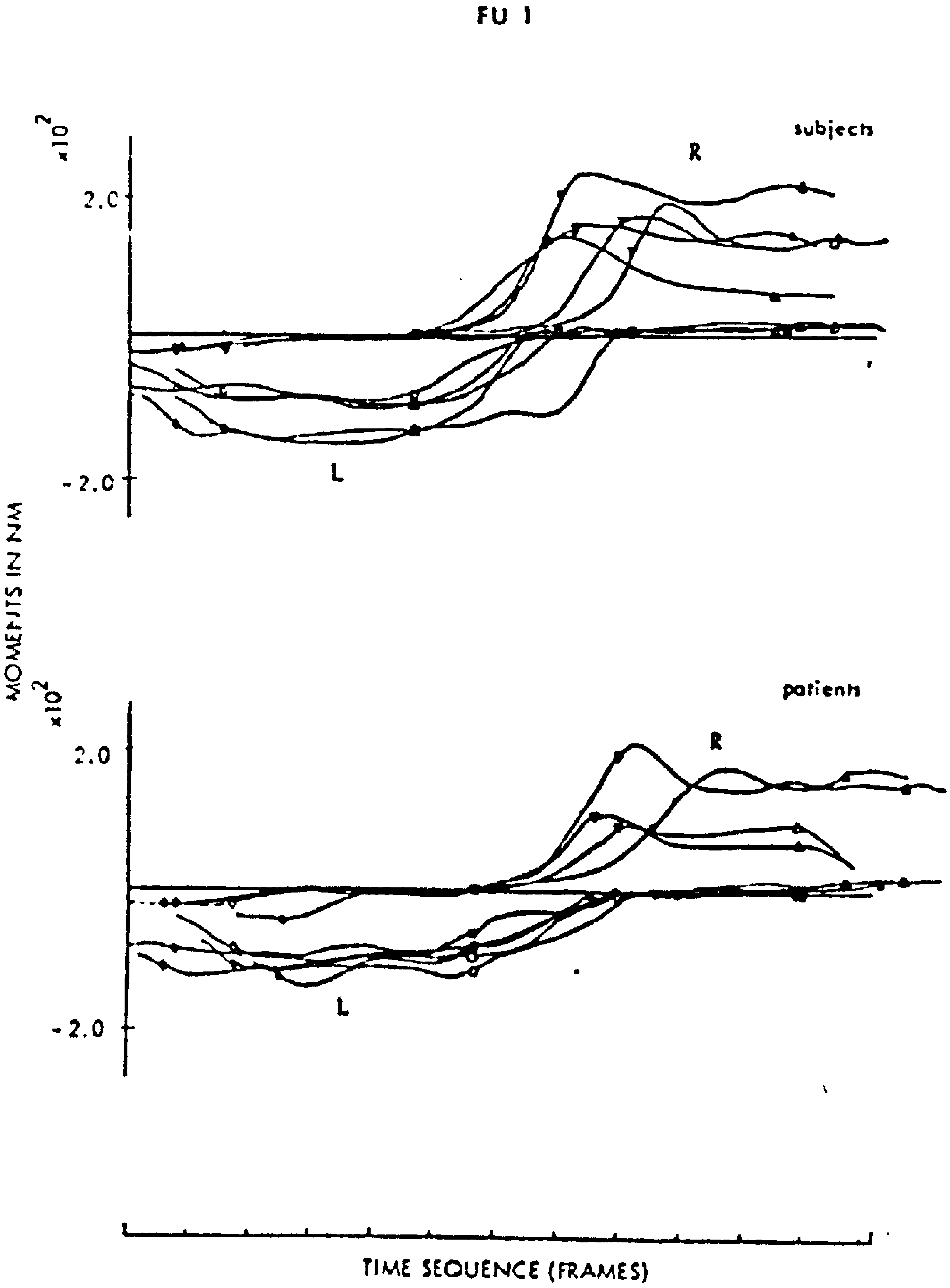


Fig. 5.47 hip moments coronal plane

LEFT HEEL STRIKE △

LEFT TOE OFF ▽

RIGHT HEELSTRIKE □

RIGHT TOE OFF ◇

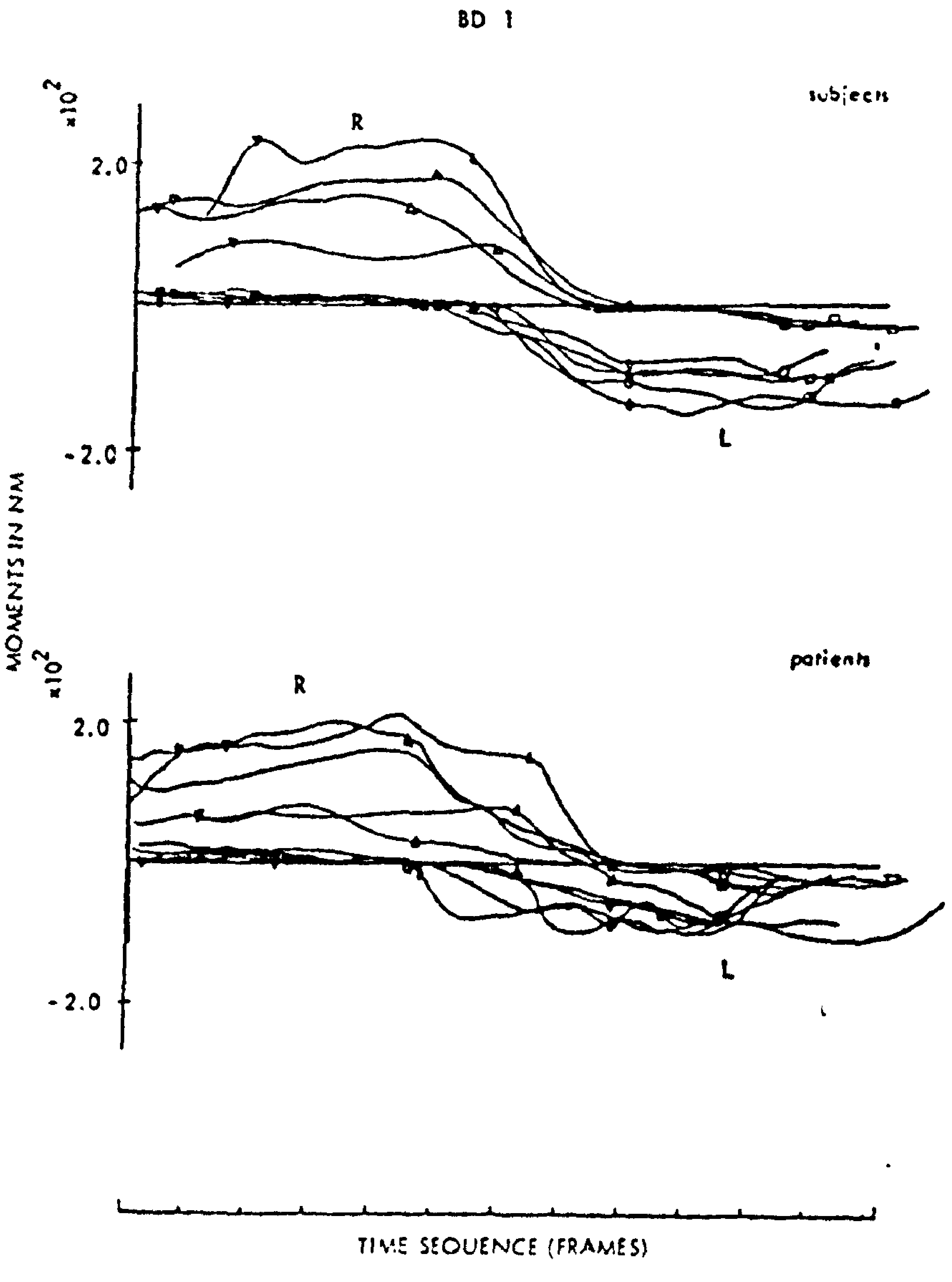


Fig. 5.48 hip moments coronal plane

LEFT HEEL STRIKE ∧

LEFT TOE OFF ▽

RIGHT HEELSTRIKE □

RIGHT TOE OFF ◇

Generally, it has been found that for the right leg the hip moment tended to be higher than the knee moment and the knee moment higher than the ankle moment. (see Fig. 5.13). For the left leg there was a tendency for the hip moments to have a higher value than the knee and the ankle moments. However, for the left leg, the knee moments were sometimes above sometimes below the values for the ankle moments.

Fig. 5.45 to 5.48 have the same characteristic shape as those for the ankle and knee, i.e. displaying the same double peak characteristic. Generally, however, the scatter of the curves at the hip level it is much more pronounced than those of the knee and ankle.

The range of hip moments calculated was 200 to 250 Nm whereas for normal level walking values of up to 150 Nm have been recorded (see Fig. 5.22).

5.5 Moments in the Transverse Plane

Only sample results for subject S1 and patient P1 (Fig. 5.17 to 5.20) are shown for the transverse plane moments. Other investigators (University of California 1947) have shown that the torque along the long axis of the limb displayed considerable scatter even for normals. The same effect was observed in the present study. It was therefore decided that it was little to be gained in collecting all the results for normal subjects and patients for this parameter. The maximum torque observed was of the order of 15 Nm for both patients and subjects.

5.6 The Angle-Angle Diagrams (Figures 5.49 to 5.56)

It was decided to present the kinematic results of this study in the form of angle-angle diagrams (Fig. 5.23 and 5.24). This decision was taken for two reasons: firstly, these diagrams incorporate a method of normalisation of the data since they eliminate the time variable. Variation in the time taken to perform a certain manoeuvre distorts the shape of the curves and make comparisons between tests difficult. Secondly, it is obvious that the most important features of the kinematics of stepping are the angles between the various limb segments.

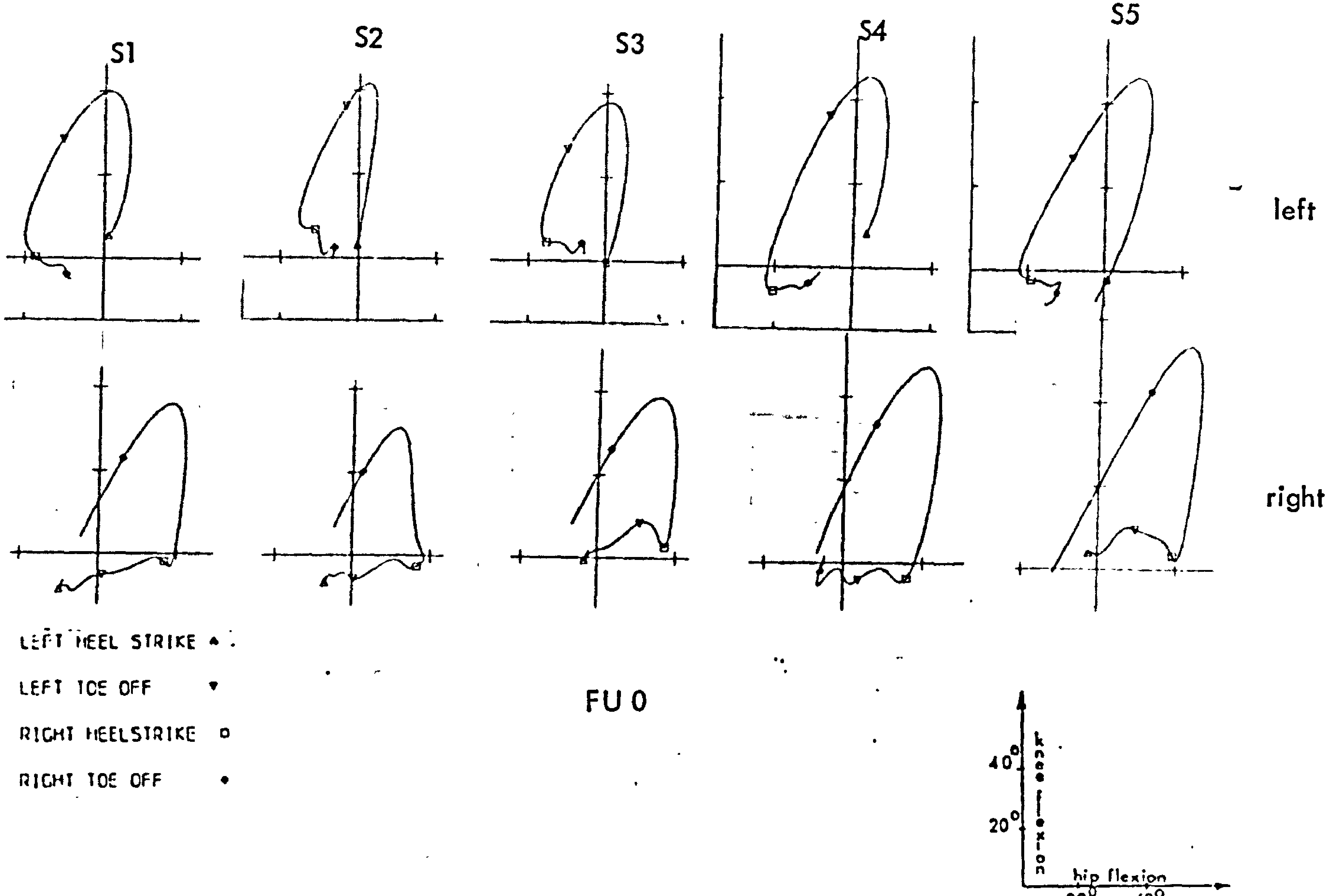

S1
S2
S3
S4
S5
left
right
LEFT HEEL STRIKE ▲
LEFT TOE OFF ▼
RIGHT HEELSTRIKE ◻
RIGHT TOE OFF ●
FU 0
knee flexion
40°
20°
hip flexion
20°
40°

Fig 5.49

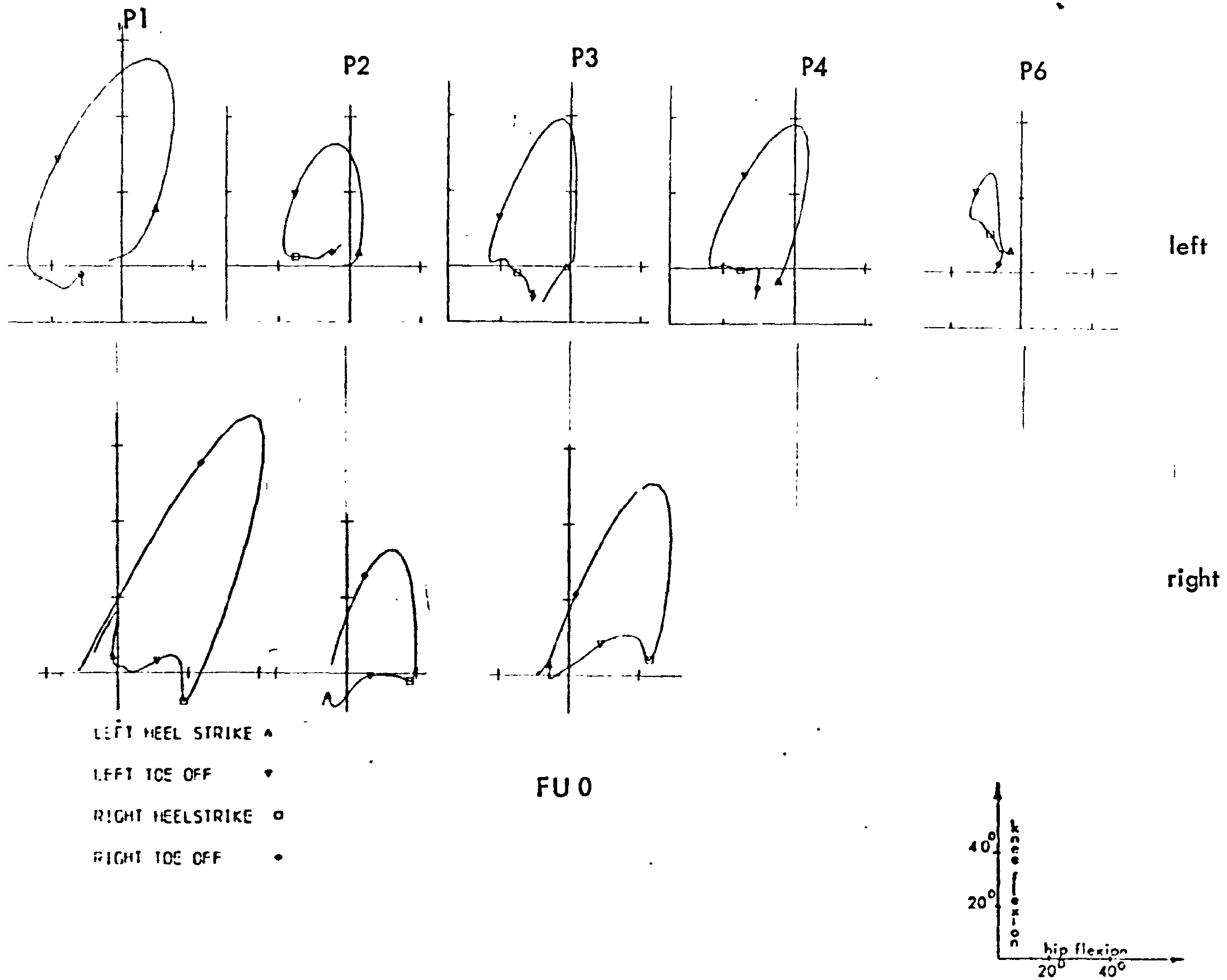

P1
P2
P3
P4
P6
left
right
LEFT HEEL STRIKE ▲
LEFT TOE OFF ▼
RIGHT HEELSTRIKE □
RIGHT TOE OFF ●
FU 0
knee flexion
40°
20°
hip flexion
20°
40°

Fig 5.50

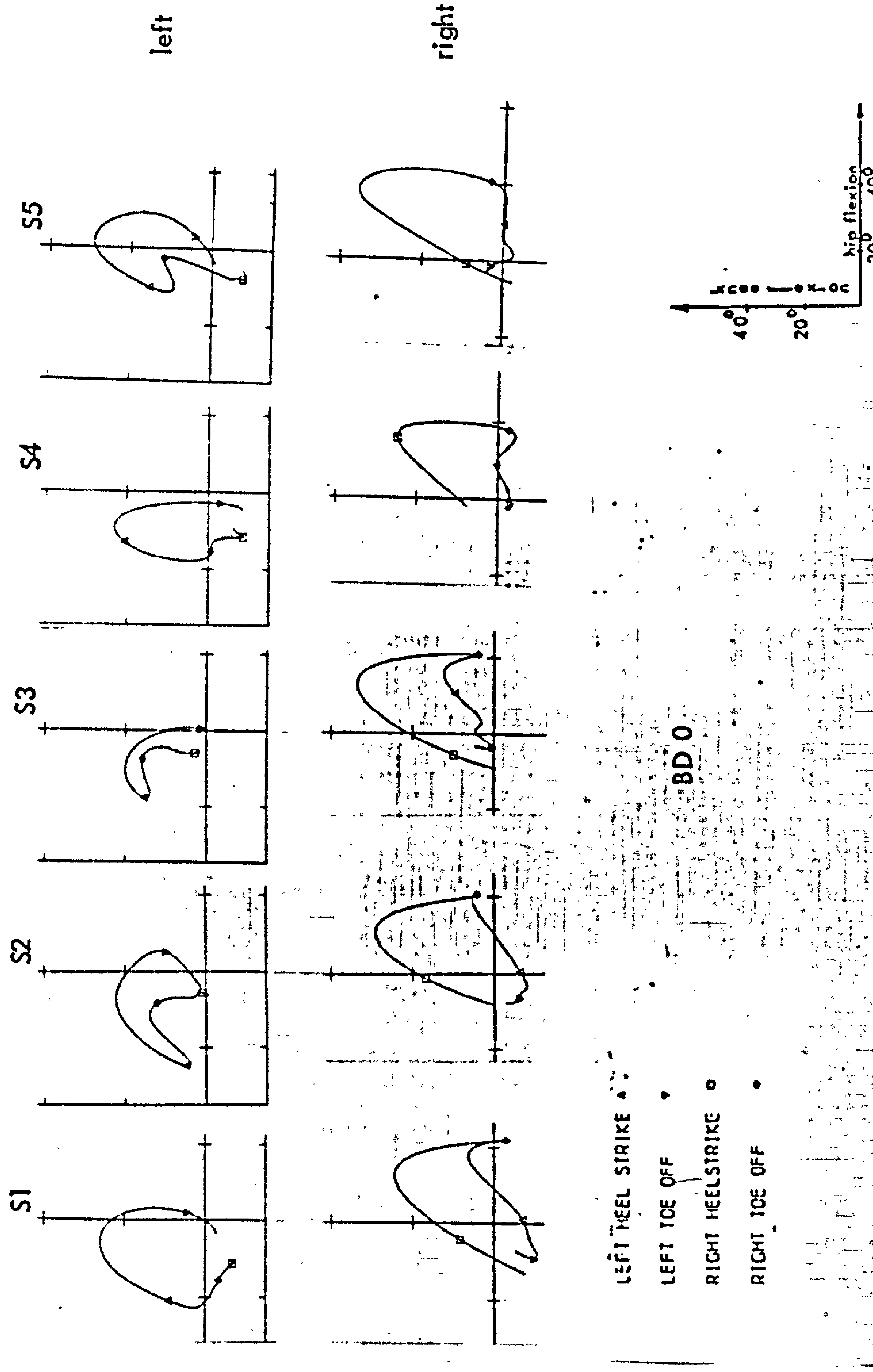

left
right
S1
S2
S3
S4
S5
BD O
LEFT HEEL STRIKE
LEFT TOE OFF
RIGHT HEELSTRIKE
RIGHT TOE OFF
knee flexion
40°
20°
hip flexion
20°
40°

Fig 5.51

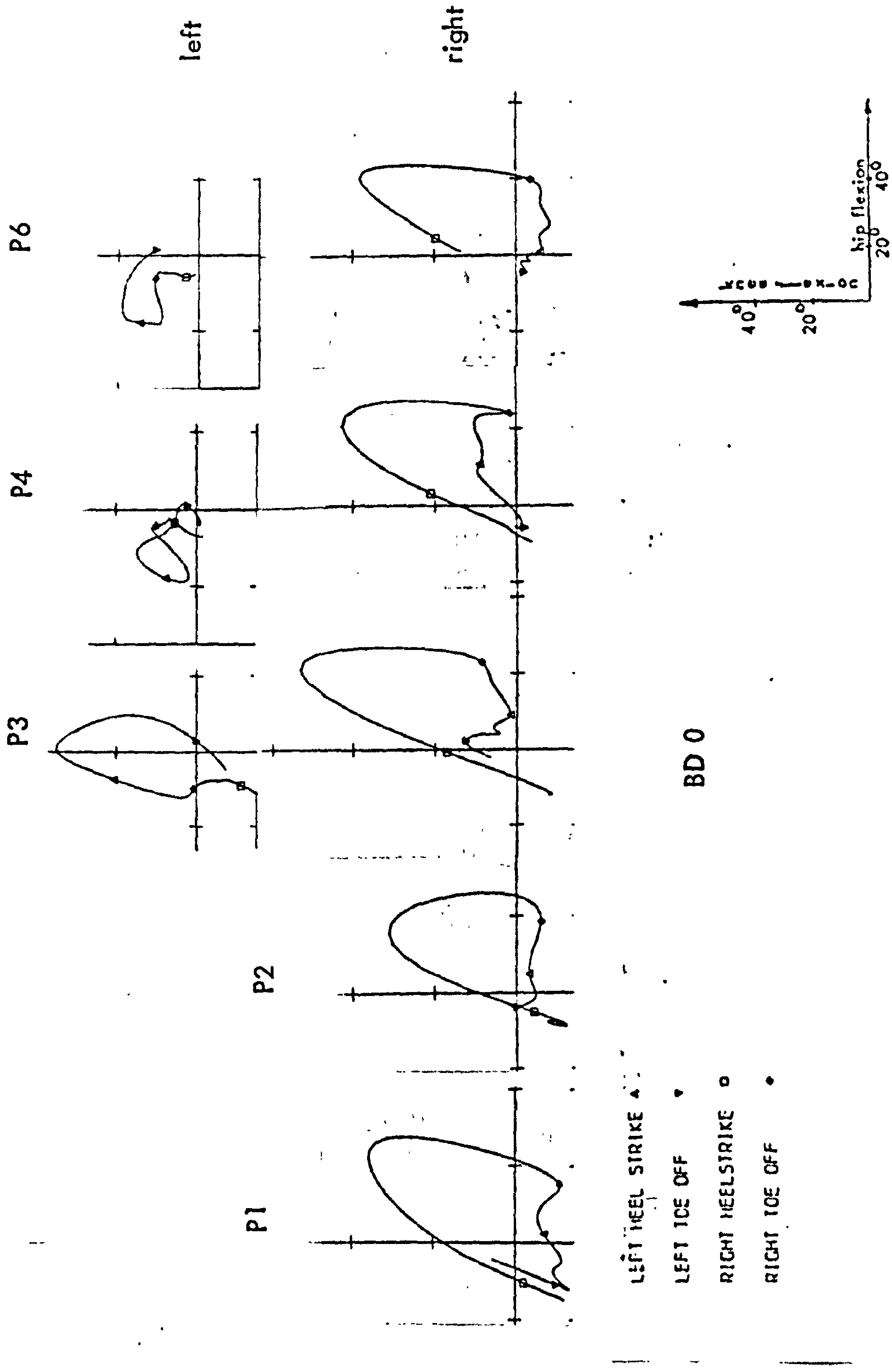

P6
P4
P3
P2
P1
left
right
BD 0
LEFT HEEL STRIKE ▲
LEFT TOE OFF ▼
RIGHT HEELSTRIKE □
RIGHT TOE OFF ●
knee flexion
40°
20°
hip flexion
0
20
40°

Fig 5.52

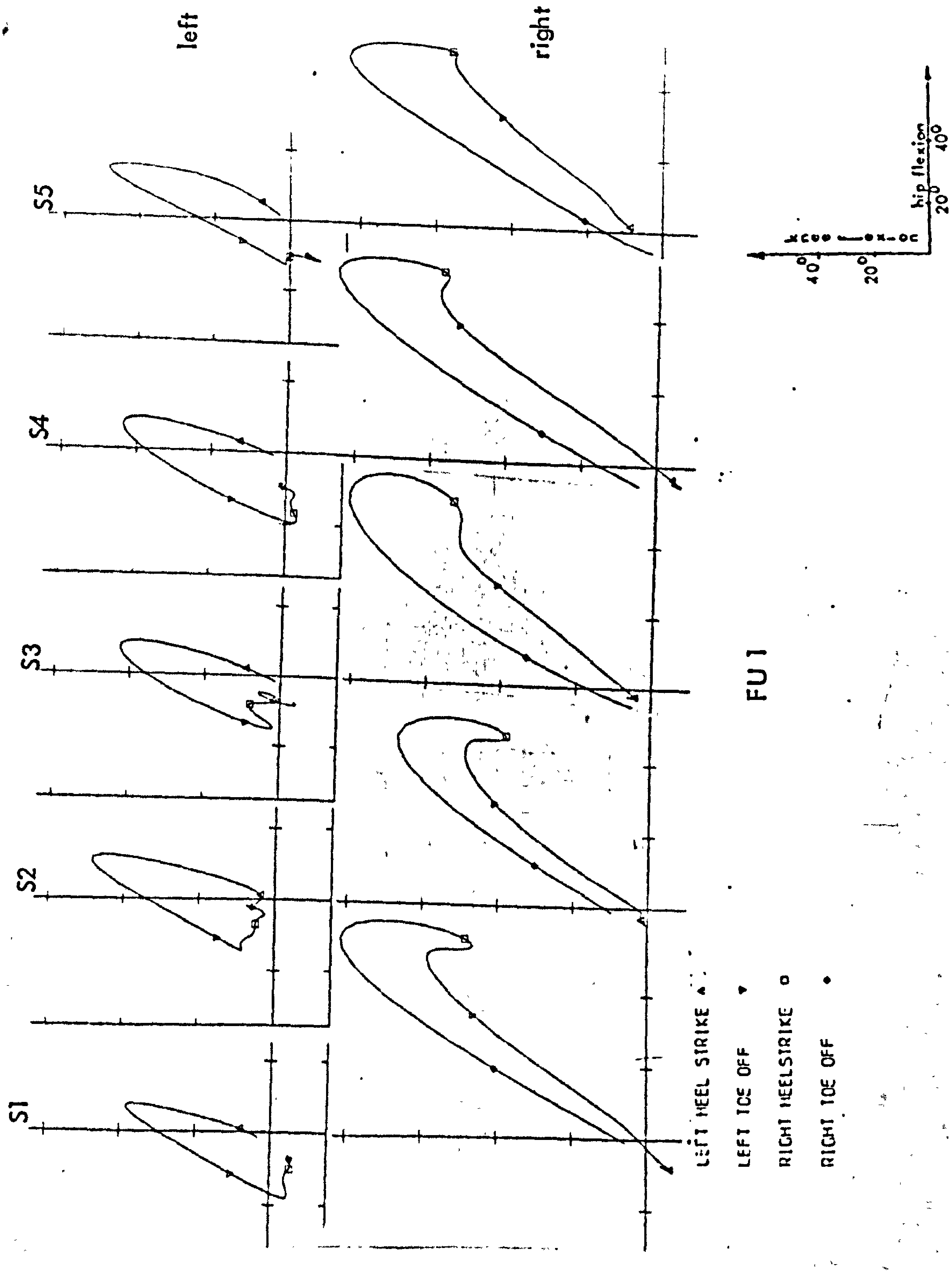

S1
S2
S3
S4
S5
left
right
FU1
LEFT HEEL STRIKE ▲
LEFT TOE OFF ▼
RIGHT HEELSTRIKE □
RIGHT TOE OFF ●
knee flexion
40°
20°
hip flexion
20°
40°

Fig 5.53

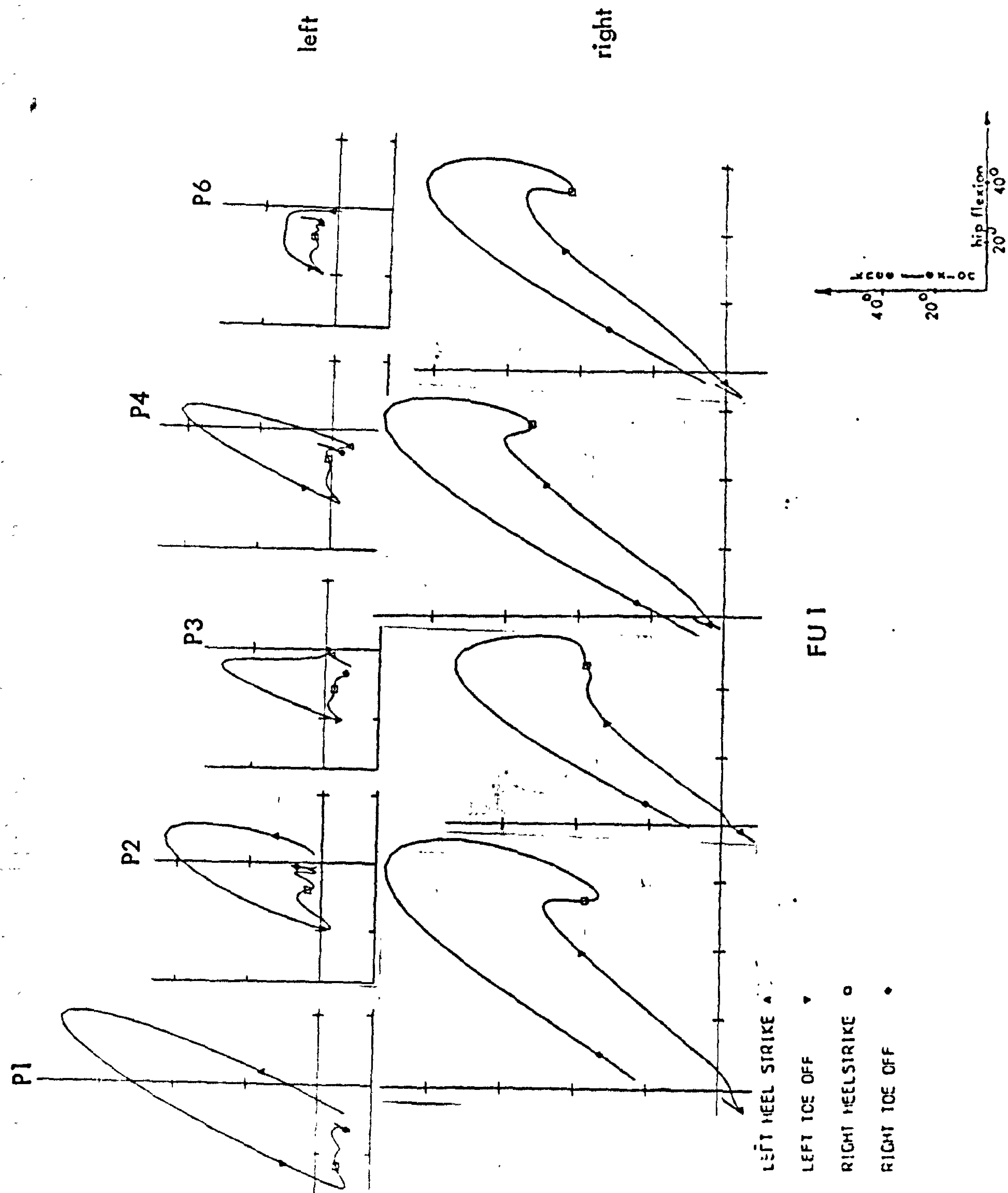

P1
P2
P3
P4
P6
left
right
FU1
LEFT HEEL STRIKE ▲
LEFT TOE OFF ▼
RIGHT HEELSTRIKE □
RIGHT TOE OFF ●
knee flexion
40°
20°
hip flexion
20°
40°

Fig 5.54

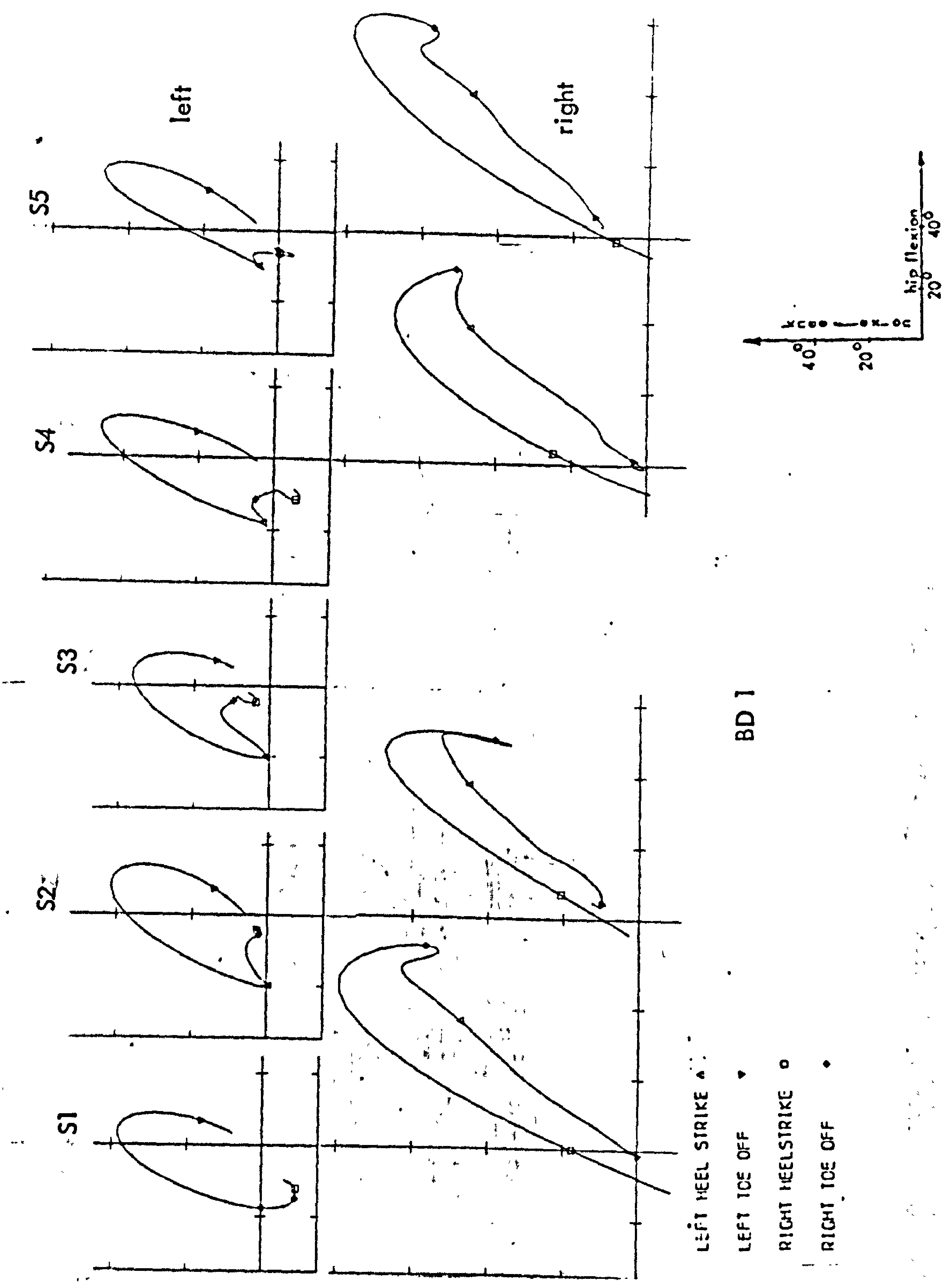

S1
S2
S3
S4
S5
left
right
BD 1
LEFT HEEL STRIKE ▲
LEFT TOE OFF ▼
RIGHT HEELSTRIKE □
RIGHT TOE OFF ◆
knee flexion
40°
20°
hip flexion
20°
40°

Fig 5.55

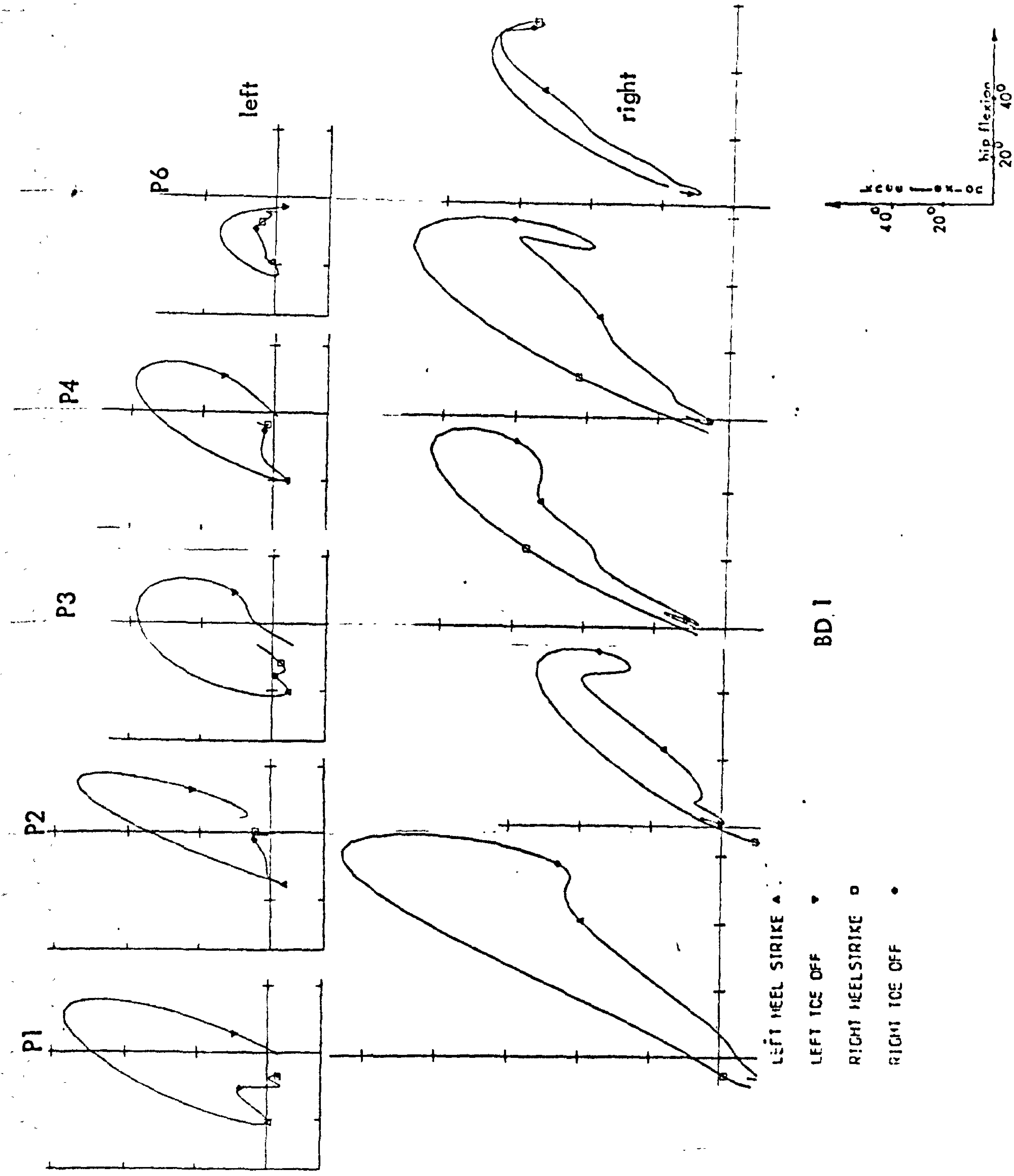

P1
P2
P3
P4
P6
left
right
BD 1
LEFT HEEL STRIKE ▲
LEFT TOE OFF ▼
RIGHT HEELSTRIKE □
RIGHT TOE OFF ●
knee flexion
40°
20°
hip flexion
20°
40°

Fig 5.56

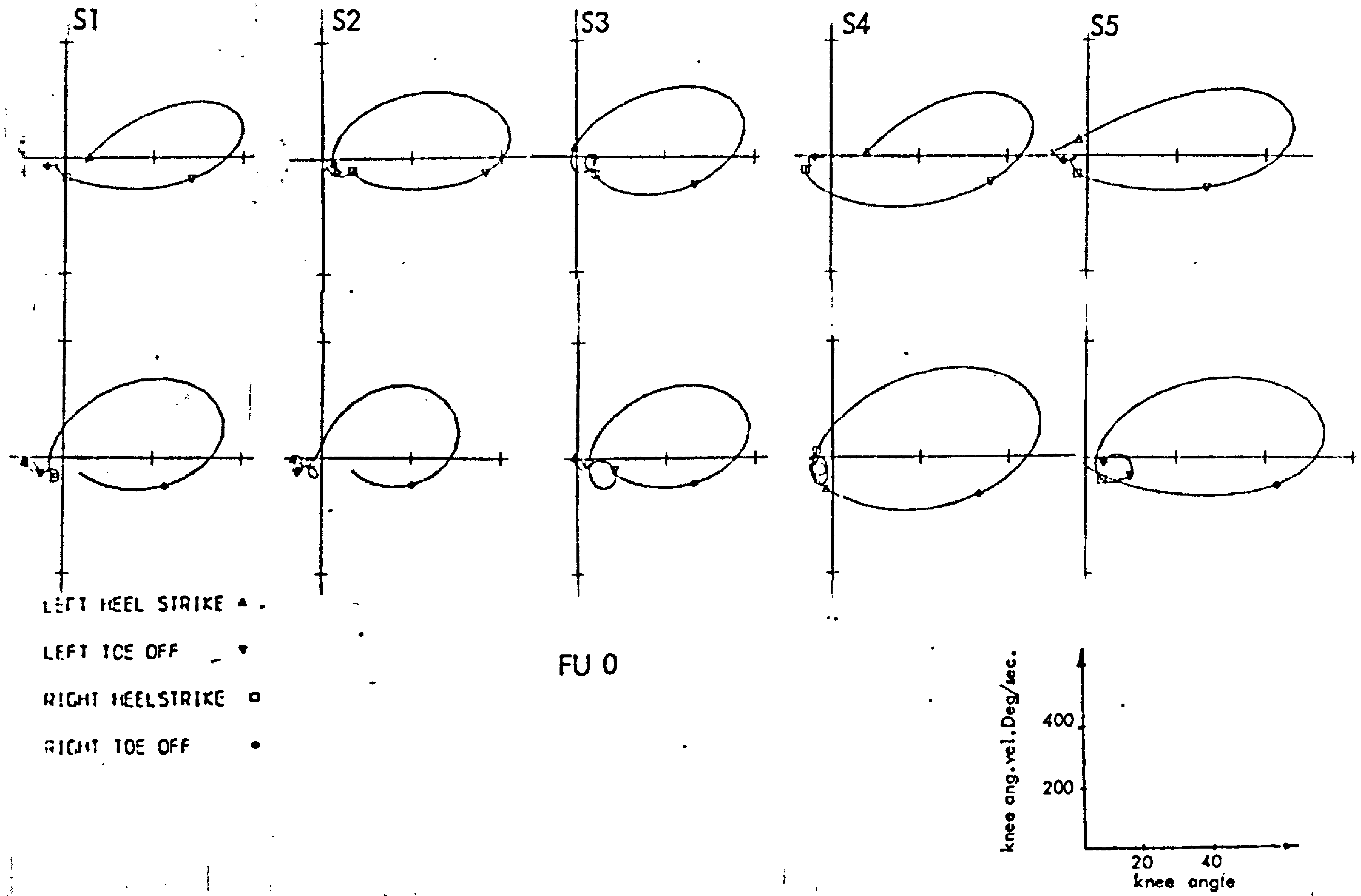

S1
S2
S3
S4
S5
LEFT HEEL STRIKE ▲
LEFT TOE OFF ▼
RIGHT HEELSTRIKE □
RIGHT TOE OFF ●
FU 0
knee ang.vel.Deg/sec.
400
200
20
40
knee angle

Fig 5.57

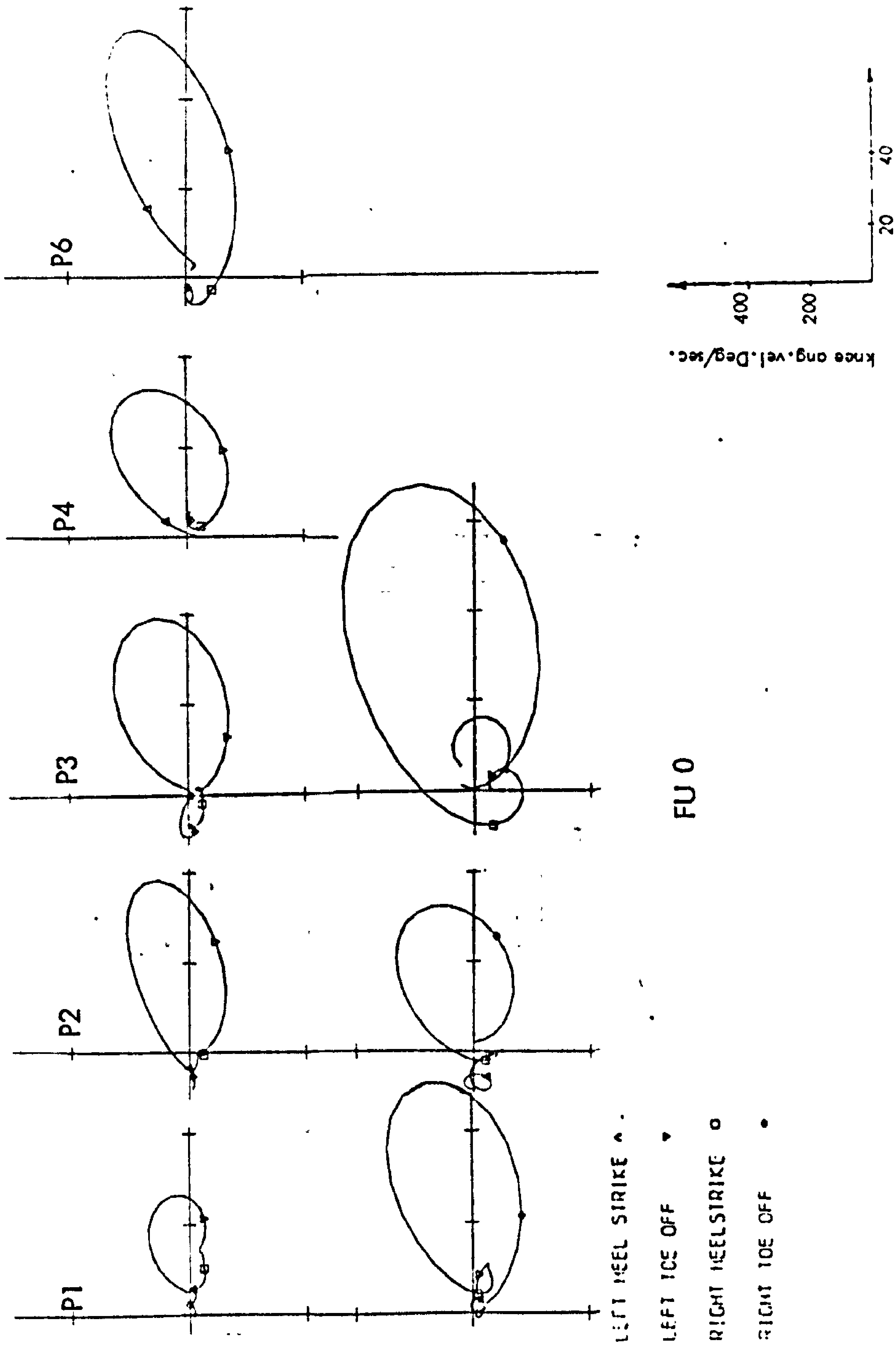

P1
P2
P3
P4
P6
FU 0
LEFT HEEL STRIKE ▲
LEFT TOE OFF ▼
RIGHT HEELSTRIKE ○
RIGHT TOE OFF ●
knee ang.vel.Deg/sec.
400
200
knee angle
20
40

Fig 5.58

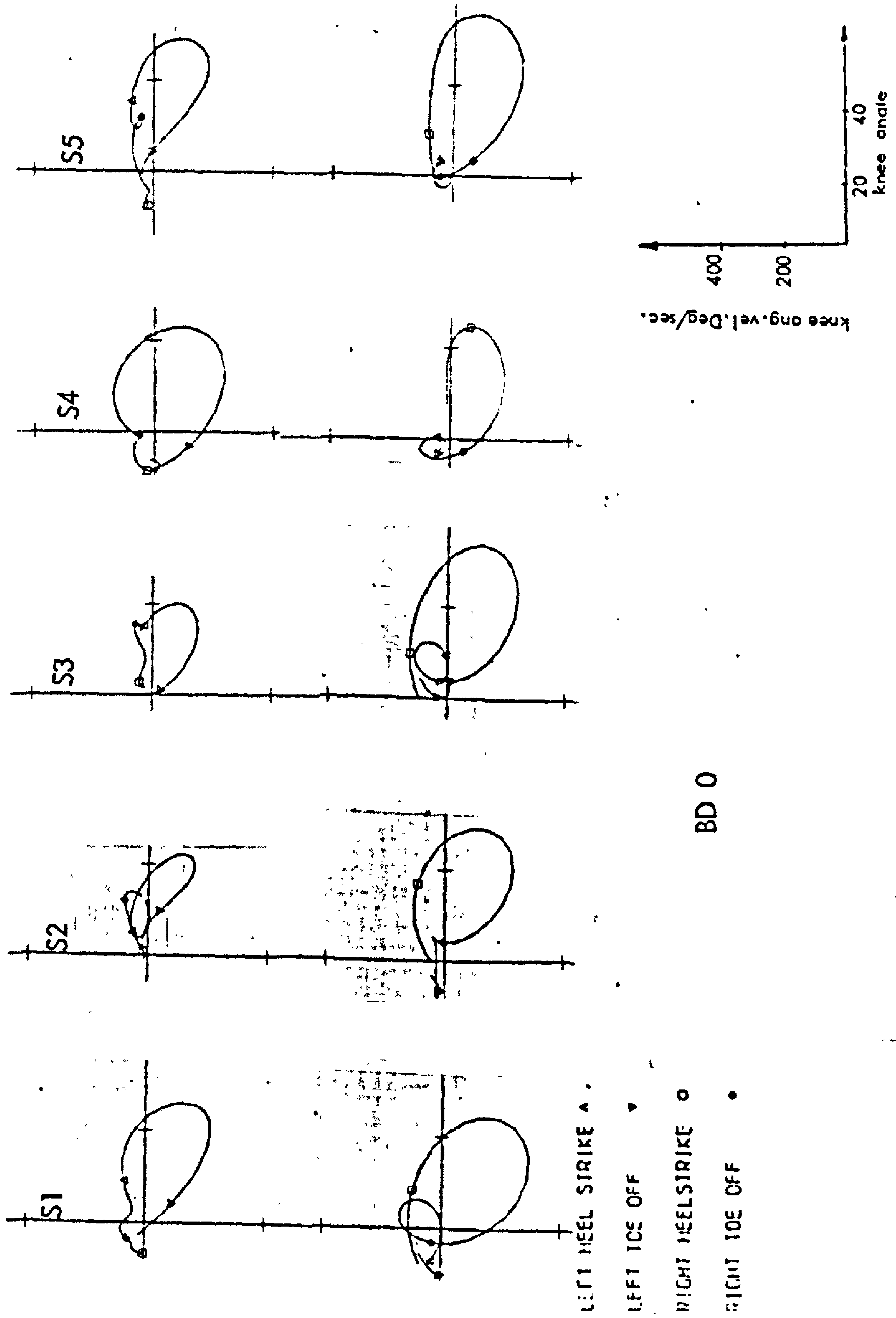

S1
S2
S3
S4
S5
BD 0
LEFT HEEL STRIKE ▲
LEFT TOE OFF ▼
RIGHT HEELSTRIKE □
RIGHT TOE OFF ●
knee ang.vel.Deg/sec.
400
200
20
40
knee angle

Fig 5.59

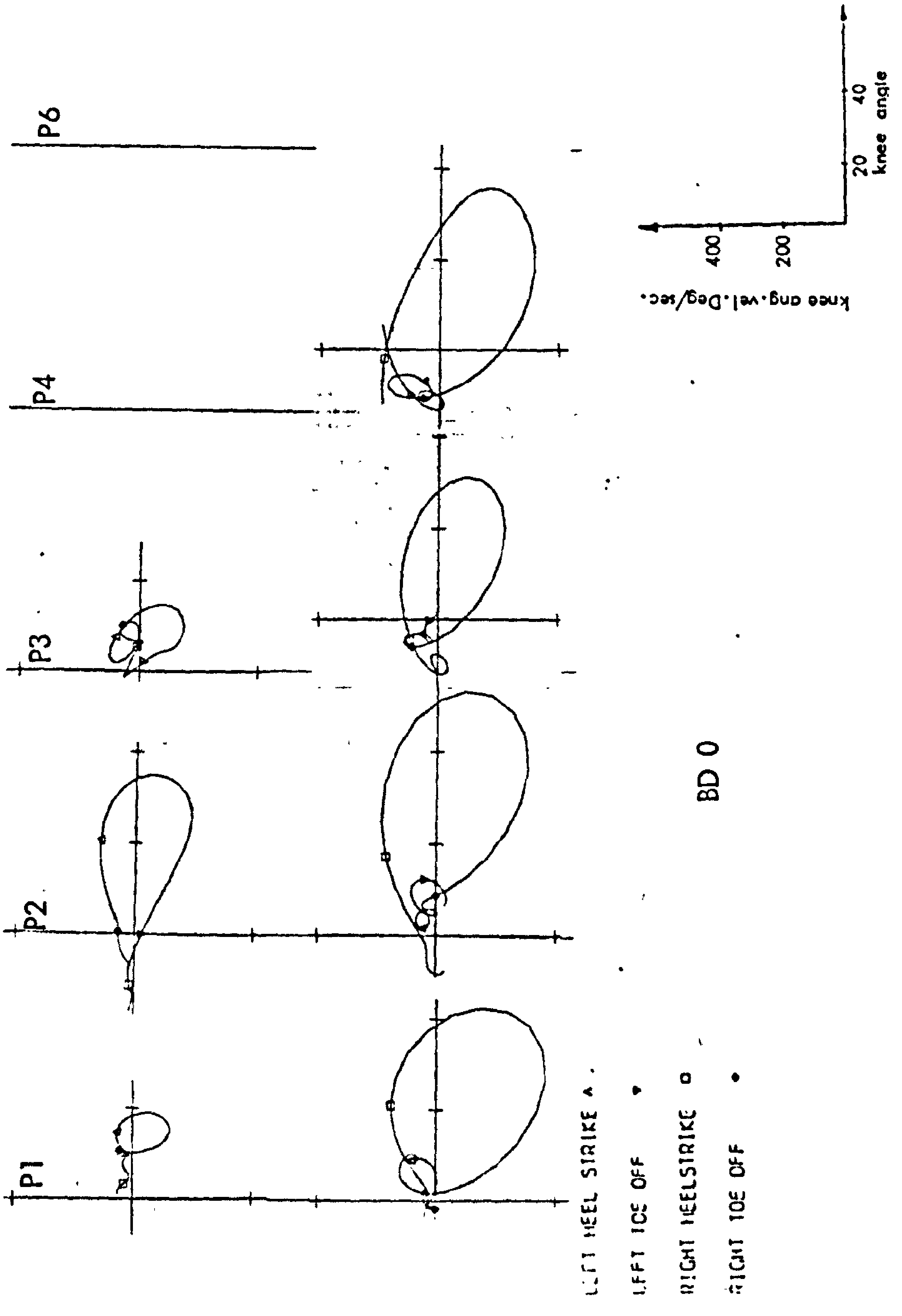

P1
P2
P3
P4
P6
LEFT HEEL STRIKE ▲
LEFT TOE OFF ▼
RIGHT HEELSTRIKE □
RIGHT TOE OFF ●
BD 0
knee ang.-vel.-Deg/sec.
400
200
20
40
knee angle

Fig 5.60

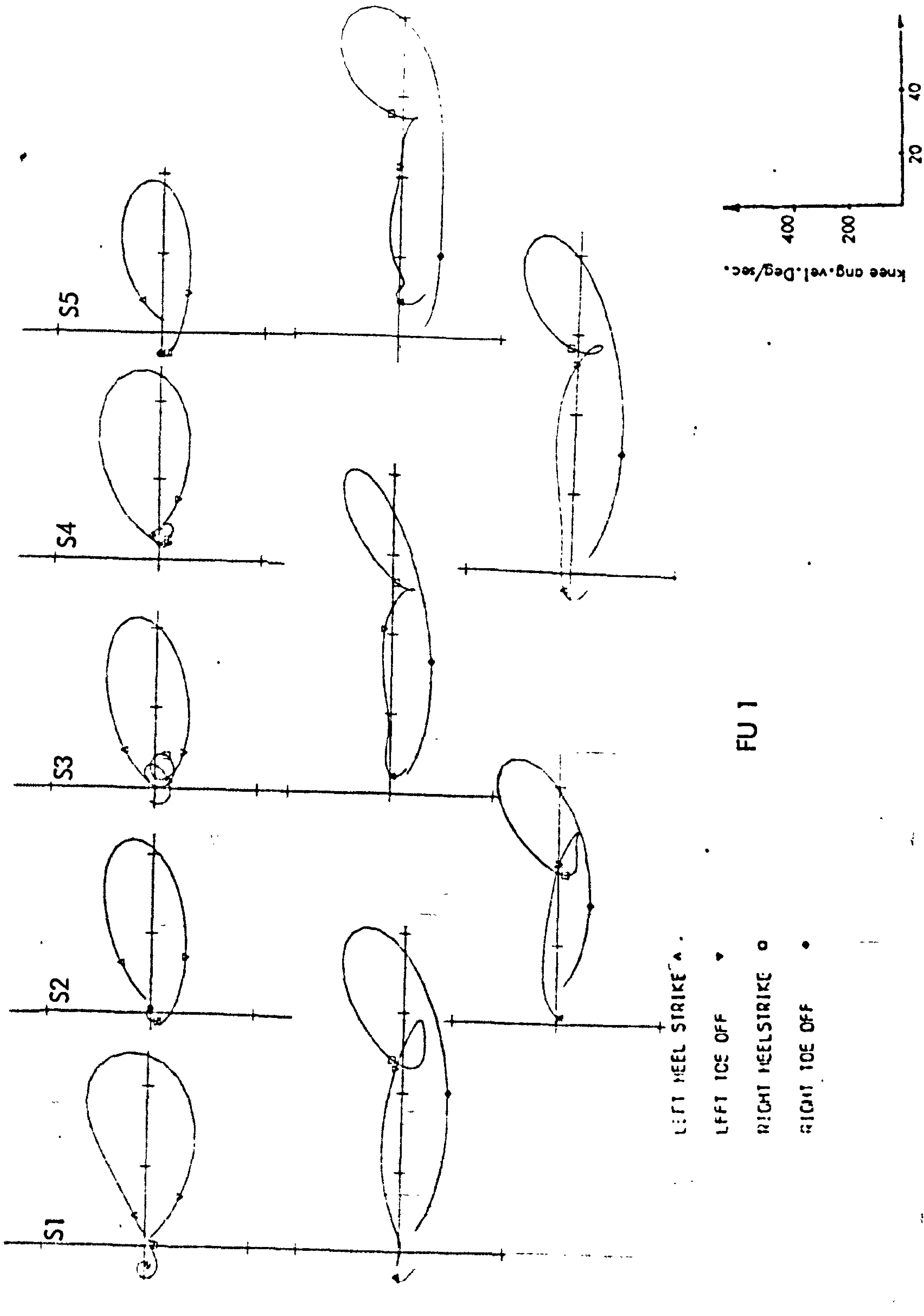

S1
S2
S3
S4
S5
FU 1
LEFT HEEL STRIKE ▲
LEFT TOE OFF ▼
RIGHT HEELSTRIKE □
RIGHT TOE OFF ◆
knee ang.vel.Deg/sec.
400
200
20
40
knee angle

Fig 5.61

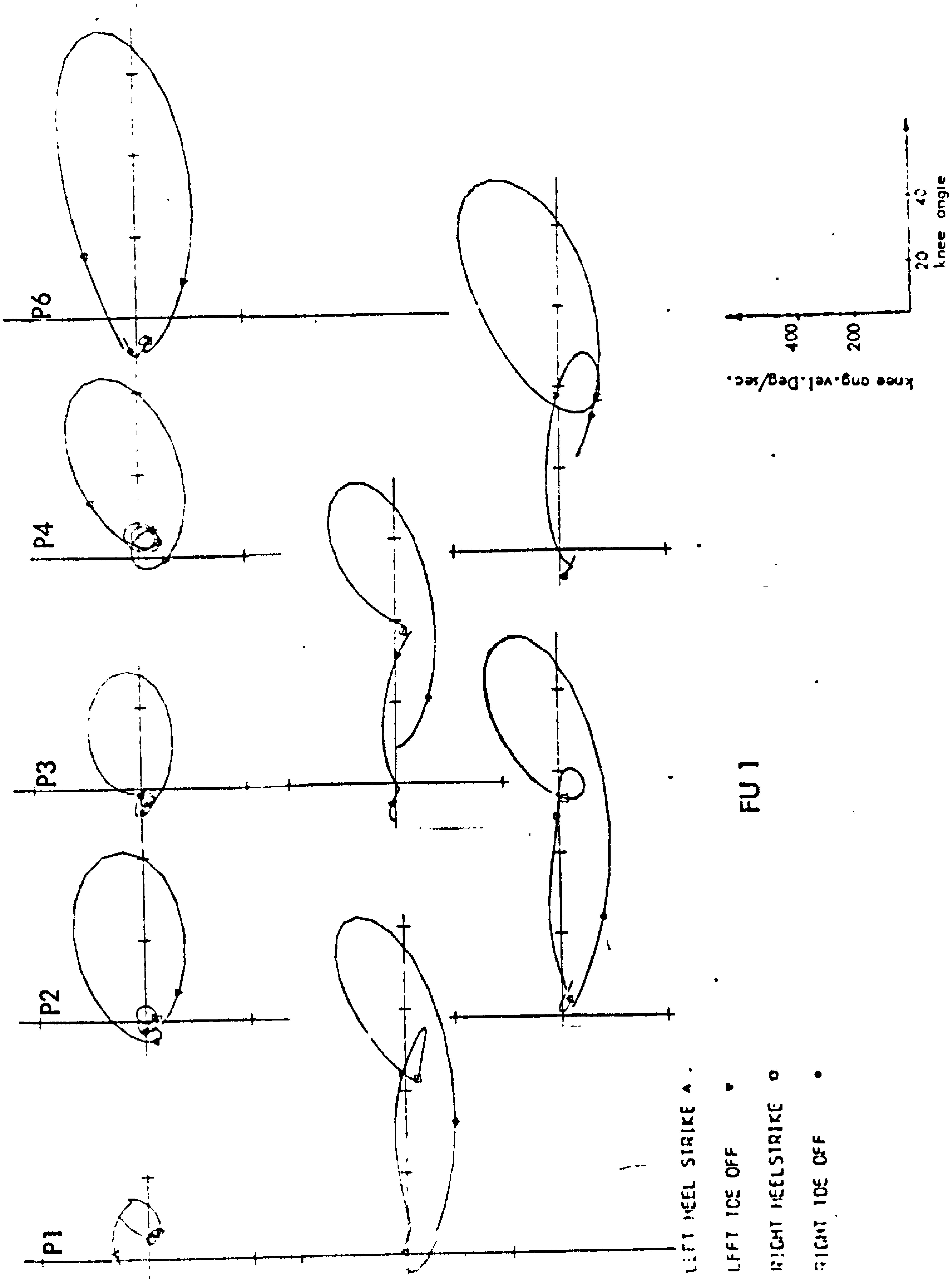

P1
P2
P3
P4
P6
LEFT HEEL STRIKE ▲
LEFT TOE OFF ▼
RIGHT HEELSTRIKE o
RIGHT TOE OFF ●
FU 1
knee ang.vel.Deg/sec.
400
200
20
40
knee angle

Fig 5.62

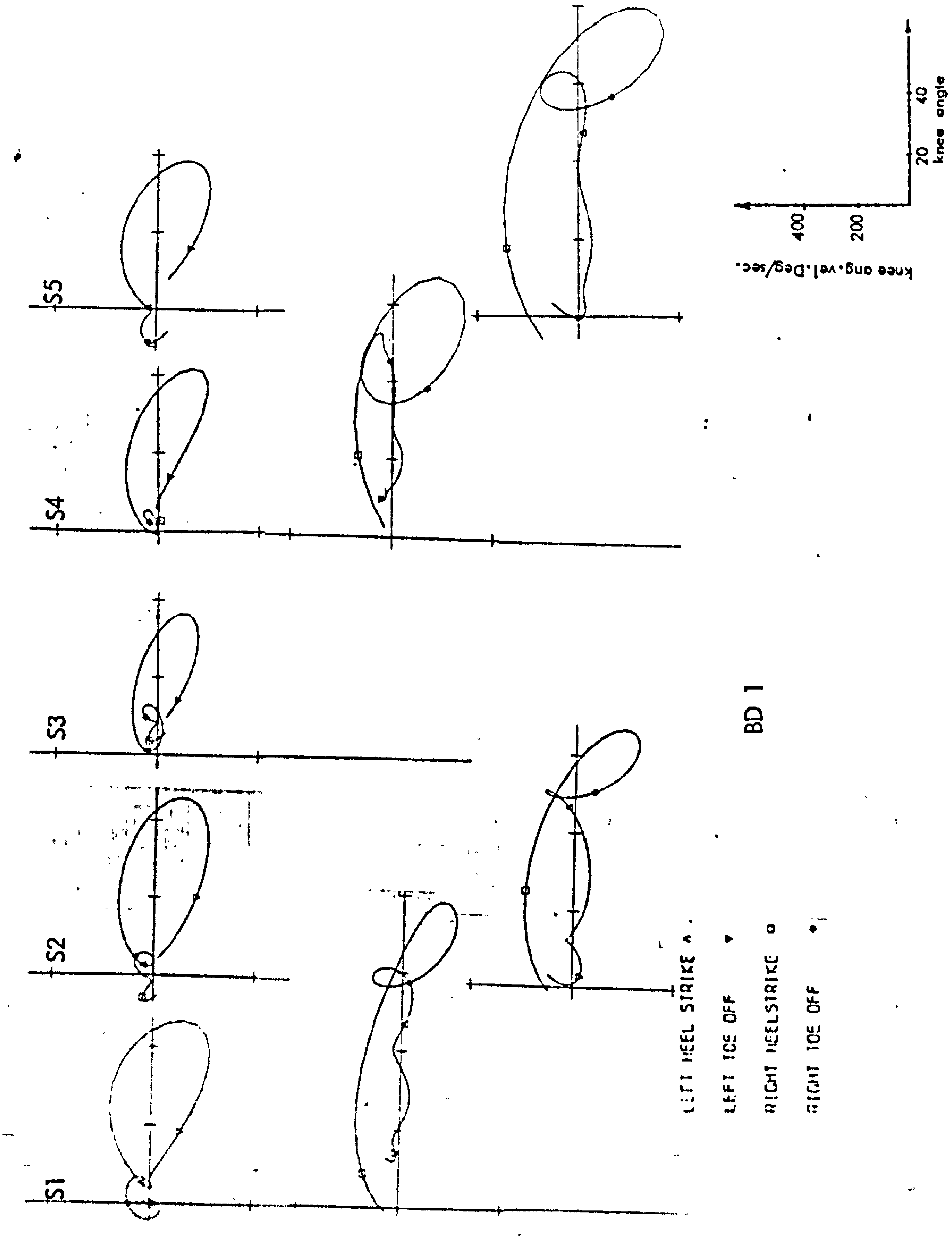

S1
S2
S3
S4
S5
BD 1
LEFT HEEL STRIKE ▲
LEFT TOE OFF ▼
RIGHT HEELSTRIKE □
RIGHT TOE OFF ●
knee ang.vel.Deg/sec.
400
200
20
40
knee angle

Fig 5.63

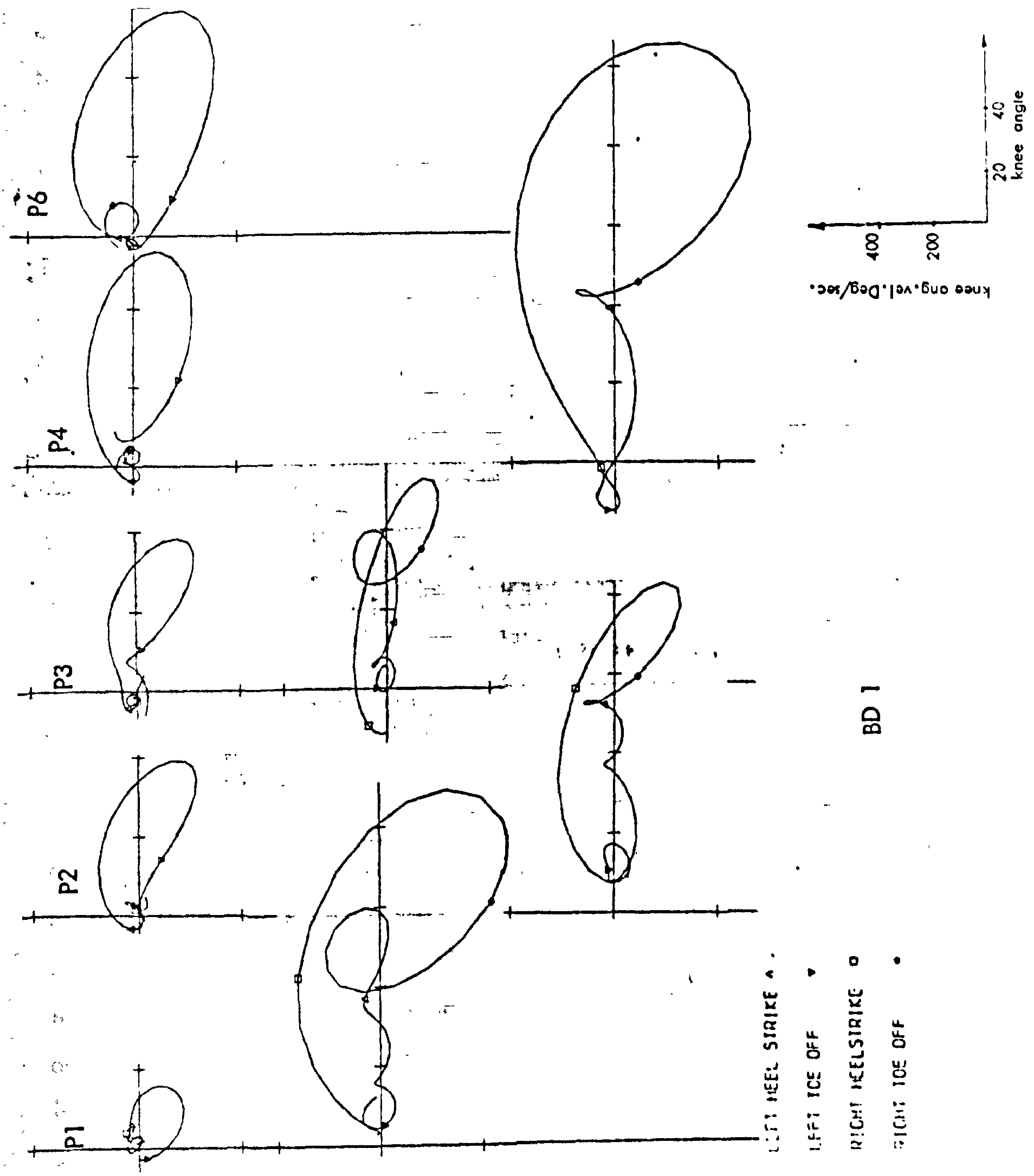

P1
P2
P3
P4
P6
LEFT HEEL STRIKE ▲
LEFT TOE OFF ▼
RIGHT HEELSTRIKE □
RIGHT TOE OFF ●
BD 1
knee ang.vel.Deg/sec.
400
200
20
40
knee angle

Fig 5.64

This study did not confirm the statement made by Grieve et al (1978) viz: "the similarities between normal conjugate movements seem remarkable and deserve exploration". It can be seen, from the diagrams presented (Fig. 5.53 to 5.56) that these curves for the conjugate pair vary within subject or patient.

It is concluded that the angle-angle diagram, represents a good visual aid for locomotion studies, but does not provide complete information.

5.7 Angle-velocity diagrams

Fig. 5.57 to 5.64 show the angular velocity at the knee plotted against knee angle.

These are presented as another way of conveying information. Instability areas can be seen apparent as small loops. These diagrams may prove useful in interpreting the rate of muscle contraction at a particular joint. However, further studies are required towards this end.

5.8 Analysis of result for one particular patient, P2 ("within-patient" comparisons)

5.8.1 Introduction The discussion so far has been based by considering all subjects and patients collectively in order to identify trends. The results obtained for one particular patient (selected arbitrarily as patient P2) will be considered in order to allow comparison "within-patient" to be made.

5.8.2 Moments in the sagittal plane Observing the moments in the sagittal plane for the ankle and knee for this patient, remarkable similarity for the curve shapes for these two joints is noted. The most important part in both manoeuvres (FU 1 and BD 1) is the double support phase (shaded area Fig. 5.65 to 5.70) where the body weight is being transferred from one leg to the other. In both cases (FU 1 and BD 1) either for the ankle and knee, the "within patient" analysis confirms the important role of the left leg on the step action. In these figures it is easier to see the result of this affecting all the joints during double support.

The coronal plane moments have confirmed the general discussion. (para. 5.4).

5.8.3 The angle-angle diagrams The thigh-knee diagrams, show differences in shape on first impression. The differences are as follows:

The left leg during FU 1 shows a certain degree of instability Fig 5.71 (oscillations in the knee) while the hip is being extended and the body is pushed forwards. The largest knee flexion on this diagram suggests that the patient is using his quadriceps in the trailing leg in order to assist the contralateral limb.

Comparing the FU 1 left leg with the BD 1 left leg, shows that in the latter manoeuvre the patient is not using his knee very much, suggesting that the calf group is being responsible for the deceleration of the movement.

However, the FU 1 and BD 1 for the right leg, shows a remarkable difference in the conjugate pairs as described by Grieve et al (1978). It is important to note that in this double stance phase, in the FU 1 manoeuvre, the knee remains "locked" at a certain angle while the hip extends as the body is being translated to the step. In this particular instant the quadriceps group is acting isometrically, in order to provide more stability during the transference of the load from one limb to the other. On the conjugate pair (BD 1) this phenomenon does not occur - gravity assists the manoeuvre and the contralateral limb is the one responsible to support.

In both cases, left and right leg, the limb leading the manoeuvre is the one which produces larger angles during the swing phase. This is due to the necessity to clear the ground (step); the same does not obtain in the trailing limb as the neurosystem had already received the necessary informations.

Grieve et al (1978) emphasise the importance of the shapes of the angle-angle diagram as an aid in itself to assess and interpret pathological cases. It is the author's view that this is an over-simplification when assessing significance of shape changes clinically, unimportant features in locomotion can produce such distortion. In the case (patient P2) analysed it is of interest to note that the difference in shape, of the diagram of the right leg (FU 1 and BD 1) occurs mainly during the swing phase which seems not to be of any importance in the detection of pathological states.

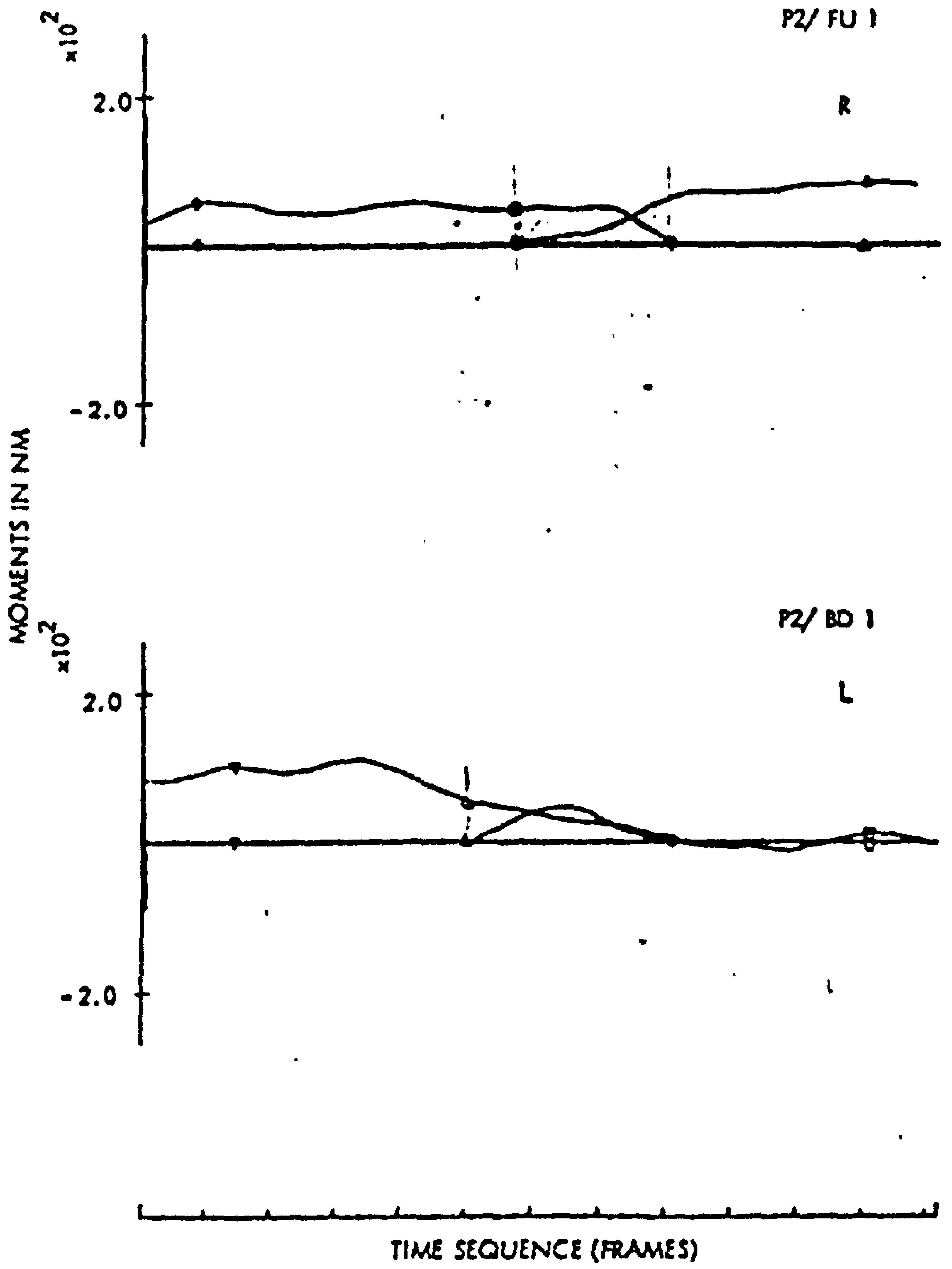
The diagrams without doubt can be of considerable help in the interpretation of human kinematics, but it has to be borne in mind that the whole of the biomechanical complexity of the action is not being reflected in these diagrams and in consequence they have to be used as an accessory tool only.

Additionally, presentation of the kinematic data in the form of angle-angle diagrams has the advantage of allowing direct comparisons to be made with the results of the preliminary study on the stepping action carried out using the Polarized light goniometer (Polgon) by D'Angelo and Grieve (1977) and Grieve et al (1978).

Fig. 5.49 and 5.50 show that the angle-angle diagrams produced during zero height step are generally similar to those obtained for walking on the level (see Fig. 5.23) for both left and right legs. However two differences can be seen: a) the zero height stepping diagram does not close completely, as in the case of level walking. This is due to the fact that the step test does not constitute a full cycle (stride) as in locomotion and in the majority of the cases (both for normals and pathologicals) the limbs do not end up with the same posture as at the start of the manoeuvre. b) in the step test it seems that there is a tendency to hyperextend the knee during the stance phase. The latter effect was interpreted as a posture adopted in order to save muscle energy during standing. This is not commonly seen in walking due to large inertia effects.

The BD O manoeuvre (Fig. 5.51 & 5.52) shows familiar curves shapes for the right leg but completely distorted curve shapes for the left leg, for both normals and pathologicals. The inconsistencies in the shapes for this manoeuvre are thought to be due to the unusual nature of this particular stepping movement. It has been observed that a certain subject may choose any convenient posture at a certain moment in time. At first sight it would appear that important features could emerge from such a diagram, but on comparisons with Fig. 5.55 and 5.56 BD 1 which represent the same movement performed on a 10% height step, a more stable diagram is seen (for both normals and pathologicals). When descending from a step, both normals and pathologicals, have less choice in posture than when walking backwards on the level.

For the FU 1 and BD 1 Fig. 5.53 to 5.56 the right leg produces the shape described by Grieve et al (1978) see Fig. 5.24. These curves did not show significant differences. between the normals and the pathologicals neither for neither FU 1 nor for BD 1. Nevertheless, differences do occur between the conjugate part of diagrams (FU 1/BD 1) within a certain subject (for both normals and patients).



Ankle moments, sagittal plane

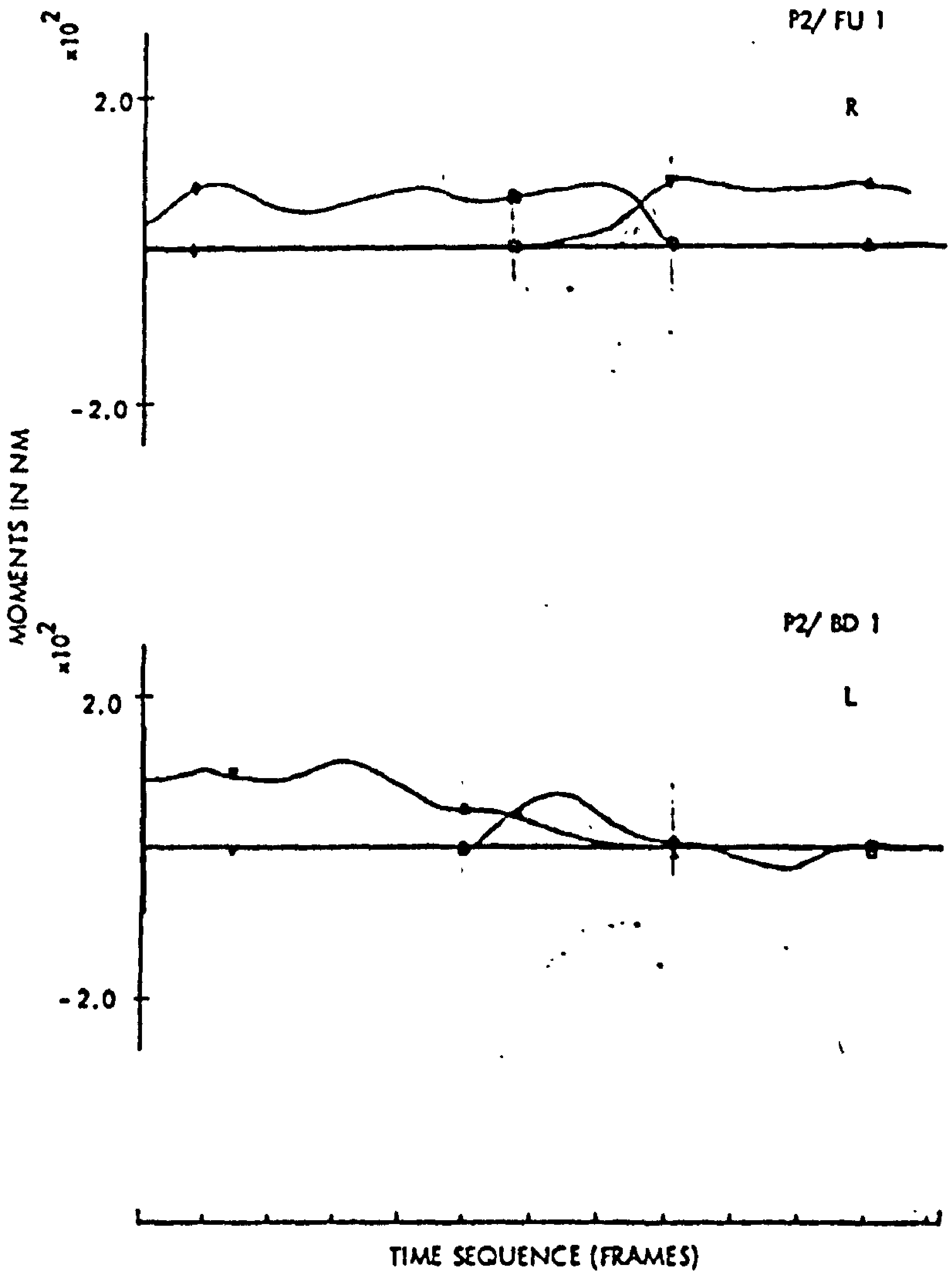
Fig. 5.65

LEFT HEEL STRIKE ^

LEFT TOE OFF ▿

RIGHT HEELSTRIKE □

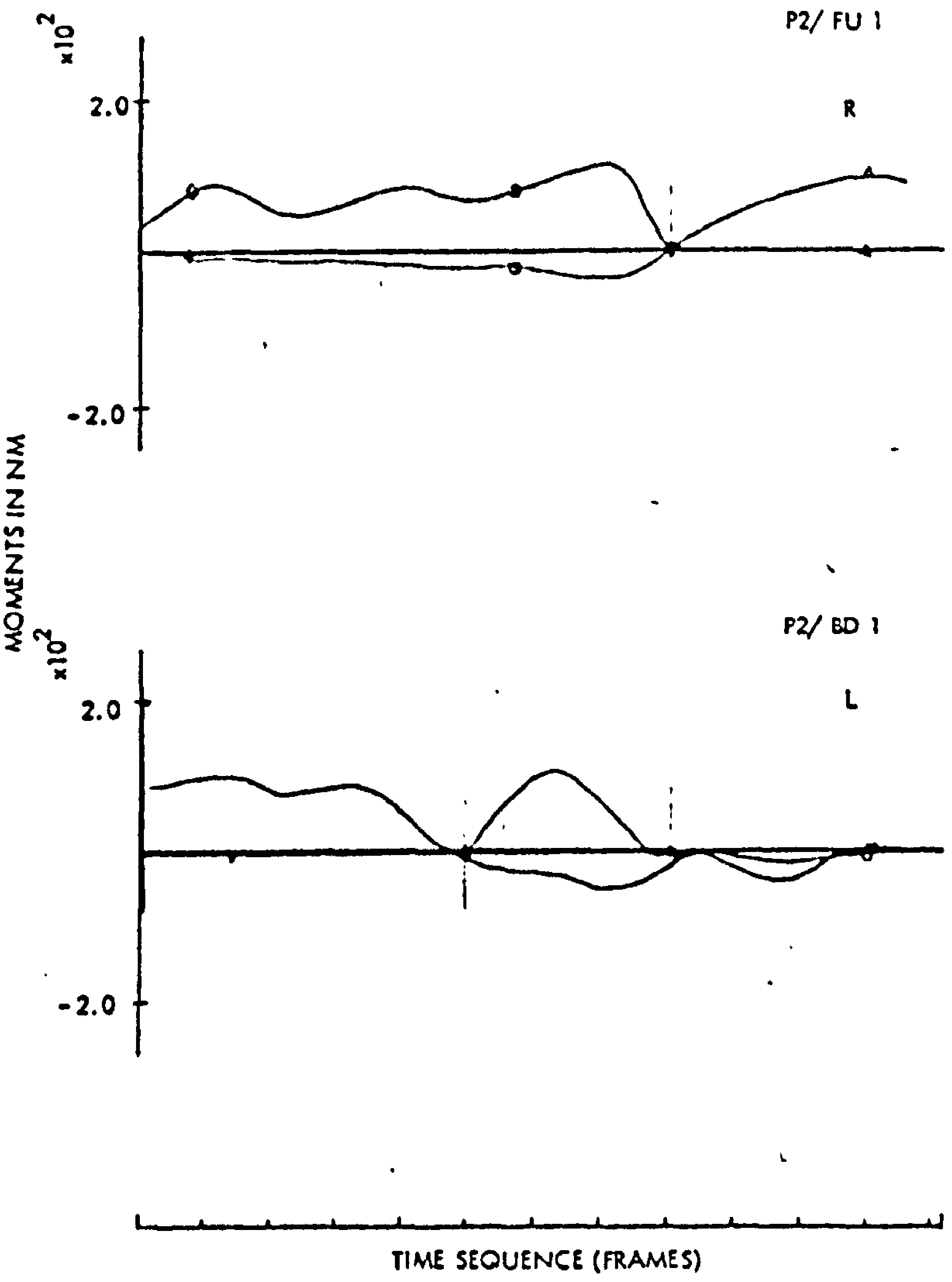
RIGHT TOE OFF ◇



Knee moments, sagittal plane

Fig.5. 66

LEFT HEEL STRIKE	^
LEFT TOE OFF	▽
RIGHT HEELSTRIKE	□
RIGHT TOE OFF	◇



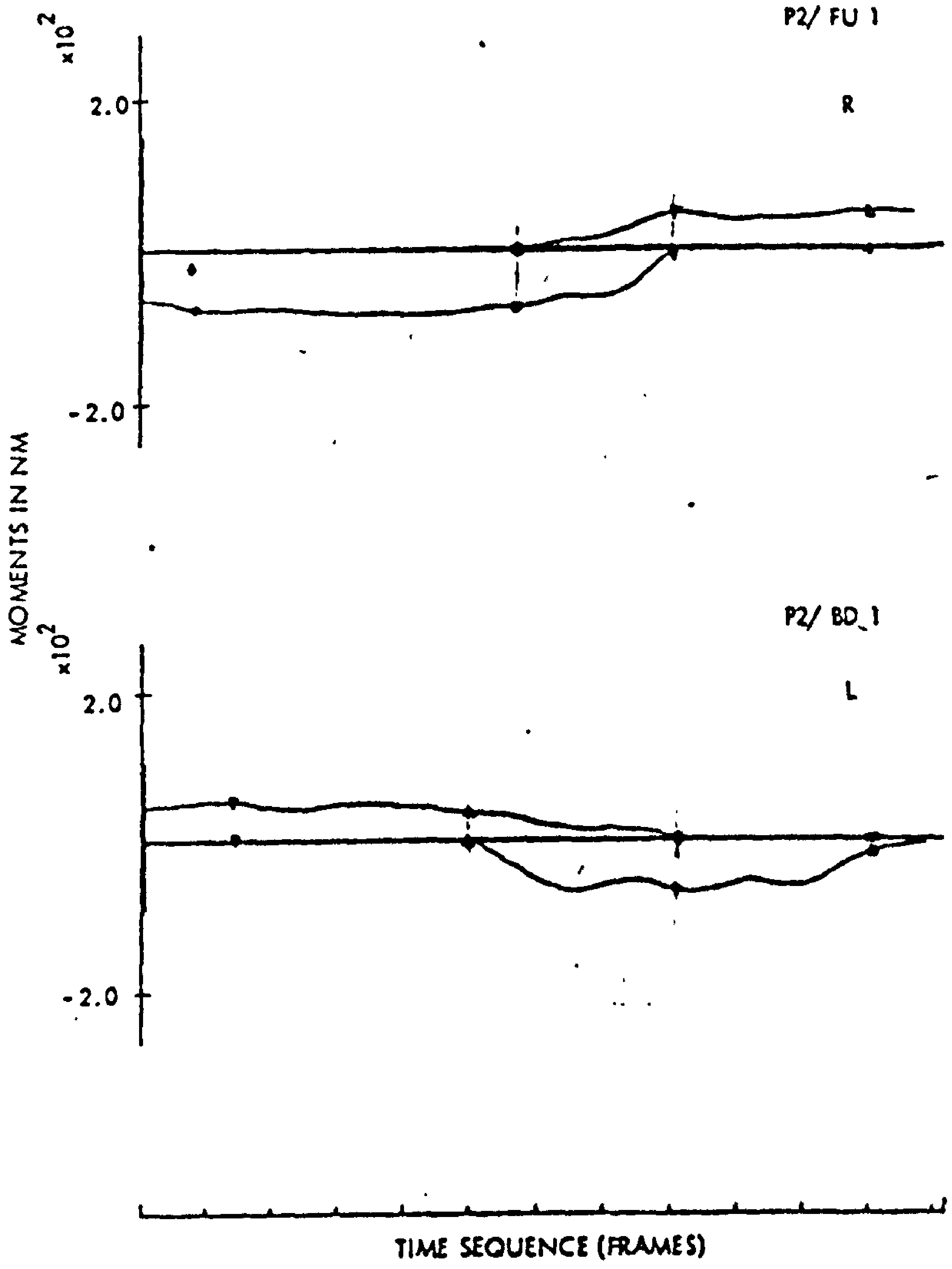
Hip moments, sagittal plane
Fig. 5.67

LEFT HEEL STRIKE ^

LEFT TOE OFF ▽

RIGHT HEELSTRIKE □

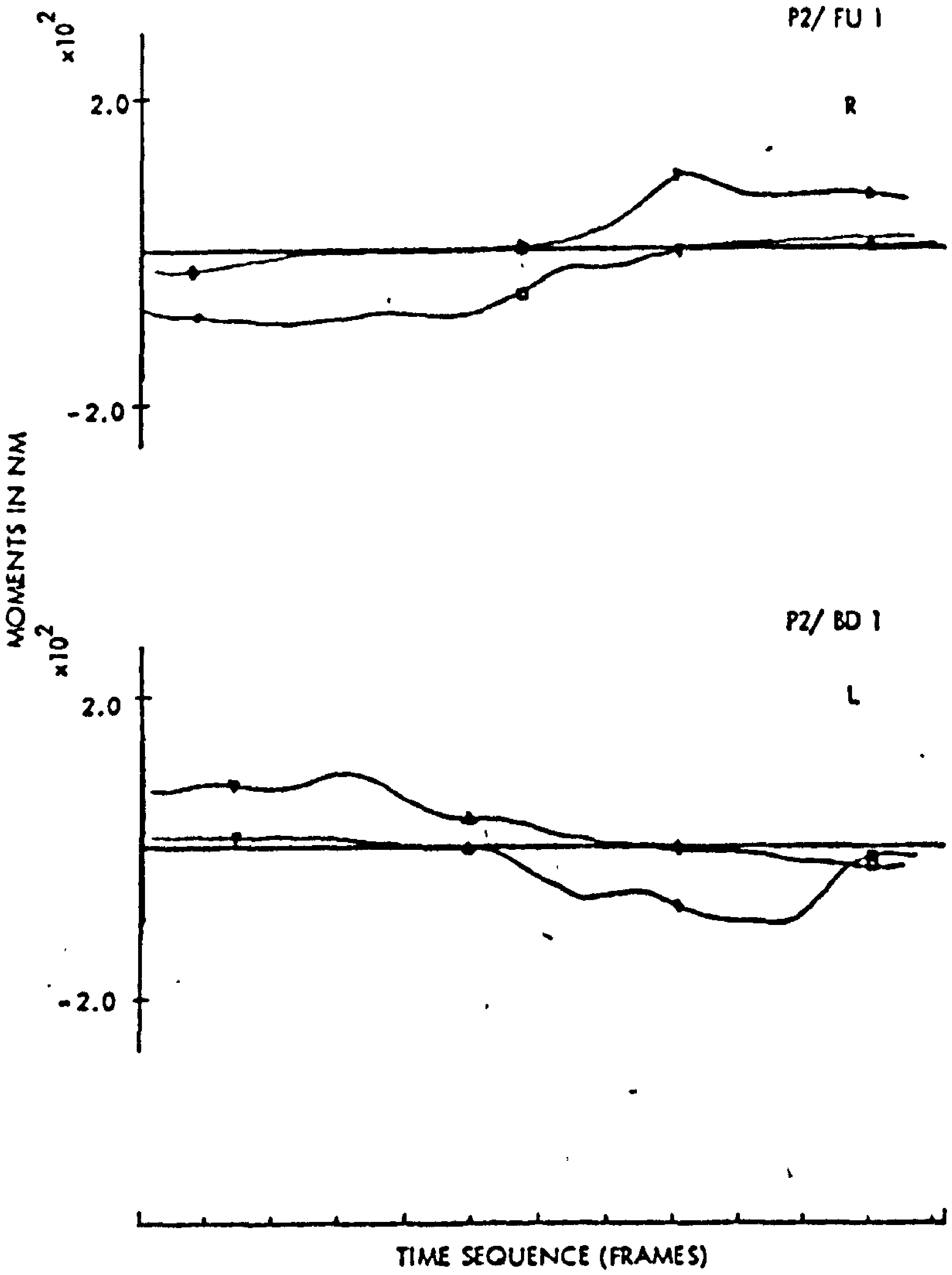
RIGHT TOE OFF ◇



Ankle moments, coronal plane

Fig. 5. 68

LEFT HEEL STRIKE	^
LEFT TOE OFF	▽
RIGHT HEELSTRIKE	□
RIGHT TOE OFF	◇



Knee moments, coronal plane

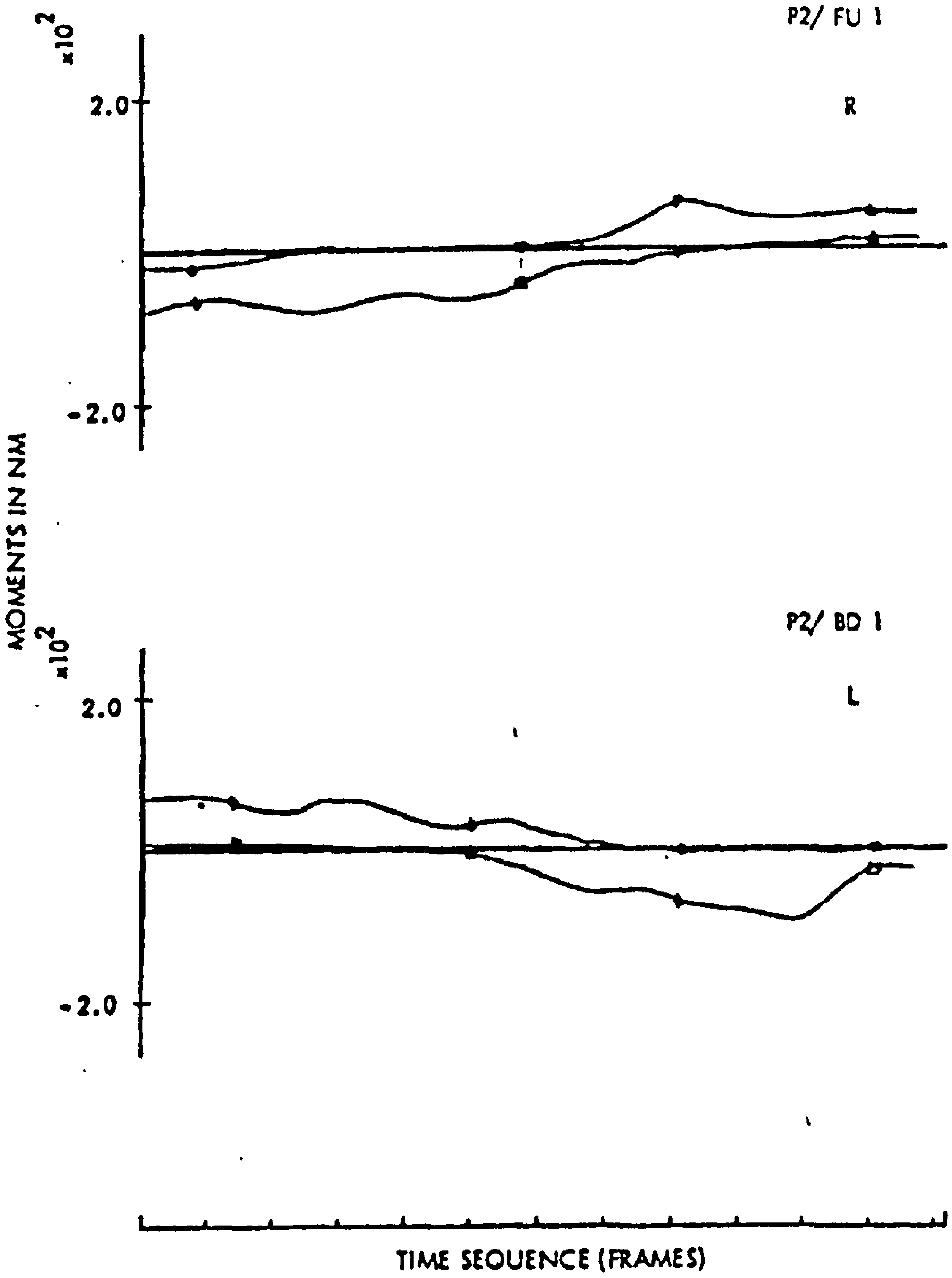
Fig. 5.69

LEFT HEEL STRIKE ^

LEFT TOE OFF ▽

RIGHT HEELSTRIKE □

RIGHT TOE OFF ◇



Hip moments, coronal plane

Fig. 5.70

LEFT HEEL STRIKE ^

LEFT TOE OFF ▽

RIGHT HEELSTRIKE □

RIGHT TOE OFF ◇

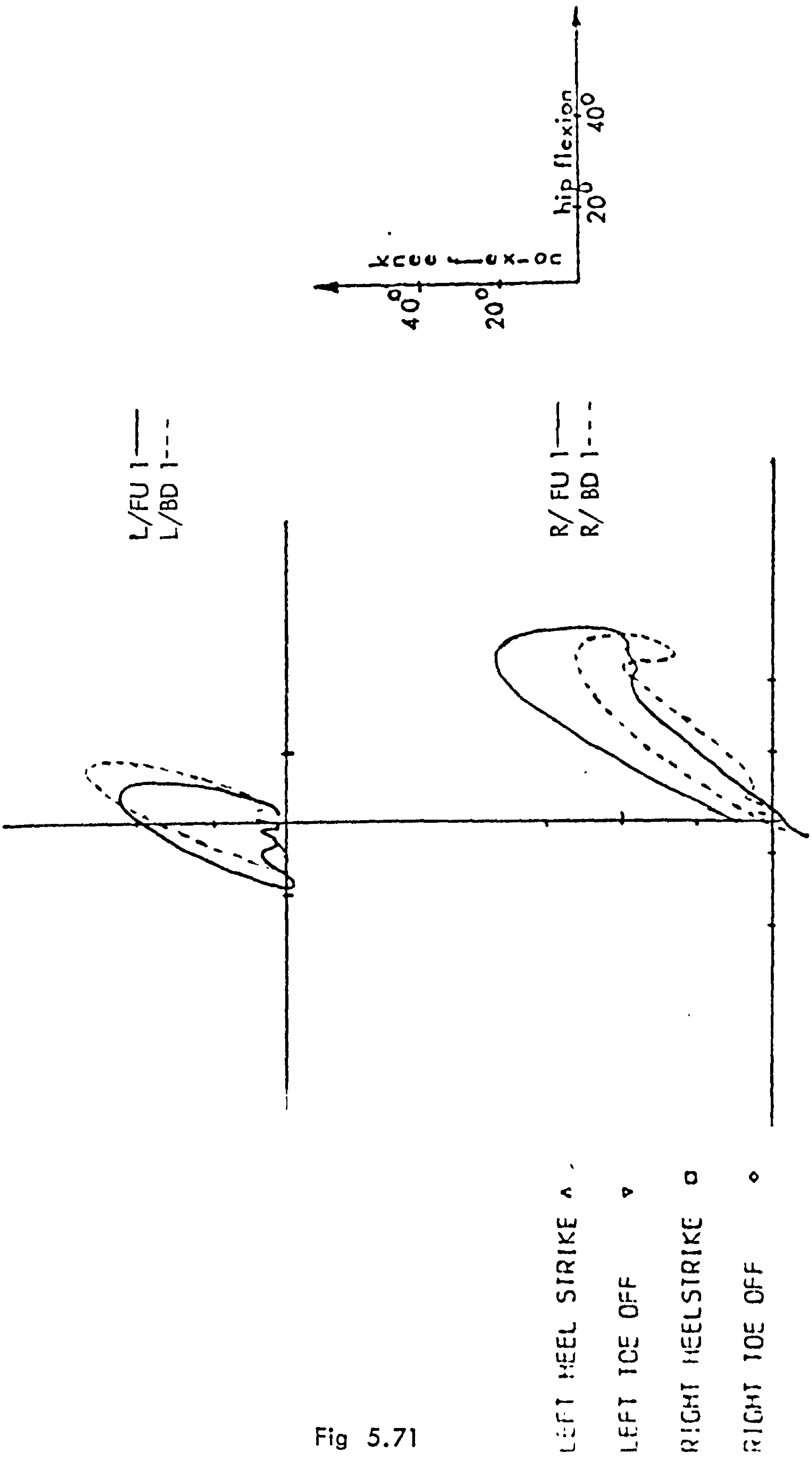

hip flexion
20°
40°
knee flexion
20°
40°
L/FU 1 ——
L/BD 1 - - -
R/FU 1 ——
R/BD 1 - - -
LEFT HEEL STRIKE
LEFT TOE OFF
RIGHT HEELSTRIKE
RIGHT TOE OFF

Fig 5.71

CHAPTER 6

CONCLUSIONS

6. CONCLUSIONS

There were no significant differences between the moments at ankle, knee or hip for step height of 0% and 10% of patient's height.

