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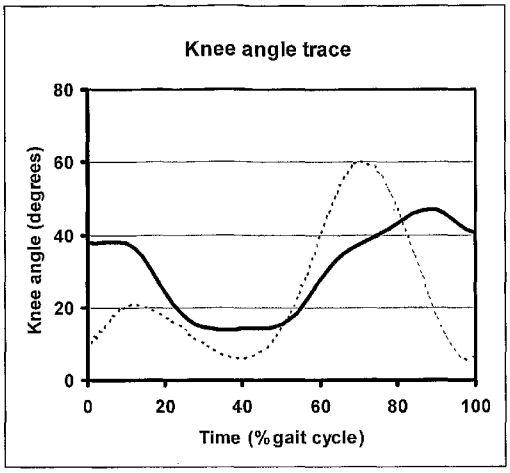


FIGURE 1

(57) **Abstract**: A system for analysis and interpretation of movement data, comprising: i. a variable difference score (VDS) generator for generating VDS data, representing variable difference scores, based on the difference between a first trace and a second trace, both traces relating to a selected movement variable of one or more animals; and ii. a movement analysis profile (MAP) generator for generating MAP data, representing a movement analysis profile for the animal, based on at least two of the variable difference scores in the generated VDS data.

WO 2009/114909 A1

MOVEMENT ANALYSIS

FILING DATA

This application is associated with and claims priority from Australian Patent Application no. 2008901359, filed on 19 March 2008, the entire contents of which are incorporated herein by reference.

FIELD

The present invention relates generally to the field of movement analysis, for example methods and systems for analysis and interpretation of movement analysis data.

BACKGROUND

Reference to any prior art in this specification is not, and should not be taken as, an acknowledgement or any form of suggestion that this prior art forms part of the common general knowledge in any country.

Analysis of a movement of an animal can provide information about characteristics of how that animal moves and might suggest why it moves in a particular manner. For example, gait analysis provides information about the characteristic fashion in which an individual walks or runs. In particular groups of patients this information might be useful to allow the diagnosis of a particular condition and to assess why the patient has a particular movement pattern. This information might be useful in prognosis of disease progression, in clinical decision making or to monitor progress over time.

A considerable proportion of the Australian population suffers from conditions affecting walking. Nearly 17% of the population (about 3.4 million) have arthritic conditions, another 217,000 have had a stroke, 100,000 have Parkinson's disease and 20,000 have

cerebral palsy. Clinical gait analysis is used to treat patients with cerebral palsy, Parkinson's disease, stroke, osteoarthritis and other conditions. Movement analysis can also be used in the design and manufacture of prostheses and orthoses. Aside from clinical applications, movement and gait analysis is used in professional sports training to optimise and/or improve athletic performance. There is increasing use of such techniques in relation to animals other than humans.

Typically, movement analysis uses a variety of electronic technologies to record movement data relating to the movement of an animal during walking or running. A graph of a relevant kinematic or kinetic variable may be plotted over the duration of a movement, e.g. over a gait cycle. The measurement technology typically measures a wide variety of variables resulting in considerable amount of data and a multiplicity of such graphs. In order to make use of the data for the purposes listed above, clinicians must examine all the data presented to them in this fashion and interpret their significance based on their clinical and technical knowledge and experience. Few clinicians have the necessary knowledge base to provide such an interpretation and this provides a significant barrier to the more widespread clinical implementation of such techniques.

Systems such as the Gillette Gait Index (GGI), as described in Schutte et al [2], provide a single compound measure reflecting how different a patient's gait is from that of the normal population. This can be useful for providing a single readily interpreted measure of how severe a patient's walking pattern is but does not contain sufficient information for any of the clinical applications listed above.

Systems are needed that can reduce the complexity of the full set of movement analysis data whilst still retaining information to support the clinical interpretation of those data.

SUMMARY

The present invention provides methods and systems for analysis and interpretation of movement data, which is useful *inter alia* in assessment, diagnosis, prognosis, prevention, clinical decision making and monitoring treatment (including monitoring the efficacy of

therapy, whether physical or pharmaceutical), monitoring injuries, and in improving movement in a subject.

Accordingly, there is provided a system for analysis and interpretation of movement data, including:

i. a variable difference score (VDS) generator for generating VDS data, representing variable difference scores, based on the difference between a first trace and a second trace, both traces relating to a selected movement variable of one or more animals; and

ii. a movement analysis profile (MAP) generator for generating MAP data, representing a movement profile for the animal, based on at least two of the variable difference scores in the generated VDS data.

The present invention also provides a method for analysis and interpretation of movement data, *including:*

i. generating VDS data, representing variable difference scores, based on the difference between a first trace and a second trace, both traces relating to a selected movement variable of one or more animals; and

ii. generating MAP data, representing a movement profile for the animal, based on at least two of the variable difference scores in the generated VDS data.

This profile data can be compared with one or more other profiles, such as an earlier profile from the same subject, eg after treatment for a movement condition, a profile of the other side of the same subject, eg comparing a movement in the left leg with the same movement in the subject's right leg, and/or with a similar profile from a different subject in order to diagnose a movement condition and/or identify a prevention or treatment regimen for the movement condition.

BRIEF DESCRIPTION OF THE DRAWINGS AND TABLES

Preferred embodiments of the invention are further described, by way of example only, with reference to the accompanying drawings, wherein:

Figure 1 is a graphical illustration of trace data varying over the duration of a single gait cycle. The bold line represents trace data for the knee angle for a patient with cerebral palsy. The dotted line represents trace data for a cohort of healthy individuals for comparative purposes.

Figure 2 is a graphical illustration of movement trace data relating to a variety of kinematic variables. The multiple line traces represent data from a number of different walks of the same patient during a single gait analysis session. Data in dark grey is from the left side and in black from the right. The grey areas represent data from a cohort of healthy individuals extending from the man value plus one standard deviation to the man value minus one standard deviation.

Figure 3 is a graphical illustration of movement trace data relating to a variety of kinetic variables. The multiple line traces represent data from a number of different walks of the same patient during a single gait analysis session. Data in dark grey are from the left side and in black from the right. The grey areas represent data from a cohort of healthy individuals extending from the man value plus one standard deviation to the man value minus one standard deviation.

Figure 4 is a graphical illustration of the same trace data as in Figure 1 with a representation of a variable difference score calculated from a difference function between the two traces superimposed in grey. In this case the difference function is the area between the traces.

Figure 5 is a histogram representing a movement analysis profile (MAP). This particular MAP is comprised of left and right variable difference scores for 9 different traces. At the right hand side is a representation of the three Movement Profile Scores (MPS). One is obtained by combing all variable difference scores for the left side, the second for the right side and the third for both sides together.

Figure 6 is a histogram representing data from the same patient as that in Figure 5 but with data captured 12 months after orthopaedic surgery which aimed to correct the patient's gait pattern. Clear improvement can be seen in many of the variable difference scores which is also reflected in the Movement Profile Scores.

Figure 7 is a block diagram showing elements comprising the Analytical and Interpretive System (AIS).

Figure 8 is a flow diagram of a VDS, MAP and MAS generator.

Figure 9 provides an overview of a Graphical User Interface.

Figure 10 is an illustration of a user interface. The MAP pane is the central vertical pane and presents the Movement Analysis Profile (or profiles) to the clinician. Selecting the *movement analysis dataset from the dataset pane (top left) specifies the data to be* displayed in the MAP (or MAPS). Selecting the type of data from the data pane (bottom left) specifies what type of data is viewed to the right of the MAP. The particular variables to be displayed will be determined by interacting with the MAP. In this case the foot progression VDS has been selected and thus the foot progression graphs are displayed. The Knowledge Base Pane at the foot of the screen gives advice on how data should be interpreted.

Figure 11 is an illustration of a user interface showing marked up gait traces. The traces in the bottom left corner have symbols representing gait abnormalities.

Figure 12 is an illustration of a user interface showing gait abnormalities grouped in relation to assumed impairments.

Figure 13 is an exemplary report generated by a user interface. Figure 13a lists the impairments. Figure 13b shows the abnormalities as symbols superimposed on gait traces. Figure 13c lists how abnormalities are related to impairments.

Table 1: General movement analysis terminology (several terms used more loosely in general movement analysis are given these specific meanings in this document).

Table 2: Terminology developed specifically in relation to the invention proposed in this patent.

DEFINITIONS

General terminology

It is to be understood that the present invention is not limited to particularly exemplified movement conditions or subjects, which may vary. It is also to be understood that the terminology used herein is for the purpose of describing particular embodiments of the present invention only, and is not intended to be limiting.

All publications, patents and patent applications cited herein, whether above or below, are hereby incorporated by reference in their entirety. However, publications mentioned herein are cited for the purpose of describing and disclosing the protocols and reagents which are reported in the publications and which might be used in connection with the subject invention. Nothing herein is to be construed as an admission that the instant invention is not entitled to antedate such disclosure by virtue of prior invention.

As used in the subject specification, the singular forms "a", "an" and "the" include plural aspects unless the context clearly dictates otherwise. Thus, for example, reference to a "trace" includes a single trace as well as two or more traces, reference to "an analysis" includes a single analysis or two or more analyses, reference to "the invention" includes single or multiple aspects of the invention, and so on.

Throughout the specification the word "comprise" and variations of the word, such as "comprising" and "comprises", means "including but not limited to" and is not intended to exclude other additives, components, integers or steps. By "consisting of" is meant including, and limited to, whatever follows the phrase "consisting of". Thus, the phrase "consisting of" indicates that the listed elements are required or mandatory, and that no

other elements may be present. By "consisting essentially of" is meant including any elements listed after the phrase, and limited to other elements that do not interfere with or contribute to the activity or action specified in the disclosure for the listed elements. Thus, the phrase "consisting essentially of" indicates that the listed elements are required or mandatory, but that no other elements are optional and may or may not be present depending upon whether or not they affect the activity or action of the listed elements.