The left leg (trailing leg) was found to be always more highly loaded than the right, in both the FU and BD manoeuvres. The calf muscular group seems to play an important role in accelerating the body upwards or absorbing the energy in decelerating the body backwards.

This is a disadvantage in the step test as a patient can mask pathology in the leading leg knee using the gastrocnemius of the trailing leg.

The angle-angle diagrams can be of considerable help in the interpretation of human motion kinematics. However to attempt to interpret pathological conditions from merely the shape of the angle-angle diagrams would be an over simplification. Analysis of the results must be done in conjunction with other information such as force actions, temporal parameters etc. During the stance phase measurement of both the forces and displacements is of importance whereas during swing phase the linear and angular displacements are most relevant. The calculations carried out clearly indicate that the forces due to the inertia effects during the stepping action are negligibly small.

No significant differences were found between the patients and the control subjects. Furthermore, an attempt to interpret "within patient" variations (as suggested by Grieve et al 1978) did not prove fruitful. Similarities in conjugate pairs when using the angle diagrams, were not found.

A positive outcome of significance has been the development of a computer program which accepts data from 2 force plates and a kinematic system and outputs 3 dimensional intersegmental, force actions, and linear and angular displacements in graphical form. This development was necessary in order to handle the enormous amount of data involved and it is now so designed that any modification/improvement considered necessary in the future development of all locomotion testing procedures can be easily accommodated.

It is concluded that the step test in its present form has no application as part of a battery of tests used for clinical purposes. Further exploration therefore, in this simple form of test, is not recommended. Future investigations should be carried out using a step of variable rise - from zero to a height that the subject/patient is capable of climbing - in order to establish a relationship between step height and the relevant biomechanical parameters.

CHAPTER 7

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APPENDICES

8.1 Computer Program

8.2 Intersegmental Moments for all Subjects and patients

8.1 Computer Program

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     1   HIPVEL(3,61),HIPACC(3,61),HIPANX(61),DELHOX(61),KNEANX(61),
     2   HIPANZ(61),DELHOZ(61),KNEANZ(61),FOTANG(61),FOTVEL(61),
     3   FOTACC(61),SHOANG(61),
     4   SOMEGX(61),SOMEGZ(61),SALFAX(61),SALFAZ(61),TOMEGX(61),
     5   TOMEGZ(61),TALFAX(61),TALFAZ(61),TETA2(61)
      DIMENSION XCGSHA(61),YCGSHA(61),ZCGSHA(61),SXGDD(61),SYGDD(61),
     1   SZGDD(61),XCGTHI(61),YCGTHI(61),ZCGTHI(61),TXGDD(61),
     2   TYGDD(61),TZGDD(61),XEST(61),ZEST(61),EMNEEX(61),
     3   EMNEEZ(61),EMHIPX(61),EMHIPZ(61),ANKMOX(61),ANKMOZ(61),
     4   TQA(61),FXK(61),FYK(61),FZK(61),KNEEMX(61),KNEEMZ(61),
     5   FXH(61),FYH(61),FZH(61),HIPMZ(61),HIPMX(61),TQK(61),
     6   TQH(61)
      DIMENSION FX(61),FY(61),FZ(61),MX(61),MY(61),MZ(61)
      DIMENSION FHOLD(3000),TOT060(61)
      DIMENSION YY(125),DFUN(61),DDFUN(61)
      DIMENSION IDENT(7),ANGDEG(10)
      COMMON /ABTFLG/ ABTFL(2)
      COMMON /BLOCK1/ SSX(10),SSY(10),SFZ(10)
      COMMON /BLOCK2/ AJC(3,125),KJC(3,125),SXL(3)
      COMMON /FHLDBK/ FHOLD
      COMMON /LADO/ LEFSID,ISIDE,JSIDE,LSIDE,JBIDE,LBIDE
      COMMON /TRYY2/ Y2A,Y2
      COMMON X1ANTES,Y1ANTES,X1A,Y1A,Z1A,X,Y,Z,HX,XL,ZL
      EQUIVALENCE (FHOLD(1),FX(1)),(FHOLD(62),FY(1)),(FHOLD(123),FZ(1))
      EQUIVALENCE (FHOLD(184),MX(1)),(FHOLD(245),MY(1)),(FHOLD(306),
     1   MZ(1))
      INTEGER SFRAME,FFRAME
      REAL IIR,IIS,IR,IS,KNEANX,KNEANZ,KNEEMX,KNEEMZ,KJC,KNEVEL
      REAL KNEACC,LENGTH,MX,MY,MZ
      LOGICAL ABTFL,FUL,LEFSID,NEWMAN,OIDENT
      DATA DEGREE / 57.29578 /
      DATA HALFPI / 1.570796 /
      DATA IFUL/3HFUL/
      DATA LADO2 / 3HKL1 /
C
C READ IN CONSTANTS FOR PATIENT, AND CALCULATE VECTOR LOCATING HIP-
C     JOINT CENTRES FROM DISTANCE BETWEEN A.S.I.SPINES.
C
  100 ABTFL(1)=.FALSE.
      CALL INPCON(BH,BM,D67,D78,D86,IDENT(1),NEXTID)
      WRITE(6,110)IDENT(1)
  110 FORMAT(35H1PATIENT CONSTANTS READ FROM DECK  ,A9,1H.)
      VH7(1)=D86*0.1829
      VH7(2)=D86*0.3049
      VH7(3)=D86*0.1219
C
C READ IN STATIC DATA FROM FILM OBSERVATIONS.
C
      CALL INPKIN (IR,IS,NCHECK,IDENT(2),NEXTID)
      WRITE(6,120)IDENT(2)
  120 FORMAT(35H0STATIC SIDE DATA READ FROM DECK   ,A9,1H.)
      IF(NCHECK.NE.8)CALL ABORT(1)
      CALL INPKIN (IIR,IIS,NCHECK,IDENT(3),NEXTID)
      WRITE(6,130)IDENT(3)
  130 FORMAT(35H0STATIC FRONT DATA READ FROM DECK  ,A9,1H.)
      IF(NCHECK.NE.13)CALL ABORT(1)
C
C READ IN AND PROCESS FORCE-PLATE DATA.  ABORT IF ERROR FLAG SET.
```

```
C
  140 ABTFL(2)=.FALSE.
      CALL INPFPD(FHOLD,NFPSET,IDENT(4),NEXTID,BM,EVNTPT)
      WRITE(6,144) IDENT(4),EVNTPT
  144 FORMAT (35H0FORCE PLATE DATA READ FROM DECK    ,A9,1H.,10X,
     1   16HEVENT POINTER  =,F8.2)
      IF (NFPSET.LE.0) CALL ABORT(2)
C
C READ FRAME NUMBERS FOR EVENTS, AND FRAME COUNT.
C
      CALL INPKMK(LHS,LTO,NHS,NTO,NF,IDENT(5),NEXTID)
      WRITE(6,150)IDENT(5)
  150 FORMAT(35H0FRAME NUMBERS READ FROM DECK       ,A9,1H.)
C
C READ KINEMATIC DATA.   SFRAME IS THE NUMBER OF POINTS PER FRAME IN
C     SIDE VIEW, INCLUDING THE FIRST THREE POINTS OF THE GRID.
C     FFRAME IS THE SAME FOR THE FRONT VIEW.   FOR EACH VIEW THE
C     NUMBER OF FRAMES IS CHECKED AGAINST NF.
C
      CALL INPKIN (X1,Y1,NSIDE,IDENT(6),NEXTID)
      WRITE(6,160)IDENT(6)
  160 FORMAT(35H0DYNAMIC SIDE DATA READ FROM DECK  ,A9,1H.)
      SFRAME=11
      IF((NF*SFRAME).NE.NSIDE)CALL ABORT(2)
      CALL INPKIN(Z1,Y2,NFRONT,IDENT(7),NEXTID)
      WRITE(6,170)IDENT(7)
  170 FORMAT(35H0DYNAMIC FRONT DATA READ FROM DECK ,A9,1H.)
      FFRAME=13
      IF((NF*FFRAME).NE.NFRONT)CALL ABORT(2)
      IF (ABTFL(1).OR.ABTFL(2)) GOTO 890
C
C DETERMINE WHETHER LEFT OR RIGHT, AND SET SIDE-DEPENDENT VALUES AND
C     POINTERS.
C
      FUL=QIDENT(IDENT(6),6,8,IFUL)
      IF(QIDENT(IDENT(2),3,5,LADO2))GOTO 180
      STEP=0.0
      IF (QIDENT(IDENT(6),9,9,1HI))STEP=0.1*BH
C
      LEFSID=.FALSE.
      CONST=432.0
      DK7=D67
      IBIDE=2
      JBIDE=1
      LBIDE=2
      KKA=1
      ISIDE=0
      JSIDE=1
      KA=1
      KB=4
      KC=2
      KSIDE=4
      LSIDE=2
      MSIDE=7
      XCONST=0.000322
      YCONST=0.000292
      XL=8.800
      ZL=5.25
      GOTO 190
C
  180 LEFSID=.TRUE.
      CONST=383.0
      DK7=D78
      IBIDE=5
      JBIDE=10
      LBIDE=9
      KKA=9
      ISIDE=5
      JSIDE=6
      KC=10
      LSIDE=7
      KA=7
      KB=10
      KSIDE=7
      MSIDE=2
      XCONST=-0.000329
      YCONST=0.000332
      XL=8.800
      ZL=-3.95
C
C CALCULATE FIXED PELVIC ANGLE, AND SET CAMERA HEIGHT.
C
  190 ANGS=ATAN(SQRT(4.0*DK7*DK7-D86*D86)/D86)
```

```
      ANGSC=ANGS*57.29577951
      HX=0.86
      HZ=HX
C
      CALL REF(IR(1),IR(2),IR(3),IS(1),IS(2),IS(3),X0,Z0,CD)
      Z0=Z0-CONST
      DO 200 I=4,8
      CALL CHANGE(X0,Z0,CD,IR(I),IS(I),XU,ZU)
      ZUZU(I-3)=ZU*YCONST
      XUXU(I-3)=XU*XCONST
  200 CONTINUE
      ANKLEX=XUXU(1)
      ANKLEY=ZUZU(1)
      AKNEEX=XUXU(2)
      AKNEEY=ZUZU(2)
      DO 210 I=3,5
      II=I+ISIDE-2
      SSSX(II)=XUXU(I)
      SSSY(II)=ZUZU(I)
  210 CONTINUE
C
C . . . AND THE SAME FOR THE FRONT CAMERA.
C
      CALL REF(IIR(1),IIR(2),IIR(3),IIS(1),IIS(2),IIS(3),X0,Z0,CD)
      Z0=Z0-375.0
      DO 220 I=4,13
      CALL CHANGE(X0,Z0,CD,IIR(I),IIS(I),XU,ZU)
      XAXA(I-3)=-XU*0.000322
  220 CONTINUE
      ANKLEZ=XAXA(KKA)
      AKNEEZ=XAXA(KC)
      DO 230 I=1,3
      JJ=I+IBIDE
      J=I+ISIDE
      SSFZ(J)=XAXA(JJ)
  230 CONTINUE
C
C IN THE NEXT STAGE THE FIRST THREE POINTS OF EACH FRAME WILL BE USED
C     TO CORRECT THE COORDINATES FOR RANDOM DISPLACEMENTS OF THE FRAME.
C
C
C
      I1A=1
      I1B=I1A
      DO 250 I=1,NSIDE,SFRAME
      CALL REF(X1(I),X1(I+1),X1(I+2),Y1(I),Y1(I+1),Y1(I+2),X0,Z0,CD)
      Z0=Z0-CONST
      K=I+3
      N=I+SFRAME-1
      DO 240 M=K,N
      CALL CHANGE(X0,Z0,CD,X1(M),Y1(M),XU,ZU)
C
C X1A(M) AND Y1A(M) REPRESENT THE VALUES OF X AND Y BEFORE PARALLAX
C     CORRECTION.
C
C THE NEXT STAGE IS TO CONVERT VANGUARD UNITS TO METRES.
C
      X1A(I1A,I1B)=XU*XCONST
      Y1A(I1A,I1B)=ZU*YCONST
      I1A=I1A+1
      IF(I1A.LT.9)GOTO 240
      I1A=1
      I1B=I1B+1
  240 CONTINUE
  250 CONTINUE
      I1A=1
      I1B=I1A
      DO 270 I=1,NFRONT,FFRAME
      CALL REF(Z1(I),Z1(I+1),Z1(I+2),Y2(I),Y2(I+1),Y2(I+2),X0,Z0,CD)
      Z0=Z0-375.0
      K=I+3
      N=I+FFRAME-1
      DO 260 M=K,N
      CALL CHANGE(X0,Z0,CD,Z1(M),Y2(M),XU,ZU)
C
C Y2 IS NOT USED FURTHER EXCEPT TO PRODUCE THE TABULATED COMPARISONS
C     OF SUBROUTINE CHECKY.   Z1A IS THE VALUE OF Z BEFORE PARALLAX
C     CORRECTION.
C
      Z1A(I1A,I1B)=-XU*0.000322
      Y2A(I1A,I1B)=ZU*0.000322
      I1A=I1A+1
      IF(I1A.LT.11) GOTO 260
      I1A=1
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      I18=I18+1                                                         FIFT2360
  260 CONTINUE                                                          FIFT2370
  270 CONTINUE                                                          FIFT2380
C                                                                       FIFT2390
C IN THE NEXT STEP THE COORDINATES ARE STORED IN THE ARRAYS XIANTES,    FIFT2400
C     YIANTES WITH A COMMON RELATIONSHIP BETWEEN SUBSCRIPTS AND THE     FIFT2410
C     TARGETS ON THE PATIENT.   THE THREE INITIAL GRID POINTS ON EACH   FIFT2420
C     FRAME ARE ELIMINATED.                                             FIFT2430
C                                                                       FIFT2440
      DO 290 K=5,SFRAME                                                 FIFT2450
      DO 280 I=1,NF                                                     FIFT2460
      XIANTES((K-4),I)=XIA((K-2),I)                                     FIFT2470
      YIANTES((K-4),I)=YIA((K-2),I)                                     FIFT2480
  280 CONTINUE                                                          FIFT2490
  290 CONTINUE                                                          FIFT2500
      IF(.NOT.LEFSID)GOTO 320                                           FIFT2510
      DO 310 K=1,4                                                      FIFT2520
      DO 300 I=1,NF                                                     FIFT2530
      XIANTES((K+6),I)=XIANTES(K,I)                                     FIFT2540
      YIANTES((K+6),I)=YIANTES(K,I)                                     FIFT2550
  300 CONTINUE                                                          FIFT2560
  310 CONTINUE                                                          FIFT2570
      CALL CHECKY(YIANTES,10,Y2A,10,NF,KA,KB)                           FIFT2580
C                                                                       FIFT2590
C SUBROUTINES PARALA AND PIRILI CORRECT FOR PARALLAX, RESPECTIVELY FOR  FIFT2600
C     THE KINEMATIC AND STATIC COORDINATES.   XL, ZL AND HX ARE THE     FIFT2610
C     CAMERA DISTANCES (FRONT, SIDE, AND HEIGHT RESPECTIVELY).   IT IS  FIFT2620
C     IMPORTANT TO NOTE THAT FOR THE LEFT CAMERA THE VALUE OF ZL IS     FIFT2630
C     NEGATIVE, TO KEEP THE CORRECT SIGN IN THE EQUATIONS.              FIFT2640
C                                                                       FIFT2650
  320 CALL PARALA(KA,KB,NF)                                             FIFT2660
      CALL CHECKY(Y,11,Y2,10,NF,KA,KB)                                  FIFT2670
      CALL PIRILI(SSSX(ISIDE+1),SSSY(ISIDE+1),SSFZ(ISIDE+1),XL,ZL,HX)   FIFT2680
C                                                                       FIFT2690
C AKNEE(X,Y,Z) AND ANKLE(X,Y,Z) ARE THE CENTRES OF THE JOINTS           FIFT2700
C     TAKEN FROM THE STATIC SHOT.   VLA(X,Y,Z) AND VLK(X,Y,Z) ARE THOSE FIFT2710
C     AFTER PARALLAX CORRECTION.   VLA(J) AND VLK(J) ARE THE VECTORS    FIFT2720
C     FROM MARKER 1 TO THE CENTRE OF THE ANKLE AND KNEE JOINTS.         FIFT2730
C                                                                       FIFT2740
C SURROUTINE POROLO CORRECTS PARALLAX FOR THE JOINT CENTRES.            FIFT2750
C                                                                       FIFT2760
      CALL POROLO(VLAX,VLAY,VLAZ,ANKLEX,ANKLEY,ANKLEZ,ZL,XL,HX)         FIFT2770
      CALL POROLO(VLKX,VLKY,VLKZ,AKNEEX,AKNEEY,AKNEEZ,ZL,XL,HX)         FIFT2780
      VLA(1)=VLAX-SSX(JSIDE)                                            FIFT2790
      VLA(2)=VLAY-SSY(JSIDE)                                            FIFT2800
      VLA(3)=VLAZ-SFZ(JSIDE)                                            FIFT2810
      VLK(1)=VLKX-SSX(JSIDE)                                            FIFT2820
      VLK(2)=VLKY-SSY(JSIDE)                                            FIFT2830
      VLK(3)=VLKZ-SFZ(JSIDE)                                            FIFT2840
C                                                                       FIFT2850
C T IS THE MATRIX WHICH RELATES THE GROUND AND SHANK SYSTEMS.           FIFT2860
C                                                                       FIFT2870
      CALL TSTAT(T)                                                     FIFT2880
C                                                                       FIFT2890
C THE VECTOR TXL DEFINES THE FORWARD DIRECTION OF THE SHANK.            FIFT2900
C                                                                       FIFT2910
      TXL(1)=T(1,1)                                                     FIFT2920
      TXL(2)=T(2,1)                                                     FIFT2930
      TXL(3)=T(3,1)                                                     FIFT2940
C                                                                       FIFT2950
C VLASTAT AND VLKSTAT REPRESENT VLA AND VLK AT STATIC CONFIGURATION     FIFT2960
C     IN THE SHANK SYSTEM.                                              FIFT2970
C                                                                       FIFT2980
      CALL AMULT(T,VLA,VLASTT)                                          FIFT2990
      CALL AMULT(T,VLK,VLKSTT)                                          FIFT3000
C                                                                       FIFT3010
C CALCULATE THE COORDINATES OF THE KNEE AND ANKLE JOINT CENTRES.        FIFT3020
C                                                                       FIFT3030
      DO 340 I=1,NF                                                     FIFT3040
C                                                                       FIFT3050
C THE SUBROUTINE THAT WILL CALCULATE T DYNAMICALLY.                     FIFT3060
C                                                                       FIFT3070
      CALL TMAT(I,T,X,Y,Z)                                              FIFT3080
C                                                                       FIFT3090
C THE ARRAY TD IS T TRANSPOSED (TO THE GROUND SYSTEM).                  FIFT3100
C                                                                       FIFT3110
      DO 330 J=1,3                                                      FIFT3120
      TD(J,J)=T(J,J)                                                    FIFT3130
  330 CONTINUE                                                          FIFT3140
      TD(1,2)=T(2,1)                                                    FIFT3150
      TD(1,3)=T(3,1)                                                    FIFT3160
      TD(2,1)=T(1,2)                                                    FIFT3170
      TD(2,3)=T(3,2)                                                    FIFT3180
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      TD(3,1)=T(1,3)
      TD(3,2)=T(2,3)
      CALL AMULT(TD,TXL,SXL)
      CALL AMULT(TD,VLASTT,VAD)
      CALL AMULT(TD,VLKSTT,EKD)
      AJC(1,I)=VAD(1)+X(JBIDE,I)
      AJC(2,I)=VAD(2)+Y(JBIDE,I)
      AJC(3,I)=VAD(3)+Z(JBIDE,I)
      KJC(1,I)=EKD(1)+X(JBIDE,I)
      KJC(2,I)=EKD(2)+Y(JBIDE,I)
      KJC(3,I)=EKD(3)+Z(JBIDE,I)
      CALL FMAT(I,FT)
C
C CALCULATION OF THE COORDINATES OF THE TAIL MARKER (M).
C
      AQUAD=(X1A(MSIDE,I)**2+(HZ-Y1A(MSIDE,I))**2)/(ZL*ZL)+1.
      BQUAD=2.0*((X1A(MSIDE,I)*(X(KSIDE,I)-X1A(MSIDE,I))+
     1    (Y(KSIDE,I)-Y1A(MSIDE,I))*(Y1A(MSIDE,I)-HZ))/ZL
     2    -Z(KSIDE,I))
      CQUAD=-DK7*DK7+(X(KSIDE,I)-X1A(MSIDE,I))**2+
     1    (Y(KSIDE,I)-Y1A(MSIDE,I))**2+Z(KSIDE,I)**2
C
C NOW CALCULATE THE ROOTS.
C
      CALL ROOTS(RX1,RX2,AQUAD,BQUAD,CQUAD)
C
C X(11,I), Y(11,I), Z(11,I) ARE THE FINAL COORDINATES OF THE
C     TAIL MARKER.
C
      Z(11,I)=RX1
      IF(.NOT.LEFSID)RX1=-RX1
      X(11,I)=X1A(MSIDE,I)+RX1*X1A(MSIDE,I)/ZL
      Y(11,I)=Y1A(MSIDE,I)+RX1*(Y1A(MSIDE,I)-HZ)/ZL
C
C DYNAMIC ANGLES  -  ANGD IS IN RADIANS AND AGDC IS IN DEGREES.
C
      ANGD=ACOS(ABS((Z(KSIDE,I)-Z(11,I))/DK7))
      ANGDC=ANGD*57.29577951
C
 C NOTE THAT TP IS THE PELVIS ROTATION MATRIX.
C
      TP(1,1)=COS(ANGD-ANGS)
      TP(1,2)=0.0
      TP(1,3)=SIN(ANGD-ANGS)
      TP(2,1)=0.0
      TP(2,2)=1.0
      TP(2,3)=0.0
      TP(3,1)=-SIN(ANGD-ANGS)
      TP(3,2)=0.0
      TP(3,3)=COS(ANGD-ANGS)
      CALL AMULT(TP,VH7,VH7C)
C
C MULTIPLY THE VECTOR VH7 BY THE MATRIX TP TO GIVE VH7C, THE VECTOR
C     LOCATING THE HIP JOINT CENTRE FROM THE A.S.I.S. MARKER AT TIME T.
C
      IF(LEFSID)VH7C(3)=-VH7C(3)
      HJC(1,I)=X(KSIDE,I)-VH7C(1)
      HJC(2,I)=Y(KSIDE,I)-VH7C(2)
      HJC(3,I)=Z(KSIDE,I)-VH7C(3)
  340 CONTINUE
      CALL TABLE1(IDENT(6),AJC,KJC,HJC,NF)
C
      IF (LEFSID) GOTO 410
      J=1
      K=2
      YF=0.037+STEP
      CX1=.30
      CZ1=.20
      GOTO 420
  410 J=8
      K=7
      YF=0.037
      CX1=-.30
      CZ1=-.20
  420 CONTINUE
      ND=NF
      NC=61
C
      IF (LEFSID) GOTO 422
      IF (FUL) GOTO 421
      NSYNCH=NEARST(EVNTPT+1.5)-NTO
      GOTO 424
  421 NSYNCH=NEARST(EVNTPT+1.5)-NHS
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      GOTO 424                                                          FIFT4020
  422 IF (FUL) GOTO 423                                                 FIFT4030
      NSYNCH=NEARST(EVNTPT+1.5)-LHS                                     FIFT4040
      GOTO 424                                                          FIFT4050
  423 NSYNCH=NEARST(EVNTPT+1.5)-LTO                                     FIFT4060
  424 CONTINUE                                                          FIFT4070
C                                                                       FIFT4080
      DO 430 I=1,ND                                                     FIFT4090
  430 SHOANG(I)=ATAN2((Y1A(J,I)-HJC(2,I)),(X1A(J,I)-HJC(1,I)))          FIFT4100
      CALL SMOOTH(50HSHOULDER ANGLE SAGITTAL PLANE***                  ,FIFT4110
     1   1,ND,SHOANG(1),1,NC,SHOANG(1),DFUN,DDFUN,0)                    FIFT4120
      DO 440 I=1,NC                                                     FIFT4130
  440 SHOANG(I)=SHOANG(I)*DEGREE                                        FIFT4140
      CALL SMOOTH(50HANKLE JOINT CENTRE X COMPONENT***                 ,FIFT4150
     1   3,ND,AJC(1,1),3,NC,AJC(1,1),ANKVEL(1,1),ANKACC(1,1),0)         FIFT4160
      CALL SMOOTH(50HANKLE JOINT CENTRE Y COMPONENT***                 ,FIFT4170
     1   3,ND,AJC(2,1),3,NC,AJC(2,1),ANKVEL(2,1),ANKACC(2,1),0)         FIFT4180
      CALL SMOOTH(50HANKLE JOINT CENTRE Z COMPONENT***                 ,FIFT4190
     1   3,ND,AJC(3,1),3,NC,AJC(3,1),ANKVEL(3,1),ANKACC(3,1),0)         FIFT4200
C                                                                       FIFT4210
      CALL SMOOTH(50HKNEE JOINT CENTRE X COMPONENT***                  ,FIFT4220
     1   3,ND,KJC(1,1),3,NC,KJC(1,1),KNEVEL(1,1),KNEACC(1,1),0)         FIFT4230
      CALL SMOOTH(50HKNEE JOINT CENTRE Y COMPONENT***                  ,FIFT4240
     1   3,ND,KJC(2,1),3,NC,KJC(2,1),KNEVEL(2,1),KNEACC(2,1),0)         FIFT4250
      CALL SMOOTH(50HKNEE JOINT CENTRE Z COMPONENT***                  ,FIFT4260
     1   3,ND,KJC(3,1),3,NC,KJC(3,1),KNEVEL(3,1),KNEACC(3,1),0)         FIFT4270
C                                                                       FIFT4280
      CALL SMOOTH(50HHIP JOINT CENTRE X COMPONENT***                   ,FIFT4290
     1   3,ND,HJC(1,1),3,NC,HJC(1,1),HIPVEL(1,1),HIPACC(1,1),0)         FIFT4300
      CALL SMOOTH(50HHIP JOINT CENTRE Y COMPONENT***                   ,FIFT4310
     1   3,ND,HJC(2,1),3,NC,HJC(2,1),HIPVEL(2,1),HIPACC(2,1),0)         FIFT4320
      CALL SMOOTH(50HHIP JOINT CENTRE Z COMPONENT***                   ,FIFT4330
     1   3,ND,HJC(3,1),3,NC,HJC(3,1),HIPVEL(3,1),HIPACC(3,1),0)         FIFT4340
      CALL SMOOTH(50HFORCE-PLATE DATA FX***                            ,FIFT4350
     1   1,ND,FHOLD(NSYNCH),1,NC,FHOLD(1),HIPMX(1),HIPMZ(1),10)         FIFT4360
      CALL SMOOTH(50HFORCE-PLATE DATA FY ***                           ,FIFT4370
     1   1,ND,FHOLD(NSYNCH+NFPSET),1,NC,FHOLD(62),HIPMX(1),HIPMZ(1),10) FIFT4380
      CALL SMOOTH(50HFORCE-PLATE DATA FZ ***                           ,FIFT4390
     1   1,ND,FHOLD(NSYNCH+NFPSET*2),1,NC,FHOLD(123),HIPMX(1),HIPMZ(1), FIFT4400
     2   10)                                                            FIFT4410
      CALL SMOOTH(50HFORCE-PLATE DATA MX ***                           ,FIFT4420
     1   1,ND,FHOLD(NSYNCH+NFPSET*3),1,NC,FHOLD(184),HIPMX(1),HIPMZ(1), FIFT4430
     2   10)                                                            FIFT4440
      CALL SMOOTH(50HFORCE-PLATE DATA MY ***                           ,FIFT4450
     1   1,ND,FHOLD(NSYNCH+NFPSET*4),1,NC,FHOLD(245),HIPMX(1),HIPMZ(1), FIFT4460
     2   10)                                                            FIFT4470
      CALL SMOOTH(50HFORCE-PLATE DATA MZ ***                           ,FIFT4480
     1   1,ND,FHOLD(NSYNCH+NFPSET*5),1,NC,FHOLD(306),HIPMX(1),HIPMZ(1), FIFT4490
     2   10)                                                            FIFT4500
      DO 510 I=1,NC                                                     FIFT4510
      HIPANX(I)=ATAN2((KJC(1,I)-HJC(1,I)),(HJC(2,I)-KJC(2,I)))          FIFT4520
      OELHOX(I)=ATAN2((AJC(1,I)-KJC(1,I)),(KJC(2,I)-AJC(2,I)))          FIFT4530
      KNEANX(I)=HIPANX(I)-OELHOX(I)                                     FIFT4540
      HIPANZ(I)=ATAN2((KJC(3,I)-HJC(3,I)),(HJC(2,I)-KJC(2,I)))          FIFT4550
      OELHOZ(I)=ATAN2((AJC(3,I)-KJC(3,I)),(KJC(2,I)-AJC(2,I)))          FIFT4560
      KNEANZ(I)=HIPANZ(I)-OELHOZ(I)                                     FIFT4570
      NZPRNT=0                                                          FIFT4580
      WRITE(6,500)                                                      FIFT4590
      ANGDEG(1)=HIPANX(I)*DEGREE                                        FIFT4600
      ANGDEG(2)=OELHOX(I)*DEGREE                                        FIFT4610
      ANGDEG(3)=KNEANX(I)*DEGREE                                        FIFT4620
      ANGDEG(4)=HIPANZ(I)*DEGREE                                        FIFT4630
      ANGDEG(5)=OELHOZ(I)*DEGREE                                        FIFT4640
      ANGDEG(6)=KNEANZ(I)*DEGREE                                        FIFT4650
      WRITE(6,500)I,(ANGDEG(IAD),IAD=1,6)                               FIFT4660
  500 FORMAT(1H ,I4,10F12.2)                                            FIFT4670
  510 CONTINUE                                                          FIFT4680
C                                                                       FIFT4690
C THE FOOT ANGLE IS MEASURED WITH RESPECT TO THE HORIZONTAL.   IT IS    FIFT4700
C     IMPORTANT TO NOTE THAT THE SHANK ANGLE (WITH RESPECT TO THE       FIFT4710
C     VERTICAL) HAS TO BE ADDED.                                        FIFT4720
C                                                                       FIFT4730
C CALL SUBROUTINE REGR FOR THE FOOT IN ORDER TO PRODUCE THE SAME NUMBER FIFT4740
C     OF OUTPUT VALUES.                                                 FIFT4750
C                                                                       FIFT4760
      DO 520 I=1,NF                                                     FIFT4770
  520 FOTANG(I)=ATAN2((Y1A(J,I)-Y1A(K,I)),(X1A(J,I)-X1A(K,I)))          FIFT4780
      CALL SMOOTH (50HFOOT ANGLE SAGGITAL PLANE***                      FIFT4790
     1,1,ND,FOTANG(1),1,NC,FOTANG(1),FOTVEL(1),FOTACC(1),0)             FIFT4800
      DO 530 I=1,NC                                                     FIFT4810
      FOTANG(I)=OELHOX(I)+HALFPI-FOTANG(I)                              FIFT4820
  530 CONTINUE                                                          FIFT4830
C                                                                       FIFT4840
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C CALCULATION OF THE TRUNK ANGLE.                                       FIFT4850
C                                                                       FIFT4860
C ANTHROPOMETRY.   BM = BODY MASS.  TM = THIGH MASS.  SFM = SHANK AND    FIFT4870
C      FOOT MASS.  THE LIMB SEGMENT MASSES ARE OBTAINED IN PROPORTION   FIFT4880
C      TO BODY MASS.                                                    FIFT4890
C                                                                       FIFT4900
      SFL=BH*.285                                                       FIFT4910
      TL=BH*.530-SFL                                                    FIFT4920
      TGRAVT=.427*TL                                                    FIFT4930
      SGRAVT=.467*SFL                                                   FIFT4940
      TM=.0946*BM                                                       FIFT4950
      SFM=.0590*BM                                                      FIFT4960
C                                                                       FIFT4970
C TK = THIGH RADIUS OF GYRATION.   SFK = RADIUS OF GYRATION FOR THE     FIFT4980
C      SHANK AND FOOT.                                                  FIFT4990
C                                                                       FIFT5000
      TK=.23*TL                                                         FIFT5010
      TINERT=TK*TK*TM                                                   FIFT5020
      SFK=.29*SFL                                                       FIFT5030
      SFINER=SFK*SFK*SFM                                                FIFT5040
      WEIGSF=SFM*9.81                                                   FIFT5050
      WEIGT=TM*9.81                                                     FIFT5060
C                                                                       FIFT5070
C VELOCITY AND ACCELERATION AT THE SHANK CENTRE OF GRAVITY.             FIFT5080
C                                                                       FIFT5090
      DO 600 I=1,NC                                                     FIFT5100
      SVX=ANKVEL(1,I)-KNEVEL(1,I)                                       FIFT5110
      SVY=ANKVEL(2,I)-KNEVEL(2,I)                                       FIFT5120
      SVZ=ANKVEL(3,I)-KNEVEL(3,I)                                       FIFT5130
      SAX=ANKACC(1,I)-KNEACC(1,I)                                       FIFT5140
      SAY=ANKACC(2,I)-KNEACC(2,I)                                       FIFT5150
      SAZ=ANKACC(3,I)-KNEACC(3,I)                                       FIFT5160
      SLONG=1.0/SFL                                                     FIFT5170
      SRATIO=SLONG*SGRAVT                                               FIFT5180
      SCOSX=COS(OELHOX(I))                                              FIFT5190
      SCOSZ=COS(OELHOZ(I))                                              FIFT5200
      SSENX=SIN(OELHOX(I))                                              FIFT5210
      SSENZ=SIN(OELHOZ(I))                                              FIFT5220
      XCOMS=SGRAVT*SSENX                                                FIFT5230
      YCOMS=SGRAVT*SCOSX                                                FIFT5240
      ZCOMS=SGRAVT*SSENZ                                                FIFT5250
      XCGSHA(I)=KJC(1,I)+XCOMS                                          FIFT5260
      YCGSHA(I)=KJC(2,I)-YCOMS                                          FIFT5270
      ZCGSHA(I)=KJC(3,I)+ZCOMS                                          FIFT5280
      STVX=SVX*SCOSX                                                    FIFT5290
      STVY=SVY*SSENX                                                    FIFT5300
      STVZ=SVZ*SCOSZ                                                    FIFT5310
      STVYZ=SVY*SSENZ                                                   FIFT5320
      STVINX=STVX+STVY                                                  FIFT5330
      STVINZ=STVZ+STVYZ                                                 FIFT5340
      SOMEGX(I)=STVINX*SLONG                                            FIFT5350
      SOMEGZ(I)=STVINZ*SLONG                                            FIFT5360
      SACCX=SAX*SCOSX                                                   FIFT5370
      SACCY=SAY*SSENX                                                   FIFT5380
      SACCZ=SAZ*SCOSZ                                                   FIFT5390
      SACCYZ=SAY*SSENZ                                                  FIFT5400
      SACINX=SACCX+SACCY                                                FIFT5410
      SACINZ=SACCZ+SACCYZ                                               FIFT5420
      SALFAX(I)=SACINX*SLONG                                            FIFT5430
      SALFAZ(I)=SACINZ*SLONG                                            FIFT5440
      SXGDD(I)=KNEACC(1,I)+SRATIO*SAX                                   FIFT5450
      SYGDD(I)=KNEACC(2,I)+SRATIO*SAY                                   FIFT5460
      SZGDD(I)=KNEACC(3,I)+SRATIO*SAZ                                   FIFT5470
      TVX=KNEVEL(1,I)-HIPVEL(1,I)                                       FIFT5480
      TVY=KNEVEL(2,I)-HIPVEL(2,I)                                       FIFT5490
      TVZ=KNEVEL(3,I)-HIPVEL(3,I)                                       FIFT5500
      TAX=KNEACC(1,I)-HIPACC(1,I)                                       FIFT5510
      TAY=KNEACC(2,I)-HIPACC(2,I)                                       FIFT5520
      TAZ=KNEACC(3,I)-HIPACC(3,I)                                       FIFT5530
      TLONG=1.0/TL                                                      FIFT5540
      TRATIO=TLONG*TGRAVT                                               FIFT5550
      TCOSX=COS(HIPANX(I))                                              FIFT5560
      TCOSZ=COS(HIPANZ(I))                                              FIFT5570
      TSENX=SIN(HIPANX(I))                                              FIFT5580
      TSENZ=SIN(HIPANZ(I))                                              FIFT5590
      XCOMT=TGRAVT*TSENX                                                FIFT5600
      YCOMT=TGRAVT*TCOSX                                                FIFT5610
      ZCOMT=TGRAVT*TSENZ                                                FIFT5620
      XCGTHI(I)=HJC(1,I)+XCOMT                                          FIFT5630
      YCGTHI(I)=HJC(2,I)-YCOMT                                          FIFT5640
      ZCGTHI(I)=HJC(3,I)+ZCOMT                                          FIFT5650
      TTVX=TVX*TCOSX                                                    FIFT5660
      TTVY=TVY*TSENX                                                    FIFT5670
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      TTVZ=TVZ*TCOSZ                                                    FIFT5680
      TTVYZ=TVY*TSENZ                                                   FIFT5690
      TTVINX=TTVX+TTVY                                                  FIFT5700
      TTVINZ=TTVZ+TTVYZ                                                 FIFT5710
      TOMEGX(I)=TTVINX*TLONG                                            FIFT5720
      TOMEGZ(I)=TTVINZ*TLONG                                            FIFT5730
      TACCX=TAX*TCOSX                                                   FIFT5740
      TACCY=TAY*TSENX                                                   FIFT5750
      TACCZ=TAZ*TCOSZ                                                   FIFT5760
      TACCYZ=TAY*TSENZ                                                  FIFT5770
      TACINX=TACCX+TACCY                                                FIFT5780
      TACINZ=TACCZ+TACCYZ                                               FIFT5790
      TALFAX(I)=TACINX*TLONG                                            FIFT5800
      TALFAZ(I)=TACINZ*TLONG                                            FIFT5810
      TXGDD(I)=HIPACC(1,I)+TRATIO*TAX                                   FIFT5820
      TYGDD(I)=HIPACC(2,I)+TRATIO*TAY                                   FIFT5830
      TZGDD(I)=HIPACC(3,I)+TRATIO*TAZ                                   FIFT5840
  600 CONTINUE                                                          FIFT5850
      ANF=NF                                                            FIFT5860
      RHS=NHS                                                           FIFT5870
      RTO=NTO                                                           FIFT5880
      ALHS=LHS                                                          FIFT5890
      ALTO=LTO                                                          FIFT5900
      SA=1./(ANF-1.)                                                    FIFT5910
      NHS=INT(1.5+60.*(RHS-1.5)*SA)                                     FIFT5920
      NTO=INT(1.5+60.*(RTO-1.5)*SA)                                     FIFT5930
      LHS=INT(1.5+60.*(ALHS-1.5)*SA)                                    FIFT5940
      LTO=INT(1.5+60.*(ALTO-1.5)*SA)                                    FIFT5950
      DO 700 I=1,NC                                                     FIFT5960
      XPROV=(MZ(I)+FX(I)*YF)/FY(I)                                      FIFT5970
      ZPROV=(FZ(I)*YF-MX(I))/FY(I)                                      FIFT5980
      XEST(I)=XPROV+CX1                                                 FIFT5990
      ZEST(I)=ZPROV+CZ1                                                 FIFT6000
  700 CONTINUE                                                          FIFT6010
      DO 710 I=1,NC                                                     FIFT6020
      TOT060(I)=FLOAT(I-1)                                              FIFT6030
      EMNEEX(I)=SFINER*SALFAX(I)                                        FIFT6040
      EMNEEZ(I)=SFINER*SALFAZ(I)                                        FIFT6050
      EMHIPX(I)=TINERT*TALFAX(I)                                        FIFT6060
      EMHIPZ(I)=TINERT*TALFAZ(I)                                        FIFT6070
  710 CONTINUE                                                          FIFT6080
      DO 770 I=1,NC                                                     FIFT6090
C                                                                       FIFT6100
C I IS THE NUMBER OF FRAMES FOR THE STANCE PHASE (FORCE PLATE).         FIFT6110
C                                                                       FIFT6120
      IF (LEFSID) GOTO 730                                              FIFT6130
      IF (FUL) GOTO 720                                                 FIFT6140
      IF (I.LE.NHS) GOTO 740                                            FIFT6150
      GOTO 750                                                          FIFT6160
  720 IF (I.GE.NHS) GOTO 740                                            FIFT6170
      GOTO 750                                                          FIFT6180
  730 IF (FUL) GOTO 734                                                 FIFT6190
      IF (I.GE.LHS) GOTO 740                                            FIFT6200
      GOTO 750                                                          FIFT6210
  734 IF (I.GE.LTO) GOTO 750                                            FIFT6220
C                                                                       FIFT6230
C ANKLE MOMENTS.                                                        FIFT6240
C                                                                       FIFT6250
  740 CONTINUE                                                          FIFT6260
      E=FY(I)*(XEST(I)-AJC(1,I))                                        FIFT6270
      EE=FY(I)*(ZEST(I)-AJC(3,I))                                       FIFT6280
      ANKMOZ(I)=FX(I)*AJC(2,I)+E                                        FIFT6290
      ANKMOX(I)=FZ(I)*AJC(2,I)+EE                                       FIFT6300
      TOA(I)=FX(I)*(AJC(3,I)-ZEST(I))+FZ(I)*(AJC(1,I)-XEST(I))+         FIFT6310
     1   MY(I)                                                          FIFT6320
C                                                                       FIFT6330
C KNEE MOMENTS.                                                         FIFT6340
C                                                                       FIFT6350
      FXK(I)=FX(I)+SFM*SXGDD(I)                                         FIFT6360
      FYK(I)=WEIGSF+FY(I)+SFM*SYGDD(I)                                  FIFT6370
      FZK(I)=FZ(I)+SFM*SZGDD(I)                                         FIFT6380
      BB=FZ(I)*(AJC(2,I)-YCGSHA(I))                                     FIFT6390
      BBBB=FY(I)*(ZCGSHA(I)-AJC(1,I))                                   FIFT6400
      AA=FX(I)*(AJC(2,I)-YCGSHA(I))                                     FIFT6410
      AAAA=FY(I)*(XCGSHA(I)-AJC(1,I))                                   FIFT6420
      GOTO760                                                           FIFT6430
  750 E=0.0                                                             FIFT6440
      EE=0.0                                                            FIFT6450
      ANKMOZ(I)=0.0                                                     FIFT6460
      ANKMOX(I)=0.0                                                     FIFT6470
      TOA(I)=0.0                                                        FIFT6480
      FXK(I)=SFM*SXGDD(I)                                               FIFT6490
      FYK(I)=WEIGSF+SFM*SYGDD(I)                                        FIFT6500
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      FZK(I)=SFM*SZGDD(I)                                               FIFT6510
      BB=0.0                                                            FIFT6520
      BBBB=0.0                                                          FIFT6530
      AA=0.0                                                            FIFT6540
      AAAA=0.0                                                          FIFT6550
  760 CONTINUE                                                          FIFT6560
      A=FXK(I)*(YCGSHA(I)-KJC(2,I))                                     FIFT6570
      AAA=FYK(I)*(KJC(1,I)-XCGSHA(I))                                   FIFT6580
      KNEEMZ(I)=ANKMOZ(I)+EMNEEX(I)+A+AA+AAA+AAAA                       FIFT6590
      B=FZK(I)*(YCGSHA(I)-KJC(2,I))                                     FIFT6600
      BBB=FYK(I)*(KJC(1,I)-ZCGSHA(I))                                   FIFT6610
      KNEEMX(I)=ANKMOX(I)+EMNEEZ(I)+B+BB+BBB+BBBB                       FIFT6620
C                                                                       FIFT6630
C HIP MOMENTS.                                                          FIFT6640
C                                                                       FIFT6650
      FXH(I)=FXK(I)+TM*TXGDD(I)                                         FIFT6660
      FYH(I)= FYK(I)+WEIGT  +TM*TYGDD(I)                                FIFT6670
      FZH(I)=FZK(I)+TM*TZGDD(I)                                         FIFT6680
      C=FXH(I)*(YCGTHI(I)-HJC(2,I))                                     FIFT6690
      CC=FYH(I)*(HJC(1,I)-XCGTHI(I))                                    FIFT6700
      CCC=FXK(I)*(KJC(2,I)-YCGTHI(I))                                   FIFT6710
      CCCC=FYK(I)*(XCGTHI(I)-KJC(1,I))                                  FIFT6720
      HIPMZ(I)=KNEEMZ(I)+EMHIPX(I)+C+CC+CCC+CCCC                        FIFT6730
      D=FZH(I)*(YCGTHI(I)-HJC(2,I))                                     FIFT6740
      DD=FYH(I)*(HJC(3,I)-ZCGTHI(I))                                    FIFT6750
      DDD=FZK(I)*(KJC(2,I)-YCGTHI(I))                                   FIFT6760
      DDDD=FYK(I)*(ZCGTHI(I)-KJC(3,I))                                  FIFT6770
      HIPMX(I)=KNEEMX(I)+EMHIPZ(I)+D+DD+DDD+DDDD                        FIFT6780
C                                                                       FIFT6790
C KNEE.                                                                 FIFT6800
C                                                                       FIFT6810
      TQK(I)=TQA(I)+FZK(I)*(XCGSHA(I)-KJC(1,I))+FZ(I)*(AJC(1,I)         FIFT6820
     1   -XCGSHA(I))+FXK(I)*(KJC(3,I)- ZCGSHA(I))+FX(I)*(ZCGSHA(I)      FIFT6830
     2   -AJC(3,I))                                                     FIFT6840
C                                                                       FIFT6850
C HIP.                                                                  FIFT6860
C                                                                       FIFT6870
      TQH(I)=TOK(I)+FZH(I)*(XCGTHI(I)-HJC(1,I))+FZK(I)*(KJC(1,I)        FIFT6880
     1   -XCGTHI(I))+FXH(I)*(HJC(3,I)-ZCGTHI(I))+FXK(I)*(ZCGTHI(I)      FIFT6890
     2   -KJC(3,I))                                                     FIFT6900
      HIPANX(I)=HIPANX(I)*DEGREE                                        FIFT6910
      KNEANX(I)=KNEANX(I)*DEGREE                                        FIFT6920
      SOMEGX(I)=SOMEGX(I)*DEGREE                                        FIFT6930
      TOMEGX(I)=TOMEGX(I)*DEGREE                                        FIFT6940
      FOTANG(I)=FOTANG(I)*DEGREE                                        FIFT6950
      WRITE (6,500)                                                     FIFT6960
      WRITE (6,500)NZPRNT,ANKMOZ(I),ANKMOX(I),KNEEMZ(I),KNEEMX(I),      FIFT6970
     1   HIPMZ(I),HIPMX(I),TQA(I),TOK(I),TQH(I)                         FIFT6980
  770 CONTINUE                                                          FIFT6990
      DO 780 I=1,NC                                                     FIFT7000
  780 WRITE(6,500)I,FOTANG(I)                                           FIFT7010
      CALL GRPTTT(IDENT(6),40HANKLE,KNEE, HIP. CORONAL PLANE          , FIFT7020
     1   20HTIME SEQUENCE FRAMES,20H MOMENTS IN NM      ,61,TOT060,     FIFT7030
     2   10HANKLE     ,1,ANKMOX(1),                                     FIFT7040
     3   10HKNEE      ,1,KNEEMX(1),                                     FIFT7050
     4   10HHIP       ,1,HIPMX(1),                                      FIFT7060
     5   LHS,LTO,NHS,NTO,0.0,61.0,-500.0,500.0)                         FIFT7070
      CALL GRPTTT(IDENT(6),40HANKLE, KNEE, HIP. TRANSVERSE PLANE      , FIFT7080
     1   20HTIME SEQUENCE-FRAMES,20H MOMENTS IN NM      ,61,TOT060,     FIFT7090
     2   10HANKLE     ,1,TQA(1),                                        FIFT7100
     3   10HKNEE      ,1,TQK(1),                                        FIFT7110
     4   10HHIP       ,1,TQH(1),                                        FIFT7120
     5   LHS,LTO,NHS,NTO,0.0,61.0,-100.0,100.0)                         FIFT7130
      CALL GRPHDT(IDENT(6),40HHIP ANGLE X KNEE ANGLE. SAGITTAL PLANE  , FIFT7140
     1   20H HIP ANGLE          ,20H KNEE ANGLE         ,61,            FIFT7150
     2   HIPANX(1),1,KNEANX(1),LHS,LTO,NHS,NTO,-35.,120.,-15.,120.)     FIFT7160
      CALL GRPHDT(IDENT(6),40H HIP ANGULAR VELOCITY, SAGITTAL PLANE   , FIFT7170
     1   20H TIME               ,20H HIP-VEL. DEG/SEC.  ,61,TOT060,     FIFT7180
     2   1,TOMEGX(1),LHS,LTO,NHS,NTO,0.,61.,-500.0,500.0)               FIFT7190
      CALL GRPHDT(IDENT(6),40HKNEE ANGLE X KNEE ANG-VEL. SAGITTAL PLA., FIFT7200
     1   20H KNEE ANGLE         ,20HANG-VEL DEG/SEC.    ,61,KNEANX(1),  FIFT7210
     2   1,SOMEGX(1),LHS,LTO,NHS,NTO,-20.,120.,-500.0,500.0)            FIFT7220
      CALL GRPHDT(IDENT(6),40HKNEE ANGLE X KNEE MOMENTS. SAGIT. PLANE , FIFT7230
     1   20H ANGLES/DEG.        ,20H MOMENTS IN NM      ,61,KNEANX(1),  FIFT7240
     2   1,KNEEMZ(1),LHS,LTO,NHS,NTO,-20.,120.,-500.,500.)              FIFT7250
      CALL GRPHDT(IDENT(6),40HKNEE ANG. VELOC.  - SAGITTAL PLANE      , FIFT7260
     1   20HTIME SEQUENCE-FRAMES,20HKNEE-VEL. DEG/SEC.  ,61,TOT060,     FIFT7270
     2   1,SOMEGX(1),LHS,LTO,NHS,NTO,0.,61.,-500.0,500.0)               FIFT7280
C                                                                       FIFT7290
      CALL GRPTTT(IDENT(6),40HANKLE, KNEE, HIP. DISPLACEMENTS         , FIFT7300
     1   20HTIME SEQUENCE-FRAMES,20H Y COORDINATE-METERS,61,TOT060,     FIFT7310
     2   10HANKLE     ,3,AJC(2,1),                                      FIFT7320
     3   10HKNEE      ,3,KJC(2,1),                                      FIFT7330
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     4   10HHIP       ,3,HJC(2,1),                                       FIFT7340
     5   LHS,LTO,NHS,NTO,0.0,61.0,0.0,1.2)                               FIFT7350
C                                                                        FIFT7360
      CALL GRPTTT(IDENT(6),40HANKLE, KNEE, HIP. ANGLES-SAGITTAL PLANE ,  FIFT7370
     1   20HTIME SEQUENCE-FRAMES,20H DEGREES            ,61,TOT060,      FIFT7380
     2   10HANKLE     ,1,FOTANG(1),                                      FIFT7390
     3   10HKNEE      ,1,KNEANX(1),                                      FIFT7400
     4   10HHIP       ,1,HIPANX(1),                                      FIFT7410
     5   LHS,LTO,NHS,NTO,0.0,61.0,-60.0,140.0)                           FIFT7420
C                                                                        FIFT7430
      CALL GRPTTT(IDENT(6),40HANKLE, KNEE, HIP. SAGITTAL PLANE         , FIFT7440
     1   20HTIME SEQUENCE FRAMES,20HMOMENTS IN NM       ,61,TOT060,      FIFT7450
     2   10HANKLE     ,1,ANKMOZ(1),                                      FIFT7460
     3   10HKNEE      ,1,KNEEMZ(1),                                      FIFT7470
     4   10HHIP       ,1,HIPMZ(1),                                       FIFT7480
     5   LHS,LTO,NHS,NTO,0.0,61.0,-500.0,500.0)                          FIFT7490
C                                                                        FIFT7500
C MANOEUVRE COMPLETE.   PROCEED TO NEXT ONE (IF ANY).                    FIFT7510
C                                                                        FIFT7520
  890 IF(NEXTID.EQ.0)STOP                                                FIFT7530
      IF(NEWMAN(IDENT(2),NEXTID))GOTO 100                                FIFT7540
      WRITE(6,900)IDENT(1)                                               FIFT7550
  900 FORMAT(35H1PATIENT CONSTANTS RETAINED FROM    ,A9,1H.)             FIFT7560
      WRITE(6,910)IDENT(2)                                               FIFT7570
  910 FORMAT(35H0STATIC SIDE DATA RETAINED FROM     ,A9,1H.)             FIFT7580
      WRITE(6,920)IDENT(3)                                               FIFT7590
  920 FORMAT(35H0STATIC FRONT DATA RETAINED FROM    ,A9,1H.)             FIFT7600
      GOTO 140                                                           FIFT7610
      END                                                                FIFT7620


      SUBROUTINE ABORT(N)                                                ABORT 10
C                                                                        ABORT 20
C PROCESSES ERROR CALLS AND SETS ABORT FLAG IF N.EQ.1 OR N.EQ.2.         ABORT 30
C                                                                        ABORT 40
      COMMON /ABTFLG/ ABTFL(2)                                           ABORT 50
      LOGICAL ABTFL                                                      ABORT 60
      WRITE (6,100)                                                      ABORT 70
  100 FORMAT (36H0ABORT ROUTINE CALLED WITH PARAMETER)                   ABORT 80
      WRITE (6,110) N                                                    ABORT 90
  110 FORMAT (1H+,35X,I3)                                                ABORT100
      IF ((N.NE.1).AND.(N.NE.2)) CALL CRASH                              ABORT110
      ABTFL(N)=.TRUE.                                                    ABORT120
      RETURN                                                             ABORT130
      END                                                                ABORT140


      FUNCTION ALGAMA(A)                                                 ALGAMA10
C                                                                        ALGAMA20
C LOG.GAMMA FUNCTION, FROM MANOVA.                                       ALGAMA30
C                                                                        ALGAMA40
      W=A                                                                ALGAMA50
      TEMP=0.                                                            ALGAMA60
      IF(W-13.) 100,100,120                                              ALGAMA70
  100 N=14.-W                                                            ALGAMA80
      TEMP=1.                                                            ALGAMA90
      DO 110 I=1,N                                                       ALGAM100
      TEMP=TEMP*W                                                        ALGAM110
  110 W=W+1.                                                             ALGAM120
      TEMP=ALOG(TEMP)                                                    ALGAM130
  120 W2=W*W                                                             ALGAM140
      ALGAMA=(.833333333333333E-01-(.277777777777777E-02-.793650793      ALGAM150
     1   E-03/W2)/W2)/W+.918938533-W+(W-.5)*ALOG(W)-TEMP                 ALGAM160
      RETURN                                                             ALGAM170
      END                                                                ALGAM180


      SUBROUTINE AMULT(A,B,C)                                            AMULT 10
C                                                                        AMULT 20
C     C(3*1) = A(3*3) * B(3*1)                                           AMULT 30
C                                                                        AMULT 40
C     B(J)=VECTOR FROM MARKER 1 TO KNEE(OR ANKLE)                        AMULT 50
C     A(IJ)=IS THE MATRIX WHICH RELATES SHANK AND GROUND SYSTEMS         AMULT 60
C     C(I)=IS THE VECTOR FROM MARKER 1 TO THE CENTRE OF THE JOINTS       AMULT 70
C     IN THE MOUVING SYSTEM                                              AMULT 80
C                                                                        AMULT 90
      DIMENSION A(3,3),B(3),C(3)                                         AMULT100
      DO 110 I=1,3                                                       AMULT110
      C(I)=0.0                                                           AMULT120
      DO 100 J=1,3                                                       AMULT130
      C(I)=C(I)+A(I,J)*B(J)                                              AMULT140
  100 CONTINUE                                                           AMULT150
  110 CONTINUE                                                           AMULT160
```

```
      RETURN
      END


      SUBROUTINE CALFPD(X,NSETS,IDENT,NPNTS)
C
C CONVERTS FORCE-PLATE DATA, READ AS VOLTAGES BY INPFPD, INTO FORCES
C     OR MOMENTS IN S.I.UNITS.   THE PARAMETERS CORRESPOND TO THOSE OF
C     INPFPD.   EACH INPUT VALUE IS MULTIPLIED BY A FACTOR MADE UP AS
C     FOLLOWS.
C
C IN THE CASE OF THE FIRST FORCE-PLATE  -
C
C          FOR FORCE  FX1 THE FACTOR IS  1. * 10. *  20. * H / 512.
C                     FY1                1. * 10. * 100. * H / 512.
C                     FZ1               -1. *  5. *  20. * H / 512.
C                     MX1                1. *  8. * 100. * H * .264/512.
C                     MY1                1. *  5. *  20. * H * .264/512.
C                     MZ1               -1. *  8. * 100. * H * .264/512.
C
C FOR THE SECOND FORCE-PLATE ONLY THE FIRST (SIGN) TERM DIFFERS, AND
C     FOLLOWS THE PATTERN  -1.  1.  1.  -1.  1.  1.  READING DOWNWARDS.
C
C FOR CONTROL SUBJECTS H HAS THE VALUE 2.5, AND FOR CLINICAL CASES IT
C     IS 1.0.
C
      DIMENSION FBASIC(6),FACTOR(6),X(NPNTS)
      INTEGER FP2,P
      LOGICAL QIDENT
      DATA FBASIC(1) / 0.3906250 /
      DATA FBASIC(2) / 1.9531250 /
      DATA FBASIC(3) / 0.1953125 /
      DATA FBASIC(4) / 0.4125000 /
      DATA FBASIC(5) / 0.0515625 /
      DATA FBASIC(6) / 0.4125000 /
      DATA FP2 / 3HFP2 /
      DATA P   / 1HP   /
C
      DO 100 J=1,6
      FACTOR(J)=FBASIC(J)
  100 CONTINUE
      NFP=3
      IF (QIDENT(IDENT,3,5,FP2)) NFP=1
      FACTOR(NFP)=-FACTOR(NFP)
      FACTOR(NFP+3)=-FACTOR(NFP+3)
      IF (QIDENT(IDENT,1,1,P)) GOTO 120
      DO 110 J=1,6
      FACTOR(J)=2.5*FACTOR(J)
  110 CONTINUE
  120 JFIRST=1
      JLAST=NSETS
      DO 140 K=1,6
      DO 130 J=JFIRST,JLAST
      X(J)=X(J)*FACTOR(K)
  130 CONTINUE
      JFIRST=JFIRST+NSETS
      JLAST=JLAST+NSETS
  140 CONTINUE
      RETURN
      END


      SUBROUTINE CHANGE(X0,Z0,CD,X,Z,XU,ZU)
      SD=SIN(CD)
      CO=COS(CD)
      XU=(X-X0)*CO+(Z-Z0)*SD
      ZU=-(X-X0)*SD+(Z-Z0)*CO
      RETURN
      END


      SUBROUTINE CHECKY(Y1,NSUBY1,Y2,NSUBY2,NF,NTARG1,NTARG2)
C
      DIMENSION IDIFF(13),Y1(NSUBY1,NF),Y2(NSUBY2,NF)
      DATA IBLANK / 1H  /
C
      WRITE (6,100) (IBLANK,J,J=NTARG1,NTARG2)
  100 FORMAT (6H1FRAME,A1,5(13H   ** TARGET ,I2,3H **,A1,3X))
      WRITE (6,110) (IBLANK,J=NTARG1,NTARG2)
  110 FORMAT (5H  NO.,5(A1,21H    Y1      Y2   DIFF ))
      DO 150 J=1,NF
      IF (MOD(J,5).EQ.1) WRITE(6,120)
  120 FORMAT (1H )
```

```
      DO 130 K=NTARG1,NTARG2                                            CHCKY130
      IDIFF(K)=NEARST(1000.0*(Y2(K,J)-Y1(K,J)))                         CHCKY140
  130 CONTINUE                                                          CHCKY150
      WRITE (6,140) J,(Y1(K,J),Y2(K,J),IDIFF(K),K=NTARG1,NTARG2)        CHCKY160
  140 FORMAT (1H ,I4,5(F8.3,F7.3,I6,1X))                                CHCKY170
  150 CONTINUE                                                          CHCKY180
C     IF (NSUBY1.EQ.11) CALL CRASH                                      CHCKY190
      RETURN                                                            CHCKY200
      END                                                               CHCKY210


      SUBROUTINE FMAT(I,T)                                              FMAT  10
      DIMENSION T(3,3)                                                  FMAT  20
      COMMON /BLOCK2/ AJC(3,125),KJC(3,125),SXL(3)                      FMAT  30
      REAL KJC                                                          FMAT  40
      VKMX=KJC(1,I)-AJC(1,I)                                            FMAT  50
      VKMY=KJC(2,I)-AJC(2,I)                                            FMAT  60
      VKMZ=KJC(3,I)-AJC(3,I)                                            FMAT  70
      VLKX=SXL(1)                                                       FMAT  80
      VLKY=SXL(2)                                                       FMAT  90
      VLKZ=SXL(3)                                                       FMAT 100
      S=-(VKMX*VLKX+VKMY*VLKY+VKMZ*VLKZ)/(VKMX*VKMX+VKMY*VKMY+VKMZ*VKMZ)FMAT 110
      CL1=+VLKX+S*VKMX                                                  FMAT 120
      CM1=+VLKY+S*VKMY                                                  FMAT 130
      CN1=+VLKZ+S*VKMZ                                                  FMAT 140
      CL=SQRT(CL1*CL1+CM1*CM1+CN1*CN1)                                  FMAT 150
      T(1,1)=CL1/CL                                                     FMAT 160
      T(1,2)=CM1/CL                                                     FMAT 170
      T(1,3)=CN1/CL                                                     FMAT 180
      CM=SQRT(VKMX*VKMX+VKMY*VKMY+VKMZ*VKMZ)                            FMAT 190
      T(2,1)=VKMX/CM                                                    FMAT 200
      T(2,2)=VKMY/CM                                                    FMAT 210
      T(2,3)=VKMZ/CM                                                    FMAT 220
      T(3,1)=T(1,2)*T(2,3)-T(1,3)*T(2,2)                                FMAT 230
      T(3,2)=T(1,3)*T(2,1)-T(1,1)*T(2,3)                                FMAT 240
      T(3,3)=T(1,1)*T(2,2)-T(1,2)*T(2,1)                                FMAT 250
      RETURN                                                            FMAT 260
      END                                                               FMAT 270


      FUNCTION FPROB (F,NU1,NU2)                                        FPROB 10
C                                                                       FPROB 20
C PROBABILITY FOR A GIVEN VARIANCE RATIO, ADAPTED FROM MANOVA.          FPROB 30
C     D.G.PEACOCK, THE SCHOOL OF PHARMACY, 10.NOVEMBER 1970.            FPROB 40
C                                                                       FPROB 50
C     INPUT PARAMETERS -                                                FPROB 60
C        F    =  RATIO OF VARIANCES.   MUST BE .GT. 1.,                 FPROB 70
C        NU1  =  DEGREES OF FREEDOM FOR NUMERATOR (LARGER) VARIANCE, AND FPROB 80
C        NU2  =  DEGREES OF FREEDOM FOR DENOMINATOR (SMALLER) VARIANCE.  FPROB 90
C                                                                       FPROB100
C     OUTPUT VALUE -  CORRESPONDING PROBABILITY, OF SO LARGE A VALUE OF FPROB110
C        F ARISING BY CHANCE SELECTION FROM A COMMON POPULATION.        FPROB120
C                                                                       FPROB130
C     SUBROUTINE USED -  ALGAMA.                                        FPROB140
C                                                                       FPROB150
C     USABLE WITH FUNCTION VALUE.                                       FPROB160
C                                                                       FPROB170
C     EXAMPLE -  FPROB (29.50, 3, 3) = 0.0100                           FPROB180
C                                                                       FPROB190
      IF (NU1.LT.0) GOTO 160                                            FPROB200
      A=0.5*FLOAT(NU1)                                                  FPROB210
      B=0.5*FLOAT(NU2)                                                  FPROB220
      TEMP=B+A*F                                                        FPROB230
      X=A*F/TEMP                                                        FPROB240
      IF(F .GT. 0. .AND. X .GT. 0.) GO TO 100                           FPROB250
      FPROB = 1.0                                                       FPROB260
      GO TO 150                                                         FPROB270
  100 XC=B/TEMP                                                         FPROB280
      AB=A+B                                                            FPROB290
      CON=0.                                                            FPROB300
      SGN=+1.                                                           FPROB310
      IF(F-1.) 110,120,120                                              FPROB320
  110 TEMP=A                                                            FPROB330
      A=B                                                               FPROB340
      B=TEMP                                                            FPROB350
      TEMP=XC                                                           FPROB360
      XC=X                                                              FPROB370
      X=TEMP                                                            FPROB380
      CON=1.                                                            FPROB390
      SGN=-1.                                                           FPROB400
  120 TOP=AB                                                            FPROB410
      BOT=B+1.                                                          FPROB420
      SUM=1.                                                            FPROB430
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      TERM=1.                                                           FPROB440
  130 TEMP=SUM                                                          FPROB450
      TERM=TERM*(TOP/BOT)*XC                                            FPROB460
      SUM=SUM+TERM                                                      FPROB470
      TOP=TOP+1.                                                        FPROB480
      BOT=BOT+1.                                                        FPROB490
      IF(SUM-TEMP) 140,140,130                                          FPROB500
  140 FPROB=ABS(CON+SGN*EXP(A*ALOG(X)+B*ALOG(XC)+ALGAMA(AB)-ALGAMA(A)   FPROB510
     1   -ALGAMA(B))*SUM/B)                                             FPROB520
  150 RETURN                                                            FPROB530
  160 F=1.000001                                                        FPROB540
      FPROB=1000000.                                                    FPROB550
      RETURN                                                            FPROB560
      END                                                               FPROB570


      SUBROUTINE GRPHOT(IDENT,LABEL,XLABEL,YLABEL,NPNTS,X,NSUB1Y,Y,LHS,  GPH1T 10
     1   LTO,NHS,NTO,XMIN,XMAX,YMIN,YMAX)                               GPH1T 20
      INTEGER XLABEL,YLABEL                                             GPH1T 30
      INTEGER YALAB                                                     GPH1T 40
      DIMENSION LABEL(4),XLABEL(2),YLABEL(2),X(NPNTS),Y(NSUB1Y,NPNTS)   GPH1T 50
      DATA NOY / 1 /                                                    GPH1T 60
      DATA YALAB / 10H NO LABEL  /                                      GPH1T 70
      WRITE (8,100) IDENT,LABEL                                         GPH1T 80
  100 FORMAT (5A10)                                                     GPH1T 90
      WRITE (8,110) XLABEL,YLABEL                                       GPH1T100
  110 FORMAT (2A10,10X,2A10)                                            GPH1T110
      WRITE (8,120) NPNTS,NOY                                           GPH1T120
  120 FORMAT (2I5)                                                      GPH1T130
      WRITE (8,130) LHS,LTO,NHS,NTO                                     GPH1T140
  130 FORMAT (4I5)                                                      GPH1T150
      WRITE (8,140) XMIN,XMAX,YMIN,YMAX                                 GPH1T160
  140 FORMAT (4E15.6)                                                   GPH1T170
      WRITE (8,150) (X(J),J=1,NPNTS)                                    GPH1T180
      WRITE (8,160) YALAB                                               GPH1T190
  150 FORMAT (5E15.6)                                                   GPH1T200
  160 FORMAT (1A10)                                                     GPH1T210
      WRITE (8,150) (Y(1,J),J=1,NPNTS)                                  GPH1T220
      RETURN                                                            GPH1T230
      END                                                               GPH1T240


      SUBROUTINE GRPTTT(IDENT,LABEL,XLABEL,YLABEL,NPNTS,X,YALAB,NSUB1A,  GPH3T 10
     1    YA,YBLAB,NSUB1B,YB,YCLAB,NSUB1C,YC,LHS,LTO,NHS,NTO,           GPH3T 20
     2    XMIN,XMAX,YMIN,YMAX)                                          GPH3T 30
      INTEGER XLABEL,YLABEL                                             GPH3T 40
      INTEGER YALAB,YBLAB,YCLAB                                         GPH3T 50
      DIMENSION LABEL(4),XLABEL(2),YLABEL(2),X(NPNTS),YA(NSUB1A,NPNTS)  GPH3T 60
      DIMENSION YB(NSUB1B,NPNTS),YC(NSUB1C,NPNTS)                       GPH3T 70
      DATA NOY / 3 /                                                    GPH3T 80
      WRITE (8,100) IDENT,LABEL                                         GPH3T 90
  100 FORMAT (5A10)                                                     GPH3T100
      WRITE (8,110) XLABEL,YLABEL                                       GPH3T110
  110 FORMAT (2A10,10X,2A10)                                            GPH3T120
      WRITE (8,120) NPNTS,NOY                                           GPH3T130
  120 FORMAT(2I5)                                                       GPH3T140
      WRITE (8,130) LHS,LTO,NHS,NTO                                     GPH3T150
  130 FORMAT (4I5)                                                      GPH3T160
      WRITE (8,140) XMIN,XMAX,YMIN,YMAX                                 GPH3T170
  140 FORMAT (4E15.6)                                                   GPH3T180
  150 FORMAT (5E15.6)                                                   GPH3T190
      WRITE (8,150) (X(J),J=1,NPNTS)                                    GPH3T200
      WRITE (8,160) YALAB                                               GPH3T210
      WRITE (8,150) (YA(1,J),J=1,NPNTS)                                 GPH3T220
      WRITE (8,160) YBLAB                                               GPH3T230
      WRITE (8,150) (YB(1,J),J=1,NPNTS)                                 GPH3T240
      WRITE (8,160) YCLAB                                               GPH3T250
      WRITE (8,150) (YC(1,J),J=1,NPNTS)                                 GPH3T260
  160 FORMAT (1A10)                                                     GPH3T270
      RETURN                                                            GPH3T280
      END                                                               GPH3T290


      SUBROUTINE INPCON(HEIGHT,AMASS,D67,D78,D86,IDENT,NEXTID)          INPCON10
C                                                                       INPCON20
C READS FROM A LINE OF AN UPDATE COMPILE FILE, AS DATA STREAM 5, FIVE   INPCON30
C     REAL VARIABLES CHARACTERISTIC OF THE PATIENT WITH MARKERS         INPCON40
C     AFFIXED, IN 5F10.3 FORMAT, PLUS THE DECK IDENTIFIER FROM COLUMNS  INPCON50
C     74 TO 82 IN A9 FORMAT.   THE FIVE VALUES ARE  -                  INPCON60
C                                                                       INPCON70
C         HEIGHT  -  IN METRES.                                         INPCON80
C         AMASS   -  MASS IN KG..                                       INPCON90
C         D67  -  )  DISTANCES IN METRES BETWEEN MARKERS ON THE PELVIS. INPCO100
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C          D78  -  )       RESPECTIVELY 6 AND 8 OVER THE RIGHT AND LEFT     INPC0110
C          D86  -  )       SUPERIOR ANTERIOR ILIAC SPINES, AND 7 OVER THE   INPC0120
C                          SACRUM.                                          INPC0130
C                                                                           INPC0140
C     IDENT CONTAINS THE DECK NAME FROM WHICH DATA ARE READ.   LEADING     INPC0150
C     BLANK, OR TRAILING, LINES ARE SKIPPED, AND READING STOPS WHEN THE    INPC0160
C     FIRST LINE OF THE FOLLOWING DECK IS READ.   THE IDENTIFIER OF        INPC0170
C     THAT DECK IS RETURNED AS NEXTID.   IF END-OF-FILE IS READ, NEXTID    INPC0180
C     IS RETURNED AS ZERO.                                                  INPC0190
C                                                                           INPC0200
C CORRECTION IDENTIFIERS OF WHICH THE FIRCT FIVE CHARACTERS ARE CCORR      INPC0210
C     ARE IGNORED AFTER THE FIRST LINE.   THE FIRST LINE ITSELF (WHICH     INPC0220
C     WILL NORMALLY BE BLANK) MUST BEAR THE TRUE DECKNAME AS               INPC0230
C     IDENTIFIER.                                                           INPC0240
C                                                                           INPC0250
C     ON ERROR HEIGHT IS RETURNED NEGATIVE.                                 INPC0260
C                                                                           INPC0270
      DIMENSION VALS(5)                                                     INPC0280
      INTEGER CCORR                                                         INPC0290
      LOGICAL QIDENT                                                        INPC0300
      DATA CCORR  /  5HCCORR       /                                        INPC0310
      DATA IBLANK / 10H            /                                        INPC0320
C                                                                           INPC0330
      IDENT=0                                                               INPC0340
      HEIGHT=-1.                                                            INPC0350
  100 READ (5,110) L,VALS,IDLOC                                             INPC0360
  110 FORMAT (A10,T1,5F10.3,T74,A9)                                         INPC0370
      IF (EOF(5).NE.0.) GOTO 130                                            INPC0380
      IF (IDENT.EQ.0) IDENT=IDLOC                                           INPC0390
      IF (IDENT.EQ.IDLOC) GOTO 120                                          INPC0400
      IF (.NOT.QIDENT(IDLOC,1,5,CCORR)) GOTO 140                            INPC0410
  120 IF (HEIGHT.GT.0.) GOTO 100                                            INPC0420
      IF (L.EQ.IBLANK) GOTO 100                                             INPC0430
      HEIGHT=VALS(1)                                                        INPC0440
      AMASS=VALS(2)                                                         INPC0450
      D67=VALS(3)                                                           INPC0460
      D78=VALS(4)                                                           INPC0470
      D86=VALS(5)                                                           INPC0480
      GOTO 100                                                              INPC0490
  130 IDLOC=0                                                               INPC0500
  140 NEXTID=IDLOC                                                          INPC0510
      RETURN                                                                INPC0520
      END                                                                   INPC0530


      SUBROUTINE INPFPD(X,NSETS,IDENT,NEXTID,AMASS,EVNTPT)                  INPFPD10
C                                                                           INPFPD20
C READS RAW FORCE-PLATE DATA FROM UPDATE COMPILE FILE, READING AT EACH     INPFPD30
C     CALL ONE COMPLETE DECK COMPRISING SIX BLOCKS EACH OF NSETS           INPFPD40
C     VALUES, AND STORING IN ARRAY X(NSETS,6).   DATA ARE READ IN THE      INPFPD50
C     FORMAT  4(I5,2X), WITH BLOCKS TERMINATED BY AN INCOMPLETE OR A       INPFPD60
C     BLANK LINE.   NSETS IS TAKEN FROM THE LENGTH OF THE FIRST BLOCK,     INPFPD70
C     AND THE SUBSEQUENT FIVE BLOCKS ARE CHECKED TO SEE THAT THEY HAVE     INPFPD80
C     THE SAME LENGTH.   ON ERROR, READING STOPS AND NSETS IS RETURNED     INPFPD90
C     NEGATIVE.                                                             INPFP100
C                                                                           INPFP110
C     THE DECK NAME FROM WHICH DATA ARE READ IS OBTAINED FROM COLUMNS      INPFP120
C     74 TO 82 OF THE COMPILE FILE, AND IS RETURNED IN A9 FORMAT AS        INPFP130
C     IDENT.   READING CONTINUES TO THE FIRST LINE OF THE FOLLOWING        INPFP140
C     DECK (SKIPPING LINES ON ERROR), AND THAT DECK-NAME IS RETURNED       INPFP150
C     AS NEXTID.   IF END-OF-FILE IS READ, NEXTID IS SET TO ZERO.          INPFP160
C                                                                           INPFP170
C CORRECTION IDENTIFIERS OF WHICH THE FIRST FIVE CHARACTERS ARE FCORR      INPFP180
C     ARE IGNORED AFTER THE FIRST LINE READ.   THE FIRST LINE ITSELF       INPFP190
C     (WHICH WILL NORMALLY BE BLANK) MUST BEAR THE TRUE DECKNAME AS        INPFP200
C     IDENTIFIER.                                                           INPFP210
C                                                                           INPFP220
C IF THE ERROR FLAG IS NOT SET, CALFPD IS CALLED TO CONVERT THE RAW        INPFP230
C     DATA TO S.I. UNITS, AND QEVENT TO LOCATE TOE-OFF OR HEEL-STRIKE      INPFP240
C     FOR SYNCHRONIZATION.   PATIENT+S MASS MUST BE SUPPLIED AS AMASS.     INPFP250
C     EVENT POINTER IS RETURNED AS EVNTPT.                                  INPFP260
C                                                                           INPFP270
      DIMENSION X(3000),LINE(4),LNCH(4)                                     INPFP280
      INTEGER FCORR                                                         INPFP290
      LOGICAL QIDENT                                                        INPFP300
      DATA FCORR  / 5HFCORR    /                                            INPFP310
      DATA IBLANK / 7H         /                                            INPFP320
C                                                                           INPFP330
      NXREAD=0                                                              INPFP340
      NSLOC=0                                                               INPFP350
      NBLOCK=0                                                              INPFP360
      NLASTB=0                                                              INPFP370
      IDLOC=0                                                               INPFP380
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  100 READ (5,110) LNCH,LINE,IDCHEK                                      INPFP390
  110 FORMAT (4A7,T1,4(I5,2X),T74,A9)                                    INPFP400
      IF (EOF(5).NE.0) GOTO 190                                          INPFP410
      IF (IDLOC.NE.0) GOTO 120                                           INPFP420
      IDLOC=IDCHEK                                                       INPFP430
  120 IF (IDLOC.EQ.IDCHEK) GOTO 125                                      INPFP440
      IF (.NOT.QIDENT(IDCHEK,1,5,FCORR)) GOTO 200                        INPFP450
  125 DO 130 J=1,4                                                       INPFP460
      IF (LNCH(5-J).NE.IBLANK) GOTO 140                                  INPFP470
  130 CONTINUE                                                           INPFP480
      IF (NXREAD.EQ.NLASTB) GOTO 100                                     INPFP490
      GOTO 160                                                           INPFP500
  140 JVALS=5-J                                                          INPFP510
      DO 150 J=1,JVALS                                                   INPFP520
      NXREAD=NXREAD+1                                                    INPFP530
      X(NXREAD)=FLOAT(LINE(J))                                           INPFP540
  150 CONTINUE                                                           INPFP550
      IF (JVALS.EQ.4) GOTO 100                                           INPFP560
  160 NBLOCK=NBLOCK+1                                                    INPFP570
      IF (NBLOCK.NE.1) GOTO 170                                          INPFP580
      NSLOC=NXREAD                                                       INPFP590
      NLASTB=NXREAD                                                      INPFP600
      GOTO 100                                                           INPFP610
  170 IF (NBLOCK.GT.6) GOTO 220                                          INPFP620
      IF (NXREAD.NE.(NLASTB+NSLOC)) GOTO 220                             INPFP630
      NLASTB=NXREAD                                                      INPFP640
      GOTO 100                                                           INPFP650
  180 NSLOC=-NSLOC                                                       INPFP660
      EVNTPT=0.                                                          INPFP670
      GOTO 210                                                           INPFP680
  190 IDCHEK=0                                                           INPFP690
  200 IF (NBLOCK.EQ.6) GOTO 210                                          INPFP700
      IF (NBLOCK.NE.5) GOTO 180                                          INPFP710
      IF (NXREAD.NE.(NLASTB+NSLOC)) GOTO 180                             INPFP720
  210 NSETS=NSLOC                                                        INPFP730
      IDENT=IDLOC                                                        INPFP740
      NEXTID=IDCHEK                                                      INPFP750
      IF (NSETS.LE.0) RETURN                                             INPFP760
      NPNTS=6*NSETS                                                      INPFP770
      CALL CALFPO(X,NSETS,IDENT,NPNTS)                                   INPFP780
      CALL QEVENT(X,NSETS,IDENT,AMASS,EVNTPT)                            INPFP790
      RETURN                                                             INPFP800
  220 NSLOC=-NSLOC                                                       INPFP810
  230 READ (5,240) IDCHEK                                                INPFP820
  240 FORMAT (T74,A9)                                                    INPFP830
      IF (EOF(5).EQ.0.) GOTO 250                                         INPFP840
      IDCHEK=0                                                           INPFP850
  250 IF (IDCHEK.EQ.IDLOC) GOTO 230                                      INPFP860
      GOTO 210                                                           INPFP870
      END                                                                INPFP880


      SUBROUTINE INPKIN(X,Y,N,IDENT,NEXTID)                              INPKIN10
C                                                                        INPKIN20
C READS X AND Y CO-ORDINATES COMPRISING KINETIC DATA, FROM UPDATE        INPKIN30
C     COMPILE FILE.   DATA ARE READ IN SEQUENCE X(1),Y(1),X(2),Y(2),     INPKIN40
C     . . . X(N),Y(N).   X AND Y DATA ARE ON STREAM 5 IN FORMAT          INPKIN50
C     J(I5,1X,I5,1X) WHERE 0.LE.J.LE.6.   DECK NAME IS READ FROM COLS.   INPKIN60
C     74 TO 82 AND IS RETURNED IN A9 FORMAT AS IDENT.   READING STOPS    INPKIN70
C     WHEN A NEW DECK IDENTIFIER IS FOUND AND THIS IS RETURNED AS        INPKIN80
C     NEXTID.   N CONTAINS NUMBER OF PAIRS READ.   TO AVOID LOSS OF      INPKIN90
C     DATA AND OTHER PROBLEMS THE FIRST TWO LINES OF EACH DECK SHOULD    INPKI100
C     BE BLANK.   IF END-OF-FILE IS READ NEXTID IS SET TO ZERO.          INPKI110
C                                                                        INPKI120
C TO PROVIDE HORIZONTAL CO-ORDINATES OF A COMMON ORDER OF MAGNITUDE,     INPKI130
C     DESPITE VARIATION IN THE WAY THE REFERENCE GRID HAS BEEN USED,     INPKI140
C     THESE CO-ORDINATES ARE MODIFIED.   AN OFFSET XDIFF, CONSTANT FOR   INPKI150
C     A GIVEN DECK AND BASED ON PATIENT P1 DATA, IS ADDED TO THE THREE   INPKI160
C     REFERENCE VALUES FOR EACH FRAME.                                   INPKI170
C                                                                        INPKI180
C FOR THREE SPECIAL DECKS FOR WHICH THE REFERENCE GRID TREATMENT WAS     INPKI190
C     GROSSLY ATYPICAL, MEAN P1 VALUES ARE INSERTED WITH ADJUSTMENT      INPKI200
C     ONLY FOR TRANSLATORY DISPLACEMENT OF EACH FRAME.                   INPKI210
C                                                                        INPKI220
C CORRECTION IDENTIFIERS OF WHICH THE FIRST FIVE CHARACTERS ARE KCORR    INPKI230
C     ARE IGNORED AFTER THE FIRST LINE.   THE FIRST LINE ITSELF (WHICH   INPKI240
C     WILL NORMALLY BE BLANK) MUST BEAR THE TRUE DECKNAME AS             INPKI250
C     IDENTIFIER.                                                        INPKI260
C                                                                        INPKI270
      DIMENSION LINE(12),LNCH(6),P1X(3,3),P1XBAR(3),P1Y(3,3),SPECID(3)   INPKI280
      DIMENSION X(1380),Y(1380)                                          INPKI290
      INTEGER UCAM(3)                                                    INPKI300
      LOGICAL FIRST,QIDENT                                               INPKI310
```

```
      DATA IBLANK / 6H      /                                               INPK1320
      DATA KCORR  / 5HKCORR  /                                              INPK1330
      DATA P1X(1,1)  /  +4588.  /, P1Y(1,1)  /  +5960.  /                   INPK1340
      DATA P1X(2,1)  /  +4588.  /, P1Y(2,1)  /  +3290.1 /                   INPK1350
      DATA P1X(3,1)  /  +5701.  /, P1Y(3,1)  /  +3289.7 /                   INPK1360
      DATA P1X(1,2)  /  +4776.3 /, P1Y(1,2)  /  +5935.  /                   INPK1370
      DATA P1X(2,2)  /  +4781.7 /, P1Y(2,2)  /  +2847.5 /                   INPK1380
      DATA P1X(3,2)  /  +5600.  /, P1Y(3,2)  /  +2845.8 /                   INPK1390
      DATA P1X(1,3)  /  +4064.5 /, P1Y(1,3)  /  +6145.  /                   INPK1400
      DATA P1X(2,3)  /  +4031.5 /, P1Y(2,3)  /  +3279.2 /                   INPK1410
      DATA P1X(3,3)  /  +4720.  /, P1Y(3,3)  /  +3272.6 /                   INPK1420
      DATA P1XBAR(1) /  +4588.  /                                           INPK1430
      DATA P1XBAR(2) /  +4779.0 /                                           INPK1440
      DATA P1XBAR(3) /  +4048.0 /                                           INPK1450
      DATA QCAM(1)   /  3HKL1         /                                     INPK1460
      DATA QCAM(2)   /  3HKR2         /                                     INPK1470
      DATA QCAM(3)   /  3HKF3         /                                     INPK1480
      DATA SPECID(1) /  9HS1KF3FUL0   /                                     INPK1490
      DATA SPECID(2) /  9HS3KL1FUL0   /                                     INPK1500
      DATA SPECID(3) /  9HS3KL1BDT0   /                                     INPK1510
C                                                                           INPK1520
      NLOC=0                                                                INPK1530
      FIRST=.TRUE.                                                          INPK1540
      IDENT=0                                                               INPK1550
C                                                                           INPK1560
  100 READ (5,110) LNCH,LINE,NXTLOC                                         INPK1570
  110 FORMAT (6(6X,A6),T1,12(I5,1X),1X,A9)                                  INPK1580
      IF (EOF(5).NE.0.) GOTO 150                                            INPK1590
      IF (.NOT.FIRST) GOTO 120                                              INPK1600
      FIRST=.FALSE.                                                         INPK1610
      IDLOC=NXTLOC                                                          INPK1620
      IDENT=NXTLOC                                                          INPK1630
  120 IF (NXTLOC.EQ.IDLOC) GOTO 130                                         INPK1640
      IF (.NOT.QIDENT(NXTLOC,1,5,KCORR)) GOTO 160                           INPK1650
  130 DO 140 K=1,6                                                          INPK1660
      IF (LNCH(K).EQ.IBLANK) GOTO 100                                       INPK1670
      NLOC=NLOC+1                                                           INPK1680
      X(NLOC)=FLOAT(LINE(2*K-1))                                            INPK1690
      Y(NLOC)=FLOAT(LINE(2*K))                                              INPK1700
  140 CONTINUE                                                              INPK1710
      GOTO 100                                                              INPK1720
C                                                                           INPK1730
  150 NXTLOC=0                                                              INPK1740
  160 NEXTID=NXTLOC                                                         INPK1750
      N=NLOC                                                                INPK1760
      DO 170 J=1,3                                                          INPK1770
      IF (.NOT.QIDENT(IDLOC,3,5,QCAM(J))) GOTO 170                          INPK1780
      KCAM=J                                                                INPK1790
      GOTO 180                                                              INPK1800
  170 CONTINUE                                                              INPK1810
      CALL ABORT                                                            INPK1820
  180 NSTEP=11+2*(KCAM/3)                                                   INPK1830
      DO 190 J=1,3                                                          INPK1840
      IF (QIDENT(IDLOC,1,9,SPECID(J))) GOTO 240                             INPK1850
  190 CONTINUE                                                              INPK1860
      XSUM=0.                                                               INPK1870
      NX=0                                                                  INPK1880
      DO 210 J=1,NLOC,NSTEP                                                 INPK1890
      DO 200 K=1,2                                                          INPK1900
      JPKL1=J+K-1                                                           INPK1910
      XSUM=XSUM+X(JPKL1)                                                    INPK1920
  200 CONTINUE                                                              INPK1930
      NX=NX+2                                                               INPK1940
  210 CONTINUE                                                              INPK1950
      XBAR=XSUM/FLOAT(NX)                                                   INPK1960
      XBARK=P1XBAR(KCAM)                                                    INPK1970
      IF (KCAM.NE.1) GOTO 214                                               INPK1980
      IF (QIDENT(IDLOC,1,1,1HS)) GOTO 214                                   INPK1990
      IF (QIDENT(IDLOC,1,2,2HP6)) GOTO 214                                  INPK1000
      XBARK=5546.0                                                          INPK1010
  214 XDIFF=XBARK-XBAR                                                      INPK1020
      DO 230 J=1,NLOC,NSTEP                                                 INPK1030
      DO 220 K=1,3                                                          INPK1040
      JPKL1=J+K-1                                                           INPK1050
      X(JPKL1)=X(JPKL1)+XDIFF                                               INPK1060
  220 CONTINUE                                                              INPK1070
  230 CONTINUE                                                              INPK1080
      RETURN                                                                INPK1090
C                                                                           INPK1100
  240 WRITE (6,250) IDLOC                                                   INPK1110
  250 FORMAT (11H0**** DECK ,A9,34H REQUIRED SPECIAL PROCESSING. ****)      INPK1120
      XSUM=0.                                                               INPK1130
      YSUM=0.                                                               INPK1140
```

```
      NX=0
      DO 270 J=1,NLOC,NSTEP
      DO 260 K=1,3
      JPKL1=J+K-1
      XSUM=XSUM+X(JPKL1)
      YSUM=YSUM+Y(JPKL1)
  260 CONTINUE
      NX=NX+3
  270 CONTINUE
      XBAR=XSUM/FLOAT(NX)
      YBAR=YSUM/FLOAT(NX)
      DO 300 J=1,NLOC,NSTEP
      XSUM=0.
      YSUM=0.
      DO 280 K=1,3
      JPKL1=J+K-1
      XSUM=XSUM+X(JPKL1)
      YSUM=YSUM+Y(JPKL1)
  280 CONTINUE
      XDIFF=XSUM/3.-XBAR
      YDIFF=YSUM/3.-YBAR
      DO 290 K=1,3
      JPKL1=J+K-1
      X(JPKL1)=P1X(K,KCAM)+XDIFF
      Y(JPKL1)=P1Y(K,KCAM)+YDIFF
  290 CONTINUE
  300 CONTINUE
      RETURN
      END


      SUBROUTINE INPKMK(LHS,LTO,IRHS,IRTO,NFRAME,IDENT,NEXTID)
C
C READS FROM A LINE OF AN UPDATE COMPILE FILE, AS DATA STREAM 5, FIVE
C     INTEGERS MARKING EVENTS IN KINEMATIC DATA, IN 5I10 FORMAT, PLUS
C     THE DECK IDENTIFIER FROM COLUMNS 74 TO 82 IN A9 FORMAT.   THE
C     FIVE INTEGERS ARE  -
C
C         LHS    -  FRAME NUMBERS (FIRST = 1) OF FIRST FRAME AFTER (OR
C                   AT) LEFT HEEL STRIKE.
C         LTO    -  THE SAME, FOR LEFT TOE-OFF.
C         IRHS   -  THE SAME, FOR RIGHT HEEL STRIKE.
C         IRTO   -  THE SAME FOR RIGHT TOE-OFF.
C         NFRAME -  THE TOTAL NUMBER OF FRAMES EXPOSED IN EACH CAMERA
C                   FOR THE MANOEUVRE.
C
C     IDENT CONTAINS THE DECK NAME FROM WHICH DATA ARE READ.   LEADING
C     BLANK, OR TRAILING, LINES ARE SKIPPED, AND READING STOPS WHEN THE
C     FIRST LINE OF THE FOLLOWING DECK IS READ.   THE IDENTIFIER OF
C     THAT DECK IS RETURNED AS NEXTID.   IF END-OF-FILE IS READ, NEXTID
C     IS RETURNED AS ZERO.
C
C CORRECTION IDENTIFIERS OF WHICH THE FIRST FIVE CHARACTERS ARE MCORR
C     ARE IGNORED AFTER THE FIRST LINE.   THE FIRST LINE ITSELF (WHICH
C     WILL NORMALLY BE BLANK) MUST BEAR THE TRUE DECKNAME AS
C     IDENTIFIER.
C
C     ON ERROR LHS IS RETURNED NEGATIVE.
C
      DIMENSION LINE(7)
      LOGICAL QIDENT
      DATA IBLANK / 10H          /
      DATA MCORR  /  5HMCORR      /
C
      IDENT=0
      LHS=-1
  100 READ (5,110) LINE
  110 FORMAT (A10,T1,5I10,T74,A9)
      IF (EOF(5).NE.0.) GOTO 130
      IF (IDENT.EQ.0) IDENT=LINE(7)
      IF (IDENT.EQ.LINE(7)) GOTO 120
      IF (.NOT.QIDENT(LINE(7),1,5,MCORR)) GOTO 140
  120 IF (LHS.GE.0) GOTO 100
      IF (LINE(1).EQ.IBLANK) GOTO 100
      LHS=LINE(2)
      LTO=LINE(3)
      IRHS=LINE(4)
      IRTO=LINE(5)
      NFRAME=LINE(6)
      GOTO 100
  130 LINE(7)=0
  140 NEXTID=LINE(7)
      RETURN
```

```
      END                                                               INPKM530


      INTEGER FUNCTION NEARST(X)                                        NEARST10
C                                                                       NEARST20
C RETURNS THE NEAREST INTEGER TO THE ARGUMENT X.                        NEARST30
C                                                                       NEARST40
      NEARST=IFIX(X+SIGN(0.5,X))                                        NEARST50
      RETURN                                                            NEARST60
      END                                                               NEARST70


      LOGICAL FUNCTION NEWMAN(ID1,ID2)                                  NEWMAN10
C                                                                       NEWMAN20
C COMPARES THE FIRST TWO CHARACTERS (TWELVE BITS) IN TWO WORDS, AND     NEWMAN30
C     RETURNS THE VALUE .TRUE. IF THEY DIFFER, AND .FALSE. IF THEY ARE  NEWMAN40
C     THE SAME.                                                         NEWMAN50
C                                                                       NEWMAN60
      NEWMAN=(ID1.AND.MASK(12)).NE.(ID2.AND.MASK(12))                   NEWMAN70
      RETURN                                                            NEWMAN80
      END                                                               NEWMAN90


      SUBROUTINE NUREGR(NDSBD1,ND,YEXT,NCSBD1,NC,FUN,DFUN,DDFUN,NK)     NUREGR10
      DIMENSION YEXT(NDSBD1,ND),FUN(NCSBD1,NC),DFUN(NCSBD1,NC),         NUREGR20
     1   DDFUN(NCSBD1,NC)                                               NUREGR30
      DIMENSION SUMCY(30),SUMSY(30)                                     NUREGR40
      DIMENSION A(30),B(30),SUMSQR(31)                                  NUREGR50
      REAL ICPEXT                                                       NUREGR60
      COMMON /SMOOTH/ A,B,C,COVERT,GRAD,GRDEXT,ICPEXT,STEP,SUMSQR,YM,Y0 NUREGR70
      DATA T      / 0.020000000 /                                       NUREGR80
      DATA TWOPI / 6.283185307 /                                        NUREGR90
      N=ND-1                                                            NUREG100
      RINT=FLOAT(N)                                                     NUREG110
      NA=(ND-3)/2                                                       NUREG120
      IF (NA.GT.30) NA=30                                               NUREG130
      IF (NA.GT.(NK+NK))NA=NK+NK                                        NUREG140
      C=TWOPI/RINT                                                      NUREG150
      COVERT=C/T                                                        NUREG160
      STEP=(YEXT(1,ND)-YEXT(1,1))                                       NUREG170
      GRAD=STEP/RINT                                                    NUREG180
      Y0=YEXT(1,1)-GRAD                                                 NUREG190
      SUMY=0.                                                           NUREG200
      SUMYSQ=0.                                                         NUREG210
      DO 100 K=1,NA                                                     NUREG220
      SUMCY(K)=0.                                                       NUREG230
      SUMSY(K)=0.                                                       NUREG240
  100 CONTINUE                                                          NUREG250
      DO 120 I=1,N                                                      NUREG260
      YI=YEXT(1,I)-Y0-GRAD*FLOAT(I)                                     NUREG270
      SUMY=SUMY+YI                                                      NUREG280
      SUMYSQ=SUMYSQ+YI*YI                                               NUREG290
      XI=C*FLOAT(I-1)                                                   NUREG300
      DO 110 K=1,NA                                                     NUREG310
      ARG=K*XI                                                          NUREG320
      SUMCY(K)=SUMCY(K)+COS(ARG)*YI                                     NUREG330
      SUMSY(K)=SUMSY(K)+SIN(ARG)*YI                                     NUREG340
  110 CONTINUE                                                          NUREG350
  120 CONTINUE                                                          NUREG360
      YM=SUMY/RINT                                                      NUREG370
      CYY=SUMYSQ-SUMY*YM                                                NUREG380
      SUMSQR(1)=CYY                                                     NUREG390
      DO 130 K=1,NA                                                     NUREG400
      A(K)=SUMCY(K)*(2./RINT)                                           NUREG410
      B(K)=SUMSY(K)*(2./RINT)                                           NUREG420
      CYY=CYY-A(K)*SUMCY(K)-B(K)*SUMSY(K)                               NUREG430
      SUMSQR(K+1)=CYY                                                   NUREG440
  130 CONTINUE                                                          NUREG450
      RC=NC-1                                                           NUREG460
      CC=TWOPI/RC                                                       NUREG470
      GRADC=GRAD*RINT/RC                                                NUREG480
      ICPEXT=YEXT(1,1)+YM                                               NUREG490
      Y0CYM=ICPEXT-GRADC                                                NUREG500
      GRDEXT=GRAD/T                                                     NUREG510
      DO 150 I=1,NC                                                     NUREG520
      FUN(1,I)=Y0CYM+GRADC*FLOAT(I)                                     NUREG530
      DFUN(1,I)=GRDEXT                                                  NUREG540
      DDFUN(1,I)=0.                                                     NUREG550
      CCI1=CC*FLOAT(I-1)                                                NUREG560
      DO 140 K=1,NK                                                     NUREG570
      RK=FLOAT(K)                                                       NUREG580
      FREQ=RK*COVERT                                                    NUREG590
      SN=SIN(RK*CCI1)                                                   NUREG600
```

```
      CS=COS(RK*CCI1)                                                   NUREG610
      HOLD=A(K)*CS+B(K)*SN                                              NUREG620
      FUN(1,I)=FUN(1,I)+HOLD                                            NUREG630
      DFUN(1,I)=DFUN(1,I)+FREQ*(-A(K)*SN+B(K)*CS)                       NUREG640
      DDFUN(1,I)=DDFUN(1,I)-FREQ*FREQ*HOLD                              NUREG650
  140 CONTINUE                                                          NUREG660
  150 CONTINUE                                                          NUREG670
      RETURN                                                            NUREG680
      END                                                               NUREG690


      SUBROUTINE PARALA(KA,KB,NF)                                       PARALA10
      DIMENSION X1ANTES(10,125),Y1ANTES(10,125),X1A(8,125),             PARALA20
     1   Y1A(8,125),Z1A(10,125),X(11,125),Y(11,125),Z(11,125)           PARALA30
      COMMON X1ANTES,Y1ANTES,X1A,Y1A,Z1A,X,Y,Z,HX,XL,ZL                 PARALA40
      COMMON /TRYY2/ Y2A(10,125),Y2(10,125),Y2FILL(380)                 PARALA50
      DO 110 J=KA,KB                                                    PARALA60
      DO 100 I=1,NF                                                     PARALA70
      DO=X1ANTES(J,I)*Z1A(J,I)                                          PARALA80
      RE=XL*ZL                                                          PARALA90
      RMI=X1ANTES(J,I)*RE-DO*XL                                         PARAL100
      FA=RE-DO                                                          PARAL110
      X(J,I)=RMI/FA                                                     PARAL120
      SOL=Z1A(J,I)*X(J,I)                                               PARAL130
      SI=SOL/XL                                                         PARAL140
      Z(J,I)=Z1A(J,I)-SI                                                PARAL150
      DOO=Y1ANTES(J,I)*Z(J,I)                                           PARAL160
      REE=HX*Z(J,I)                                                     PARAL170
      REMI=(DOO-REE)/ZL                                                 PARAL180
      Y(J,I)=Y1ANTES(J,I)-REMI                                          PARAL190
      Y2(J,I)=Y2A(J,I)-(Y2A(J,I)-HX)*X(J,I)/XL                          PARAL200
  100 CONTINUE                                                          PARAL210
  110 CONTINUE                                                          PARAL220
      RETURN                                                            PARAL230
      END                                                               PARAL240


      SUBROUTINE PIRILI(SSSX,SSSY,SSFZ,XL,ZL,HX,LADO)                   PIRILI10
      DIMENSION SSSX(3),SSSY(3),SSFZ(3)                                 PIRILI20
      COMMON /BLOCKI/ SSX(10),SSY(10),SFZ(10)                           PIRILI30
      COMMON /LADO/ LEFSID,ISIDE,JSIDE,LSIDE,JBIDE,LBIDE                PIRILI40
      LOGICAL LEFSID                                                    PIRILI50
      DO 1 I=1,3                                                        PIRILI60
      J=ISIDE+I                                                         PIRILI70
      DA=SSSX(I)*SSFZ(I)                                                PIRILI80
      RE=XL*ZL                                                          PIRILI90
      RMI=SSSX(I)*RE-DA*XL                                              PIRIL100
      FA=RE-DA                                                          PIRIL110
      SSX(J)=RMI/FA                                                     PIRIL120
      SOL=SSFZ(I)*SSX(J)                                                PIRIL130
      SI=SOL/XL                                                         PIRIL140
      SFZ(J)=SSFZ(I)-SI                                                 PIRIL150
      DOA=SSSY(I)*SFZ(J)                                                PIRIL160
      REE=HX*SFZ(J)                                                     PIRIL170
      REMI=(DOA-REE)/ZL                                                 PIRIL180
      SSY(J)=SSSY(I)-REMI                                               PIRIL190
1     CONTINUE                                                          PIRIL200
      RETURN                                                            PIRIL210
      END                                                               PIRIL220


      SUBROUTINE POROLO(X,Y,Z,A,B,C,ZL,XL,HX)                           POROL010
      X=(A*XL*ZL-A*C*XL)/(XL*ZL-C*A)                                    POROL020
      Z=C-C*X/XL                                                        POROL030
      Y=B-(B*Z-HX*Z)/ZL                                                 POROL040
      RETURN                                                            POROL050
      END                                                               POROL060


      SUBROUTINE QEVENT(X,NSETS,IDENT,AMASS,EVNTPT)                     QEVENT10
C                                                                       QEVENT20
C PROCESSES FORCE PLATE DATA, AFTER READING BY INPFPD AND CONVERSION TO QEVENT30
C     S.I.UNITS BY CALFPD.   DATA ARE SEARCHED FROM THE ZERO-LOAD END   QEVENT40
C     TO LOCATE ITS LIMIT AT HEEL-STRIKE OR TOE-OFF.   LOCATION IS      QEVENT50
C     RETURNED, AS SUBSCRIPT OF X COINCIDING WITH EVENT, IN EVNTPT.     QEVENT60
C     THIS HAS TYPE REAL AND THUS INCLUDES A FRACTIONAL PART.           QEVENT70
C                                                                       QEVENT80
C MEAN VALUE OF ZERO-LOAD REGION IS THEN CALCULATED AND VALUES ARE      QEVENT90
C     ADJUSTED TO THIS ZERO DATUM.   THE ADJUSTED DATA ARE RELOCATED TO QEVEN100
C     FILL THE WHOLE ARRAY OF 500 BY 6 WORDS, SUPPLYING ZERO FILL AT    QEVEN110
C     THE END WITH NO FOOT CONTACT.                                     QEVEN120
C                                                                       QEVEN130
      DIMENSION FHOLD(500,6),LABEL(2),X(NSETS,6)                        QEVEN140
```

```
      LOGICAL BACKWD,QIDENT
      COMMON /FHLDBK/ FHOLD
      DATA LABEL(1)  /  8H FORWARD   /
      DATA LABEL(2)  /  8HBACKWARD   /
C
      BACKWD=QIDENT(IDENT,3,8,6HFP1FUL).OR.QIDENT(IDENT,3,8,6HFP2BDT)
      CRIT=5.0*AMASS
      NSTPL1=NSETS+1
      JJ=1
      IF(BACKWD) JJ=NSTPL1-JJ
      CRITL=X(JJ,2)+0.1*CRIT
      XSUM=0.
C
C SEARCH (FORWARD OR BACKWARD) FOR BREAK FROM ZERO-LOAD LEVEL.
C
      DO 120 J=1,NSETS
      JJ=J
      IF (BACKWD) JJ=NSTPL1-JJ
      XNOW=X(JJ,2)
      IF (J.EQ.1) GOTO 110
      IF (XNOW.GE.CRITL) GOTO 80
      IF (XLAST.GE.CRITL) GOTO 90
      IF (XNOW.LE.XLAST) GOTO 100
   80 XLAST=XNOW
   90 XLEVEL=XSUM/FLOAT(JLEVEL)
      JTEST=JLEVEL+7
      TEST=XLEVEL+CRIT
      IF ((J.LT.JTEST).AND.(XNOW.LT.TEST)) GOTO 120
      JTSTL1=J-1
      GOTO 130
C
  100 IF ((JLEVEL+1).EQ.J) GOTO 110
      JLEVEL=JLEVEL+1
      JJ=JLEVEL
      IF (BACKWD) JJ=NSTPL1-JJ
      XSUM=XSUM+X(JJ,2)
      GOTO 100
  110 JLEVEL=J
      XLAST=XNOW
      XSUM=XSUM+XNOW
  120 CONTINUE
      GOTO 300
C
C SEARCH COMPLETE.   JLEVEL POINTS TO LAST ELEMENT BEFORE RISE STARTS.
C      XLEVEL IS MEAN VALUE UP TO AND INCLUDING THAT POINT.   JTSTL1
C      POINTS TO LAST ELEMENT BEFORE TEST POINT WHERE LOAD EXCEEDS CRIT
C      (I.E. ABOUT HALF THE PATIENT≠S WEIGHT).
C
C TREATMENT NOW DEPENDS ON THE STEEPNESS OF THE RISE.
C
  130 CONTINUE
      WRITE (6,140) JLEVEL,JTSTL1,XLEVEL
  140 FORMAT (1H ,60X,19H*** QEVENT CHECK  -,2I6,F10.4,4H ***)
      IF (JTSTL1-JLEVEL-1) 150,160,170
C
C VERY STEEP.   SET POINTER HALF WAY ACROSS GAP.
C
  150 EVNTPT=FLOAT(JLEVEL)+0.5
      B=0.
      GOTO 200
C
C STEEP.   SET POINTER BY HOW FAR FIRST POINT HAS JUMPED, UP TO HALFWAY.
C
  160 JJ=JTSTL1
      IF (BACKWD) JJ=NSTPL1-JJ
      EVNTPT=FLOAT(JTSTL1)-(X(JJ,2)-XLEVEL)/(CRIT+CRIT)
      B=0.
      GOTO 200
C
C GRADUAL.  FIT STRAIGHT LINE THROUGH POINTS JLEVEL TO JTSTL1, AND
C      USE INTERCEPT WITH XLEVEL.
C
  170 TSUM=0.
      TTSUM=0.
      TXSUM=0.
      XSUM=0.
      XXSUM=0.
      DO 180 J=JLEVEL,JTSTL1
      JJ=J
      IF (BACKWD) JJ=NSTPL1-JJ
      XNOW=X(JJ,2)
      TJ=FLOAT(J)
      TSUM=TSUM+TJ
```

```
      TTSUM=TTSUM+TJ*TJ
      TXSUM=TXSUM+TJ*XNOW
      XSUM=XSUM+XNOW
      XXSUM=XXSUM+XNOW*XNOW
  180 CONTINUE
      FN=FLOAT(JTSTL1-JLEVEL+1)
      B=(TXSUM*FN-TSUM*XSUM)/(TTSUM*FN-TSUM*TSUM)
      A=(XSUM-B*TSUM)/FN
      EVNTPT=(XLEVEL-A)/B
      WRITE (6,190) TSUM,TTSUM,TXSUM,XSUM,XXSUM,A,B,EVNTPT
  190 FORMAT (28H0*** QEVENT BY LINEAR FIT  -,5E20.10,4H ***/1H0,67X,
     1   3E20.10,4H ***)
C
C EVENT LOCATED.   INVERT IF NECESSARY, THEN ADJUST DATUM.
C
  200 J2=JLEVEL-1
      IF (J2.LE.0) J2=1
      IF (.NOT. BACKWD) GOTO 210
      EVNTPT=FLOAT(NSTPL1)-EVNTPT
      J1=NSTPL1-J2
      J2=NSETS
      GOTO 220
  210 J1=1
  220 FACTOR=1./FLOAT(J2-J1+1)
      JFILL=500-NSETS
      DO 290 K=1,6
      KINV=7-K
      XSUM=0.
      DO 230 J=J1,J2
      XSUM=XSUM+X(J,KINV)
  230 CONTINUE
      XDATUM=FACTOR*XSUM
      IF (KINV.EQ.2) XDATM2=XDATUM
      IF (.NOT.BACKWD) GOTO 260
      DO 240 J=1,NSETS
      FHOLD(J,KINV)=X(J,KINV)-XDATUM
  240 CONTINUE
      DO 250 J=NSTPL1,500
      FHOLD(J,KINV)=0.
  250 CONTINUE
      GOTO 290
  260 DO 270 J=1,NSETS
      JINV=NSTPL1-J
      JJ=JINV+JFILL
      FHOLD(JJ,KINV)=X(JINV,KINV)-XDATUM
  270 CONTINUE
      DO 280 J=1,JFILL
      FHOLD(J,KINV)=0.0
  280 CONTINUE
  290 CONTINUE
      IF (.NOT.BACKWD) EVNTPT=EVNTPT+FLOAT(JFILL)
      NSHOLD=NSETS
      NSETS=500
      GOTO 320
C
C SYNCHRONIZATION FAILURE ROUTINE.
C
  300 WRITE (6,310) IDENT
  310 FORMAT (53H0SYNCHRONIZATION FAILURE IN QEVENT, WHILE PROCESSING ,
     1   5HDECK ,A9)
      CALL ABORT(2)
      RETURN
C
C WRITE GRAPH PLOTTING INFORMATION TO TAPE8
C
  320 J=1
      IF (BACKWD) J=2
      WRITE (8,330) IDENT,LABEL(J)
  330 FORMAT (A9,4X,A8,29H-SEARCHING SYNCHRONIZATION    )
      IF (H.EQ.0) GOTO 350
      IF (BACKWD) GOTO 340
      J1=JLEVEL
      J2=JTSTL1
      GOTO 360
  340 J1=NSTPL1-JTSTL1
      J2=NSTPL1-JLEVEL
      GOTO 360
  350 J1=0
      J2=0
  360 WRITE (8,370) NSHOLD,J1,J2
  370 FORMAT (3I6)
      FMIN=0.
      FMAX=0.
```

```
      IF (BACKWD) GOTO380                                               QEVE1810
      J1=JFILL+1                                                        QEVE1820
      J2=500                                                            QEVE1830
      GOTO 390                                                          QEVE1840
  380 J1=1                                                              QEVE1850
      J2=NSHOLD                                                         QEVE1860
  390 DO 400 J=J1,J2                                                    QEVE1870
      IF (FHOLD(J,2).GT.FMAX) FMAX=FHOLD(J,2)                           QEVE1880
      IF (FHOLD(J,2).LT.FMIN) FMIN=FHOLD(J,2)                           QEVE1890
  400 CONTINUE                                                          QEVE1900
      WRITE (8,410) EVNTPT,FMIN,EVNTPT,FMAX                             QEVE1910
  410 FORMAT (5E15.6)                                                   QEVE1920
      IF (B.EQ.0.) GOTO 430                                             QEVE1930
      A=A-XDATM2                                                        QEVE1940
      IF (.NOT.BACKWD) A=A-B*FLOAT(JFILL)                               QEVE1950
      TMIN=(FMIN-A)/B                                                   QEVE1960
      TMAX=(FMAX-A)/B                                                   QEVE1970
      IF (.NOT.BACKWD) GOTO 420                                         QEVE1980
      TMIN=FLOAT(NSTPL1)-TMIN                                           QEVE1990
      TMAX=FLOAT(NSTPL1)-TMAX                                           QEVE2000
  420 T1=FLOAT(J1)                                                      QEVE2010
      T2=FLOAT(J2)                                                      QEVE2020
      XLEVEL=XLEVEL-XDATM2                                              QEVE2030
      WRITE (8,410) T1,XLEVEL,T2,XLEVEL                                 QEVE2040
      WRITE (8,410) TMIN,FMIN,TMAX,FMAX                                 QEVE2050
  430 WRITE (8,440) (J,J=J1,J2)                                         QEVE2060
  440 FORMAT (5(I6,9H.0000E+00))                                        QEVE2070
      WRITE (8,410) (FHOLD(J,2),J=J1,J2)                                QEVE2080
      RETURN                                                            QEVE2090
      END                                                               QEVE2100


      LOGICAL FUNCTION QIDENT(IDENT,ICOL1,ICOL2,ICOMP)                  QIDENT10
C                                                                       QIDENT20
C COMPARES THE CHARACTERS ICOL1 TO ICOL2 OF THE CHARACTER STRING IDENT  QIDENT30
C      WITH THE CORRESPONDING LEFTMOST (ICOL2-ICOL1+1) CHARACTERS OF    QIDENT40
C      ICOMP, AND RETURNS THE VALUE .TRUE. IF THE SAME, .FALSE. IF      QIDENT50
C      DIFFERENT.                                                       QIDENT60
C                                                                       QIDENT70
C      FOR EXAMPLE,  QIDENT(8HSHAMBLES,2,4,3HHAM)  IS .TRUE..           QIDENT80
C                                                                       QIDENT90
      NBITS=6*(ICOL2-ICOL1+1)                                           QIDEN100
      MSKBIT=.NOT.MASK(60-NBITS)                                        QIDEN110
      IDLOC=SHIFT(IDENT,(6*ICOL2))                                      QIDEN120
      ICLOC=SHIFT(ICOMP,NBITS)                                          QIDEN130
      QIDENT=(IDLOC.AND.MSKBIT).EQ.(ICLOC.AND.MSKBIT)                   QIDEN140
      RETURN                                                            QIDEN150
      END                                                               QIDEN160


      SUBROUTINE REF(PX1,PX2,PX3,PZ1,PZ2,PZ3,X0,Z0,CD)                  REF   10
      Z32=PZ3-PZ2                                                       REF   20
      X32=PX3-PX2                                                       REF   30
      AM=Z32/X32                                                        REF   40
      CL=(PX3*PZ2-PX2*PZ3)/X32                                          REF   50
      X0=(PX1+AM*(PZ1-CL))/(1.+AM*AM)                                   REF   60
      Z0=AM*X0+CL                                                       REF   70
      CD=ATAN(AM)                                                       REF   80
      RETURN                                                            REF   90
      END                                                               REF  100


      SUBROUTINE ROOTS(RX1,RX2,A,B,C)                                   ROOTS 10
      BBY2A=0.5*B/A                                                     ROOTS 20
      DISC=(BBY2A)**2-C/A                                               ROOTS 30
      IF(DISC.GE.0.)GOTO 1                                              ROOTS 40
      RX1=-BBY2A                                                        ROOTS 50
      RX2=100.0                                                         ROOTS 60
      GOTO4                                                             ROOTS 70
 1    ROOT=SQRT(DISC)                                                   ROOTS 80
      RX1=-BBY2A-ROOT                                                   ROOTS 90
      RX2=0.0                                                           ROOTS100
 4    RETURN                                                            ROOTS110
      END                                                               ROOTS120


      SUBROUTINE SMOOTH(LABEL,NDSBD1,ND,Y,NCSBD1,NC,FUN,DFUN,DDFUN,NK)  SMOOTH10
C                                                                       SMOOTH20
C PROVIDES AN INTERFACE THROUGH WHICH THE HARMONIC ANALYSIS ROUTINE     SMOOTH30
C      NUREGR IS CALLED.                                                SMOOTH40
C                                                                       SMOOTH50
      DIMENSION LABEL(5),Y(NDSBD1,ND),FUN(NCSBD1,NC),DFUN(NCSBD1,NC),   SMOOTH60
     1   DDFUN(NCSBD1,NC)                                               SMOOTH70
```

```
      DIMENSION A(30),B(30),SUMSQR(31),HOLDY(320)
      REAL ICPEXT
      COMMON /SMOOTH/ A,B,C,COVERT,GRAD,GRDEXT,ICPEXT,STEP,SUMSQR,YM,YO
C
      WRITE (6,90)
   90 FORMAT (1H0)
      WRITE (6,100) LABEL
  100 FORMAT (52H SMOOTHING AND DIFFERENTIATION BY FOURIER REGRESSION,
     1   7H   -   ,5A10/1H )
      IF (NK.EQ.0) NK=NEARST(FLOAT(ND-1)/20.)
      JTOP=5
      IF (JTOP.GT.NC) JTOP=NC
      IF (JTOP.GT.ND) JTOP=ND
      DO 150 J=1,ND
      HOLDY(J)=Y(1,J)
  150 CONTINUE
      CALL NUREGR(NDSBD1,ND,Y,NCSBD1,NC,FUN,DFUN,DDFUN,NK)
C+    WRITE (6,200) ND,NC,NK
  200 FORMAT (25H0NUMBER OF DATA POINTS  =,I4,10X,10HNUMBER OF ,
     1   16HFITTED POINTS  =I4,10X,25HDEGREE OF FITTED MODEL  =,I4)
C+    WRITE (6,210) ICPEXT,GRDEXT,STEP
  210 FORMAT (13H0INTERCEPT  =,E14.5,12X,18HLINEAR GRADIENT  =,E14.5,
     1   8X,14HSTEP LENGTH  =,E14.5)
C+    WRITE (6,220)
  220 FORMAT (49H0DEGREE      COSINE            SINE          MODULUS,
     1   53H         RESIDUAL    DEGREES    RESIDUAL         RESIDUAL,
     2   25H        PROB2.     MODULUS*/
     3   58H   NK          COEFFT          COEFFT                   SUM,
     4   52HSQUARES    FREEDOM    VARIANCE         STD.DEVN        ,
     5   17H          OMEGA**2)
      NA=(ND-4)/2
      IF (NA.GT.30) NA=30
      IF (NA.GT.(NK+NK))NA=NK+NK
      NDEGF=ND-3
      VARNCE=SUMSQR(1)/FLOAT(NDEGF)
      STDEV=SQRT(VARNCE)
C+    WRITE (6,230) SUMSQR(1),NDEGF,VARNCE,STDEV
  230 FORMAT (5H0   0,45X,E15.5,I8,2E15.5)
      DO 270 J=1,NA
      F2=(SUMSQR(J)-SUMSQR(J+1))/(VARNCE+VARNCE)
      PROB2=1.
      IF (F2.GT.1.) PROB2=FPROB(F2,2,NDEGF)
      NDEGF=NDEGF-2
      VARNCE=SUMSQR(J+1)/FLOAT(NDEGF)
      STDEV=SQRT(VARNCE)
      OMEGA=COVERT*FLOAT(J)
      RMOD=SQRT(A(J)*A(J)+B(J)*B(J))
      SQMOD=OMEGA*OMEGA*RMOD
C+    IF (MOD(J,5).EQ.1) WRITE (6,240)
  240 FORMAT (1H )
C+    WRITE (6,250) J,A(J),B(J),RMOD,SUMSQR(J+1),NDEGF,VARNCE,STDEV,
C+   1   PROB2,SQMOD
  250 FORMAT (1H ,I4,4E15.5,I8,2E15.5,F11.4,E13.3)
C+    IF (J.EQ.NK) WRITE (6,260)
  260 FORMAT (1H+,127X,6H******)
  270 CONTINUE
      TSTEP1=0.02
      TSTEP2=TSTEP1*FLOAT(ND-1)/FLOAT(NC-1)
C+    WRITE (6,280)
  280 FORMAT(1H0/47H ****** INPUT ******     ********************** ,
     1   29HOUTPUT **********************/19H  TIME          VALUE,
     2   41H          TIME          VALUE          VELOCITY,
     3   17H     ACCELERATION)
C+    DO 300 J=1,JTOP
C+    T1=TSTEP1*FLOAT(J-1)
C+    T2=TSTEP2*FLOAT(J-1)
C+    IF(MOD(J,5).EQ.1) WRITE (6,240)
C+    WRITE (6,290) T1,HOLDY(J),T2,FUN(1,J),DFUN(1,J),DDFUN(1,J)
  290 FORMAT (1H ,F5.2,E15.5,F10.4,3E15.5)
  300 CONTINUE
      WRITE (6,310)
  310 FORMAT (1H0/50H FRAME      TIME                INPUT          FITTED,
     1   33H          RESIDUAL          RESID. //22H  NO.     (SECONDS)   ,
     2   51H      VALUE               VALUE          DIFFERENCE      ,
     3   13HSTD.DEVIATION/1H )
      YOYM=YO+YM
      STDEV=SQRT(SUMSQR(NK+1)/FLOAT(ND-NK-NK-3))
      RCHECK=0.
      SCHECK=0.
      DO 350 I=1,ND
      YCHECK=YOYM+GRAD*FLOAT(I)
      CI1=C*FLOAT(I-1)
      TIME=0.02*FLOAT(I-1)
```

I

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      DO 320 J=1,NK
      RJCI1=FLOAT(J)*CI1
      YCHECK=YCHECK+A(J)*COS(RJCI1)+B(J)*SIN(RJCI1)
  320 CONTINUE
      YDIFF=HOLDY(I)-YCHECK
      RATIO=YDIFF/STDEV
      RCHECK=RCHECK+RATIO
      SCHECK=SCHECK+RATIO*RATIO
      IF (ABS(RATIO).GT.2.3)
     1WRITE (6,330) I,TIME,HOLDY(I),YCHECK,YDIFF,RATIO
  330 FORMAT (1H ,I4,F13.3,E18.5,2E16.5,F13.2)
C*    IF (MOD(I,5).EQ.0) WRITE (6,330)
C*    IF (I.EQ.ND) GOTO 350
C*    IF (MOD(I,50).EQ.0) WRITE (6,340)
C*340 FORMAT (1H1/1H0)
  350 CONTINUE
      WRITE (6,360) RCHECK,SCHECK
  360 FORMAT (1H0,32X,35HSUMS OF RATIOS AND THEIR SQUARES  -,2F13.2)
      RETURN
      END


      SUBROUTINE TABLE1(ID,AJC,KJC,HJC,NF)
C
C IMPROVISED TABULATION OF JOINT CENTRE CO-ORDINATES.
C
      REAL KJC
      DIMENSION AJC(3,NF),KJC(3,NF),HJC(3,NF)
C
      LABEL=(ID.AND.7777 0077 0077 7777 7700B) .OR.
     +   0000 5000 5000 0000 0057B
      WRITE(6,100)
  100 FORMAT(1H1/1H ,20X,39HCARTESIAN CO-ORDINATES OF JOINT CENTRES)
      LINES=23
      DO 150 J=1,NF
      IF(J.EQ.1)WRITE(6,110)
  110 FORMAT(31H0FRAME      ******* ANKLE *******,4X
     +   21H******* KNEE *******,4X,21H******** HIP ********/
     +   5H  NO.,3(25H        X        Y        Z ))
      LINES=LINES+1
      IF(MOD(J,5).NE.1)GOTO 140
      WRITE(6,120)
  120 FORMAT(1H ,I4,2X,3F8.4,1X,3F8.4,1X,3F8.4,1X,2F8.4)
      LINES=LINES+1
      IF(LINES.LT.58) GOTO 140
      WRITE(6,130)LABEL
  130 FORMAT(1H1,A10)
      WRITE(6,110)
      WRITE(6,120)
      LINES=6
  140 SHANK=SQRT((AJC(1,J)-KJC(1,J))**2+(AJC(2,J)-KJC(2,J))**2+(AJC(3,J)
     1     -KJC(3,J))**2)
      THIGH=SQRT((KJC(1,J)-HJC(1,J))**2+(KJC(2,J)-HJC(2,J))**2+(KJC(3,J)
     1     -HJC(3,J))**2)
      WRITE(6,120)J,(AJC(K,J),K=1,3),(KJC(K,J),K=1,3),(HJC(K,J),K=1,3)
     1    ,SHANK,THIGH
  150 CONTINUE
      RETURN
      END


      SUBROUTINE TMAT(I,T,X,Y,Z)
      DIMENSION T(3,3),X(11,125),Y(11,125),Z(11,125)
      COMMON /BLOCK2/ AJC(3,125),KJC(3,125),SXL(3)
      COMMON /LADO/ LEFSID,ISIDE,JSIDE,LSIDE,JBIDE,LBIDE
      LOGICAL LEFSID
      VKMX=X((ISIDE+3),I)-X(JBIDE,I)
      VKMY=Y((ISIDE+3),I)-Y(JBIDE,I)
      VKMZ=Z((ISIDE+3),I)-Z(JBIDE,I)
      VLKX=X(JBIDE,I)-X(LBIDE,I)
      VLKY=Y(JBIDE,I)-Y(LBIDE,I)
      VLKZ=Z(JBIDE,I)-Z(LBIDE,I)
      S=-(VKMX*VLKX+VKMY*VLKY+VKMZ*VLKZ)/(VKMX*VKMX+VKMY*VKMY+VKMZ*VKMZ)
      CL1=-VLKX-S*VKMX
      CM1=-VLKY-S*VKMY
      CN1=-VLKZ-S*VKMZ
      CL=SQRT(CL1*CL1+CM1*CM1+CN1*CN1)
      T(1,1)=CL1/CL
      T(1,2)=CM1/CL
      T(1,3)=CN1/CL
      CM=SQRT(VKMX*VKMX+VKMY*VKMY+VKMZ*VKMZ)
      T(2,1)=VKMX/CM
      T(2,2)=VKMY/CM
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      T(2,3)=VKMZ/CM                                                    TMAT 230
      T(3,1)=T(1,2)*T(2,3)-T(1,3)*T(2,2)                                TMAT 240
      T(3,2)=T(1,3)*T(2,1)-T(1,1)*T(2,3)                                TMAT 250
      T(3,3)=T(1,1)*T(2,2)-T(1,2)*T(2,1)                                TMAT 260
      RETURN                                                            TMAT 270
      END                                                               TMAT 280


      SUBROUTINE TSTAT(T)                                               TSTAT 10
      DIMENSION T(3,3)                                                  TSTAT 20
      COMMON /BLOCK1/ SSX(10),SSY(10),SFZ(10)                           TSTAT 30
      COMMON /LADO/ LEFSID,ISIDE,JSIDE,LSIDE,JBIDE,LBIDE                TSTAT 40
      LOGICAL LEFSID                                                    TSTAT 50
      VKMX=SSX(ISIDE+3)-SSX(JSIDE)                                      TSTAT 60
      VKMY=SSY(ISIDE+3)-SSY(JSIDE)                                      TSTAT 70
      VKMZ=SFZ(ISIDE+3)-SFZ(JSIDE)                                      TSTAT 80
      VLKX=SSX(JSIDE)-SSX(LSIDE)                                        TSTAT 90
      VLKY=SSY(JSIDE)-SSY(LSIDE)                                        TSTAT100
      VLKZ=SFZ(JSIDE)-SFZ(LSIDE)                                        TSTAT110
      S=-(VKMX*VLKX+VKMY*VLKY+VKMZ*VLKZ)/(VKMX*VKMX+VKMY*VKMY+VKMZ*VKMZ)TSTAT120
      CL1=-VLKX-S*VKMX                                                  TSTAT130
      CM1=-VLKY-S*VKMY                                                  TSTAT140
      CN1=-VLKZ-S*VKMZ                                                  TSTAT150
      CL=CL1*CL1+CM1*CM1+CN1*CN1                                        TSTAT160
      CL=SQRT(CL)                                                       TSTAT170
      T(1,1)=CL1/CL                                                     TSTAT180
      T(1,2)=CM1/CL                                                     TSTAT190
      T(1,3)=CN1/CL                                                     TSTAT200
      CL2=VKMX                                                          TSTAT210
      CM2=VKMY                                                          TSTAT220
      CN2=VKMZ                                                          TSTAT230
      CM=CL2*CL2+CM2*CM2+CN2*CN2                                        TSTAT240
      CM=SQRT(CM)                                                       TSTAT250
      T(2,1)=CL2/CM                                                     TSTAT260
      T(2,2)=CM2/CM                                                     TSTAT270
      T(2,3)=CN2/CM                                                     TSTAT280
C                                                                       TSTAT290
C     THE CROSS PRODUCT TO DEFINE THE 3RD AXIS                          TSTAT300
C                                                                       TSTAT310
      T(3,1)=T(1,2)*T(2,3)-T(1,3)*T(2,2)                                TSTAT320
      T(3,2)=T(1,3)*T(2,1)-T(1,1)*T(2,3)                                TSTAT330
      T(3,3)=T(1,1)*T(2,2)-T(1,2)*T(2,1)                                TSTAT340
      RETURN                                                            TSTAT350
      END                                                               TSTAT360


      PROGRAM CHKRD (INPUT,OUTPUT,TAPE5=INPUT,TAPE6=OUTPUT)             CHKRD 10
      DIMENSION IR(8),IS(8),XUXU(10),ZUZU(10),IIR(13),IIS(13),          CHKRD 20
     1   XAXA(10),SSSX(8),SSSY(8),SSFZ(8)                               CHKRD 30
      DIMENSION X1(1320),Y1(1320),Z1(1560),Y2(1560)                     CHKRD 40
      DIMENSION IDENT(6)                                                CHKRD 50
      INTEGER SFRAME,FFRAME                                             CHKRD 60
      REAL IIR,IIS,IR,IS,KJC,KNEVEL,KNEACC                              CHKRD 70
      LOGICAL LEFSID,NEWMAN,QIDENT                                      CHKRD 80
      COMMON /CHECK/ NCHECK,NF,SFRAME,NSIDE,NFBY11,FFRAME,NFRONT,NFBY13 CHKRD 90
      DATA LAD02/3HKL1/                                                 CHKRD100
C                                                                       CHKRD110
C READ IN CONSTANTS FOR PATIENT, AND CALCULATE VECTOR LOCATING HIP-     CHKRD120
C     JOINT CENTRES FROM DISTANCE BETWEEN A.S.I.SPINES.                 CHKRD130
C                                                                       CHKRD140
  100 CALL INPCON(BH,BM,D67,D78,D86,IDENT(1),NEXTID)                    CHKRD150
      WRITE(6,110)IDENT(1)                                              CHKRD160
  110 FORMAT(35H1PATIENT CONSTANTS READ FROM DECK  ,A9,1H.)             CHKRD170
C                                                                       CHKRD180
C READ IN STATIC DATA FROM FILM OBSERVATIONS.                           CHKRD190
C                                                                       CHKRD200
      CALL INPKIN (IR,IS,NCHECK,IDENT(2),NEXTID)                        CHKRD210
      WRITE(6,120)IDENT(2)                                              CHKRD220
  120 FORMAT(35H STATIC SIDE DATA READ FROM DECK   ,A9,1H.)             CHKRD230
      IF(NCHECK.NE.8)CALL ABORT                                         CHKRD240
      CALL INPKIN (IIR,IIS,NCHECK,IDENT(3),NEXTID)                      CHKRD250
      WRITE(6,130)IDENT(3)                                              CHKRD260
  130 FORMAT(35H STATIC FRONT DATA READ FROM DECK  ,A9,1H.)             CHKRD270
      IF(NCHECK.NE.13)CALL ABORT                                        CHKRD280
C                                                                       CHKRD290
C READ FRAME NUMBERS FOR EVENTS, AND FRAME COUNT.                       CHKRD300
C                                                                       CHKRD310
  140 CALL INPKMK(LHS,LTO,NHS,NTO,NF,IDENT(4),NEXTID)                   CHKRD320
      WRITE(6,150)IDENT(4)                                              CHKRD330
  150 FORMAT(35H FRAME NUMBERS READ FROM DECK      ,A9,1H.)             CHKRD340
C                                                                       CHKRD350
C READ KINEMATIC DATA.   SFRAME IS THE NUMBER OF POINTS PER FRAME IN    CHKRD360
C     SIDE VIEW, INCLUDING THE FIRST THREE POINTS OF THE GRID.          CHKRD370
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C     FFRAME IS THE SAME FOR THE FRONT VIEW.   FOR EACH VIEW THE           CHKRD380
C     NUMBER OF FRAMES IS CHECKED AGAINST NF.                               CHKRD390
C                                                                           CHKRD400
      CALL INPKIN (X1,Y1,NSIDE,IDENT(5),NEXTID)                             CHKRD410
      WRITE(6,160)IDENT(5)                                                  CHKRD420
  160 FORMAT(35H DYNAMIC SIDE DATA READ FROM DECK  ,A9,1H.)                 CHKRD430
      SFRAME=11                                                             CHKRD440
      IF((NF*SFRAME).NE.NSIDE)CALL ABORT                                    CHKRD450
      CALL INPKIN(Z1,Y2,NFRONT,IDENT(6),NEXTID)                             CHKRD460
      WRITE(6,170)IDENT(6)                                                  CHKRD470
  170 FORMAT(35H DYNAMIC FRONT DATA READ FROM DECK ,A9,1H.)                 CHKRD480
      FFRAME=13                                                             CHKRD490
      IF((NF*FFRAME).NE.NFRONT)CALL ABORT                                   CHKRD500
C                                                                           CHKRD510
      IF(NEXTID.EQ.0)STOP                                                   CHKRD520
      IF(NEWMAN(IDENT(2),NEXTID))GOTO 100                                   CHKRD530
      WRITE(6,900)IDENT(1)                                                  CHKRD540
  900 FORMAT(35H0PATIENT CONSTANTS RETAINED FROM   ,A9,1H.)                 CHKRD550
      WRITE(6,910)IDENT(2)                                                  CHKRD560
  910 FORMAT(35H STATIC SIDE DATA RETAINED FROM    ,A9,1H.)                 CHKRD570
      WRITE(6,920)IDENT(3)                                                  CHKRD580
  920 FORMAT(35H STATIC FRONT DATA RETAINED FROM   ,A9,1H.)                 CHKRD590
      GOTO 140                                                              CHKRD600
      END                                                                   CHKRD610


      PROGRAM COMPARE(TAPE1,TAPE2,OUTPUT,TAPE6=OUTPUT)                      COMPAR10
C                                                                           COMPAR20
C COMPARES THE TWO CODED FILES TAPE1 AND TAPE2.   WRITES TO OUTPUT.        COMPAR30
C     LINE LENGTH PROCESSED IS 80 CHARACTERS.   NUMBER OF BAD LINES         COMPAR40
C     COMPARED IS LIMITED TO MAXBAD, SET ON LINE COMPAR90.                  COMPAR50
C                                                                           COMPAR60
      DIMENSION L1(8),L2(8)                                                 COMPAR70
      DATA LINCNT /  0 /                                                    COMPAR80
      DATA MAXBAD / 20 /                                                    COMPAR90
C                                                                           COMPA100
      REWIND 1                                                              COMPA110
      REWIND 2                                                              COMPA120
  100 READ (1,110) L1                                                       COMPA130
  110 FORMAT (8A10)                                                         COMPA140
      READ (2,110) L2                                                       COMPA150
      IF (EOF(1).NE.0.) GOTO 160                                            COMPA160
      IF (EOF(2).NE.0.) GOTO 190                                            COMPA170
      LINCNT=LINCNT+1                                                       COMPA180
      DO 120 J=1,8                                                          COMPA190
      IF (L1(J).NE.L2(J)) GOTO 130                                          COMPA200
  120 CONTINUE                                                              COMPA210
      GOTO 100                                                              COMPA220
  130 WRITE (6,140) LINCNT,L1,L2                                            COMPA230
  140 FORMAT (5H0LINE,I4,9H MISMATCH,4X,8A10/1H ,21X,8A10)                  COMPA240
      MAXBAD=MAXBAD-1                                                       COMPA250
      IF (MAXBAD.NE.0) GOTO 100                                             COMPA260
      WRITE (6,150)                                                         COMPA270
  150 FORMAT (22H0COMPARISON ABANDONED./1H0)                                COMPA280
      STOP                                                                  COMPA290
  160 IF (EOF(2).EQ.0.) GOTO 180                                            COMPA300
      WRITE (6,170) LINCNT                                                  COMPA310
  170 FORMAT (23H0COMPARISON COMPLETE.  ,I5,17H LINES PROCESSED./1H0)       COMPA320
      STOP                                                                  COMPA330
  180 NDIST=1                                                               COMPA340
      GOTO 200                                                              COMPA350
  190 NDIST=2                                                               COMPA360
  200 WRITE (6,210) NDIST,LINCNT                                            COMPA370
  210 FORMAT (24H0UNEQUAL LENGTHS.   FILE,I2,11H ENDS AFTER,I5,             COMPA380
     +   7H LINES./1H0)                                                     COMPA390
      STOP                                                                  COMPA400
      END                                                                   COMPA410


      SUBROUTINE CH11TB(NAMEX,NAMEY,X,Y,NDIM1,NDIM2)                        CH11TB10
C                                                                           CH11TB20
C TABULATES PAIRS OF CO-ORDINATES IN THE ARRAYS X(NDIM1,NDIM2) AND          CH11TB30
C     Y(NDIM1,NDIM2).   THE ACTUAL VALUES OF X(J,1),Y(J,1),J=1,NDIM1)       CH11TB40
C     ARE LISTED FIRST, FOLLOWED BY SCALED DIFFERENCES BETWEEN              CH11TB50
C     SUCCESSIVE CORRESPONDING ELEMENTS.   NDIM1 MUST BE .LE. 11.           CH11TB60
C                                                                           CH11TB70
C NAMEX, NAMEY ARE LEFT-JUSTIFIED CHARACTER STRINGS IDENTIFYING THE         CH11TB80
C     VARIABLES TABULATED.   A POSSIBLE CALL MIGHT HAVE THE FORM  -         CH11TB90
C                                                                           CH11T100
C             CALL CH11TB(5HXX123,5HYY312,XX123,YY312,9,120)                CH11T110
C                                                                           CH11T120
      DIMENSION LDIFFS(22),X(NDIM1,NDIM2),Y(NDIM1,NDIM2)                    CH11T130
      DATA IBLANK / 4H     /                                                CH11T140
```

```
C                                                                       CH11T150
      IF (NDIM1.LE.11) GOTO 110                                         CH11T160
      WRITE (6,100) NDIM1                                               CH11T170
  100 FORMAT (34HODIMENSION TOO LARGE FOR CHKTBL  =,I6)                 CH11T180
      RETURN                                                            CH11T190
C                                                                       CH11T200
  110 WRITE (6,120) NAMEX,NAMEY                                         CH11T210
  120 FORMAT (18H1ARRAY X HAS NAME ,A7,22H AND ARRAY Y HAS NAME ,A7/1H )CH11T220
      DO 140 J=1,NDIM1                                                  CH11T230
      WRITE (6,130) J,X(J,1),J,Y(J,1)                                   CH11T240
  130 FORMAT (3H0X(,I2,7H,1)    =,E15.6,15X,2HY(,I2,7H,1)    =,E15.6)   CH11T250
  140 CONTINUE                                                          CH11T260
      IF (NDIM2.EQ.1) RETURN                                            CH11T270
      DIFMAX=0.                                                         CH11T280
      DO 160 J=2,NDIM2                                                  CH11T290
      DO 150 K=1,NDIM1                                                  CH11T300
      DIFF=ABS(X(K,J)-X(K,(J-1)))                                       CH11T310
      IF (DIFF.GT.DIFMAX) DIFMAX=DIFF                                   CH11T320
      DIFF=ABS(Y(K,J)-Y(K,(J-1)))                                       CH11T330
      IF (DIFF.GT.DIFMAX) DIFMAX=DIFF                                   CH11T340
  150 CONTINUE                                                          CH11T350
  160 CONTINUE                                                          CH11T360
      AFACTR=ALOG10(999./DIFMAX)                                        CH11T370
      IF (AFACTR.LT.0.) AFACTR=AFACTR-1.                                CH11T380
      FACTOR=10.**INT(AFACTR)                                           CH11T390
C                                                                       CH11T400
      WRITE (6,170) FACTOR                                              CH11T410
  170 FORMAT (1H0/38H DIFFERENCES ARE TABULATED IN THE FORM,1PE7.0,     CH11T420
     +   42H*(X(J,N)-X(J,N-1)) IN THE FOLLOWING TABLE./1H )             CH11T430
      WRITE (6,180) (IBLANK,J,J,J=1,NDIM1)                              CH11T440
  180 FORMAT (4H  N ,9(A4,2HDX,I1,4H  DY,I1),2(A3,2HDX,I2,3H DY,I2))    CH11T450
      WRITE (6,200)                                                     CH11T460
      LTOP=NDIM1+NDIM1                                                  CH11T470
      LINES=LTOP+9                                                      CH11T480
      DO 220 J=2,NDIM2                                                  CH11T490
      DO 190 K=1,NDIM1                                                  CH11T500
      KK=K+K                                                            CH11T510
      LDIFFS(KK-1)=NEARST(FACTOR*(X(K,J)-X(K,(J-1))))                   CH11T520
      LDIFFS(KK)=NEARST(FACTOR*(Y(K,J)-Y(K,(J-1))))                     CH11T530
  190 CONTINUE                                                          CH11T540
      WRITE (6,200) J,(LDIFFS(L),L=1,LTOP)                              CH11T550
  200 FORMAT (1H ,I3,11(I7,I5))                                         CH11T560
      IF (MOD(J,5).NE.0) GOTO 220                                       CH11T570
      WRITE (6,200)                                                     CH11T580
      LINES=LINES+6                                                     CH11T590
      IF (LINES.LT.58) GOTO 220                                         CH11T600
      WRITE (6,210)                                                     CH11T610
  210 FORMAT (1H1)                                                      CH11T620
      WRITE (6,180) (IBLANK,L,L,L=1,NDIM1)                              CH11T630
      WRITE (6,200)                                                     CH11T640
      LINES=3                                                           CH11T650
  220 CONTINUE                                                          CH11T660
C                                                                       CH11T670
      WRITE (6,210)                                                     CH11T680
      RETURN                                                            CH11T690
      END                                                               CH11T700


      SUBROUTINE CH13TB(NAMEX,NAMEY,X,Y,NDIM1,NDIM2)                    CH13T810
C                                                                       CH13TA20
C TABULATES PAIRS OF CO-ORDINATES IN THE ARRAYS X(NDIM1,NDIM2) AND      CH13TB30
C     Y(NDIM1,NDIM2).   THE ACTUAL VALUES OF X(J,1),Y(J,1),J=1,NDIM1)   CH13TB40
C     ARE LISTED FIRST, FOLLOWED BY SCALED DIFFERENCES BETWEEN          CH13TH50
C     SUCCESSIVE CORRESPONDING ELEMENTS.   NDIM1 MUST BE .LE. 13.       CH13TH60
C                                                                       CH13TB70
C NAMEX, NAMEY ARE LEFT-JUSTIFIED CHARACTER STRINGS IDENTIFYING THE     CH13TH80
C     VARIABLES TABULATED.   A POSSIBLE CALL MIGHT HAVE THE FORM  -     CH13TB90
C                                                                       CH13T100
C             CALL CH13TB(5HXX123,5HYY312,XX123,YY312,13,120)           CH13T110
C                                                                       CH13T120
      DIMENSION LDIFFS(26),X(NDIM1,NDIM2),Y(NDIM1,NDIM2)                CH13T130
      DATA IBLANK / 4H     /                                            CH13T140
C                                                                       CH13T150
      IF (NDIM1.LE.13) GOTO 110                                         CH13T160
      WRITE (6,100) NDIM1                                               CH13T170
  100 FORMAT (34HODIMENSION TOO LARGE FOR CHKTBL  =,I6)                 CH13T180
      RETURN                                                            CH13T190
C                                                                       CH13T200
  110 WRITE (6,120) NAMEX,NAMEY                                         CH13T210
  120 FORMAT (18H1ARRAY X HAS NAME ,A7,22H AND ARRAY Y HAS NAME ,A7/1H )CH13T220
      DO 140 J=1,NDIM1                                                  CH13T230
      WRITE (6,130) J,X(J,1),J,Y(J,1)                                   CH13T240
  130 FORMAT (3H0X(,I2,7H,1)    =,E15.6,15X,2HY(,I2,7H,1)    =,E15.6)   CH13T250
```

```
  140 CONTINUE
      IF (NDIM2.EQ.1) RETURN
      DIFMAX=0.
      DO 160 J=2,NDIM2
      DO 150 K=1,NDIM1
      DIFF=ABS(X(K,J)-X(K,(J-1)))
      IF (DIFF.GT.DIFMAX) DIFMAX=DIFF
      DIFF=ABS(Y(K,J)-Y(K,(J-1)))
      IF (DIFF.GT.DIFMAX) DIFMAX=DIFF
  150 CONTINUE
  160 CONTINUE
      AFACTR=ALOG10(999./DIFMAX)
      IF (AFACTR.LT.0.) AFACTR=AFACTR-1.
      FACTOR=10.**INT(AFACTR)
C
      WRITE (6,170) FACTOR
  170 FORMAT (1H0/38H DIFFERENCES ARE TABULATED IN THE FORM,1PE7.0,
     +   42H*(X(J,N)-X(J,N-1)) IN THE FOLLOWING TABLE./1H )
      WRITE (6,180) (IBLANK,J,J,J=1,NDIM1)
  180 FORMAT (4H  N ,9(A2,2HDX,I1,4H  DY,I1),4(A1,2HDX,I2,3H DY,I2))
      WRITE (6,200)
      LTOP=NDIM1+NDIM1
      LINES=LTOP+9
      DO 220 J=2,NDIM2
      DO 190 K=1,NDIM1
      KK=K+K
      LDIFFS(KK-1)=NEARST(FACTOR*(X(K,J)-X(K,(J-1))))
      LDIFFS(KK)=NEARST(FACTOR*(Y(K,J)-Y(K,(J-1))))
  190 CONTINUE
      WRITE (6,200) J,(LDIFFS(L),L=1,LTOP)
  200 FORMAT (1H ,I3,13(I5,I5))
      IF (MOD(J,5).NE.0) GOTO 220
      WRITE (6,200)
      LINES=LINES+6
      IF (LINES.LT.58) GOTO 220
      WRITE (6,210)
  210 FORMAT (1H1)
      WRITE (6,180) (IBLANK,L,L,L=1,NDIM1)
      WRITE (6,200)
      LINES=3
  220 CONTINUE
C
      WRITE (6,210)
      RETURN
      END
```

```
      PROGRAM DRVFPD(INPUT,OUTPUT,TAPE5=INPUT,TAPE6=OUTPUT)
C
C DRIVES INPFPD/CALFPD/LISFPD TO PRODUCE FORCE-PLATE LISTINGS.
C
      DIMENSION X(1920)
  100 CALL INPFPD(X,NSETS,IDENT,NEXTID)
      NPNTS=6*NSETS
      CALL LISFPD(X,NSETS,IDENT,NPNTS)
      IF (NEXTID.NE.0) GOTO 100
      STOP
      END
```

```
      PROGRAM DRVQVT(INPUT,OUTPUT,TAPE5=INPUT,TAPE6=OUTPUT,TAPE8)
C
C        PULLS OFF FORCE PLATE DATA TO DRIVE QEVENT.
C
      DIMENSION X(3000)
  100 CALL INPFPD(X,NSETS,IDENT,NEXTID)
      WRITE (6,144) IDENT,EVNPT
  144 FORMAT (35HFORCE PLATE DATA READ FROM DECK    ,A9,1H.,10X,
     1       16HEVENT POINTER  =,F8.2)
      NPNTS=6*NSETS
      IF (NEXTID.NE.0) GOTO 100
      STOP
      END
```

```
      PROGRAM FIDDLE(TAPE5,TAPE6,OUTPUT)
C
C PROCESSES SOURCE DATA FOR NON-STANDARD DECKS S3KL1FULO AND S3KL1BDTO.
C     THESE HAVE ONLY TEN TARGETS PER FRAME AND ARE MODIFIED BY FIDDLE,
C     WHICH REPEATS THE FIRST TARGET CO-ORDINATES TO ESTABLISH AN
C     ELEVEN TARGET STRUCTURE.
C
C     FIDDLE READS AN UPDATE COMPILE FILE (USING INPKIN) AND WRITES
```

```
C     A NEW SOURCE FILE.
C
      DIMENSION X(2000),Y(2000),NX(2000),NY(2000)
  100 CALL INPKIN(X,Y,N,IDENT,NEXTID)
  110 WRITE(6,120)IDENT
  120 FORMAT(6H*DECK,,A9/1H /1H )
      DO 130 J=1,N
      NX(J)=NEARST(X(J))
      NY(J)=NEARST(Y(J))
  130 CONTINUE
      WRITE(6,140) (NX(J),NY(J),NX(J),NY(J),(NX(J+K),NY(J+K),K=1,9),
     +  J=1,N,10)
  140 FORMAT(12(1H+,I4,1X),1H )
      IF (NEXTID.NE.0) GOTO 100
      REWIND 6
      STOP
      END


      PROGRAM FPDTBL(INPUT,OUTPUT,TAPE8,TAPE5=INPUT,TAPE6=OUTPUT)
C
C LISTS FORCE-PLATE DATA, UNSMOOTHED BUT CONVERTED TO ABSOLUTE UNITS
C     AND SYNCHRONIZED.
C
C USES SUBROUTINES CALFPD,INPCON,INPFPD,INPKMK,NEARST,NEWMAN,QEVENT,
C     QIDENT
C
      DIMENSION EVNTPT(2),FP1(3000),FP2(3000),IDENT(4),MARK(4),
     1   MKLABL(4),NSYNCH(2)
      LOGICAL FUL,NEWMAN,QIDENT
      COMMON /FHLDBK/ FP2
      DATA GCONST    / 9.810 /
      DATA IBLANK    / 3H    /
      DATA IFUL      / 3HFUL /
      DATA MKLABL(1) / 3HLHS /
      DATA MKLABL(2) / 3HLTO /
      DATA MKLABL(3) / 3HRHS /
      DATA MKLABL(4) / 3HRTO /
  100 CALL INPCON(BH,BM,D67,D78,D86,IDENT(1),NEXTID)
      WRITE (6,110) IDENT(1)
  110 FORMAT(40H1PATIENT CONSTANTS READ FROM DECK       ,A9,1H.)
      BWT=BM*GCONST
  120 CALL INPFPD(FP2,NFPSET,IDENT(2),NEXTID,BM,EVNTPT(1))
      WRITE (6,130) IDENT(2),EVNTPT(1)
  130 FORMAT (40H0FIRST FORCE-PLATE DATA READ FROM DECK  ,A9,1H.,10X,
     1   16HEVENT POINTER =,F8.2)
      IF (NFPSET.LE.0) CALL ABORT
      DO 140 J=1,3000
      FP1(J)=FP2(J)
  140 CONTINUE
      CALL INPFPD(FP2,NFPSET,IDENT(3),NEXTID,BM,EVNTPT(2))
      WRITE (6,150) IDENT(3),EVNTPT(2)
  150 FORMAT (40H0SECOND FORCE-PLATE DATA READ FROM DECK ,A9,1H.,10X,
     1   16HEVENT POINTER  =,F8.2)
      IF (NFPSET.LE.0) CALL ABORT
      CALL INPKMK(MARK(1),MARK(2),MARK(3),MARK(4),NF,IDENT(4),NEXTID)
      WRITE (6,160) IDENT(4),MARK,NF
  160 FORMAT (40H0FRAME NUMBERS READ FROM DECK           ,A9,1H.,10X,
     1   5I8)
      FUL=QIDENT(IDENT(2),6,8,IFUL)
      IF (FUL) GOTO 170
      NSYNCH(1)=NEARST(EVNTPT(1)+0.5)-MARK(1)
      NSYNCH(2)=NEARST(EVNTPT(2)+0.5)-MARK(4)
      GOTO 180
  170 NSYNCH(1)=NEARST(EVNTPT(1)+0.5)-MARK(2)
      NSYNCH(2)=NEARST(EVNTPT(2)+0.5)-MARK(3)
  180 LABEL=(IDENT(2).AND.MASK(12)).OR.SHIFT(1R/,42).OR.
     1   SHIFT(IDENT(2).AND.77 7777 7700B,12)
      WRITE (6,190) LABEL,BM,BWT
  190 FORMAT (1H1/6(1H /),1H ,35X,5HCASE ,A7,8X,18HMASS OF PATIENT  =,
     1   F7.2,4H KG.,7X,9HWEIGHT  =,F7.1,8H NEWTONS/1H )
      WRITE (6,200)
  200 FORMAT (1H0,35X,45HCINE          ********* FORCE PLATE 1 *********,
     1   35H   ********* FORCE PLATE 2 *********/1H ,35X,11HFRAME EVENT,
     2   2(3(9H  FORCE  ),8H MOMENT )/1H ,35X,10H NO.      ,
     3   2(35H     X        Y        Z        Y )/1H )
      LINES=14
      DO 250 J=1,NF
      IMARK=IBLANK
      DO 210 K=1,4
      IF (J.EQ.MARK(K)) IMARK=MKLABL(K)
  210 CONTINUE
      J1=J+NSYNCH(1)
```

```
      J2=J+NSYNCH(2)
      WRITE (6,220) J,IMARK,FP1(J1),FP1(J1+500),FP1(J1+1000),
     1   FP1(J1+2000),FP2(J2),FP2(J2+500),FP2(J2+1000),FP2(J2+2000)
  220 FORMAT (1H ,35X,I4,3X,A3,2(3(F8.1,1X),F8.3))
      IF (MOD(J,5).NE.0) GOTO 250
      WRITE (6,230)
  230 FORMAT (1H )
      LINES=LINES+6
      IF (J.GE.(NF-1)) GOTO 250
      IF (LINES.LE.85) GOTO 250
      WRITE (6,240) LABEL
  240 FORMAT (1H1/6(1H /),1H ,35X,5HCASE ,A7,10H CONTINUED/1H )
      WRITE (6,200)
      LINES=14
  250 CONTINUE
      IF (LINES.LT.67) WRITE (6,260)
  260 FORMAT (1H1)
      IF (NEXTID.NE.0) GOTO 270
      WRITE (6,260)
      STOP
  270 IF (NEWMAN(IDENT(1),NEXTID)) GOTO 100
      WRITE (6,280) IDENT(1)
  280 FORMAT (40H1PATIENT CONSTANTS RETAINED FROM DECK    ,A9,1H.)
      GOTO 120
      END


      PROGRAM KINCHK(INPUT,OUTPUT,TAPE5=INPUT,TAPE6=OUTPUT)
C
C USES INPKIN TO READ DECKS OF KINEMATIC DATA AND THEN LISTS THEM WITH
C     CO-ORDINATE PAIRS FOR EACH MARKER ARRANGED IN COLUMNS.
C
C KINSMT AND KINREG ARE THEN CALLED TO SHOW UP DEVIANT POINTS IN THE
C     DATA SET.
C
C USES SUBROUTINES INPKIN, KINREG, KINSMT, AND QIDENT.
C
      DIMENSION IDENT(2),X(2000),Y(2000)
      INTEGER VALUES
      LOGICAL QIDENT,STATIC
      DATA IBLANK / 3H    /
      DATA IX     / 2H X  /
      DATA IXNEG  / 2H-X  /
      DATA IY     / 2H Y  /
      DATA IZ     / 2H Z  /
      DATA VALUES / 10H   VALUES  /
  100 CALL SIMKIN(X,Y,N,IDENT,NEXTID)
      STATIC=QIDENT(IDENT,6,9,4HSTAT)
      NCOLS=11
      IF (STATIC) NCOLS=8
      L1=IX
      L2=IY
      IF (.NOT.QIDENT(IDENT,3,5,3HKR2)) GOTO 110
      L1=IXNEG
      GOTO 120
  110 IF (.NOT.QIDENT(IDENT,3,5,3HKF3)) GOTO 120
      L1=IZ
      NCOLS=13
      IF (STATIC) NCOLS=11
  120 NFRAME=N/NCOLS
      WRITE (6,130) IDENT(1)
  130 FORMAT (1H1/10H DECKNAME ,A9/1H )
      WRITE (6,140) N,NFRAME
  140 FORMAT (25H0NUMBER OF POINTS READ  =,I6,15X,
     +   33HCORRESPONDING NUMBER OF FRAMES  =,I5)
      IF ((NFRAME*NCOLS).NE.N) WRITE (6,150)
  150 FORMAT (1H+,98X,33HWARNING  -  PRODUCT IS NOT EXACT.)
      NF=1
      NFIRST=1
      NLAST=8
  160 NLINES=8
      JFIRST=NFIRST
      JLAST=NLAST
  170 WRITE (6,180) (IBLANK,J,J=NFIRST,NLAST)
  180 FORMAT (6H0FRAME,8(A3,9H* MARKER ,I2,2H *))
      WRITE (6,190) (L1,L2,J=NFIRST,NLAST)
  190 FORMAT (6H  NO. ,8(5X,A2,4X,A2,3X))
      WRITE (6,200)
  200 FORMAT (1H )
  210 WRITE (6,220) NF,(X(J),Y(J),J=JFIRST,JLAST)
  220 FORMAT (1H ,I4,8(4X,2F6.0))
      IF (MOD(NF,5).NE.0) GOTO 230
      WRITE (6,200)
```

```
      NLINES=NLINES+6                                                   KINCH570
  230 NF=NF+1                                                           KINCH580
      JFIRST=JFIRST+NCOLS                                               KINCH590
      IF (JFIRST.GT.N) GOTO 260                                         KINCH600
      JLAST=JLAST+NCOLS                                                 KINCH610
      IF (JLAST.GT.N) JLAST=N                                           KINCH620
      IF (NLINES.LT.59) GOTO 210                                        KINCH630
  240 WRITE (6,130) IDENT(1)                                            KINCH640
      NLINES=6                                                          KINCH650
      IF (NF.NE.1) GOTO 170                                             KINCH660
      WRITE (6,250)                                                     KINCH670
  250 FORMAT (1H0)                                                      KINCH680
      GOTO 160                                                          KINCH690
  260 IF (NLAST.EQ.NCOLS) GOTO 280                                      KINCH700
      NF=1                                                              KINCH710
      NFIRST=9                                                          KINCH720
      NLAST=NCOLS                                                       KINCH730
      IF (.NOT.STATIC) GOTO 240                                         KINCH740
      WRITE (6,270) IDENT(1)                                            KINCH750
  270 FORMAT (5(1H0/),10H DECKNAME ,A9/1H )                             KINCH760
      GOTO 160                                                          KINCH770
  280 WRITE (6,130) IDENT(1)                                            KINCH780
      IDENT(2)=SHIFT(((L1.AND.MASK(12)).OR.(VALUES.AND.                 KINCH790
     1   (.NOT.MASK(12)))),54)                                          KINCH800
      CALL KINSMT(IDENT,NCOLS,NFRAME,X,10)                              KINCH810
      IDENT(2)=SHIFT(((L2.AND.MASK(12)).OR.(VALUES.AND.                 KINCH820
     1   (.NOT.MASK(12)))),54)                                          KINCH830
      CALL KINSMT(IDENT,NCOLS,NFRAME,Y,10)                              KINCH840
      IF (NEXTID.EQ.0) STOP                                             KINCH850
      GOTO 100                                                          KINCH860
      END                                                               KINCH870


      PROGRAM KINREF(INPUT,OUTPUT,TAPE5=INPUT,TAPE6=OUTPUT)             KINREF10
C                                                                       KINREF20
C MEAN VALUES FOR REFERENCE MARKERS.   FOR USE ON PI/FULO.              KINREF30
C                                                                       KINREF40
      DIMENSION X(1600),Y(1600),SX(3),SY(3)                             KINREF50
      LOGICAL QIDENT                                                    KINREF60
  100 CALL INPKIN(X,Y,N,IDENT,NEXTID)                                   KINREF70
      NSTEP=11                                                          KINREF80
      IF (QIDENT(IDENT,4,5,2HF3)) NSTEP=13                              KINREF90
      DO 110 J=1,3                                                      KINRE100
      SX(J)=0.                                                          KINRE110
      SY(J)=0.                                                          KINRE120
  110 CONTINUE                                                          KINRE130
      NPNTS=0                                                           KINRE140
      DO 130 K=1,N,NSTEP                                                KINRE150
      DO 120 J=1,3                                                      KINRE160
      SX(J)=SX(J)+X(K+J-1)                                              KINRE170
      SY(J)=SY(J)+Y(K+J-1)                                              KINRE180
  120 CONTINUE                                                          KINRE190
      NPNTS=NPNTS+1                                                     KINRE200
  130 CONTINUE                                                          KINRE210
      WRITE (6,140)IDENT,(SX(J),SY(J),J=1,3)                            KINRE220
  140 FORMAT (1H0/1H0,A9,3(2F12.1,6X))                                  KINRE230
      FACTOR=1./FLOAT(NPNTS)                                            KINRE240
      DO 150 J=1,3                                                      KINRE250
      SX(J)=FACTOR*SX(J)                                                KINRE260
      SY(J)=FACTOR*SY(J)                                                KINRE270
  150 CONTINUE                                                          KINRE280
      WRITE (6,160)N,(SX(J),SY(J),J=1,3),NPNTS                          KINRE290
  160 FORMAT (1H0,I9,1X,3(2F12.2,6X),I10)                               KINRE300
      IF (NEXTID.NE.0) GOTO 100                                         KINRE310
      STOP                                                              KINRE320
      END                                                               KINRE330


      SUBROUTINE KINREG(NOSBDI,ND,YEXT,NK)                              KINREG10
      DIMENSION YEXT(NOSBDI,ND)                                         KINREG20
      DIMENSION SUMCY(30),SUMSY(30)                                     KINREG30
      DIMENSION A(30),B(30),SUMSQR(31)                                  KINREG40
      REAL ICPEXT                                                       KINREG50
      COMMON /SMOOTH/ A,B,C,COVERT,GRAD,GRDEXT,ICPEXT,STEP,SUMSQR,YM,YO KINREG60
      DATA T     / 0.020000000 /                                        KINREG70
      DATA TWOPI / 6.283185307 /                                        KINREG80
      N=ND-1                                                            KINREG90
      RINT=FLOAT(N)                                                     KINRE100
      NA=NK                                                             KINRE110
      C=TWOPI/RINT                                                      KINRE120
      COVERT=C/T                                                        KINRE130
      GRAD=(YEXT(1,ND)-YEXT(1,1))/RINT                                  KINRE140
      STEP=(YEXT(1,ND)-YEXT(1,1))                                       KINRE150
```

```
      GRAD=STEP/RINT                                                    KINRE160
      Y0=YEXT(1,1)-GRAD                                                 KINRE170
      SUMY=0.                                                           KINRE180
      SUMYSQ=0.                                                         KINRE190
      DO 100 K=1,NA                                                     KINRE200
      SUMCY(K)=0.                                                       KINRE210
      SUMSY(K)=0.                                                       KINRE220
  100 CONTINUE                                                          KINRE230
      DO 120 I=1,N                                                      KINRE240
      YI=YEXT(1,I)-Y0-GRAD*FLOAT(I)                                     KINRE250
      SUMY=SUMY+YI                                                      KINRE260
      SUMYSQ=SUMYSQ+YI*YI                                               KINRE270
      XI=C*FLOAT(I-1)                                                   KINRE280
      DO 110 K=1,NA                                                     KINRE290
      ARG=K*XI                                                          KINRE300
      SUMCY(K)=SUMCY(K)+COS(ARG)*YI                                     KINRE310
      SUMSY(K)=SUMSY(K)+SIN(ARG)*YI                                     KINRE320
  110 CONTINUE                                                          KINRE330
  120 CONTINUE                                                          KINRE340
      YM=SUMY/RINT                                                      KINRE350
      CYY=SUMYSQ-SUMY*YM                                                KINRE360
      SUMSQR(1)=CYY                                                     KINRE370
      DO 130 K=1,NA                                                     KINRE380
      A(K)=SUMCY(K)*(2./RINT)                                           KINRE390
      B(K)=SUMSY(K)*(2./RINT)                                           KINRE400
      CYY=CYY-A(K)*SUMCY(K)-B(K)*SUMSY(K)                               KINRE410
      SUMSQR(K+1)=CYY                                                   KINRE420
  130 CONTINUE                                                          KINRE430
      ICPEXT=YEXT(1,1)+YM                                               KINRE440
      GRDEXT=GRAD/T                                                     KINRE450
      RETURN                                                            KINRE460
      END                                                               KINRE470


      SUBROUTINE KINSMT(LABEL,NDSBD1,ND,Y,NK)                           KINSMT10
C                                                                       KINSMT20
C PROVIDES AN INTERFACE THROUGH WHICH THE HARMONIC ANALYSIS ROUTINE     KINSMT30
C     KINREG IS CALLED, TO PROVIDE CHECKING OF KINEMATIC DATA.          KINSMT40
C                                                                       KINSMT50
      DIMENSION LABEL(2),Y(NDSBD1,ND)                                   KINSMT60
      DIMENSION A(30),B(30),SUMSQR(31)                                  KINSMT70
      REAL ICPEXT                                                       KINSMT80
      COMMON /SMOOTH/ A,B,C,COVERT,GRAD,GRDEXT,ICPEXT,STEP,SUMSQR,YM,Y0 KINSMT90
C                                                                       KINSM100
      WRITE (6,90)                                                      KINSM110
   90 FORMAT (1H0)                                                      KINSM120
      WRITE (6,100) LABEL                                               KINSM130
  100 FORMAT (52H SMOOTHING AND DIFFERENTIATION BY FOURIER REGRESSION,  KINSM140
     1   16H    -   DECKNAME ,2A10)                                     KINSM150
      IF (NK.EQ.0) NK=NEARST(FLOAT(ND-1)/20.)                           KINSM160
      WRITE (6,160)                                                     KINSM170
  160 FORMAT (1H0/50H FRAME     MARKER             INPUT          FITTED,KINSM180
     1   33H          RESIDUAL         RESID. //22H  NO.         NO.    ,KINSM190
     2   51H       VALUE             VALUE          DIFFERENCE     ,    KINSM200
     3   13HSTD.DEVIATION/1H )                                          KINSM210
      DO 200 JCOLS=1,NDSBD1                                             KINSM220
      CALL KINREG(NDSBD1,ND,Y(JCOLS,1),NK)                              KINSM230
      Y0YM=Y0+YM                                                        KINSM240
      STDEV=SQRT(SUMSQR(NK+1)/FLOAT(ND-NK-NK-3))                        KINSM250
      DO 190 I=1,ND                                                     KINSM260
      YCHECK=Y0YM+GRAD*FLOAT(I)                                         KINSM270
      CI1=C*FLOAT(I-1)                                                  KINSM280
      DO 170 J=1,NK                                                     KINSM290
      RJCI1=FLOAT(J)*CI1                                                KINSM300
      YCHECK=YCHECK+A(J)*COS(RJCI1)+B(J)*SIN(RJCI1)                     KINSM310
  170 CONTINUE                                                          KINSM320
      YDIFF=Y(JCOLS,I)-YCHECK                                           KINSM330
      RATIO=YDIFF/STDEV                                                 KINSM340
      IF (ABS(RATIO).GT.2.3)                                            KINSM350
     1   WRITE (6,180) I,JCOLS,Y(JCOLS,I),YCHECK,YDIFF,RATIO            KINSM360
  180 FORMAT (1H ,I4,I10,3X,E18.5,2E16.5,F13.2)                         KINSM370
  190 CONTINUE                                                          KINSM380
  200 CONTINUE                                                          KINSM390
      RETURN                                                            KINSM400
      END                                                               KINSM410


      PROGRAM KMKCHK(TAPE5,OUTPUT,TAPE6=OUTPUT)                         KMKCHK10
C                                                                       KMKCHK20
      LOGICAL FUL,OIDENT                                                KMKCHK30
C                                                                       KMKCHK40
      WRITE (6,100)                                                     KMKCHK50
      LINES=0                                                           KMKCHK60
```

```
  100 FORMAT (50H1   IDENT         LHS        LTO        RHS        RTO,      KMKCHK70
     +   13H     NFRAMES /1H )                                              KMKCHK80
  110 CALL INPKMK(LHS,LTO,NHS,NTO,NF,ID,NEXTID)                             KMKCHK90
      FUL=QIDENT(ID,6,8,3HFUL)                                              KMKCH100
      WRITE (6,120) ID,LHS,LTO,NHS,NTO,NF                                   KMKCH110
  120 FORMAT (1H ,A9,5I10)                                                  KMKCH120
      LINES=LINES+1                                                         KMKCH130
      IF (MOD(LINES,5).EQ.0) WRITE (6,120)                                  KMKCH140
      IF (LHS.LT.0) WRITE (6,130)                                           KMKCH150
  130 FORMAT (1H+,60X,6(10H**********))                                     KMKCH160
      IF (NHS.LE.NTO) WRITE (6,130)                                         KMKCH170
      IF (LHS.LE.LTO) WRITE (6,130)                                         KMKCH180
      IF (FUL) GOTO 140                                                     KMKCH190
      IF (NTO.LE.LHS) WRITE (6,130)                                         KMKCH200
      IF (NF.LE.NHS) WRITE (6,130)                                          KMKCH210
      GOTO 150                                                              KMKCH220
  140 IF (LTO.LE.NHS) WRITE (6,130)                                         KMKCH230
      IF (NF.LE.LHS) WRITE (6,130)                                          KMKCH240
  150 IF (NEXTID.NE.0) GOTO 110                                             KMKCH250
      STOP                                                                  KMKCH260
      END                                                                   KMKCH270


      SUBROUTINE LISFPD(X,NSETS,IDENT,NPNTS)                                LISFPD10
C                                                                           LISFPD20
C LISTS FORCE PLATE DATA FROM INPFPD                                        LISFPD30
C                                                                           LISFPD40
      DIMENSION X(NPNTS)                                                    LISFPD50
C                                                                           LISFPD60
      J=1                                                                   LISFPD70
  100 WRITE (6,110) IDENT                                                   LISFPD80
  110 FORMAT (17H1****** DECKNAME ,A9,7H ******)                            LISFPD90
      IF (J.NE.1) WRITE (6,120)                                             LISFP100
  120 FORMAT (1H+,33X,10HCONTINUED.)                                        LISFP110
      WRITE (6,130)                                                         LISFP120
  130 FORMAT (52H0POINT     ************* FORCES (NEWTONS) ***********,     LISFP130
     1    46H      ********* MOMENTS (NEWTON METRES *********/7H  NO.  ,    LISFP140
     2    2(46H    X-COMPONENT    Y-COMPONENT    Z-COMPONENT )/1H )         LISFP150
      NLINES=5                                                              LISFP160
  140 WRITE (6,150) J,(X(K),K=J,NPNTS,NSETS)                                LISFP170
  150 FORMAT (1H ,I4,2(3X,3(F12.5,1X)))                                     LISFP180
      J=J+1                                                                 LISFP190
      IF (J.GT.NSETS) RETURN                                                LISFP200
      IF (MOD(J,5).NE.1) GOTO 140                                           LISFP210
      NLINES=NLINES+6                                                       LISFP220
      IF (NLINES.GT.57) GOTO 100                                            LISFP230
      WRITE (6,160)                                                         LISFP240
  160 FORMAT (1H )                                                          LISFP250
      GOTO 140                                                              LISFP260
      END                                                                   LISFP270


      PROGRAM LISKIN(INPUT,OUTPUT,TAPE5=INPUT,TAPE6=OUTPUT)                 LISKN 10
C                                                                           LISKN 20
C USES INPKIN TO READ DECKS OF KINEMATIC DATA AND THEN LISTS THEM WITH      LISKN 30
C     CO-ORDINATE PAIRS FOR EACH MARKER ARRANGED IN COLUMNS.                LISKN 40
C                                                                           LISKN 50
C USES SUBROUTINES QIDENT AND INPKIN.                                       LISKN 60
C                                                                           LISKN 70
      DIMENSION X(2000),Y(2000)                                             LISKN 80
      LOGICAL QIDENT,STATIC                                                 LISKN 90
      DATA IBLANK / 3H    /                                                 LISKN100
      DATA IX     / 2H X  /                                                 LISKN110
      DATA IXNEG  / 2H-X  /                                                 LISKN120
      DATA IY     / 2H Y  /                                                 LISKN130
      DATA IZ     / 2H Z  /                                                 LISKN140
  100 CALL INPKIN(X,Y,N,IDENT,NEXTID)                                       LISKN150
      STATIC=QIDENT(IDENT,6,9,4HSTAT)                                       LISKN160
      NCOLS=11                                                              LISKN170
      IF (STATIC) NCOLS=8                                                   LISKN180
      L1=IX                                                                 LISKN190
      L2=IY                                                                 LISKN200
      IF (.NOT.QIDENT(IDENT,3,5,3HKR2)) GOTO 110                            LISKN210
      L1=IXNEG                                                              LISKN220
      GOTO 120                                                              LISKN230
  110 IF (.NOT.QIDENT(IDENT,3,5,3HKF3)) GOTO 120                            LISKN240
      L1=IZ                                                                 LISKN250
      NCOLS=13                                                              LISKN260
      IF (STATIC) NCOLS=11                                                  LISKN270
  120 NFRAME=N/NCOLS                                                        LISKN280
      WRITE (6,130) IDENT                                                   LISKN290
  130 FORMAT (1H1/10H DECKNAME ,A9/1H )                                     LISKN300
      WRITE (6,140) N,NFRAME                                                LISKN310
```

```
  140 FORMAT (25H0NUMBER OF POINTS READ  =,I6,15X,                       LISKN320
     +    33HCORRESPONDING NUMBER OF FRAMES  =,I5)                       LISKN330
      IF ((NFRAME*NCOLS).NE.N) WRITE (6,150)                             LISKN340
  150 FORMAT (1H+,98X,33HWARNING  -  PRODUCT IS NOT EXACT.)              LISKN350
      NF=1                                                               LISKN360
      NFIRST=1                                                           LISKN370
      NLAST=8                                                            LISKN380
  160 NLINES=8                                                           LISKN390
      JFIRST=NFIRST                                                      LISKN400
      JLAST=NLAST                                                        LISKN410
  170 WRITE (6,180) (IBLANK,J,J=NFIRST,NLAST)                            LISKN420
  180 FORMAT (6H0FRAME,8(A3,9H* MARKER ,I2,2H *))                        LISKN430
      WRITE (6,190) (L1,L2,J=NFIRST,NLAST)                               LISKN440
  190 FORMAT (6H  NO. ,8(5X,A2,4X,A2,3X))                                LISKN450
      WRITE (6,200)                                                      LISKN460
  200 FORMAT (1H )                                                       LISKN470
  210 WRITE (6,220) NF,(X(J),Y(J),J=JFIRST,JLAST)                        LISKN480
  220 FORMAT (1H ,I4,8(4X,2F6.0))                                        LISKN490
      IF (MOD(NF,5).NE.0) GOTO 230                                       LISKN500
      WRITE (6,200)                                                      LISKN510
      NLINES=NLINES+6                                                    LISKN520
  230 NF=NF+1                                                            LISKN530
      JFIRST=JFIRST+NCOLS                                                LISKN540
      IF (JFIRST.GT.N) GOTO 260                                          LISKN550
      JLAST=JLAST+NCOLS                                                  LISKN560
      IF (JLAST.GT.N) JLAST=N                                            LISKN570
      IF (NLINES.LT.59) GOTO 210                                         LISKN580
  240 WRITE (6,130) IDENT                                                LISKN590
      NLINES=6                                                           LISKN600
      IF (NF.NE.1) GOTO 170                                              LISKN610
      WRITE (6,250)                                                      LISKN620
  250 FORMAT (1H0)                                                       LISKN630
      GOTO 160                                                           LISKN640
  260 IF (NLAST.EQ.NCOLS) GOTO 280                                       LISKN650
      NF=1                                                               LISKN660
      NFIRST=9                                                           LISKN670
      NLAST=NCOLS                                                        LISKN680
      IF (.NOT.STATIC) GOTO 240                                          LISKN690
      WRITE (6,270) IDENT                                                LISKN700
  270 FORMAT (5(1H0/),10H DECKNAME ,A9/1H )                              LISKN710
      GOTO 160                                                           LISKN720
  280 IF (NEXTID.EQ.0) STOP                                              LISKN730
      GOTO 100                                                           LISKN740
      END                                                                LISKN750


      SUBROUTINE SIMKIN(X,Y,N,IDENT,NEXTID)                              SIMKIN10
C                                                                        SIMKIN20
C READS X AND Y CO-ORDINATES COMPRISING KINETIC DATA, FROM UPDATE        SIMKIN30
C     COMPILE FILE.  DATA ARE READ IN SEQUENCE X(1),Y(1),X(2),Y(2),      SIMKIN40
C     . . . X(N),Y(N).   X AND Y DATA ARE ON STREAM 5 IN FORMAT          SIMKIN50
C     J(I5,1X,I5,1X) WHERE 0.LE.J.LE.6.   DECK NAME IS READ FROM COLS.   SIMKIN60
C     74 TO 82 AND IS RETURNED IN A9 FORMAT AS IDENT.   READING STOPS    SIMKIN70
C     WHEN A NEW DECK IDENTIFIER IS FOUND AND THIS IS RETURNED AS        SIMKIN80
C     NEXTID.   N CONTAINS NUMBER OF PAIRS READ.   TO AVOID LOSS OF      SIMKIN90
C     DATA AND OTHER PROBLEMS THE FIRST LINE OF EACH DECK SHOULD BE      SIMKI100
C     BLANK.   IF END-OF-FILE IS READ NEXTID IS SET TO ZERO.             SIMKI110
C                                                                        SIMKI120
C NOTE THAT THIS IS AN EARLY AND SIMPLE VERSION OF INPKIN.               SIMKI130
C                                                                        SIMKI140
      DIMENSION X(1400),Y(1400),LINE(12),LNCH(6)                         SIMKI150
      LOGICAL FIRST,QIDENT                                               SIMKI160
      DATA IBLANK / 6H      /                                            SIMKI170
C                                                                        SIMKI180
      NLOC=0                                                             SIMKI190
      FIRST=.TRUE.                                                       SIMKI200
      IDENT=0                                                            SIMKI210
C                                                                        SIMKI220
  100 READ (5,110) LNCH,LINE,NXTLOC                                      SIMKI230
  110 FORMAT (6(6X,A6),T1,12(I5,1X),1X,A9)                               SIMKI240
      IF (EOF(5).NE.0.) GOTO 140                                         SIMKI250
      IF (.NOT.FIRST) GOTO 120                                           SIMKI260
      FIRST=.FALSE.                                                      SIMKI270
      IDLOC=NXTLOC                                                       SIMKI280
      IDENT=NXTLOC                                                       SIMKI290
  120 IF (NXTLOC.EQ.IDLOC) GOTO 124                                      SIMKI300
      IF (.NOT.QIDENT(NXTLOC,1,5,5HKCORR)) GOTO 150                      SIMKI310
  124 DO 130 K=1,6                                                       SIMKI320
      IF (LNCH(K).EQ.IBLANK) GOTO 100                                    SIMKI330
      NLOC=NLOC+1                                                        SIMKI340
      X(NLOC)=FLOAT(LINE(2*K-1))                                         SIMKI350
      Y(NLOC)=FLOAT(LINE(2*K))                                           SIMKI360
  130 CONTINUE                                                           SIMKI370
```

```
      GOTO 100                                                          SIMKI380
C                                                                       SIMKI390
  140 NXTLOC=0                                                          SIMKI400
  150 NEXTID=NXTLOC                                                     SIMKI410
      N=NLOC                                                            SIMKI420
      RETURN                                                            SIMKI430
      END                                                               SIMKI440


      PROGRAM TESFPD(INPUT,OUTPUT,TAPE7,TAPE5=INPUT,TAPE6=OUTPUT)       TESFPD10
C                                                                       TESFPD20
C TESTS INPFPD.                                                         TESFPD30
C                                                                       TESFPD40
      DIMENSION X(1920)                                                 TESFPD50
C                                                                       TESFPD60
      CALL CONNEC(7)                                                    TESFPD70
  100 CALL INPFPD(X,N,ID,NX)                                            TESFPD80
      WRITE (6,110) N,ID,NX                                             TESFPD90
  110 FORMAT (1H1/1H0,I5,33H SETS OF 6 VALUES READ FROM DECK ,A9,1H.,   TESFP100
     +  10X,14H(NEXT DECK IS ,A9,2H.)/1H0)                              TESFP110
      IF (N.GT.0) GOTO 140                                              TESFP120
      WRITE (7,120) ID                                                  TESFP130
  120 FORMAT (15H0ERROR IN DECK ,A9,1H./1H )                            TESFP140
      WRITE (6,130)                                                     TESFP150
  130 FORMAT (16H ERROR FLAG SET./1H0)                                  TESFP160
      GOTO 190                                                          TESFP170
C                                                                       TESFP180
  140 WRITE (6,150)                                                     TESFP190
  150 FORMAT (1H ,3X,4HF(X),6X,4HF(Y),6X,4HF(Z),6X,4HM(X),6X,4HM(Y),    TESFP200
     +   6X,4HM(Z)/1H0)                                                 TESFP210
      NV=6*N                                                            TESFP220
      DO 170 J=1,N                                                      TESFP230
      WRITE (6,160) (X(K),K=J,NV,N)                                     TESFP240
  160 FORMAT (1H ,6(F8.0,2X))                                           TESFP250
  170 CONTINUE                                                          TESFP260
      WRITE (7,180) ID                                                  TESFP270
  180 FORMAT (6H0DECK ,A9,20H READ WITHOUT ERROR./1H )                  TESFP280
  190 IF (NX.NE.0) GOTO 100                                             TESFP290
      STOP                                                              TESFP300
      END                                                               TESFP310


      PROGRAM TESKIN(INPUT,OUTPUT,TAPE5=INPUT,TAPE6=OUTPUT)             TESKIN10
C                                                                       TESKIN20
C TESTS INPKIN.                                                         TESKIN30
C                                                                       TESKIN40
      DIMENSION A(1400),B(1400)                                         TESKIN50
      COMMON A,B                                                        TESKIN60
  100 CALL INPKIN(A,B,NPAIRS,ID,NEXT)                                   TESKIN70
      WRITE (6,110) NPAIRS,ID,NEXT                                      TESKIN80
  110 FORMAT (1H1/1H0,I5,26H PAIRS X,Y READ FROM DECK ,A9,1H.,10X,      TESKIN90
     +   15H(NEXT IDENT IS ,A9,2H.)/1H0)                                TESKI100
      NTOP=NPAIRS                                                       TESKI110
      IF (NTOP.GT.36) NTOP=18                                           TESKI120
      WRITE (6,120) (A(J),B(J),J=1,NTOP)                                TESKI130
  120 FORMAT (6(1H ,2F8.0,2X))                                          TESKI140
      IF (NTOP.EQ.NPAIRS) GOTO 140                                      TESKI150
      WRITE (6,130)                                                     TESKI160
  130 FORMAT (20H0    ETCETERA, TO  -/1H )                              TESKI170
      NLOW=6*(NPAIRS/6)-5                                               TESKI180
      WRITE (6,120) (A(J),B(J),J=NLOW,NPAIRS)                           TESKI190
  140 IF (NEXT.NE.0) GOTO 100                                           TESKI200
      STOP                                                              TESKI210
      END                                                               TESKI220


      PROGRAM TRYQEV(QEVDAT,OUTPUT,TAPE5=QEVDAT,TAPE6=OUTPUT)           TRYQEV10
C                                                                       TRYQEV20
C TESTS SUBROUTINE QEVENT.                                              TRYQEV30
C                                                                       TRYQEV40
      DIMENSION X(15),Y(15),Z(15,6)                                     TRYQEV50
      LOGICAL FORWRD                                                    TRYQEV60
      IDENT=9H**FP1BDT*                                                 TRYQEV70
      FORWRD=.TRUE.                                                     TRYQEV80
  100 READ (5,110) X                                                    TRYQEV90
  110 FORMAT (15F5.0)                                                   TRYQE100
      IF (EOF(5).EQ.0.) GOTO 120                                        TRYQE110
      IF (.NOT.FORWRD) STOP                                             TRYQE120
      FORWRD=.FALSE.                                                    TRYQE130
      IDENT=9H**FP1FUL*                                                 TRYQE140
      REWIND 5                                                          TRYQE150
      GOTO 100                                                          TRYQE160
  120 DO 140 J=1,15                                                     TRYQE170
```

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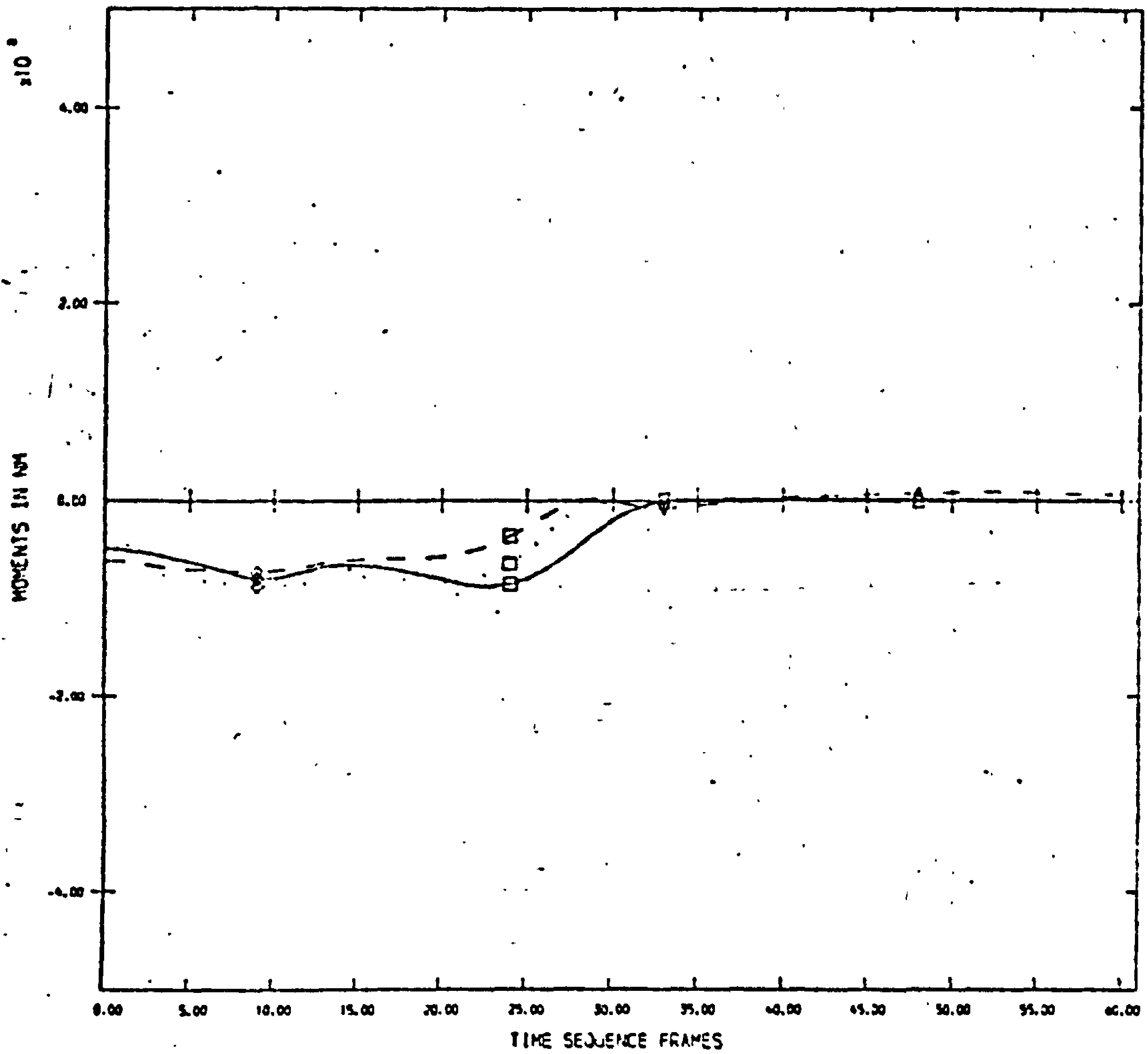
      JJ=J                                                              TRYQE180
      IF (.NOT.FORWRD) JJ=16-J                                          TRYQE190
      Y(J)=X(JJ)                                                        TRYQE200
      DO 130 K=1,6                                                      TRYQE210
      Z(J,K)=Y(J)                                                       TRYQE220
  130 CONTINUE                                                          TRYQE230
  140 CONTINUE                                                          TRYQE240
      WRITE (6,150)                                                     TRYQE250
  150 FORMAT (1H0/1H )                                                  TRYQE260
      CALL QEVENT(Z,15,IDENT,2.000000001,EVNTPT)                        TRYQE270
      WRITE (6,160) IDENT,EVNTPT                                        TRYQE280
  160 FORMAT(1H0,A9,F12.3)                                              TRYQE290
      WRITE (6,170) Y,Z                                                 TRYQE300
  170 FORMAT (1H0,15F8.4)                                               TRYQE310
      GOTO 100                                                          TRYQE320
      END                                                               TRYQE330