Unless defined otherwise, all technical and scientific terms used herein have the same meanings as commonly understood by one of ordinary skill in the art to which this invention belongs. Although any materials and methods similar or equivalent to those described herein can be used to practice or test the present invention, the preferred materials and methods are now described.

Reference to "user interface" includes user interface automatically, user interface manually as well as user interface semi-automatically.

General movement analysis terminology (see Table 1)

As used herein, the term "movement" refers to any movement of any part of any animal, or the relative movement of two or more parts of any animal. "Parts" include a limb or part thereof, hip, pelvis, jaw, neck, back. "Movement analysis dataset" refers to a dataset of measurements of a specific animal on a specific occasion ("session") describing a specific movement under specific conditions including certain variables ("movement variables") measured over the time course of that movement using a "movement analysis system". This includes "kinematic variables" describing the movement itself or "kinetic variables" describing the forces and moments that bring about the movement including effects of gravity, inertia, joint or ground reactions or forces within muscles or other joint structures. A movement analysis dataset may include data from a single instance of the movement or from multiple repetitions of this. A "trial" represents data arising from a single instance of the movement. Thus the movement analysis dataset may include data from several trials.

As used herein, the term "movement condition" means any condition arising from an

abnormal movement, such as a condition affecting balance and/or stability. Examples of movement conditions include conditions which are associated with an abnormal movement of a limb or part thereof, hip, pelvis, jaw, neck or back, including gait affecting conditions.

As used herein the terms "treating" and "preventing" mean any treatment of prevention of a movement condition in an animal. "Treatment" and "prevention" includes: (a) inhibiting the condition, i.e., arresting its development; or (b) relieving or ameliorating the symptoms of the condition, i.e., cause regression of the symptoms of the condition. The effect may be therapeutic in terms of a partial or complete cure of the condition.

The term "diagnosis" means the process of identifying a movement condition and/or any condition giving rise to a movement condition.

The subject in which a movement condition is assessed, diagnosed or treated may be any subject capable of movement. For example, the subject may be a human or a mammal of economical importance and/or social importance to humans, for instance, carnivores other than humans (such as cats and dogs), swine (pigs, hogs, and wild boars), ruminants (such as cattle, oxen, sheep, giraffes, deer, goats, bison, and camels), horses, and birds including those kinds of birds that are endangered, kept in zoos, and fowl, and more particularly domesticated fowl, e.g. poultry, such as turkeys, chickens, ducks, geese, guinea fowl, and the like, as they are also of economical importance to humans. The term does not denote a particular age. Thus, both adult and newborn subjects are intended to be covered.

A "trace" represented by trace data refers to a subset of movement analysis data representing the variation in a particular variable measured over the time course of a particular movement of a particular trial. This includes movement analysis data that has been time-normalised over the period of that movement (see Figure 1). It often represents such data from one cycle of the repetition of a repeating (or repeatable) movement pattern. Trace data represents a plurality of values of a measured quantity as it evolves over time, i.e. a trace has a plurality of values in a time series. These values are typically spaced in time by equal intervals, e.g. a trace may have 10, or 50, or 100, or any other number of spaced data points over the movement. "Trace" includes "average trace" which refers to a

dataset of the average values of more than one trace calculated at each time interval across the time course of the movement. Average traces may include traces from a number of different repetitions of a movement from the same animal, from different animals or some combination of different repetitions and different animals. A particular embodiment would be a "reference trace" which refers to the average across a range of animals to be used for comparison purposes. This will often be a range of animals considered to be normal in some sense and which can be used to compare with traces from animals which might be expected to differ from normal.

Example trace data, plotted as traces, for a plurality of kinematic and kinetic types of movements are shown in Figure 2 and Figure 3.

Terminology developed to describe this invention (see Table 2)

A "variable difference score" (VDS) refers to a single parameter representing the difference between two traces representing the same variable from different movements and/or different animals or groups of animals and/or different occasions. Typically one trace will represent data for a particular animal on a particular occasion and the other trace will represent some reference data from an animal or animals (for example the mean trace of a sample of animals considered normal in some sense). In this case the second trace will be referred to as the "reference trace". A particular embodiment might define a VDS as the area between two traces when each is plotted as a graph against time. This is illustrated in Figure 4. Another embodiment would be such a score defined as the root mean square difference between the traces calculated over the different time intervals of the trace.

"Movement analysis profile" (MAP) refers to a dataset of two or more VDS representing some aspect of the movement analysis data. Such a profile can be represented in a number of ways either graphically or numerically. A particular embodiment of a MAP is as a histogram with the different bars representing the different VDSs that comprise that MAP. This is illustrated in Figure 5. In this the VDS for the principal kinematic variables for both left and right sides are plotted as columns. To the left of these the movement profile

score (see below) for the left side (being the RMS value of all VDS for the left side) and for the right side (defined analogously) and a total score (being the RMS value of all VDS for the pelvis and the right limb and the left limb) are also represented as columns. If multiple trials have been analysed then these columns might represent the average of the VDS across the trials and the standard deviation across the trials can be indicated by error bars (as illustrated). A particularly useful form of this is where the MAP is calculated as the difference between a trace representing one individual animal and a representative trace representing data from a number of animals considered to be normal in some sense. In this case the MAP gives the clinician a clear indication of where the largest differences between the patient and the reference traces lie (the variables with the highest VDS) and the magnitude of the VDS indicates the magnitude of that difference (in degrees).

A MAP may be for clinical analysis, sports training, and classification matching purposes. For example, the aim of treatment of a subject may be to achieve a movement that more closely matches the movement of some healthy/normal population. A MAP comprising VDSs calculated as the difference between traces from that subject and corresponding normal traces thus indicates which variables differ from normal and by how much. The two MAPs depicted in Figure 5 and Figure 6 represent such data from the same girl before and after surgery. It can be seen that VDSs for foot progression (Foot Prog), ankle dorsiflexion (Ank Dors), knee flexion (Knee Flex) bilaterally and for hip rotation (Hip Rot) on the right side have all reduced following surgery suggesting more normal movement patterns but that the other VDSs are relatively unchanged. The MAP can thus be used to assess what specific effects the surgery has had on the subject's movements.

"Movement profile score" (MPS) refers to a single score produced by some mathematical combination of the VDSs comprising the movement analysis profile. A particular embodiment of a MPS would be the average or root mean square value of theVDSs comprising a given MAP.

A MPS may also be used for clinical analysis, sports training, and classification matching purposes. For example, in the example given above the overall improvement in the movement as a result of surgery might be measured by comparing the MPS calculated

from the movement analysis data collected pre-operatively with that collected post-operatively. Three different MPSs are illustrated in Figure 5 and Figure 6. The first is the root mean square value of all illustrated traces for the left leg, the second is the equivalent value for the right leg. The third is the root mean square value of VDSs representing movements of both legs. It can be seen that all three MPSs are lower after surgery than before surgery and this might be used to quantify how much closer the subjects gait pattern has become to that of the normal/healthy population.

DETAILED DESCRIPTION

The present invention is based on the premise that a graphical or numerical representation of a movement analysis profile (MAP) can be used to guide analysis and interpretation of movement data. Analytical and interpretive system and methods is provided which presents the data in the form of a MAP and allows further investigation of the total data guided by the information contained within the MAP.

Accordingly, one embodiment provides an analytical and interpretive system (AIS) based on:

a VDS generator for generating data representing VDS based on a difference between some trace or traces representing the movement of a given the subject and a second reference trace representing the average trace of a group of individuals considered to have no pathology affecting the movement being considered.

a MAP generator for generating data representing a MAP for the subject based on at least two of the VDSs thus generated.

System

Figure 7 thus depicts the AIS 701 and how it relates to various data sources. Movement analysis data is captured from a subject 702 using a movement analysis system 703. The data recorded by such a motion analysis system is stored in a movement analysis database 704. The movement analysis system 703 and database 704 are independent of the present invention; any movement analysis system and database can be used that records variables

over time in such a manner that VDSs and a MAP can be generated. The components depicted in Figure 7 may be co-located, possibly all on the same computer, or distributed over a number of computers linked through a data network such as the Internet. Furthermore, the modules 1 to 5 may be in the form of software modules running on an Intel-based personal computer operating Microsoft 'Windows', or an Apple personal computer. The modules 1 to 5 may be written in a programming language such as Java. Alternatively, various components of the AIS 701 could be distributed over a plurality of locations, and at least part of the modules 1 to 5 could be provided by application-specific hardware components, such as application-specific integrated circuits (ASICs) or field-programmable gate arrays (FPGAs).

The interpretation of movement analysis data often requires reference to other clinical data relating to the subject. This might include, but is not restricted to anthropometric measures, the results of a clinical examination, the subject's medical or surgical history and video recordings. This information is depicted in Figure 7 as being recorded in some clinical database 705 which may be either electronic or paper based.

The AIS 701 is able to obtain movement analysis data from the movement analysis database and clinical data from the clinical database. These data are then stored within the AIS database 706. Within the AIS are VDS and MPI generators 707. These generate relevant scores on the basis of the data in the AIS database 706 and may write these scores back to the AIS database 706.

The scores generated by the VDS and MPS generators 706 and used to form the MAP upon which the graphical user interface (GUI) 708 is based. The interpreting clinician 709 can view and interact with the GUI 708 to investigate other data stored within the AIS database 706 which can be displayed graphically in a number of different formats. These data may include those from the subject on one occasion or a number of occasions. They may also include comparative data from other subjects either individually or combined in some manner (such as average trace data from some reference population).

The GUI 708 may also be used by the interpreting clinician to search for patients with data

stored within the AIS database 706 which is similar to that of the patient data being interpreted. Having a similar MAP is a necessary but not sufficient condition to ensure this. Searching for patients with matching MAPs offers the potential of rapid searching through large databases to provide potential matches which can then be further investigated with slower more refined techniques.