      PROGRAM UPEDBK(TAPE1,TAPE2,OUTPUT,TAPE6=OUTPUT)                   UPEDBK10
C                                                                       UPEDBK20
C EDITS AN UPDATE INPUT FILE TO ENSURE THAT THE FIRST TWO LINES OF EACH UPEDBK30
C     DECK ARE BLANK, BLANK LINES BEING INSERTED IF NECESSARY.   THE    UPEDBK40
C     ORIGINAL SOURCE FILE IS TAPE1 AND THE EDITED VERSION IS TAPE2.    UPEDBK50
C     ADDITIONAL BLANK LINES IMMEDIATELY FOLLOWING A *DECK CARD ARE     UPEDBK60
C     ELIMINATED.   BLANK LINES ELSEWHERE REMAIN UNCHANGED.   THE       UPEDBK70
C     LINE LENGTH PROCESSED IS 72 CHARACTERS.                           UPEDBK80
C                                                                       UPEDBK90
      DIMENSION LINE(9)                                                 UPEDB100
      LOGICAL NUDECK                                                    UPEDB110
      DATA IBLANK     /  8H          /                                  UPEDB120
      DATA IDECK      /  5H*DECK     /                                  UPEDB130
      DATA ND         /  0 /                                            UPEDB140
      DATA NI         /  0 /                                            UPEDB150
      DATA NL         /  0 /                                            UPEDB160
      DATA NUDECK     / .FALSE. /                                       UPEDB170
C                                                                       UPEDB180
  100 READ (1,110) LTEST,LINE                                           UPEDB190
  110 FORMAT (A5,T1,9A8)                                                UPEDB200
      IF (EOF(1).NE.0.) GOTO 200                                        UPEDB210
      IF (NUDECK) GOTO 140                                              UPEDB220
  120 IF (LTEST.NE.IDECK) GOTO 170                                      UPEDB230
      WRITE (2,130) LINE                                                UPEDB240
  130 FORMAT (9A8/1H /1H )                                              UPEDB250
      NUDECK=.TRUE.                                                     UPEDB260
      ND=ND+1                                                           UPEDB270
      NI=NI+2                                                           UPEDB280
      NL=NL+3                                                           UPEDB290
      GOTO 100                                                          UPEDB300
  140 DO 150 J=1,9                                                      UPEDB310
      IF (LINE(J).NE.IBLANK) GOTO 160                                   UPEDB320
  150 CONTINUE                                                          UPEDB330
      NI=NI-1                                                           UPEDB340
      GOTO 100                                                          UPEDB350
  160 NUDECK=.FALSE.                                                    UPEDB360
      GOTO 120                                                          UPEDB370
  170 WRITE (2,180) LINE                                                UPEDB380
  180 FORMAT (9A8)                                                      UPEDB390
      NL=NL+1                                                           UPEDB400
      GOTO 100                                                          UPEDB410
C                                                                       UPEDB420
  200 REWIND 1                                                          UPEDB430
      REWIND 2                                                          UPEDB440
      WRITE (6,210) NL,ND,NI                                            UPEDB450
  210 FORMAT (1H0,I6,40H LINES WRITTEN TO EDITED FILE, INCLUDING/       UPEDB460
     1   1H ,I6,33H LINES WITH *DECK DIRECTIVES, AND/                   UPEDB470
     2   1H ,I6,50H BLANK LINES NEWLY INSERTED, LESS REDUNDANT BLANK ,  UPEDB480
     3   14HLINES DELETED./1H )                                         UPEDB490
      STOP                                                              UPEDB500
      END                                                               UPEDB510
```

8.2 Intersegmental Moments for all Subjects and Patients

PI/L/FULO



ANKLE.KNEE. HIP. CORONAL PLANE

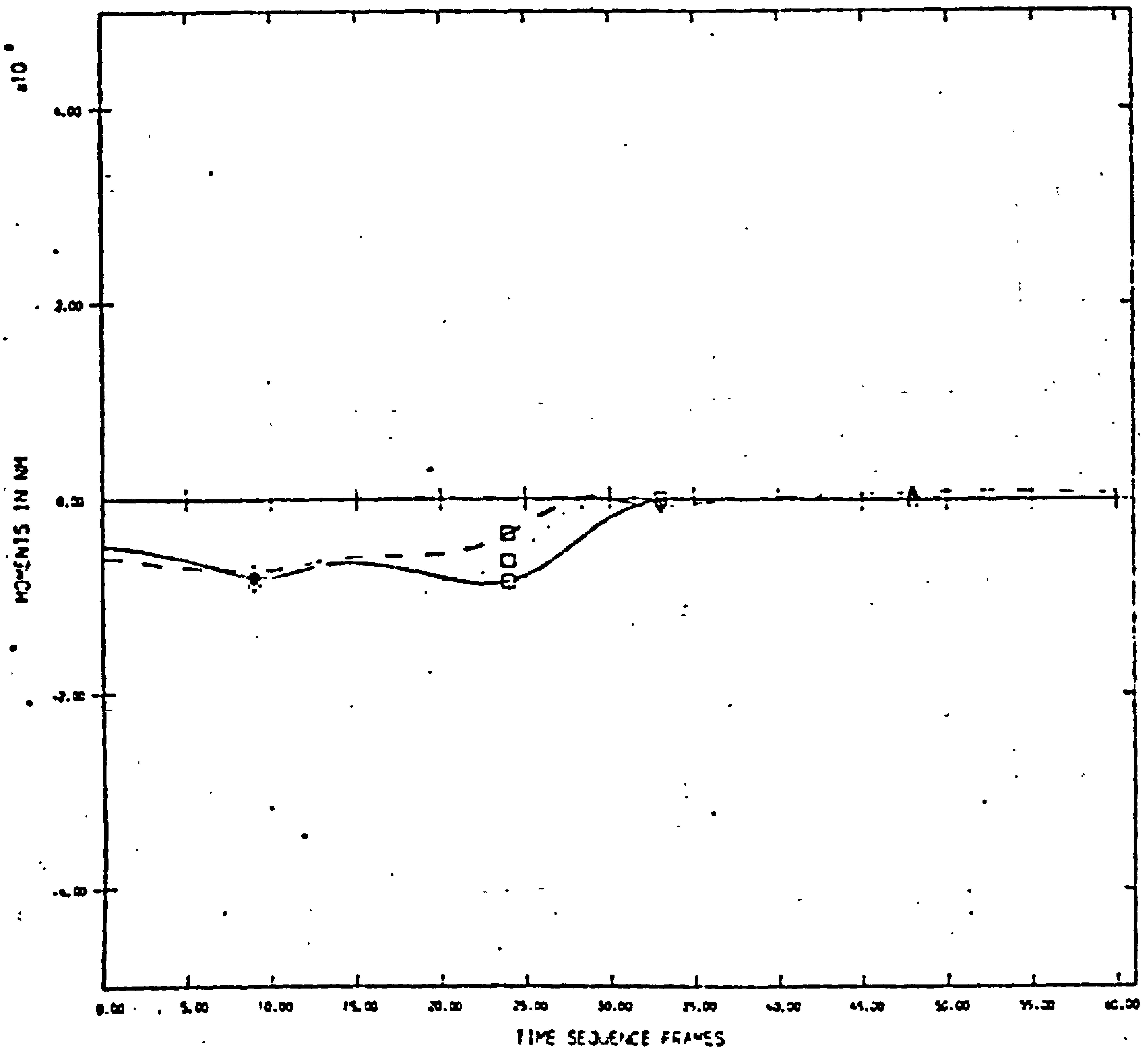
LEFT HEEL STRIKE △ CONTINUOUS ANKLE

LEFT TOE OFF ▽ DASHED KNEE

RIGHT HEELSTRIKE □ DOTTED HIP

RIGHT TOE OFF ◇

P1/L/FULO



ANKLE, KNEE, HIP, CORONAL PLANE

LEFT HEEL STRIKE ▵

LEFT TOE OFF ▿

RIGHT HEELSTRIKE □

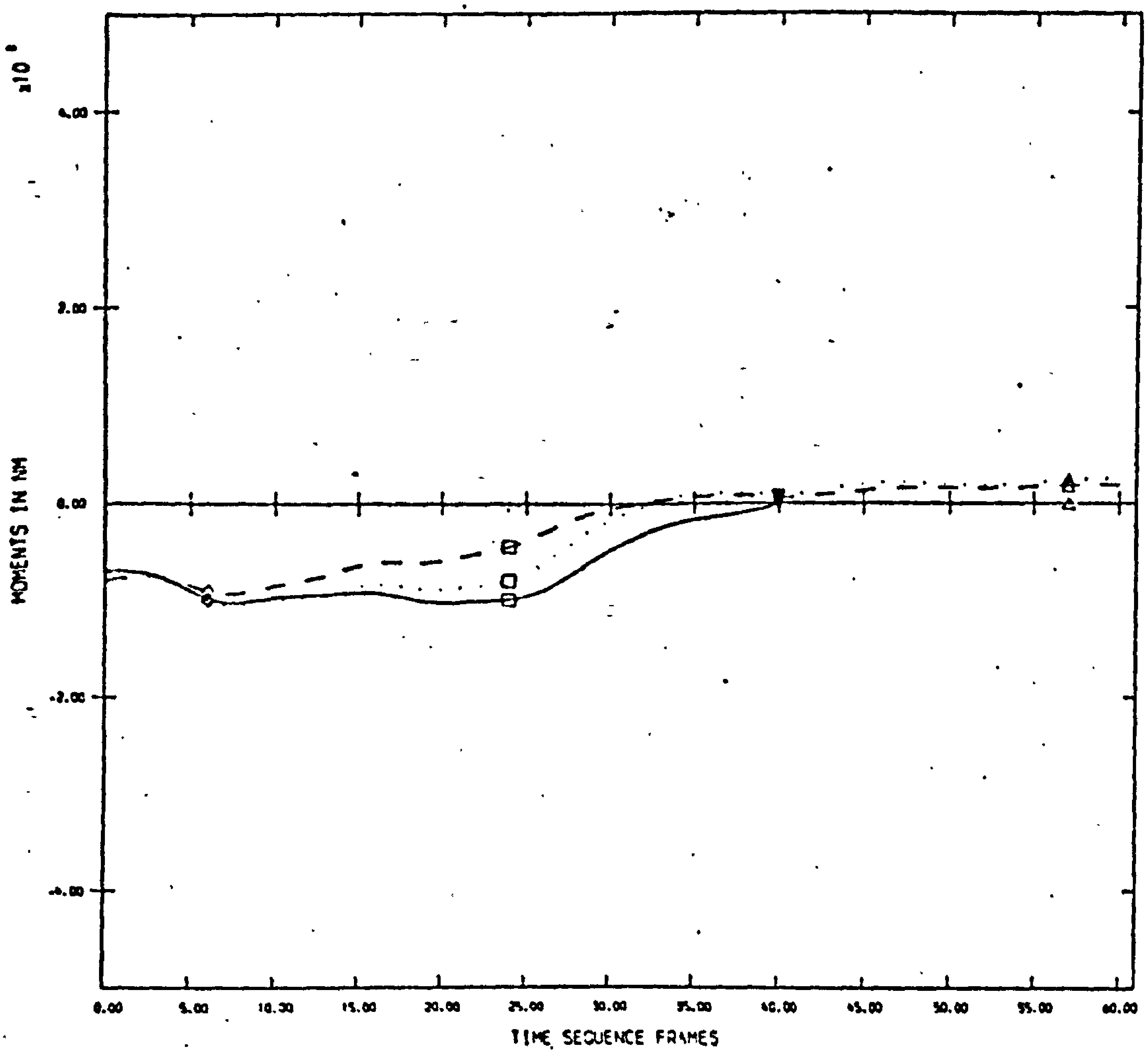
RIGHT TOE OFF ◇

CONTINUOUS ANKLE

DASHED KNEE

DOTTED HIP

P4/L/FULO

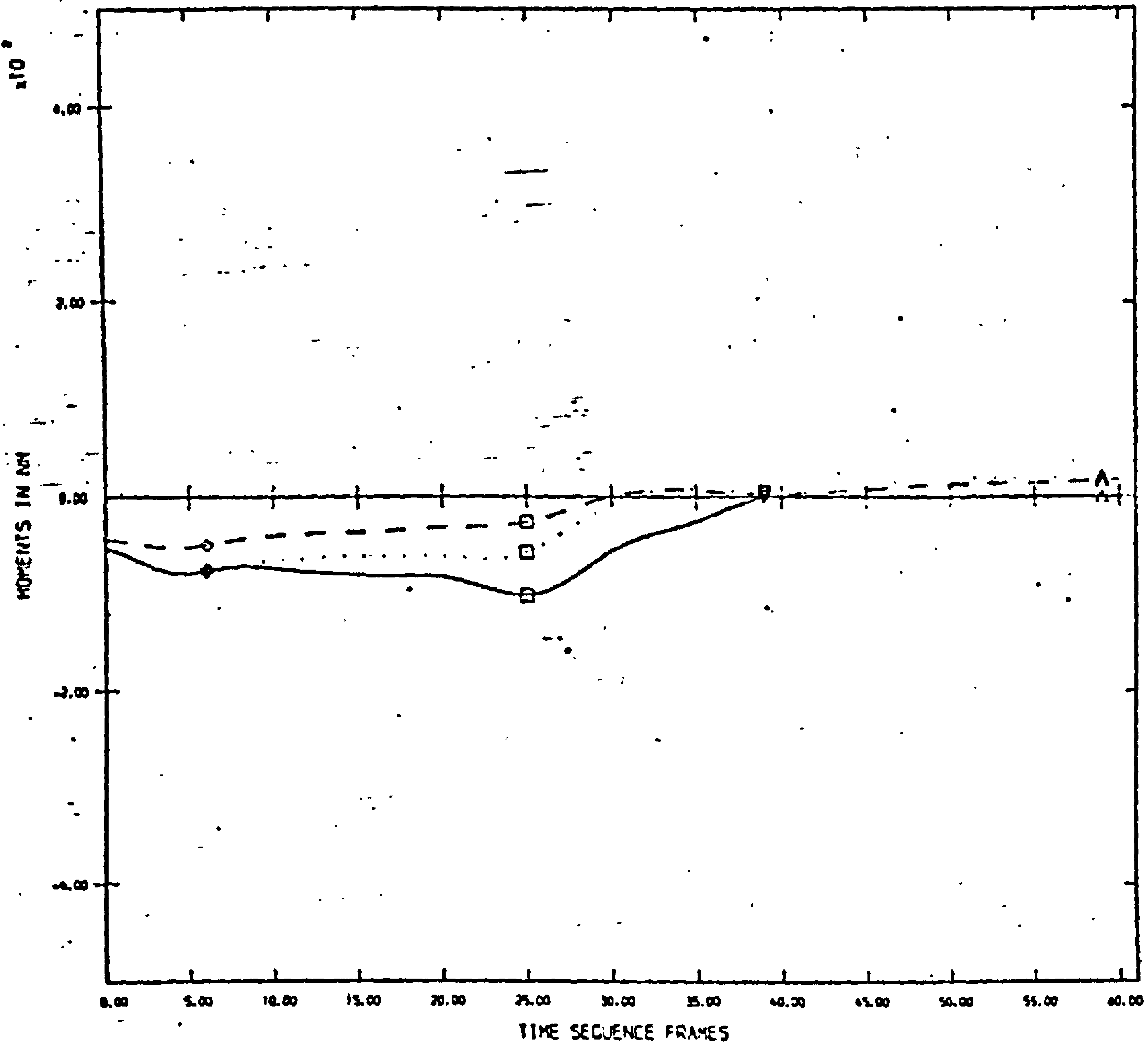


ANKLE,KNEE, HIP, CORONAL PLANE

LEFT HEEL STRIKE	△
LEFT TOE OFF	▽
RIGHT HEELSTRIKE	□
RIGHT TOE OFF	◇

CONTINUOUS	ANKLE
DASHED	KNEE
DOTTED	HIP

P6/L/FULO



ANKLE,KNEE, HIP. CORONAL PLANE

LEFT HEEL STRIKE △

LEFT TOE OFF ▽

RIGHT HEELSTRIKE □

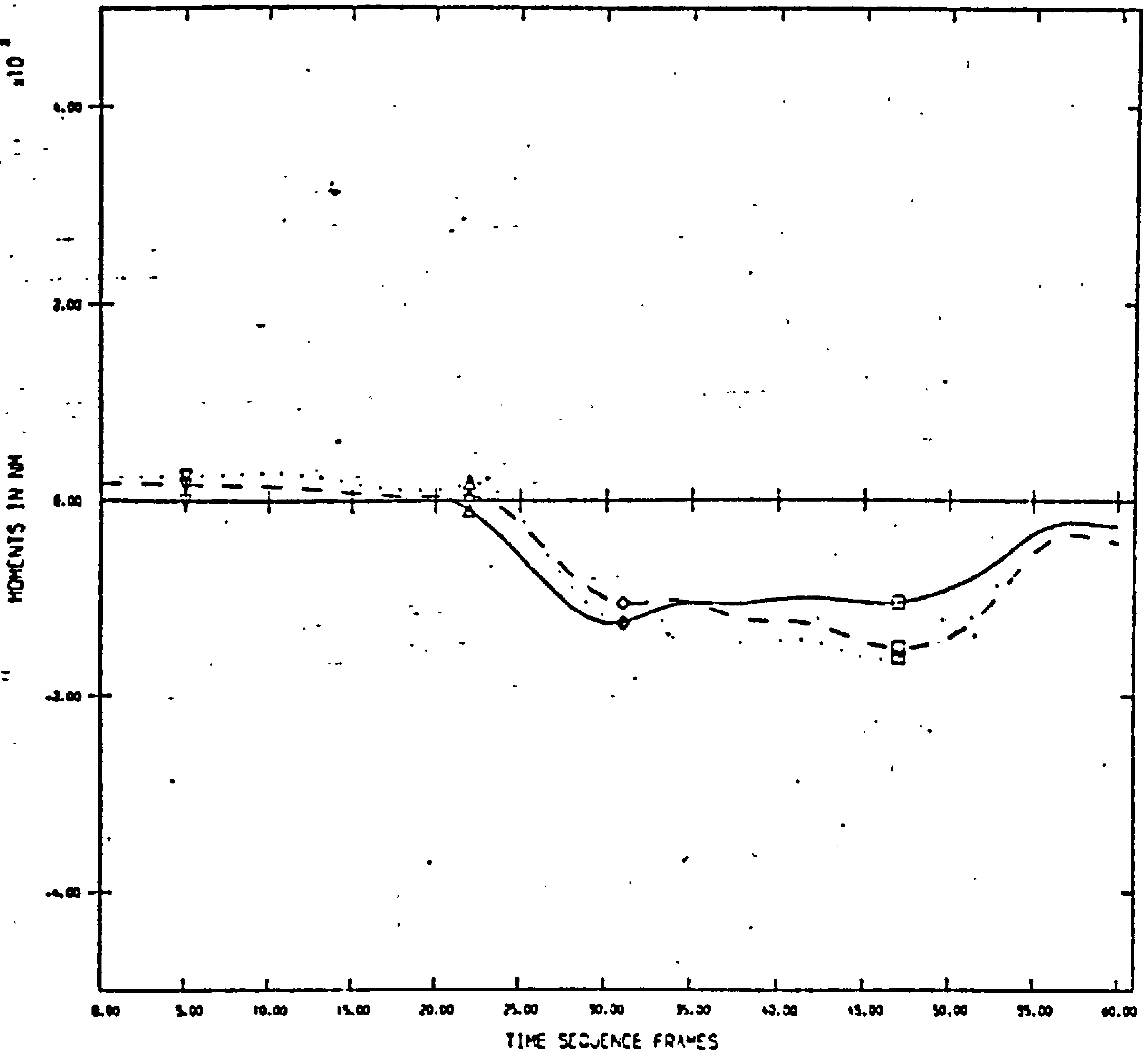
RIGHT TOE OFF ◇

CONTINUOUS ANKLE

DASHED KNEE

DOTTED HIP

P3/L/BOTO



ANKLE.KNEE. HIP. CORONAL PLANE

LEFT HEEL STRIKE △

LEFT TOE OFF ▽

RIGHT HEELSTRIKE □

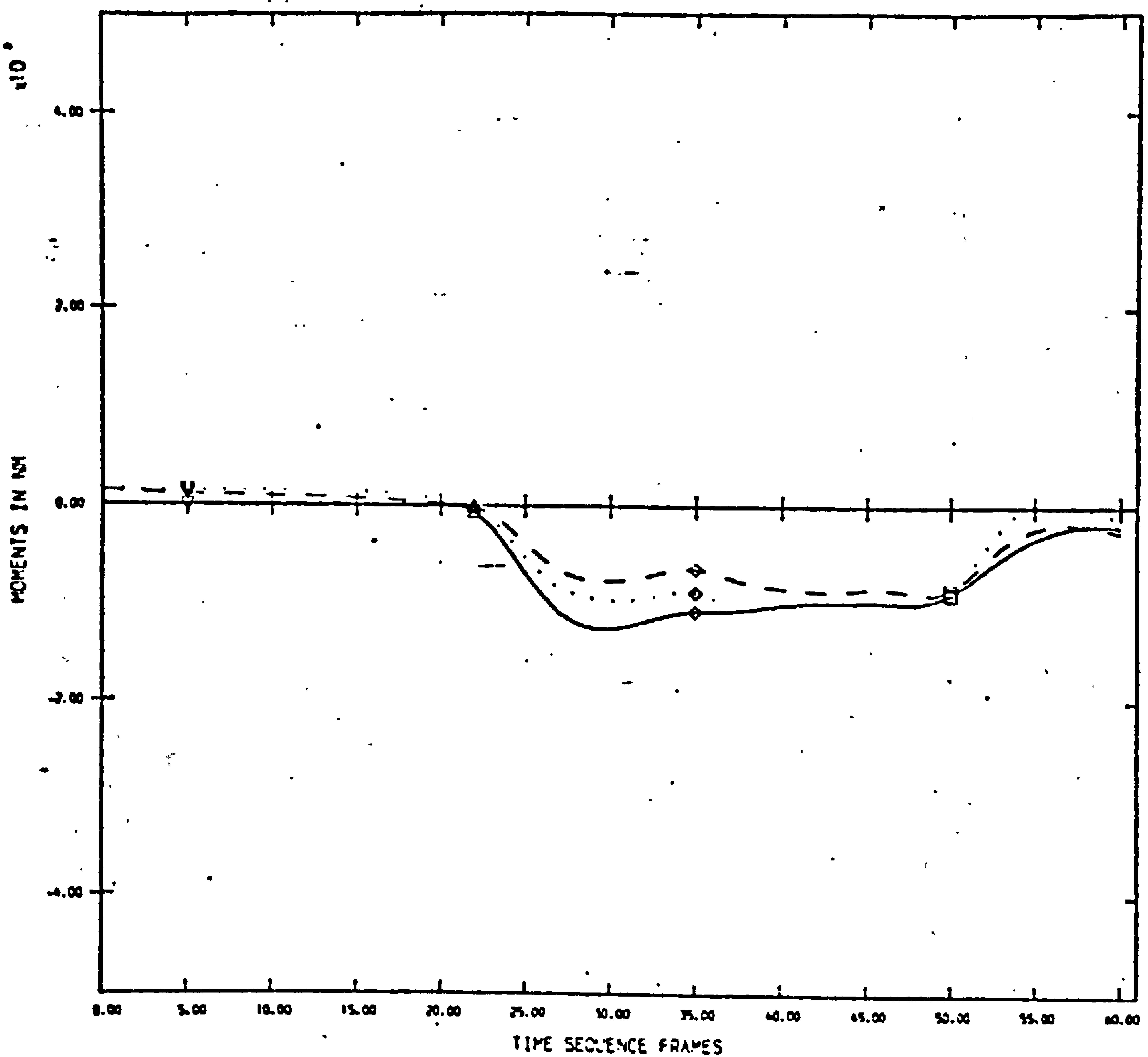
RIGHT TOE OFF ◇

CONTINUOUS ANKLE

DASHED KNEE

DOTTED HIP

P4/L/BDTO

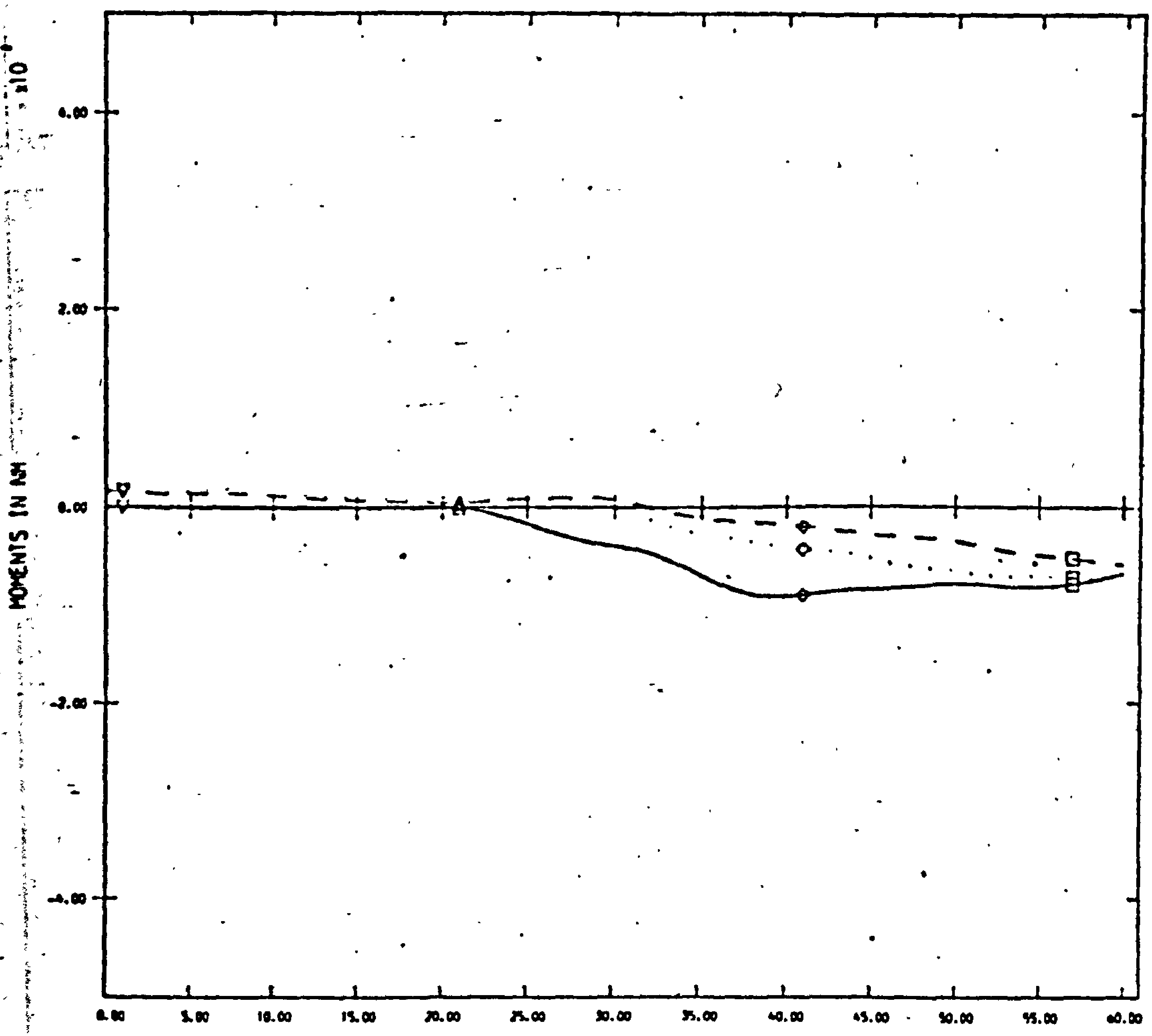


ANKLE, KNEE, HIP, CORONAL PLANE

LEFT HEEL STRIKE △
LEFT TOE OFF ▽
RIGHT HEELSTRIKE □
RIGHT TOE OFF ◇

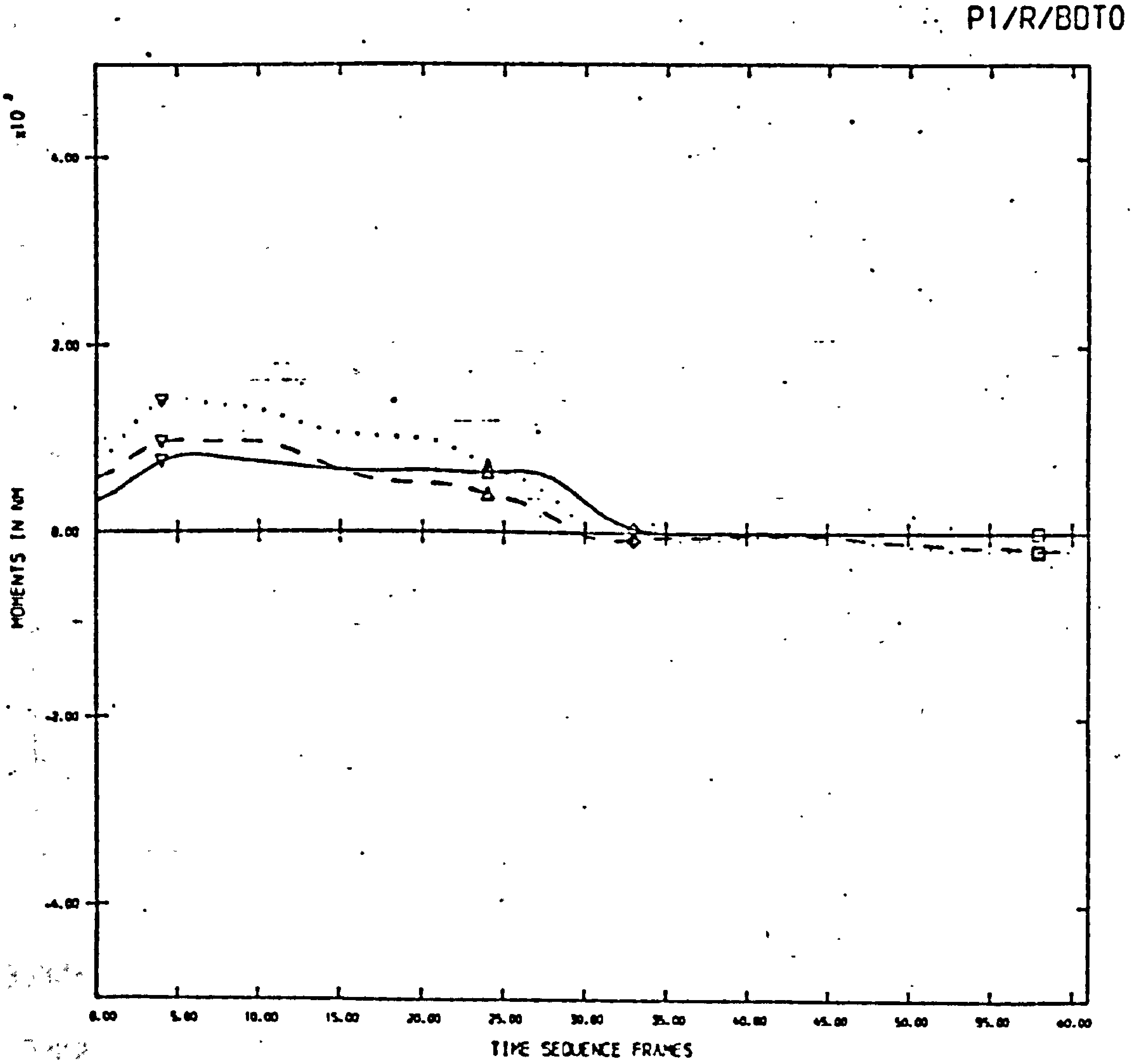
CONTINUOUS ANKLE
DASHED KNEE
DOTTED HIP

P6/L/BDTO



ANKLE.KNEE. HIP. CORONAL PLANE

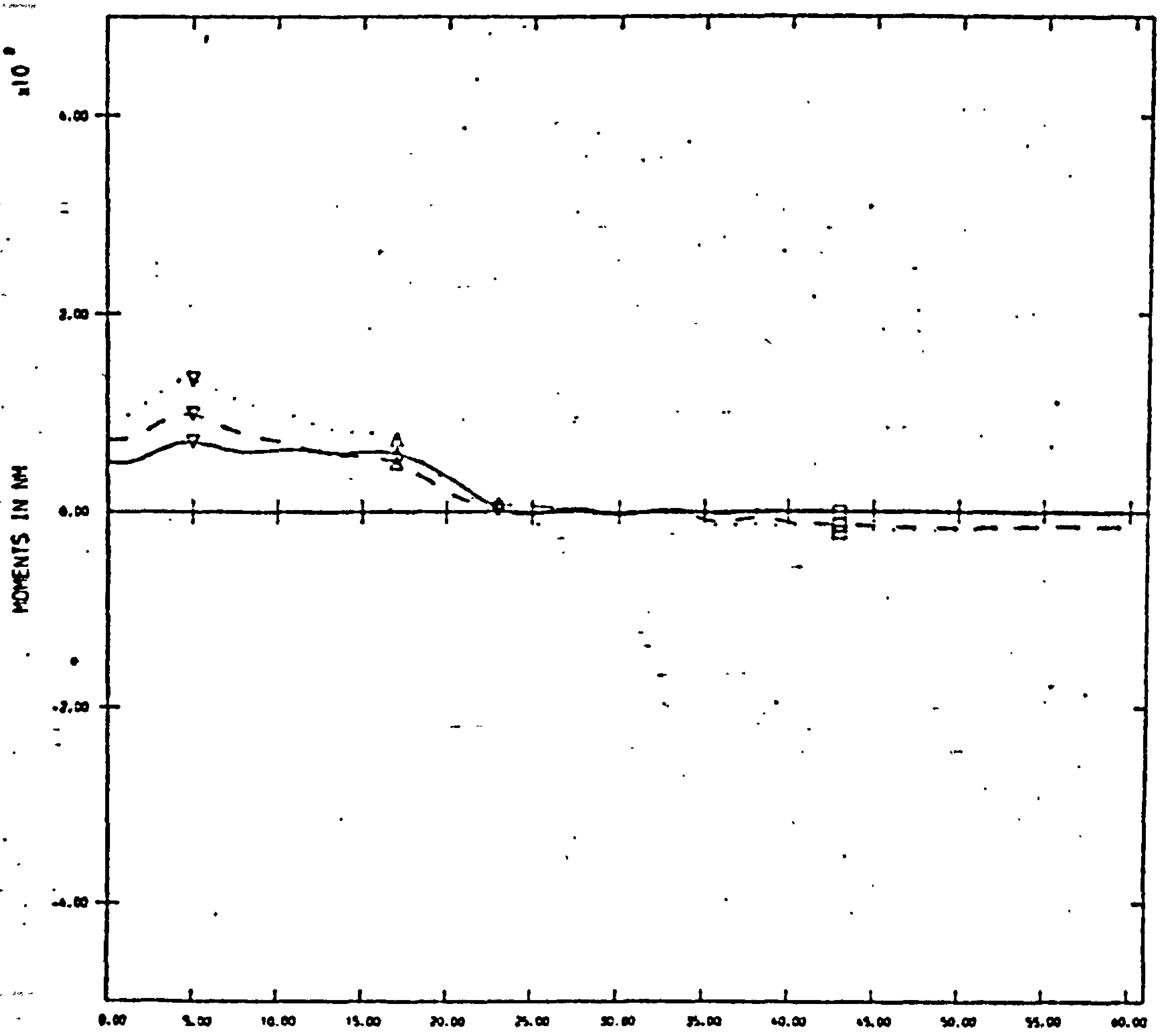
LEFT HEEL STRIKE	△	CONTINUOUS	ANKLE
LEFT TOE OFF	▽	DASHED	KNEE
RIGHT HEELSTRIKE	□	DOTTED	HIP
RIGHT TOE OFF	◇		



ANKLE.KNEE. HIP. CORONAL PLANE

LEFT HEEL STRIKE	△	CONTINUOUS	ANKLE
LEFT TOE OFF	▽	DASHED	KNEE
RIGHT HEELSTRIKE	□	DOTTED	HIP
RIGHT TOE OFF	◇		

P2/R/BDTO



ANKLE,KNEE, HIP, CORONAL PLANE

LEFT HEEL STRIKE △

LEFT TOE OFF ▽

RIGHT HEELSTRIKE □

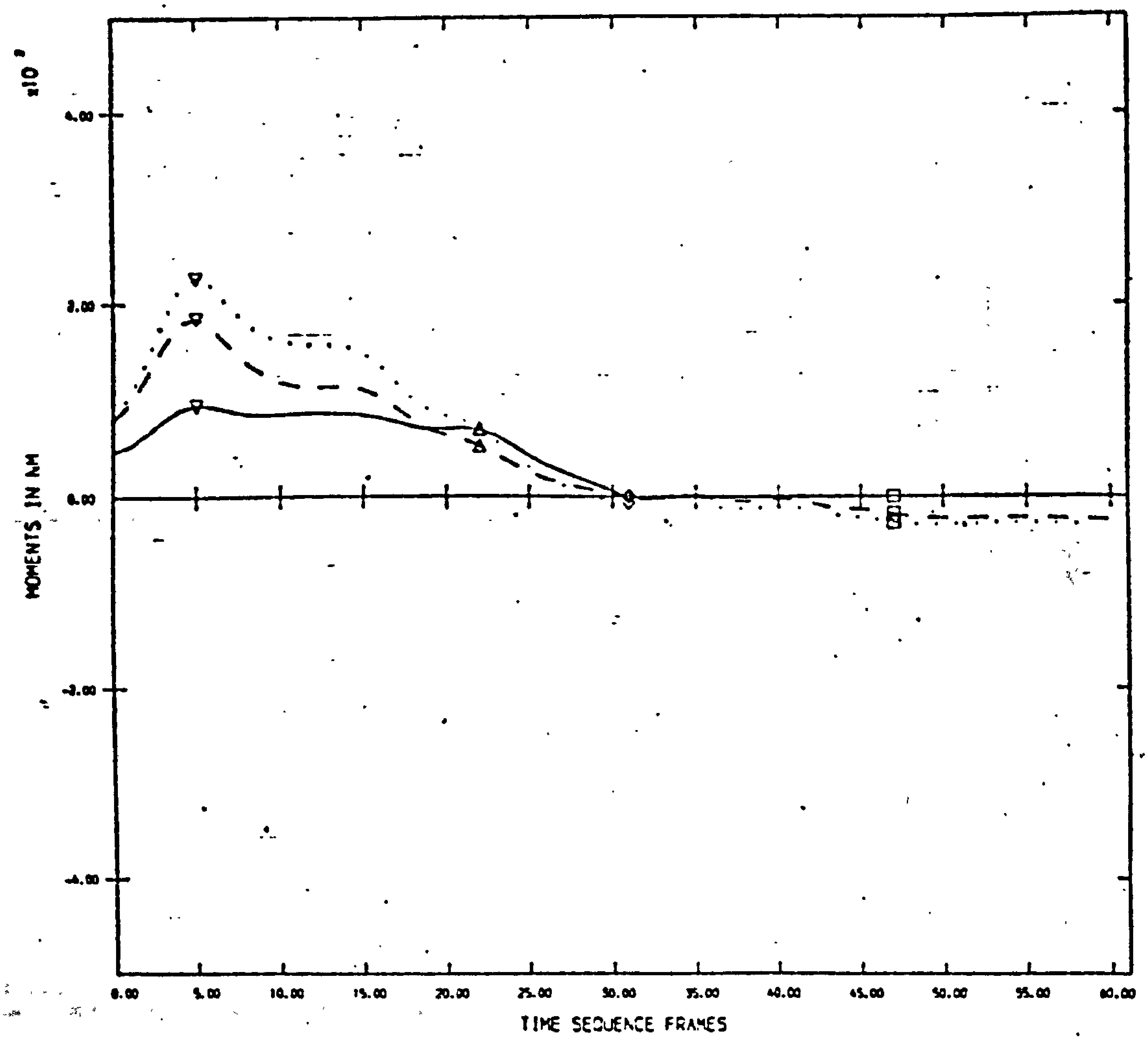
RIGHT TOE OFF ◇

CONTINUOUS ANKLE

DASHED KNEE

DOTTED HIP

P3/R/BDTO

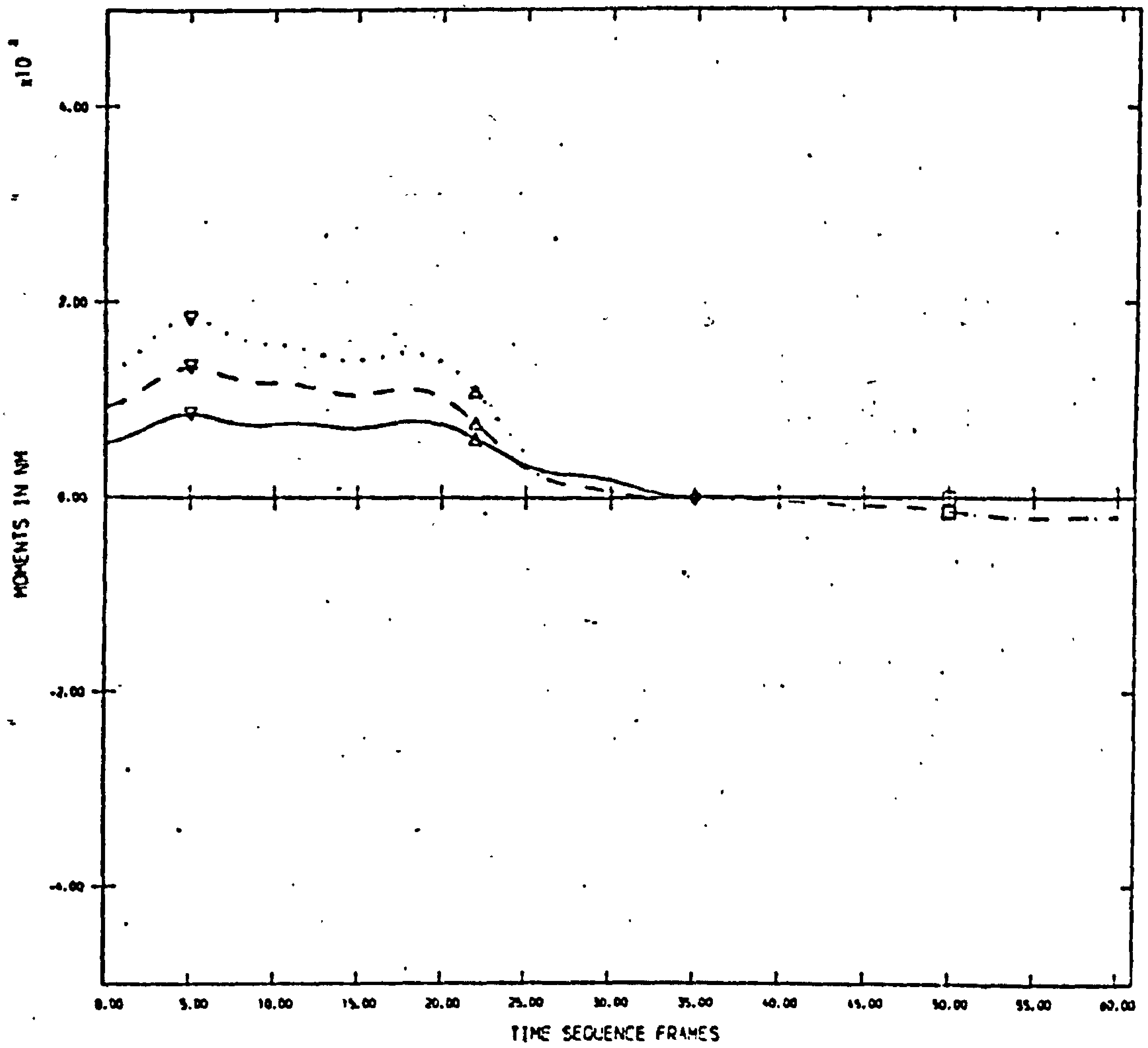


ANKLE.KNEE. HIP. CORONAL PLANE

LEFT HEEL STRIKE △
LEFT TOE OFF ▽
RIGHT HEELSTRIKE □
RIGHT TOE OFF ◇

CONTINUOUS ANKLE
DASHED KNEE
DOTTED HIP

P4/R/BDTO



ANKLE.KNEE. HIP. CORONAL PLANE

LEFT HEEL STRIKE △

LEFT TOE OFF ▽

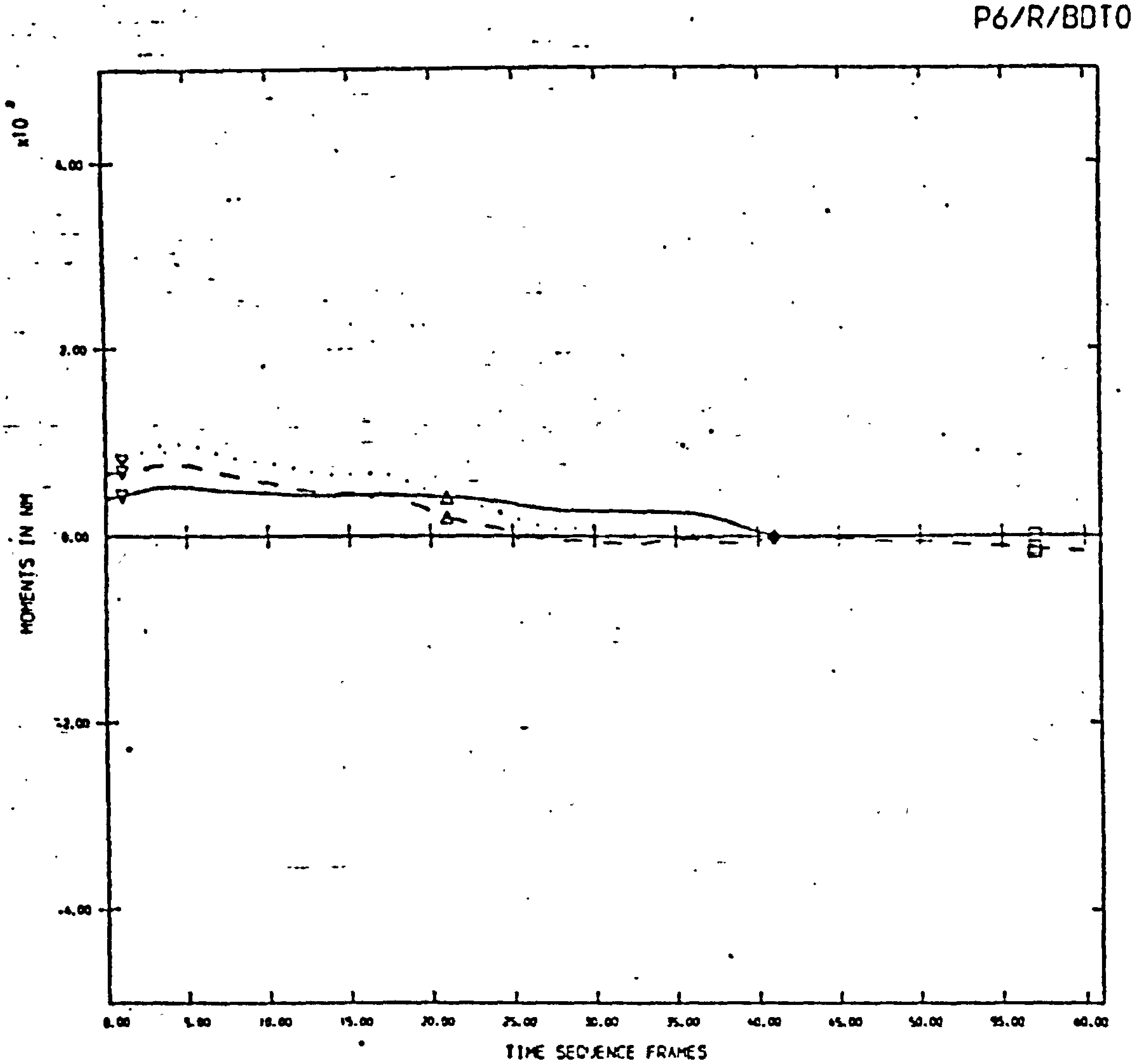
RIGHT HEELSTRIKE □

RIGHT TOE OFF ◇

CONTINUOUS ANKLE

DASHED KNEE

DOTTED HIP

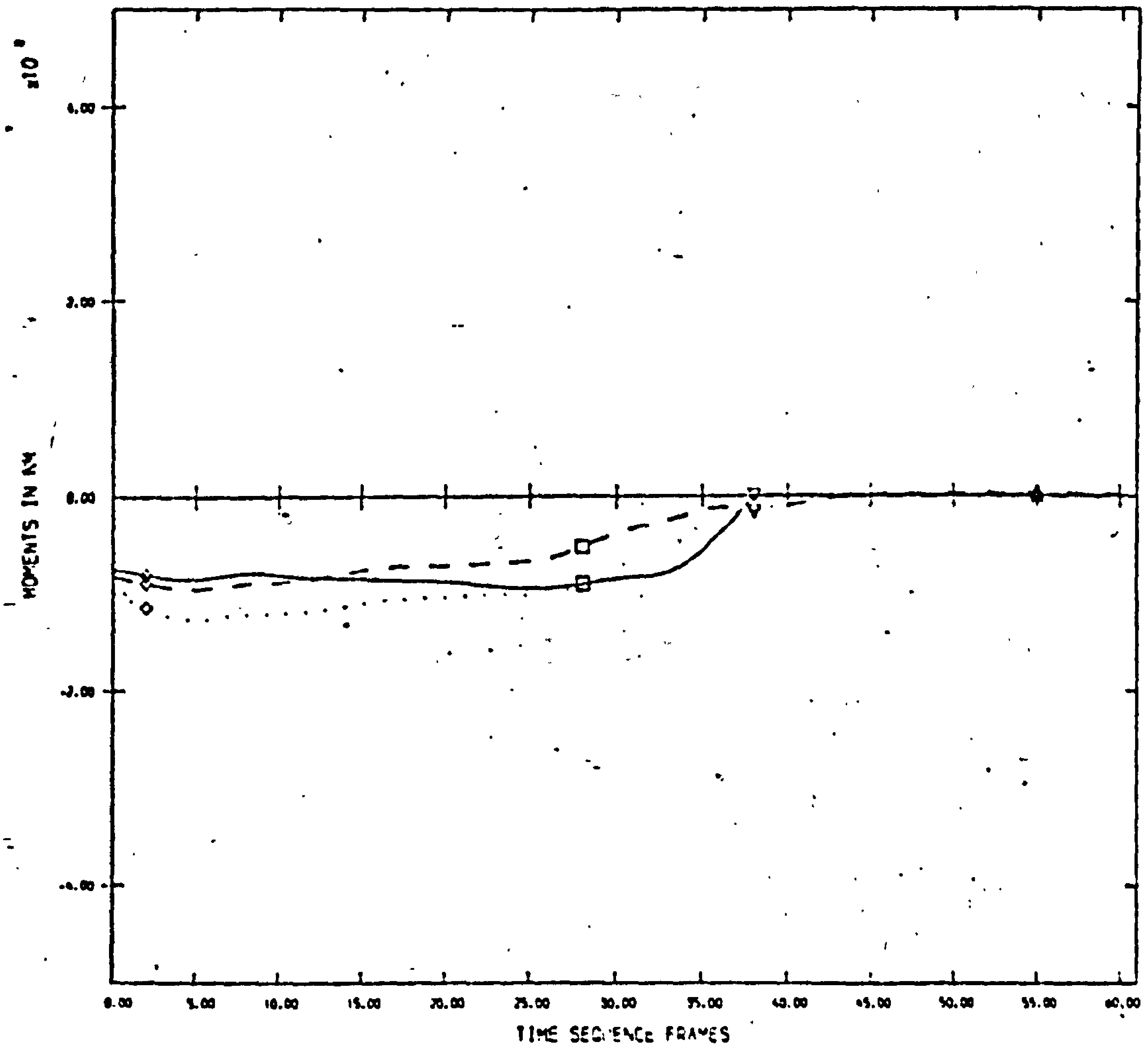


ANKLE, KNEE, HIP. CORONAL PLANE

LEFT HEEL STRIKE △
LEFT TOE OFF ▽
RIGHT HEELSTRIKE □
RIGHT TOE OFF ◇

CONTINUOUS ANKLE
DASHED KNEE
DOTTED HIP

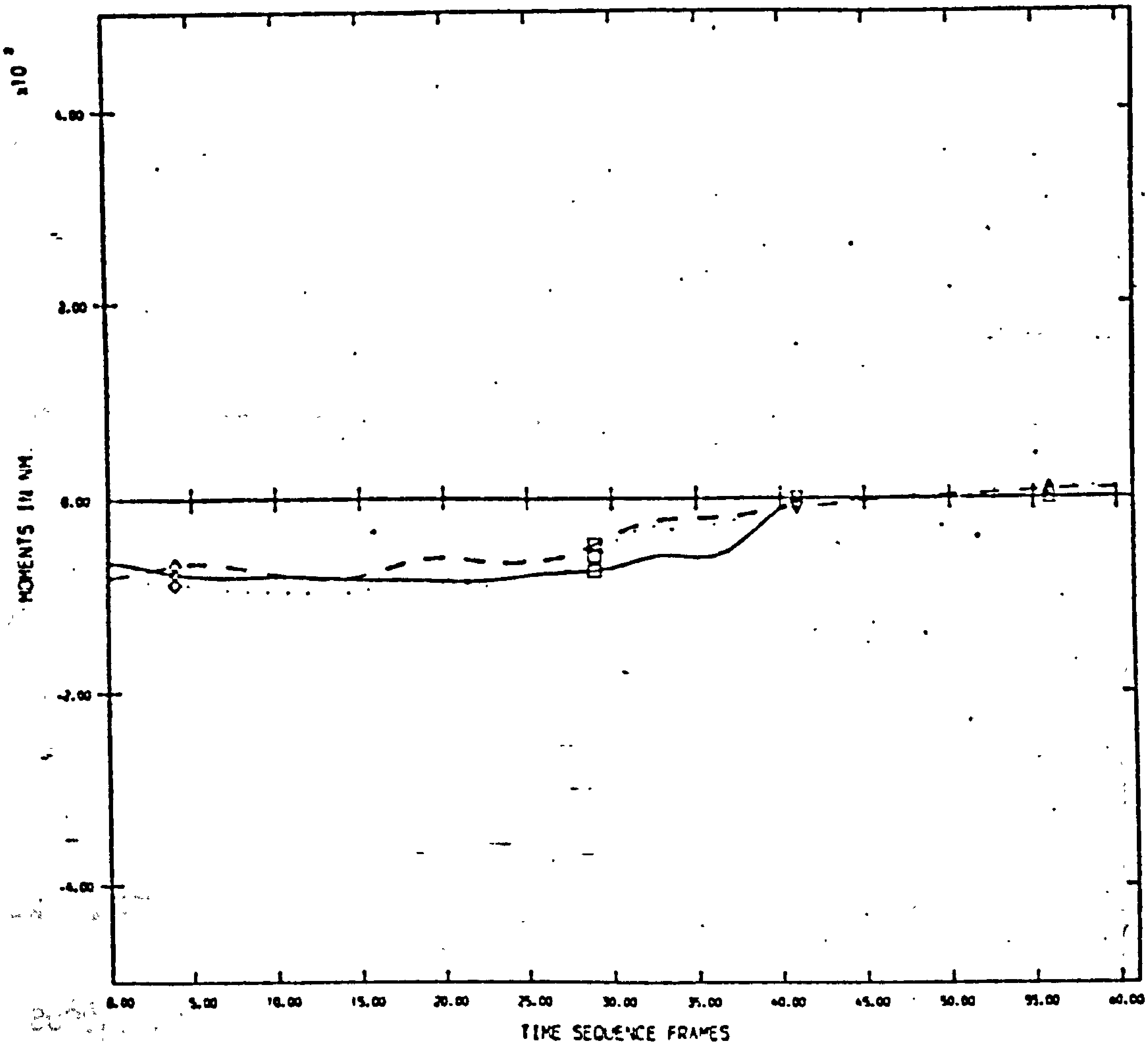
P1/L/FUL1



ANKLE.KNEE. HIP. CORONAL PLANE

LEFT HEEL STRIKE	△	CONTINUOUS	ANKLE
LEFT TOE OFF	▽	DASHED	KNEE
RIGHT HEELSTRIKE	□	DOTTED	HIP
RIGHT TOE OFF	◇		

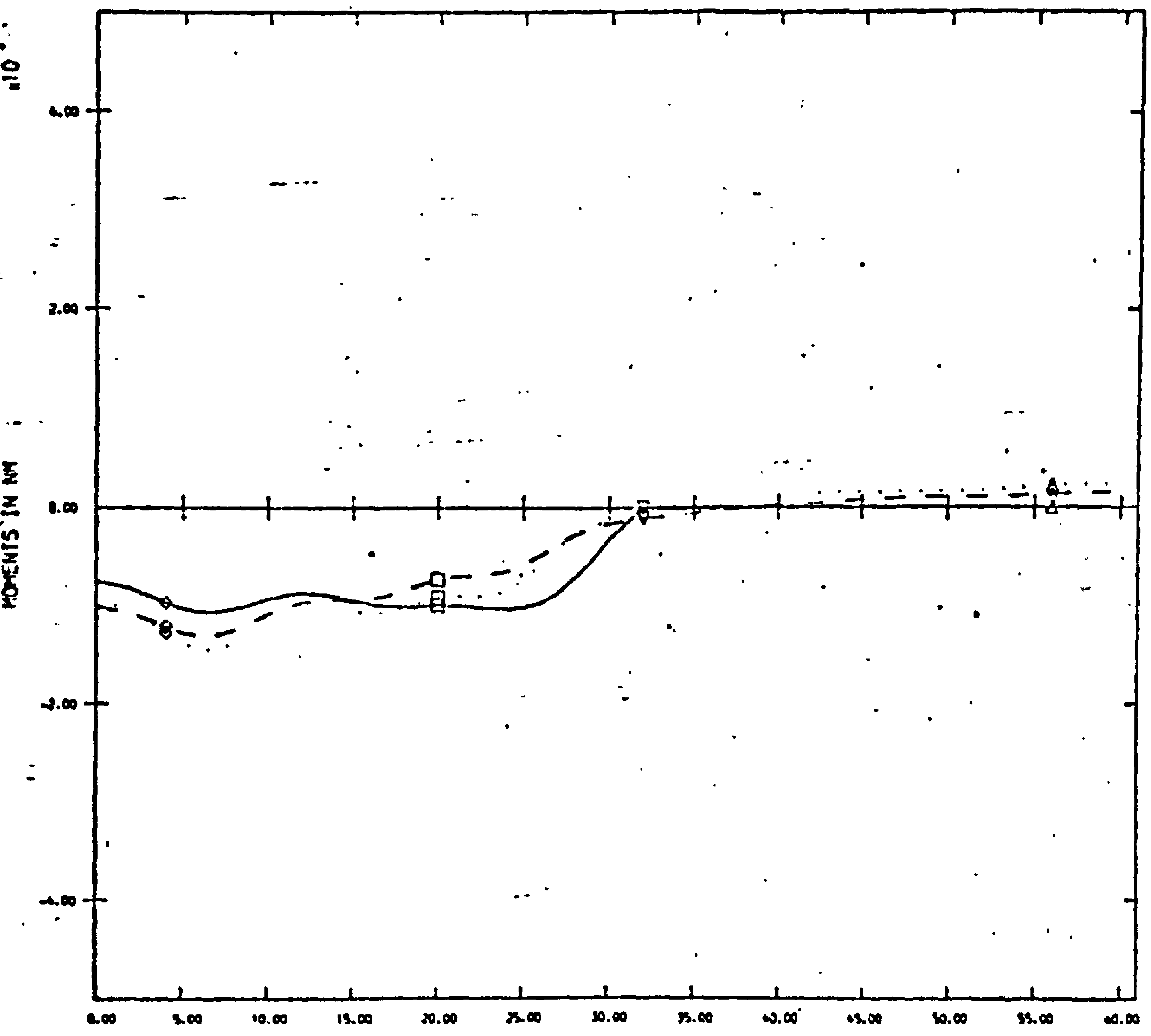
P2/L/FUL1



ANKLE.KNEE. HIP. CORONAL PLANE

LEFT HEEL STRIKE	△	CONTINUOUS	ANKLE
LEFT TOE OFF	▽	DASHED	KNEE
RIGHT HEELSTRIKE	□	DOTTED	HIP
RIGHT TOE OFF	◇		

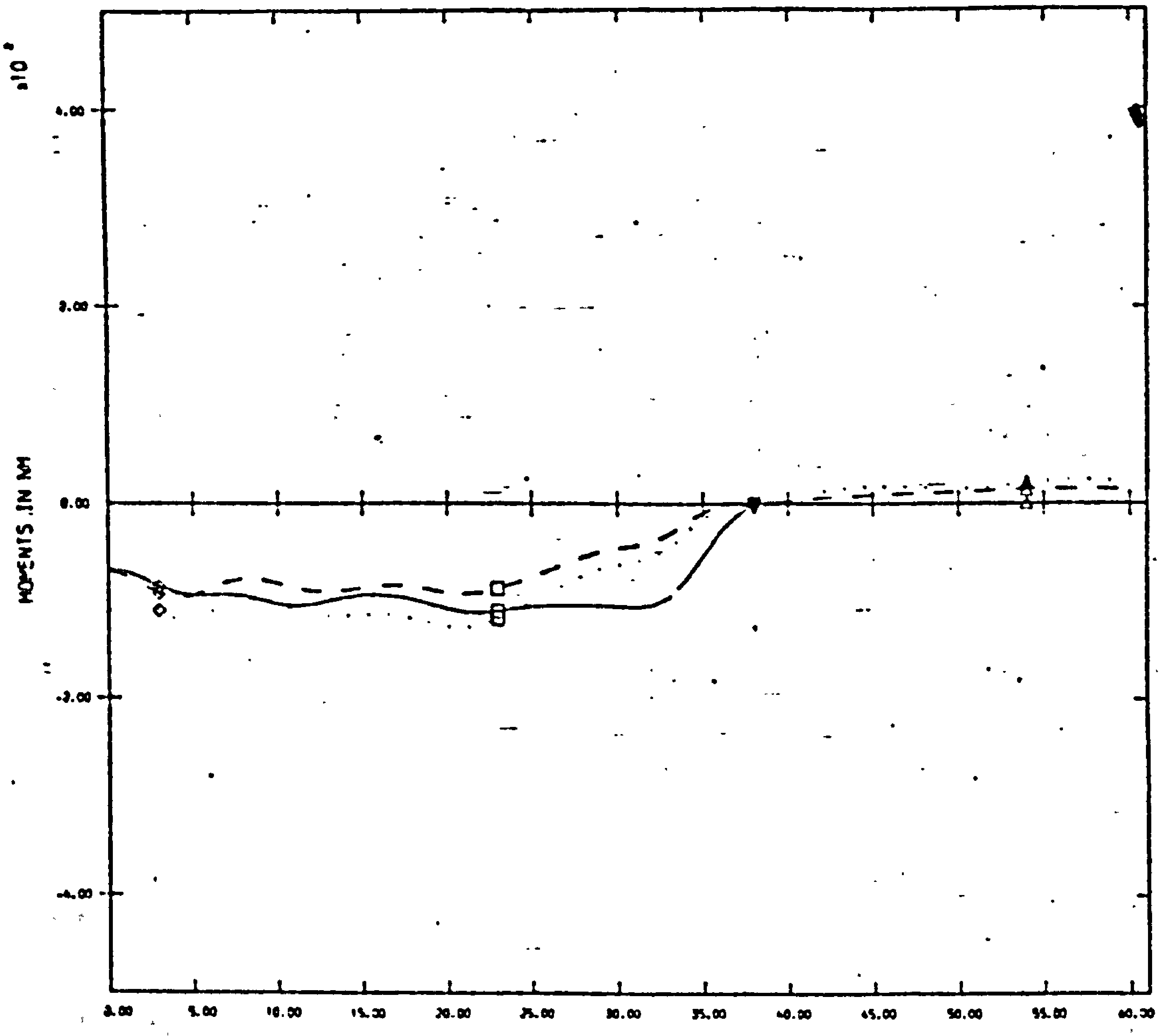
P3/L/FUL1



ANKLE.KNEE. HIP. CORONAL PLANE

LEFT HEEL STRIKE	△	CONTINUOUS	ANKLE
LEFT TOE OFF	▽	DASHED	KNEE
RIGHT HEELSTRIKE	□	DOTTED	HIP
RIGHT TOE OFF	◇		

P4/L/FUL1



ANKLE,KNEE, HIP, CORONAL PLANE

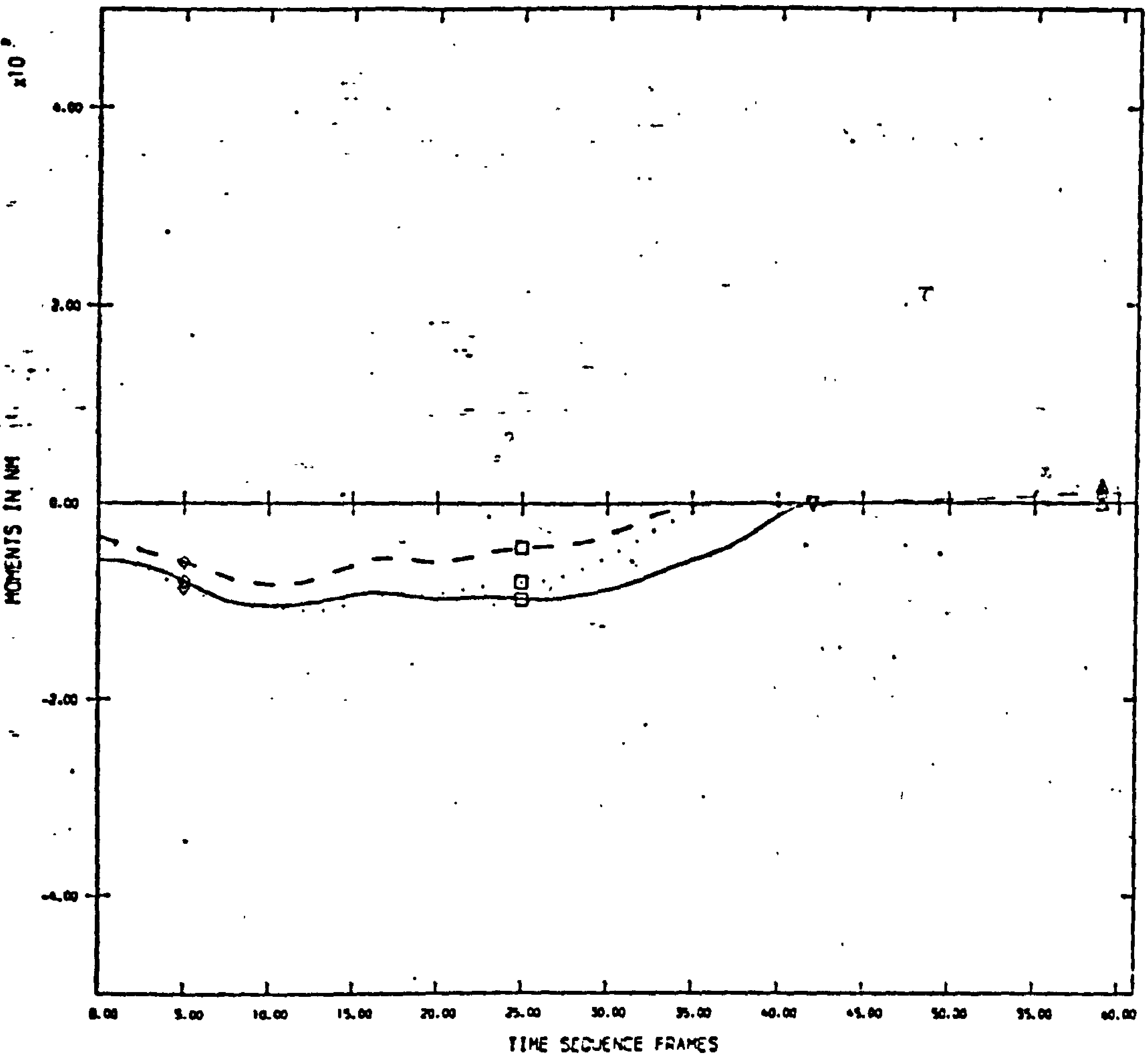
LEFT HEEL STRIKE △ CONTINUOUS ANKLE

LEFT TOE OFF ▽ DASHED KNEE

RIGHT HEELSTRIKE □ DOTTED HIP

RIGHT TOE OFF ◇

P6/L/FUL1

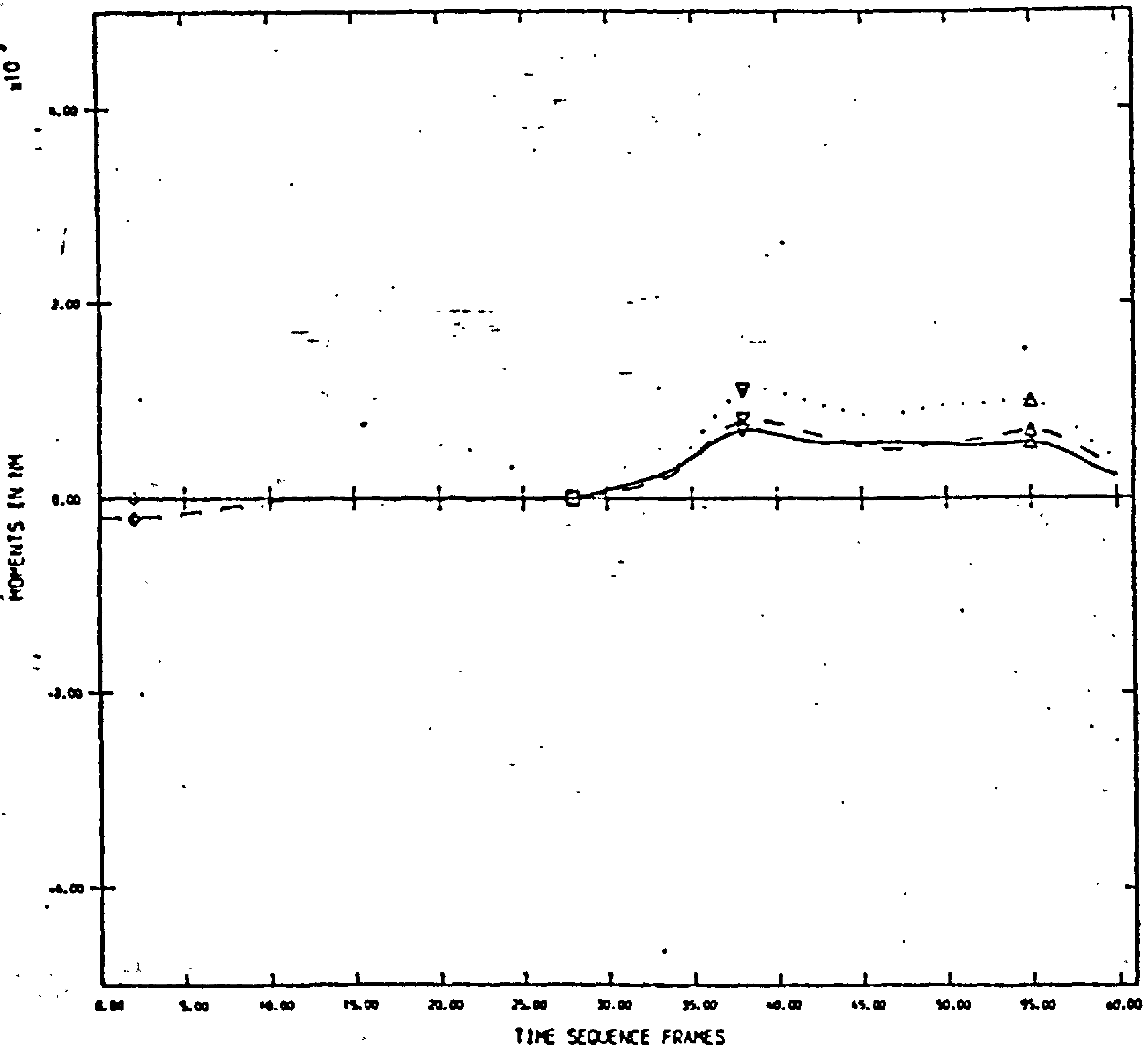


ANKLE.KNEE. HIP. CORONAL PLANE

LEFT HEEL STRIKE △
LEFT TOE OFF ▽
RIGHT HEELSTRIKE □
RIGHT TOE OFF ◇

CONTINUOUS	ANKLE
DASHED	KNEE
DOTTED	HIP

P1/R/FUL1



ANKLE,KNEE, HIP. CORONAL PLANE

LEFT HEEL STRIKE. △

LEFT TOE OFF ▽

RIGHT HEELSTRIKE □

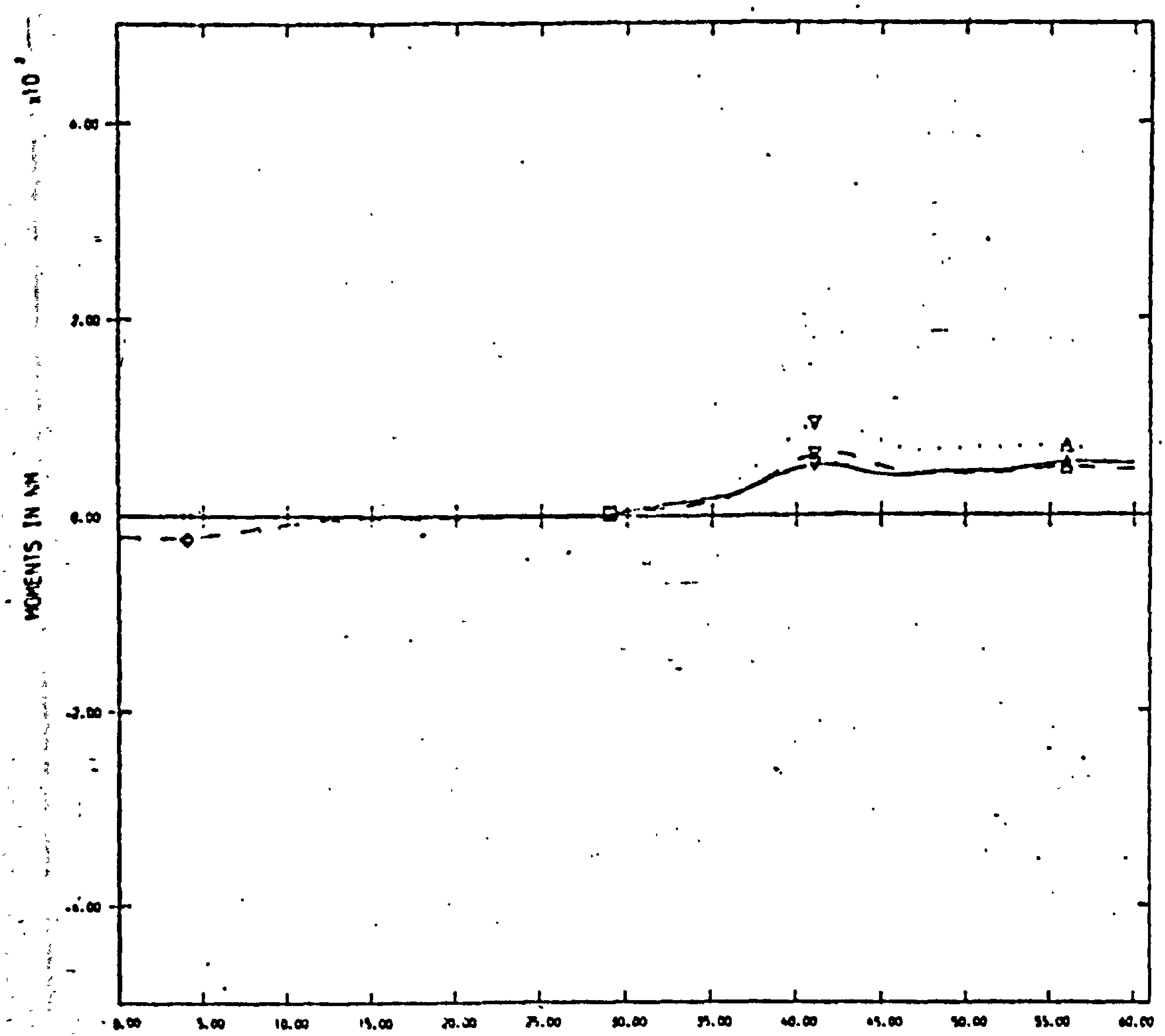
RIGHT TOE OFF ◇

CONTINUOUS ANKLE

DASHED KNEE

DOTTED HIP

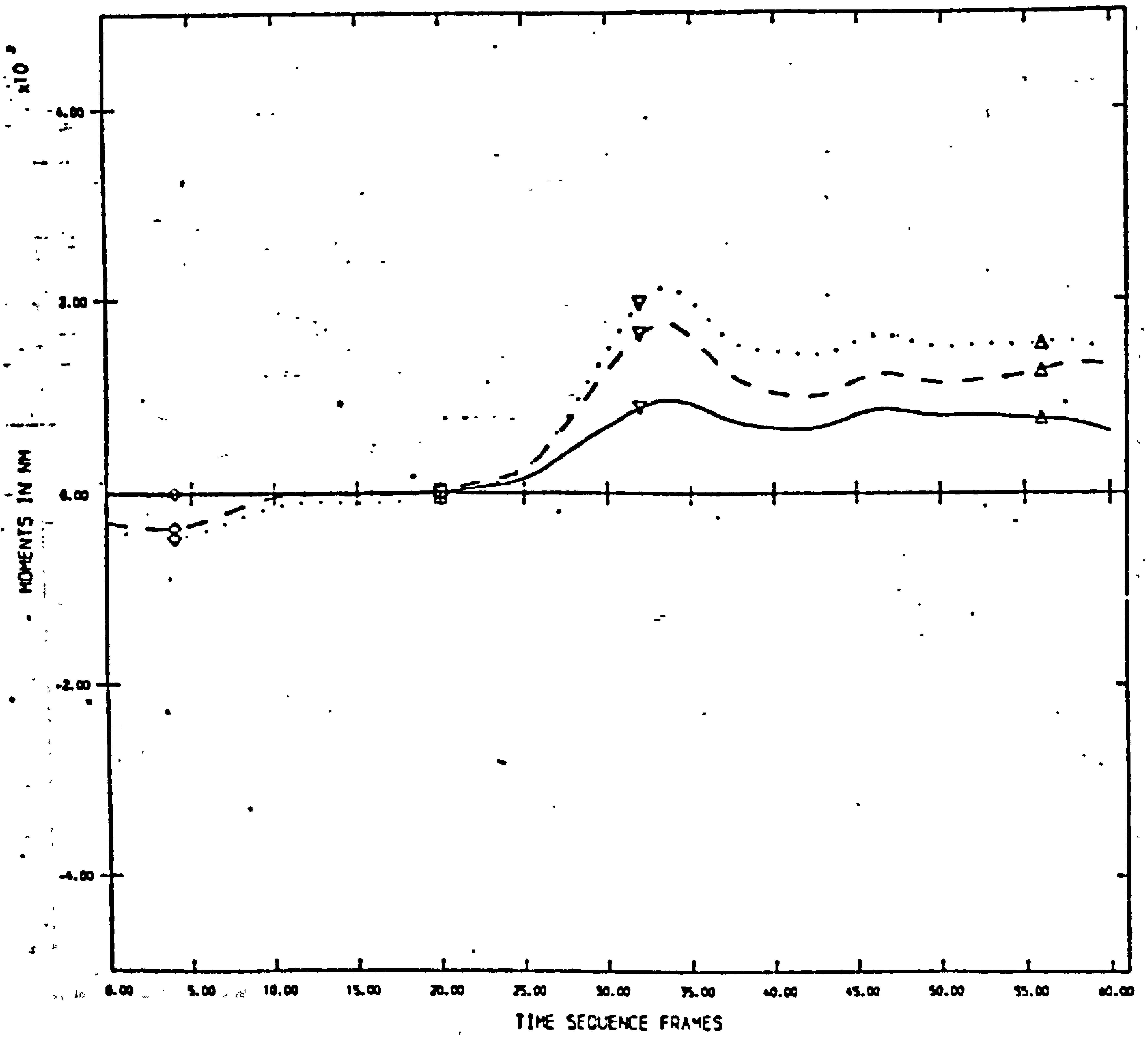
P2/R/FUL1



ANKLE.KNEE. HIP. CORONAL PLANE

LEFT HEEL STRIKE	△	CONTINUOUS	ANKLE
LEFT TOE OFF	▽	DASHED	KNEE
RIGHT HEELSTRIKE	□	DOTTED	HIP
RIGHT TOE OFF	◇		

P3/R/FUL1



ANKLE.KNEE. HIP. CORONAL PLANE

LEFT HEEL STRIKE △

LEFT TOE OFF ▽

RIGHT HEELSTRIKE □

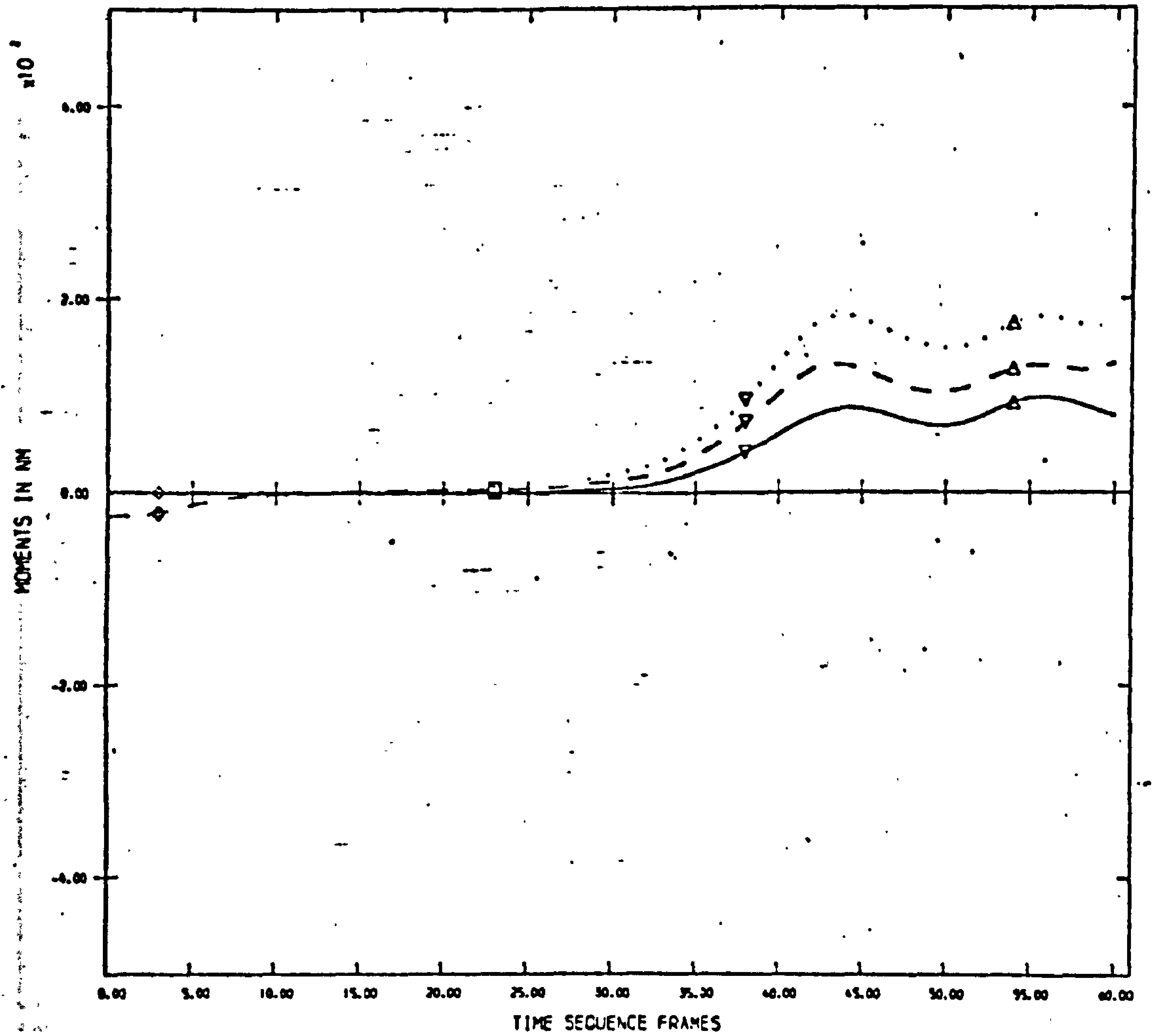
RIGHT TOE OFF ◇

CONTINUOUS ANKLE

DASHED KNEE

DOTTED HIP

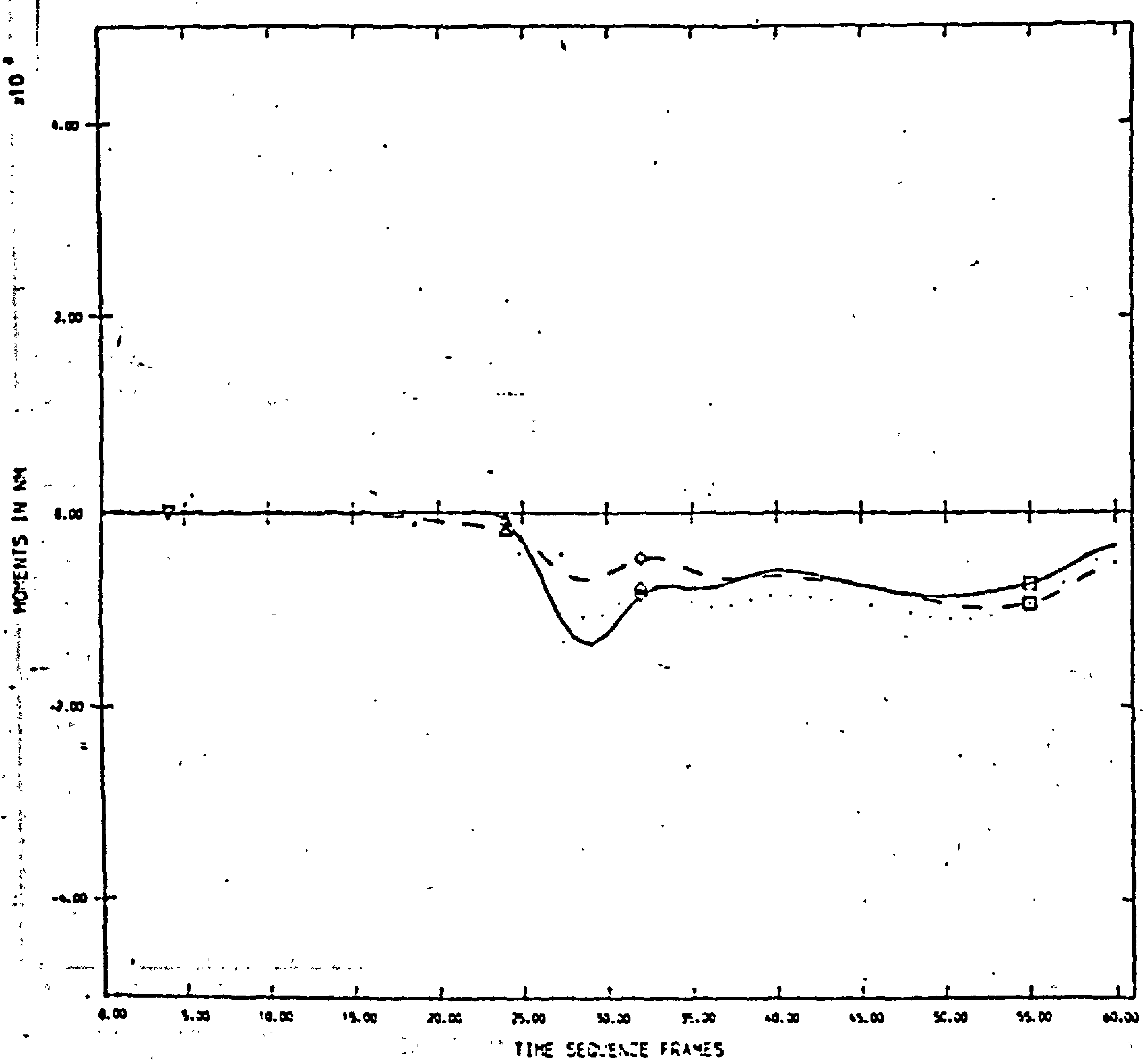
P4/R/FUL1



ANKLE.KNEE, HIP, CORONAL PLANE

LEFT HEEL STRIKE	△	CONTINUOUS	ANKLE
LEFT TOE OFF	▽	DASHED	KNEE
RIGHT HEELSTRIKE	□	DOTTED	HIP
RIGHT TOE OFF	◇		

P1/L/BDT1



ANKLE.KNEE. HIP. CORONAL PLANE

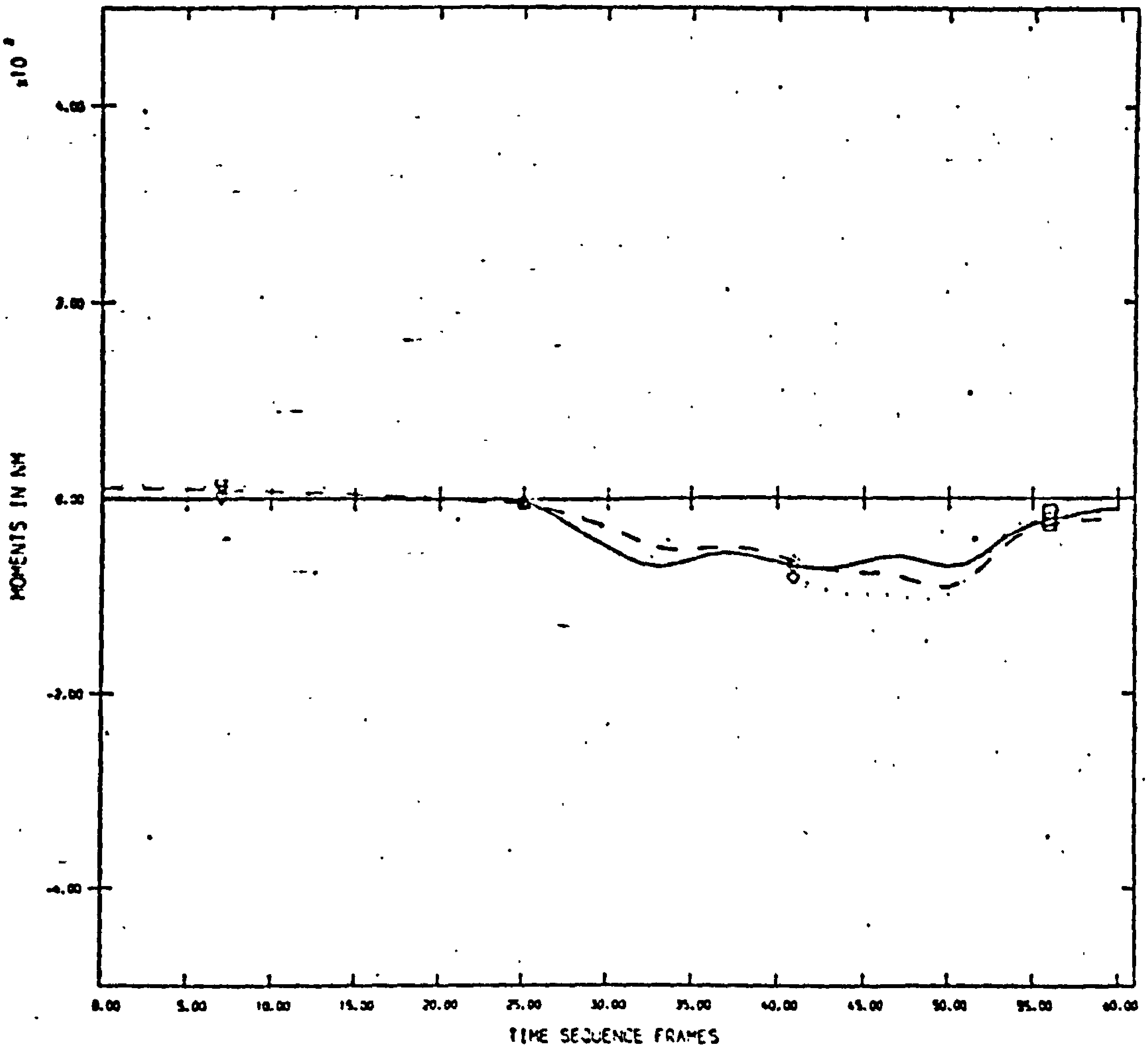
LEFT HEEL STRIKE △ CONTINUOUS ANKLE

LEFT TOE OFF ▽ DASHED KNEE

RIGHT HEELSTRIKE □ DOTTED HIP

RIGHT TOE OFF ◇

P2/L/BOT1



ANKLE.KNEE. HIP. CORONAL PLANE

LEFT HEEL STRIKE △

LEFT TOE OFF ▽

RIGHT HEELSTRIKE □

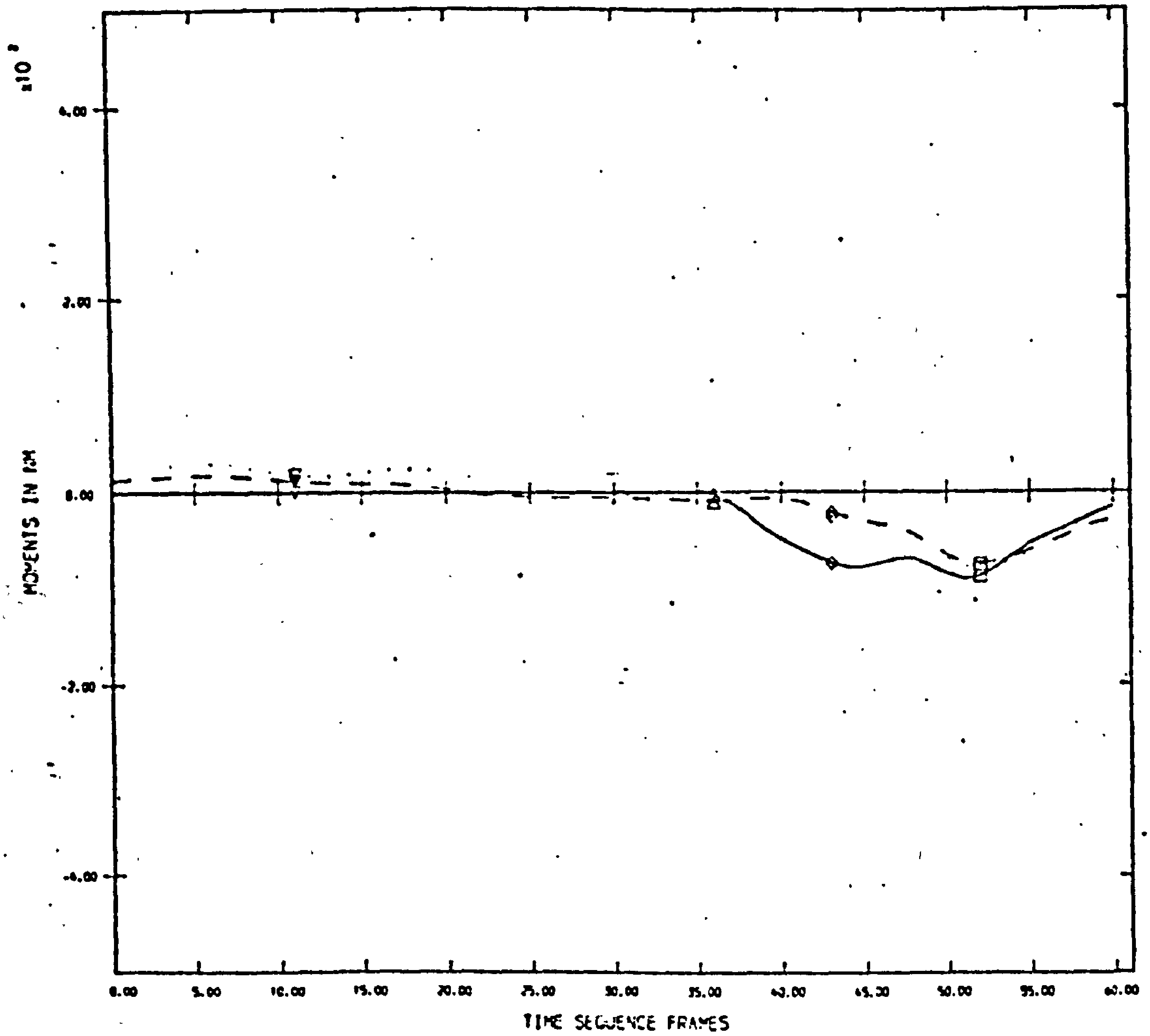
RIGHT TOE OFF ○

CONTINUOUS ANKLE

DASHED KNEE

DOTTED HIP

P3/L/BDT1

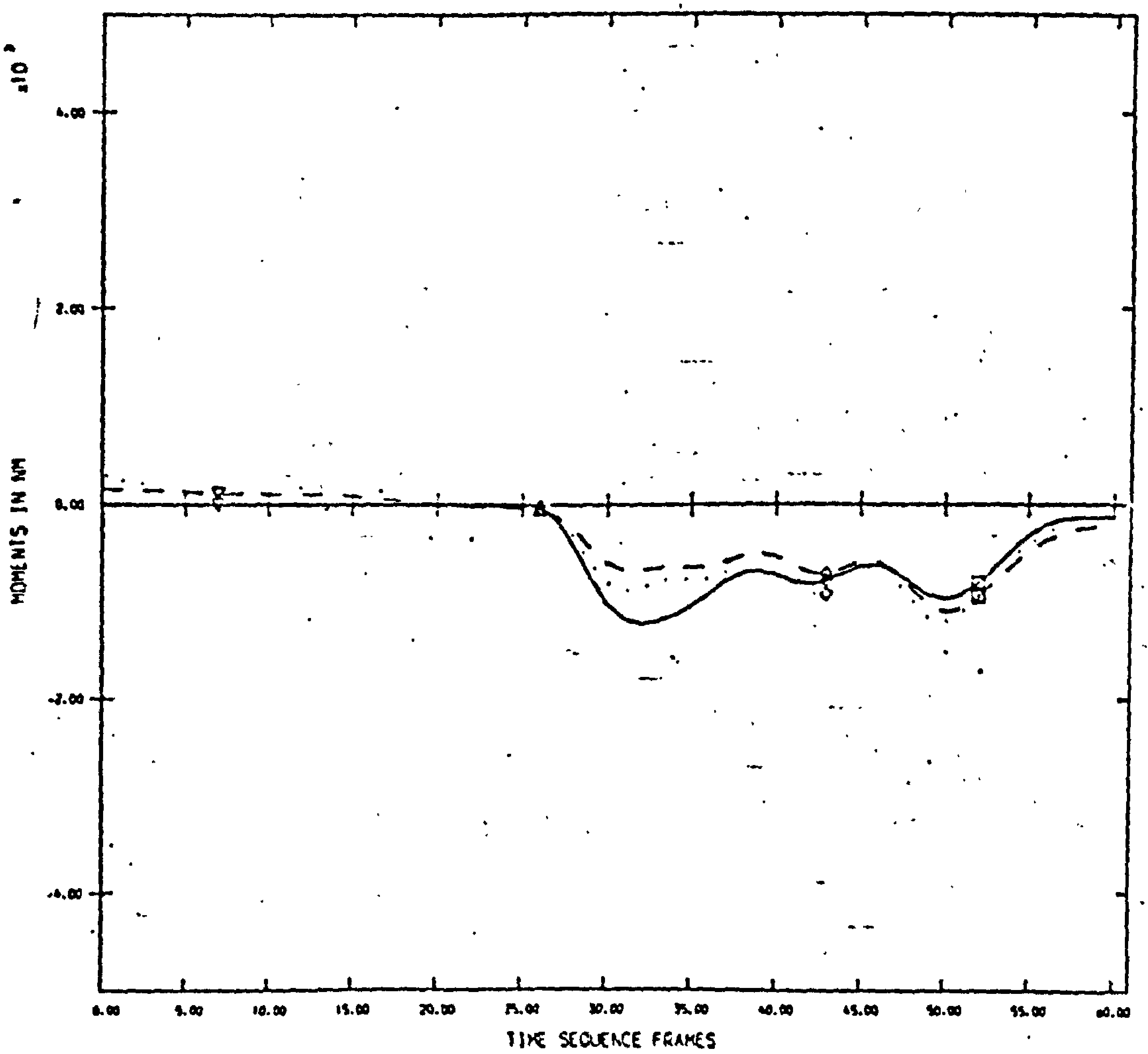


ANKLE,KNEE, HIP. CORONAL PLANE

LEFT HEEL STRIKE △
LEFT TOE OFF ▽
RIGHT HEELSTRIKE □
RIGHT TOE OFF ◇

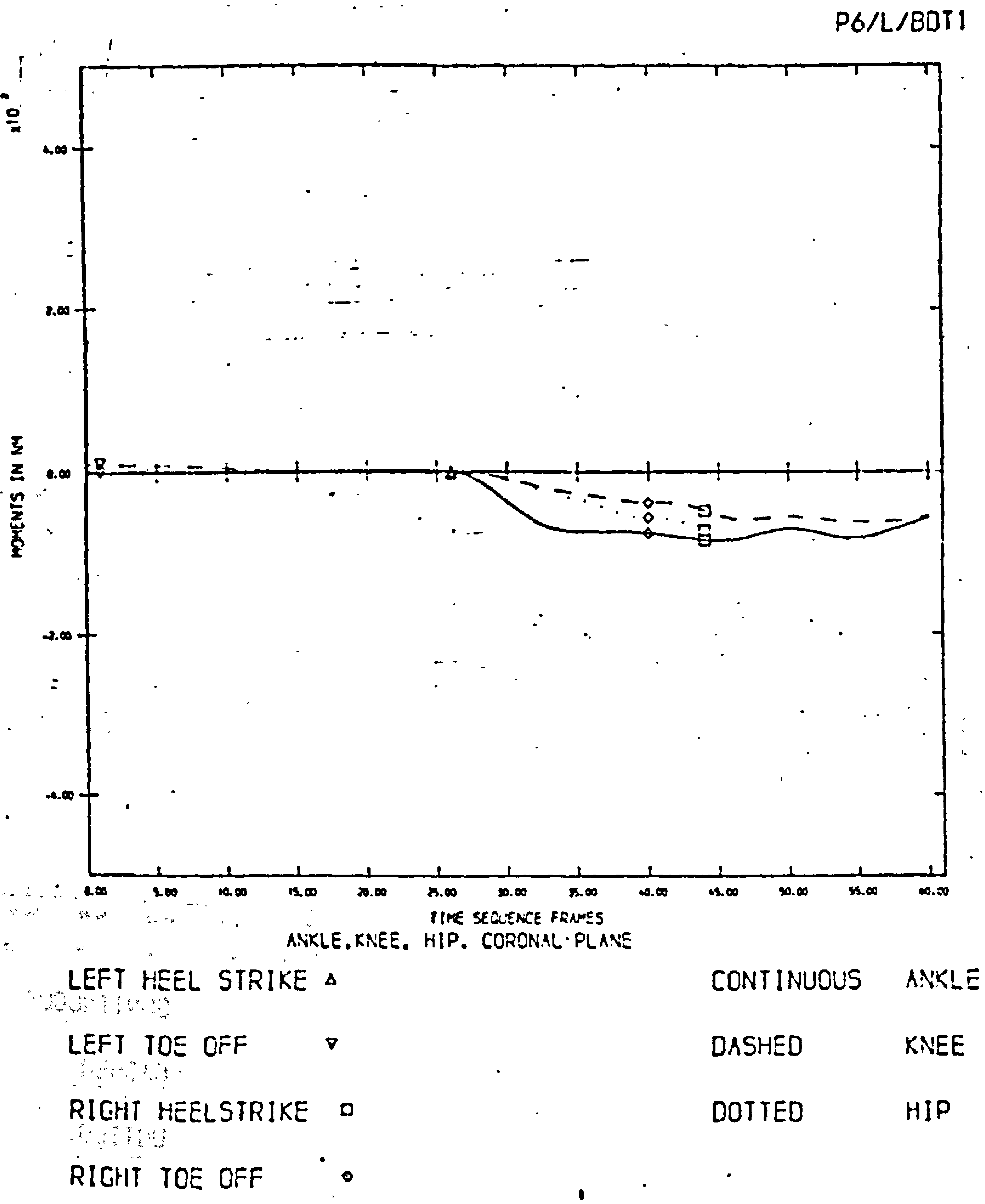
CONTINUOUS ANKLE
DASHED KNEE
DOTTED HIP

P4/L/BDT1



ANKLE,KNEE, HIP, CORONAL PLANE

LEFT HEEL STRIKE	△	CONTINUOUS	ANKLE
LEFT TOE OFF	▽	DASHED	KNEE
RIGHT HEELSTRIKE	□	DOTTED	HIP
RIGHT TOE OFF	○		


P6/L/BDT1
x10 ³
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MOMENTS IN NM
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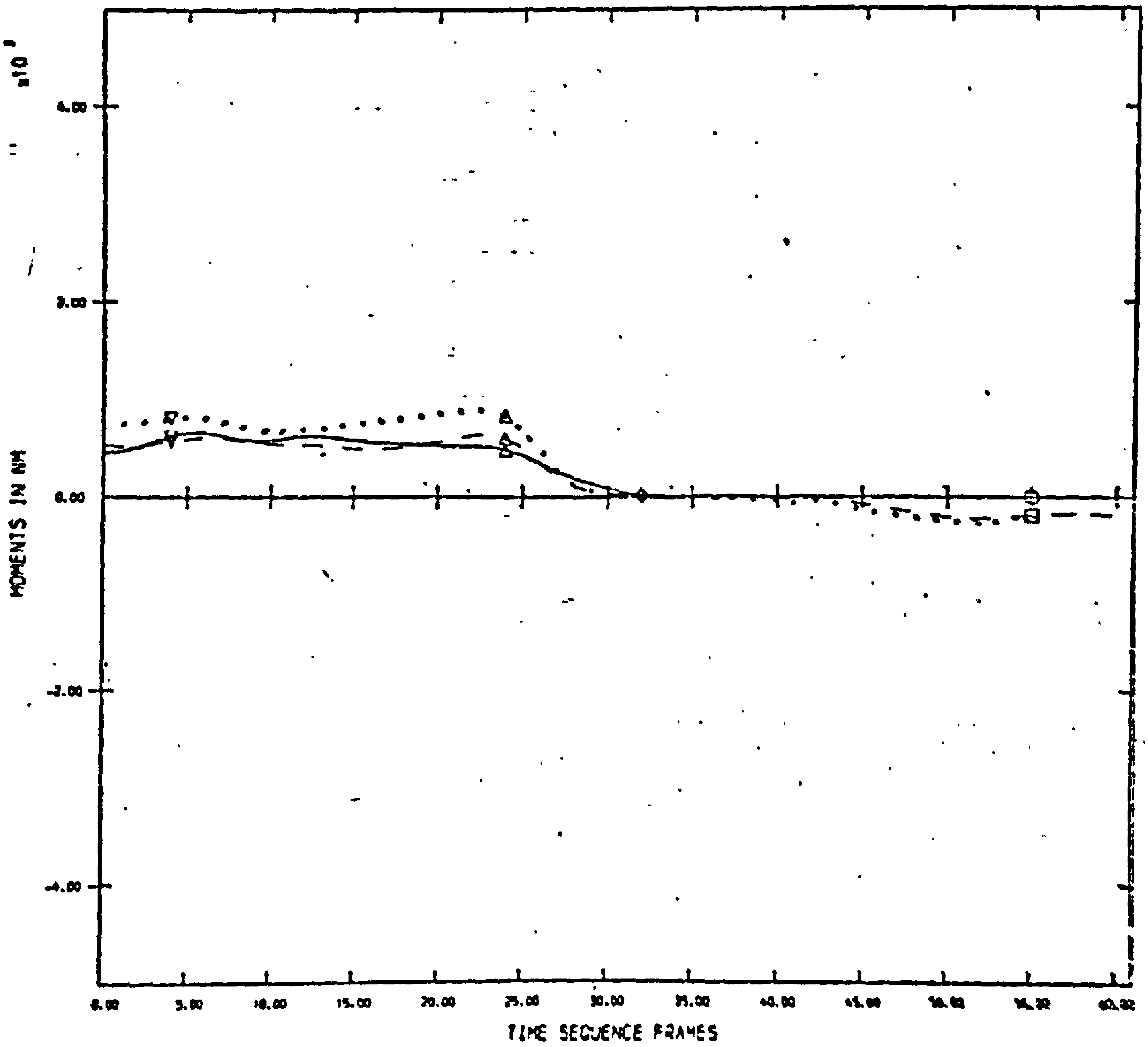
45.00
50.00
55.00
60.00
TIME SEQUENCE FRAMES
ANKLE, KNEE, HIP, CORONAL PLANE
LEFT HEEL STRIKE △
LEFT TOE OFF ▽
RIGHT HEELSTRIKE □
RIGHT TOE OFF ◇
CONTINUOUS ANKLE
DASHED KNEE
DOTTED HIP

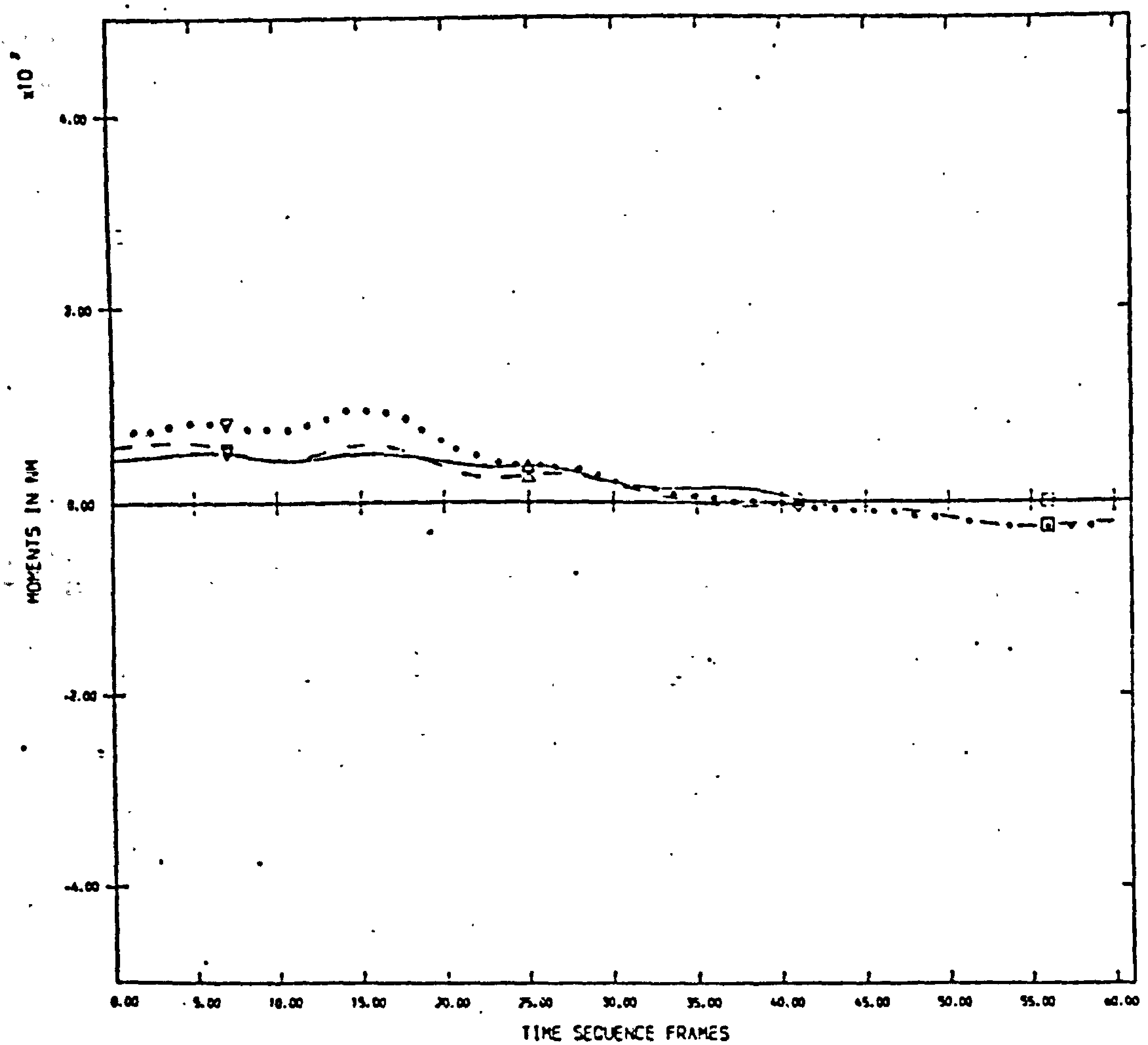
P1/R/BDT1



ANKLE, KNEE, HIP, CORONAL PLANE

LEFT HEEL STRIKE	△	CONTINUOUS	ANKLE
LEFT TOE OFF	▽	DASHED	KNEE
RIGHT HEELSTRIKE	□	DOTTED	HIP
RIGHT TOE OFF	◇		

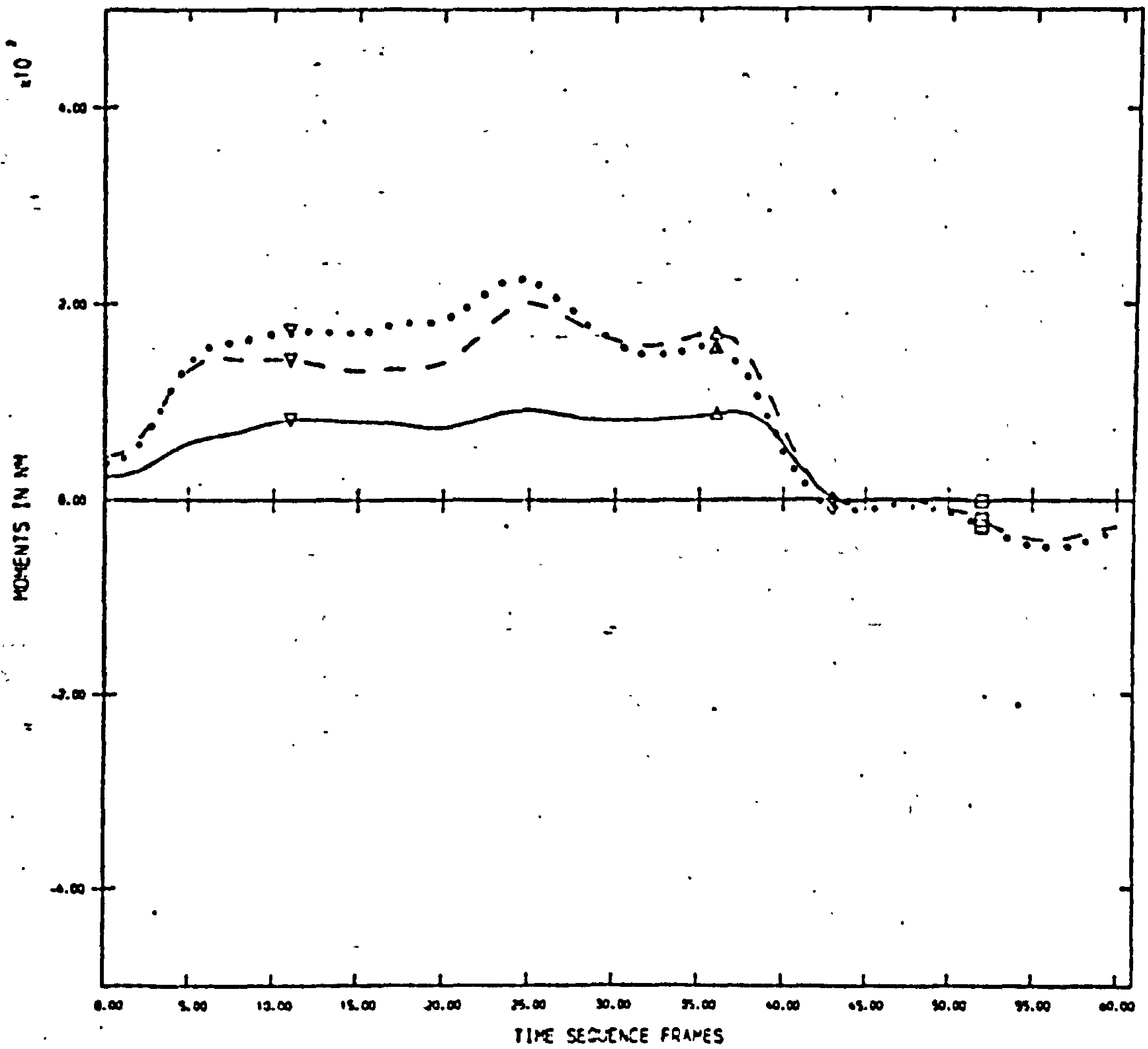
P2/R/BOT1



ANKLE.KNEE. HIP. CORONAL PLANE

LEFT HEEL STRIKE	△	CONTINUOUS	ANKLE
LEFT TOE OFF	▽	DASHED	KNEE
RIGHT HEELSTRIKE.	□	DOTTED	HIP
RIGHT TOE OFF	◇		

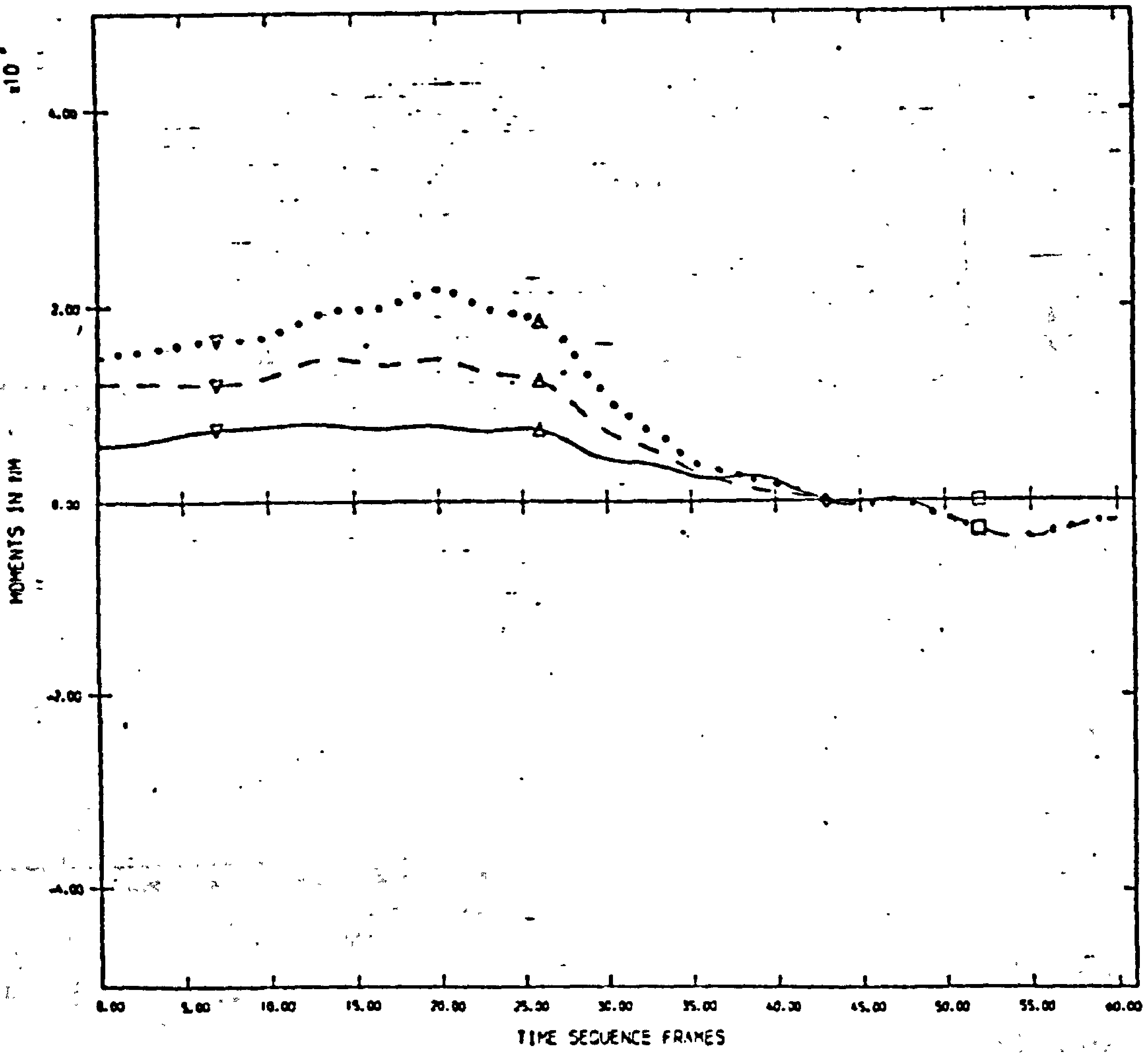
P3/R/BDT1



ANKLE, KNEE, HIP, CORONAL PLANE

LEFT HEEL STRIKE	△	CONTINUOUS	ANKLE
LEFT TOE OFF	▽	DASHED	KNEE
RIGHT HEELSTRIKE	□	DOTTED	HIP
RIGHT TOE OFF	◇		

P4/R/BDT1



ANKLE,KNEE, HIP. CORONAL PLANE

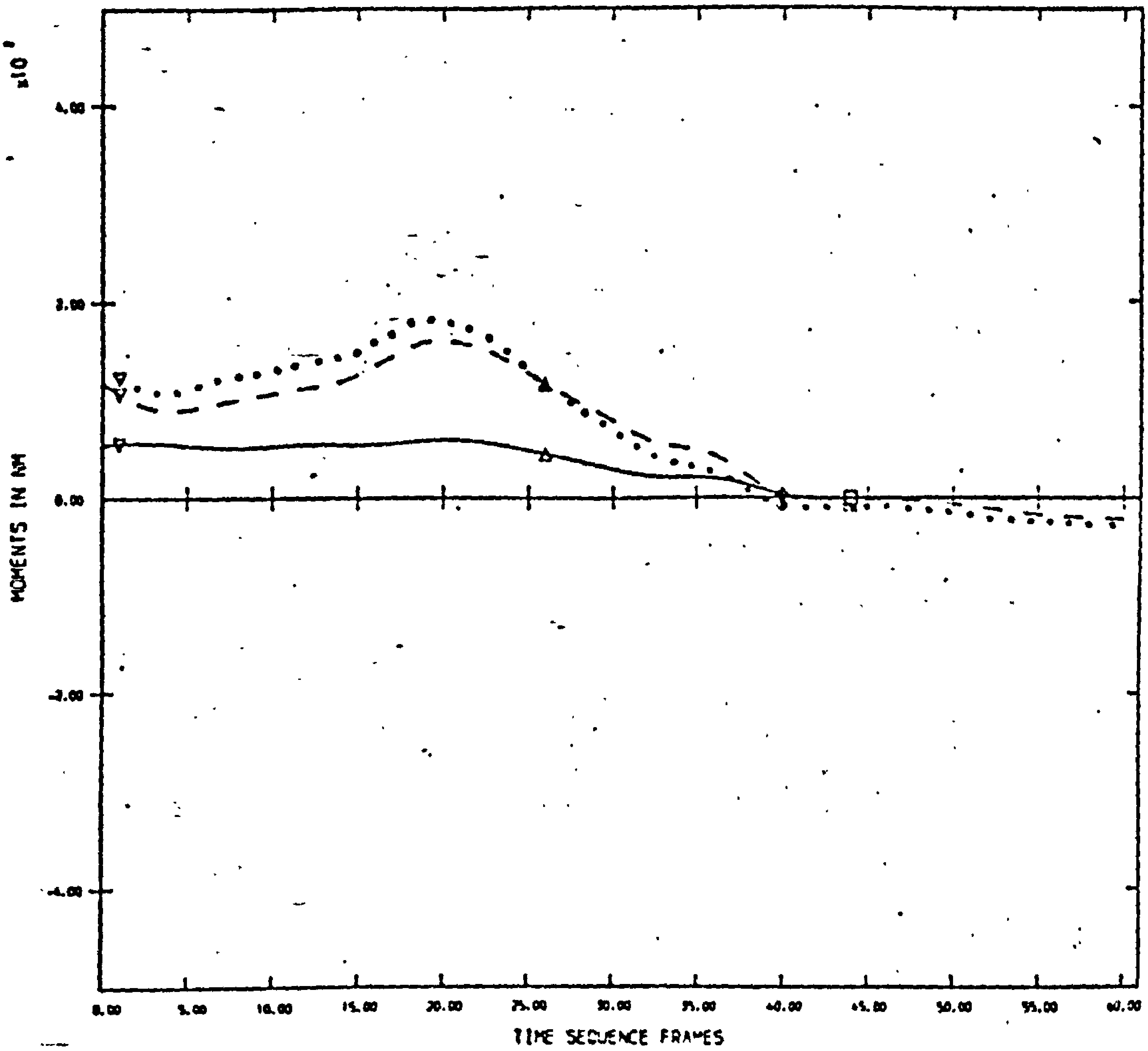
LEFT HEEL STRIKE △ CONTINUOUS ANKLE

LEFT TOE OFF ▽ DASHED KNEE

RIGHT HEELSTRIKE □ DOTTED HIP

RIGHT TOE OFF ◇

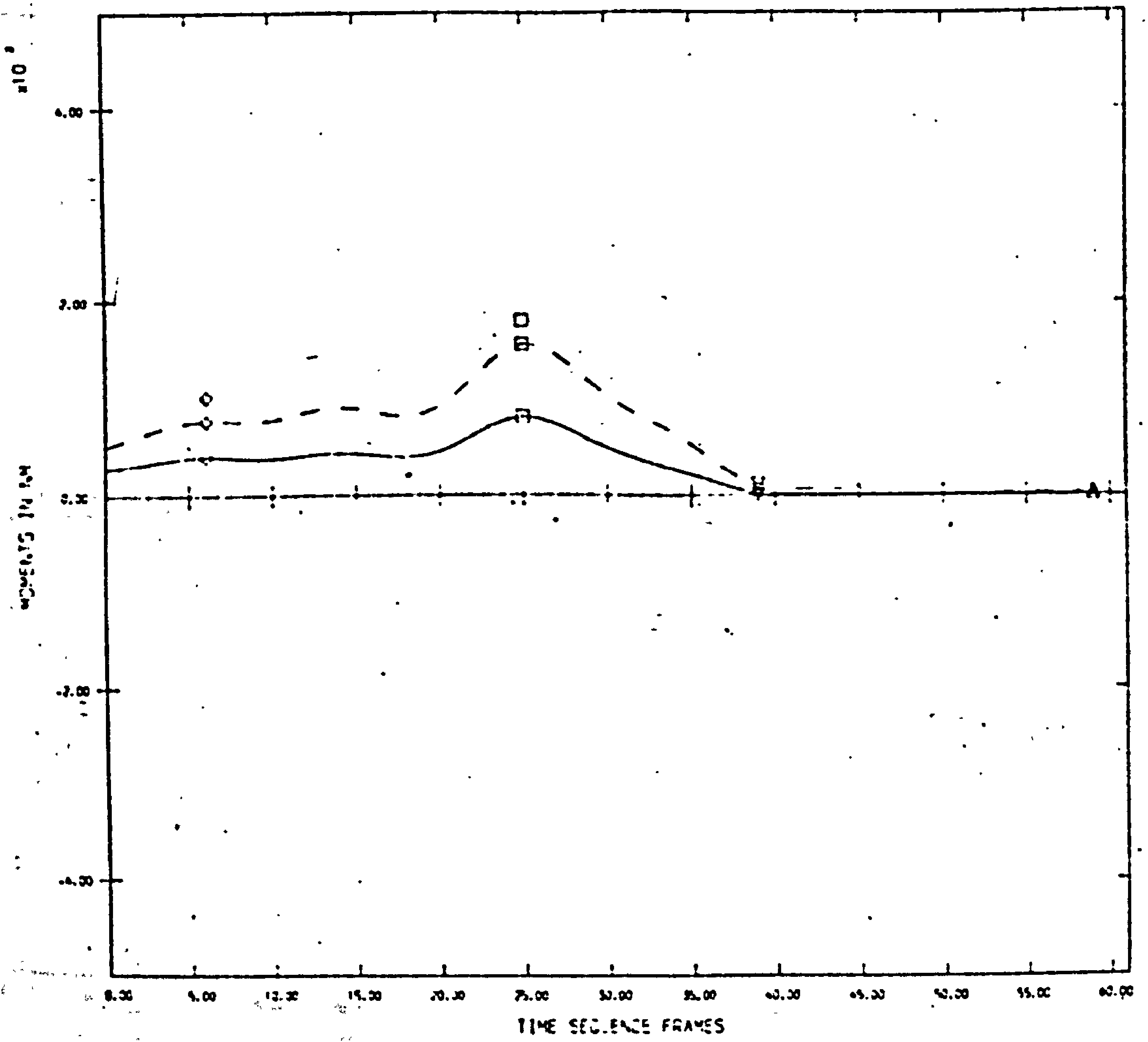
P6/R/BDT1



ANKLE.KNEE. HIP. CORONAL PLANE

LEFT HEEL STRIKE	△	CONTINUOUS	ANKLE
LEFT TOE OFF	▽	DASHED	KNEE
RIGHT HEELSTRIKE	□	DOTTED	HIP
RIGHT TOE OFF	◇		

P6/L/FULO

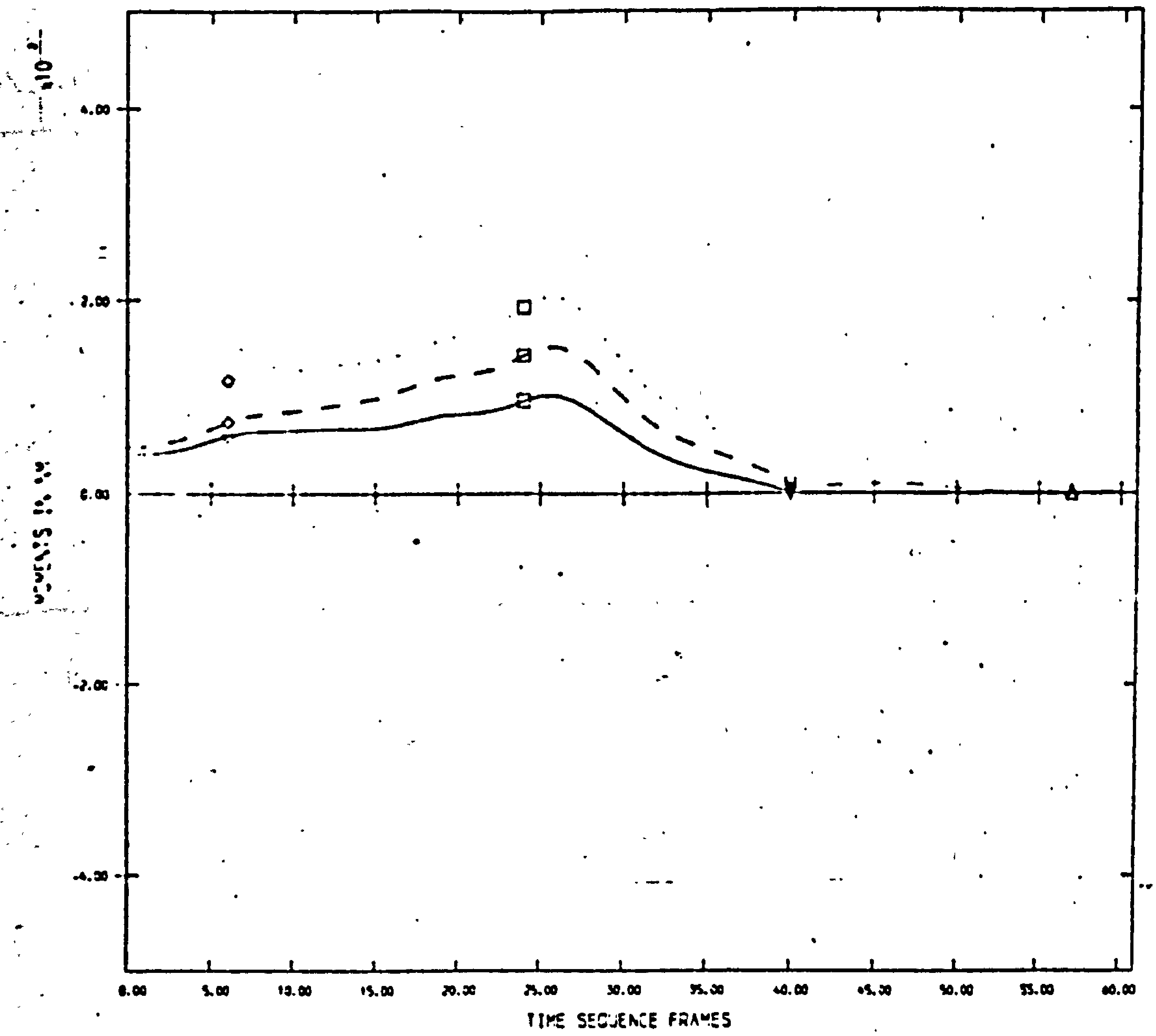


ANKLE, KNEE, HIP, SAGITTAL PLANE

LEFT HEEL STRIKE △
LEFT TOE OFF ▽
RIGHT HEELSTRIKE □
RIGHT TOE OFF ◇

CONTINUOUS ANKLE
DASHED KNEE
DOTTED HIP

P4/L/FULO

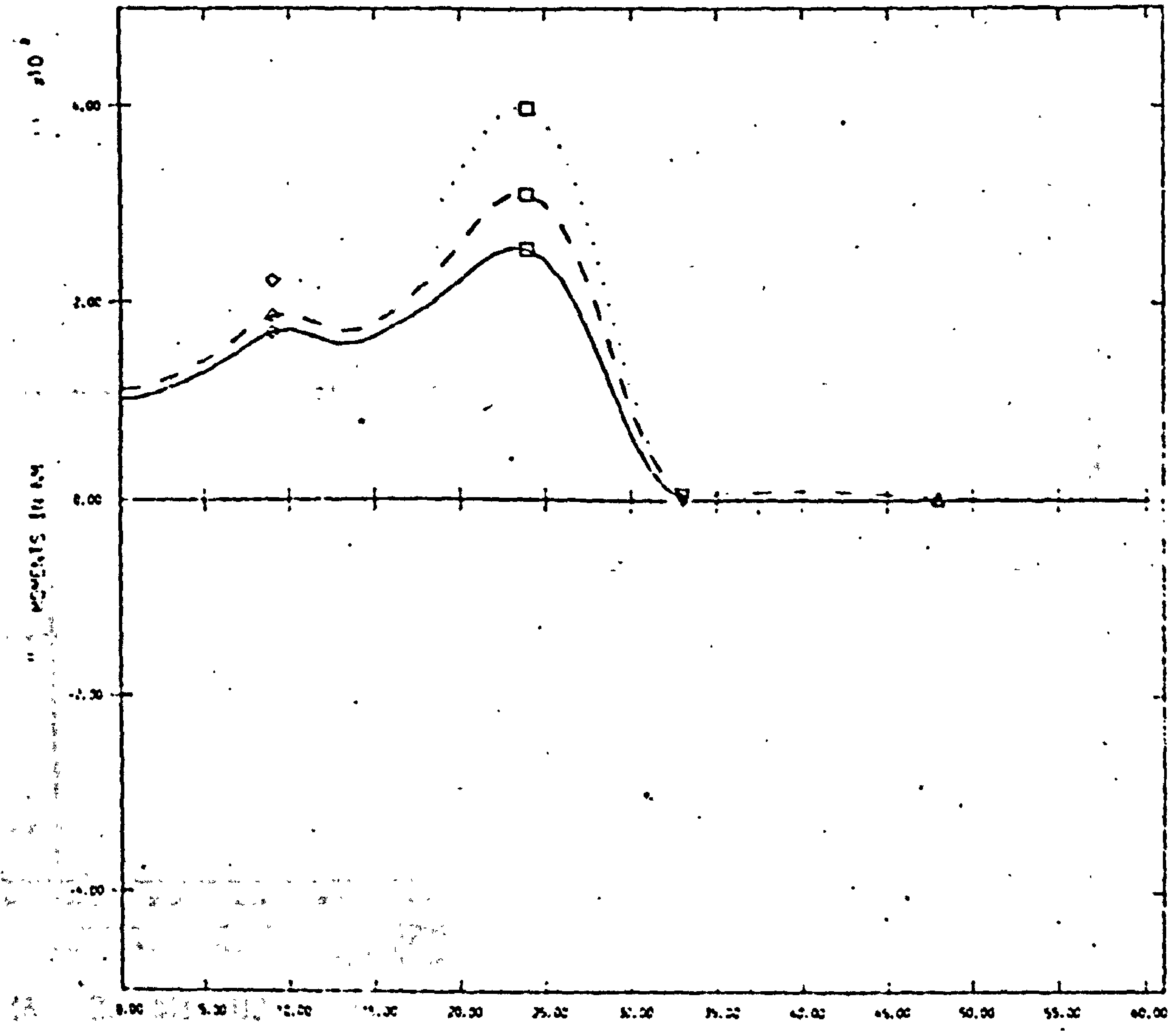


ANKLE, KNEE, HIP, SAGITTAL PLANE

LEFT HEEL STRIKE △
LEFT TOE OFF ▽
RIGHT HEELSTRIKE □
RIGHT TOE OFF ◇

CONTINUOUS ANKLE
DASHED KNEE
DOTTED HIP

P1/L/FULO



ANKLE, KNEE, HIP, SAGITTAL PLANE

LEFT HEEL STRIKE △

LEFT TOE OFF ▽

RIGHT HEELSTRIKE □

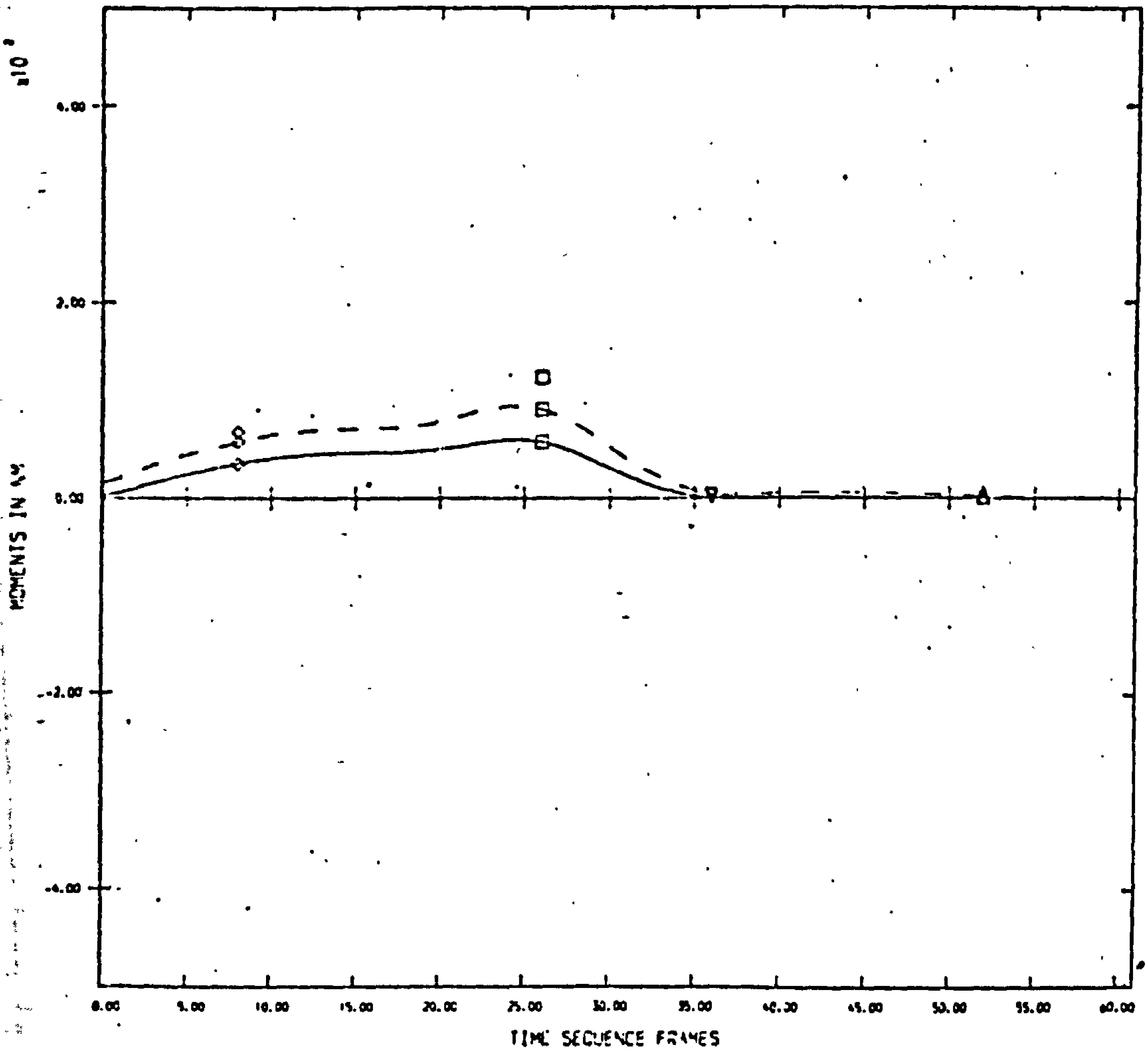
RIGHT TOE OFF ◇

CONTINUOUS ANKLE

DASHED KNEE

DOTTED HIP

P2/L/FULO



ANKLE, KNEE, HIP, SAGITTAL PLANE

LEFT HEEL STRIKE △

LEFT TOE OFF ▽

RIGHT HEELSTRIKE □

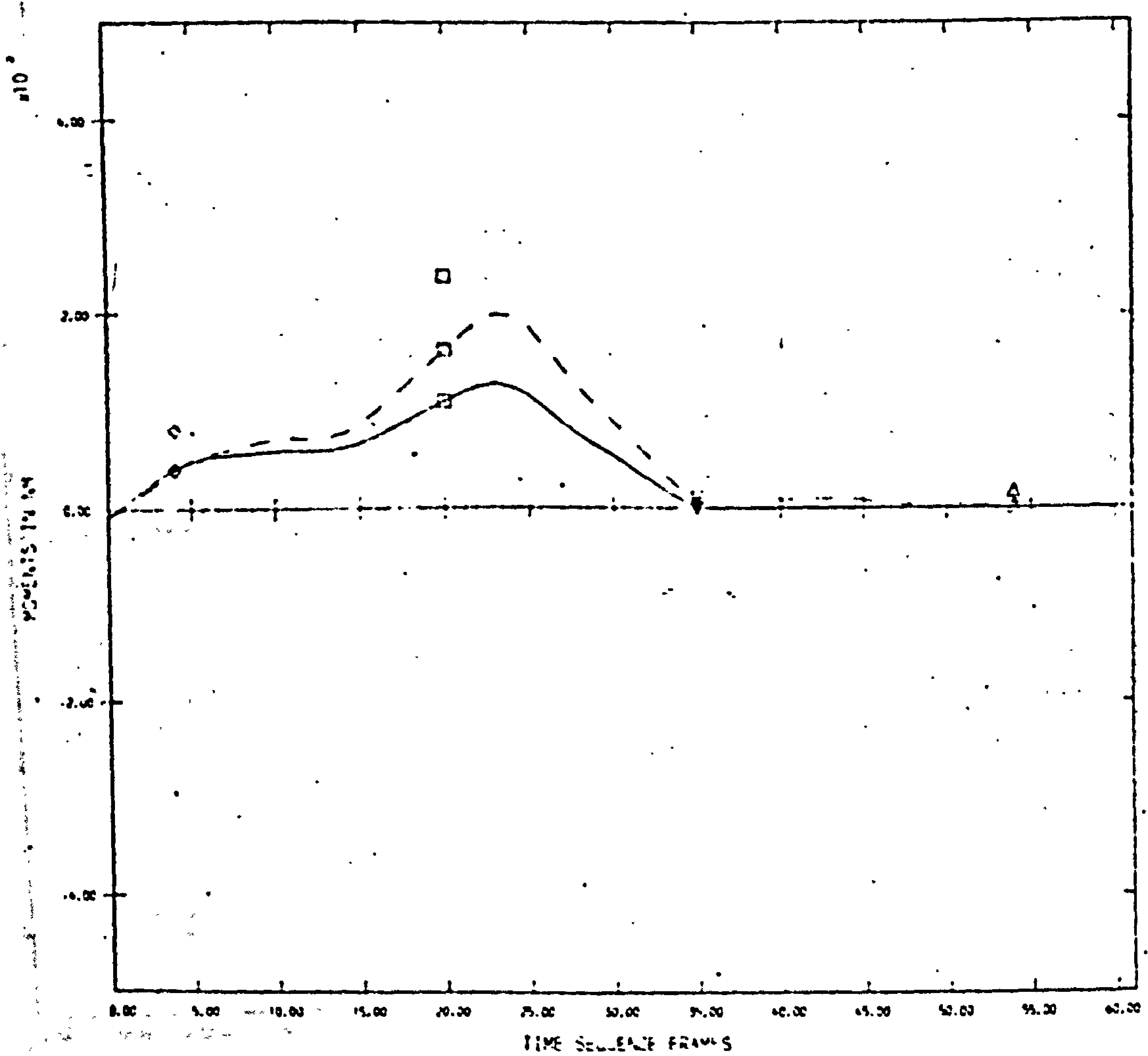
RIGHT TOE OFF ◇

CONTINUOUS ANKLE

DASHED KNEE

DOTTED HIP

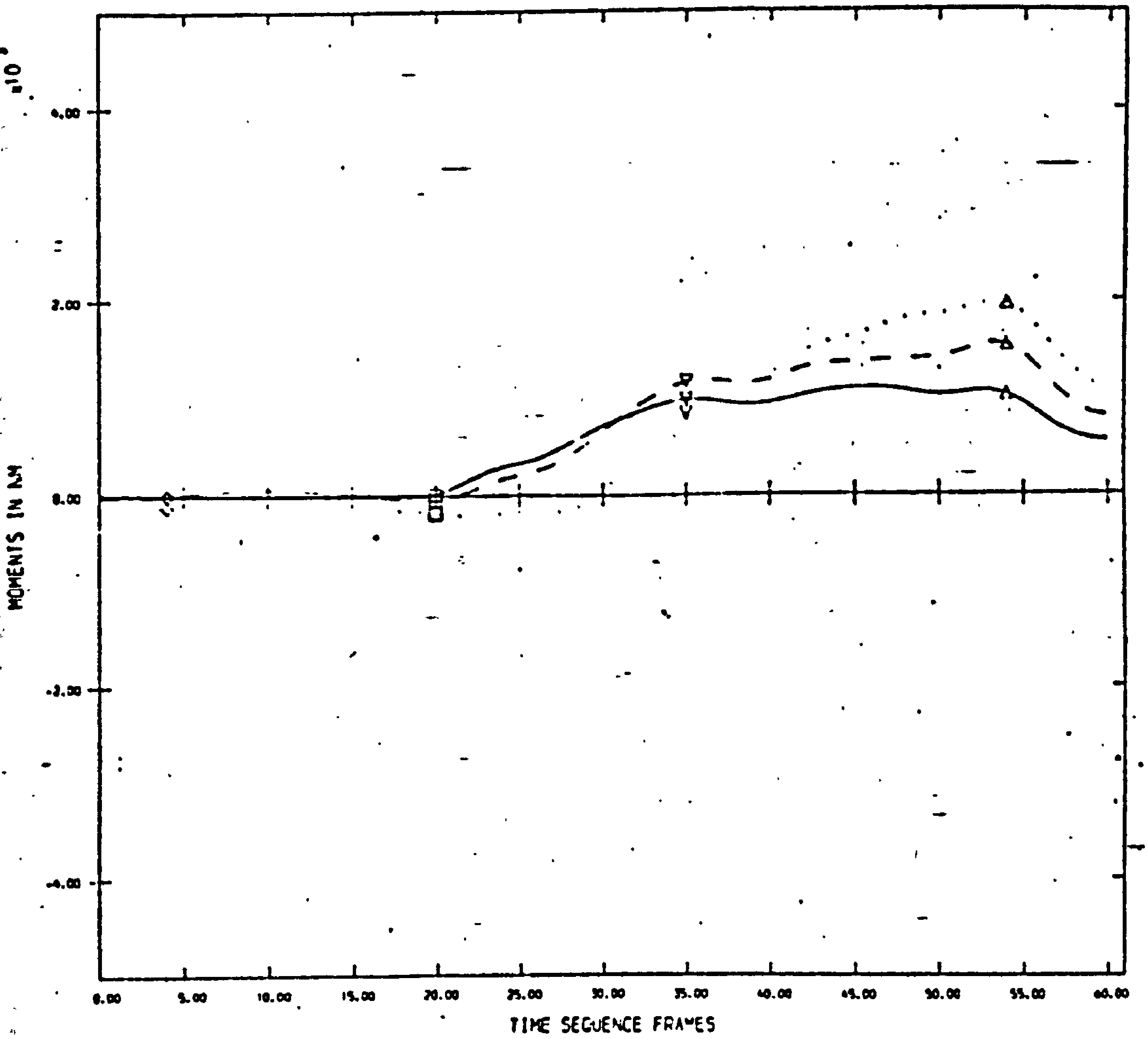
P3/L/FULO



ANKLE, KNEE, HIP, SAGITTAL PLANE

LEFT HEEL STRIKE	^	CONTINUOUS	ANKLE
LEFT TOE OFF	v	DASHED	KNEE
RIGHT HEELSTRIKE	□	DOTTED	HIP
RIGHT TOE OFF	◇		

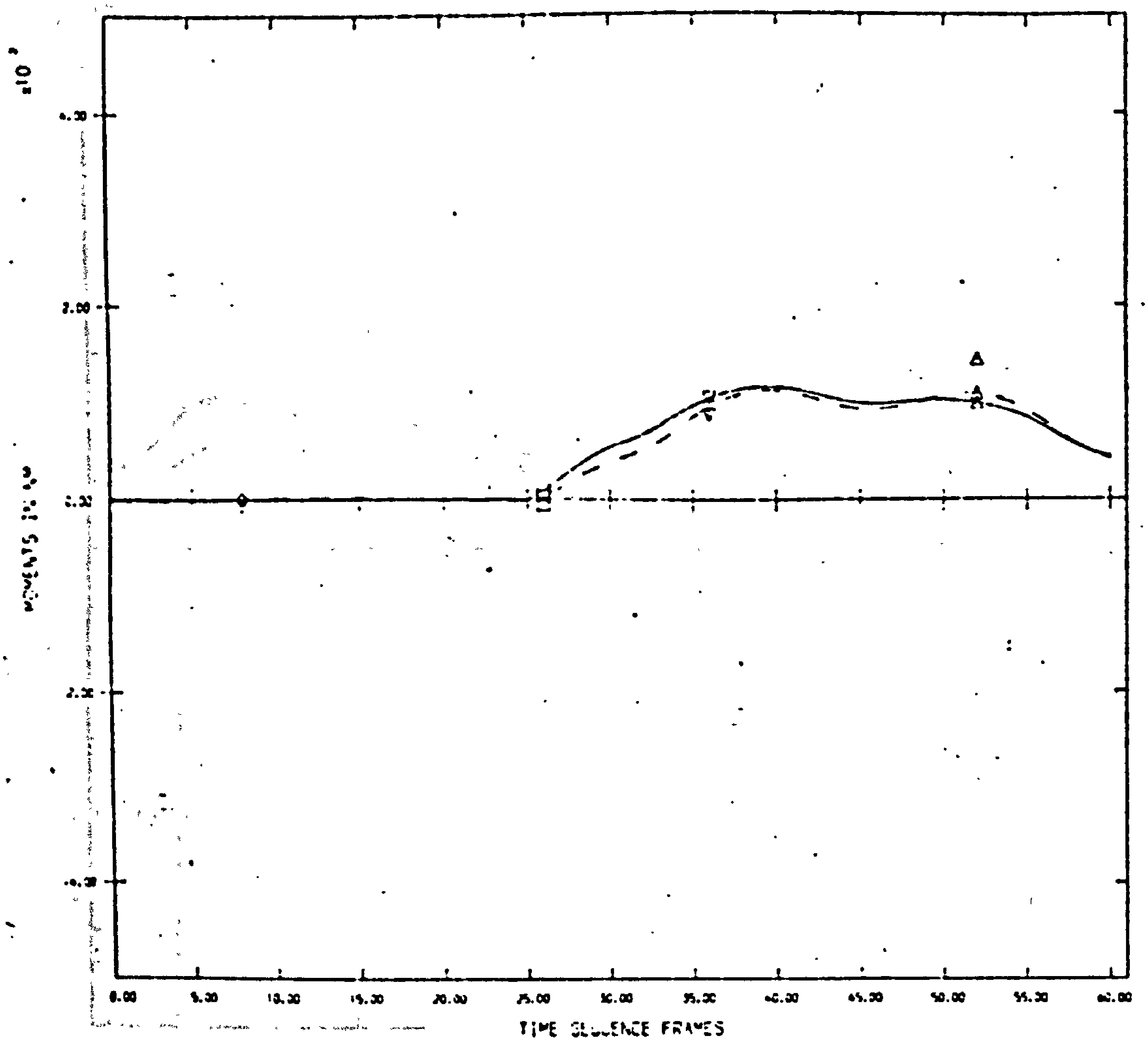
P3/R/FULO



ANKLE. KNEE. HIP. SAGITTAL PLANE

LEFT HEEL STRIKE	△	CONTINUOUS	ANKLE
LEFT TOE OFF	▽	DASHED	KNEE
RIGHT HEELSTRIKE	□	DOTTED	HIP
RIGHT TOE OFF	◇		

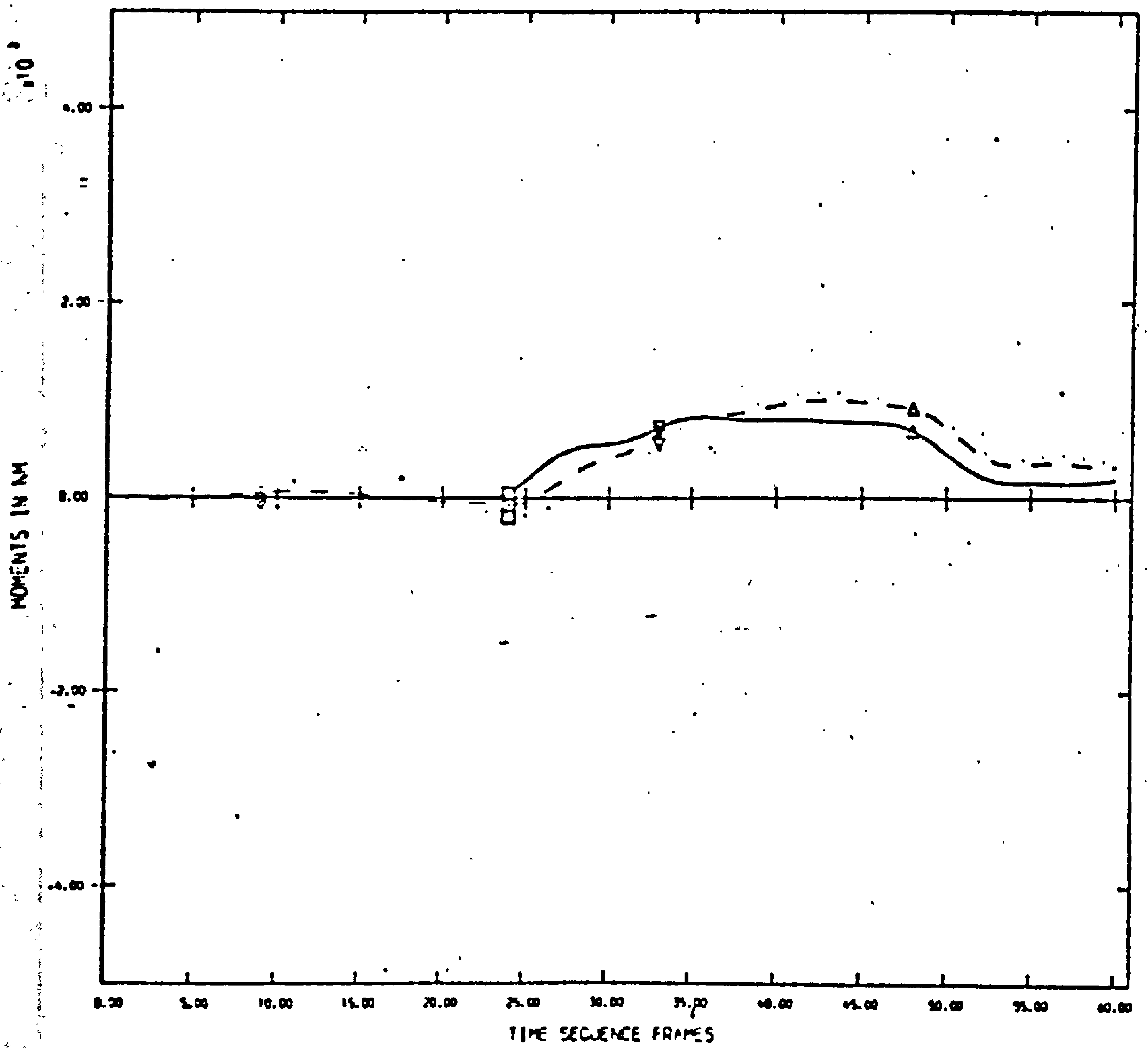
P2/R/FULO



ANKLE, KNEE, HIP, SAGITTAL PLANE

LEFT HEEL STRIKE	△	CONTINUOUS	ANKLE
LEFT TOE OFF	▽	DASHED	KNEE
RIGHT HEELSTRIKE	□	DOTTED	HIP
RIGHT TOE OFF	◇		

PI/R/FULO



ANKLE, KNEE, HIP. SAGITTAL PLANE

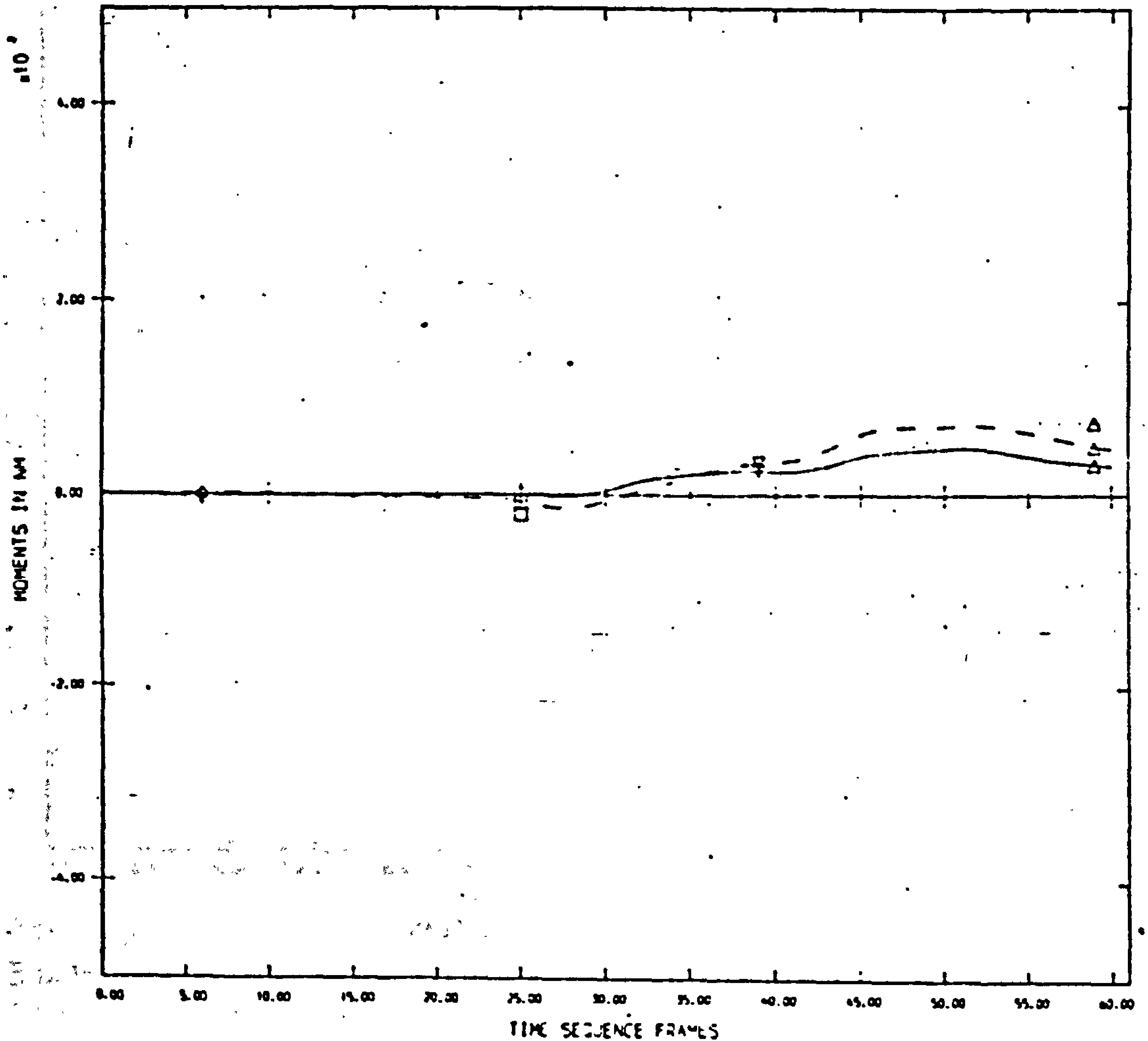
LEFT HEEL STRIKE △ CONTINUOUS ANKLE

LEFT TOE OFF ▽ DASHED KNEE

RIGHT HEELSTRIKE □ DOTTED HIP

RIGHT TOE OFF ◇

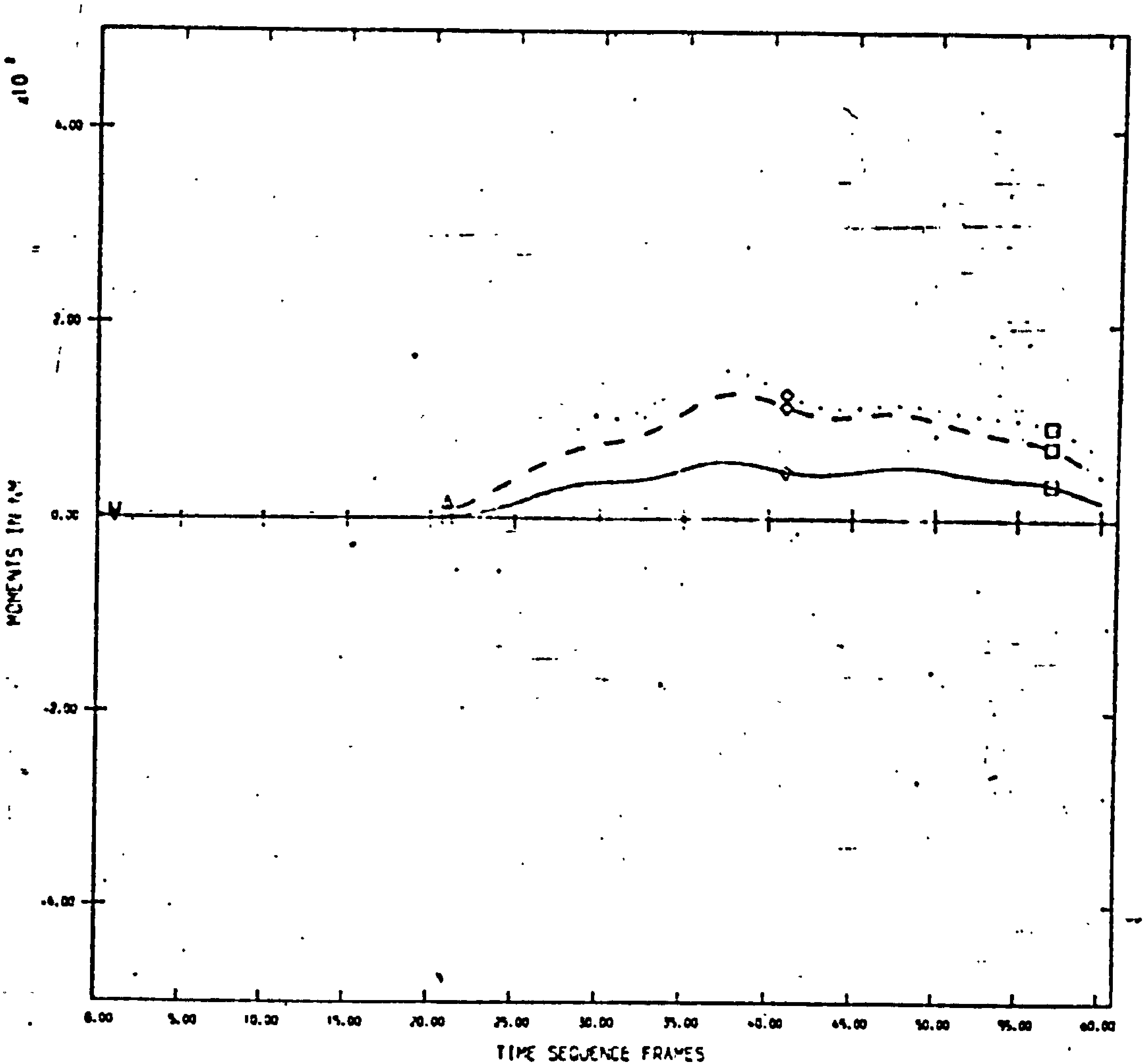
P6/R/FULO



ANKLE, KNEE, HIP, SAGITTAL PLANE

LEFT HEEL STRIKE	△	CONTINUOUS	ANKLE
LEFT TOE OFF	▽	DASHED	KNEE
RIGHT HEELSTRIKE	□	DOTTED	HIP
RIGHT TOE OFF	◇		

P6/L/BDTO



ANKLE, KNEE, HIP, SAGITTAL PLANE

LEFT HEEL STRIKE △

LEFT TOE OFF ▽

RIGHT HEELSTRIKE □

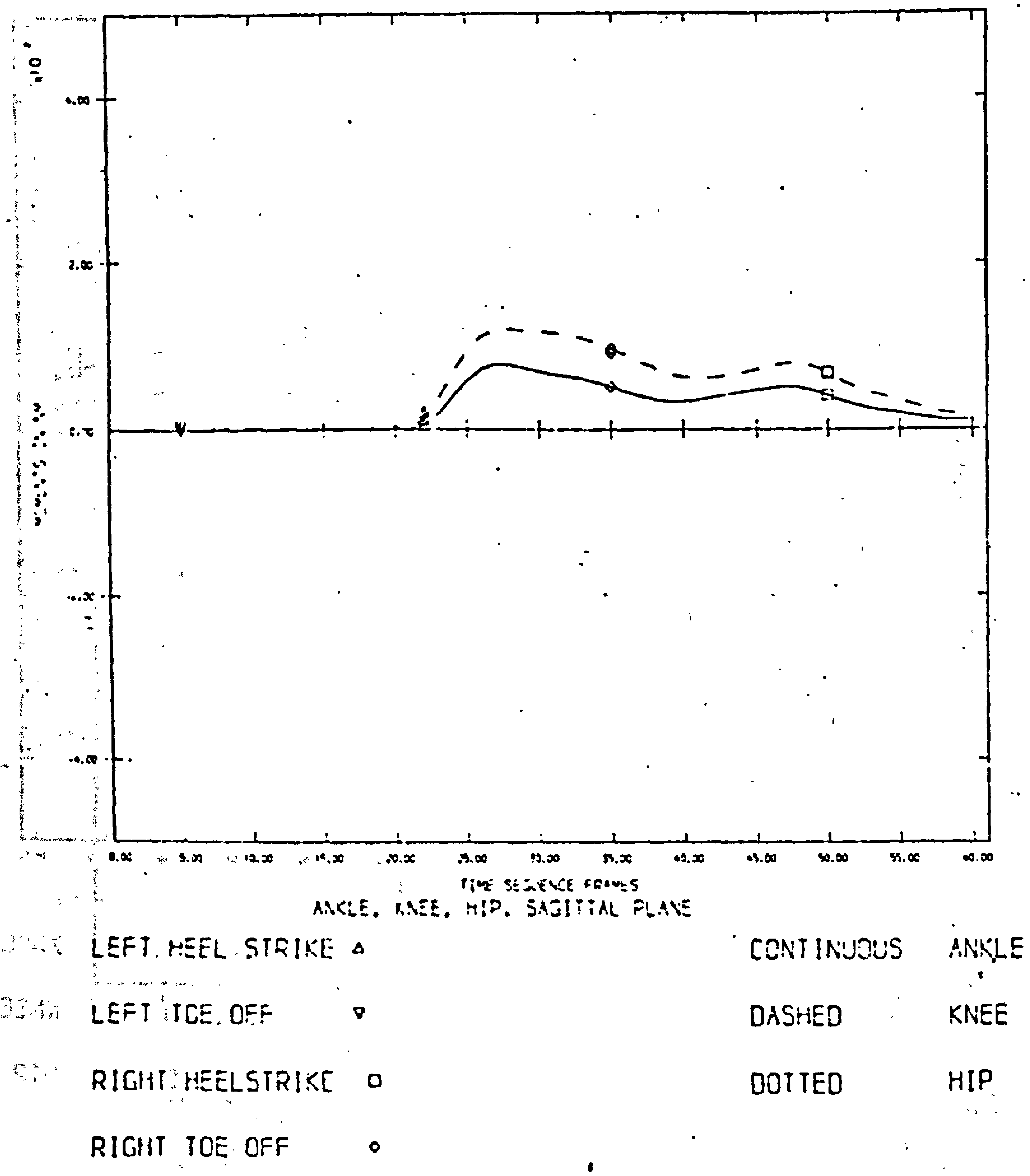
RIGHT TOE OFF ◇