Once the interpreting clinician has identified a matching subject or subjects they will then be able to view the treatment history and relevant outcomes for that subject or subjects using the GUI (708). This may be useful in determining clinical decision making for the patient whose data is being examined.

The AIS may also include some expert knowledge base 710. This incorporates the opinion of expert clinicians which can be linked to the data stored within the AIS database. Thus when data for a subject has specific characteristics the GUI might prompt the interpreting clinician to interpret the data in a particular manner. This might include suggesting particular treatments that might be appropriate or suggesting other data that should be considered.

The AIS 701 includes analysis modules, shown in Figure 7, implemented for example in software code, for analysing the movement analysis data.

Module 1: AIS Database

The AIS database 706 stores data relating to the specific individuals. This will include movement analysis data (parameters for specific sessions and variables for specific trials) but may also include other clinical data which might be measurements (e.g. from physical examination), images (e.g. radiology), video clips or other in other formats.

Module 2: VDS and MAP Generators (Figure 8)

The VDS comprising the particular MAP to be used by the AIS must first be defined in the

MAP specifier 801. A particular embodiment will generally but not necessarily focus on a MAP comprised of one particular set of VDSs.

The reference trace is then generated by the reference trace generator 802. First the movement analysis data that is to comprise the reference traces is nominated. This is located in the AIS database and used to calculate the reference traces. A particular embodiment will generally but not necessarily use the same reference data as a basis for all calculations and in this case the reference traces might be calculated outside the AIS and stored in a location to which the AIS has access.

Let v_{ijt} denote a trace, being the n_t+1 different values of a variable labelled i for a trial labelled j measured at n_t evenly spaced time intervals over the time course of some movement. In calculating the reference trace the trials will be those of from individuals belonging to the reference dataset. These will often but not necessarily be a group of individuals considered to have no pathology affecting movement.

The reference trace r_{it} might be calculated using the expression

$$r_{it} = \frac{\sum_{j=1}^{N_r} v_{ijt}}{N_r} \qquad \text{Equation 1}$$

Where the sum is over the N_r trials from the reference group.

The VDS generator 803 then locates the data, which for the specified individual to be analysed in the AIS database. This might be one or several trials. The VDSs for the individual trial or trials are calculated and if more than one trial is analysed then summary statistics for those trials calculated.

The VDS for the variable labelled i for the trial labelled j, VDS_{ij}, will then be given by the expression

$$VDS_{ij} = diff(v_{ijt}, r_{it}) \qquad \text{Equation 2}$$

where $diff(v_{ijt}, r_{it})$ represents some difference function between the trace and the reference trace. Perhaps the most obvious such difference function is the root mean square difference between these traces which can be written

$$VDS_{ij} = \sqrt{\frac{\sum_{t=0}^{n}\left(v_{ijt} - r_{it}\right)^2}{(n+1)}} \qquad \text{Equation 3}$$

where the summation is over the n+1 different instants of time when data was recorded for each movement analysis dataset.

If multiple trials are available within the dataset then some summary statistics giving a representative value for the VDS and its distribution is calculated. Perhaps the most obvious such statistics are the mean VDS ($\overline{VDS}_i$) and its standard deviation (σ_{VDS_i}) where

$$\overline{VDS}_i = \frac{\sum_{j=1}^{J} VDS_{ij}}{J} \qquad \text{Equation 4}$$

and

$$\sigma_{VDS_i} = \sqrt{\frac{\sum_{j=1}^{J}\left(VDS_{ij} - \overline{VDS}_i\right)^2}{(J-1)}} \qquad \text{Equation 5}$$

The MAP generator 804 then combines the VDS or summary statistics to generate the MAP. This is often represented as a movement analysis profile in the form of a histogram, examples of which are given in Figures 5 and 6.

The I VDSs can then be combined to form a single MPS for each trial (MPS_j) in the MPS generator 805. One way of doing this would be to calculate the RMS value across the I VDSs

$$MPS_j = \sqrt{\frac{\sum_{i=1}^{I} VDS_{ij}^{\,2}}{I}} \qquad \text{Equation 6}$$

(although the mean value could be used as an alternative).

Summary statistics giving a representative value of the MPS and its distribution can then be calculated. The most obvious of these are the mean ($\overline{MPS}$) and standard deviation (σ_{MAS}):

$$\overline{MPS} = \frac{\sum_{i=1}^{I} MPS_i}{I} \qquad \text{Equation 7}$$

and

$$\sigma_{MPS} = \sqrt{\frac{\sum_{i=1}^{I} MPS_i}{(I-1)}} \qquad \text{Equation 8}$$

Similar mathematical techniques can be used to calculate a variety of similar variables which may have uses in the clinical interpretation of data. If difference scores between the same variables for the right and left sides of the same trial data are calculated then the resulting MAP and MPS will indicate the left/right symmetry of the movement pattern. If different sub-sets of the movement variables are selected then the resulting MAP and MPS might be useful. For example, in conditions in which the major features are in a particular anatomical plane it might be useful to use a MAP and MPS constituted of all or only some of the variables associated with that plane. Similarly in a condition affecting a specific joint it might be useful to use a MAP and MPS constituted of one or all the variables associated with that joint.

Module 3: User Interface

The graphical user interface 708 is displayed on a computer monitor and is the means by which the clinician interacts with the AIS. It may be generated using stand-alone software

programs or alternatively using a Web browser (e.g. Internet Explorer, Firefox, Safari or Navigator) accessing the analysis system 102 AIS over a network. The user interface 708 includes components that allow the clinician to view the data generated by VDS and MAP generator 707 and use this as a basis for clinical interpretation of the data and to explore other data stored within the AIS database. It thus includes components for displaying measurements, images and video, and graphical representations of movement variables.

Figure 9 illustrates an overview of the layout of one particular embodiment of the GUI and Figure 10 a sample of the GUI using this layout. The MAP or MAPs generated by the system are displayed in the MAP pane 901. The dataset pane 902 allows the clinician to specify the movement analysis datasets for which the MAP or MAPs are displayed. In Figure 10 two sets of barefoot data captured on different occasions is specified and is displayed in the MAP pane. By interacting with the MAP different data is displayed in the data pane 904. For example if the clinician highlights the foot progression difference score column on the MAP then data relating to foot progression will be displayed in the data pane. If two or more MAPs are selected for display then the same data for each MAP will be displayed. The type of data to be displayed in the data bar is specified in the data type pane 903. In Figure 10 the clinician has specified that specific kinematic data be displayed and this is what appears in the data pane.

The knowledge base pane allows information from the expert knowledge base 710 to be displayed. This is also specific to the particular column of the MAP that has been highlighted. In Figure 10 the information displayed suggests other data that might be worth exploring and treatment options that might be considered for the foot progression data that is displayed.

The search pane 906 allows the clinician to search the AIS database for patients similar to the current patient using the techniques described below in the section on the data mining module. These can then be pulled up to be presented in the GUI to allow the clinician to compare data for those patients with those for the current patient.

Mark up

The user interface allows the user to view gait traces for a range of different variables and to identify gait abnormalities within these. The interface may allow the user to enter the details of each gait abnormality into a gait abnormalities data base. These details may include the trace, the side of the body affected, the time during the gait cycle at which it occurs and the nature of the abnormality. Typical abnormalities may include differences in magnitude, timing or slope of features of the traces. They may be depicted by various symbols superimposed on the gait traces.

In the embodiment shown in Figure 11 the traces for knee flexion are displayed in the bottom left hand corner. Features of the trace representing too much (⊕) knee flexion in loading response and terminal stance have been marked by mouse-clicking on the trace. The details of these features (e.g. too much/left/knee flexion/in loading response) have been stored in the abnormalities data base.

Interpretation

The user interface may also allow the user to group abnormalities that are assumed to be related to some underlying impairment. Thus as shown in Figure 12 the user has grouped impairments in the pelvic rotation, hip rotation and foot progression traces together. The user interface may also allow data from other sources (e.g. clinical examination, medical imaging etc.) to be grouped with the abnormalities. Details of these groupings may be stored in an impairment database. The user may also be able to name the assumed impairment within this database.

In the embodiment shown in Figure 12 two abnormalities: (i) too much pelvic tilt throughout stance: and (ii) too much hip flexion throughout stance, have been grouped as related to Impairment 1 and the details of this have been stored in the impairments database.

Report generator

The user interface also allows generation of a report. This report might include a listing of the impairments that the user assumes are related to gait abnormalities and a visualisation

of one or more gait traces with abnormalities marked with various symbols superimposed on the traces. The report might also include comparison data, matching data and/or treatment data.

The report might be designed to be visualised on a computer screen or printed out. Figure 13 shows three pages of a report that has been generated by a particular embodiment of this invention. The first page lists the impairments, the second page depicts the abnormalities as symbols superimposed on the gait traces and the final page lists how which abnormalities are related to which impairments.

The user interface may be user interface automatically or user interface manually or user interface semi-automatically.

Module 4: Data mining module

The data mining module 709 allows the AIS database to be interrogated for other patients within the AIS database who have similar movement variables to the one being analysed. Similarity between two trials can be quantified by calculating the variable difference score between those two traces. Two traces that are similar will have a low difference scores for all variables and thus a low total difference score will represent two trials that are similar. Thus equations 2 and 3 would be modified and such that they reflect the differences between two ordinary traces rather than a trace and a representative trace. If the two traces are u_{it} and v_{it} then the total difference score (TDS) might be calculated using

$$TDS = \frac{\sum_{i=1}^{I} \sqrt{\frac{\sum_{t=0}^{n} (v_{it} - u_{it})^2}{(n+1)}}}{I} \qquad \text{Equation 8.}$$

A necessary, but not sufficient, precondition for the TDS to be similar is that the MAP for two traces be similar. If the MAPs are calculated and stored in the AIS database then this could be searched to find patients with MAPs similar to the individual being analysed.