CONTINUOUS ANKLE

DASHED KNEE

DOTTED HIP

P4/L/BDTO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DEGREES
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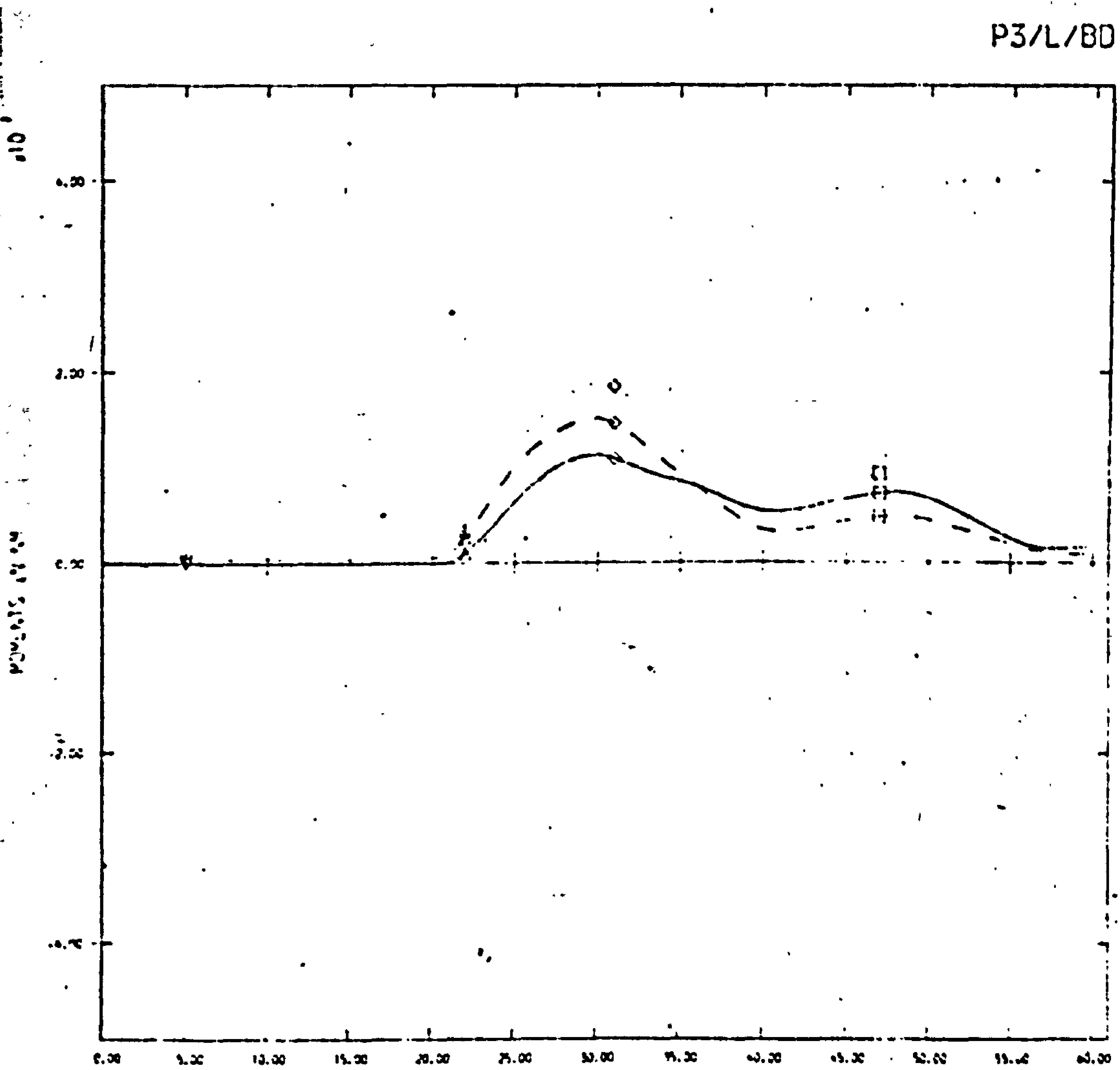
60.00
TIME SEQUENCE FRAMES
ANKLE, KNEE, HIP, SAGITTAL PLANE
LEFT HEEL STRIKE △
LEFT TOE OFF ▽
RIGHT HEELSTRIKE □
RIGHT TOE OFF ◇
CONTINUOUS ANKLE
DASHED KNEE
DOTTED HIP

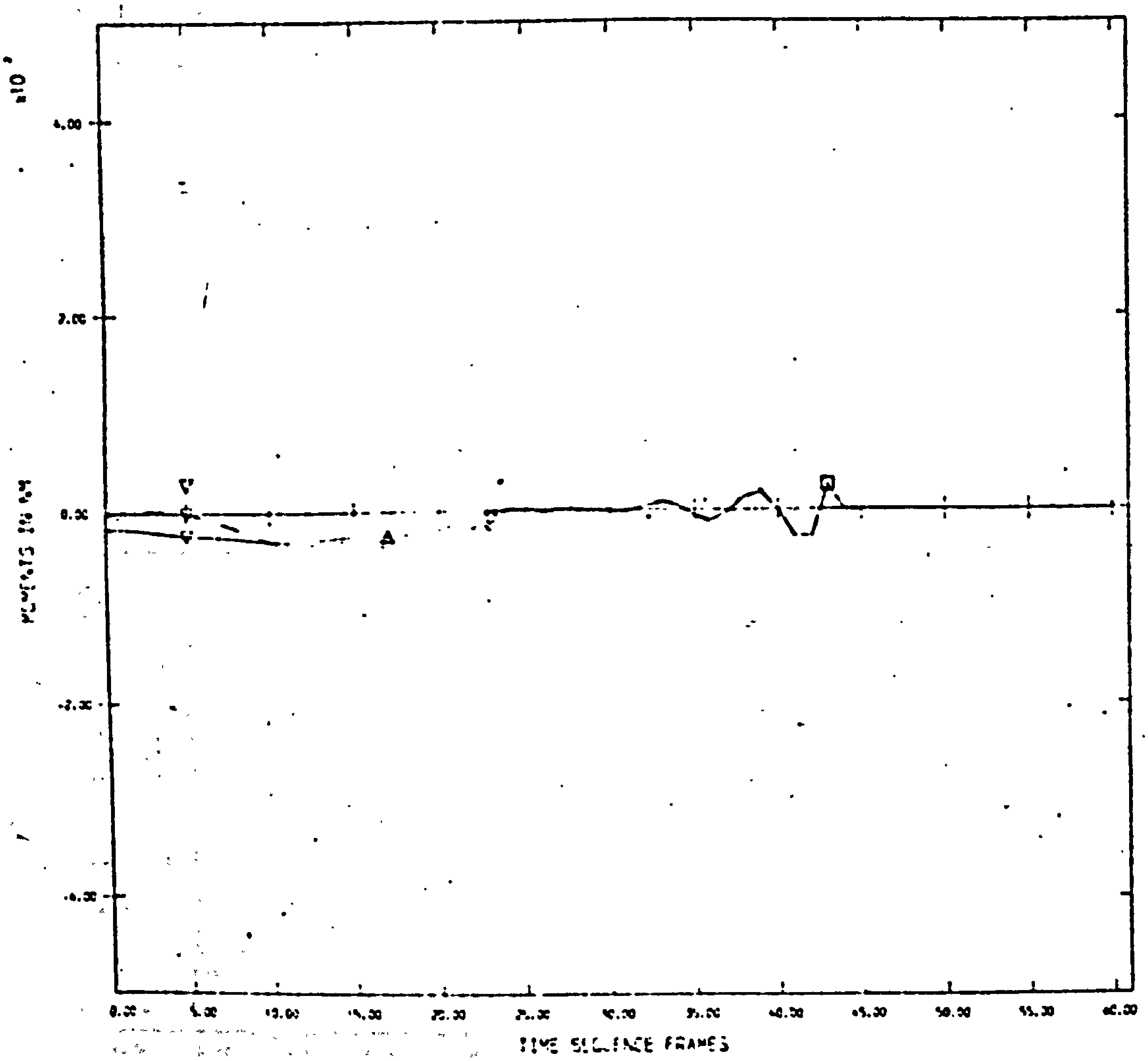
P3/L/BDTO



ANKLE, KNEE, HIP, SAGITTAL PLANE

LEFT HEEL STRIKE	△	CONTINUOUS	ANKLE
LEFT TOE OFF	▽	DASHED	KNEE
RIGHT HEELSTRIKE	□	DOTTED	HIP
RIGHT TOE OFF	◇		

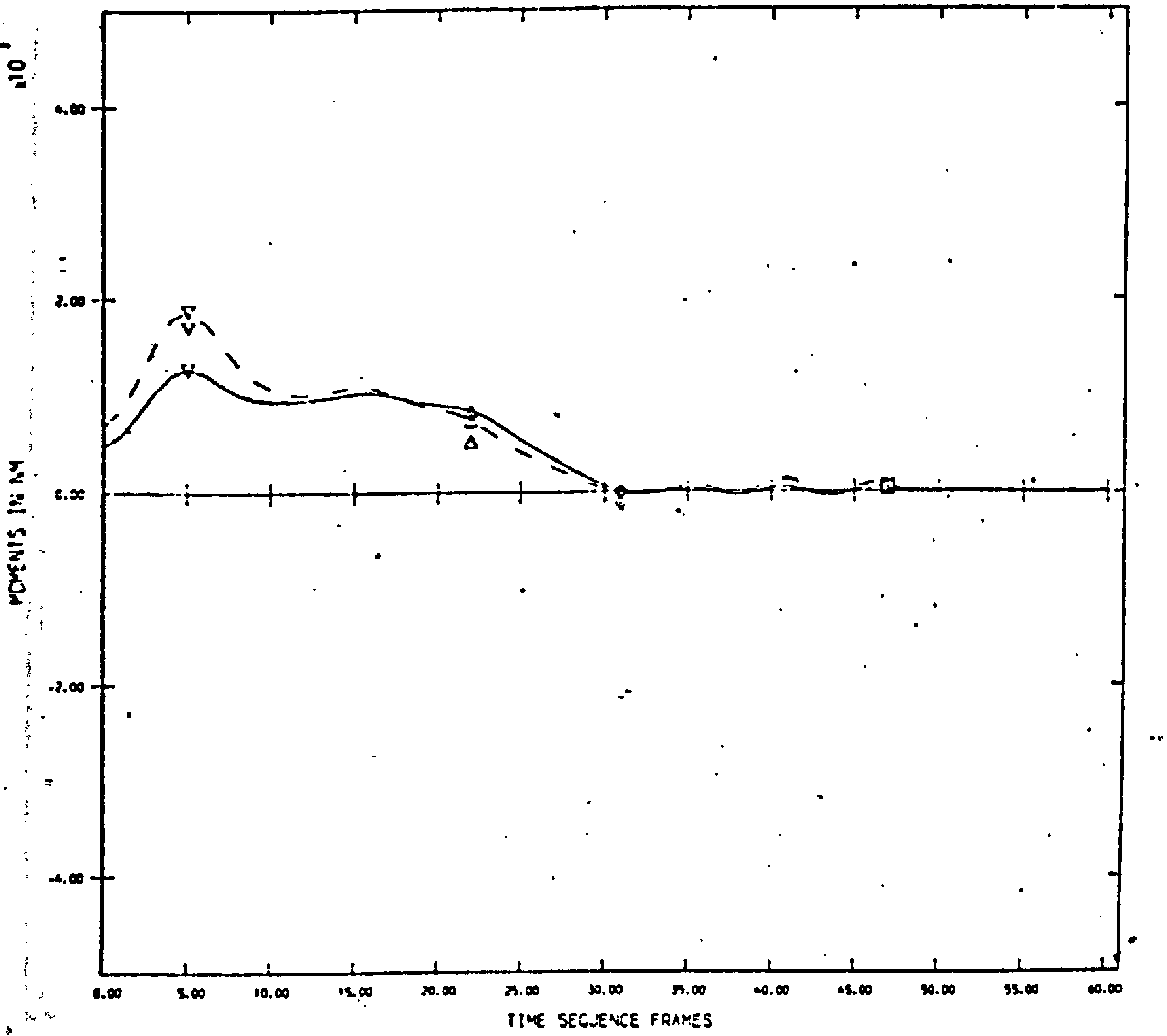
P2/R/BDTO



ANKLE, KNEE, HIP, SAGITTAL PLANE

LEFT HEEL STRIKE	△	CONTINUOUS	ANKLE
LEFT TOE OFF	▽	DASHED	KNEE
RIGHT HEELSTRIKE	□	DOTTED	HIP
RIGHT TOE OFF	◇		

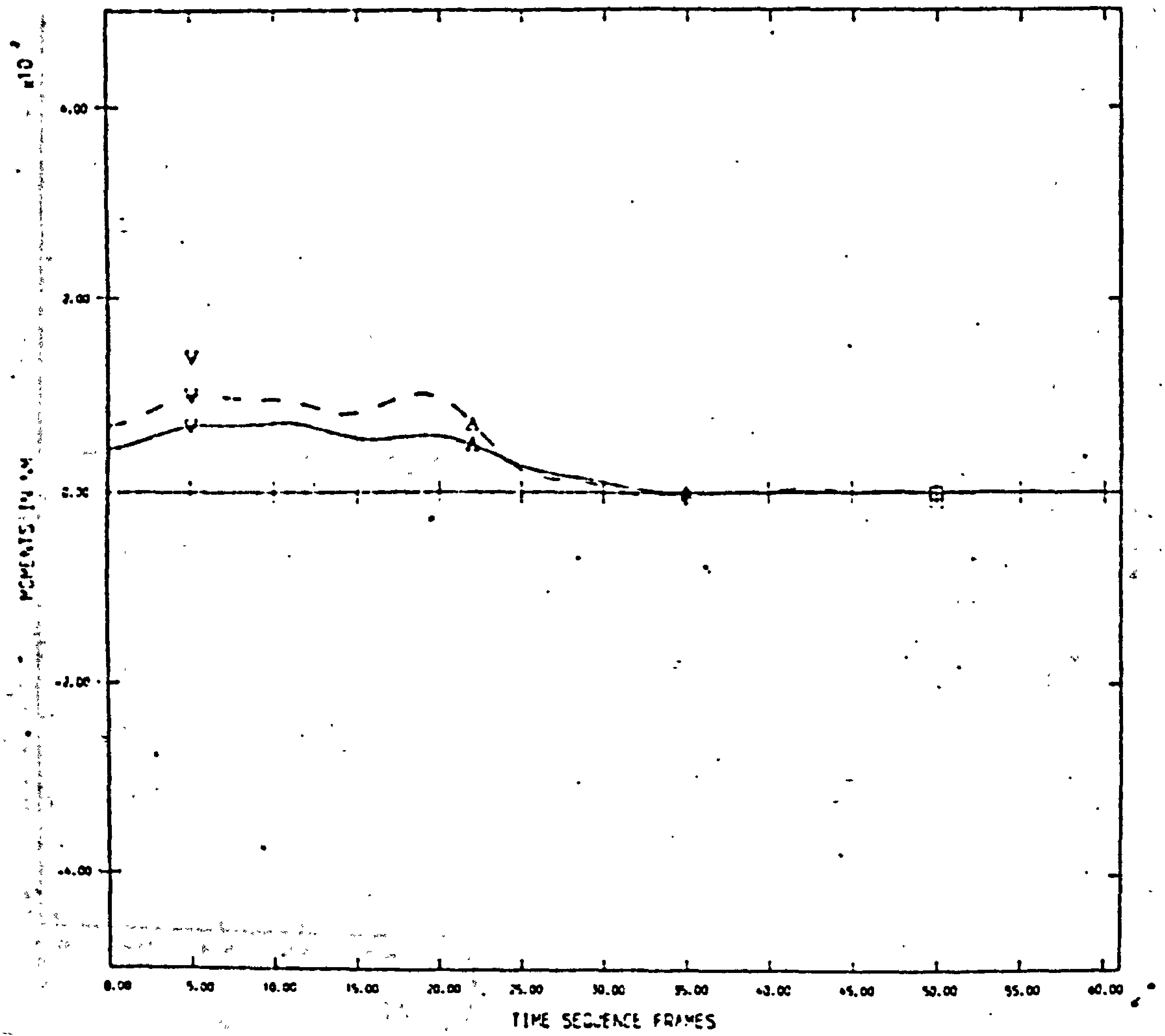
P3/R/BDTO



ANKLE, KNEE, HIP, SAGITTAL PLANE

LEFT HEEL STRIKE	△	CONTINUOUS	ANKLE
LEFT TOE OFF	▽	DASHED	KNEE
RIGHT HEELSTRIKE	□	DOTTED	HIP
RIGHT TOE OFF	◇		

P4/R/BDTO



ANKLE, KNEE, HIP, SAGITTAL PLANE

LEFT HEEL STRIKE △

LEFT TOE OFF ▽

RIGHT HEELSTRIKE □

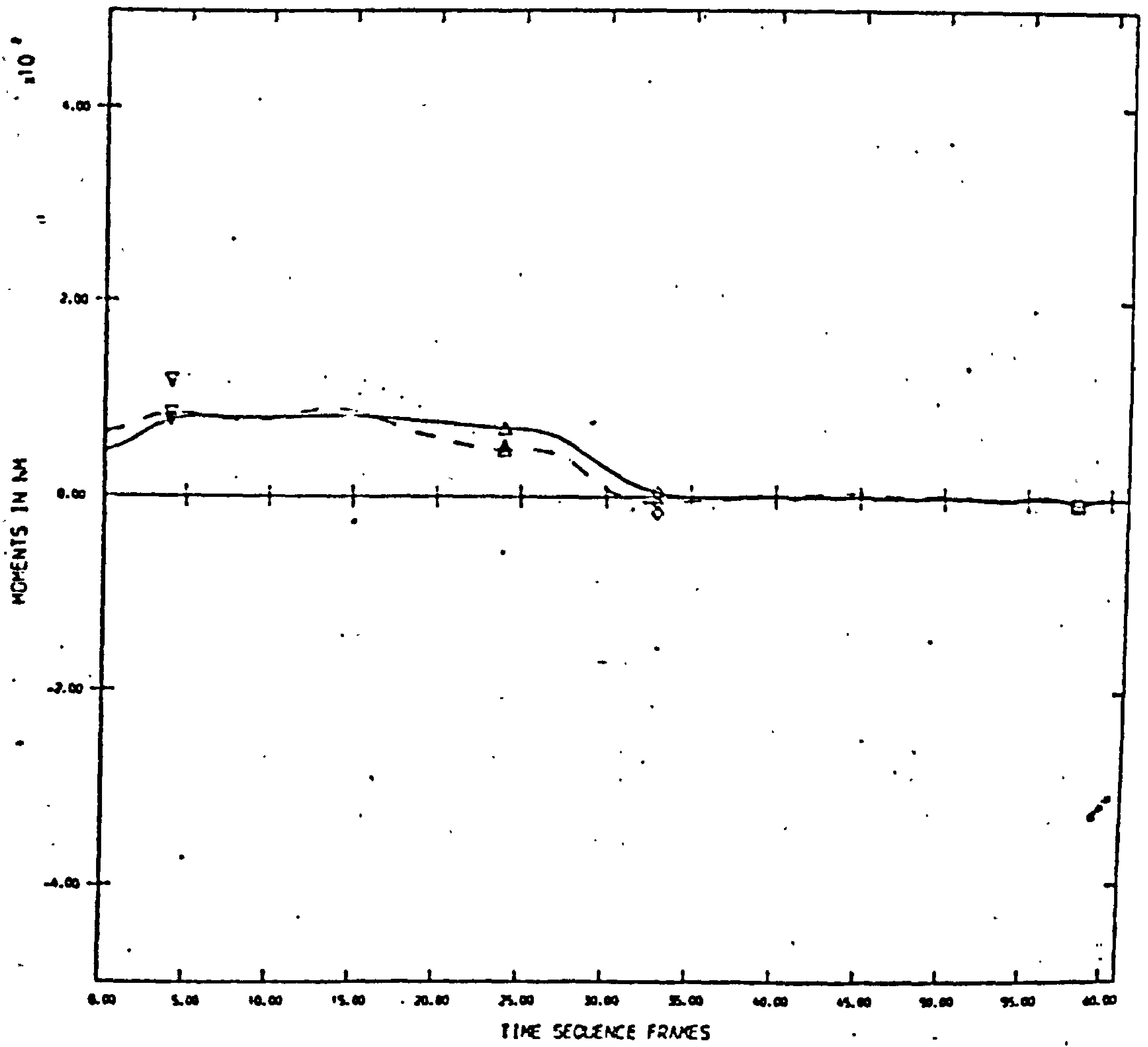
RIGHT TOE OFF ◇

CONTINUOUS ANKLE

DASHED KNEE

DOTTED HIP

P1/R/BDTO



ANKLE, KNEE, HIP, SAGITTAL PLANE

LEFT HEEL STRIKE △

LEFT TOE OFF ▽

RIGHT HEELSTRIKE □

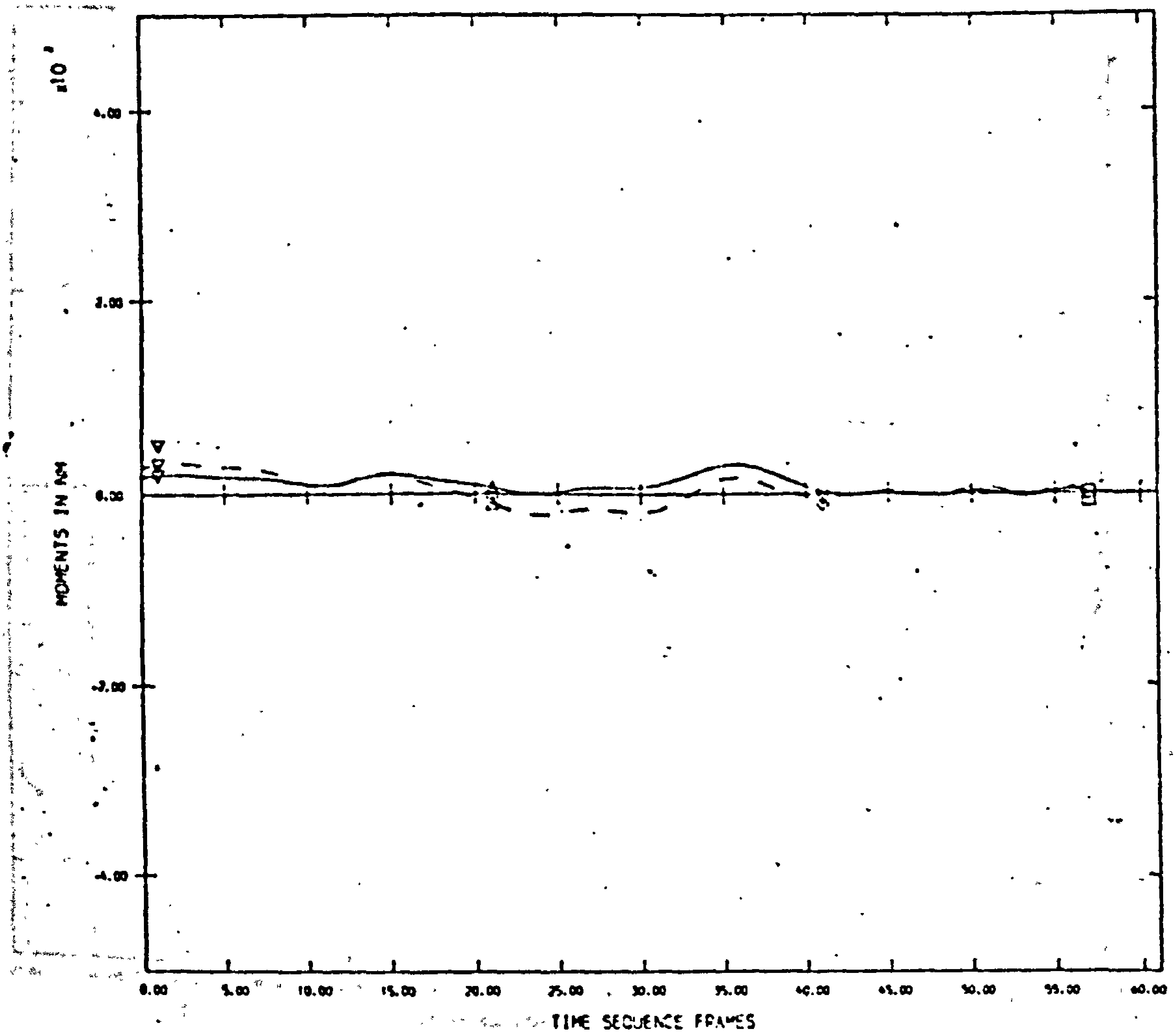
RIGHT TOE OFF ◇

CONTINUOUS ANKLE

DASHED KNEE

DOTTED HIP

P6/R/BDTO



ANKLE, KNEE, HIP, SAGITTAL PLANE

LEFT HEEL STRIKE △

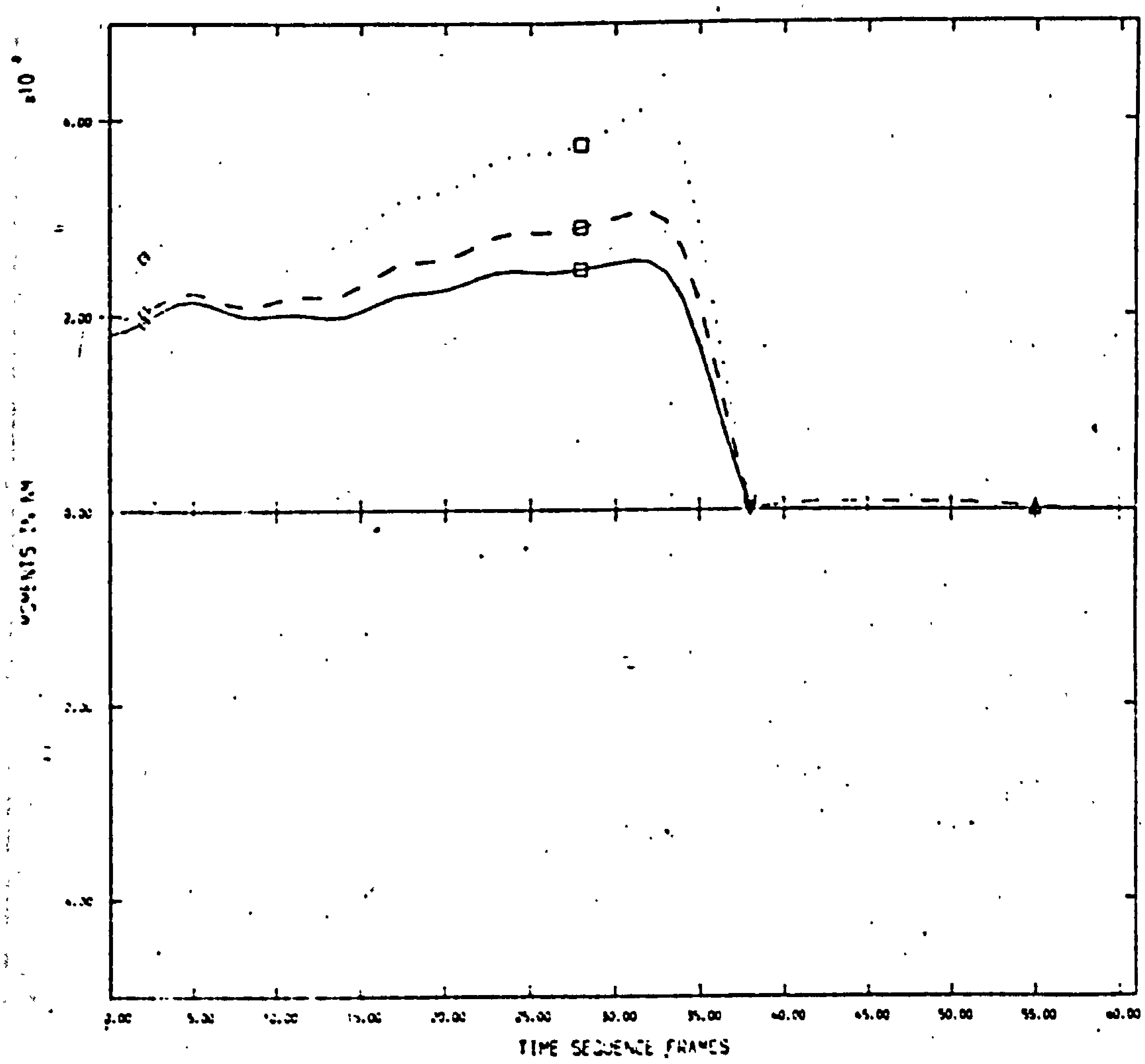
LEFT TOE OFF ▽

RIGHT HEELSTRIKE □

RIGHT TOE OFF ◇

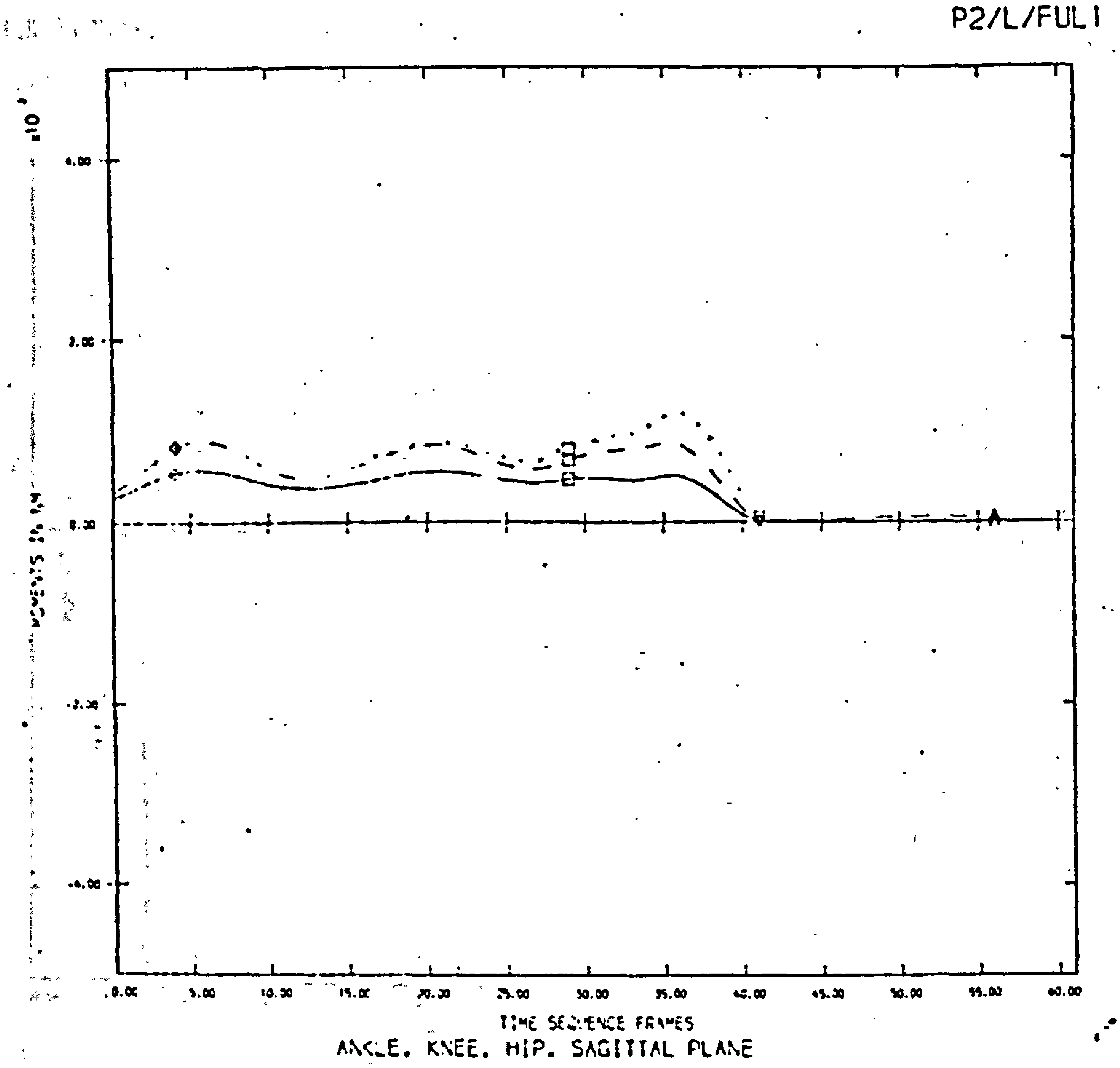
CONTINUOUS	ANKLE
DASHED	KNEE
DOTTED	HIP

PI/L/FUL1



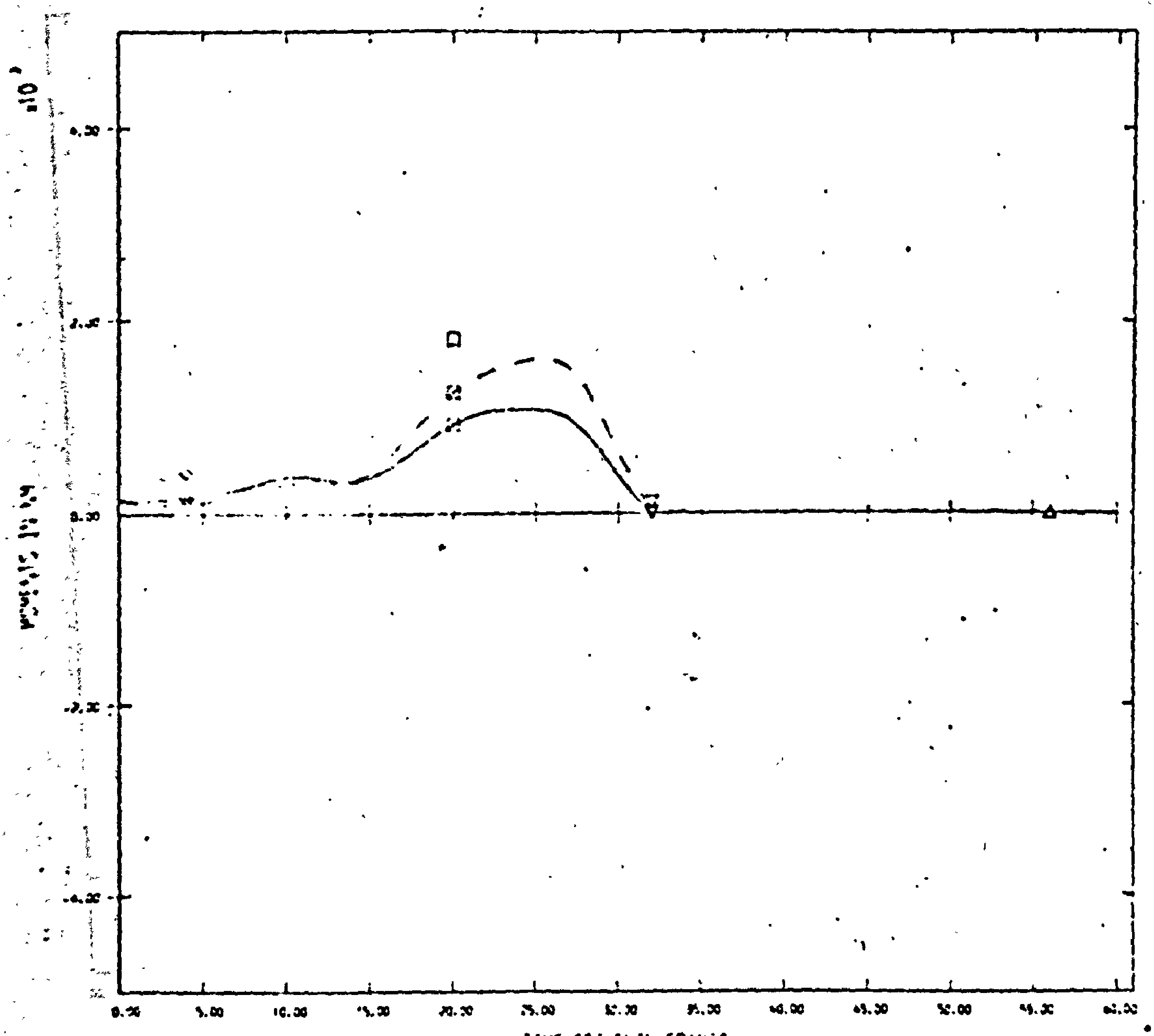
ANKLE, KNEE, HIP, SAGITTAL PLANE

LEFT HEEL STRIKE	△	CONTINUOUS	ANKLE
LEFT TOE OFF	▽	DASHED	KNEE
RIGHT HEELSTRIKE	□	DOTTED	HIP
RIGHT TOE OFF	◇		



LEFT HEEL STRIKE	△	CONTINUOUS	ANKLE
LEFT TOE OFF	▽	DASHED	KNEE
RIGHT HEELSTRIKE	□	DOTTED	HIP
RIGHT TOE OFF	◇		

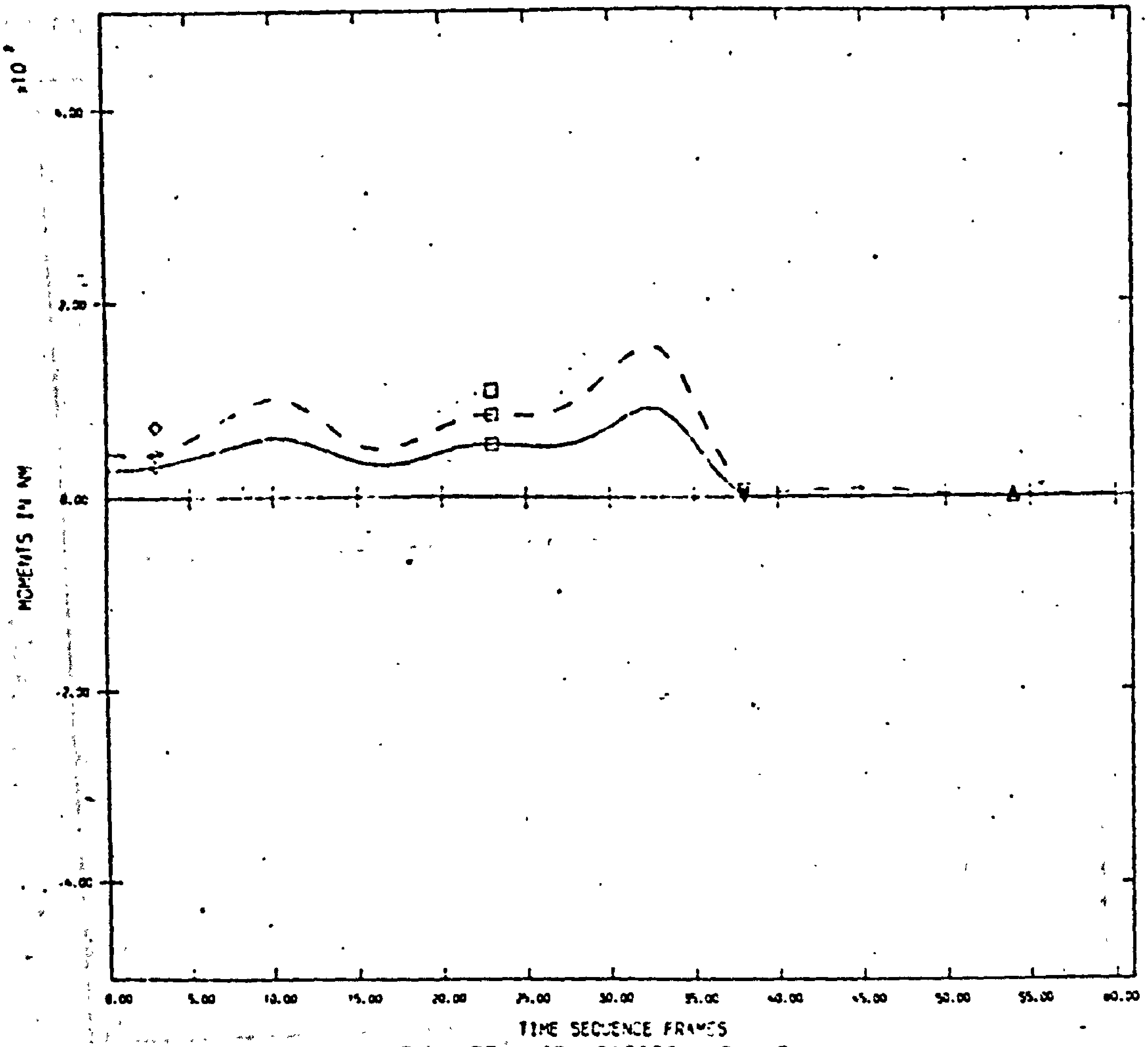
P3/L/FUL1



ANKLE, KNEE, HIP, SAGITTAL PLANE

LEFT HEEL STRIKE	^	CONTINUOUS	ANKLE
LEFT TOE OFF	v	DASHED	KNEE
RIGHT HEELSTRIKE	▫	DOTTED	HIP
RIGHT TOE OFF	◦		

P4/L/FUL1



ANKLE, KNEE, HIP. SAGITTAL PLANE

LEFT HEEL STRIKE △

LEFT TOE OFF ▽

RIGHT HEELSTRIKE □

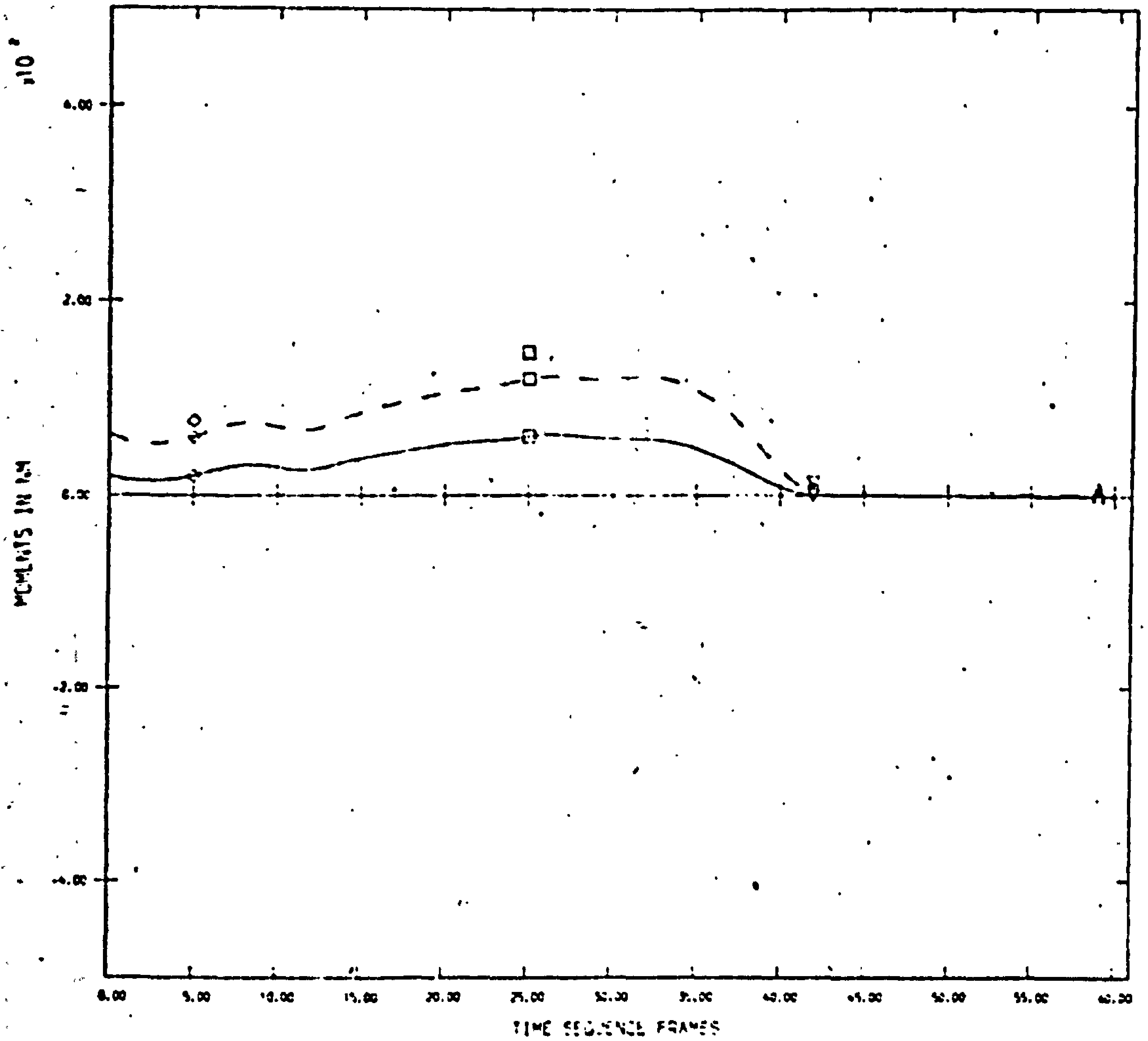
RIGHT TOE OFF ◇

CONTINUOUS ANKLE

DASHED KNEE

DOTTED HIP

P6/L/FUL1

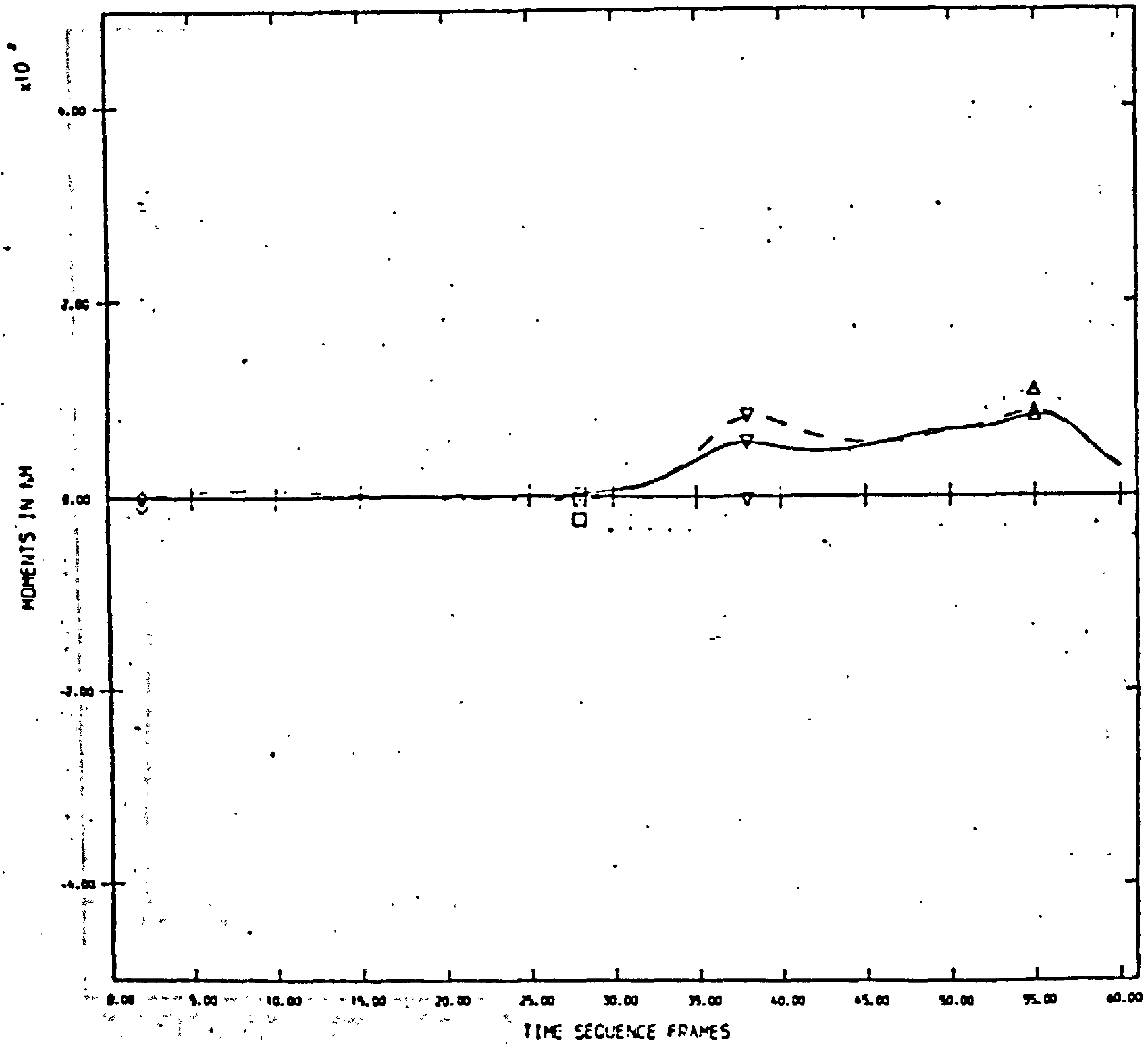


ANKLE, KNEE, HIP, SAGITTAL PLANE

LEFT HEEL STRIKE △
LEFT TOE OFF ▽
RIGHT HEELSTRIKE □
RIGHT TOE OFF ◇

CONTINUOUS ANKLE
DASHED KNEE
DOTTED HIP

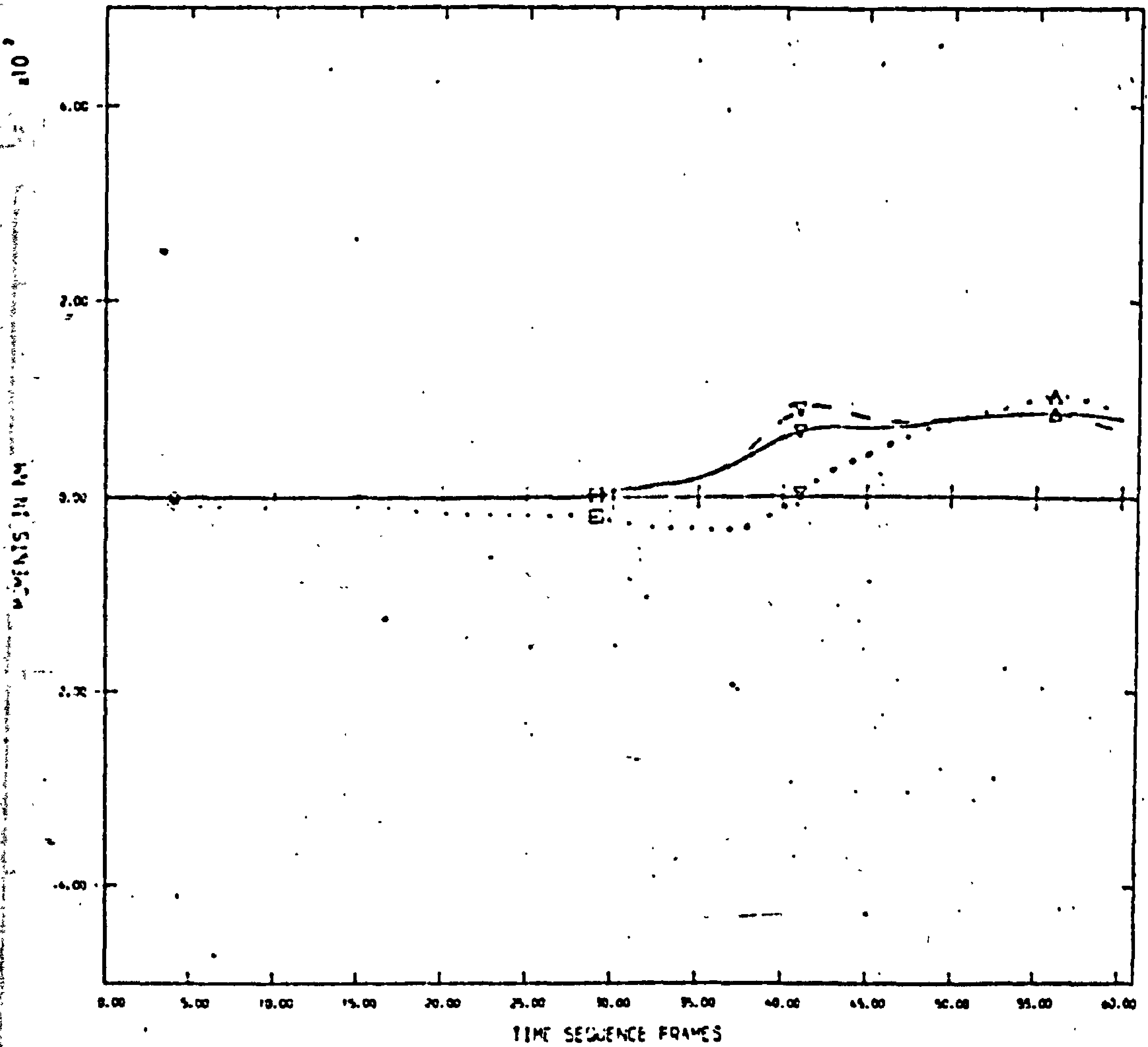
P1/R/FUL1



ANKLE, KNEE, HIP, SAGITTAL PLANE

LEFT HEEL STRIKE △	CONTINUOUS	ANKLE
LEFT TOE OFF ▽	DASHED	KNEE
RIGHT HEELSTRIKE □	DOTTED	HIP
RIGHT TOE OFF ◇		

P2/R/FUL1

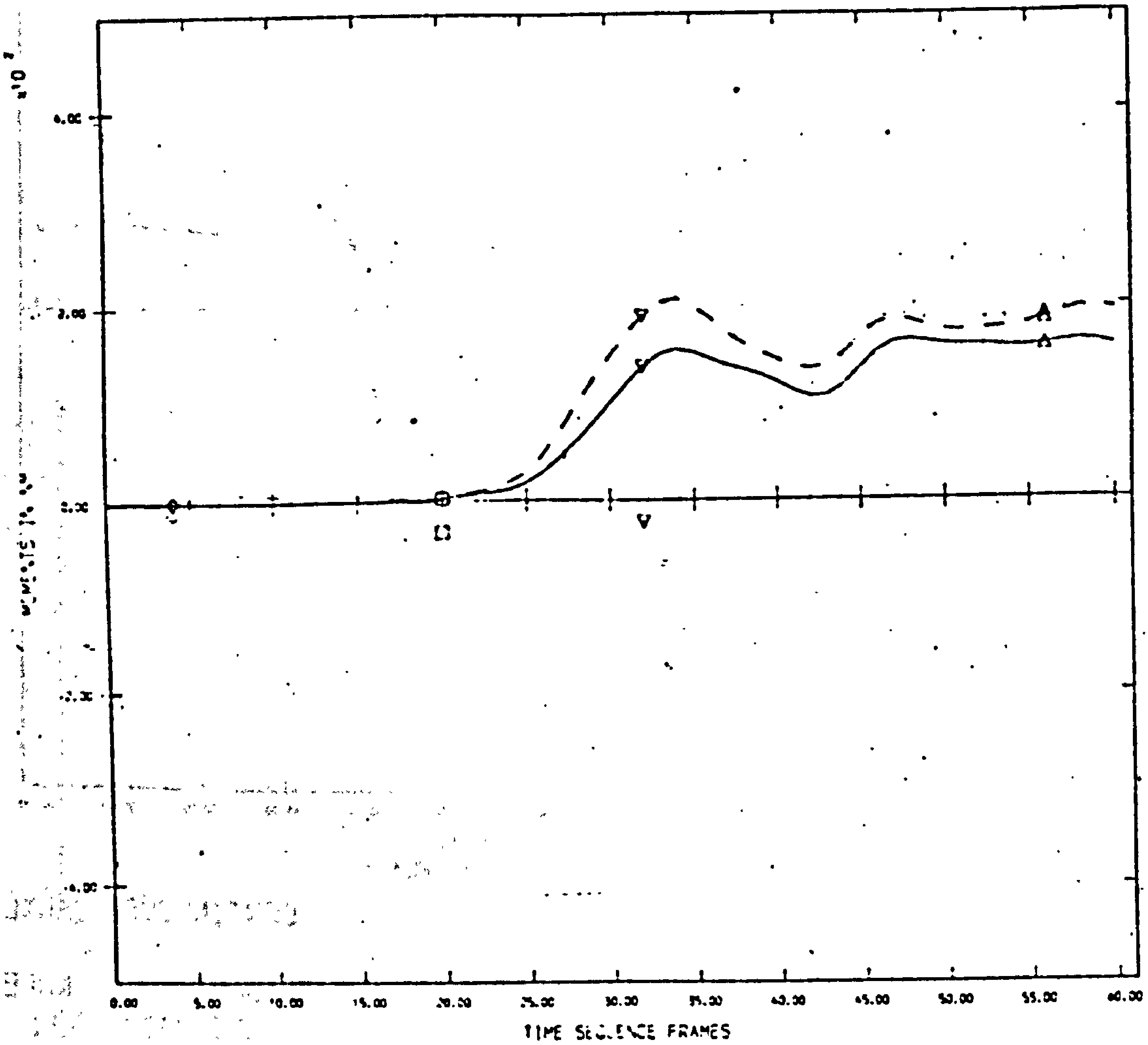


ANKLE, KNEE, HIP, SAGITTAL PLANE

LEFT HEEL STRIKE △
LEFT TOE OFF ▽
RIGHT HEELSTRIKE □
RIGHT TOE OFF ◇

CONTINUOUS ANKLE
DASHED KNEE
DOTTED HIP

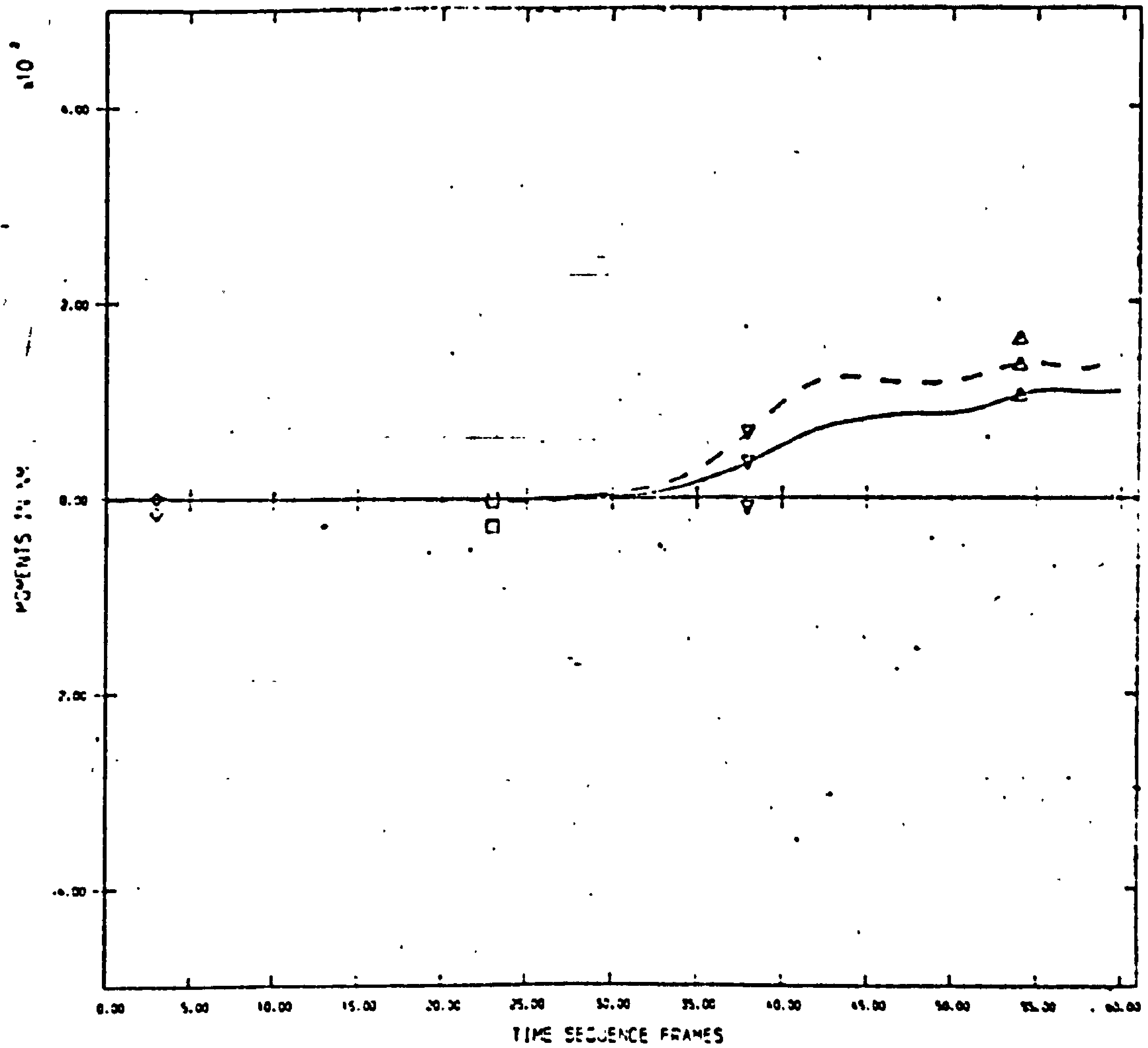
P3/R/FUL1



ANKLE, KNEE, HIP, SAGITTAL PLANE

LEFT HEEL STRIKE	△	CONTINUOUS	ANKLE
LEFT TOE OFF	▽	DASHED	KNEE
RIGHT HEELSTRIKE	□	DOTTED	HIP
RIGHT TOE OFF	◇		

P4/R/FUL1



ANKLE, KNEE, HIP, SAGITTAL PLANE

LEFT HEEL STRIKE △

LEFT TOE OFF ▽

RIGHT HEELSTRIKE □

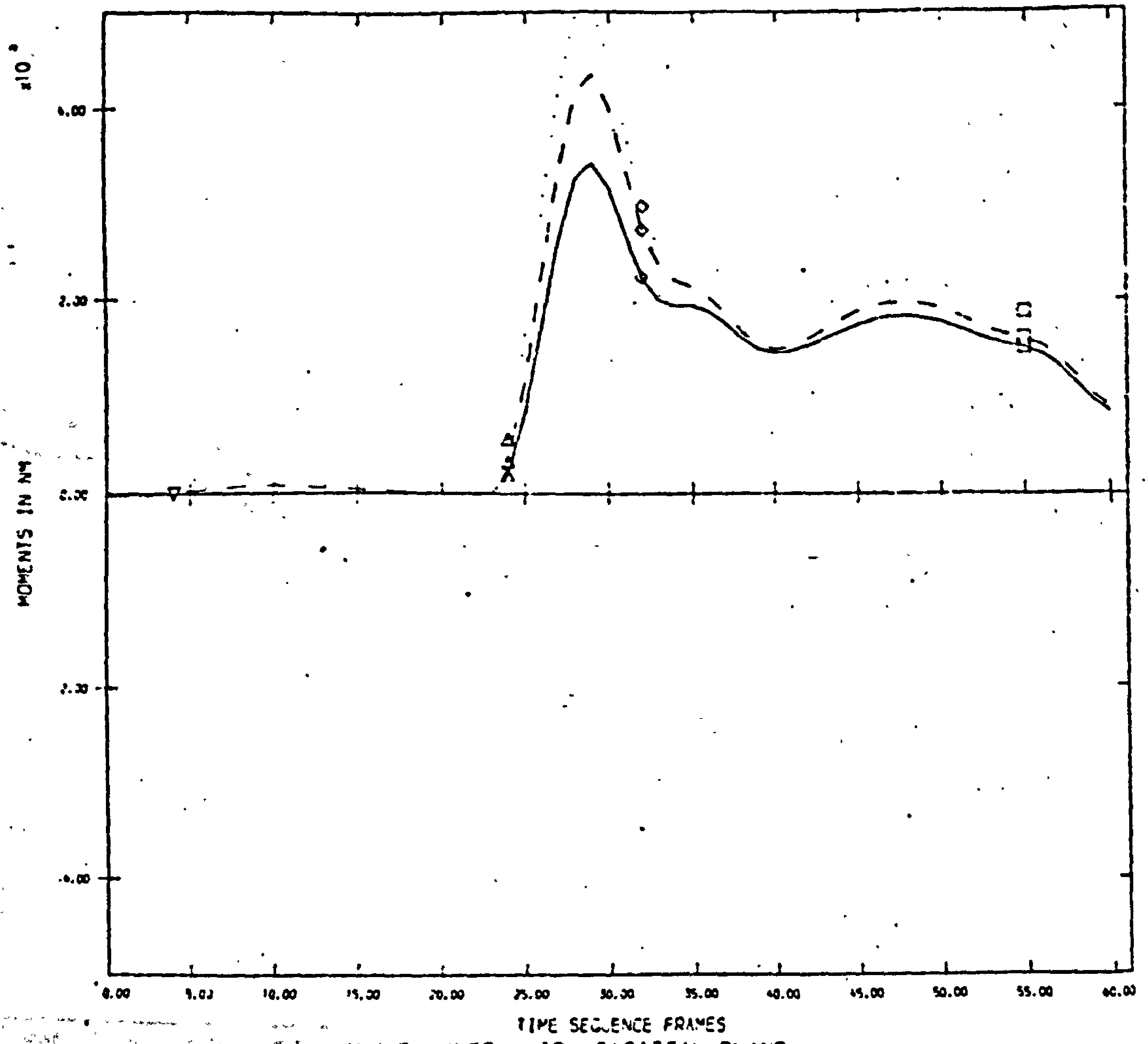
RIGHT TOE OFF ◇

CONTINUOUS ANKLE

DASHED KNEE

DOTTED HIP

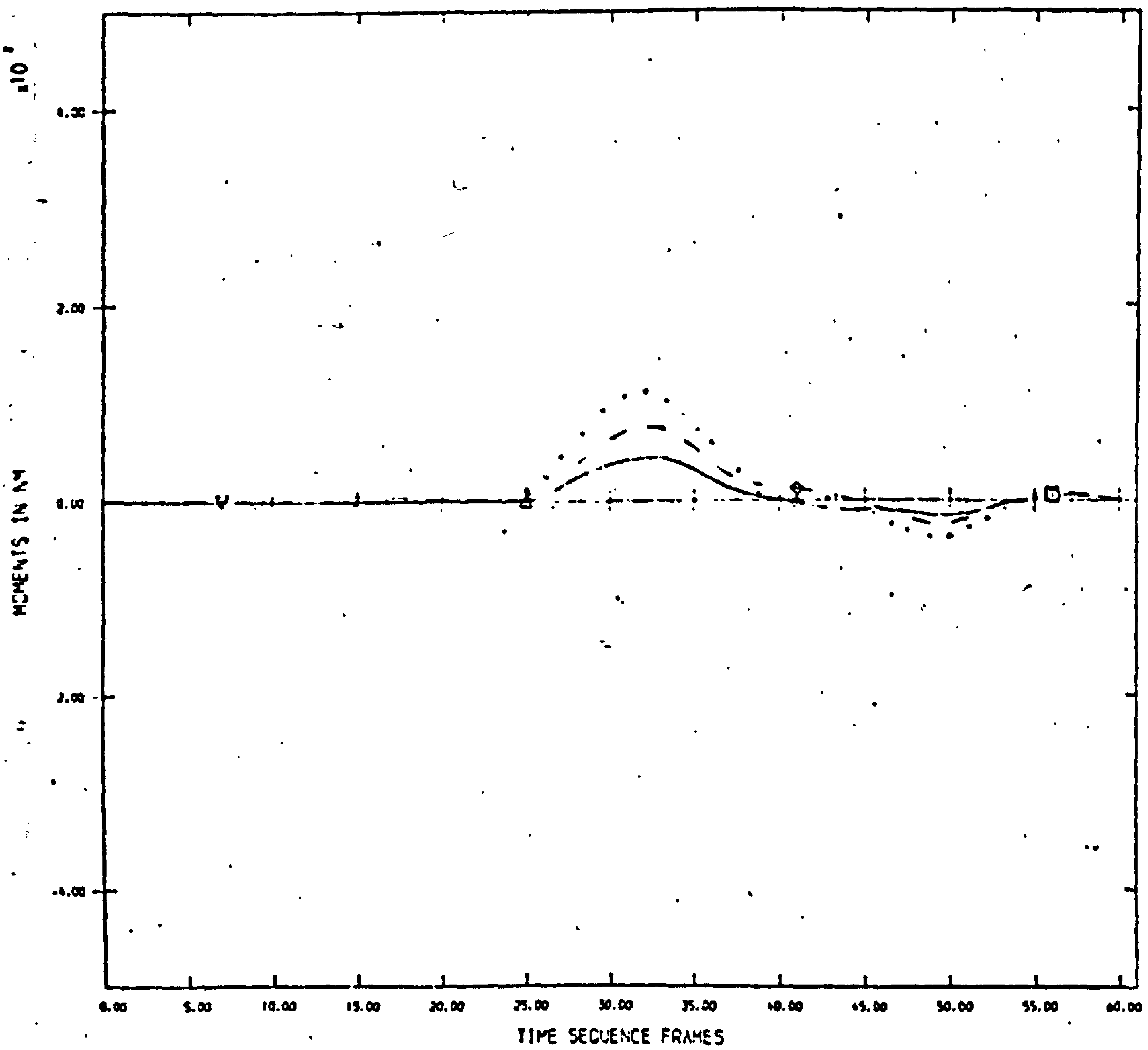
P1/L/BDT1



ANKLE, KNEE, HIP, SAGITTAL PLANE

LEFT HEEL STRIKE	△	CONTINUOUS	ANKLE
LEFT TOE OFF	▽	DASHED	KNEE
RIGHT HEELSTRIKE	□	DOTTED	HIP
RIGHT TOE OFF	◇		

P2/L/BDT1



ANKLE, KNEE, HIP, SAGITTAL PLANE

LEFT HEEL STRIKE △

LEFT TOE OFF ▽

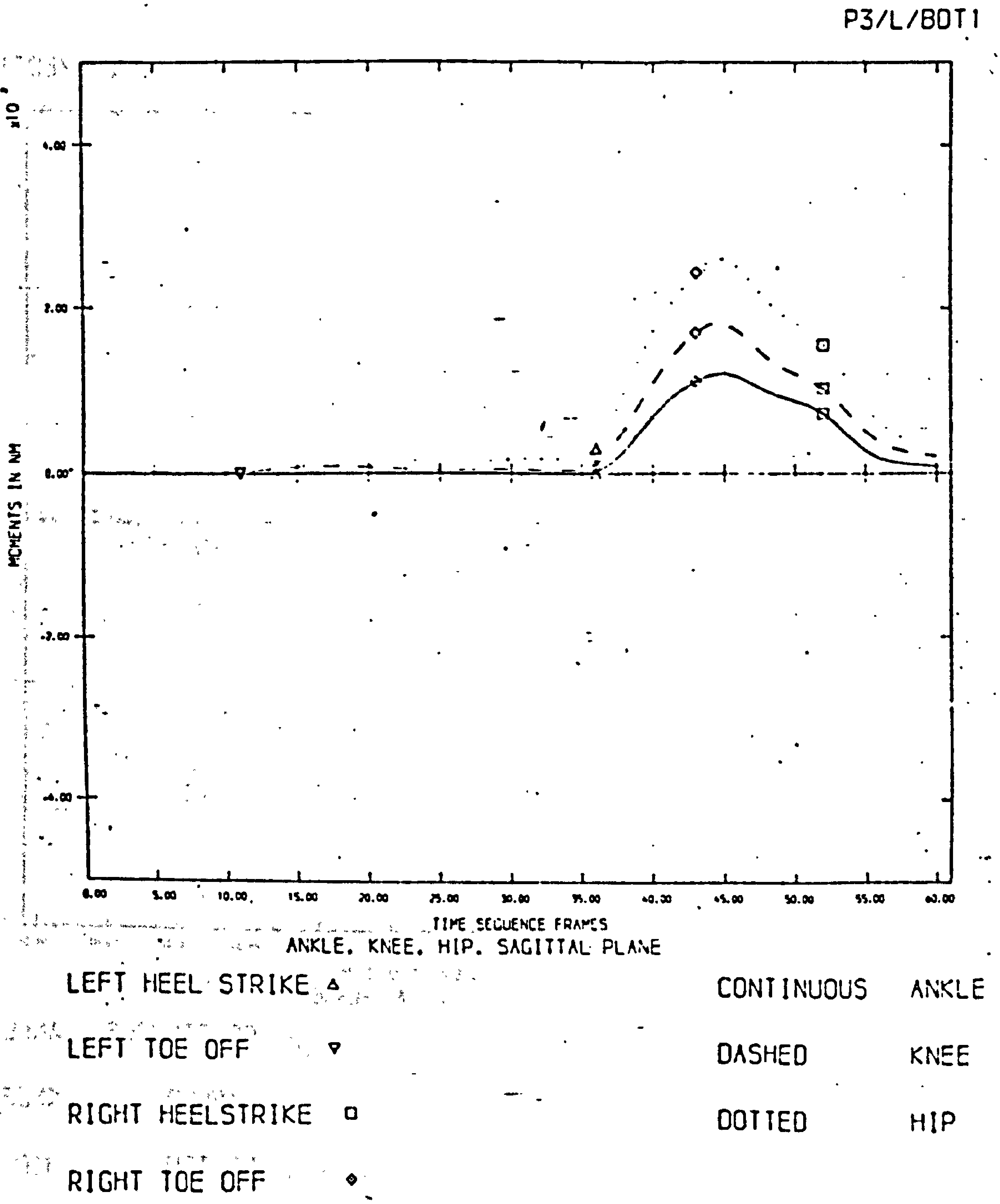
RIGHT HEELSTRIKE □

RIGHT TOE OFF ◇

CONTINUOUS ANKLE

DASHED KNEE

DOTTED HIP


P3/L/BDT1
x10²
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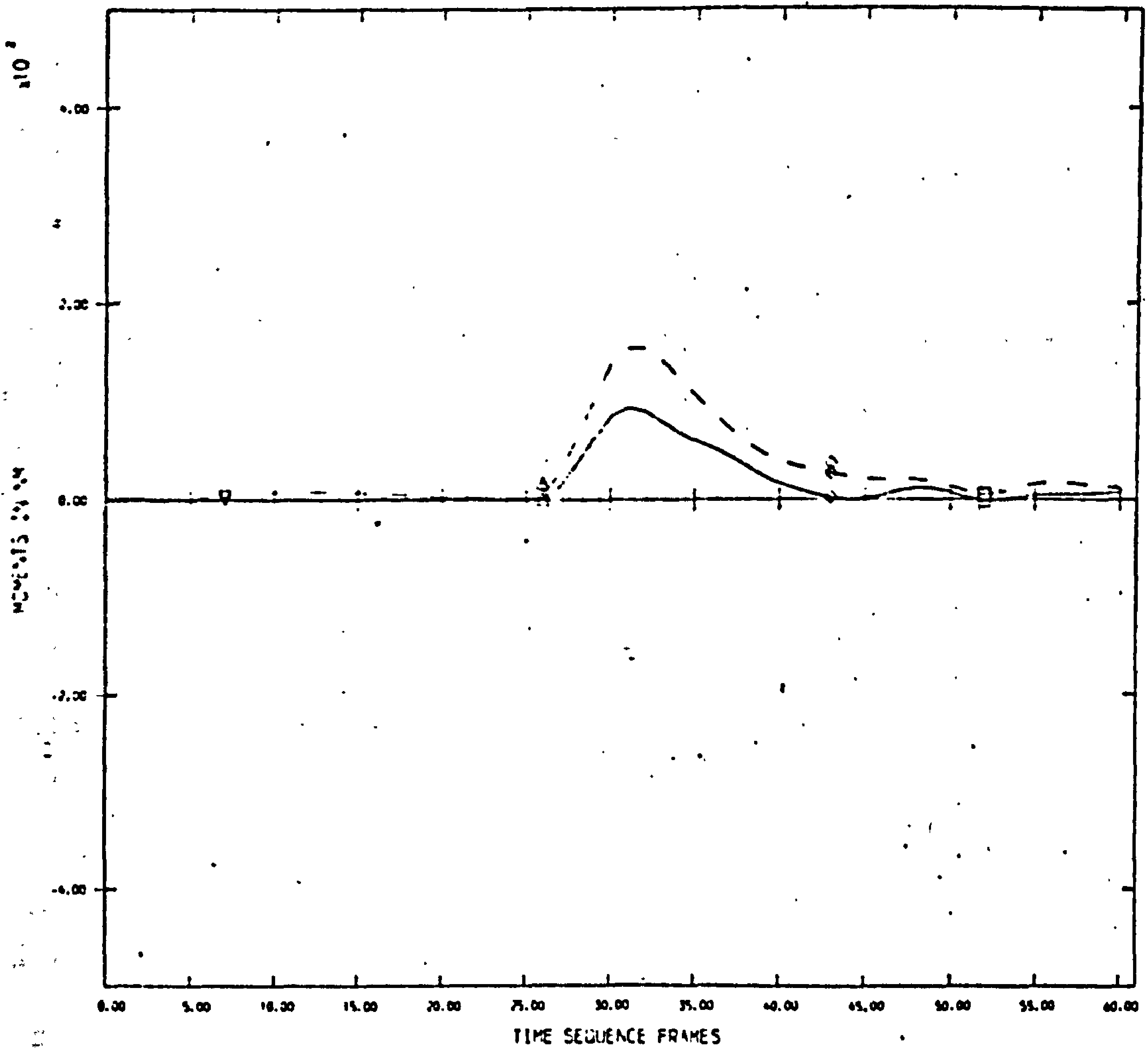
TIME SEQUENCE FRAMES
ANKLE, KNEE, HIP, SAGITTAL PLANE
LEFT HEEL STRIKE △
LEFT TOE OFF ▽
RIGHT HEELSTRIKE □
RIGHT TOE OFF ◇
CONTINUOUS ANKLE
DASHED KNEE
DOTTED HIP

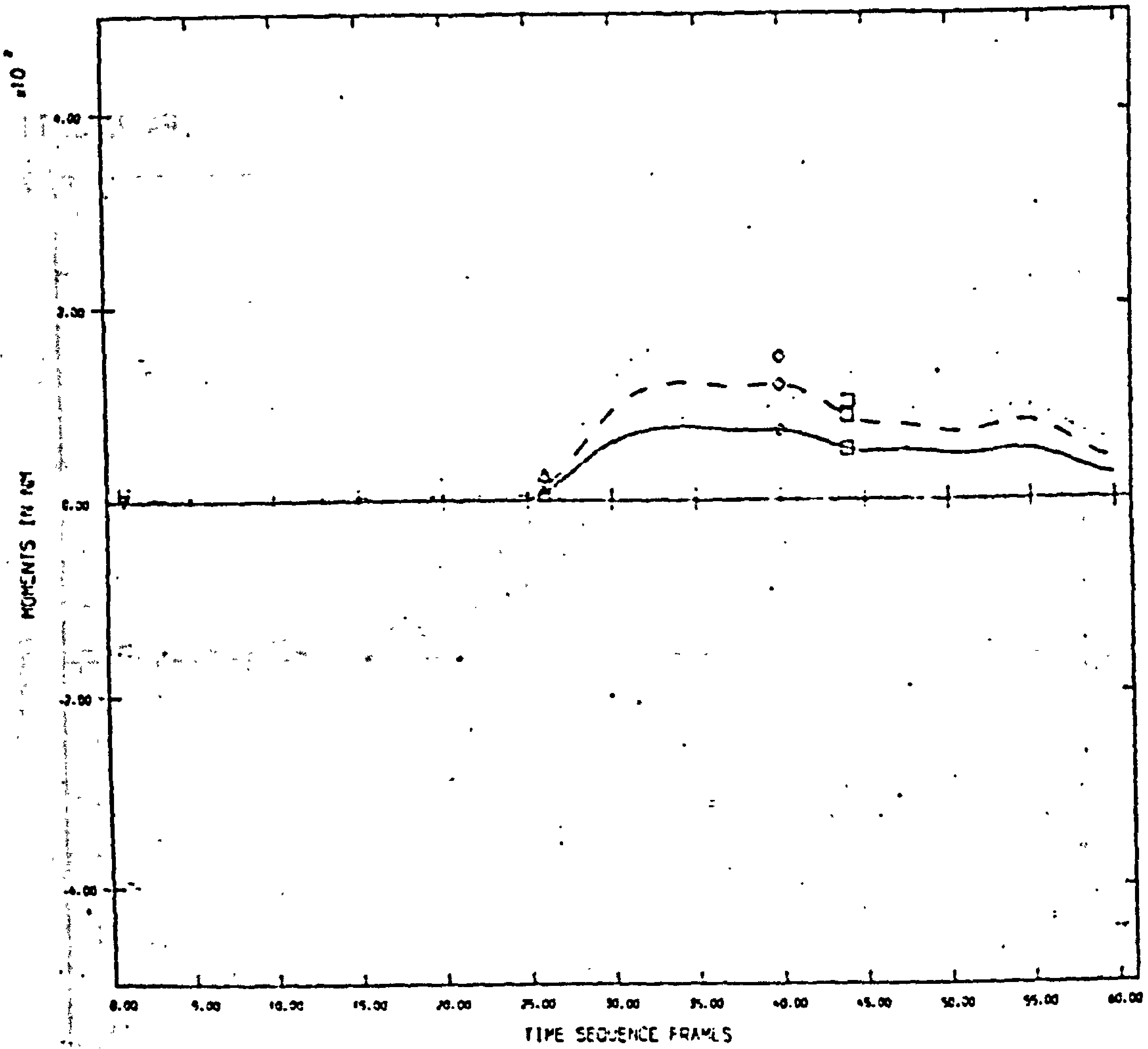
P4/L/BDT1



ANKLE, KNEE, HIP, SAGITTAL PLANE

LEFT HEEL STRIKE	△	CONTINUOUS	ANKLE
LEFT TOE OFF	▽	DASHED	KNEE
RIGHT HEELSTRIKE	□	DOTTED	HIP
RIGHT TOE OFF	◇		

P6/L/BDT1



ANKLE. KNEE. HIP. SAGITTAL PLANE

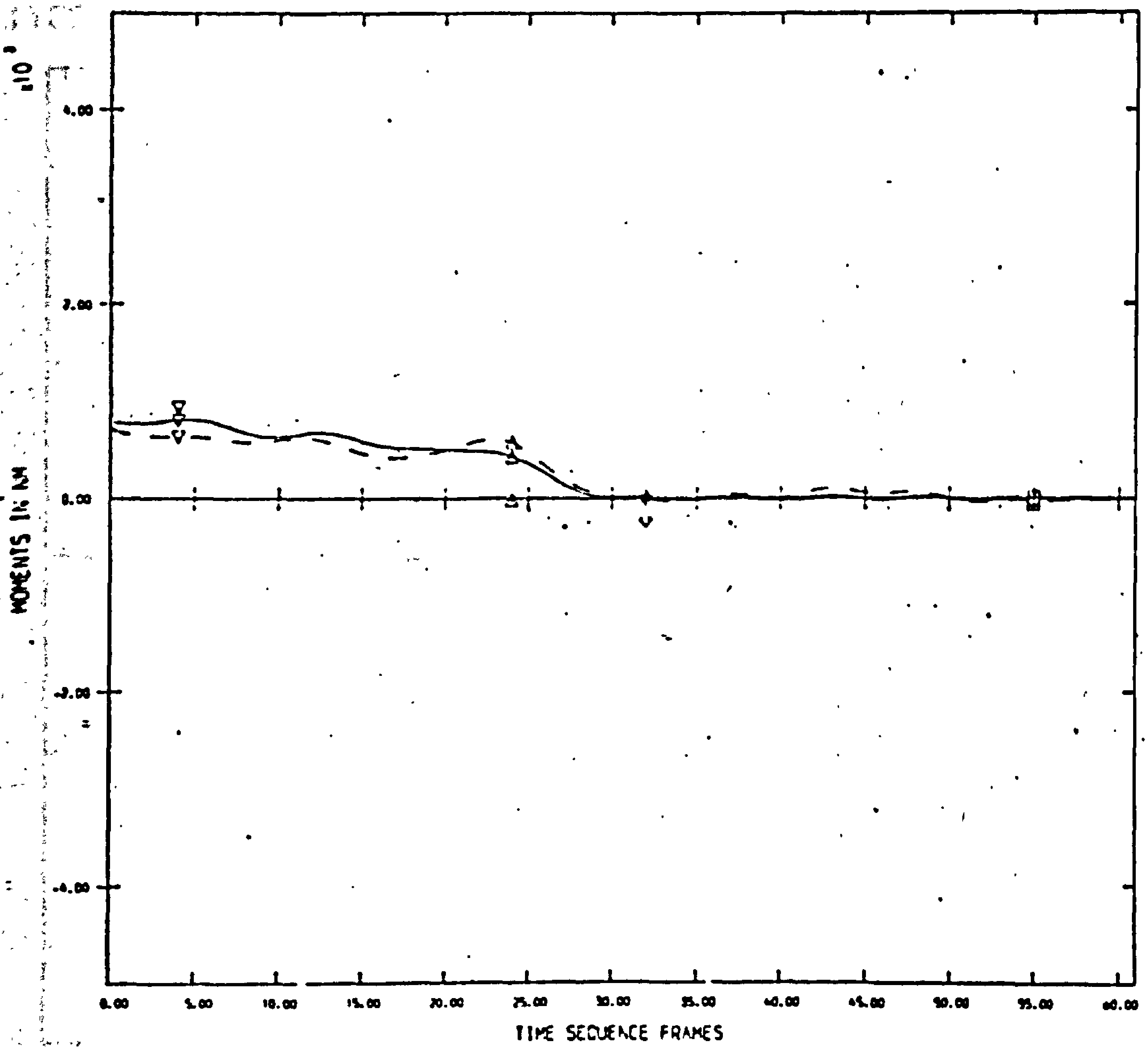
LEFT HEEL STRIKE △ CONTINUOUS ANKLE

LEFT TOE OFF ▽ DASHED KNEE

RIGHT HEELSTRIKE □ DOTTED HIP

RIGHT TOE OFF ◇

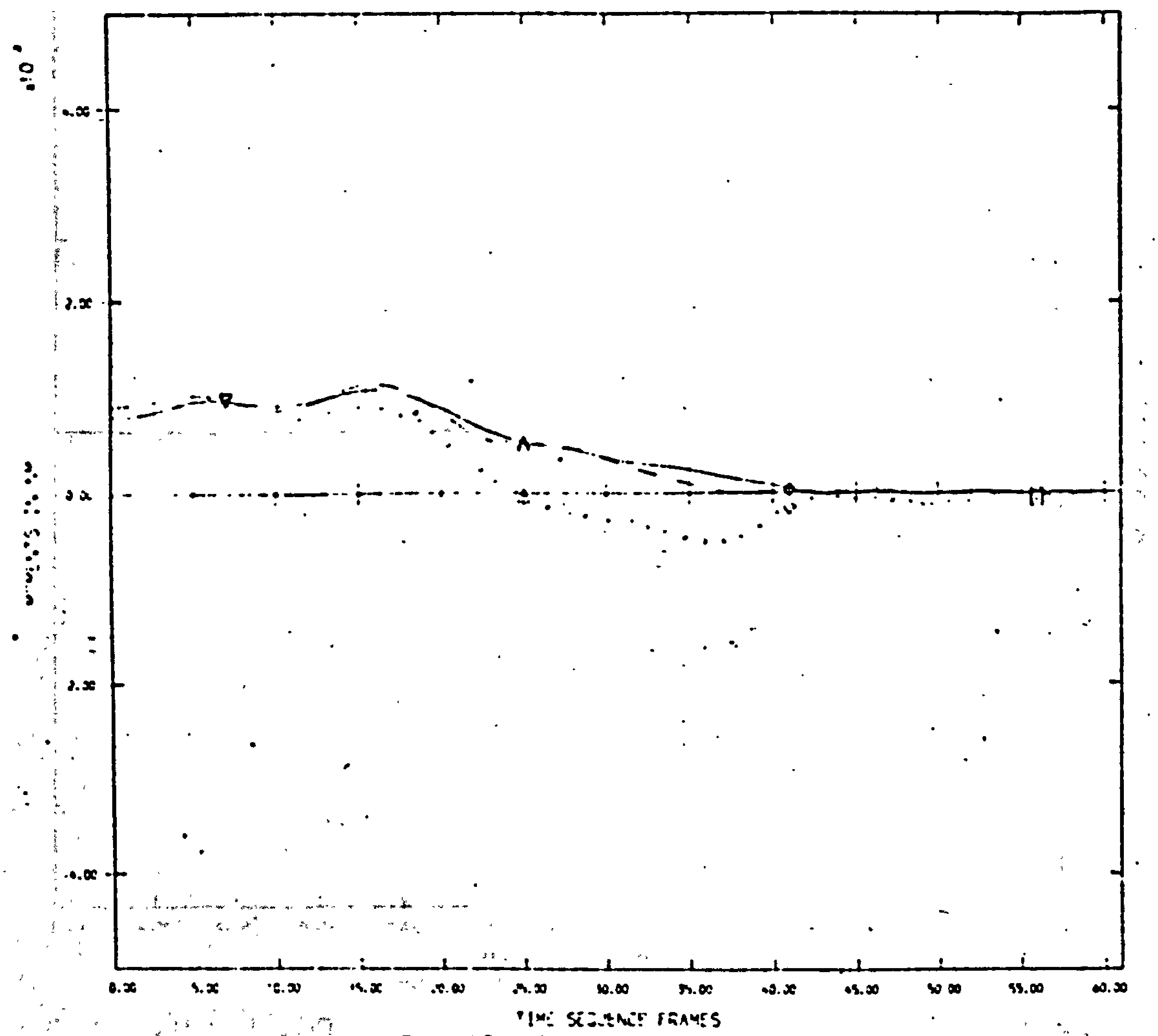
P1/R/BDT1



ANKLE. KNEE. HIP. SAGITTAL PLANE

LEFT HEEL STRIKE	△	CONTINUOUS	ANKLE
LEFT TOE OFF	▽	DASHED	KNEE
RIGHT HEELSTRIKE	□	DOTTED	HIP
RIGHT TOE OFF	◇		

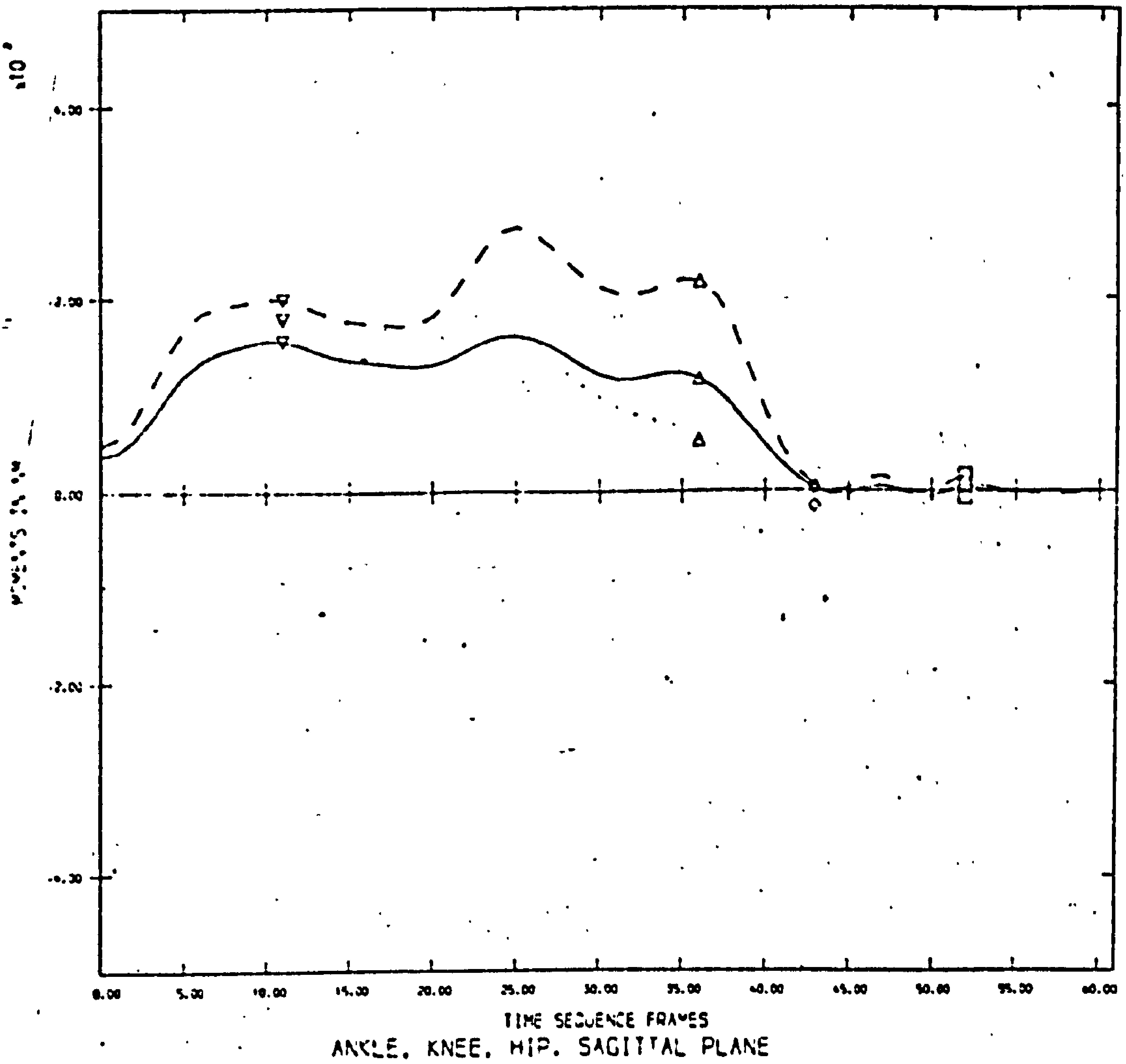
P2/R/BDT1



ANKLE, KNEE, HIP, SAGITTAL PLANE

LEFT HEEL STRIKE	△	CONTINUOUS	ANKLE
LEFT TOE OFF	▽	DASHED	KNEE
RIGHT HEELSTRIKE	□	DOTTED	HIP
RIGHT TOE OFF	◇		

P3/R/BDT1



LEFT HEEL STRIKE △

LEFT TOE OFF ▽

RIGHT HEELSTRIKE □

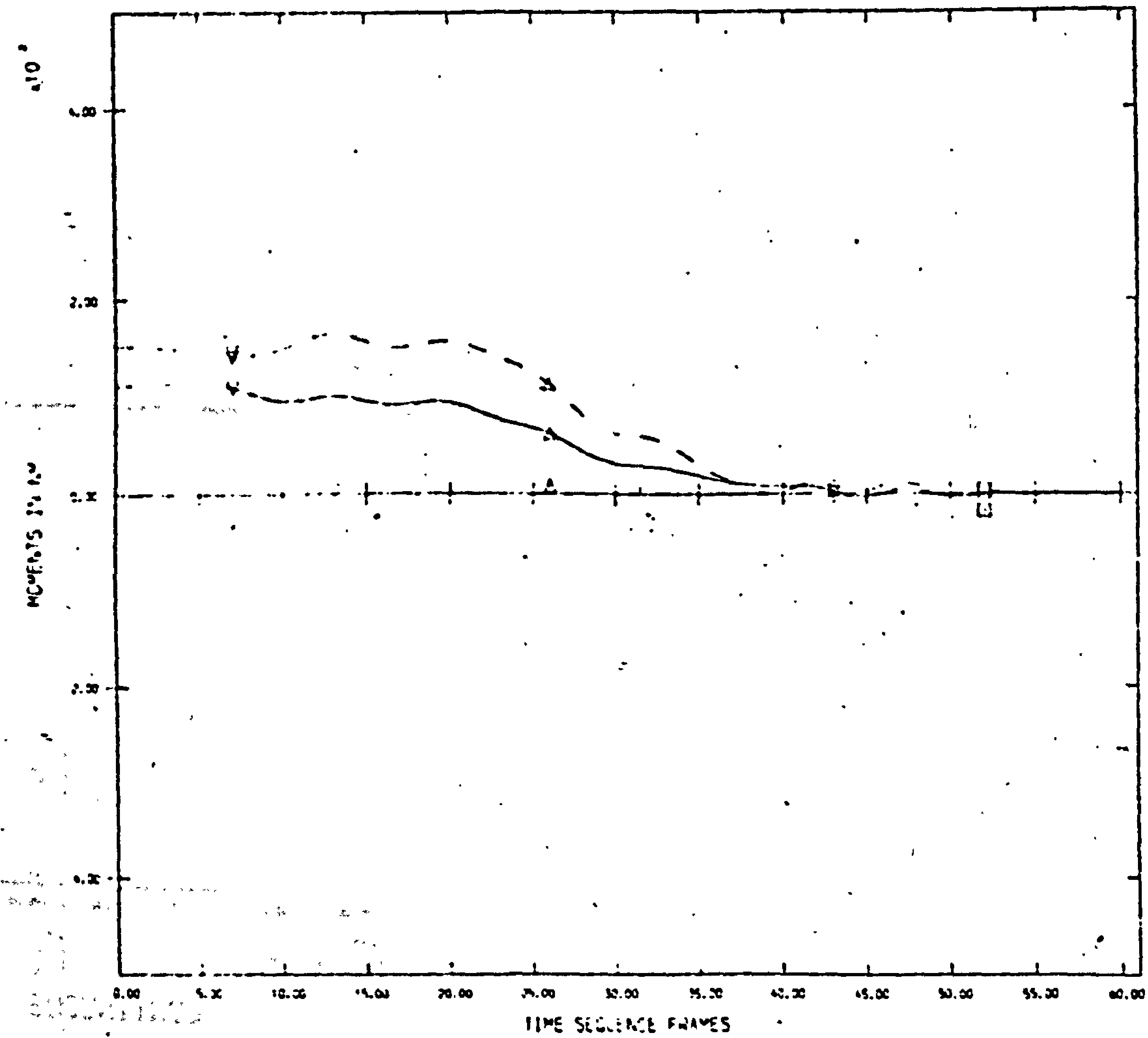
RIGHT TOE OFF ◇

CONTINUOUS ANKLE

DASHED KNEE

DOTTED HIP

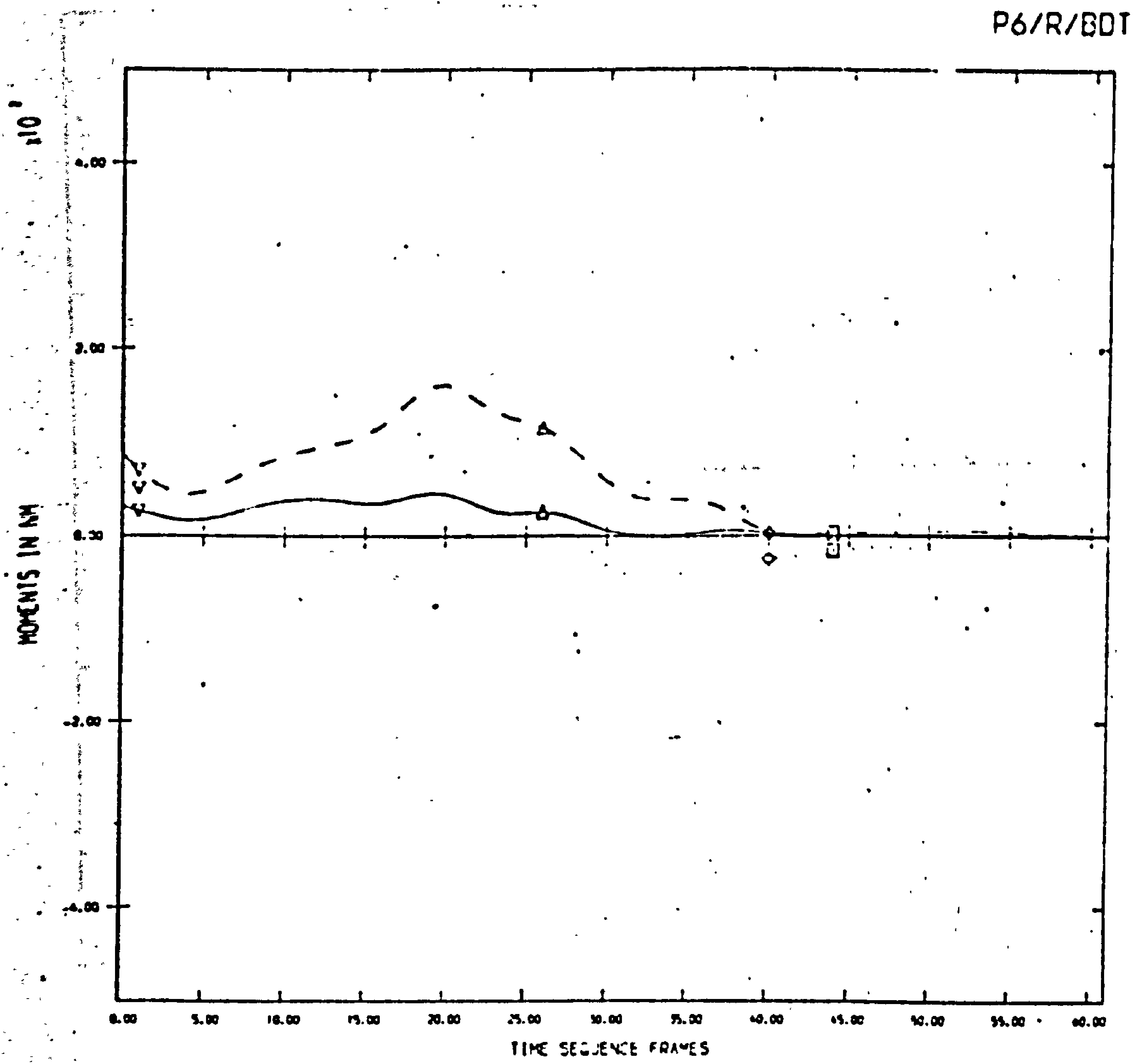
P4/R/BOT1



ANKLE, KNEE, HIP, SAGITTAL PLANE

LEFT HEEL STRIKE	△	CONTINUOUS	ANKLE
LEFT TOE OFF	▽	DASHED	KNEE
RIGHT HEELSTRIKE	□	DOTTED	HIP
RIGHT TOE OFF	◇		

P6/R/BDT1



ANKLE. KNEE. HIP. SAGITTAL PLANE

LEFT HEEL STRIKE △

LEFT TOE OFF ▽

RIGHT HEELSTRIKE □

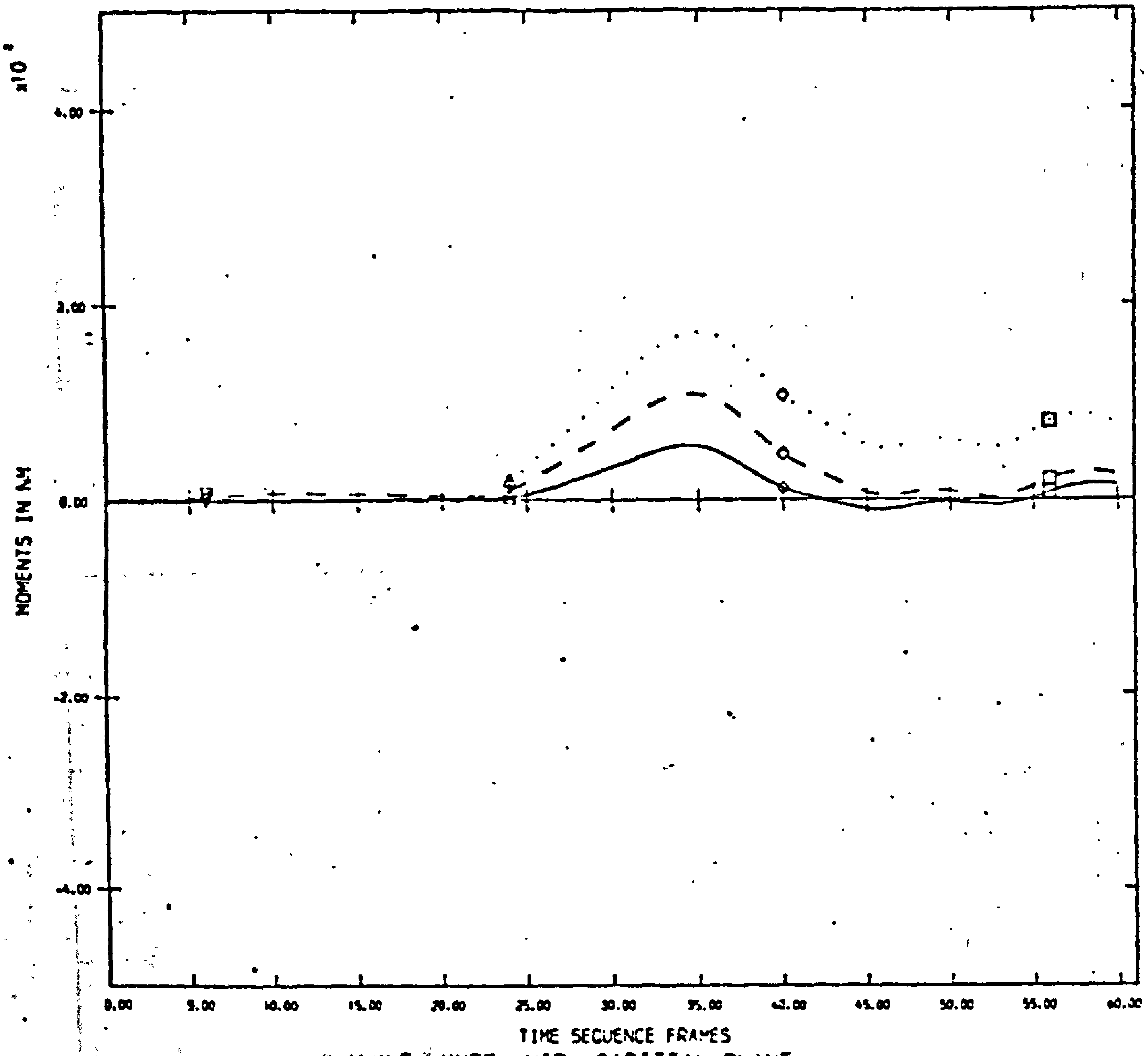
RIGHT TOE OFF ◇

CONTINUOUS ANKLE

DASHED KNEE

DOTTED HIP

S1/L/BDTO

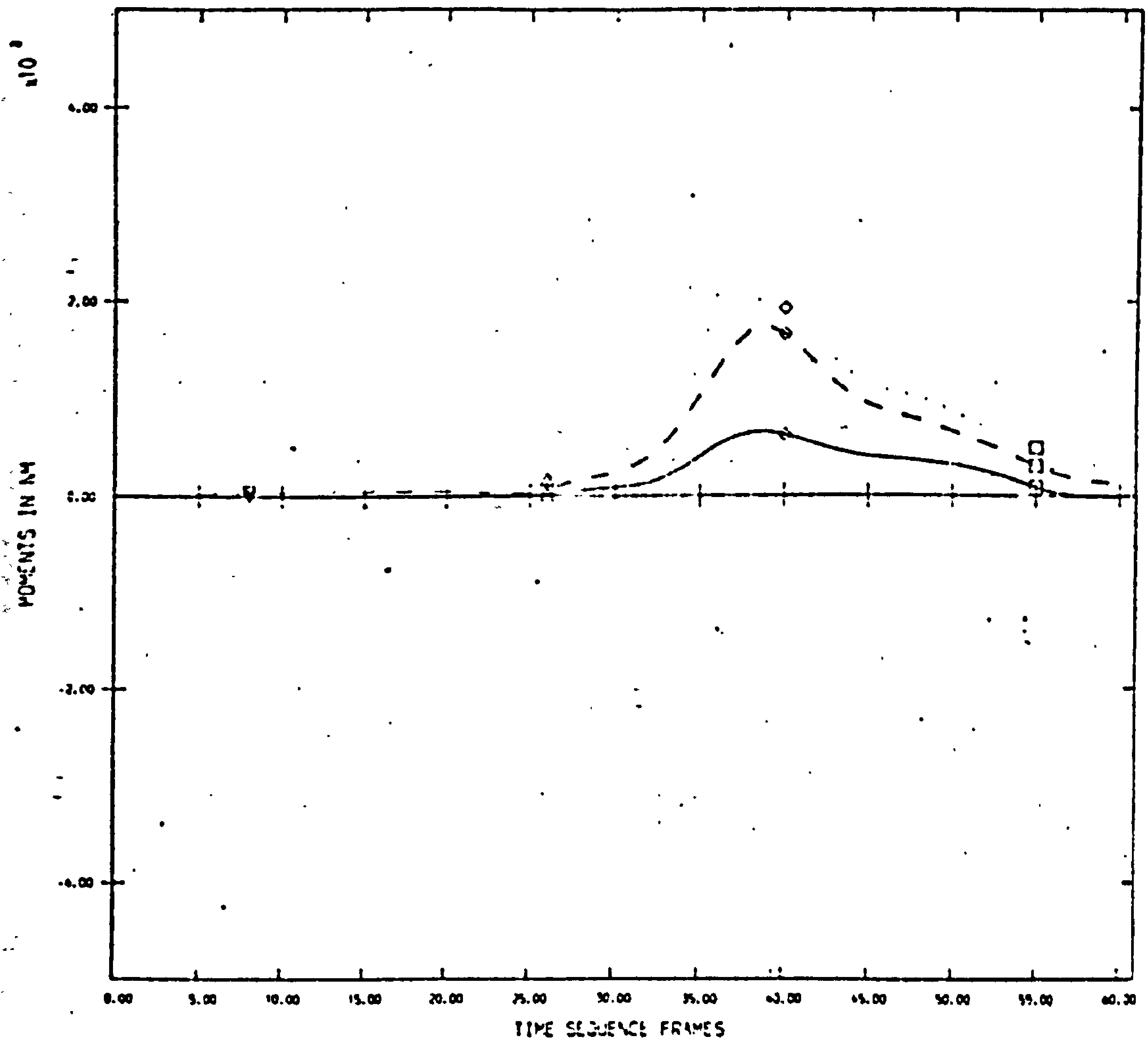


ANKLE, KNEE, HIP, SAGITTAL PLANE

LEFT HEEL STRIKE △
LEFT TOE OFF ▽
RIGHT HEELSTRIKE □
RIGHT TOE OFF ◇

CONTINUOUS	ANKLE
DASHED	KNEE
DOTTED	HIP

S2/L/BDTO



ANKLE, KNEE, HIP, SAGITTAL PLANE

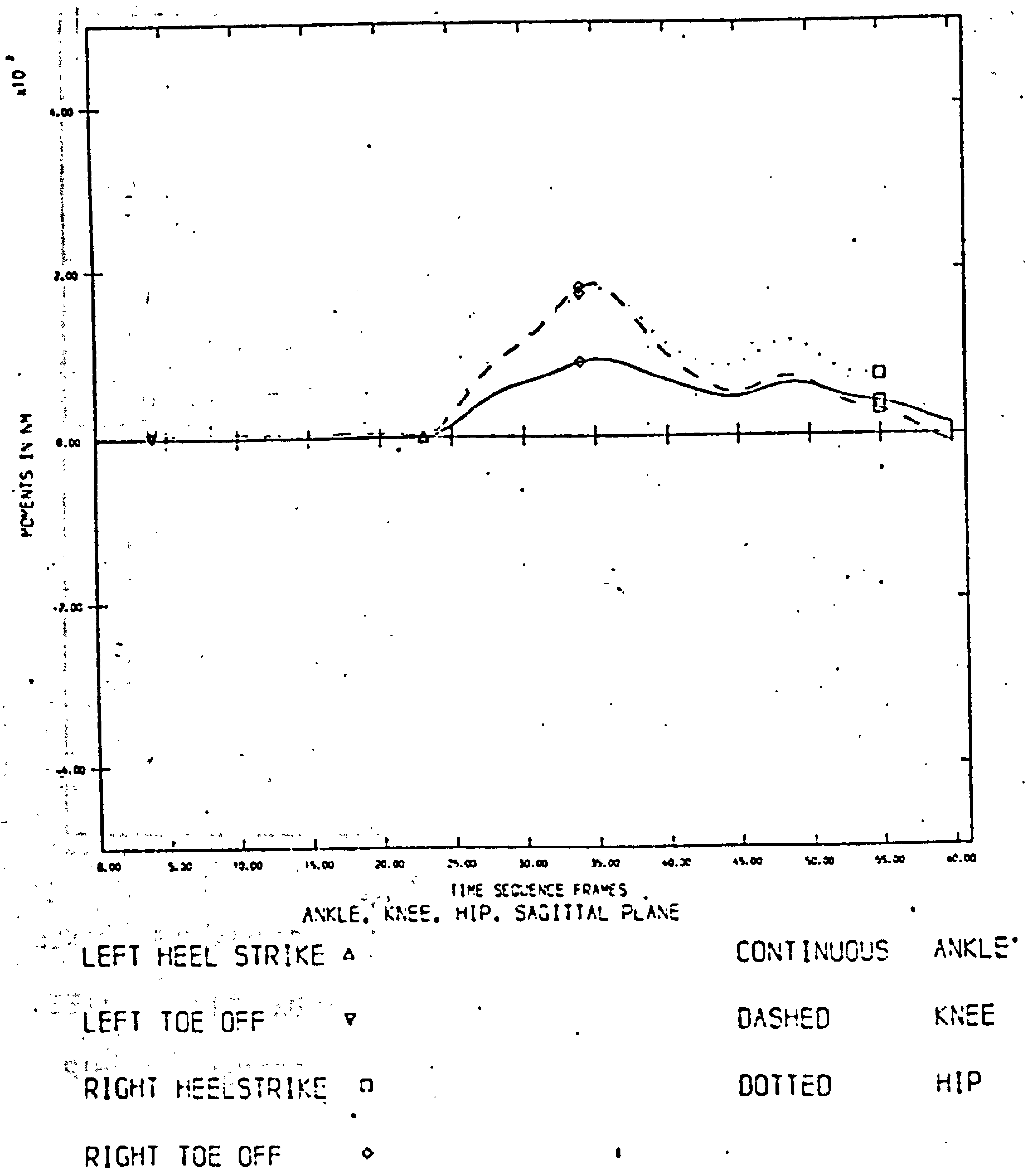
LEFT HEEL STRIKE △ CONTINUCUS ANKLE

LEFT TOE OFF ▽ DASHED KNEE

RIGHT HEELSTRIKE □ DOTTED HIP

RIGHT TOE OFF ◇

S5/L/BDTO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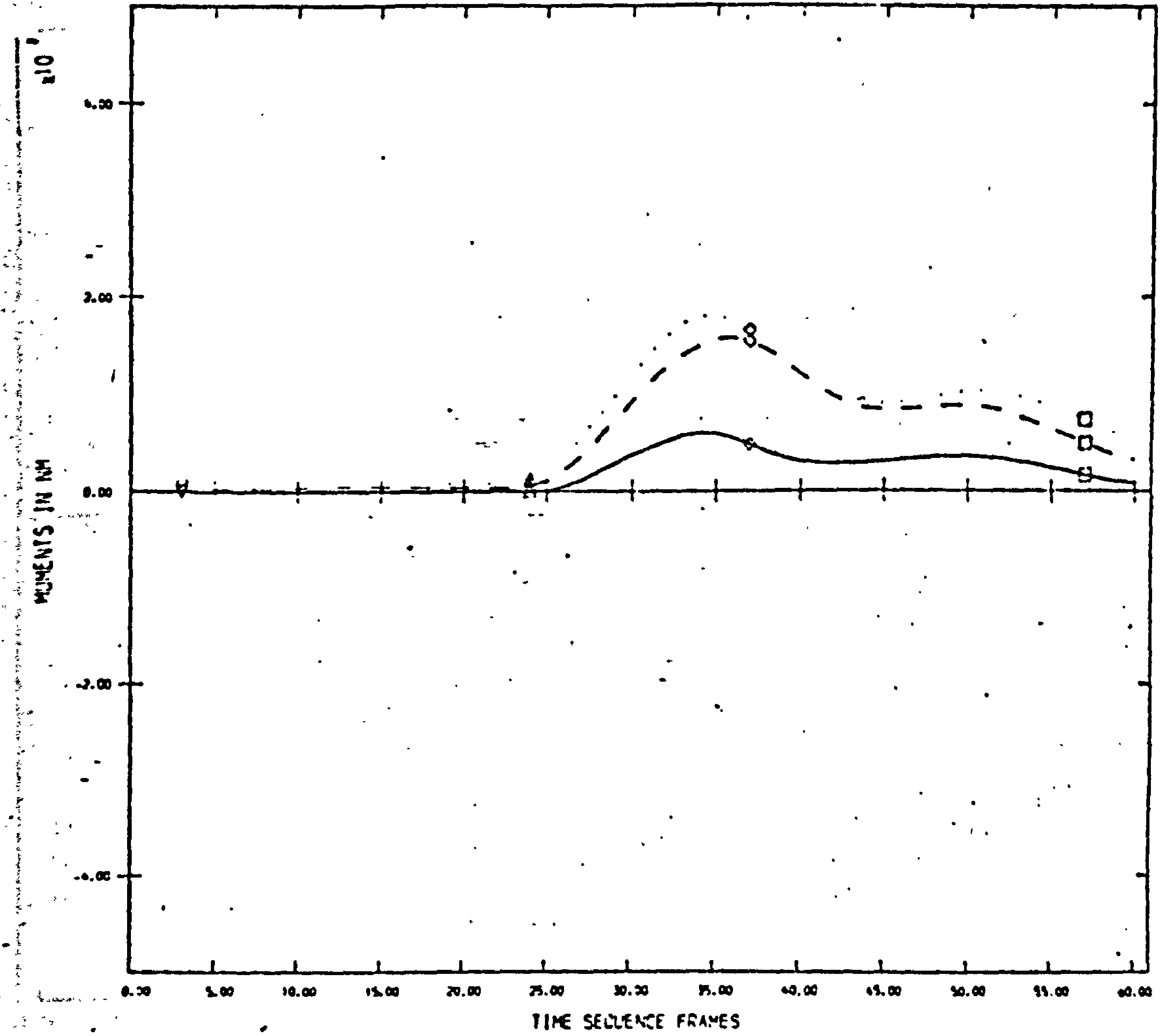
TIME SEQUENCE FRAMES
ANKLE, KNEE, HIP, SAGITTAL PLANE
LEFT HEEL STRIKE △
LEFT TOE OFF ▽
RIGHT HEELSTRIKE □
RIGHT TOE OFF ◇
CONTINUOUS ANKLE
DASHED KNEE
DOTTED HIP

S3/L/BOTO



ANKLE, KNEE, HIP, SAGITTAL PLANE

LEFT HEEL STRIKE △

LEFT TOE OFF ▽

RIGHT HEELSTRIKE □

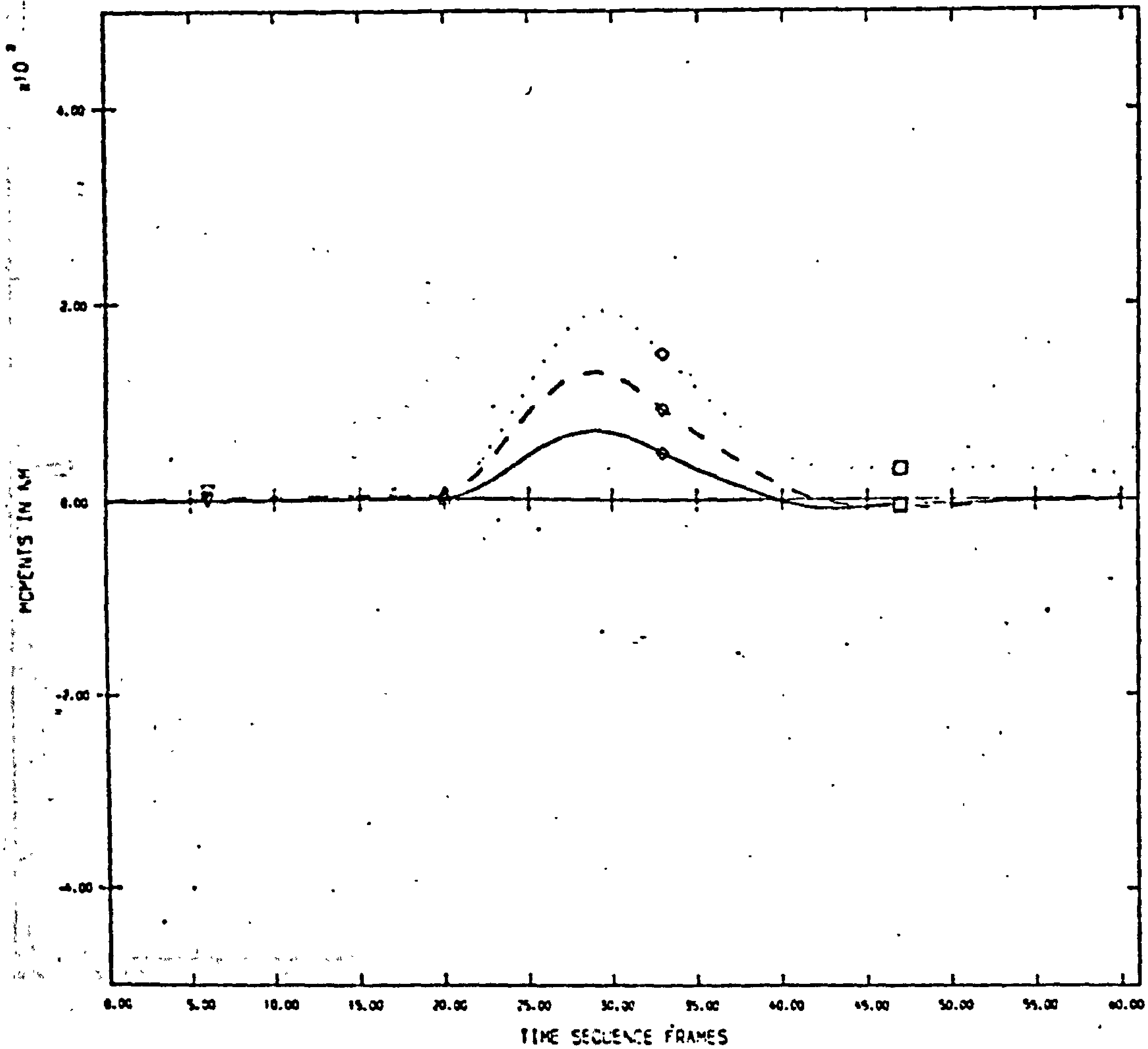
RIGHT TOE OFF ○