This would allow rapid searching of large databases as a precursor to using an equation similar to Equation 8 to identify patients who are actually similar within this group. The degree of similarity can be specified by the clinician in terms of the maximum TDS that will be accepted as representing similar traces, this might have a value such as 20°, 15°, 10°, 9°, 8°, 7°, 6°, 5°, 4°, 3°, 2°, or 1°.

The TDS as calculated using an equation similar to Equation 8 can also be used to identify clusters of similar patients using techniques based on difference such as multi-dimensional scaling or self-organising maps.

A further extension of these techniques might be to create a MAP and MPS based on a reference dataset representing some group of individuals thought to be similar in some way. For example Rodda and Graham [1] have proposed four different categories of children with diplegic cerebral palsy based on their gait pattern. A reference group could be drawn from patients identified as being from a specific category. The MPS derived from this data would show how close the subject is to matching the gait pattern of patients in that particular category. Comparing MPS scores derived from patients from the different groups might allow allocation of patients to the different categories in either an absolute or fuzzy sense.

Module 5: Expert knowledge base

The expert knowledge base 710 stores data relating to expert clinicians' opinions of features of movement analysis and other clinical data. It is structured in such a manner that the opinions are related to a specific VDS on the MAP and the type of data viewed by the clinician on the GUI 708.

APPLICATIONS

Embodiments of the invention have numerous applications. For example, a MAP may be used in the assessment, diagnosis, prevention and/or treatment of a movement condition, especially when a MAP is compared with one or more other MAPs. For example, the use

of gait analysis data in planning complex orthopaedic surgery for children with cerebral palsy is now well established. Surgical planning without gait analysis leads to different recommendations and such surgery has unpredictable outcomes. In Australia and many other parts of the developed world, gait analysis is now seen as an essential pre-requisite for such complex surgery. Surgeons unfamiliar with gait analysis often find difficulty with the complexity of the data presented to them for interpretation. The use of a MAP of a patient having cerebral palsy can be used as a starting point to identify the major differences features of the patients gait pattern. Once these have been established the GUI of the AIS allow the surgeon to explore the data in a structured fashion and the expert knowledge base might help guide his or her interpretation of the data and clinical decision making. Using the search capabilities of the system to identify similar patients and establish what treatment they had received, and what the outcomes of that surgery where in terms of changes to the MAP will augment such decision making.

The National Centre for Medical Rehabilitative Research (NCMRR) of the US National Institutes of Health (NIH) has recognized and defined the role of movement analysis in enhancing the function of people with a much wider range of disabilities. Applications of gait analysis have been described in relation to surgical management of stroke, traumatic brain injury, osteoarthritis and spinal cord injury; for predicting fall risk in the elderly and for assessment of patients with Parkinson's disease. Hence, embodiments of the present invention have application in numerous movement conditions.

In addition, movement analysis is used in a growing number of sports institutes around the world; for example, movement analysis can be used to enhance the performance of an athlete. Thus a MAP of an under-achieving athlete can be compared with one or more MAPs from higher-achieving athletes, to thereby determine how to improve the performance of the under-achieving athlete.

Moreover, its potential for detecting lameness in horses has also been demonstrated. Accordingly the MAP of an injured animal can be compared with one or more MAPs of a normal animal in order to diagnose the gait-affecting condition of the injured animal and thus the best treatment for the injured animal.

In some embodiments the treatment may include designating a future time to repeat the movement analysis. This has particular application to monitoring the efficacy of a treatment.

Some embodiments may also be used in the design of a treatment for a particular movement condition. For example, the MAPs from a subject pre- and post-treatment may be compared to determine the efficacy of the treatment and hence determine whether the treatment is useful for other subjects with the same movement condition.

Thus, embodiments of the invention may also be used in the development of a treatment regimen. For example, subjects having a particular movement condition can be subjected to one of a plurality of possible treatments to thereby determine the most effective treatment for the particular movement condition.

Many modifications will be apparent to those skilled in the art without departing from the scope of the present invention as herein described with reference to the accompanying drawings.

REFERENCES

1. Rodda, J. and H.K. Graham, *Classification of gait patterns in spastic hemiplegia and spastic diplegia: a basis for a management algorithm.* Eur J Neurol, 2001. **8 Suppl 5**. 98-108.
2. Schutte, L.M., U. Narayanan, J.L. Stout, P. Selber, J.R. Gage, et al., *An index for quantifying deviations from normal gait.* Gait Posture, 2000. **11**. 25-31.

CLAIMS

1. A system for analysis and interpretation of movement data, comprising:
   (i) a variable difference score (VDS) generator for generating VDS data, representing variable difference scores, based on the difference between a first trace and a second trace, both traces relating to a selected movement variable of one or more animals; and
   (ii) a movement analysis profile (MAP) generator for generating MAP data, representing a movement analysis profile for the animal, based on at least two of the variable difference scores in the generated VDS data.

2. A system as claimed in claim 1, wherein the VDS data are generated using a root mean square difference between the traces.

3. A system as claimed in claim 1 or claim 2, wherein the VDS data are generated using the average absolute difference between the traces.

4. A system as claimed in any one of the preceding claims, wherein the VDS data are generated using an integral function of the difference between the traces.

5. A system as claimed in any one of the preceding claims, comprising a comparison generator for generating matching data representing one or more stored movement analysis profiles that match the movement profile.

6. A system as claimed in any one of the preceding claims, comprising a classifier for generating classification data representing groups of stored movement analysis profiles classified by similarities in stored movement analysis profiles of each group.

7. A system as claimed in any one of the preceding claims, comprising a treatment generator for generating treatment data indicative of an assessment, diagnosis and/or treatment based on clinical history data associated with the matching data.

8. A system as claimed in claim 5, wherein the matching data is useable for biometric identification.

9. A system as claimed in any of claims 1 to 8, wherein the first trace relates to a measurement of the selected movement variable in a first animal of the one or more animals, and the second trace relates to measurements of the selected movement variable averaged from a normal or healthy population of the one or more animals.

10. A system as claimed in any of claims 1 to 8, wherein the first trace relates to a measurement of the selected movement variable in a first animal of the one or more animals, and the second trace relates to measurements of the selected movement variable averaged from a population of the one or more animals having a movement condition.

11. A system as claimed in any of claims 1 to 8, wherein the first trace relates to a measurement of the selected movement variable on a first side of a first animal of the one or more animals, and the second trace relates to a measurement of the selected movement variable on a second side of the first animal.

12. A system as claimed in any one of the preceding claims, wherein the variable difference score (VDS), movement analysis profile (MAP), comparison data, matching data, and/or treatment data is displayed on a user interface.

13. A system as claimed in claim 12, wherein the variable difference score (VDS), movement analysis profile (MAP), comparison data, matching data, and/or treatment data is supplied to the user interface automatically or manually.

14. A system as claimed in claim 12 or claim 13, wherein the user interface allows differences to be represented by a number of symbols superimposed on a trace.

15. A system as claimed in any one of the preceding claims, further comprising a report generator for generating a report including a variable difference score (VDS), movement analysis profile (MAP), comparison data, matching data and/or treatment data.

16. A system as claimed in any one of the preceding claims, wherein the selected movement variable relates to a kinematic and/or kinetic variable(s).

17. A system as claimed in any one of the preceding claims, wherein each trace represents one or more cycles of a movement related to the selected movement variable.

18. A system as claimed in any one of the preceding claims, wherein one trace represents an average of traces from a plurality of sets of the selected movement variable.

19. A system as claimed in any one of the preceding claims, wherein the selected movement variable is related to gait.

20. A system as claimed in any one of the preceding claims, wherein the movement analysis profile (MAP) data are compared with a plurality of reference data.

21. A system of claim 20, wherein the plurality of reference data includes a plurality of different therapeutic regimens for a movement condition.

22. A system as claimed in any one of the preceding claims, comprising:
(i) one or more measurement databases;
(ii) a query server program that receives query profile data from one or more users of the system;
(iii) a database searching program that compares query data with the data in the one or more measurement databases; and

(iv) a report generator for generating a report comprising information representative of the degree of correlation, if any, between said query data and reference data.

23. A system of any one of the preceding claims for use in an assessment of a movement condition.

24. A system of any one of the preceding claims for use in a diagnosis of a movement condition.

25. A system of any one of the preceding claims for use in the treatment or prevention of a movement condition.

26. A system as claimed in claim 5, wherein the matching data is generated based on selected matching criteria.

27. A system as claimed in claim 26, wherein the matching criteria include:

(i) selected movement scores present in the movement profile and at least one of the stored movement profiles, used for matching; and

(ii) a selected degree of score similarity for each selected score.

28. A system as claimed in claim 27, wherein the selected degree of score similarity is 20°, 15°, 10°, 9°, 8°, 7°, 6°, 5°, 4°, 3°, 2°, or 1°.

29. A method for analysis and interpretation of movement data, including:

(i) generating VDS data, representing variable difference scores, based on the difference between a first trace and a second trace, both traces relating to a selected movement variable of one or more animals; and

(ii) generating MAP data, representing a movement profile for the animal, based on at least two of the variable difference scores in the generated VDS data.

30. A method as claimed in claim 29, wherein the VDS data are generated using a root mean square difference between the traces.

31. A method as claimed in claim 29 or claim 30, wherein the VDS data are generated using the average absolute difference between the traces.

32. A method as claimed in any one of claims 29 to 31, wherein the VDS data are generated using an integral function of the difference between the traces.

33. A method as claimed in any one of claim 29 to 32, comprising generating matching data representing one or more stored movement analysis profiles that match the movement profile.

34. A method as claimed in any one of claim 29 to 33, comprising generating classification data representing groups of stored movement analysis profiles classified by similarities in stored movement profiles of each group.

35. A method as claimed in any one of claims 29 to 34, comprising generating treatment data indicative of an assessment, diagnosis and/or treatment based on clinical history data associated with the matching data.

36. A method as claimed in claim 35, wherein the matching data is useable for biometric identification.

37. A method as claimed in any one of claims 29 to 36, wherein the first trace relates to a measurement of the selected movement variable in a first animal of the one or more animals, and the second trace relates to measurements of the selected movement variable averaged from a normal or healthy population of the one or more animals.

38. A method as claimed in any one of claims 29 to 36, wherein the first trace relates to a measurement of the selected movement variable in a first animal of the one or

more animals, and the second trace relates to measurements of the selected movement variable averaged from a population of the one or more animals having a movement condition.

39. A method as claimed in any one of claims 29 to 36, wherein the first trace relates to a measurement of the selected movement variable on a first side of a first animal of the one or more animals, and the second trace relates to a measurement of the selected movement variable on a second side of the first animal.

40. A method as claimed in any one of claims 29 to 39, wherein the variable difference score (VDS), movement analysis profile (MAP), comparison data, matching data, and/or treatment data is displayed on a user interface.

41. A method as claimed in claim 40, wherein the variable difference score (VDS), movement analysis profile (MAP), comparison data, matching data, and/or treatment data is supplied to the user interface automatically or manually.

42. A method as claimed in claim 40 or claim 41, wherein the user interface allows differences to be represented by a number of symbols superimposed on a trace.

43. A method as claimed in any one of claims 29 to 42, further comprising a report generator for generating a report including a variable difference score (VDS), movement analysis profile (MAP), comparison data, matching data and/or treatment data.

44. A method as claimed in any one of claims 29 to 43, wherein the selected movement variable relates to a kinematic and/or kinetic variable(s).

45. A method as claimed in any one of claims 29 to 44, wherein each trace represents one or more cycles of a movement related to the selected movement variable.

46. A method as claimed in any one of claims 29 to 45, wherein one trace represents an average of traces from a plurality of sets of the selected movement variable.

47. A method as claimed in any one of claims 29 to 46, wherein the selected movement variable is related to gait.

48. A method as claimed in any one of claims 29 to 47, wherein the movement analysis profile (MAP) data are compared with a plurality of reference data.

49. A method as claimed in claim 48, wherein the plurality of reference data includes a plurality of different therapeutic regimens for a movement condition.

50. A method of as claimed in any one of claims 29 to 49, comprising:
(i) receiving query profile data from one or more users;
(ii) comparing the query profile data with data in one or more measurement databases; and
(iii) generating reports comprising information representative of the degree of correlation, if any, between said query profile data and reference data.

51. A method of any one of the claims 29 to 50 for use in an assessment of a movement condition.

52. A method of any one of claims 29 to 51 for use in a diagnosis of a movement condition.

53. A method of any one of claims 29 to 52 for use in the treatment or prevention of a movement condition.

54. A method as claimed in claim 33, wherein the matching data is generated based on selected matching criteria.

55. A method as claimed in claim 54, wherein the matching criteria include:

(i) selected movement scores present in the movement profile and at least one of the stored movement profiles, used for matching; and

(ii) a selected degree of score similarity for each selected score.

56. A method as claimed in claim 47, wherein the selected degree of score similarity is 20°, 15°, 10°, 9°, 8°, 7°, 6°, 5°, 4°, 3°, 2°, or 1°.

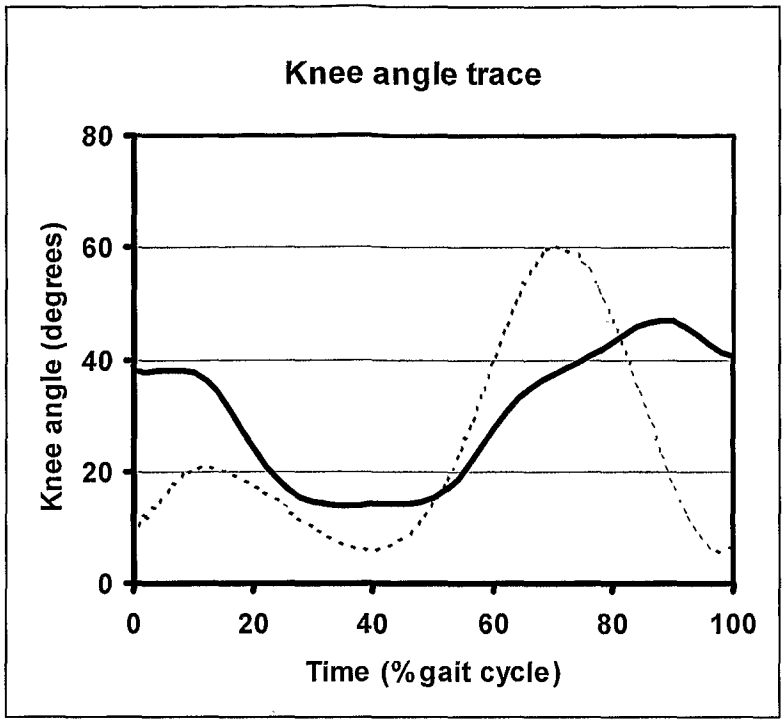

Knee angle trace
Knee angle (degrees)
80
60
40
20
0
0
20
40
60
80
100
Time (%gait cycle)

FIGURE 1

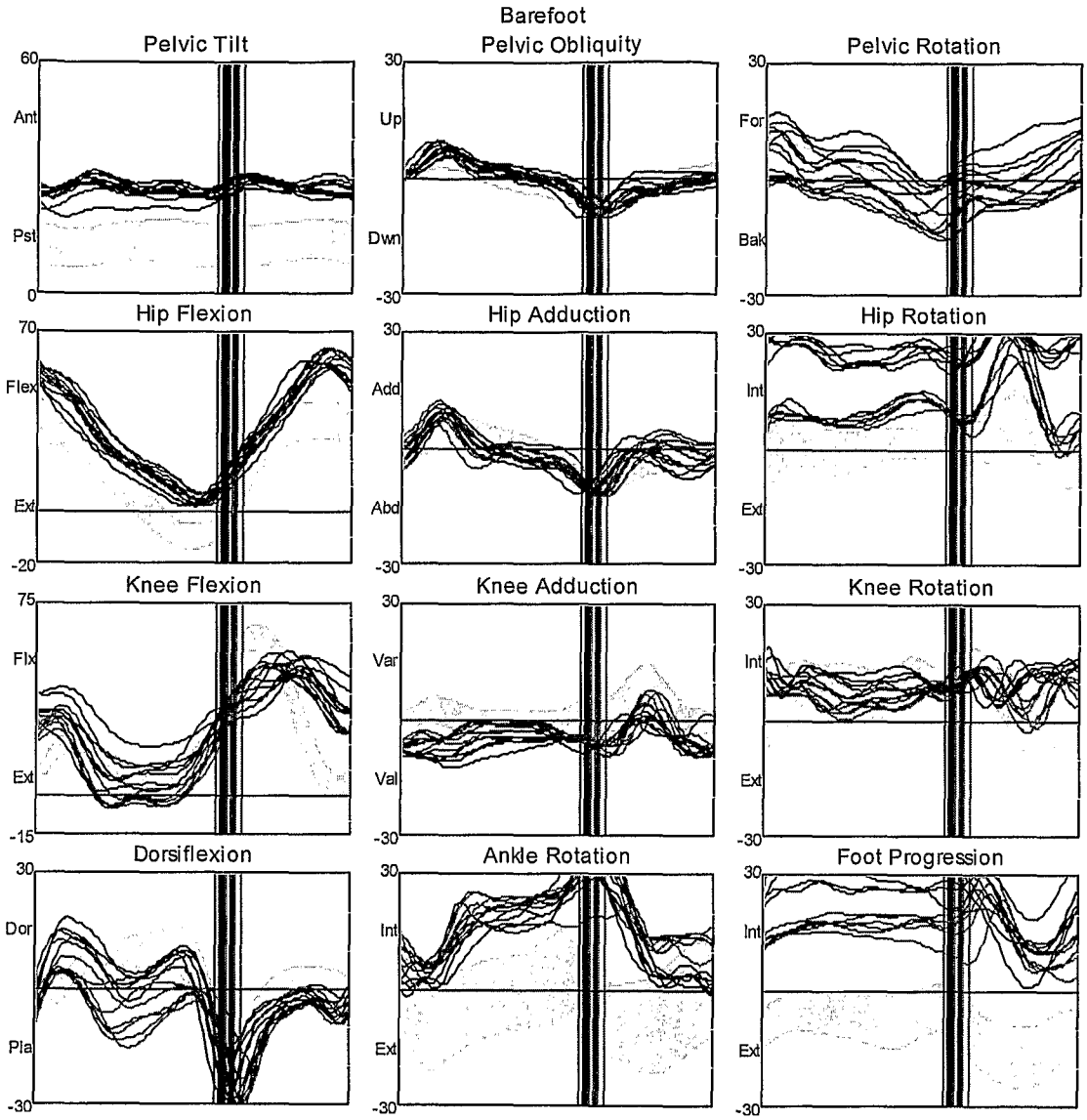

Barefoot
Pelvic Tilt
60
Ant
Pst
0
Pelvic Obliquity
30
Up
Dwn
-30
Pelvic Rotation
30
For
Bak
-30
Hip Flexion
70
Flex
Ext
-20
Hip Adduction
30
Add
Abd
-30
Hip Rotation
30
Int
Ext
-30
Knee Flexion
75
Flx
Ext
-15
Knee Adduction
30
Var
Val
-30
Knee Rotation
30
Int
Ext
-30
Dorsiflexion
30
Dor
Pla
-30
Ankle Rotation
30
Int
Ext
-30
Foot Progression
30
Int
Ext
-30