CONTINUOUS ANKLE

DASHED KNEE

DOTTED HIP

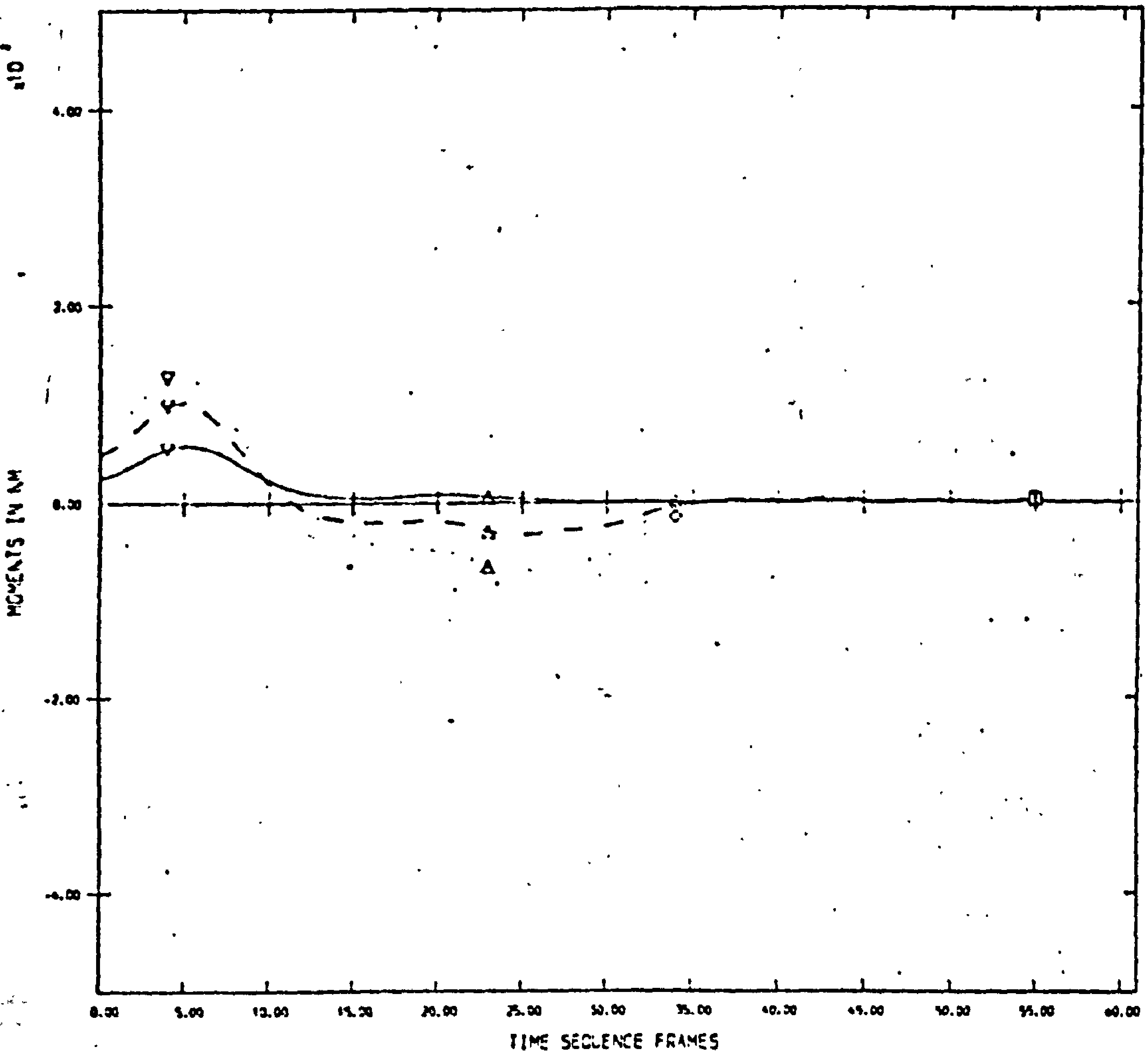
S4/L/BOTO



ANKLE, KNEE, HIP, SAGITTAL PLANE

LEFT HEEL STRIKE	△	CONTINUOUS	ANKLE
LEFT TOE OFF	▽	DASHED	KNEE
RIGHT HEELSTRIKE	□	DOTTED	HIP
RIGHT TOE OFF	◇		

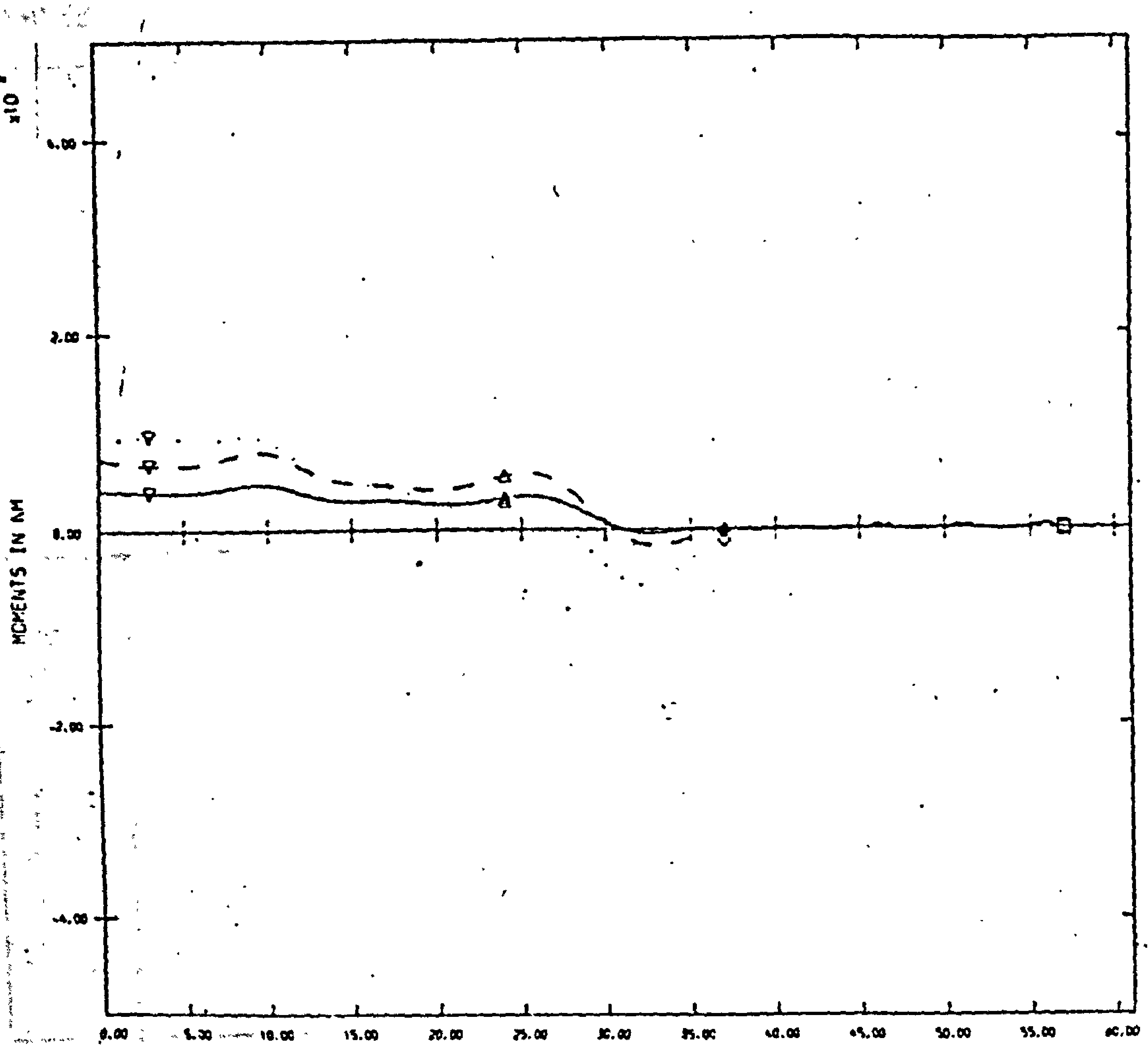
S5/R/BOTO



ANKLE, KNEE, HIP. SAGITTAL PLANE

LEFT HEEL STRIKE	△	CONTINUOUS	ANKLE
LEFT TOE OFF	▽	DASHED	KNEE
RIGHT HEELSTRIKE	□	DOTTED	HIP
RIGHT TOE OFF	◇		

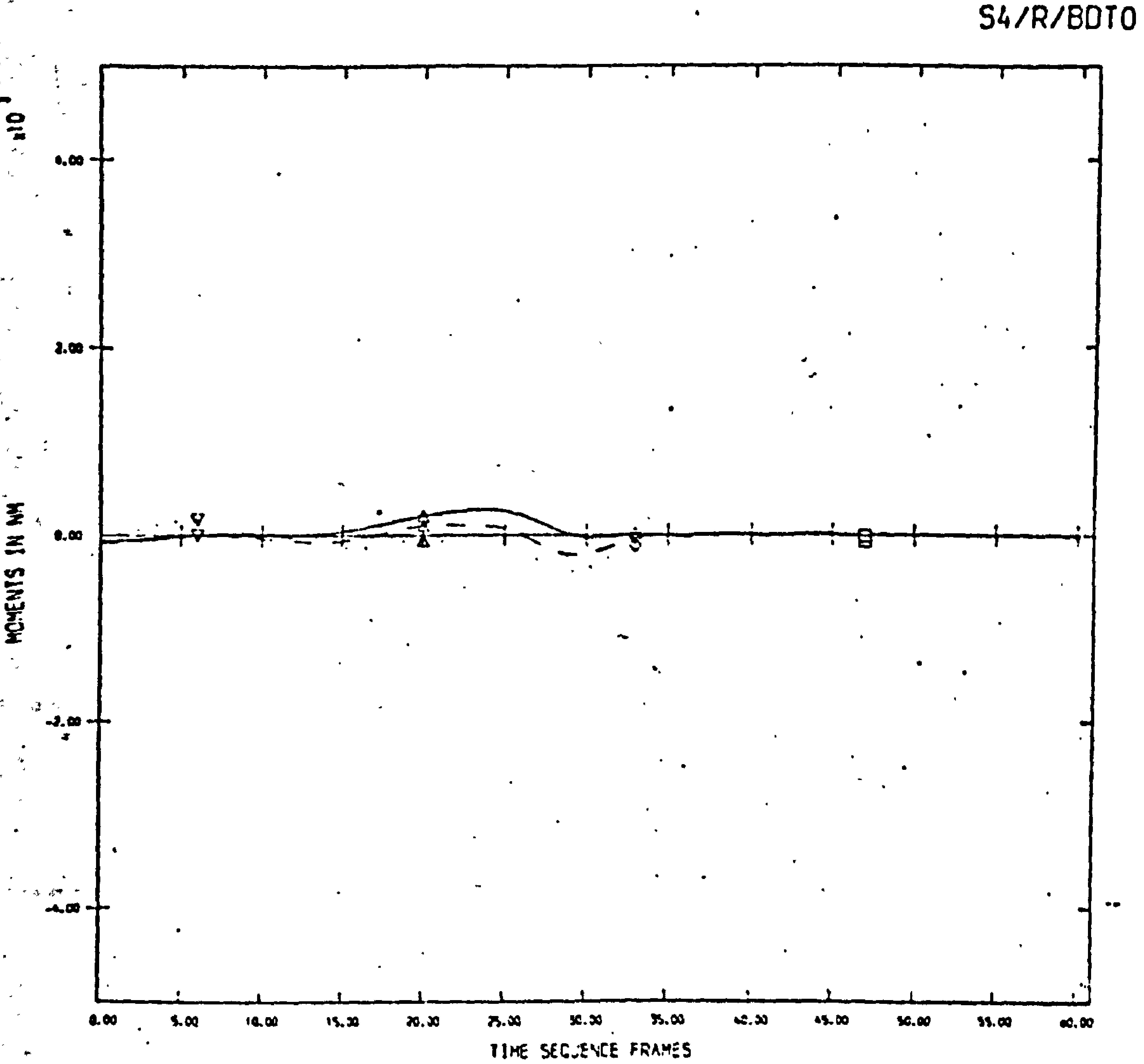
S3/R/BDTO



ANKLE, KNEE, HIP, SAGITTAL PLANE

LEFT HEEL STRIKE △
LEFT TOE OFF ▽
RIGHT HEELSTRIKE □
RIGHT TOE OFF ◇

CONTINUOUS ANKLE
DASHED KNEE
DOTTED HIP

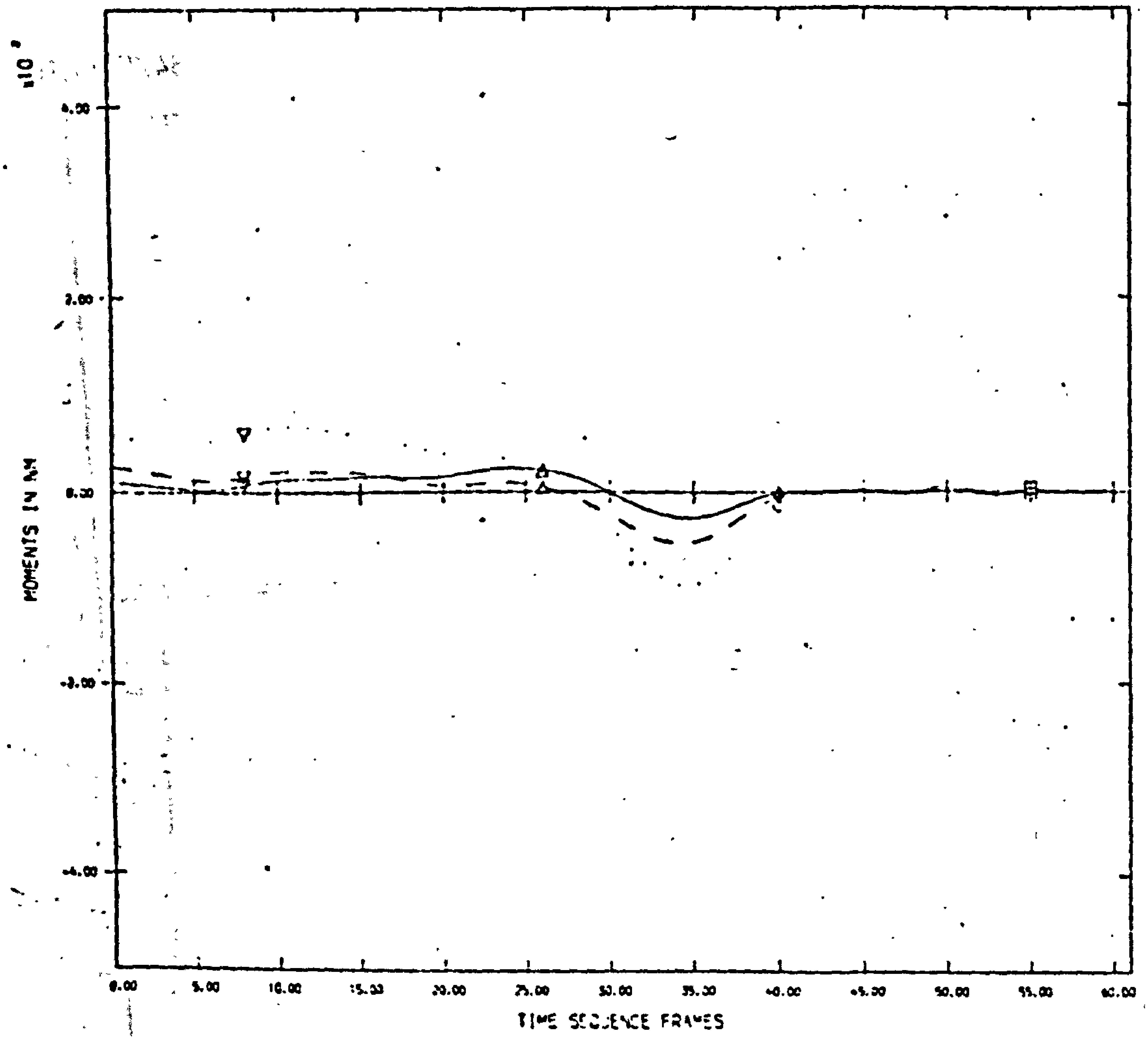


ANKLE. KNEE. HIP. SAGITTAL PLANE

LEFT HEEL STRIKE △
LEFT TOE OFF ▽
RIGHT HEELSTRIKE □
RIGHT TOE OFF ○

CONTINUOUS ANKLE
DASHED KNEE
DOTTED HIP

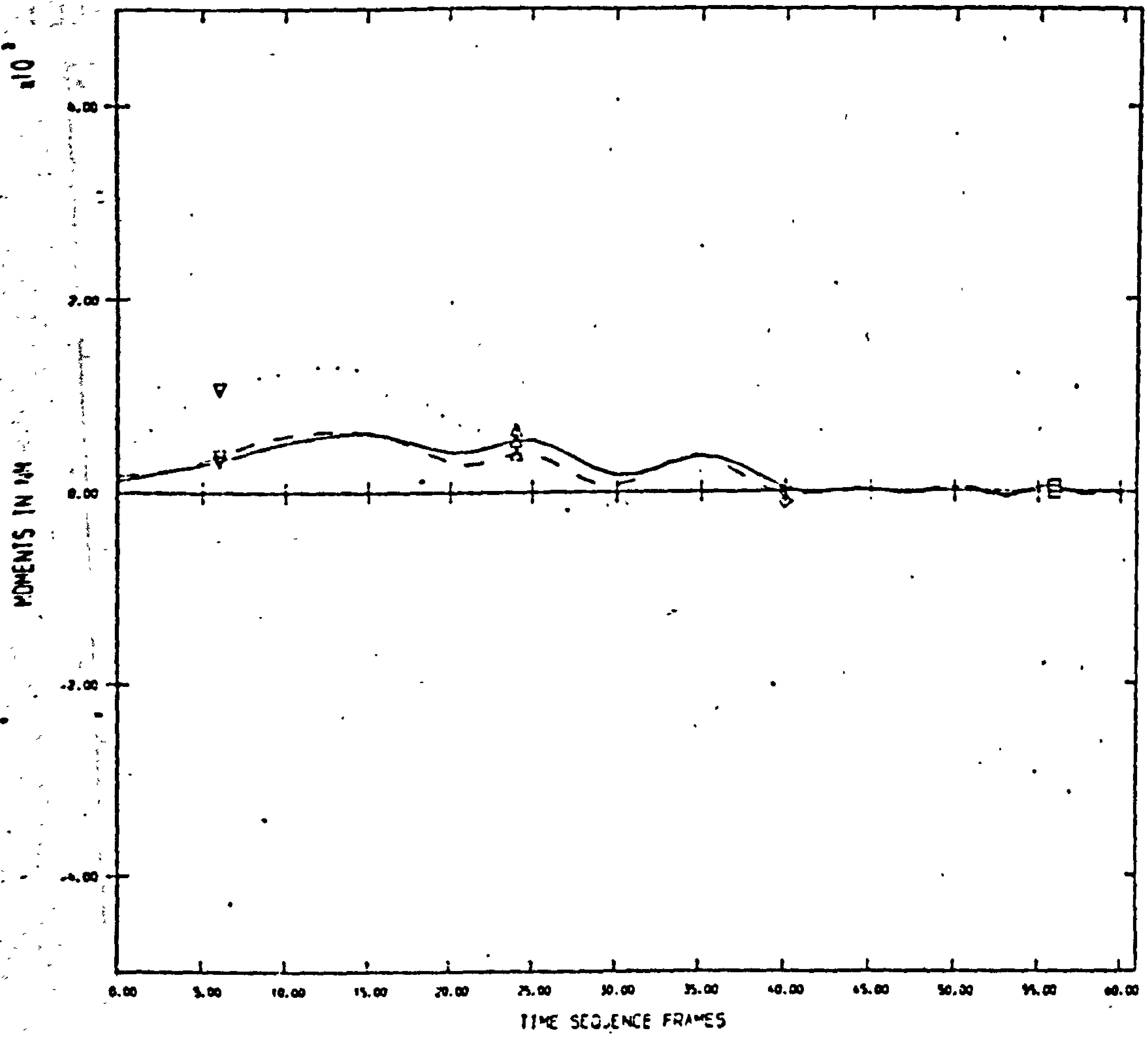
S2/R/BDTO



ANKLE, KNEE, HIP, SAGITTAL PLANE

LEFT HEEL STRIKE	△	CONTINUOUS	ANKLE
LEFT TOE OFF	▽	DASHED	KNEE
RIGHT HEELSTRIKE	□	DOTTED	HIP
RIGHT TOE OFF	◇		

S1/R/BDTO



ANKLE, KNEE, HIP, SAGITTAL PLANE

LEFT HEEL STRIKE △

LEFT TOE OFF ▽

RIGHT HEELSTRIKE □

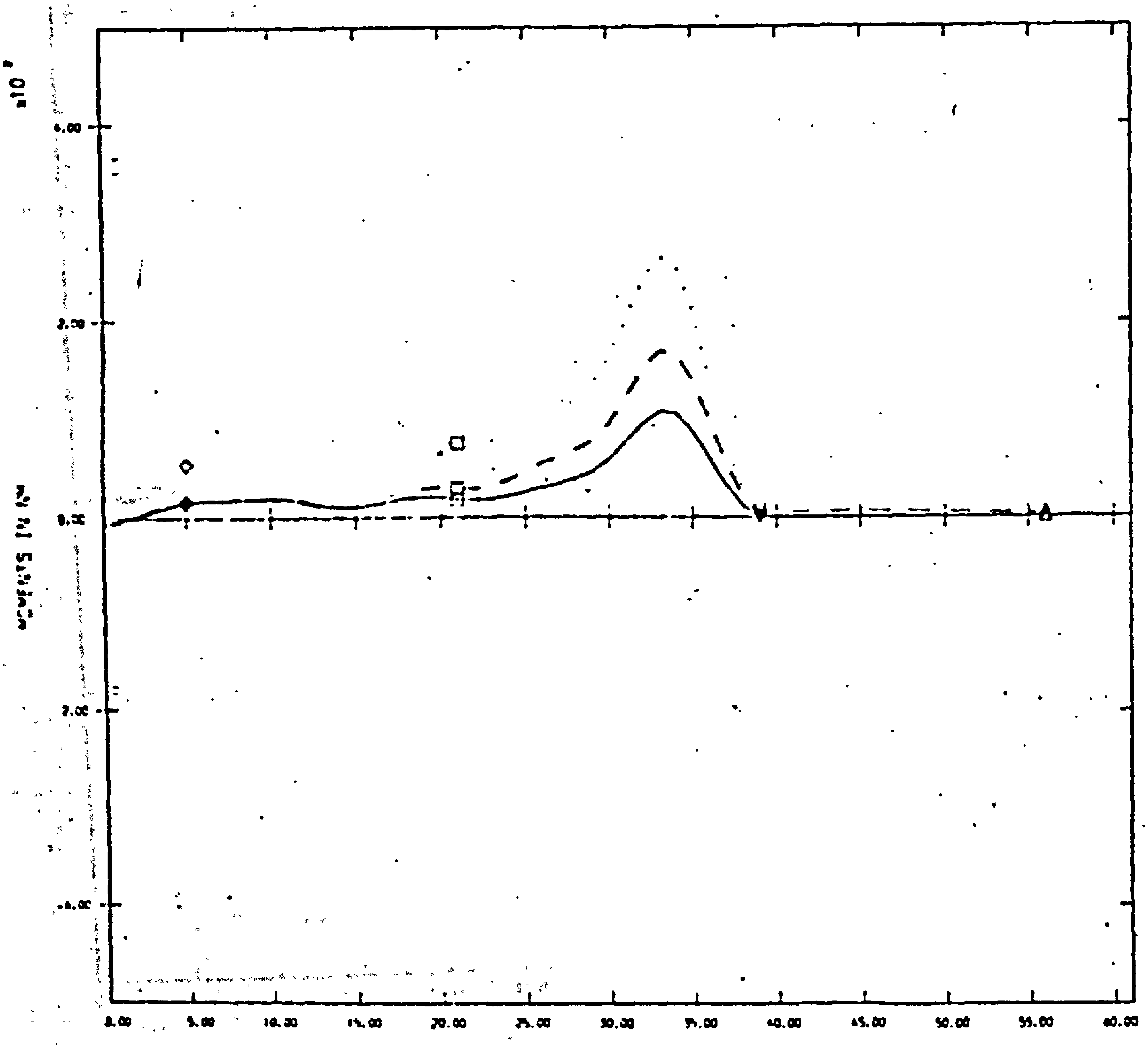
RIGHT TOE OFF ◇

CONTINUOUS ANKLE

DASHED KNEE

DOTTED HIP

S1/L/FUL1

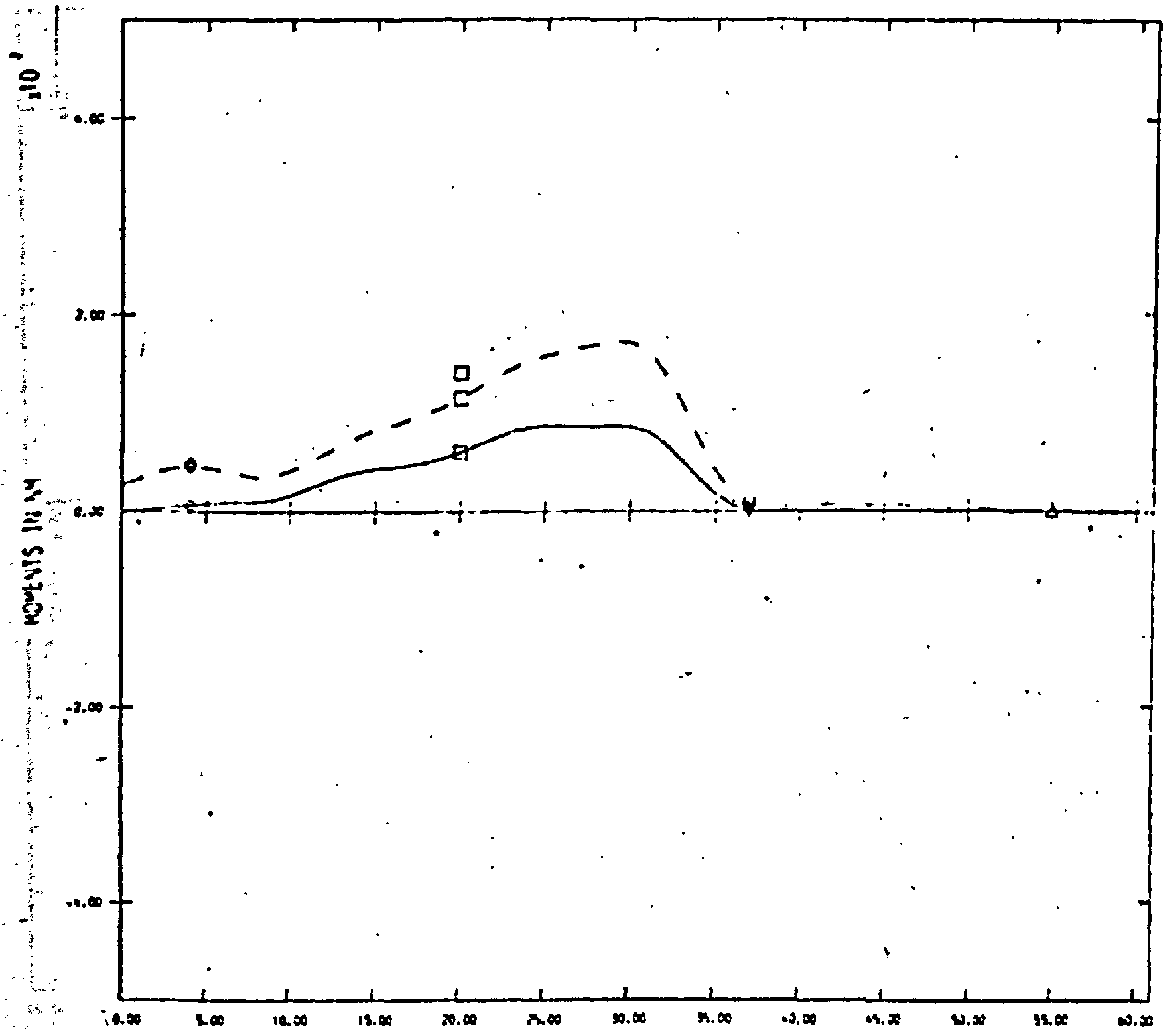


ANKLE, KNEE, HIP, SAGITTAL PLANE

LEFT HEEL STRIKE △
LEFT TOE OFF ▽
RIGHT HEELSTRIKE □
RIGHT TOE OFF ◇

CONTINUOUS ANKLE
DASHED KNEE
DOTTED HIP

S2/L/FUL1

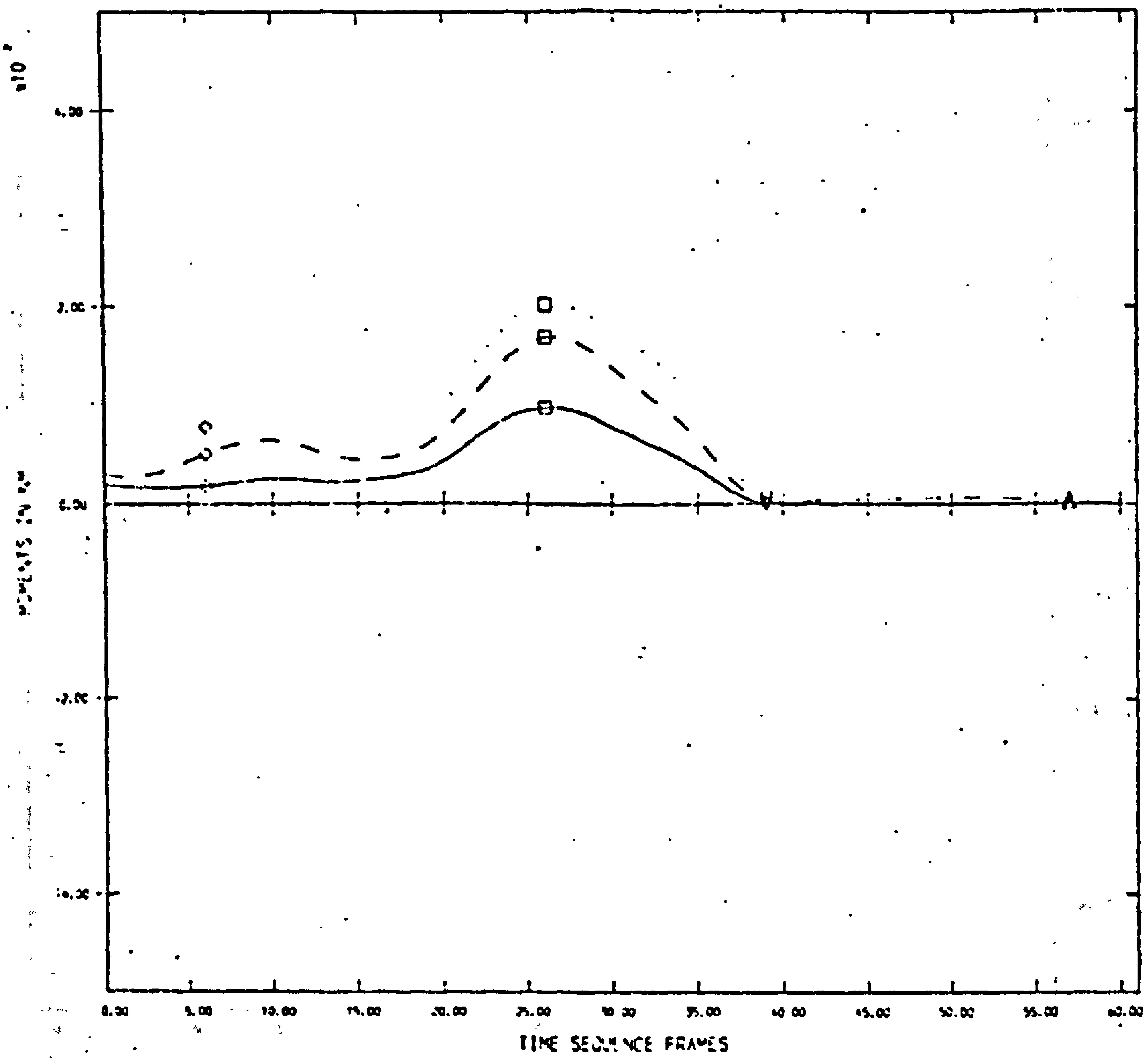


ANKLE, KNEE, HIP, SAGITTAL PLANE

LEFT HEEL STRIKE △
LEFT TOE OFF ▽
RIGHT HEELSTRIKE □
RIGHT TOE OFF ◇

CONTINUOUS	ANKLE
DASHED	KNEE
DOTTED	HIP

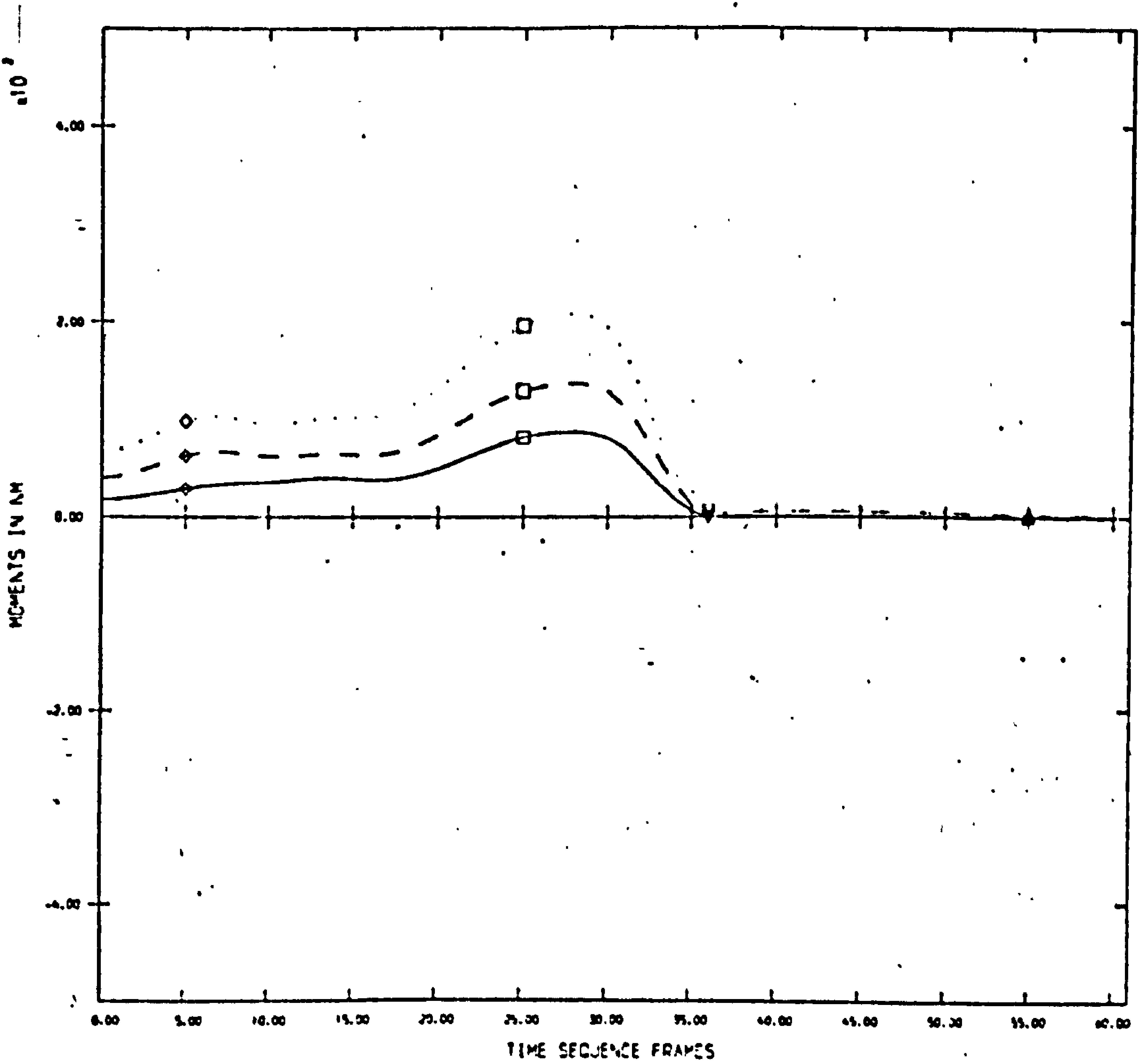
S3/L/FUL1



ANKLE, KNEE, HIP, SAGITTAL PLANE

LEFT HEEL STRIKE	△	CONTINUOUS	ANKLE
LEFT TOE OFF	▽	DASHED	KNEE
RIGHT HEELSTRIKE	□	DOTTED	HIP
RIGHT TOE OFF	◇		

S4/L/FUL1



ANKLE, KNEE, HIP, SAGITTAL PLANE

LEFT HEEL STRIKE △

LEFT TOE OFF ▽

RIGHT HEELSTRIKE □

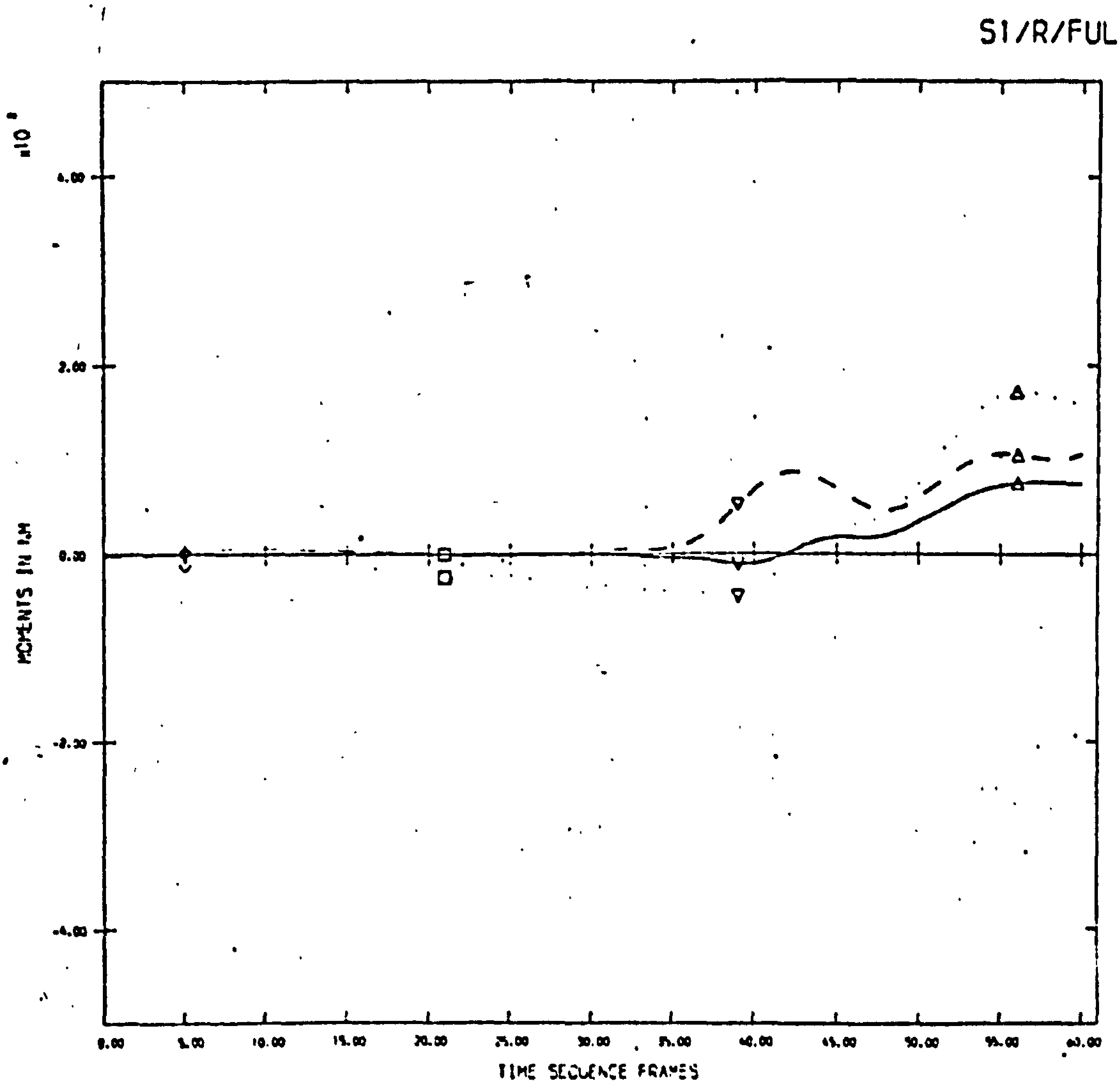
RIGHT TOE OFF ◇

CONTINUOUS ANKLE

DASHED KNEE

DOTTED HIP

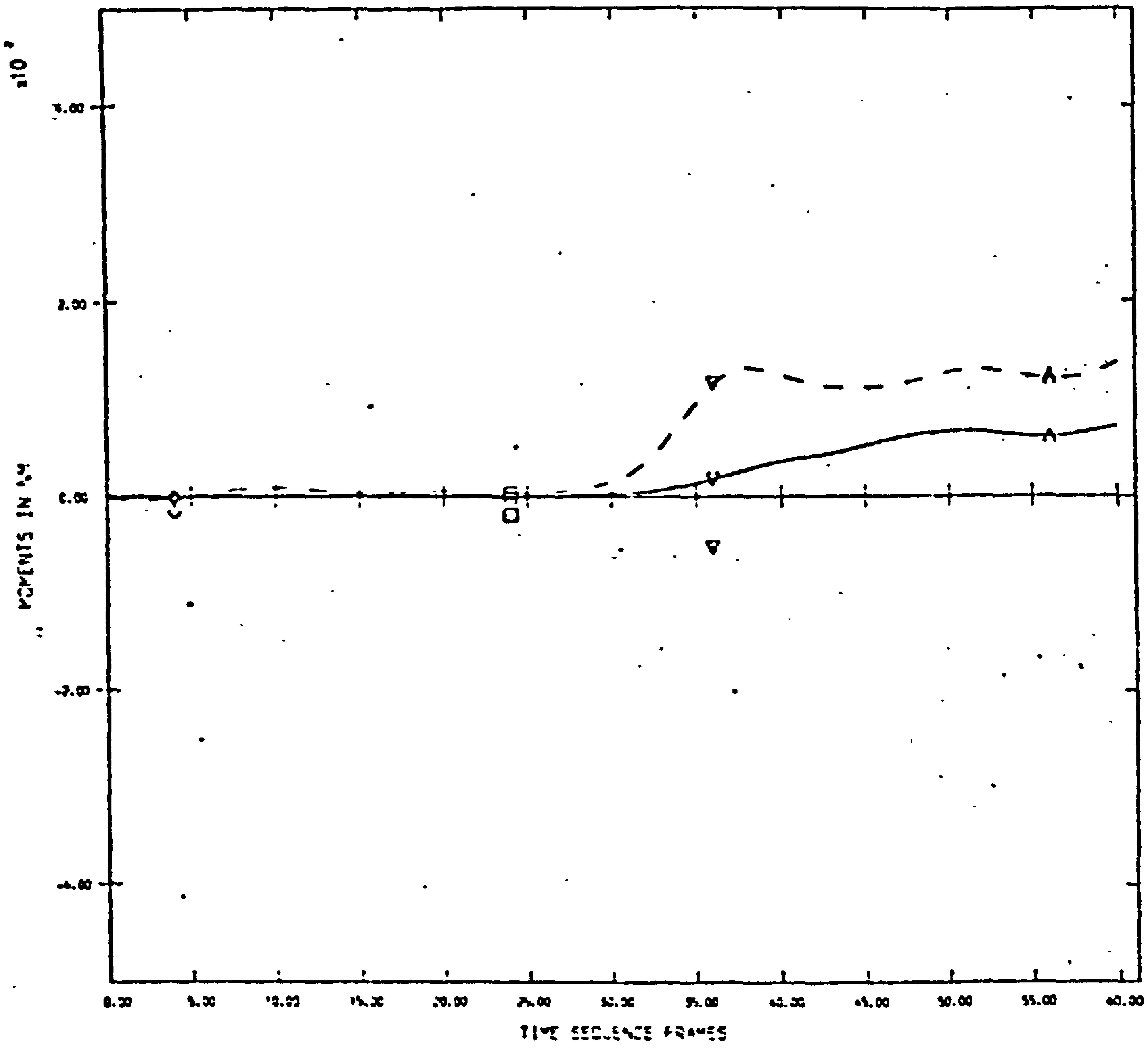
S1/R/FUL1



ANKLE, KNEE, HIP, SAGITTAL PLANE

LEFT HEEL STRIKE	△	CONTINUOUS	ANKLE
LEFT TOE OFF	▽	DASHED	KNEE
RIGHT HEELSTRIKE	□	DOTTED	HIP
RIGHT TOE OFF	◇		

S5/R/FUL1



ANKLE, KNEE, HIP, SAGITTAL PLANE

LEFT HEEL STRIKE △

LEFT TOE OFF ▽

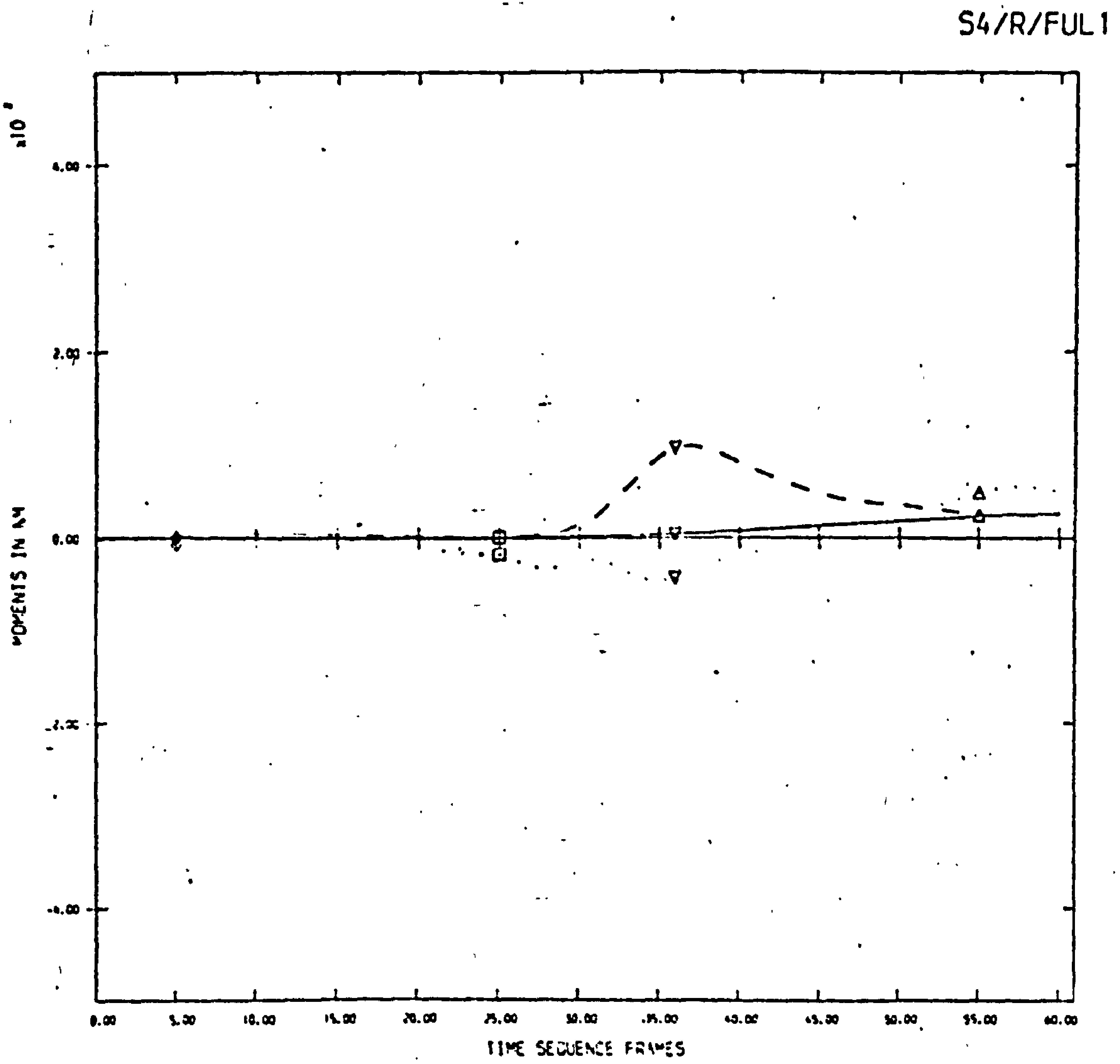
RIGHT HEELSTRIKE □

RIGHT TOE OFF ◇

CONTINUOUS ANKLE

DASHED KNEE

DOTTED HIP



ANKLE, KNEE, HIP, SAGITTAL PLANE

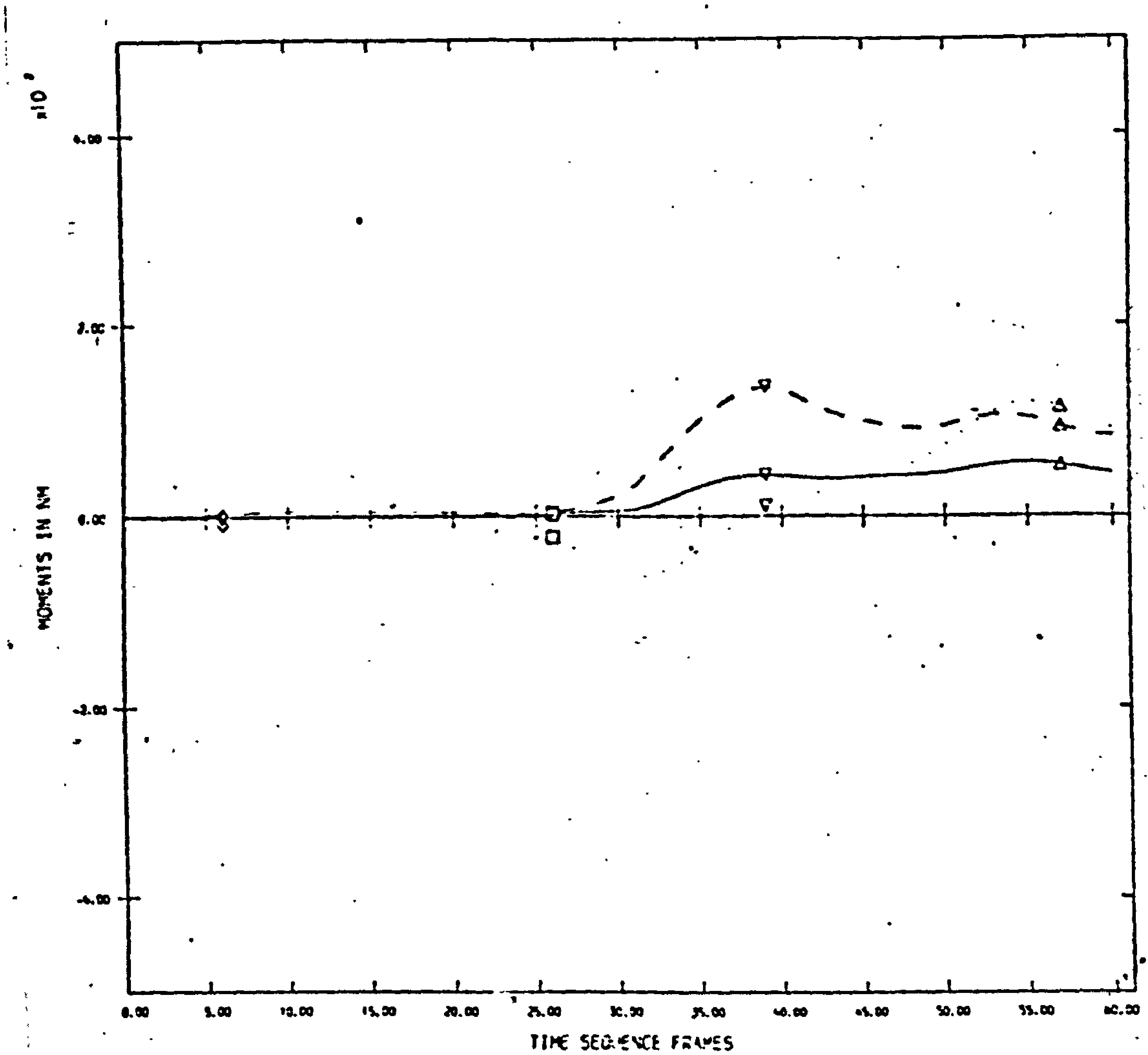
LEFT HEEL STRIKE △ CONTINUOUS ANKLE

LEFT TOE OFF ▽ DASHED KNEE

RIGHT HEELSTRIKE □ DOTTED HIP

RIGHT TOE OFF ◇

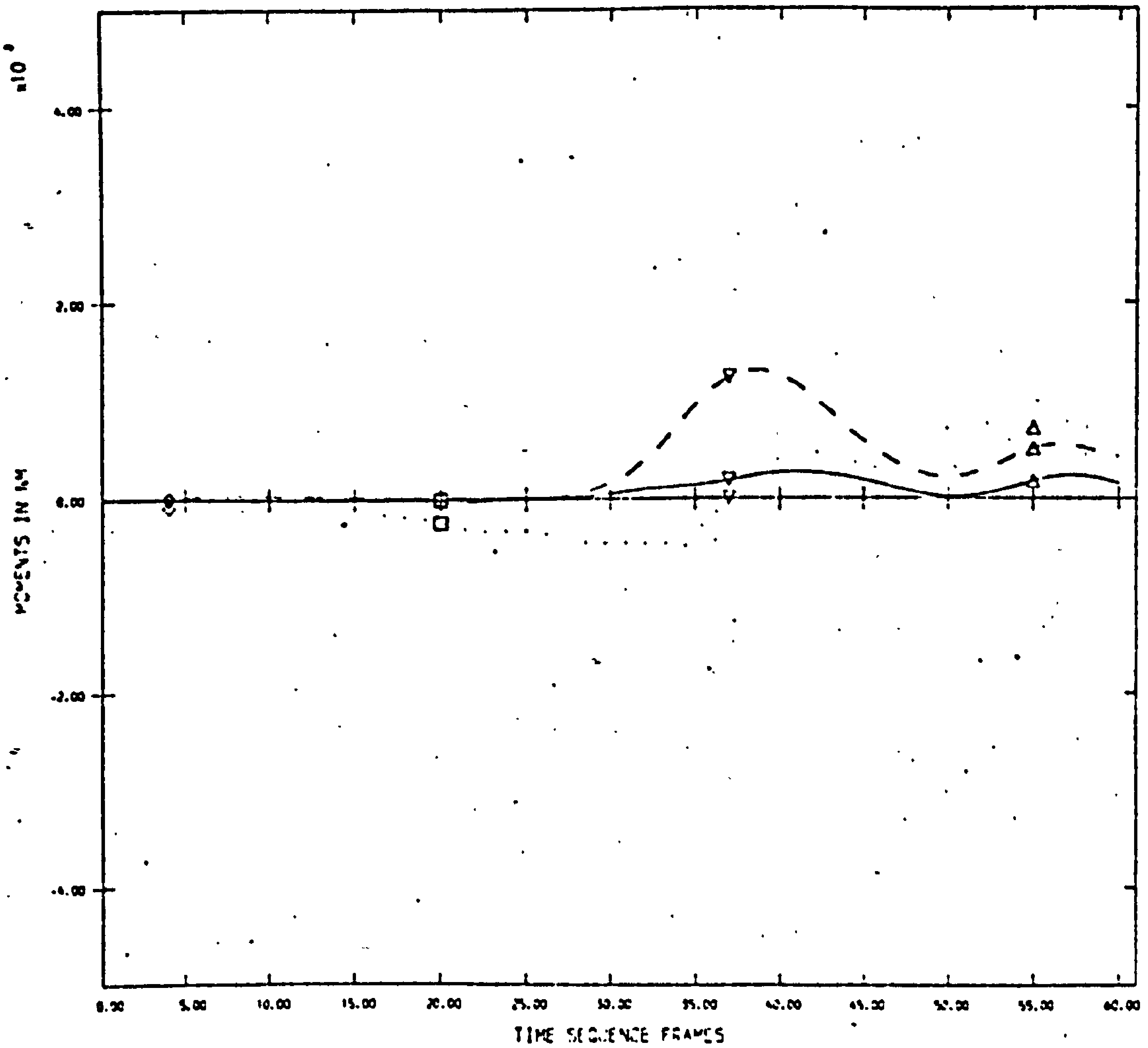
S3/R/FUL1



ANKLE, KNEE, HIP, SAGITTAL PLANE

LEFT HEEL STRIKE	△	CONTINUOUS	ANKLE
LEFT TOE OFF	▽	DASHED	KNEE
RIGHT HEELSTRIKE	□	DOTTED	HIP
RIGHT TOE OFF	◇		

S2/R/FUL1

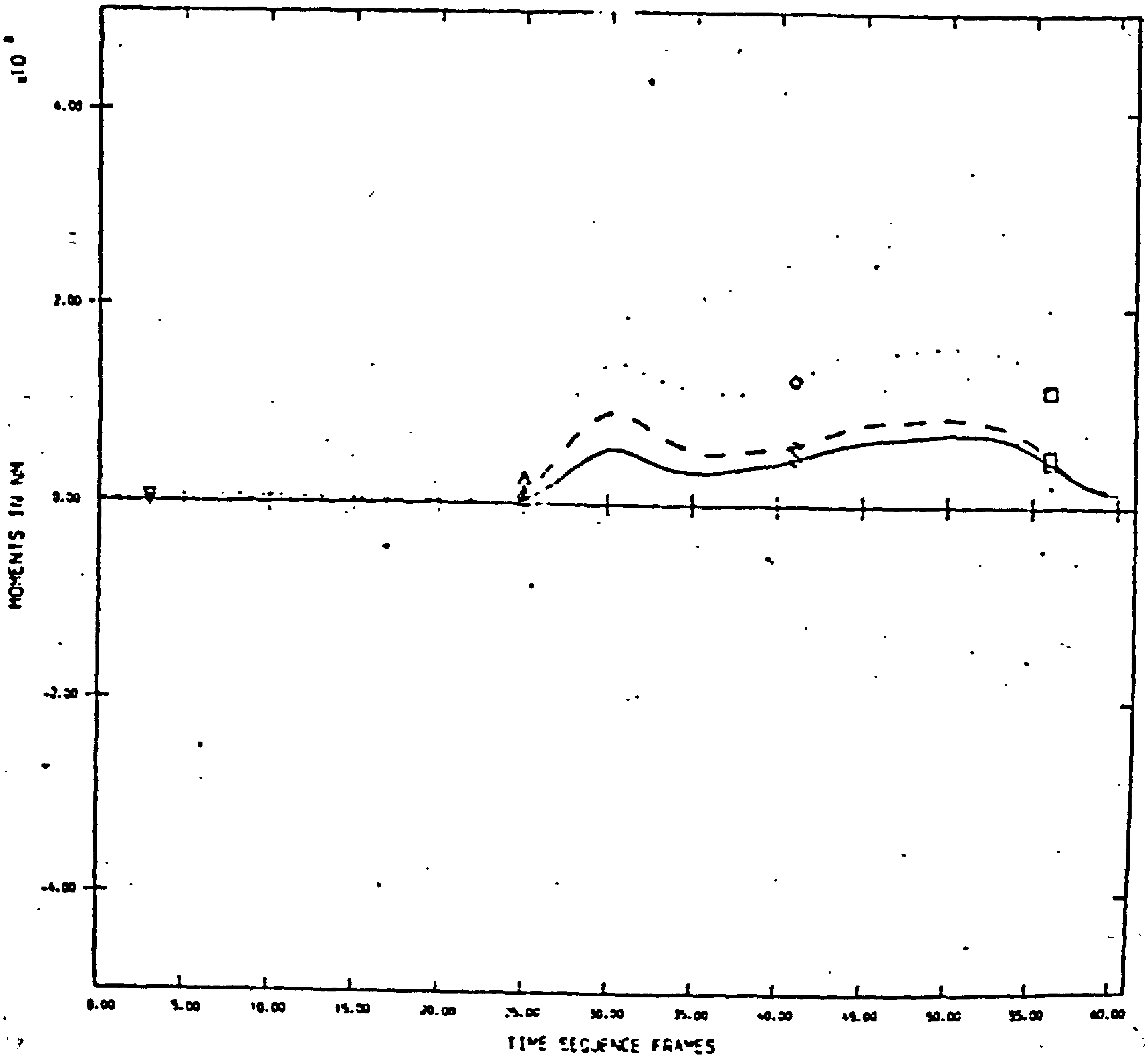


ANKLE, KNEE, HIP, SAGITTAL PLANE

LEFT HEEL STRIKE △
LEFT TOE OFF ▽
RIGHT HEELSTRIKE □
RIGHT TOE OFF ◇

CONTINUOUS ANKLE
DASHED KNEE
DOTTED HIP

S1/L/BDT1



ANKLE, KNEE, HIP, SAGITTAL PLANE

LEFT HEEL STRIKE △

LEFT TOE OFF ▽

RIGHT HEELSTRIKE □

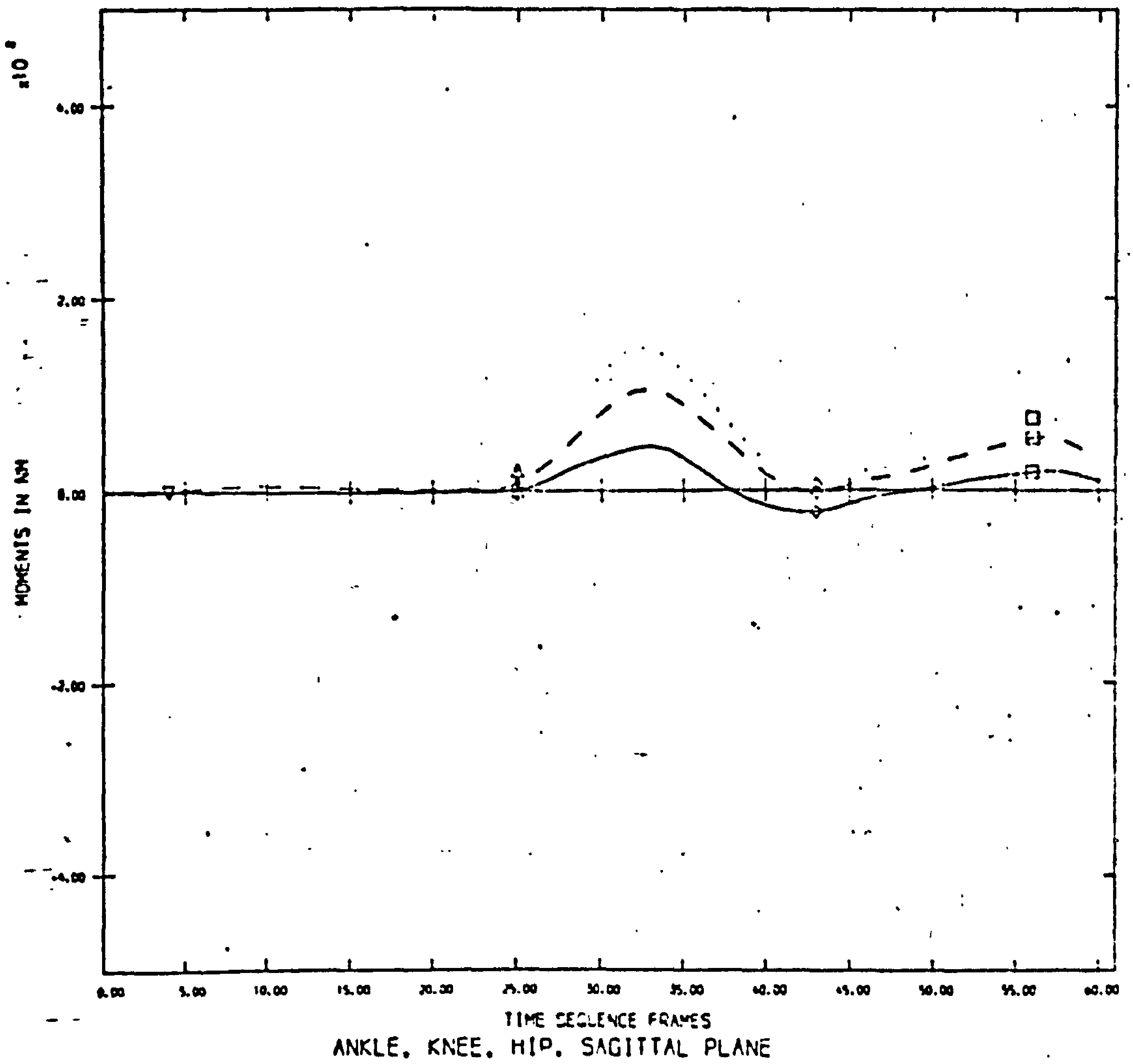
RIGHT TOE OFF ◇

CONTINUOUS ANKLE

DASHED KNEE

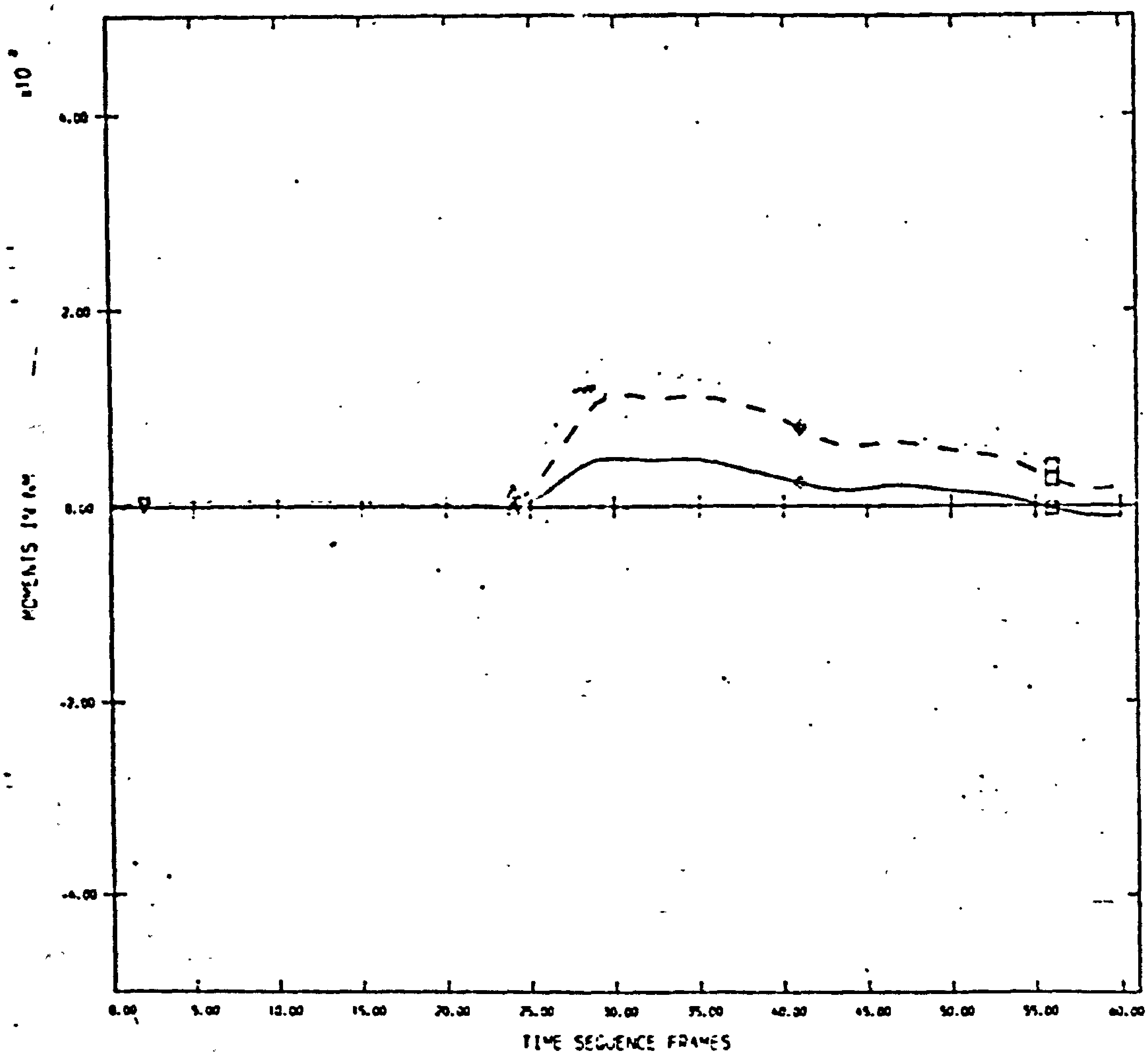
DOTTED HIP

S2/L/BDT1



LEFT HEEL STRIKE	△	CONTINUOUS	ANKLE
LEFT TOE OFF	▽	DASHED	KNEE
RIGHT HEELSTRIKE	□	DOTTED	HIP
RIGHT TOE OFF	◇		

S3/L/BDT1

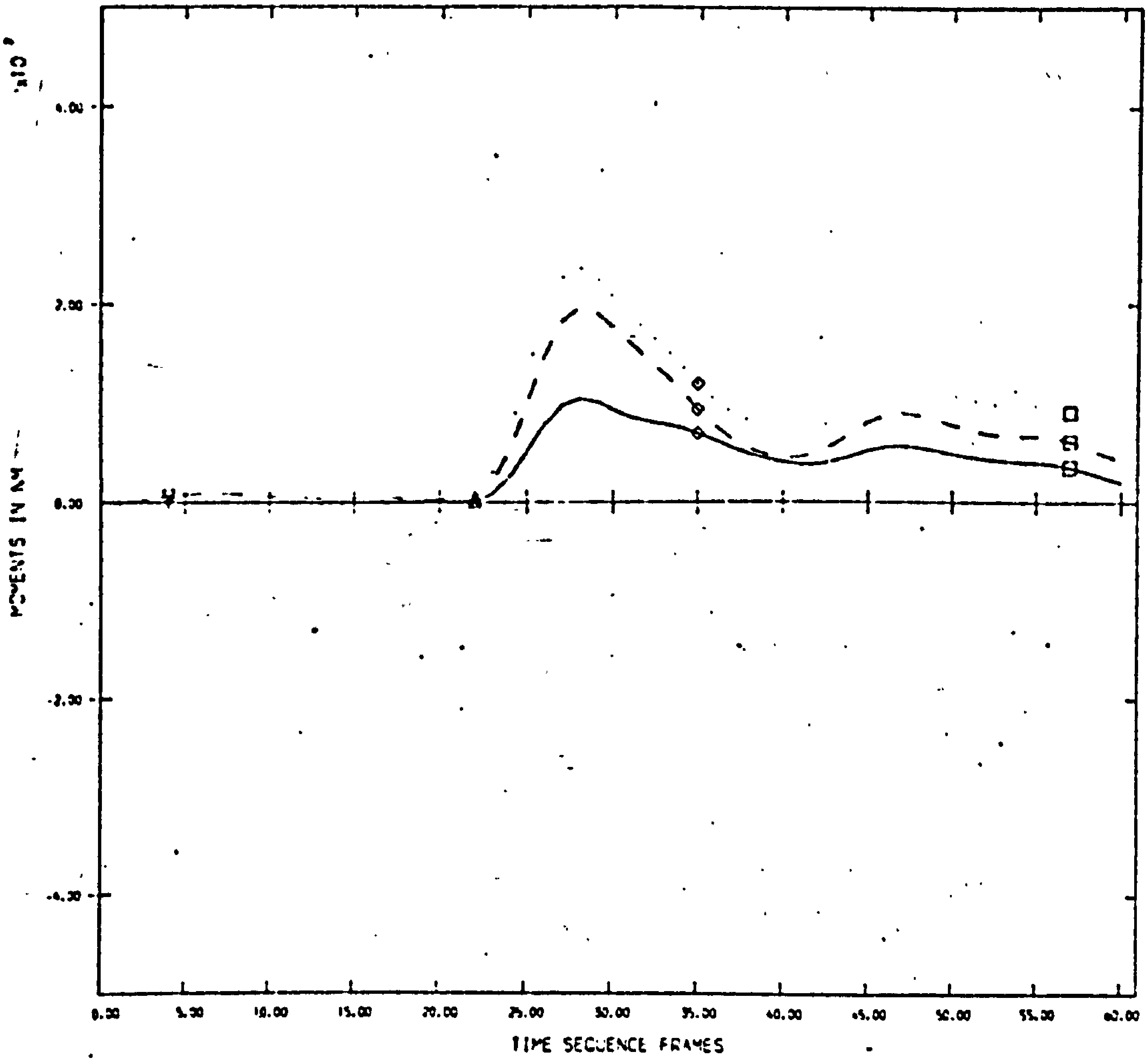


ANKLE, KNEE, HIP, SAGITTAL PLANE

LEFT HEEL STRIKE △
LEFT TOE OFF ▽
RIGHT HEELSTRIKE □
RIGHT TOE OFF ◇

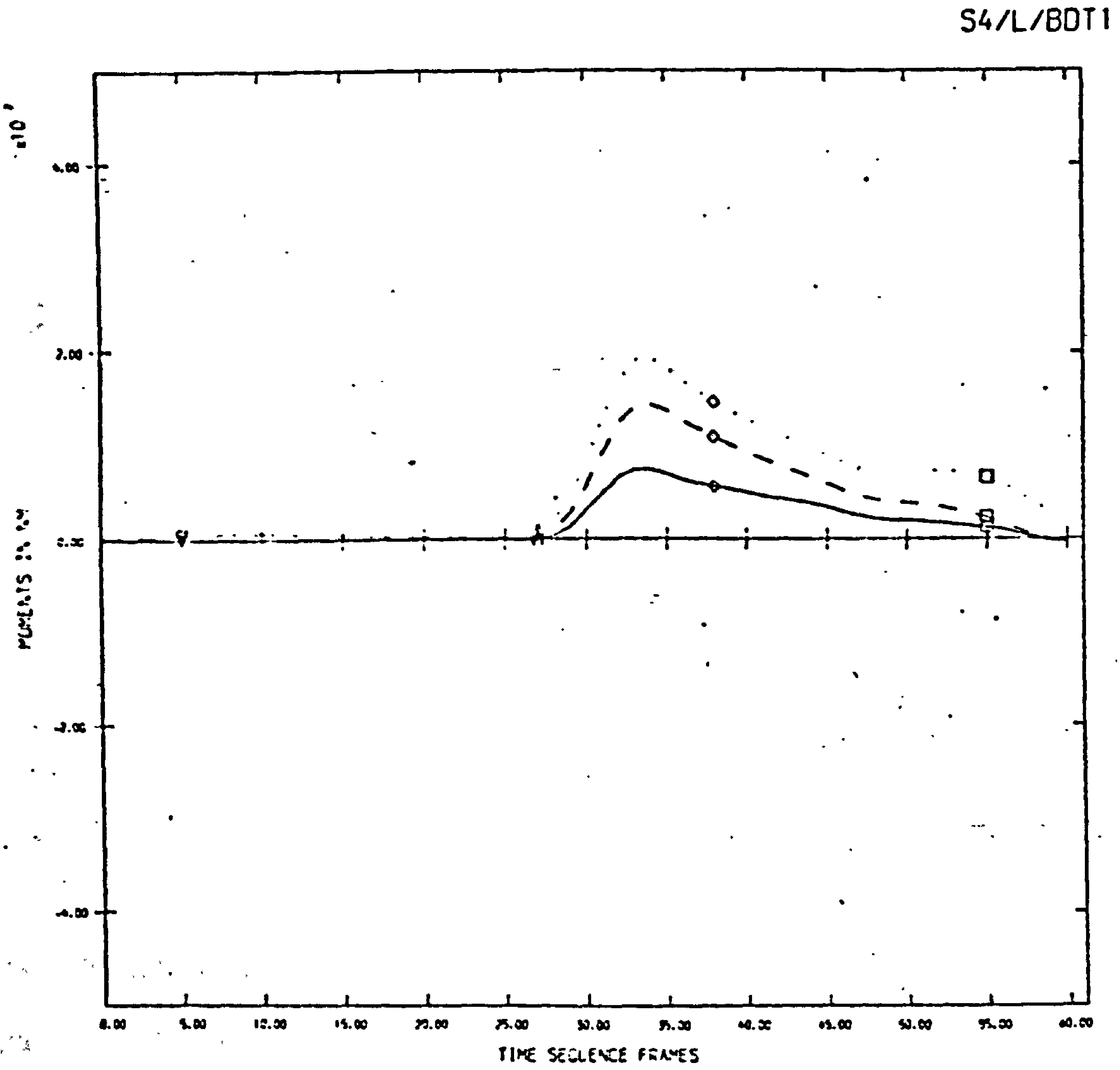
CONTINUOUS ANKLE
DASHED KNEE
DOTTED HIP

S5/L/BDT1



ANKLE, KNEE, HIP, SAGITTAL PLANE

LEFT HEEL STRIKE	△	CONTINUOUS.	ANKLE
LEFT TOE OFF	▽	DASHED	KNEE
RIGHT HEELSTRIKE	◻	DOTTED	HIP
RIGHT TOE OFF	◇		

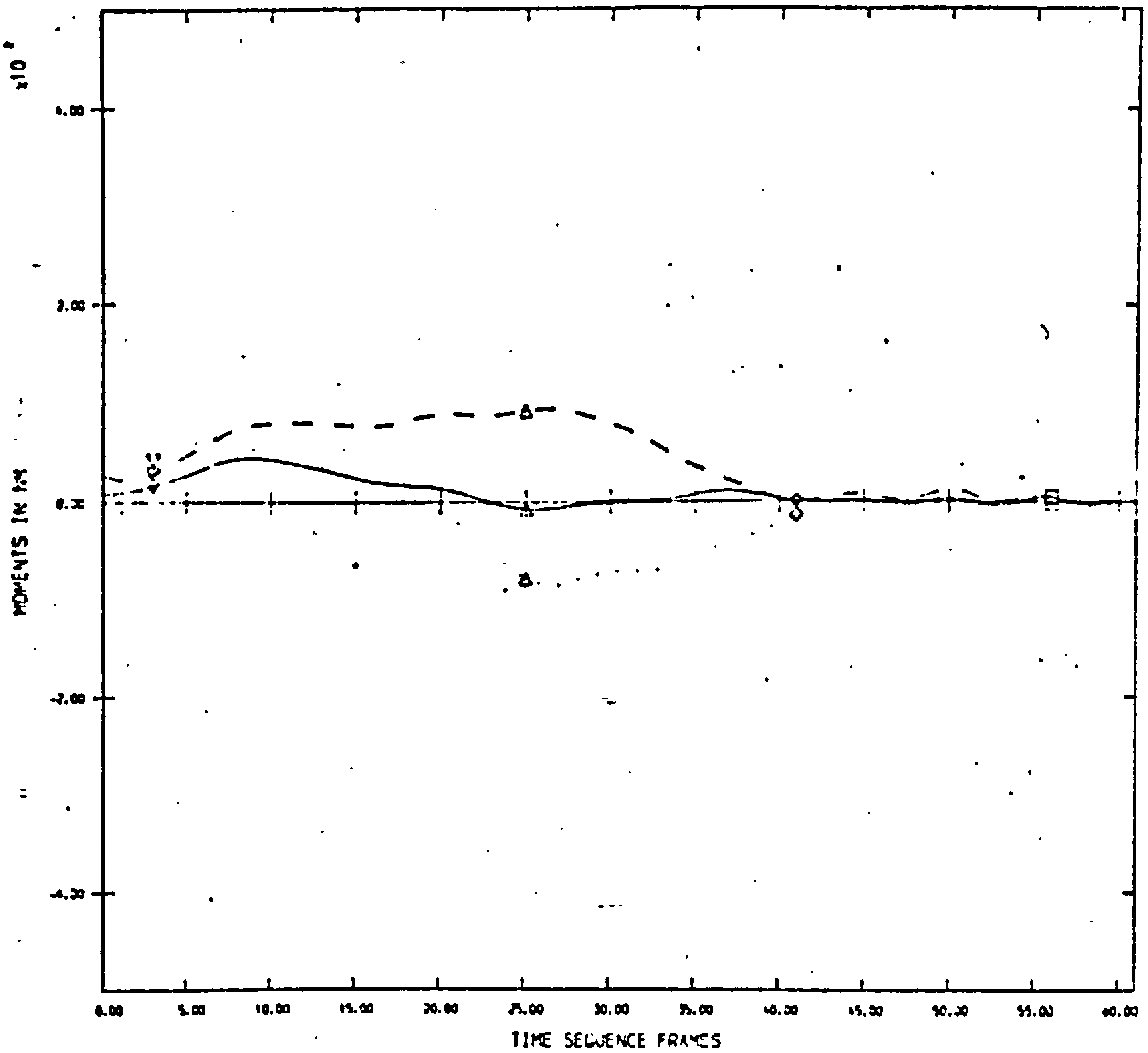


ANKLE, KNEE, HIP, SAGITTAL PLANE

LEFT HEEL STRIKE △
LEFT TOE OFF ▽
RIGHT HEELSTRIKE □
RIGHT TOE OFF ◇

CONTINUOUS ANKLE
DASHED KNEE
DOTTED HIP

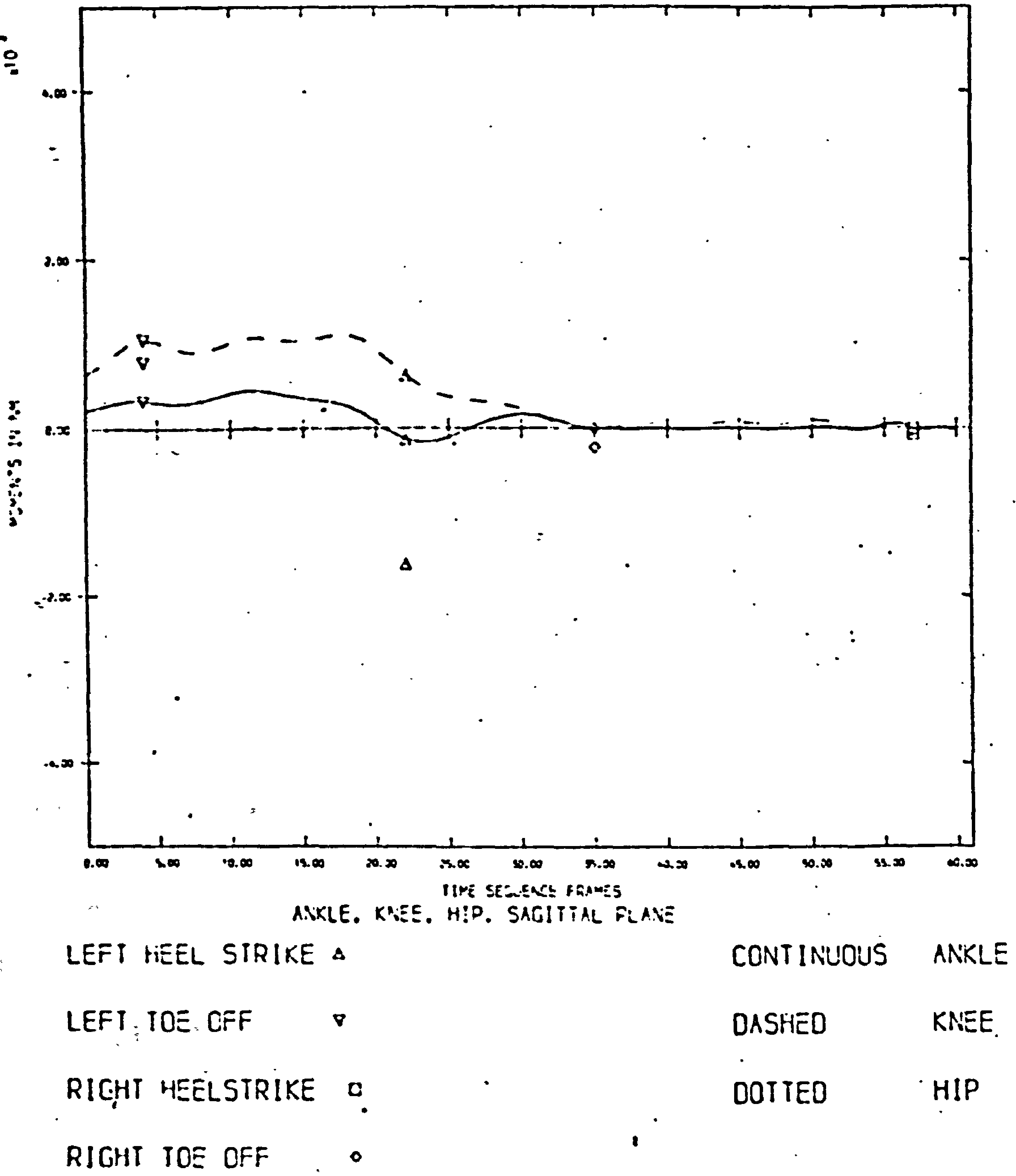
S1/R/BDT1



ANKLE. KNEE. HIP. SAGITTAL PLANE

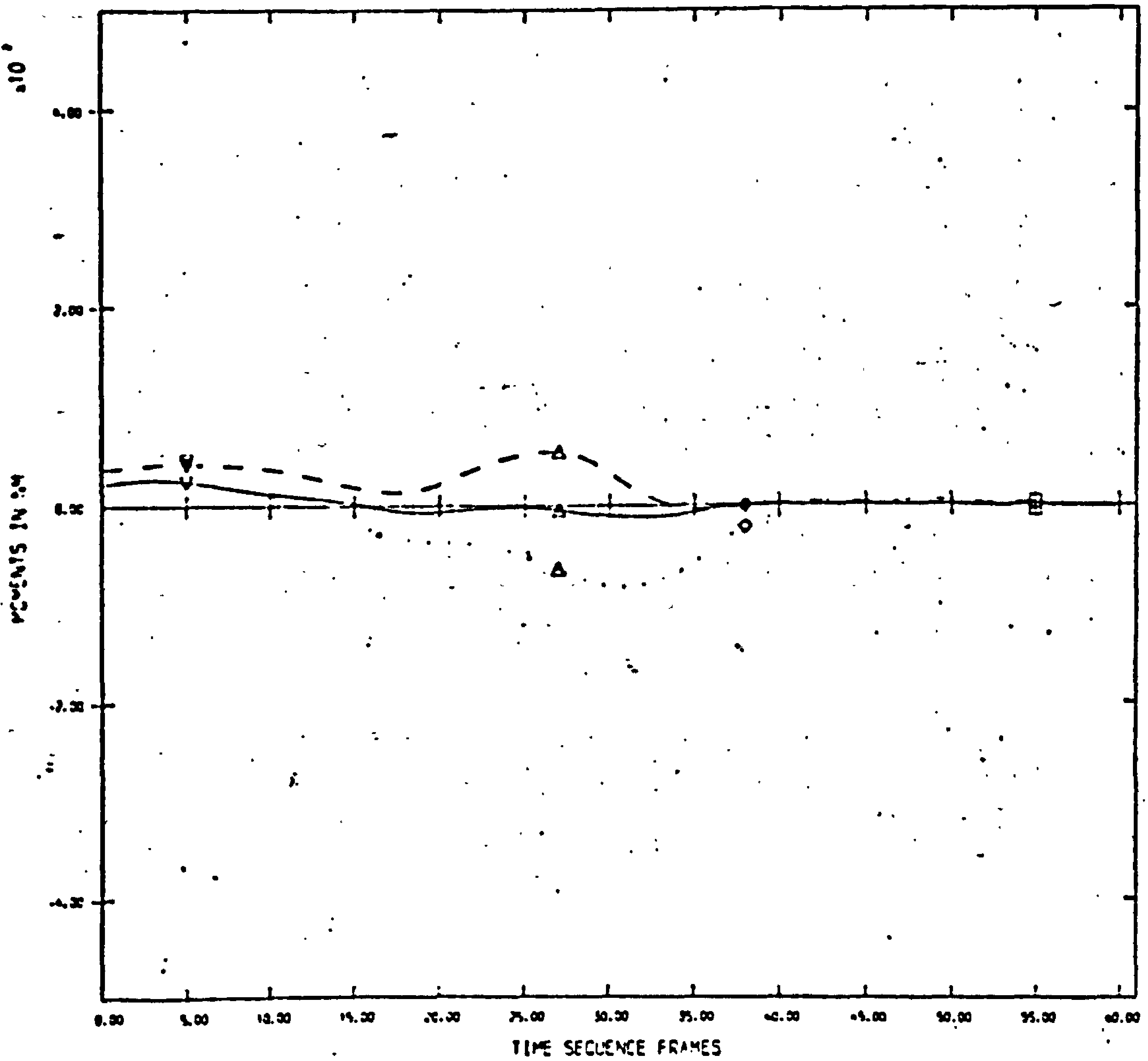
LEFT HEEL STRIKE	△	CONTINUOUS	ANKLE
LEFT TOE OFF	▽	DASHED	KNEE
RIGHT HEELSTRIKE	□	DOTTED	HIP
RIGHT TOE OFF	◇		

S5/R/BDT1



ANKLE, KNEE, HIP, SAGITTAL PLANE

S4/R/BDT1

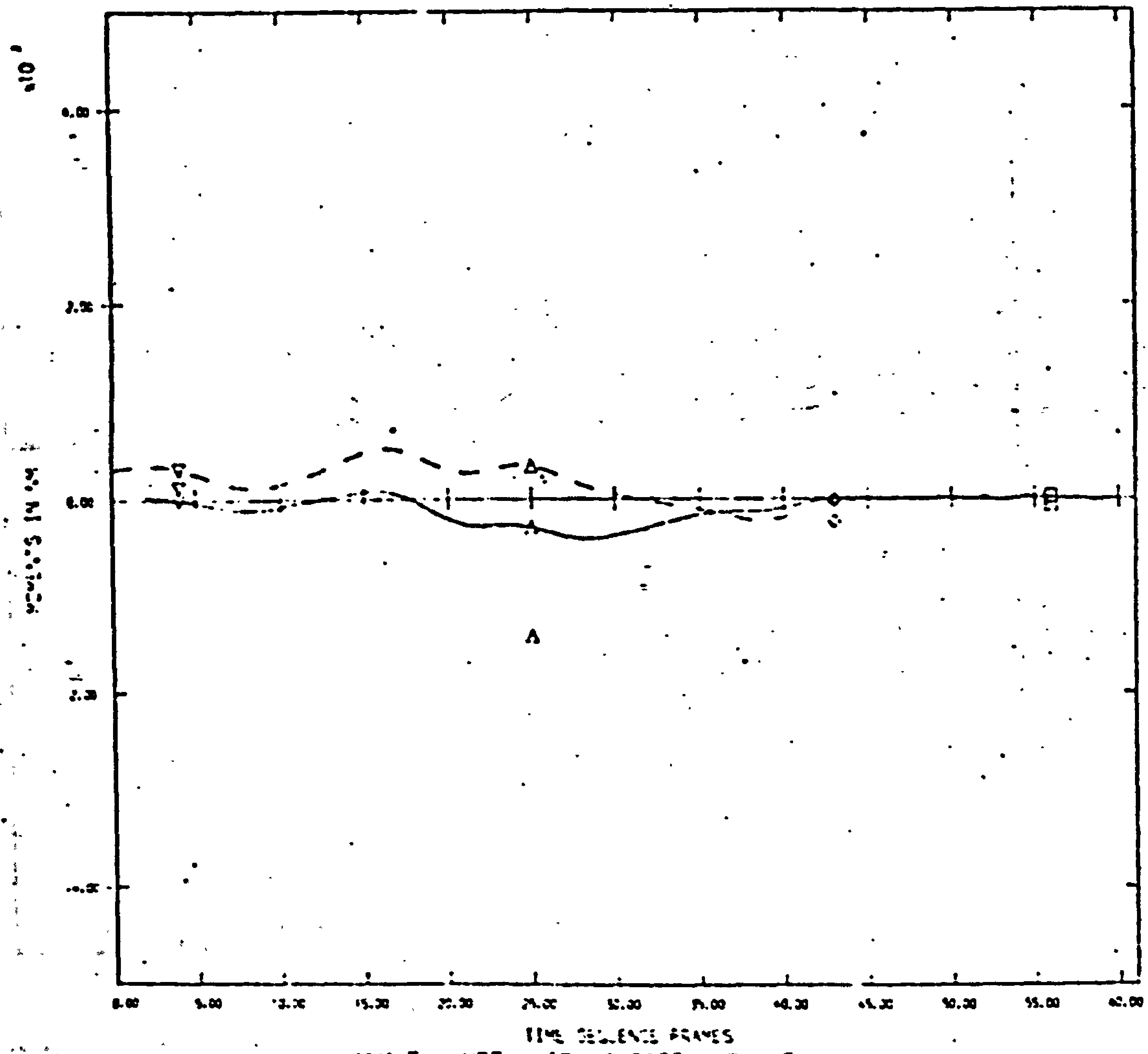


ANKLE, KNEE, HIP, SAGITTAL PLANE

LEFT HEEL STRIKE △
LEFT TOE OFF ▽
RIGHT HEELSTRIKE □
RIGHT TOE OFF ◇

CONTINUOUS ANKLE
DASHED KNEE
DOTTED HIP

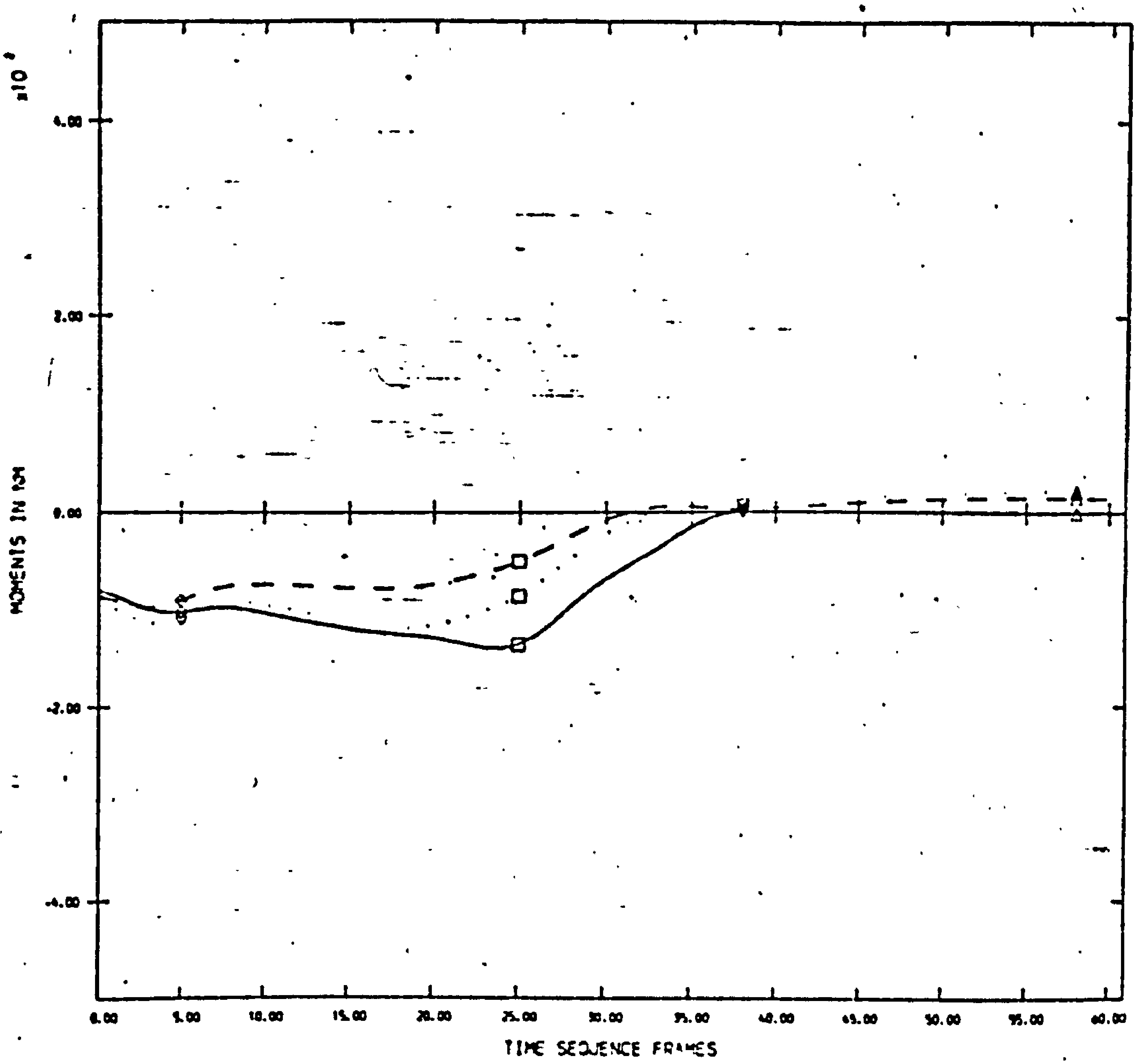
S2/R/BDT1



ANKLE, KNEE, HIP, SAGITTAL PLANE

LEFT HEEL STRIKE	△	CONTINUOUS	ANKLE
LEFT TOE OFF	▽	DASHED	KNEE
RIGHT HEELSTRIKE	□	DOTTED	HIP
RIGHT TOE OFF	◇		

SI/L/FULO



ANKLE.KNEE. HIP. CORONAL PLANE

LEFT HEEL STRIKE △

LEFT TOE OFF ▽

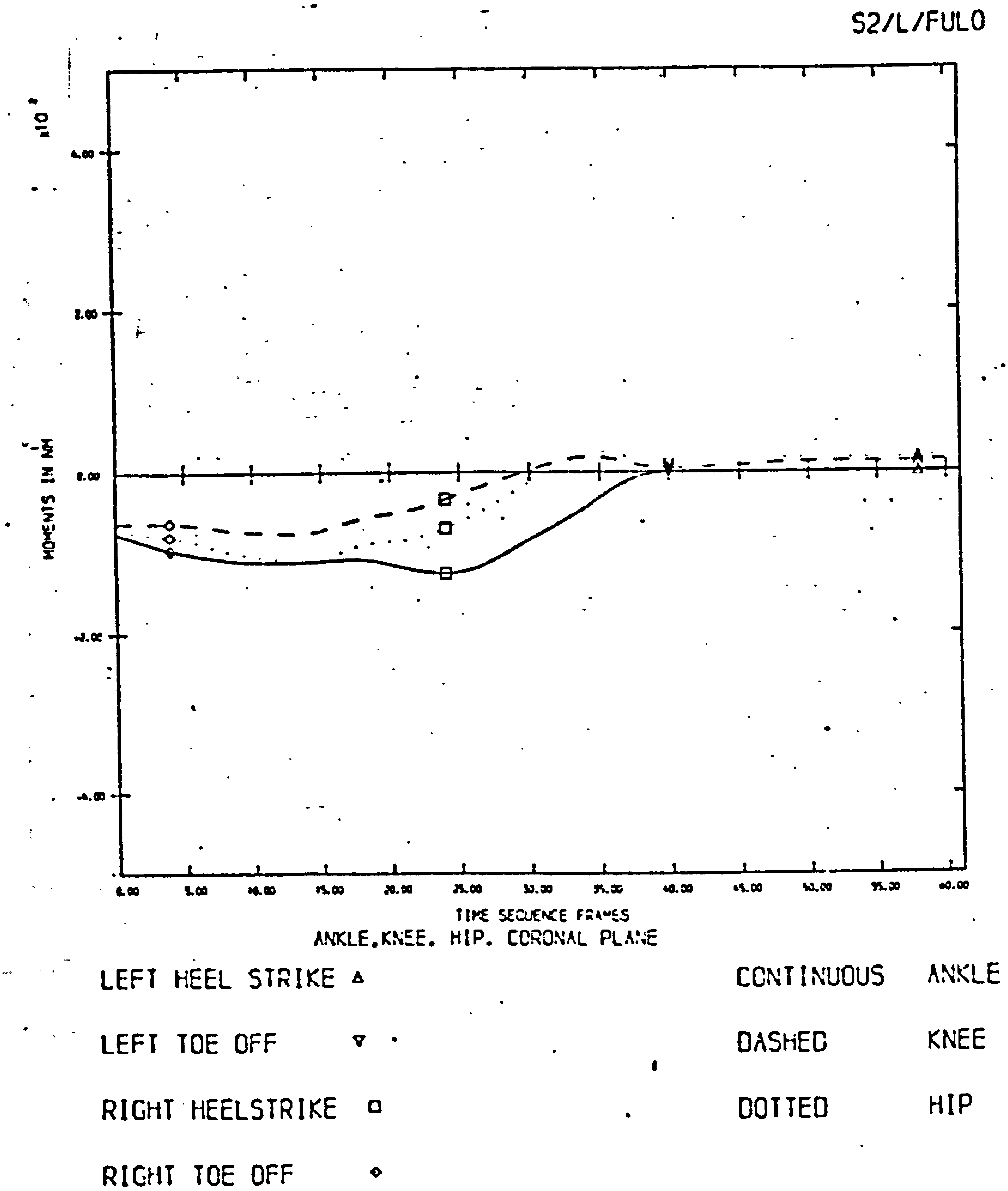
RIGHT HEELSTRIKE □

RIGHT TOE OFF ◇

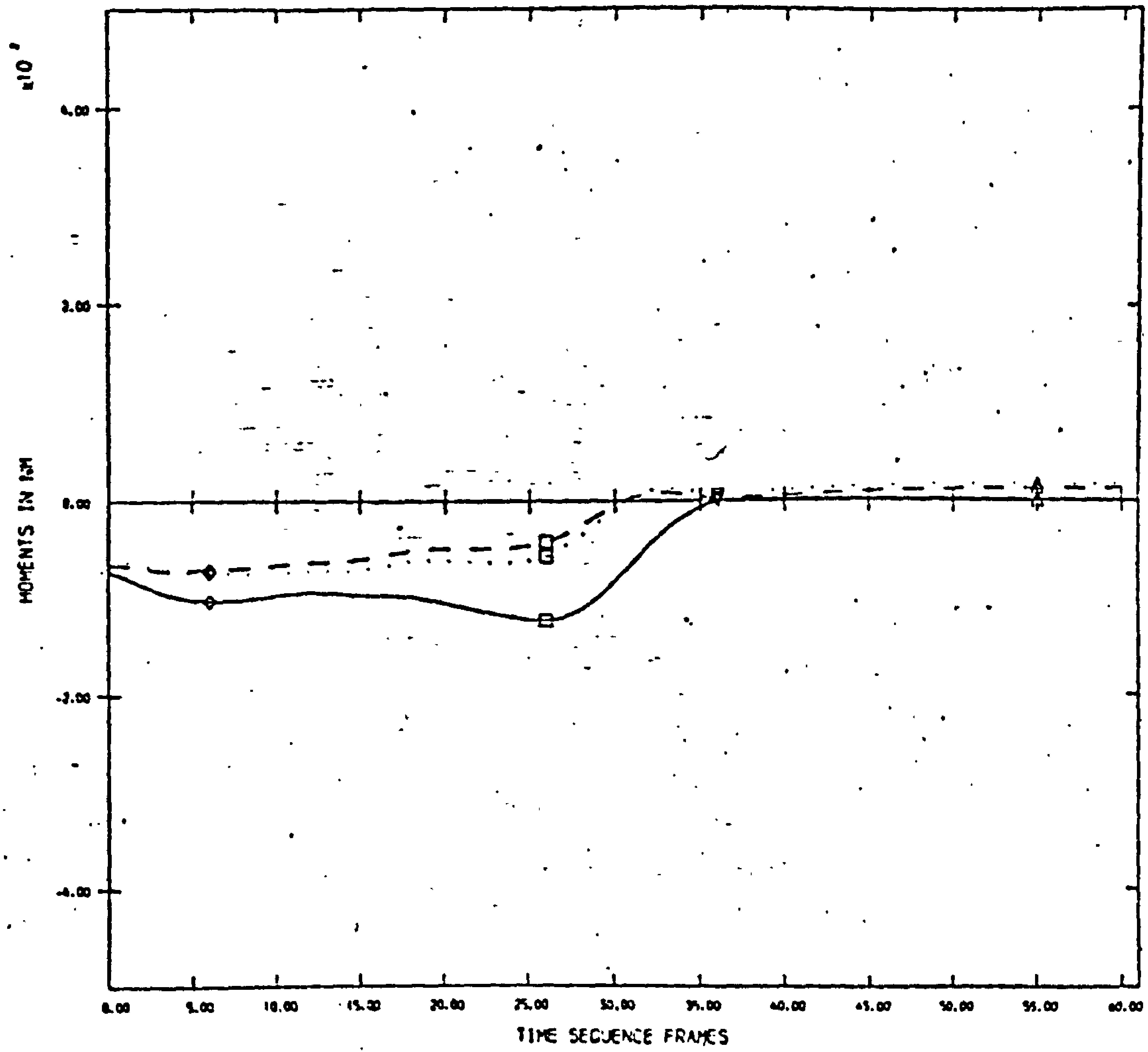
CONTINUOUS ANKLE

DASHED KNEE

DOTTED HIP


S2/L/FULO
x10 ²
MOMENTS IN NM
4.00
2.00
0.00
-2.00
-4.00
0.00
5.00
10.00
15.00
20.00
25.00
30.00
35.00
40.00
45.00
50.00
55.00
60.00
TIME SEQUENCE FRAMES
ANKLE, KNEE, HIP. CORONAL PLANE
LEFT HEEL STRIKE △
LEFT TOE OFF ▽
RIGHT HEELSTRIKE □
RIGHT TOE OFF ◇
CONTINUOUS ANKLE
DASHED KNEE
DOTTED HIP

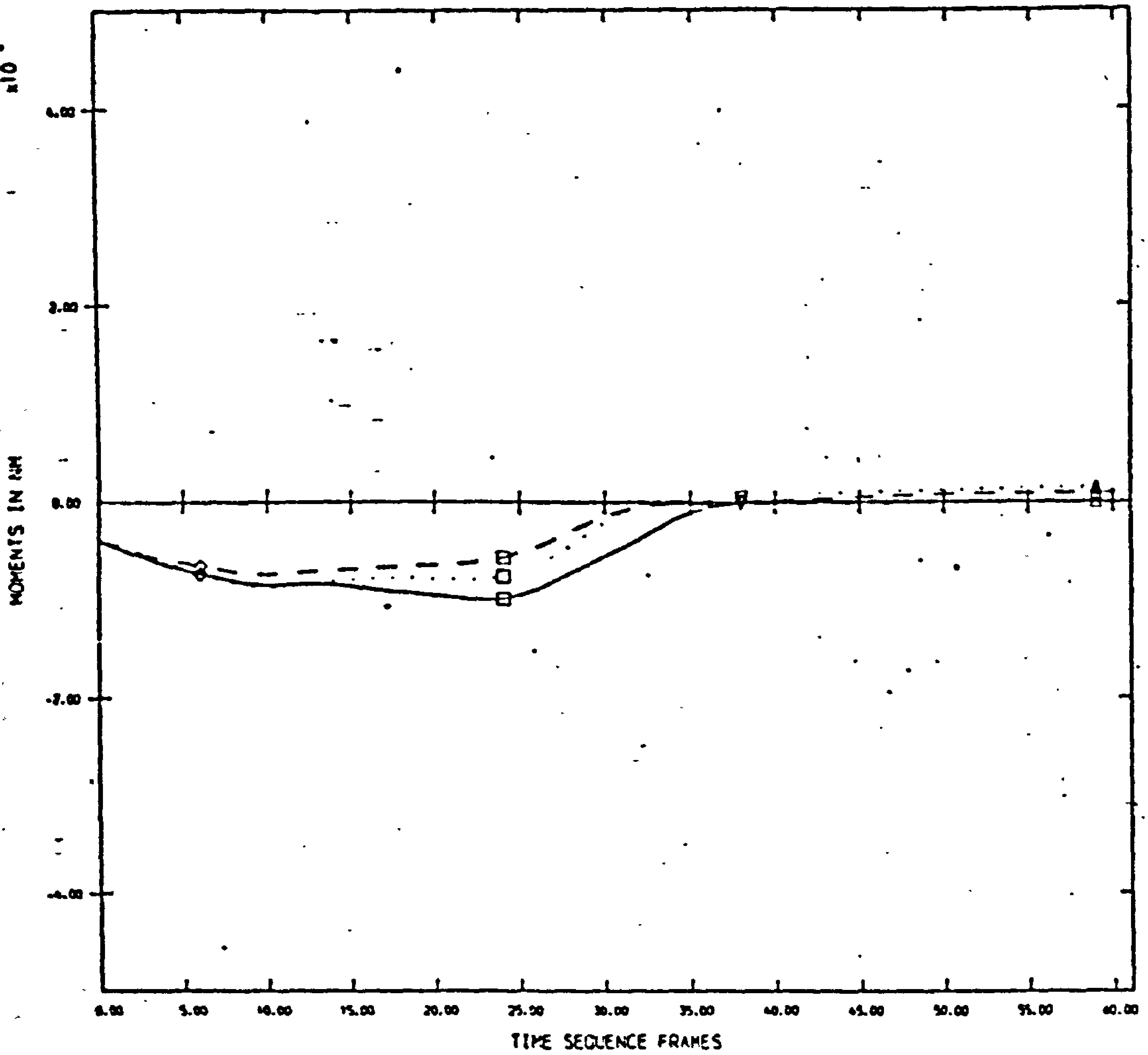
S3/L/FULO



ANKLE.KNEE. HIP. CORONAL PLANE

LEFT HEEL STRIKE	△	CONTINUOUS	ANKLE
LEFT TOE OFF	▽	DASHED	KNEE
RIGHT HEELSTRIKE	□	DOTTED	HIP
RIGHT TOE OFF	◇		

S4/L/FULO



ANKLE.KNEE. HIP. CORONAL PLANE

LEFT HEEL STRIKE △

LEFT TOE OFF ▽

RIGHT HEELSTRIKE □

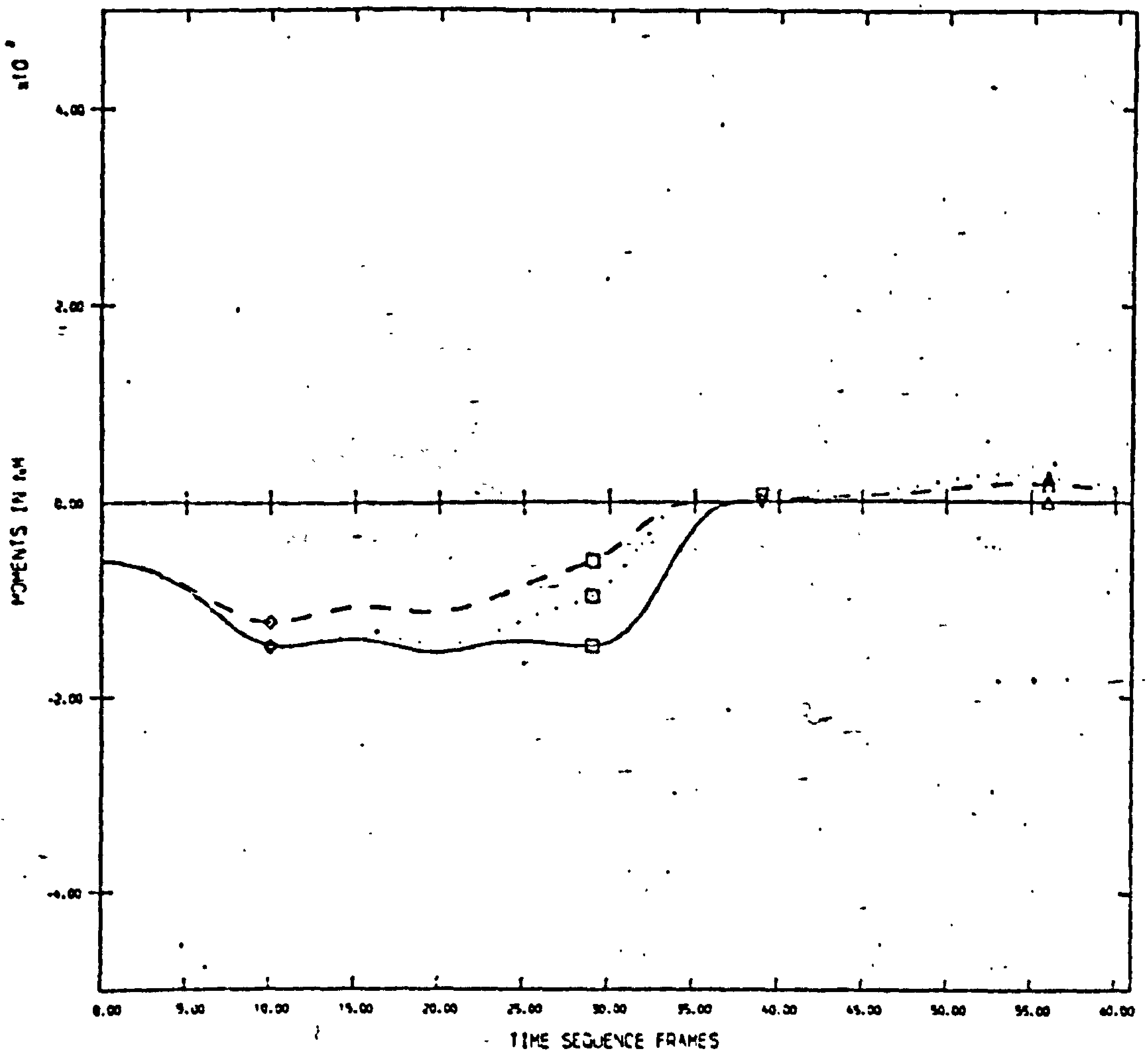
RIGHT TOE OFF ◇

CONTINUOUS ANKLE

DASHED KNEE

DOTTED HIP

S5/L/FULO



ANKLE, KNEE, HIP. CORONAL PLANE

LEFT HEEL STRIKE △

LEFT TOE OFF ▽

RIGHT HEELSTRIKE □

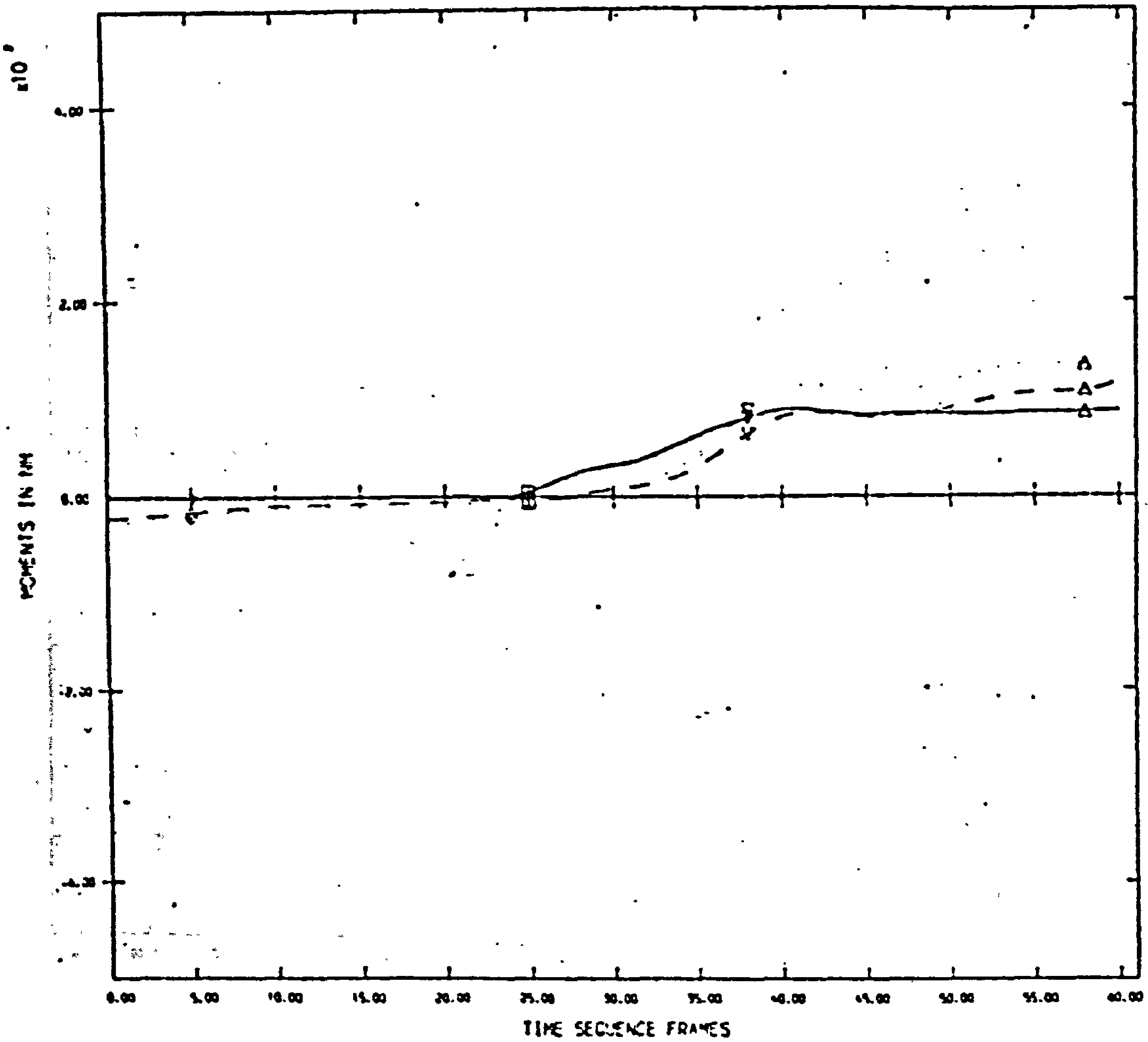
RIGHT TOE OFF ◇

CONTINUOUS ANKLE

DASHED KNEE

DOTTED HIP

S1/R/FULO

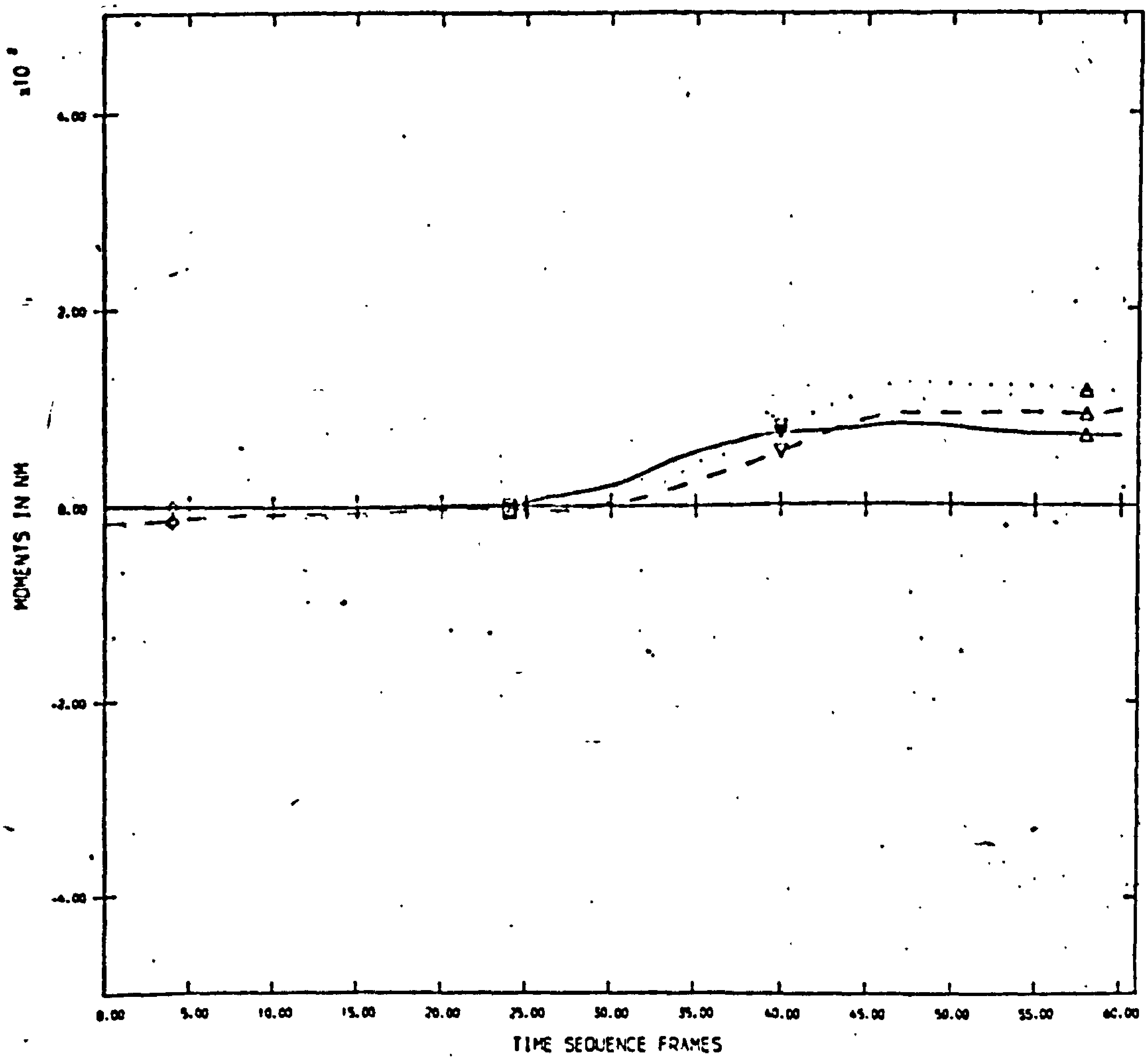


ANKLE, KNEE, HIP, CORONAL PLANE

LEFT HEEL STRIKE △
LEFT TOE OFF ▽
RIGHT HEELSTRIKE □
RIGHT TOE OFF ◇

CONTINUOUS ANKLE
DASHED KNEE
DOTTED HIP

S2/R/FULO



ANKLE,KNEE, HIP. CORONAL PLANE

LEFT HEEL STRIKE △

LEFT TOE OFF ▽

RIGHT HEELSTRIKE □

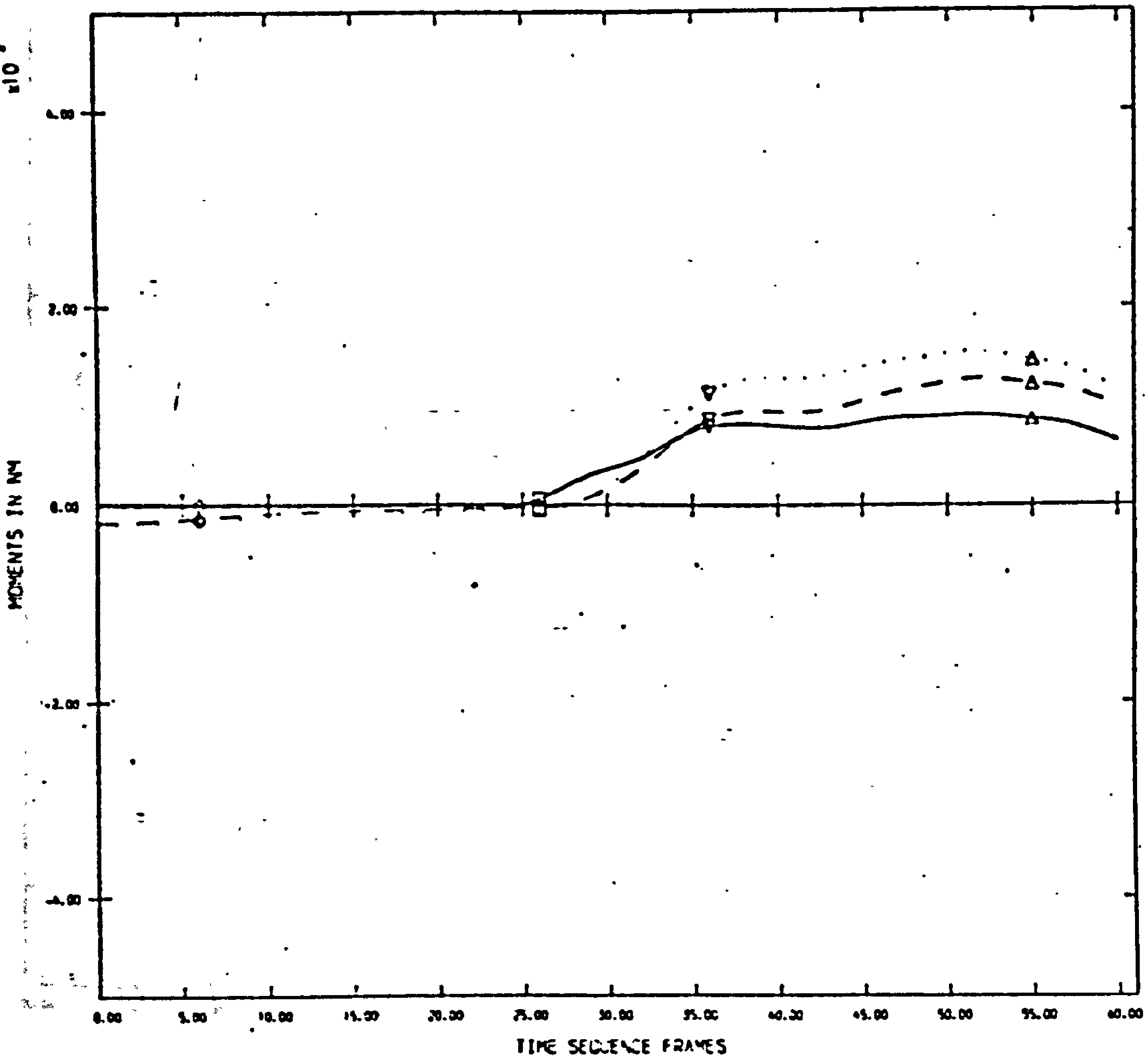
RIGHT TOE OFF ◇

CONTINUOUS ANKLE

DASHED KNEE

DOTTED HIP

S3/R/FULO