FIGURE 2

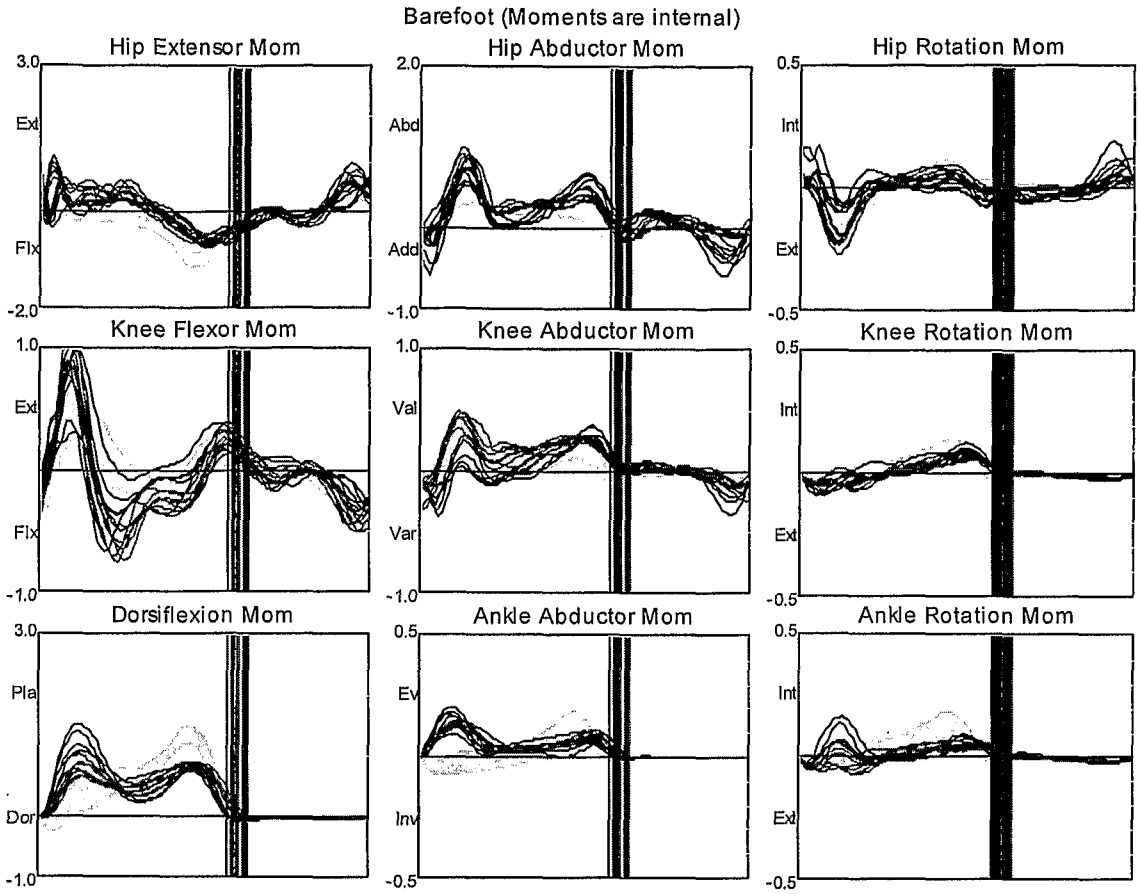

Barefoot (Moments are internal)
Hip Extensor Mom
3.0
Ext
Flx
-2.0
Hip Abductor Mom
2.0
Abd
Add
-1.0
Hip Rotation Mom
0.5
Int
Ext
-0.5
Knee Flexor Mom
1.0
Ext
Flx
-1.0
Knee Abductor Mom
1.0
Val
Var
-1.0
Knee Rotation Mom
0.5
Int
Ext
-0.5
Dorsiflexion Mom
3.0
Pla
Dor
-1.0
Ankle Abductor Mom
0.5
Ev
Inv
-0.5
Ankle Rotation Mom
0.5
Int
Ext
-0.5

FIGURE 3

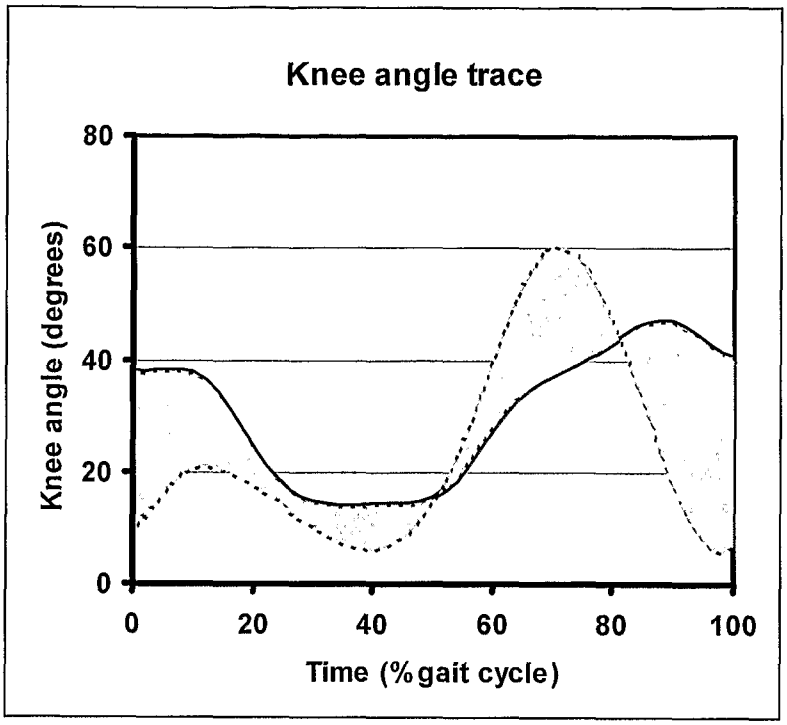

Knee angle trace
Knee angle (degrees)
80
60
40
20
0
0
20
40
60
80
100
Time (% gait cycle)

FIGURE 4

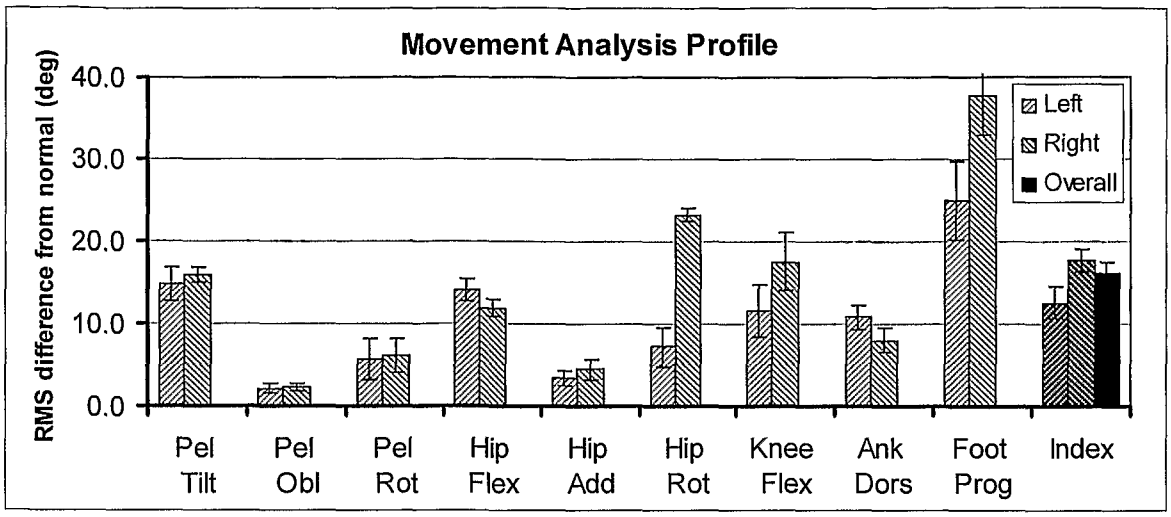


FIGURE 5

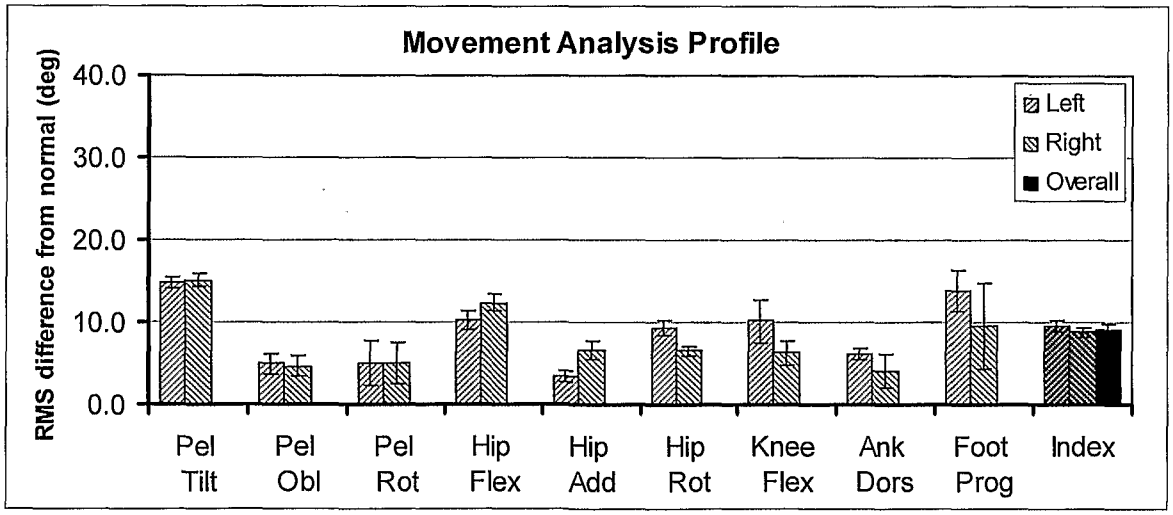


FIGURE 6

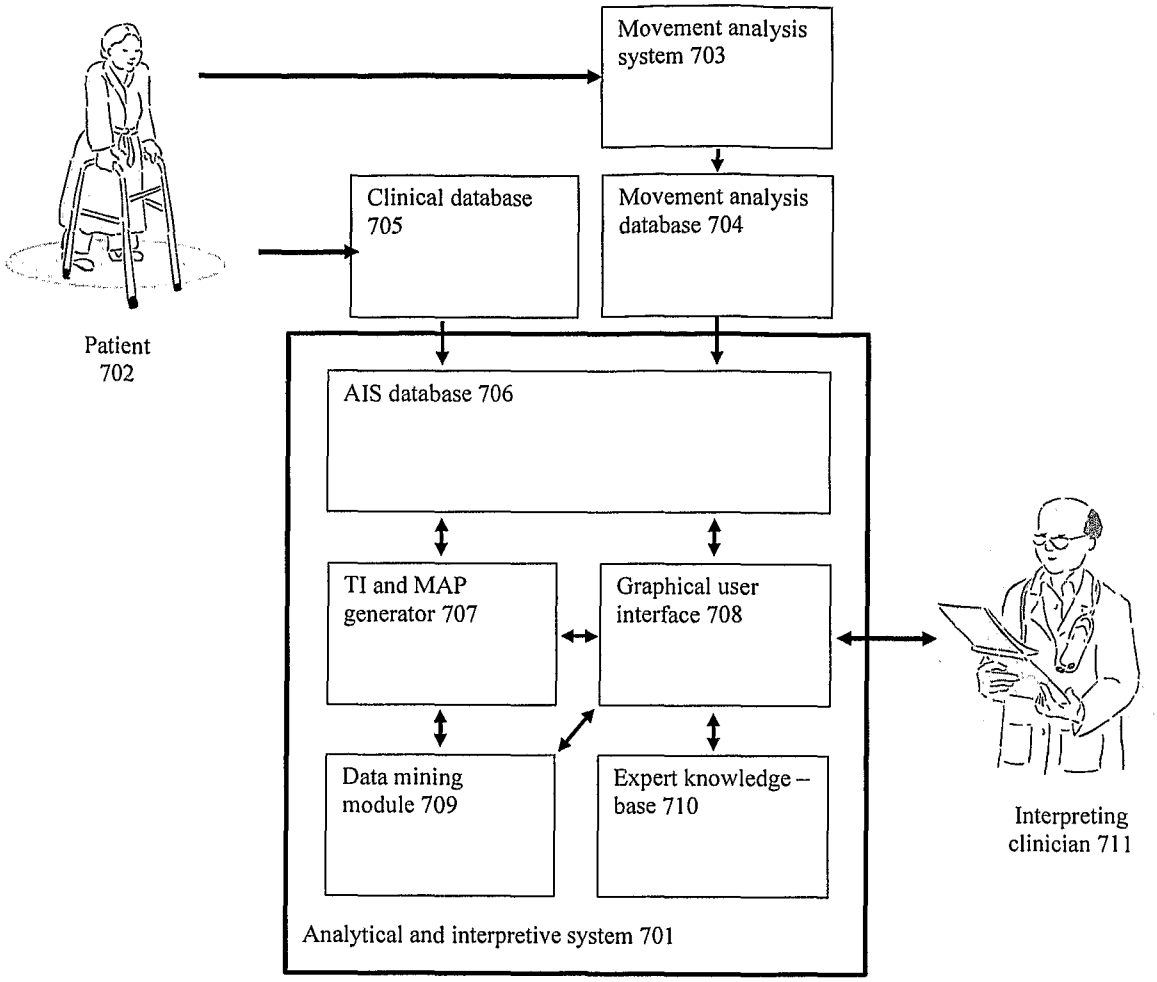

Movement analysis system 703
Clinical database 705
Movement analysis database 704
Patient 702
AIS database 706
TI and MAP generator 707
Graphical user interface 708
Data mining module 709
Expert knowledge – base 710
Interpreting clinician 711
Analytical and interpretive system 701

FIGURE 7

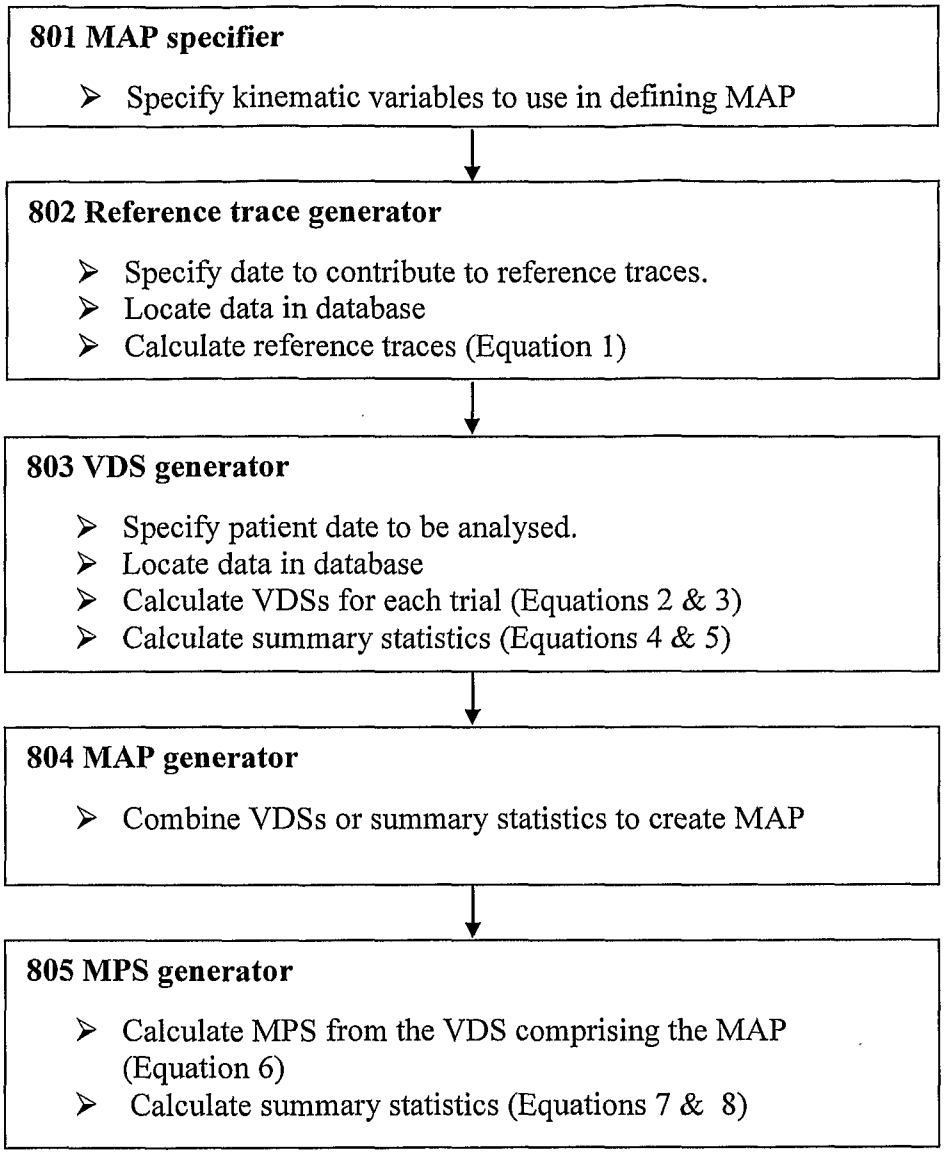

801 MAP specifier
Specify kinematic variables to use in defining MAP
802 Reference trace generator
Specify date to contribute to reference traces.
Locate data in database
Calculate reference traces (Equation 1)
803 VDS generator
Specify patient date to be analysed.
Locate data in database
Calculate VDSs for each trial (Equations 2 & 3)
Calculate summary statistics (Equations 4 & 5)
804 MAP generator
Combine VDSs or summary statistics to create MAP
805 MPS generator
Calculate MPS from the VDS comprising the MAP (Equation 6)
Calculate summary statistics (Equations 7 & 8)