ANKLE, KNEE, HIP. CORONAL PLANE

LEFT HEEL STRIKE △

LEFT TOE OFF ▽

RIGHT HEELSTRIKE □

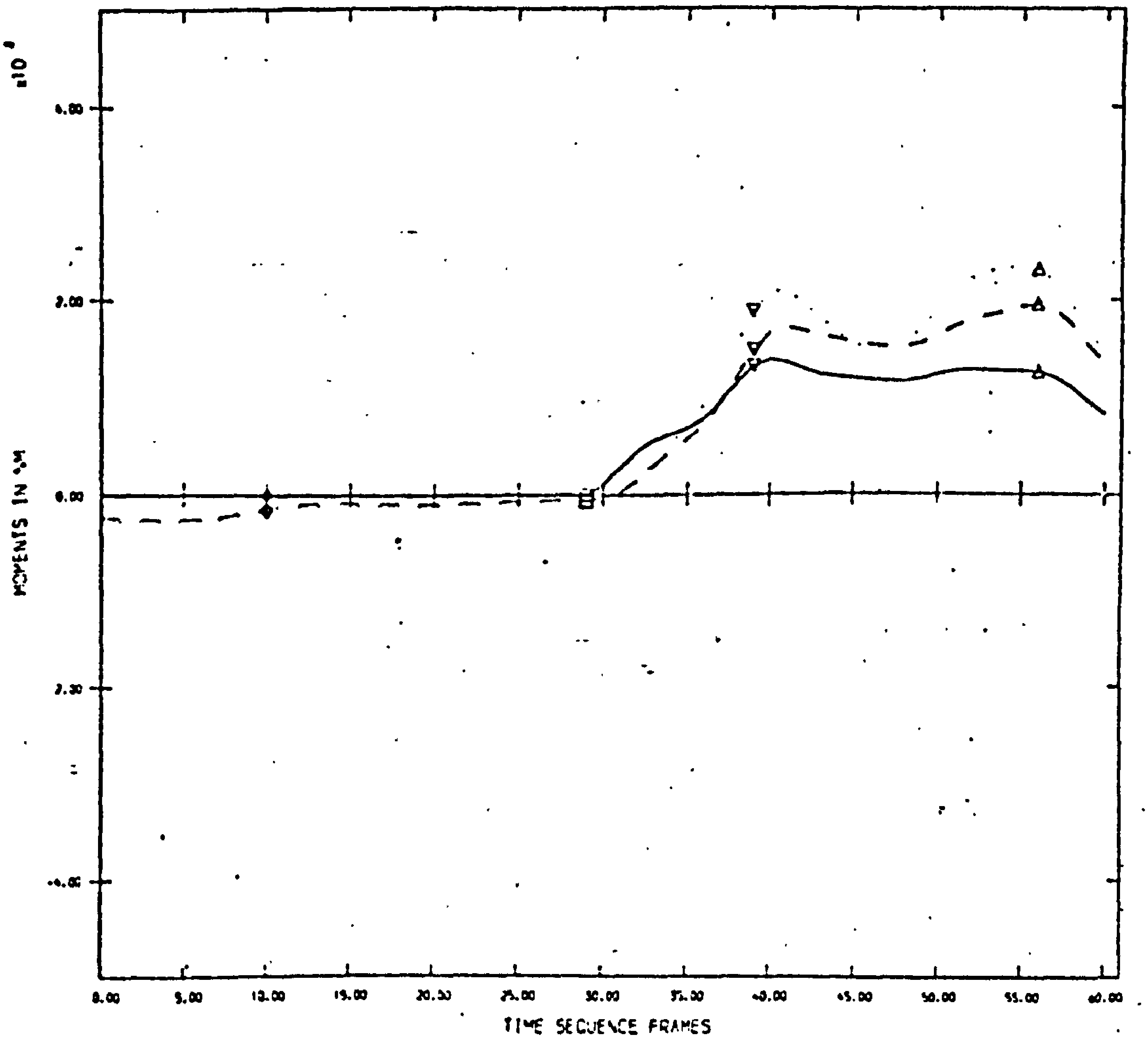
RIGHT TOE OFF ◇

CONTINUOUS ANKLE

DASHED KNEE

DOTTED HIP

S5/R/FULO

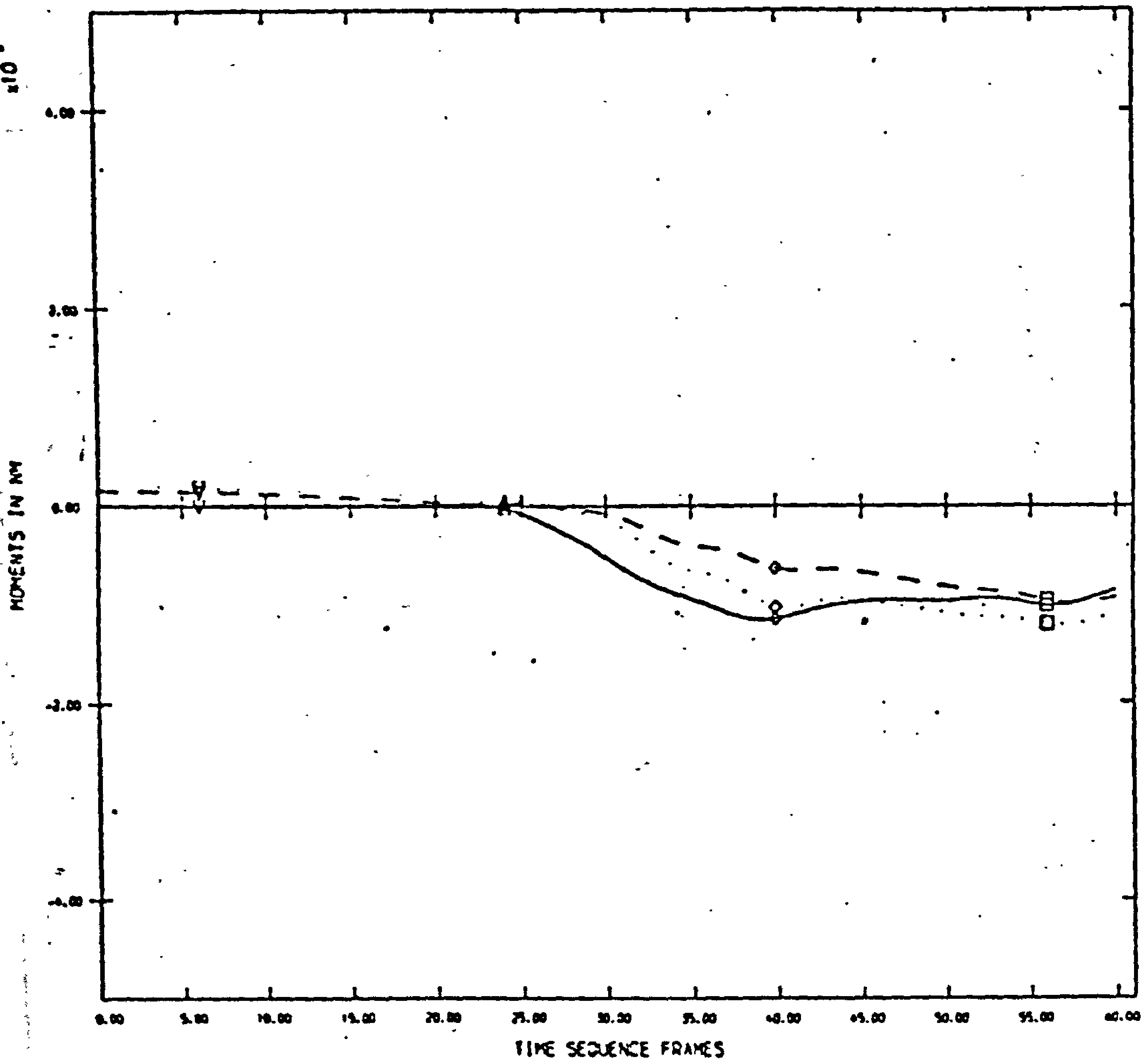


ANKLE.KNEE. HIP. CORONAL PLANE

LEFT HEEL STRIKE △
LEFT TOE OFF ▽
RIGHT HEELSTRIKE □
RIGHT TOE OFF ◇

CONTINUOUS ANKLE
DASHED KNEE
DOTTED HIP

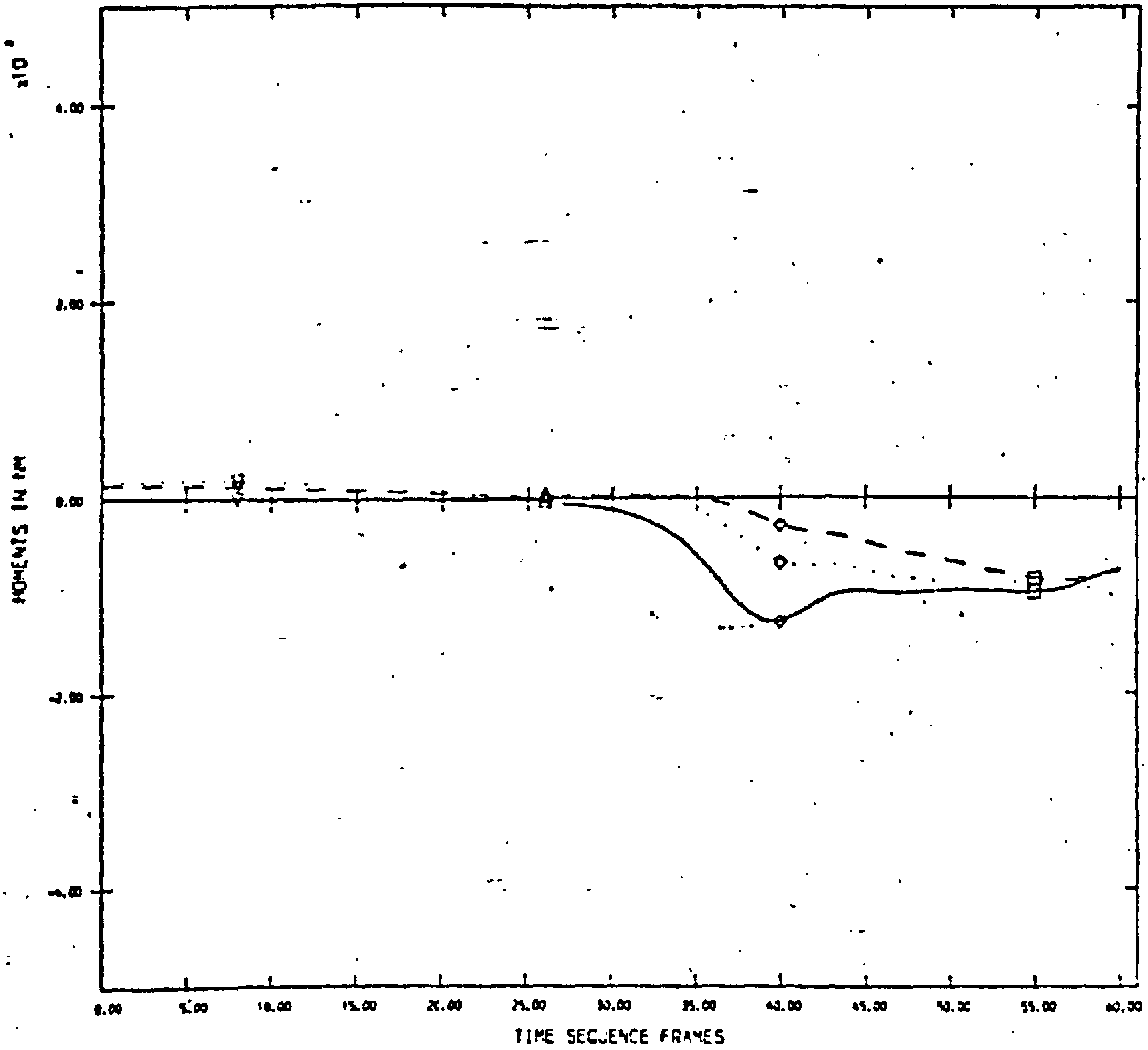
S1/L/BDTO



ANKLE.KNEE. HIP. CORONAL PLANE

LEFT HEEL STRIKE	△	CONTINUOUS	ANKLE
LEFT TOE OFF	▽	DASHED	KNEE
RIGHT HEELSTRIKE	□	DOTTED	HIP
RIGHT TOE OFF	◇		

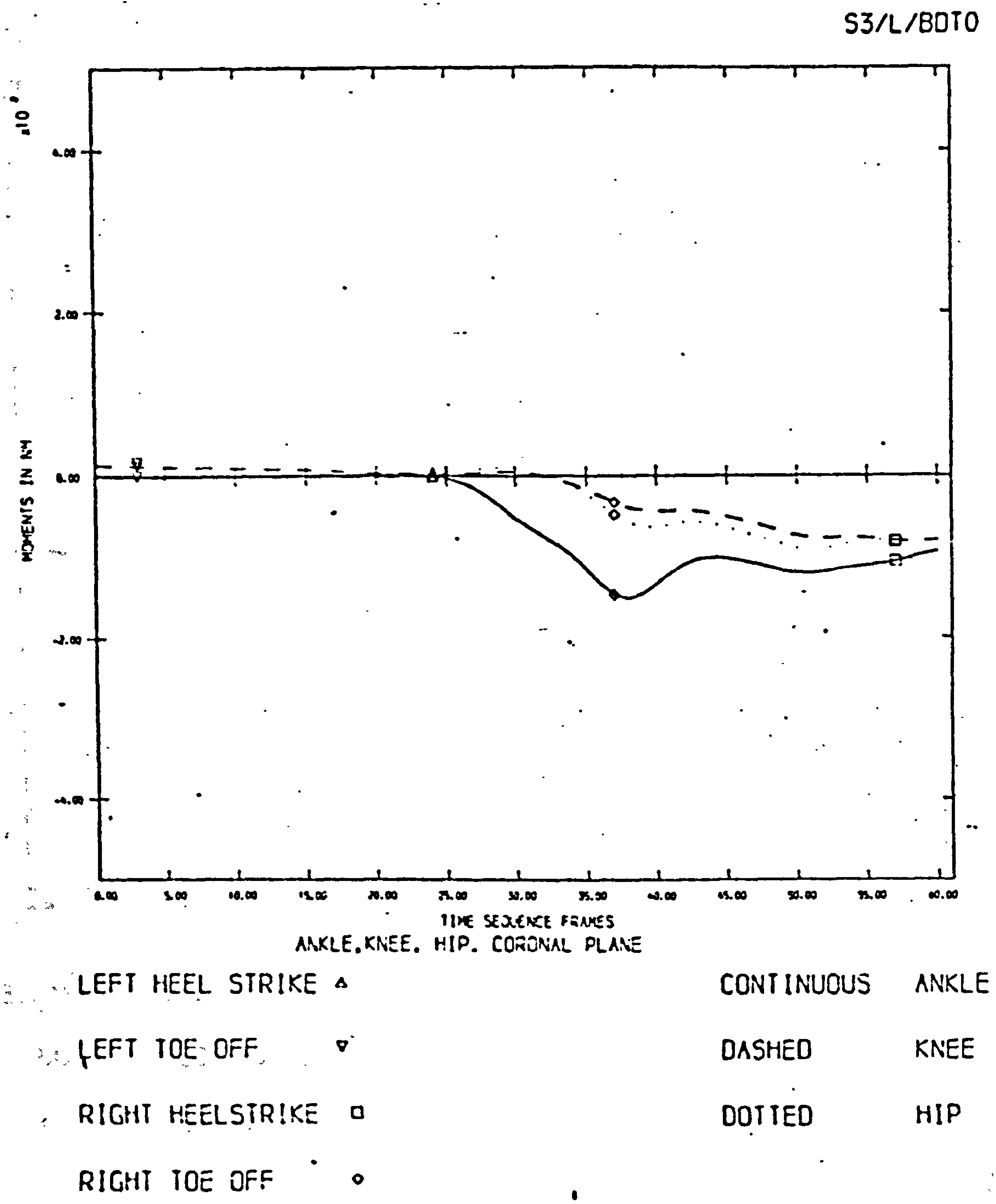
S2/L/BDTO



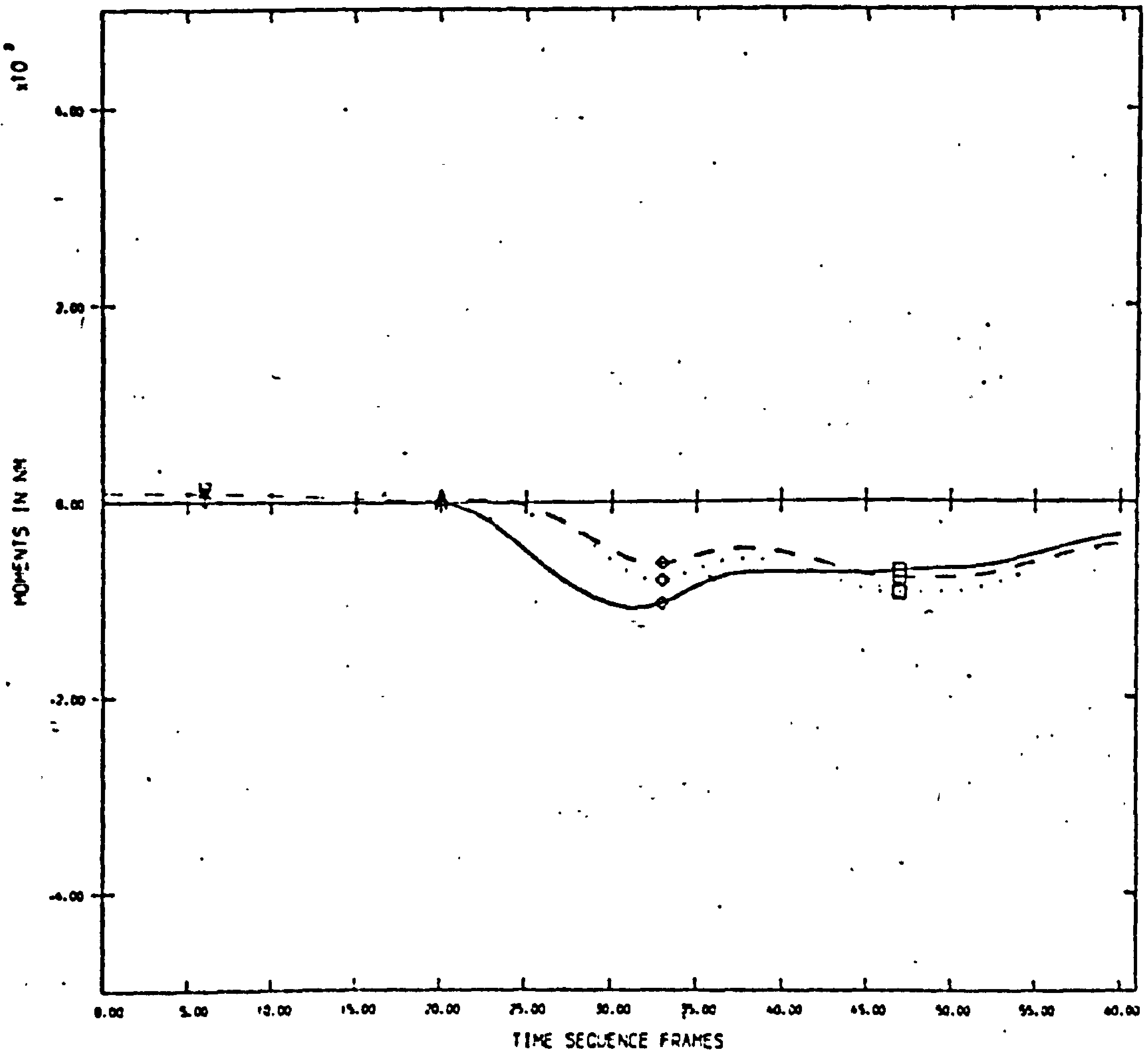
ANKLE.KNEE, HIP, CORONAL PLANE

LEFT HEEL STRIKE △
LEFT TOE OFF ▽
RIGHT HEELSTRIKE □
RIGHT TOE OFF ◇

CONTINUOUS ANKLE
DASHED KNEE
DOTTED HIP


S3/L/BDTO
x10
4.00
2.00
0.00
-2.00
-4.00
MOMENTS IN NM
0.00
5.00
10.00
15.00
20.00
25.00
30.00
35.00
40.00
45.00
50.00
55.00
60.00
TIME SEQUENCE FRAMES
ANKLE, KNEE, HIP. CORONAL PLANE
LEFT HEEL STRIKE △
LEFT TOE OFF ▽
RIGHT HEELSTRIKE □
RIGHT TOE OFF ◇
CONTINUOUS ANKLE
DASHED KNEE
DOTTED HIP

S4/L/BDTO



ANKLE.KNEE. HIP. CORONAL PLANE

LEFT HEEL STRIKE △

LEFT TOE OFF ▽

RIGHT HEELSTRIKE □

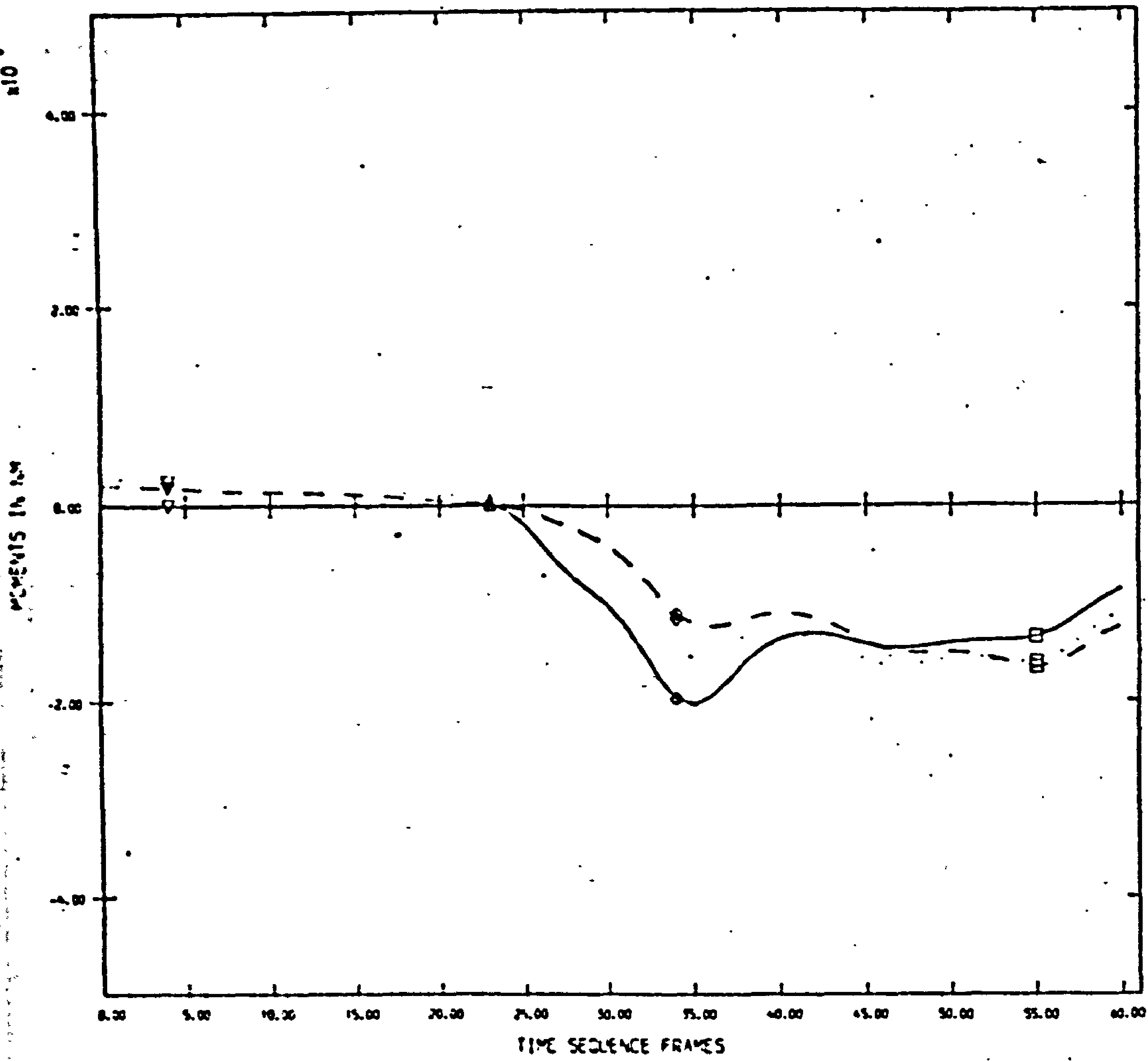
RIGHT TOE OFF ◇

CONTINUOUS ANKLE

DASHED KNEE

DOTTED HIP

S5/L/BDTO

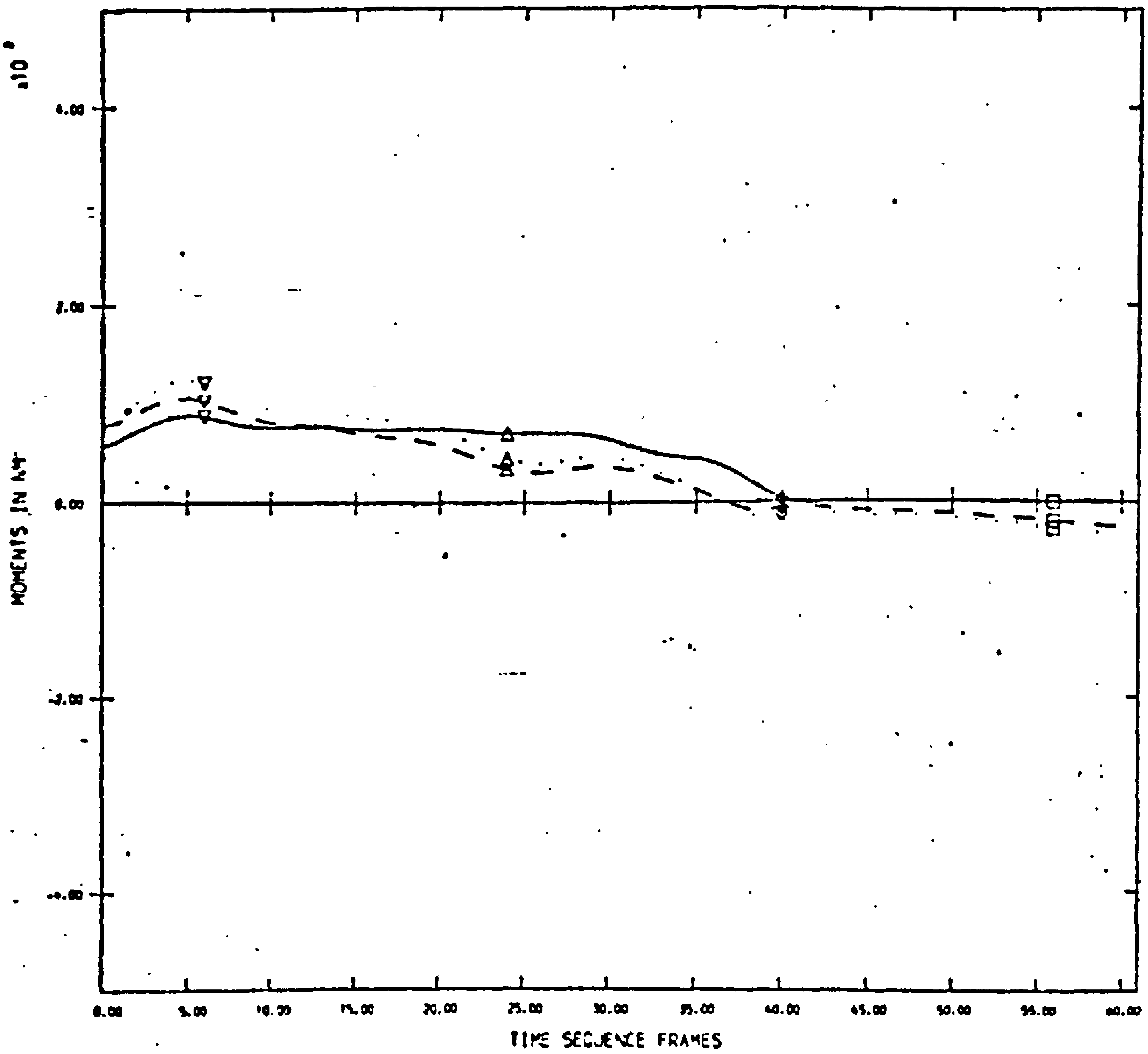


ANKLE.KNEE. HIP. CORONAL PLANE

LEFT HEEL STRIKE △
LEFT TOE OFF ▽
RIGHT HEELSTRIKE □
RIGHT TOE OFF ◇

CONTINUOUS ANKLE
DASHED KNEE
DOTTED HIP

S1/R/BDTO

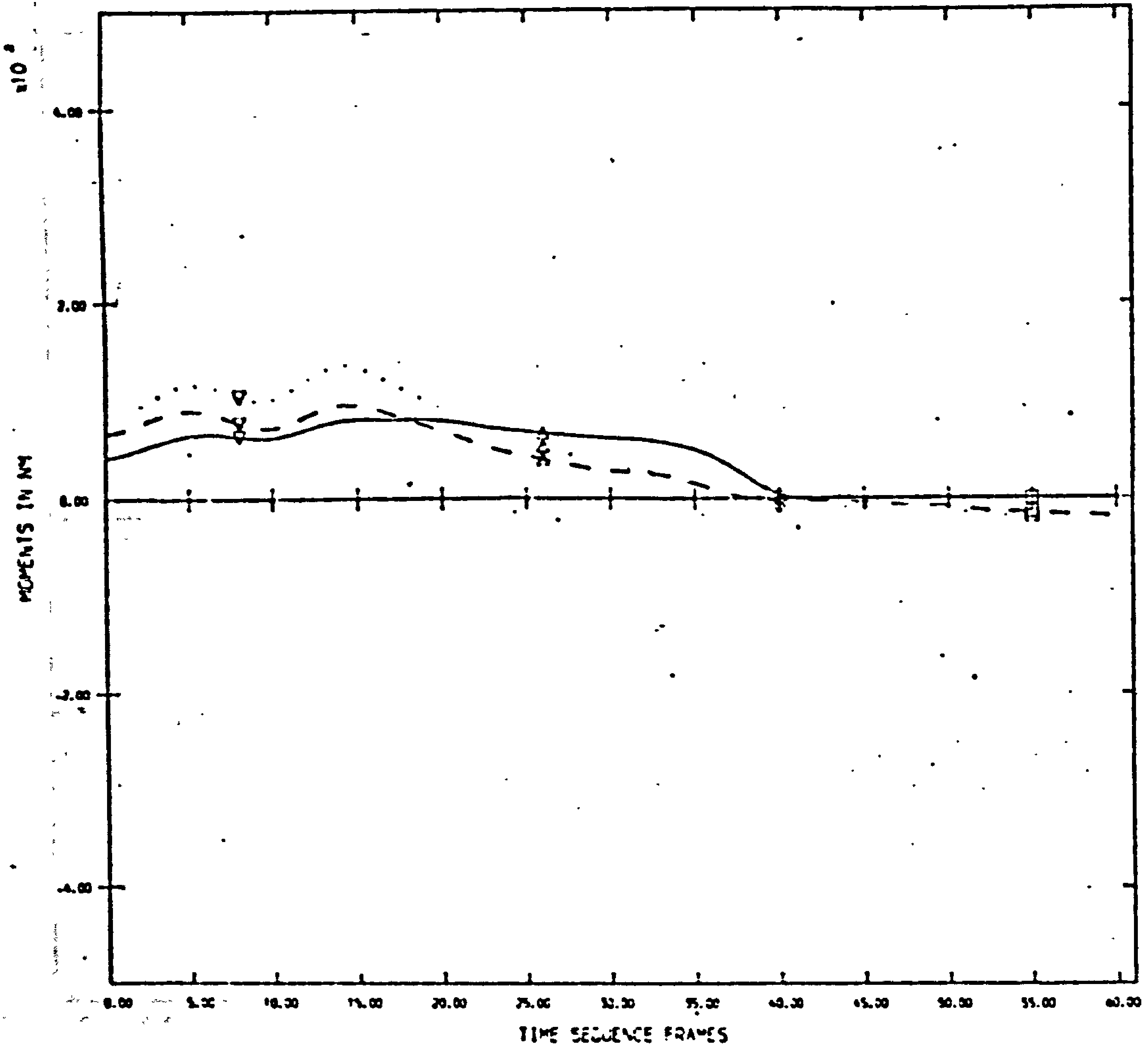


ANKLE,KNEE, HIP. CORONAL PLANE

LEFT HEEL STRIKE △
LEFT TOE OFF ▽
RIGHT HEELSTRIKE □
RIGHT TOE OFF ◇

CONTINUOUS ANKLE
DASHED KNEE
DOTTED HIP

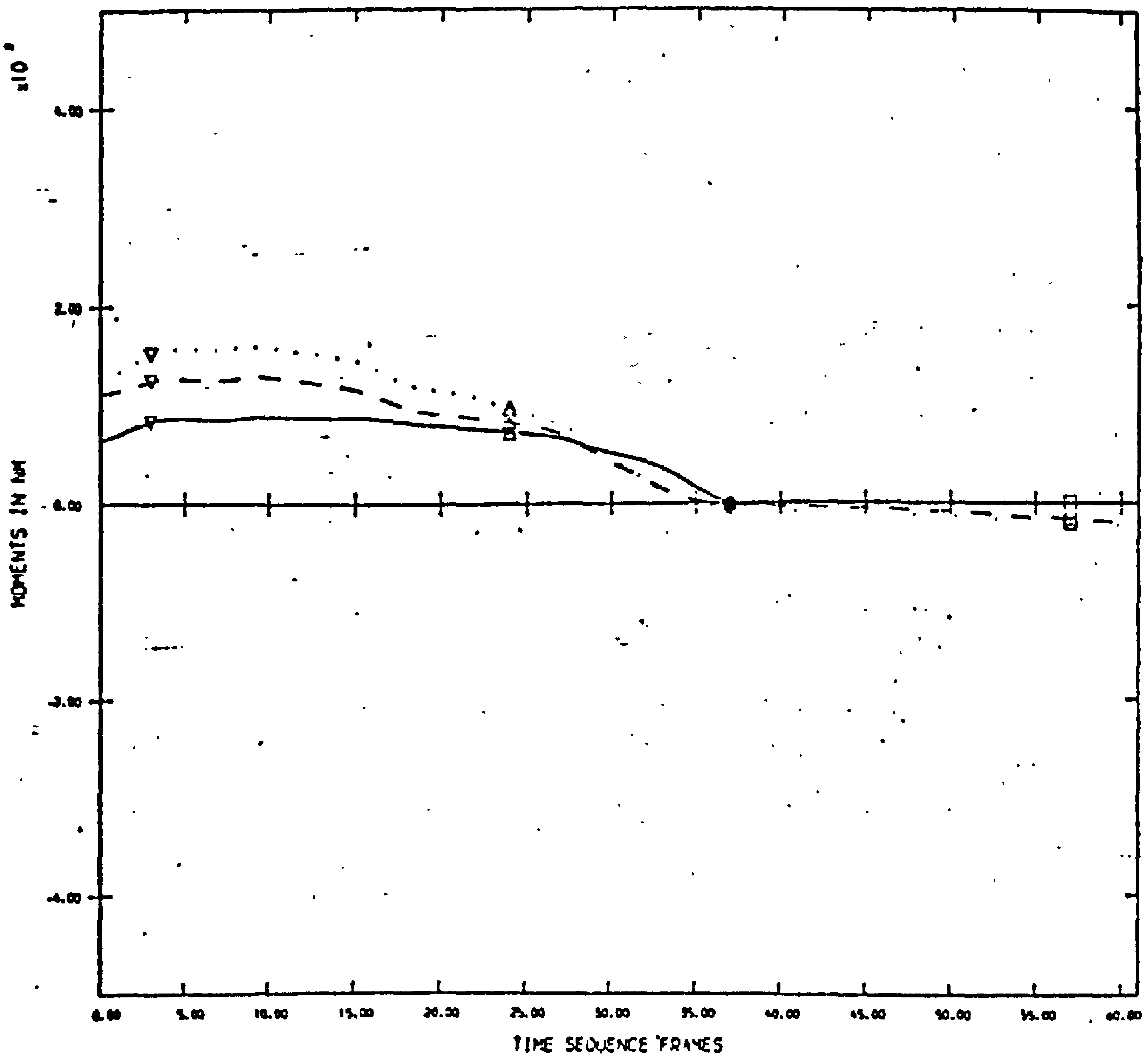
S2/R/BDTO



ANKLE,KNEE, HIP, CORONAL PLANE

LEFT HEEL STRIKE	△	CONTINUOUS	ANKLE
LEFT TOE OFF	▽	DASHED	KNEE
RIGHT HEELSTRIKE	□	DOTTED	HIP
RIGHT TOE OFF	◇		

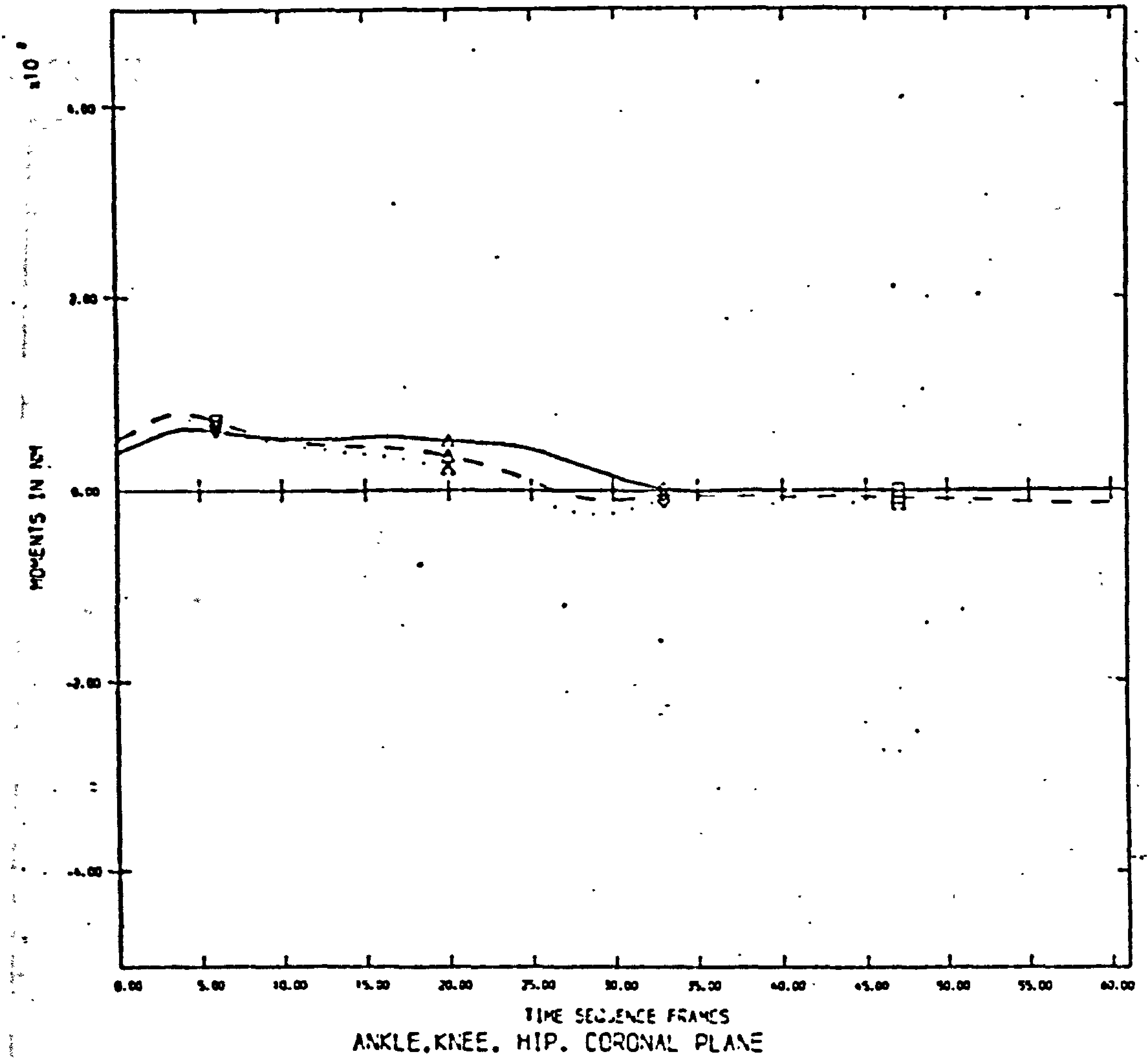
S3/R/BDTO



ANKLE.KNEE. HIP. CORONAL PLANE

LEFT HEEL STRIKE	△	CONTINUOUS	ANKLE
LEFT TOE OFF	▽	DASHED	KNEE
RIGHT HEELSTRIKE	□	DOTTED	HIP
RIGHT TOE OFF	◇		

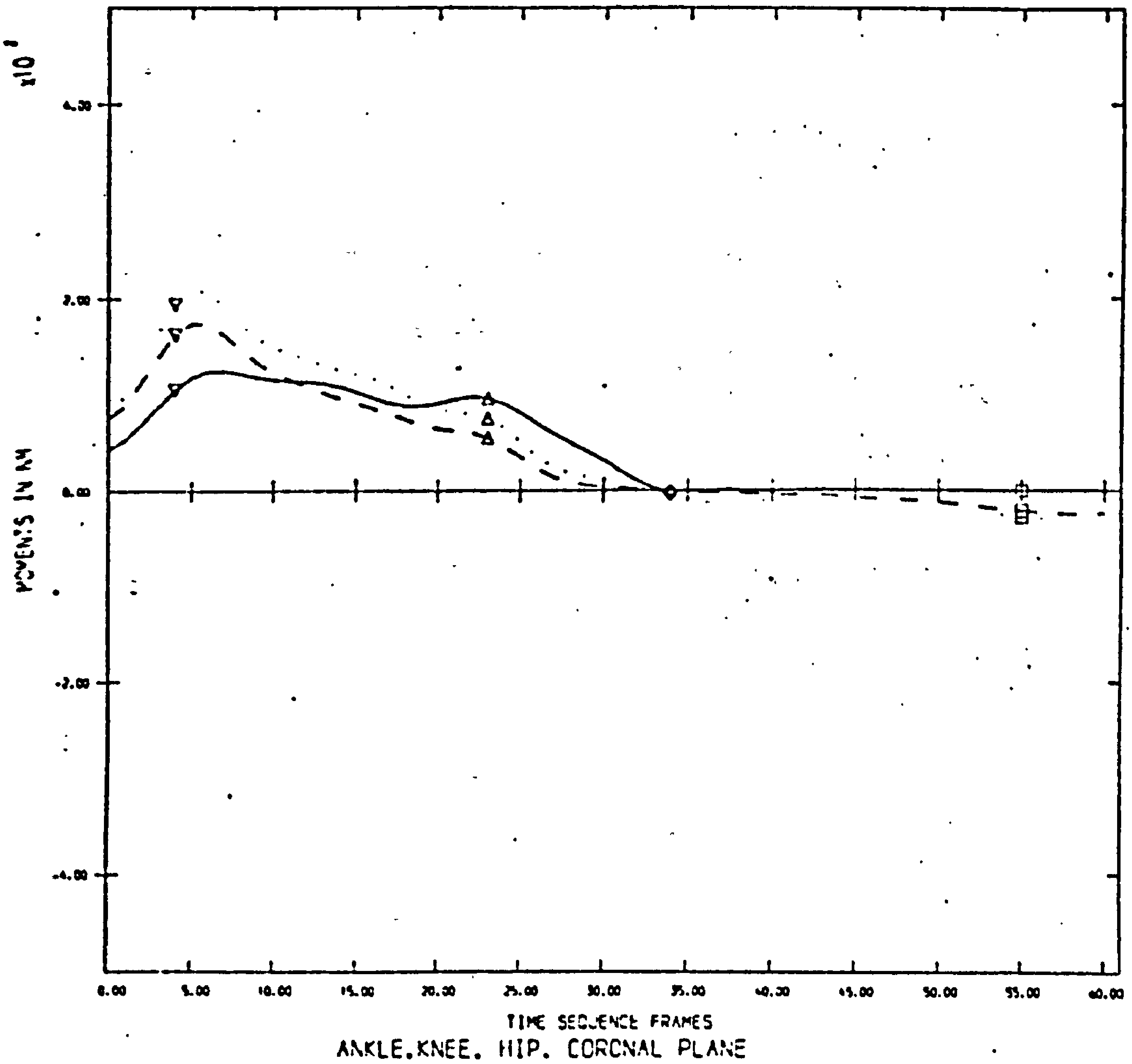
S4/R/BDTO



ANKLE.KNEE. HIP. CORONAL PLANE

LEFT HEEL STRIKE	△	CONTINUOUS	ANKLE
LEFT TOE OFF	▽	DASHED	KNEE
RIGHT HEELSTRIKE	□	DOTTED	HIP
RIGHT TOE OFF	◇		

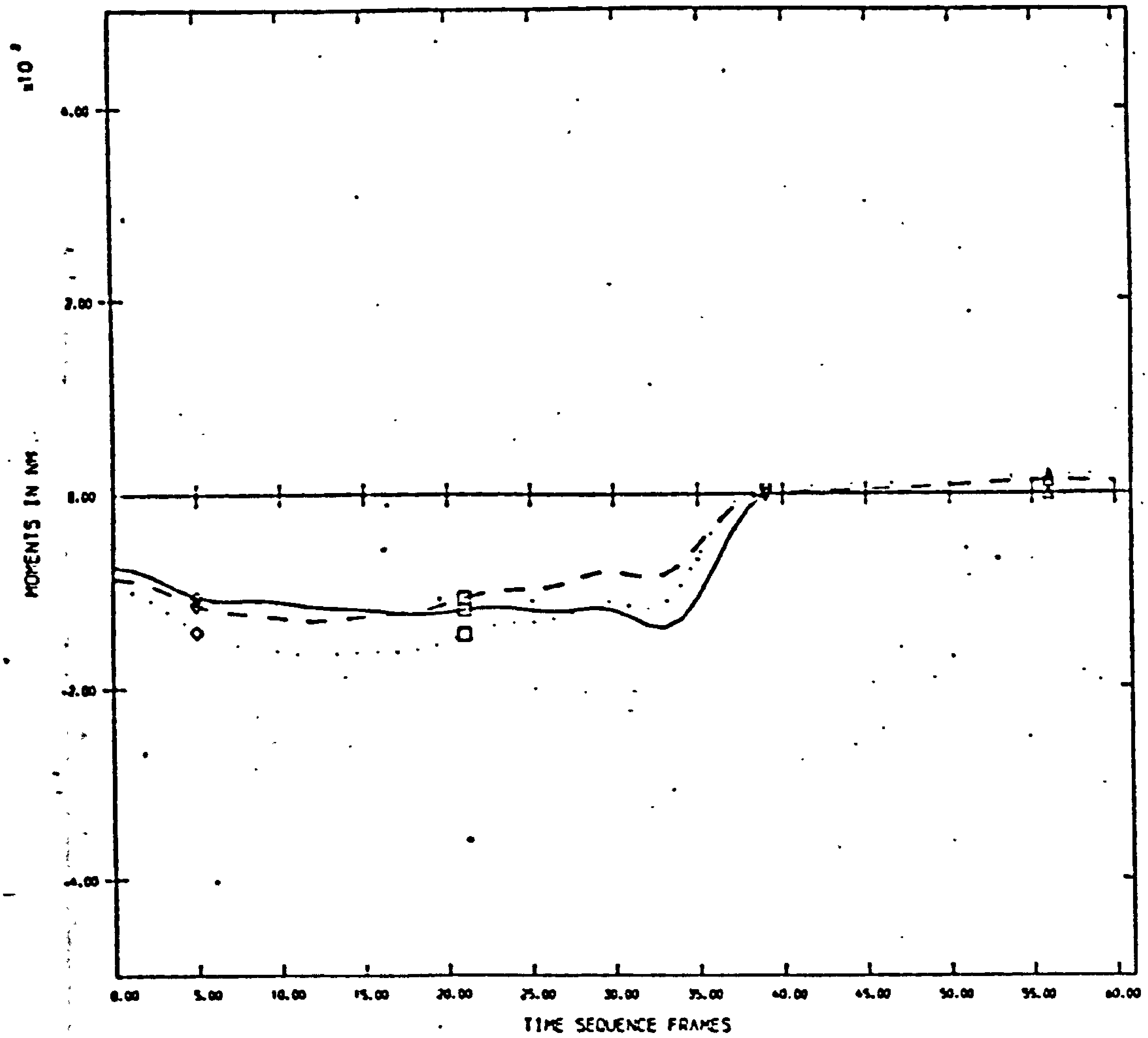
S5/R/BDTO



ANKLE.KNEE. HIP. CORONAL PLANE

LEFT HEEL STRIKE	△	CONTINUOUS	ANKLE
LEFT TOE OFF	▽	DASHED	KNEE
RIGHT HEELSTRIKE	□	DOTTED	HIP
RIGHT TOE OFF	◇		

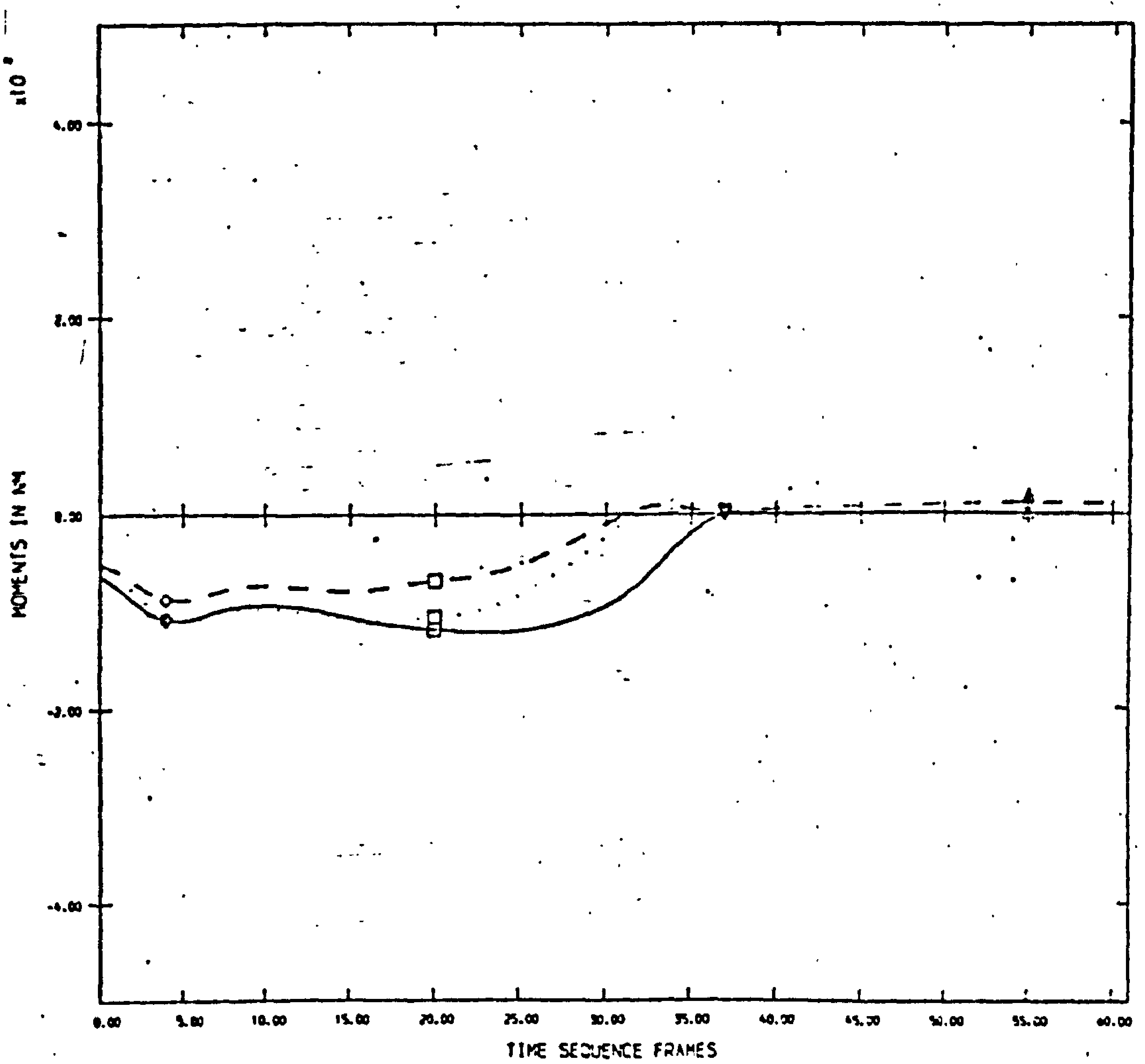
S1/L/FUL1



ANKLE, KNEE, HIP, CORONAL PLANE

LEFT HEEL STRIKE	△	CONTINUOUS	ANKLE
LEFT TOE OFF	▽	DASHED	KNEE
RIGHT HEELSTRIKE	□	DOTTED	HIP
RIGHT TOE OFF	◇		

S2/L/FUL1



ANKLE.KNEE. HIP. CORONAL PLANE

LEFT HEEL STRIKE △

LEFT TOE OFF ▽

RIGHT HEELSTRIKE □

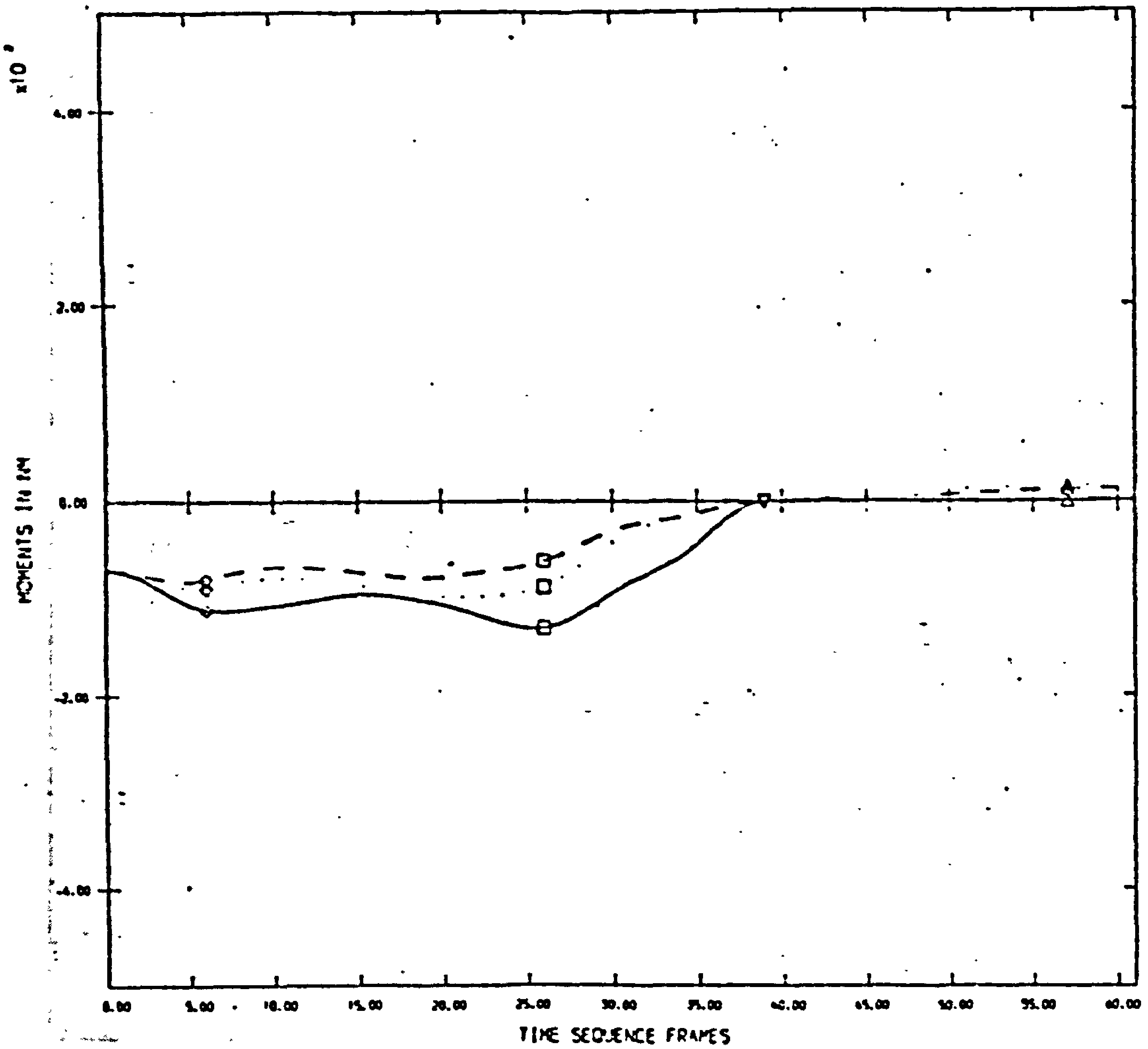
RIGHT TOE OFF ◇

CONTINUOUS ANKLE

DASHED KNEE

DOTTED HIP

S3/L/FUL1



ANKLE,KNEE, HIP, CORONAL PLANE

LEFT HEEL STRIKE △

LEFT TOE OFF ▽

RIGHT HEELSTRIKE □

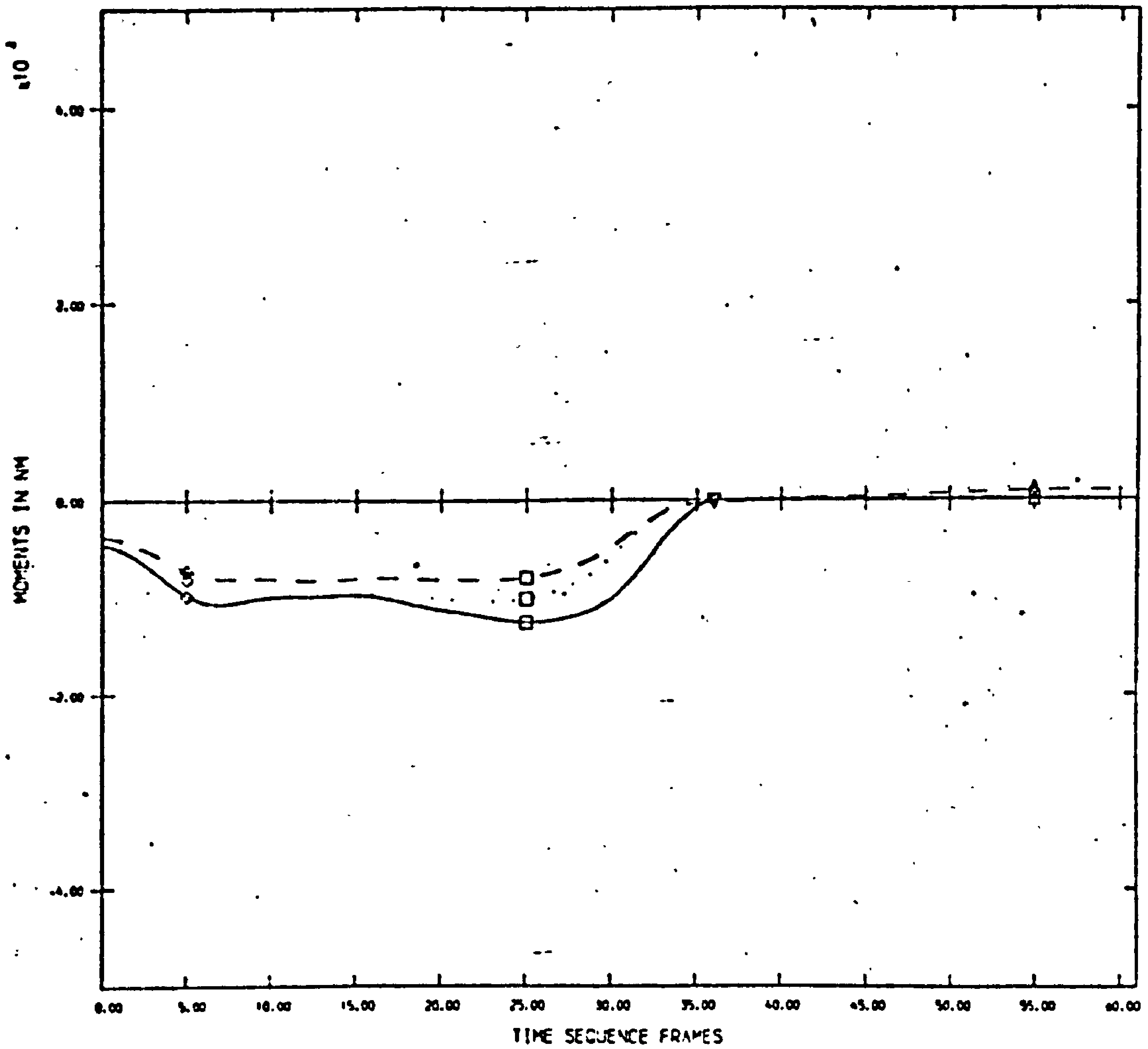
RIGHT TOE OFF ◇

CONTINUOUS ANKLE

DASHED KNEE

DOTTED HIP

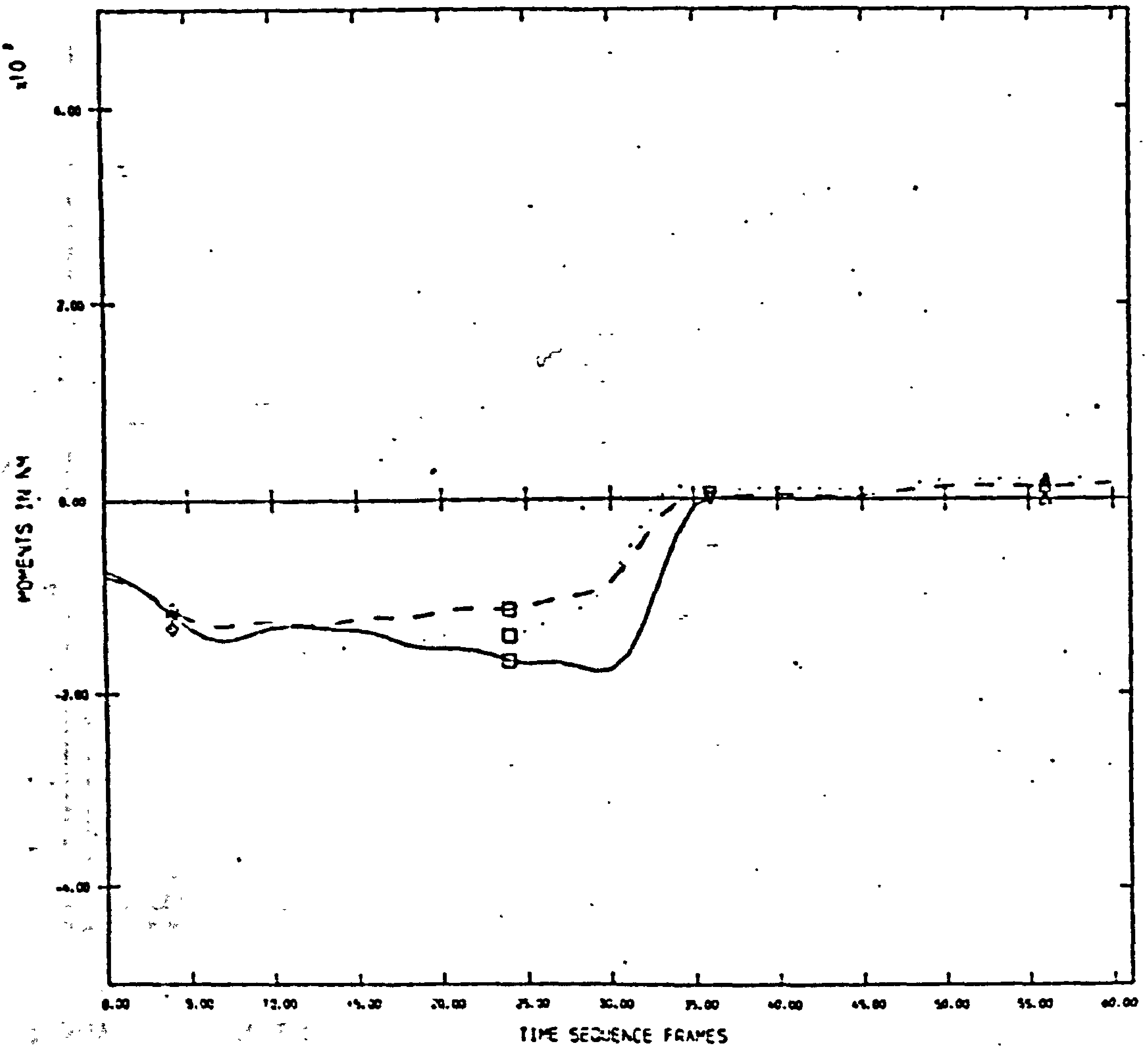
S4/L/FUL1



ANKLE.KNEE. HIP. CORONAL PLANE

LEFT HEEL STRIKE	△	CONTINUOUS	ANKLE
LEFT TOE OFF	▽	DASHED	KNEE
RIGHT HEELSTRIKE	□	DOTTED	HIP
RIGHT TOE OFF	◇		

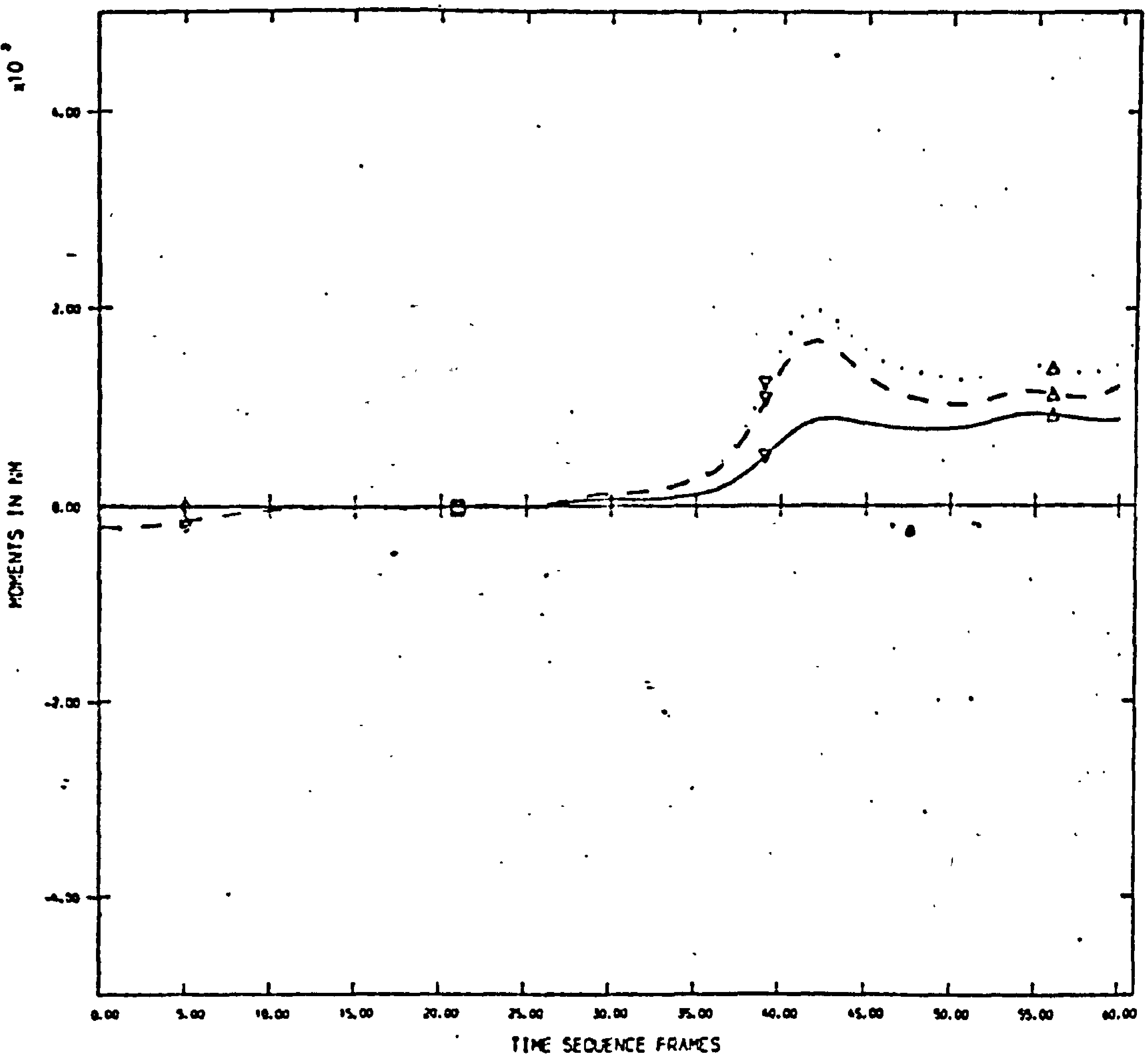
S5/L/FUL1



ANKLE,KNEE, HIP, CORONAL PLANE

LEFT HEEL STRIKE	△	CONTINUOUS	ANKLE
LEFT TOE OFF	▽	DASHED	KNEE
RIGHT HEELSTRIKE	□	DOTTED	HIP
RIGHT TOE OFF	◇		

S1/R/FUL1



ANKLE.KNEE. HIP. CORONAL PLANE

LEFT HEEL STRIKE △

LEFT TOE OFF ▽

RIGHT HEELSTRIKE □

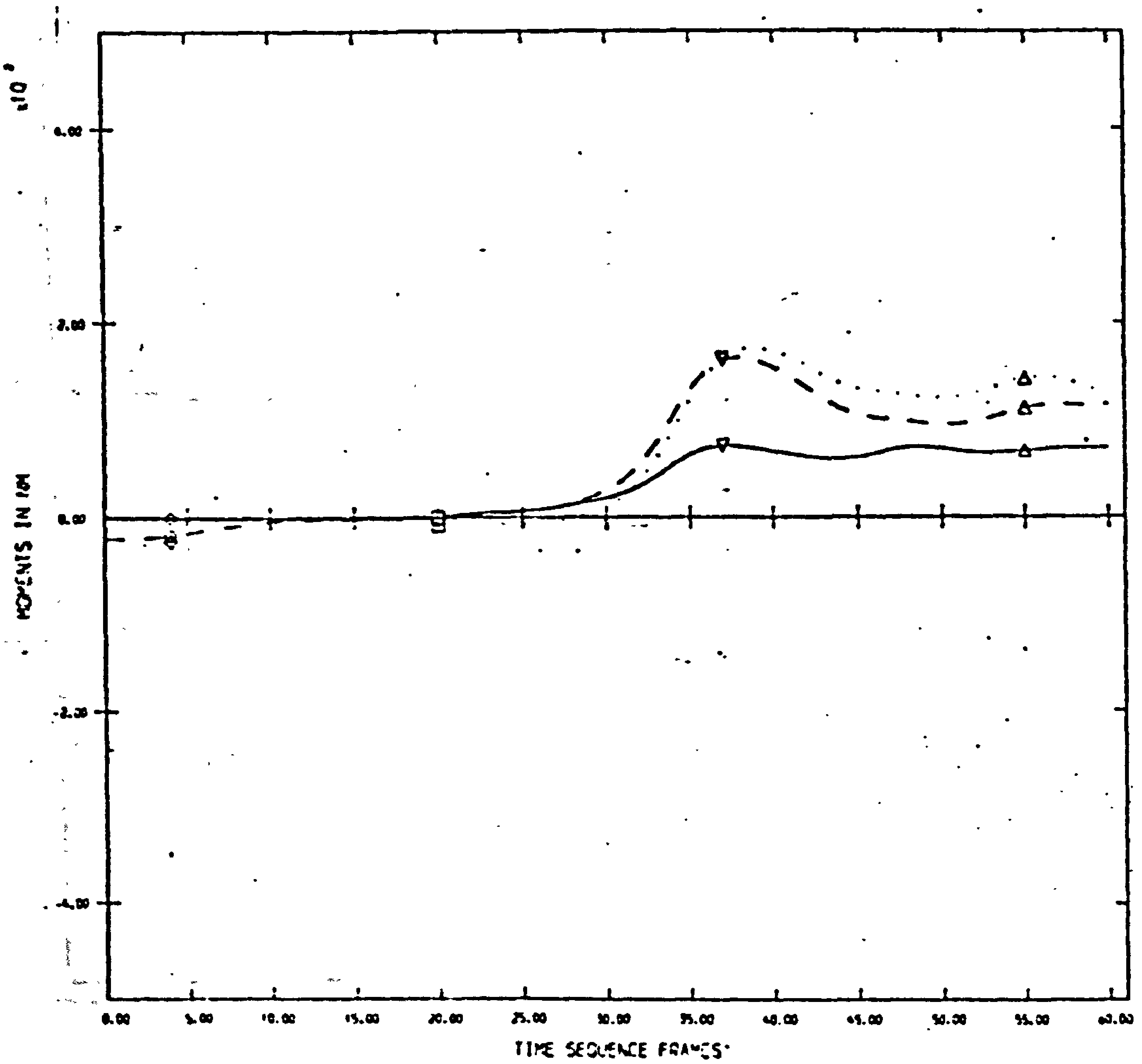
RIGHT TOE OFF ◇

CONTINUOUS ANKLE

DASHED KNEE

DOTTED HIP

S2/R/FUL1



ANKLE.KNEE. HIP. CORONAL PLANE

LEFT HEEL STRIKE △

LEFT TOE OFF ▽

RIGHT HEELSTRIKE □

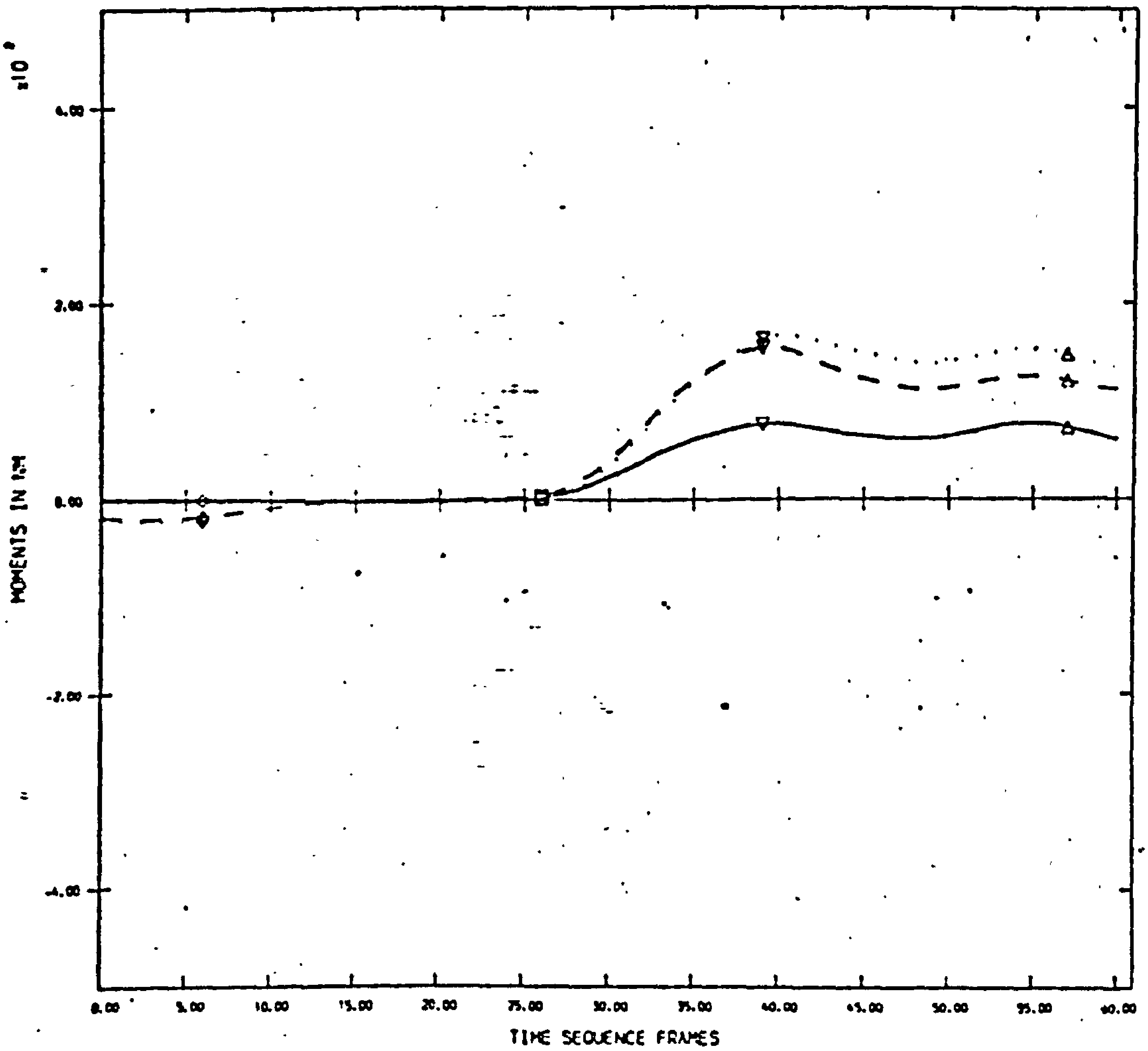
RIGHT TOE OFF ◇

CONTINUOUS ANKLE

DASHED KNEE

DOTTED HIP

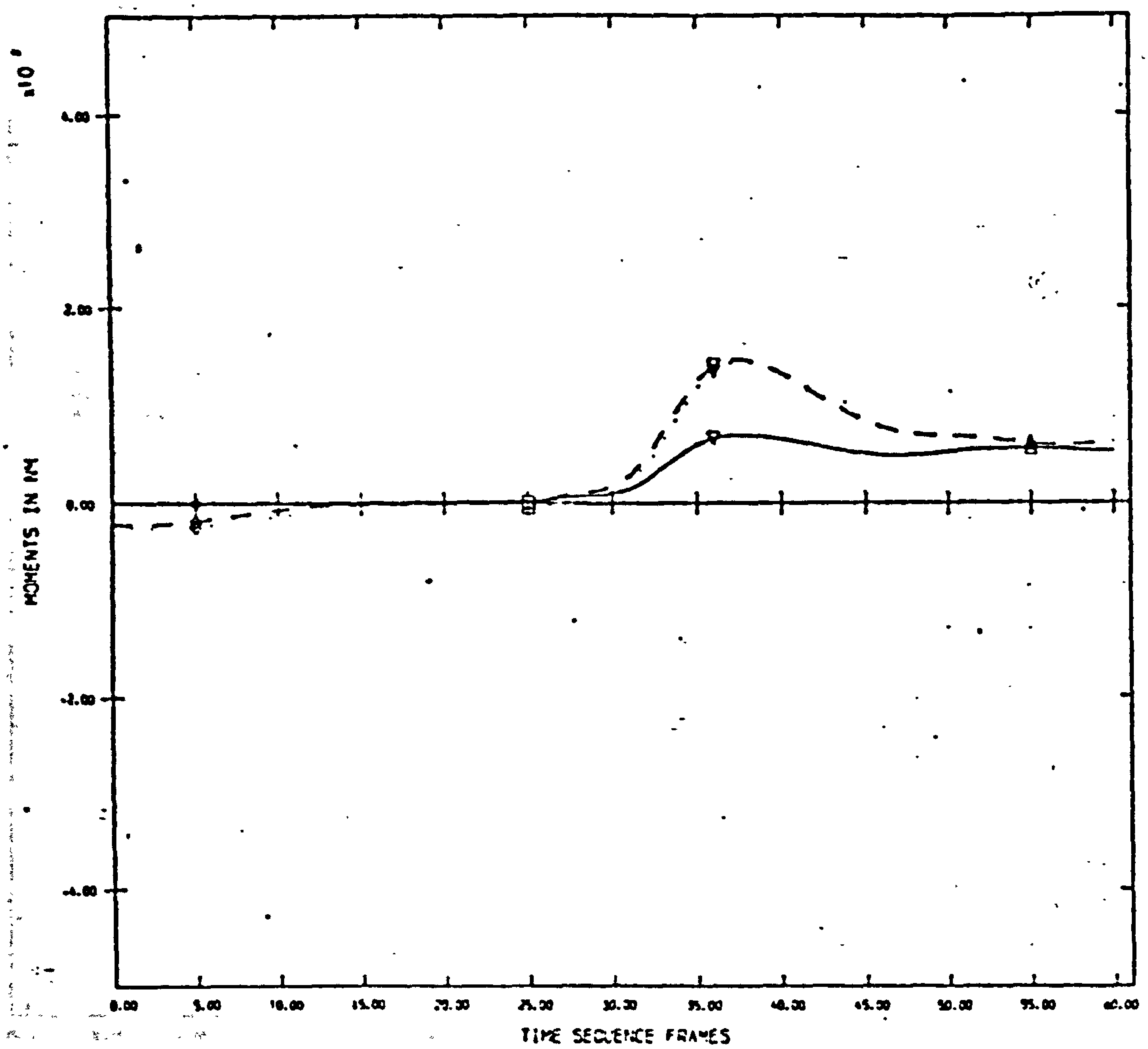
S3/R/FUL1



ANKLE,KNEE, HIP. CORONAL PLANE

LEFT HEEL STRIKE	△	CONTINUOUS	ANKLE
LEFT TOE OFF .	▽	DASHED	KNEE
RIGHT HEELSTRIKE	□	DOTTED	HIP
RIGHT TOE OFF	◇		

S4/R/FUL1

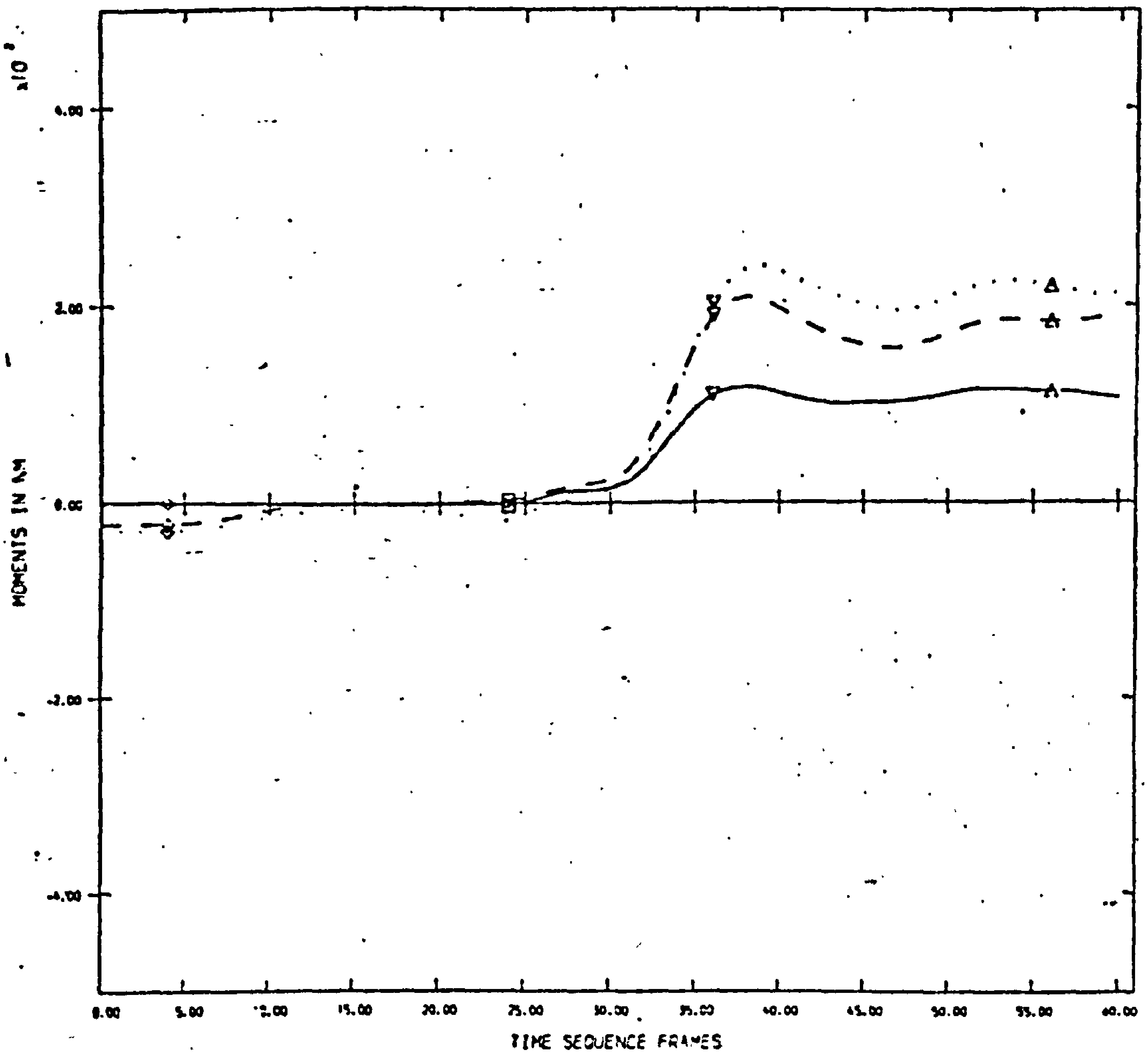


ANKLE.KNEE; HIP. CORONAL PLANE

LEFT HEEL STRIKE △
LEFT TOE OFF ▽
RIGHT HEELSTRIKE □
RIGHT TOE OFF ◇

CONTINUOUS ANKLE
DASHED KNEE
DOTTED HIP

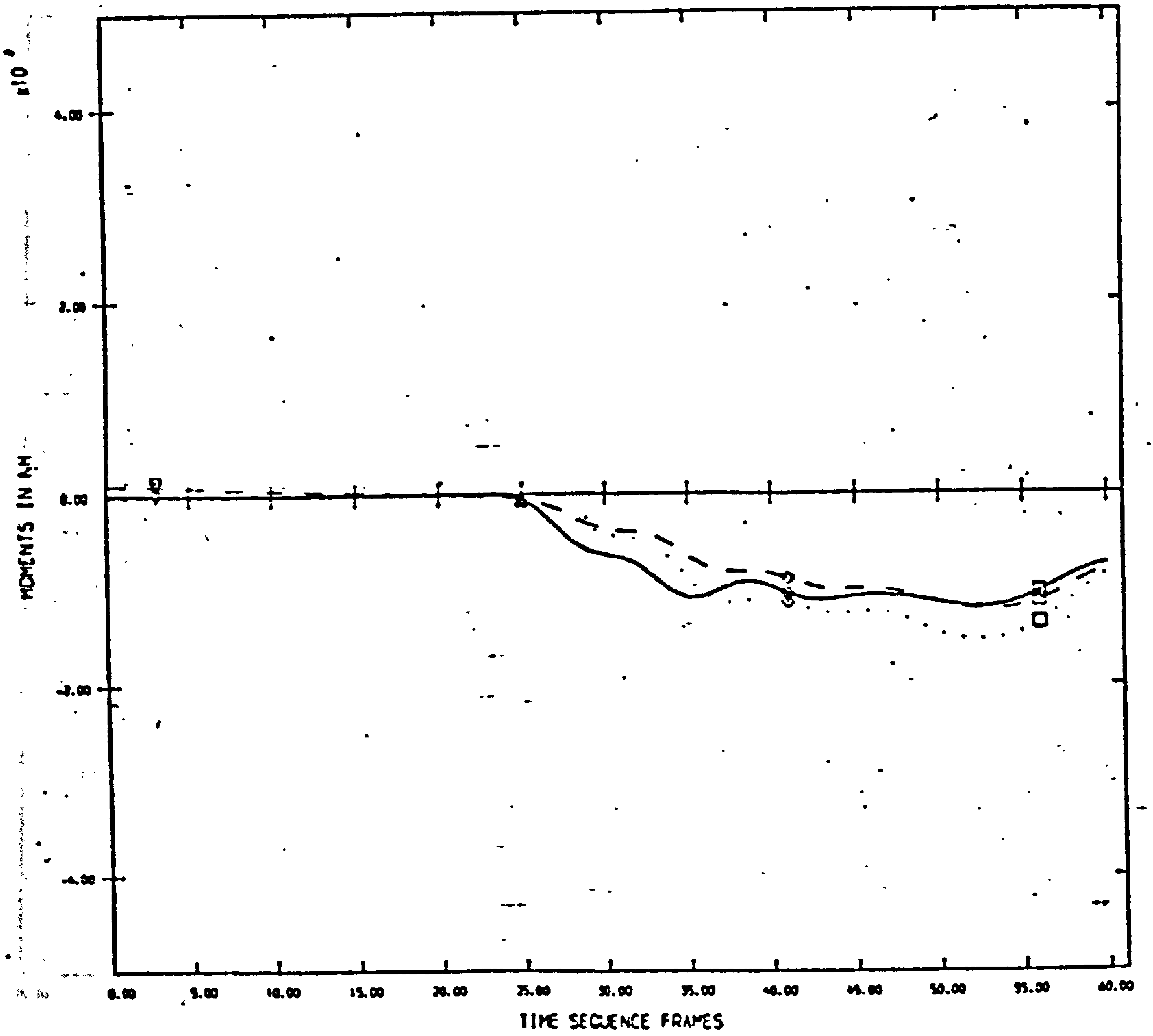
S5/R/FUL1



ANKLE.KNEE. HIP. CORONAL PLANE

LEFT HEEL STRIKE	△	CONTINUOUS	ANKLE
LEFT TOE OFF	▽	DASHED	KNEE
RIGHT HEELSTRIKE	□	DOTTED	HIP
RIGHT TOE OFF	◇		

S1/L/BDT1



ANKLE, KNEE, HIP. CORONAL PLANE

LEFT HEEL STRIKE △

LEFT TOE OFF ▽

RIGHT HEELSTRIKE □

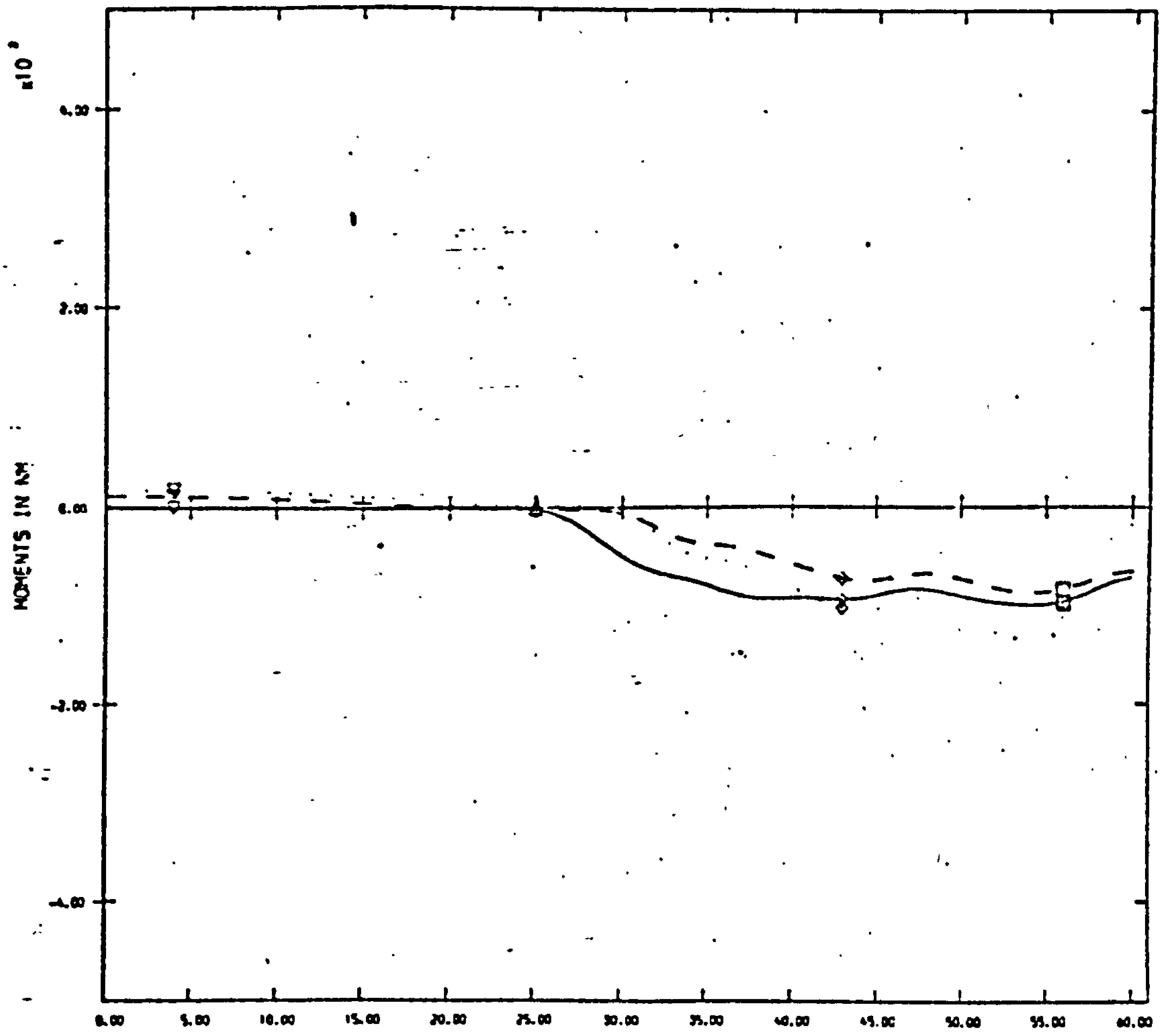
RIGHT TOE OFF ◇

CONTINUOUS ANKLE

DASHED KNEE

DOTTED HIP

S2/L/BDT1

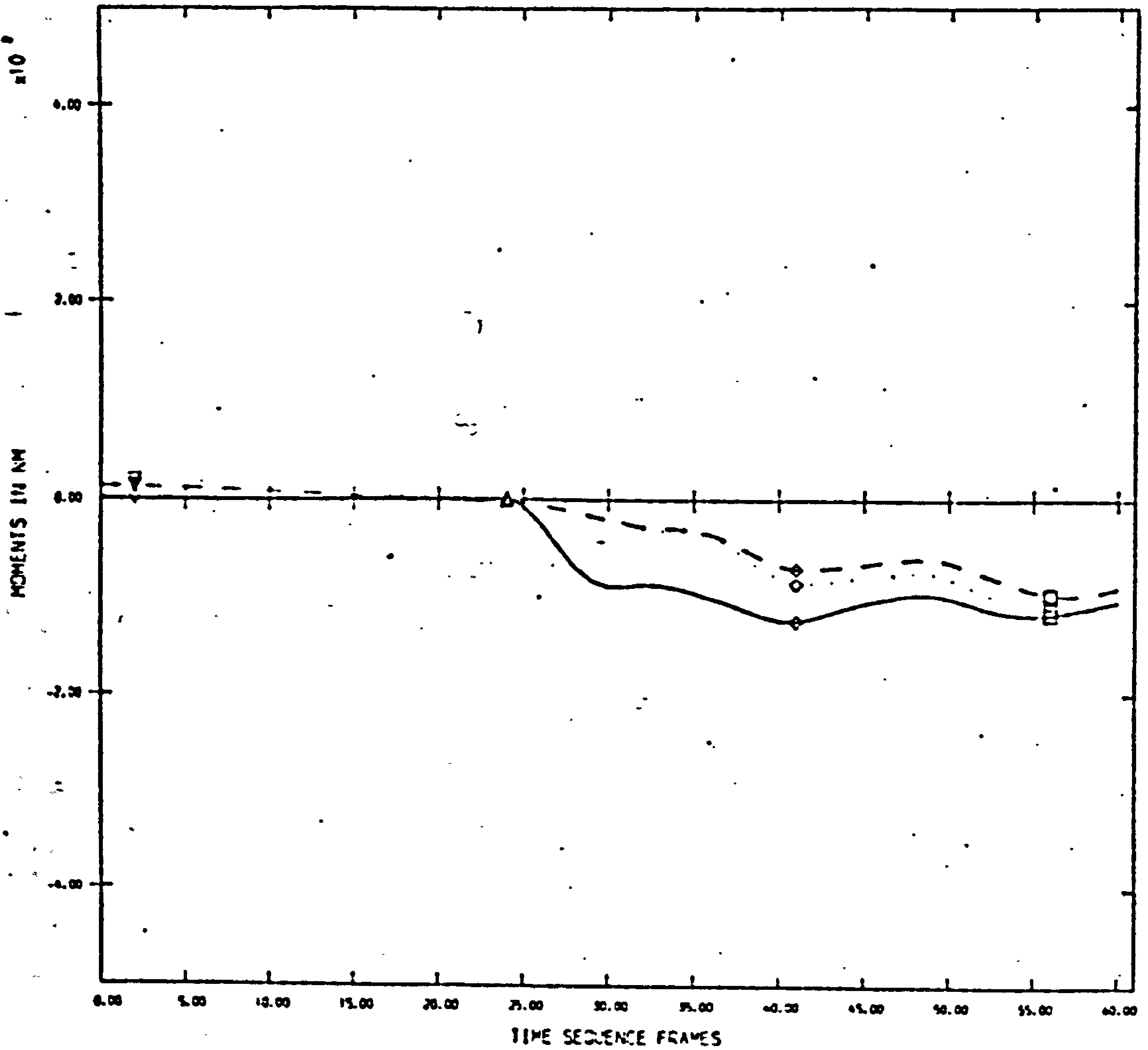


ANKLE.KNEE. HIP. CORONAL PLANE

LEFT HEEL STRIKE △
LEFT TOE OFF ▽
RIGHT HEELSTRIKE □
RIGHT TOE OFF ◇

CONTINUOUS ANKLE
DASHED KNEE
DOTTED HIP

S3/L/BDT1



ANKLE, KNEE, HIP, CORONAL PLANE

LEFT HEEL STRIKE △

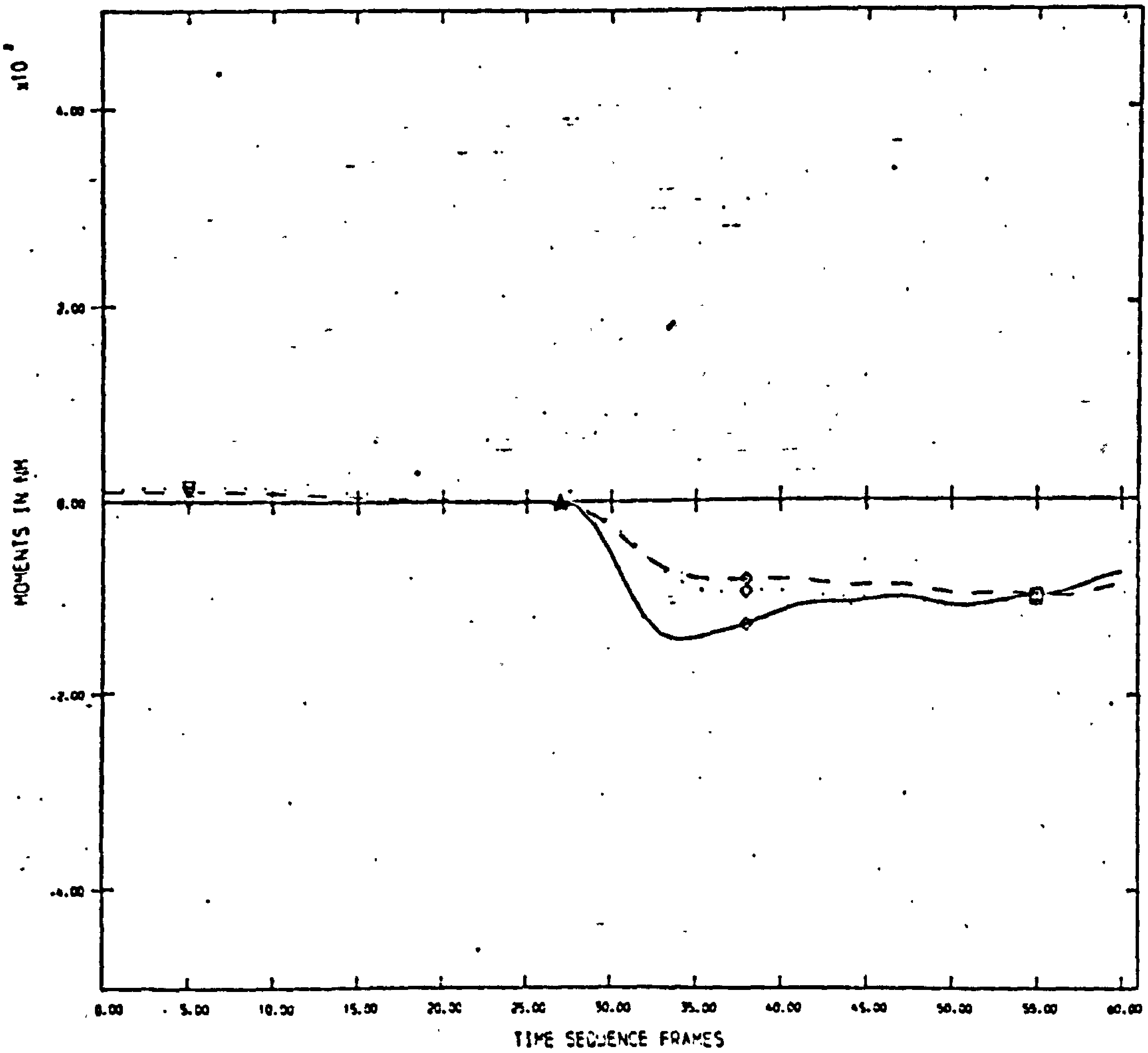
LEFT TOE OFF ▽

RIGHT HEELSTRIKE □

RIGHT TOE OFF ◇

CONTINUOUS	ANKLE
DASHED	KNEE
DOTTED	HIP

S4/L/BDT1

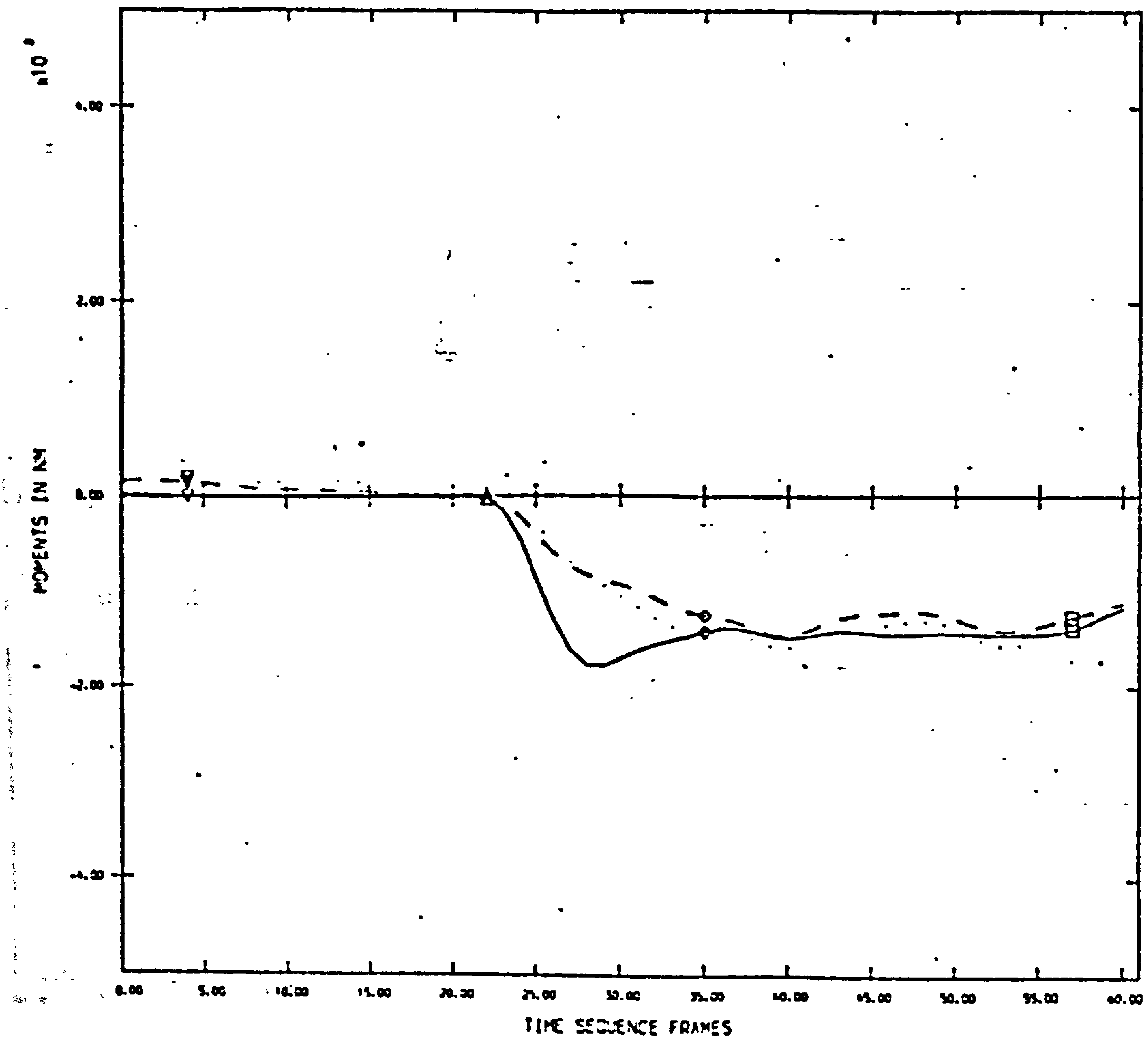


ANKLE, KNEE, HIP, CORONAL PLANE

LEFT HEEL STRIKE △
LEFT TOE OFF ▽
RIGHT HEELSTRIKE □
RIGHT TOE OFF ◇

CONTINUOUS ANKLE
DASHED KNEE
DOTTED HIP

S5/L/BOT1

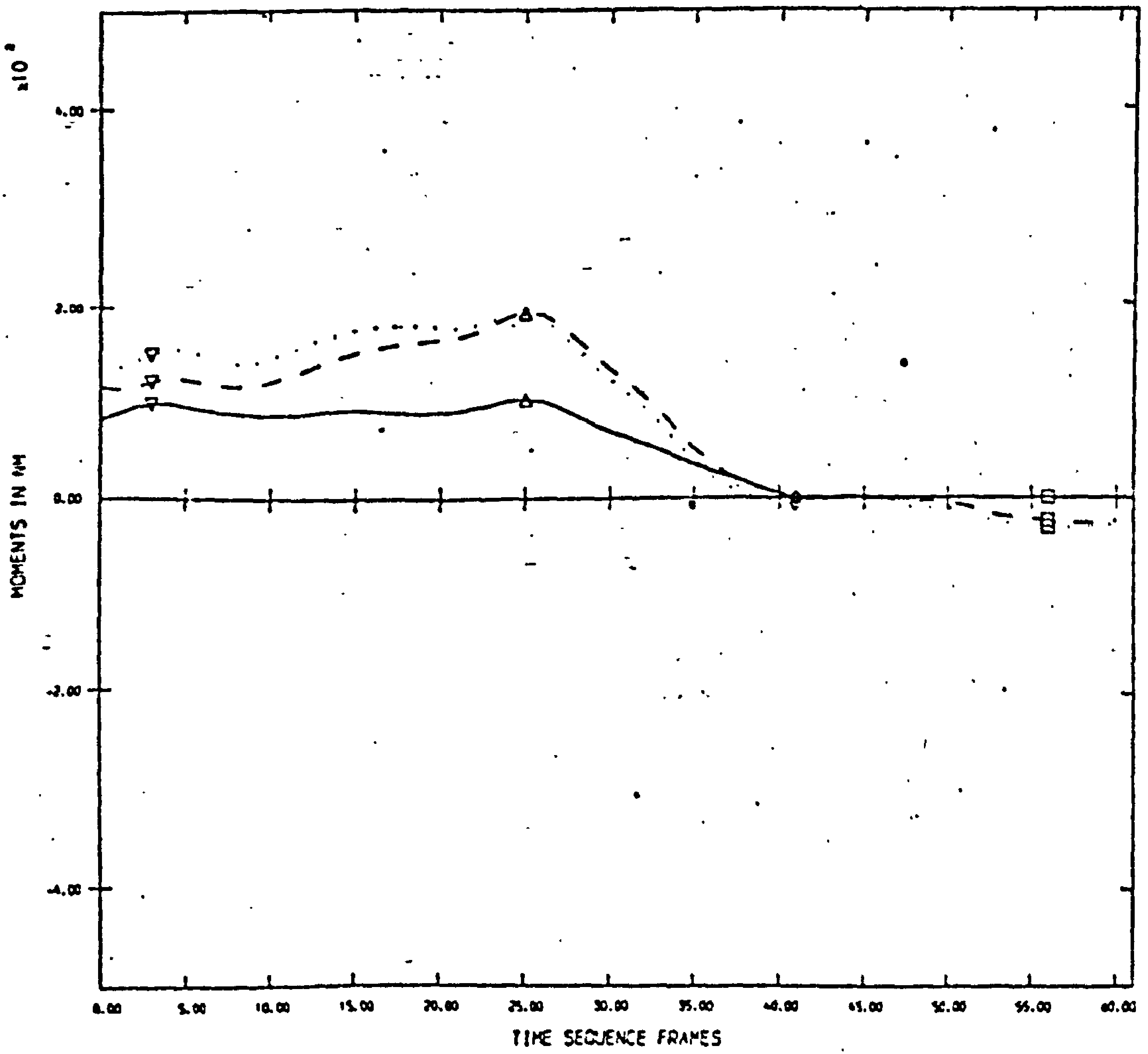


ANKLE.KNEE, HIP. CORONAL PLANE

LEFT HEEL STRIKE △
LEFT TOE OFF ▽
RIGHT HEELSTRIKE □
RIGHT TOE OFF ◇

CONTINUOUS ANKLE
DASHED KNEE
DOTTED HIP

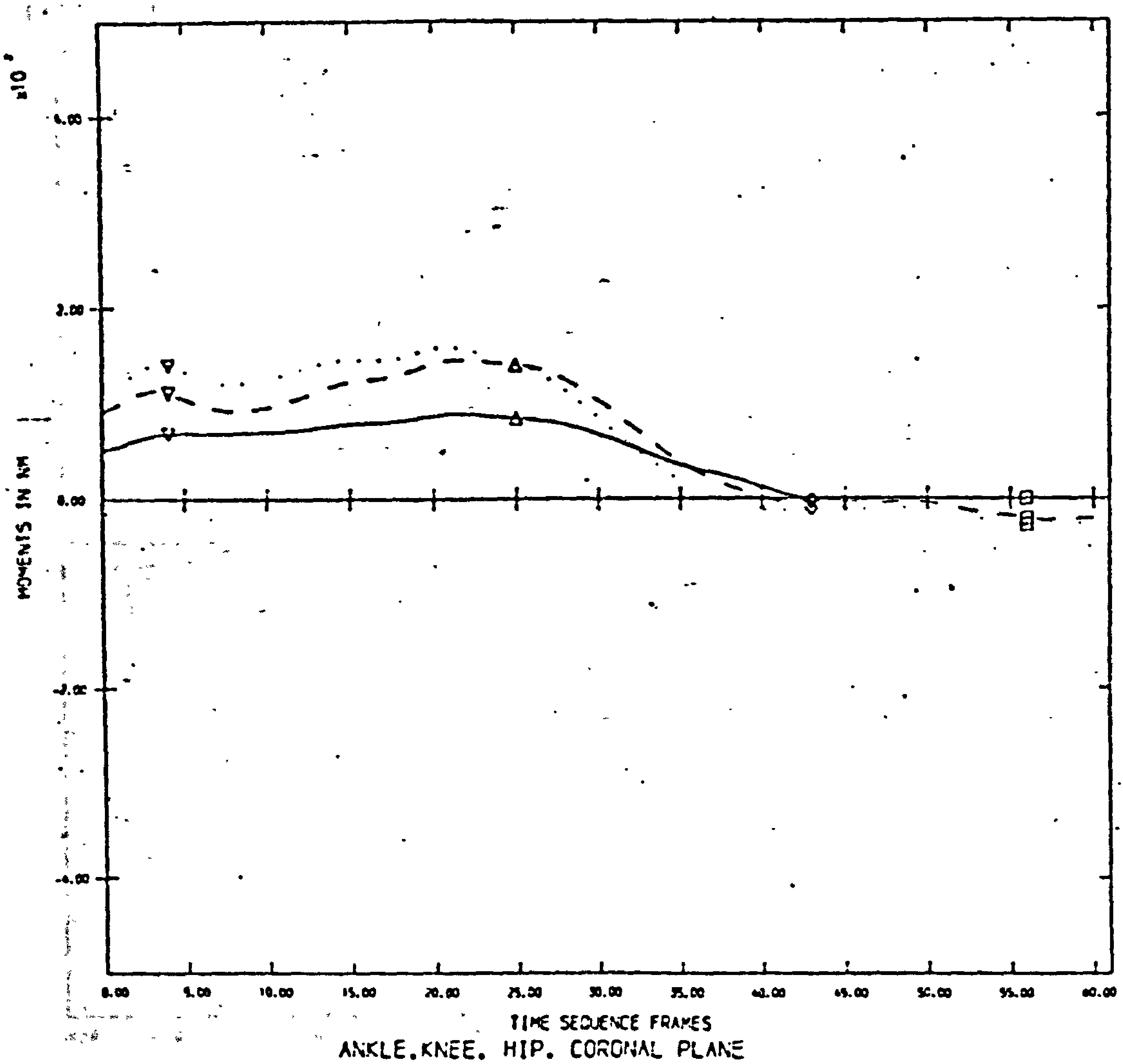
S1/R/BDT1



ANKLE,KNEE, HIP, CORONAL PLANE

LEFT HEEL STRIKE	△	CONTINUOUS	ANKLE
LEFT TOE OFF	▽	DASHED	KNEE
RIGHT HEELSTRIKE	□	DOTTED	HIP
RIGHT TOE OFF	◇		

S2/R/BOT1



ANKLE.KNEE. HIP. CORONAL PLANE

LEFT HEEL STRIKE △

LEFT TOE OFF ▽

RIGHT HEELSTRIKE □

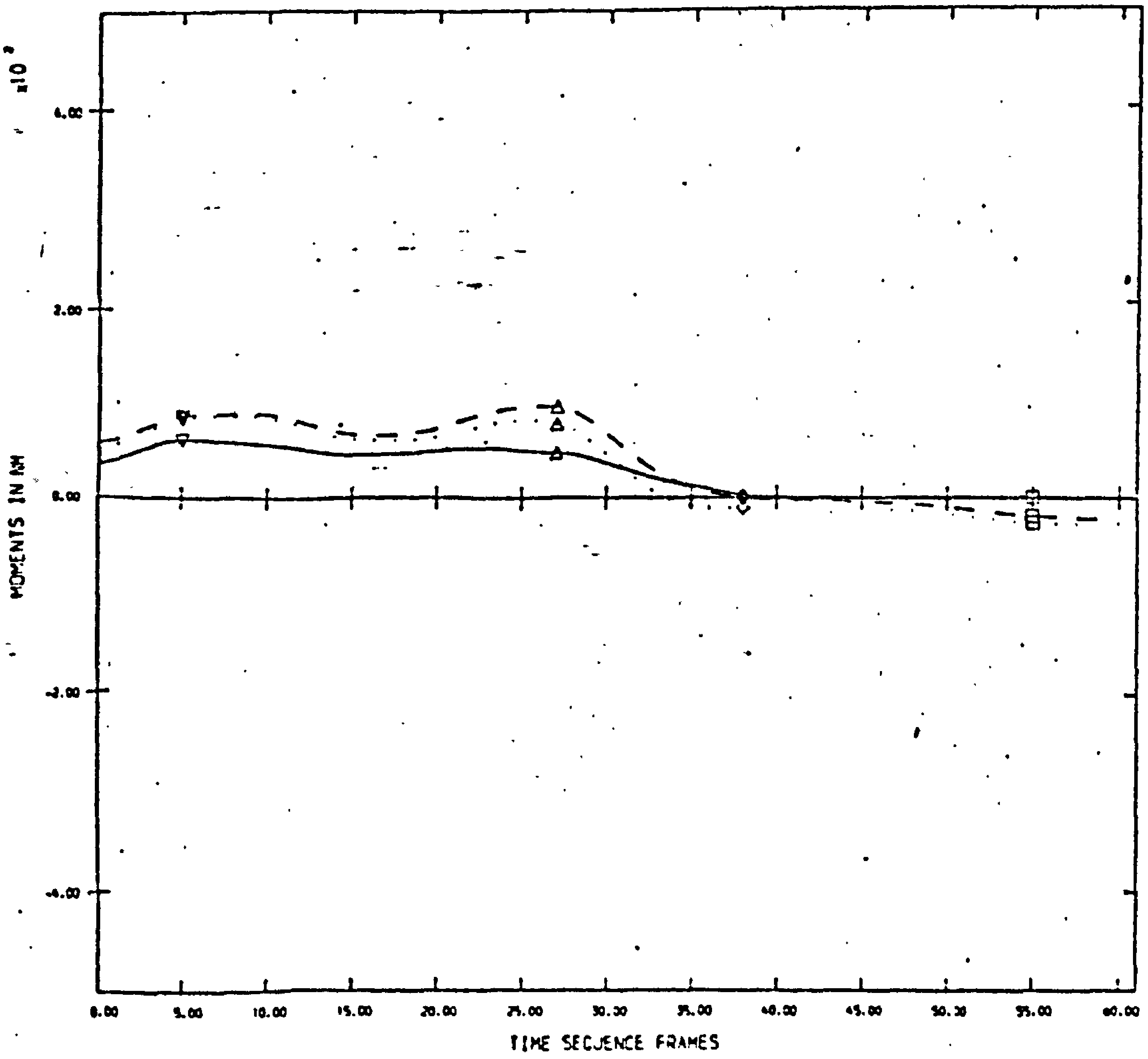
RIGHT TOE OFF ◇

CONTINUOUS ANKLE

DASHED KNEE

DOTTED HIP

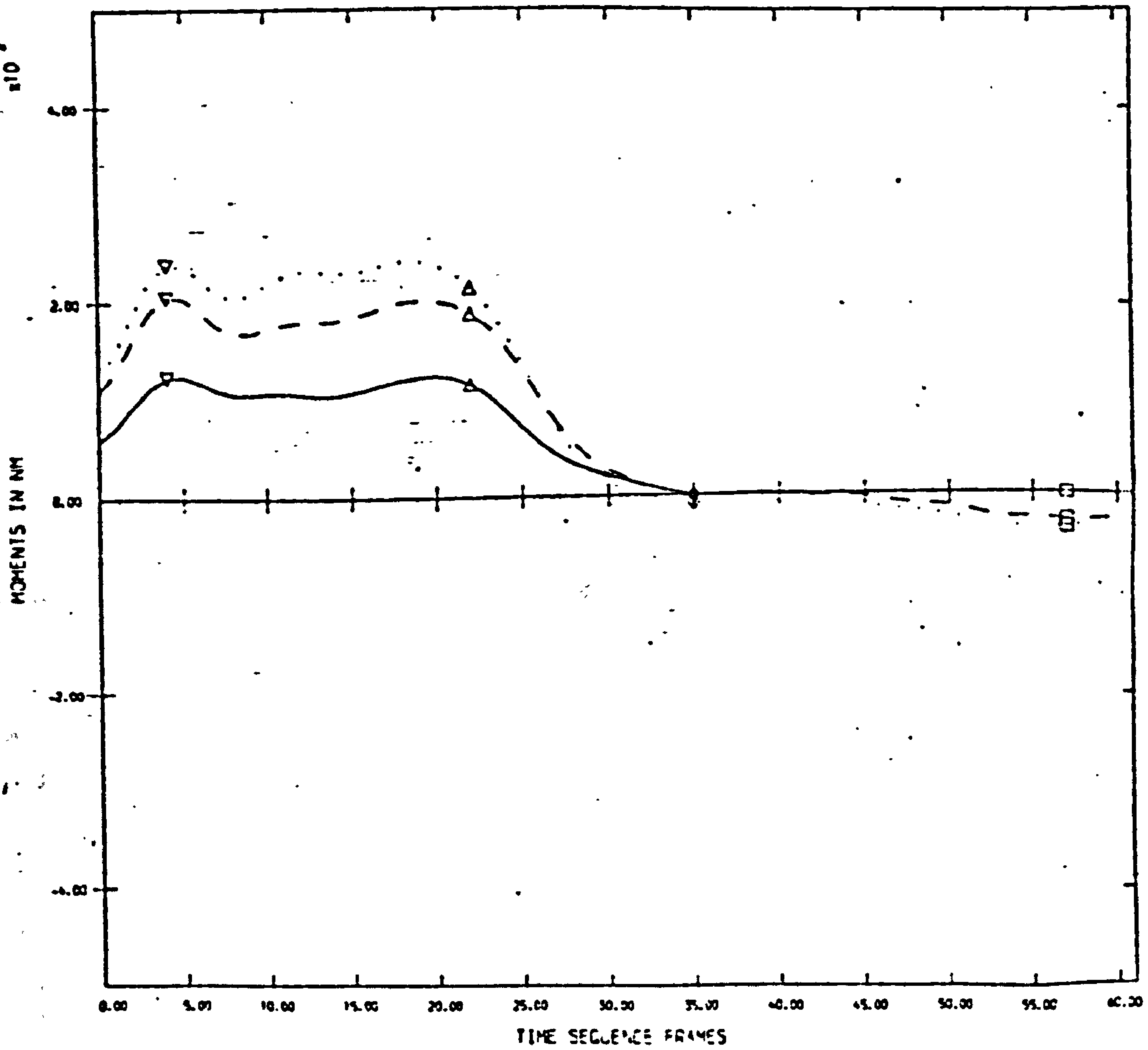
S4/R/BDT1



ANKLE,KNEE, HIP, CORONAL PLANE

LEFT HEEL STRIKE	△	CONTINUOUS	ANKLE
LEFT TOE OFF	▽	DASHED	KNEE
RIGHT HEELSTRIKE	□	DOTTED	HIP
RIGHT TOE OFF	◇		

S5/R/BOT1



ANKLE.KNEE. HIP. CORONAL PLANE

LEFT HEEL STRIKE △ CONTINUOUS ANKLE

LEFT TOE OFF ▽ DASHED KNEE

RIGHT HEELSTRIKE □ DOTTED HIP

RIGHT TOE OFF ◇