FIGURE 8

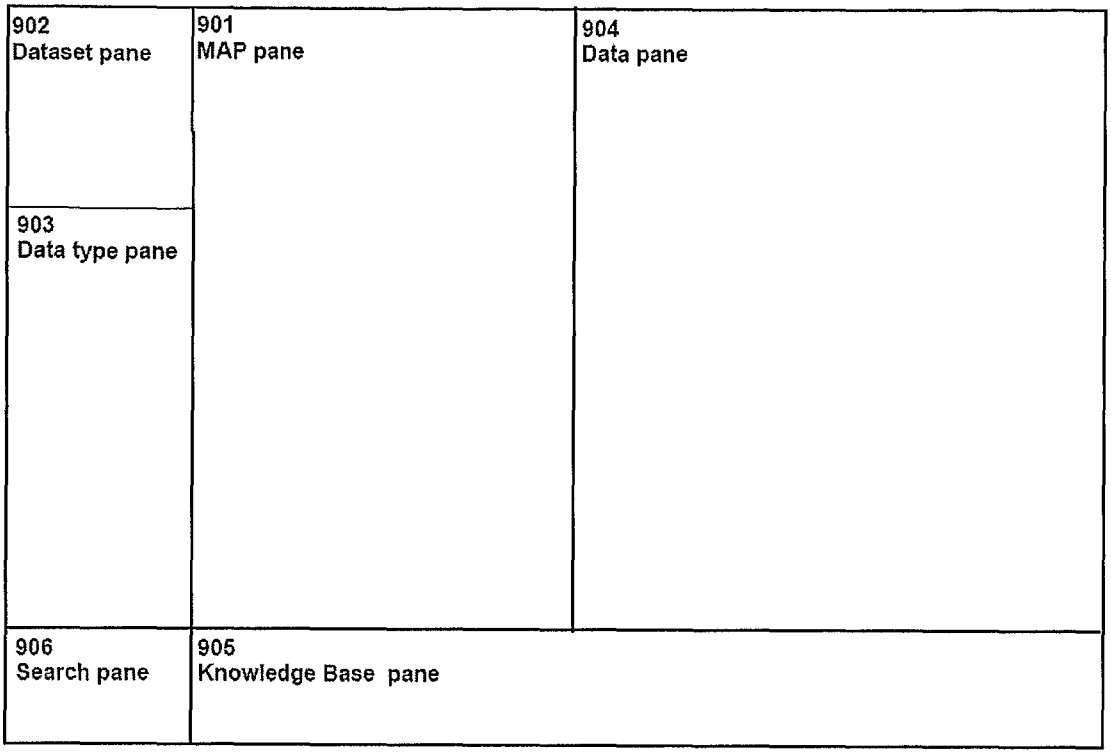

902
Dataset pane
901
MAP pane
904
Data pane
903
Data type pane
906
Search pane
905
Knowledge Base pane

FIGURE 9

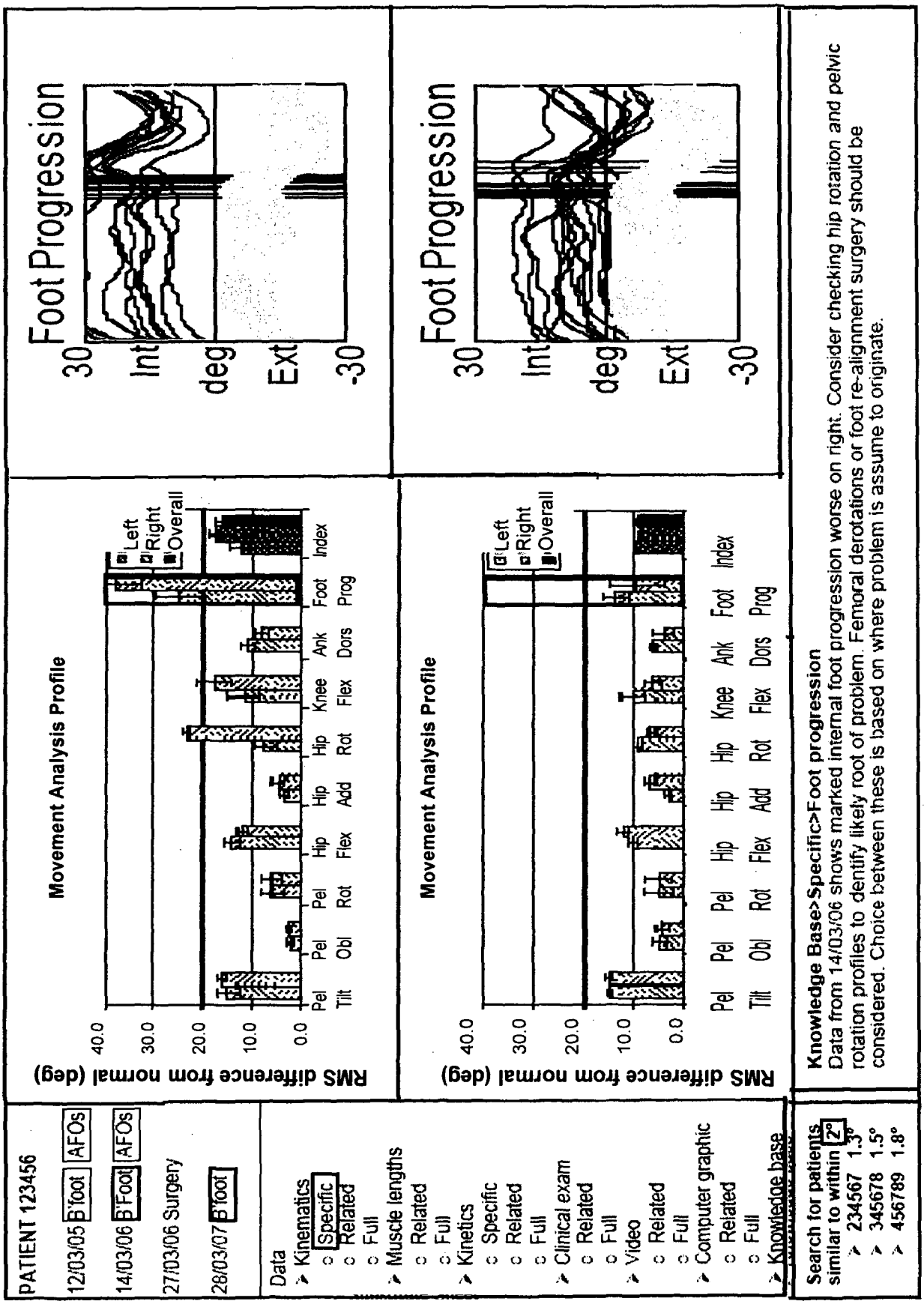

PATIENT 123456
12/03/05 B'foot AFOs
14/03/06 B'Foot AFOs
27/03/06 Surgery
28/03/07 B'foot
Data
Kinematics
Specific
Related
Full
Muscle lengths
Related
Full
Kinetics
Specific
Related
Full
Clinical exam
Related
Full
Video
Related
Full
Computer graphic
Related
Full
Knowledge base
Movement Analysis Profile
RMS difference from normal (deg)
40.0
30.0
20.0
10.0
0.0
Left
Right
Overall
Pel Tilt
Pel Obl
Pel Rot
Hip Flex
Hip Add
Hip Rot
Knee Flex
Ank Dors
Foot Prog
Index
Foot Progression
30
Int
deg
Ext
-30
Search for patients similar to within 2°
234567 1.3°
345678 1.5°
456789 1.8°
Knowledge Base>Specific>Foot progression
Data from 14/03/06 shows marked internal foot progression worse on right. Consider checking hip rotation and pelvic rotation profiles to dentify likely root of problem. Femoral derotations or foot re-alignment surgery should be considered. Choice between these is based on where problem is assume to originate.

FIGURE 10

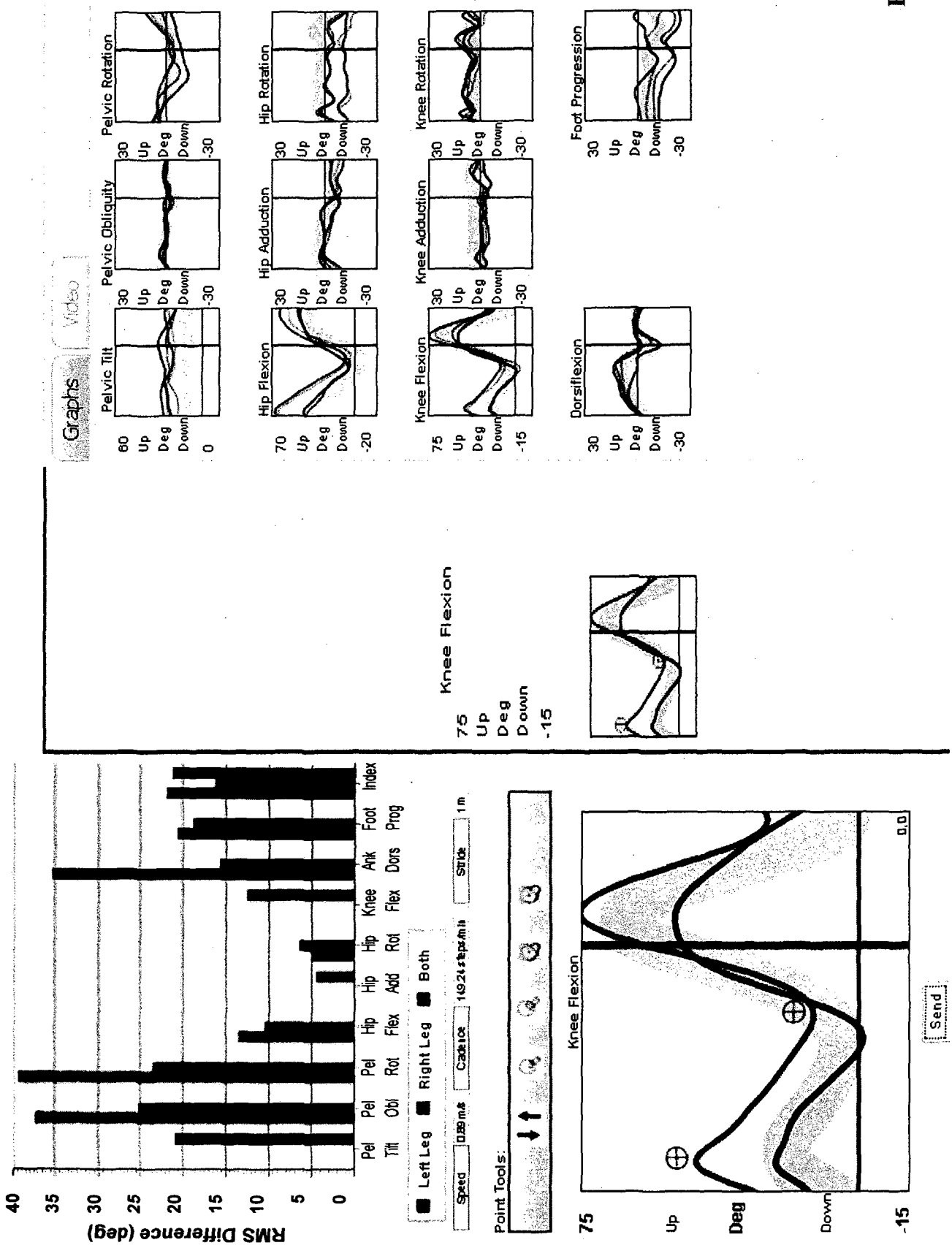

Graphs
Video
Pelvic Tilt
Pelvic Obliquity
Pelvic Rotation
Hip Flexion
Hip Adduction
Hip Rotation
Knee Flexion
Knee Adduction
Knee Rotation
Dorsiflexion
Foot Progression
Up
Deg
Down
RMS Difference (deg)
Left Leg
Right Leg
Both
Point Tools:
Speed
Cadence
Stride
Send

FIGURE 11

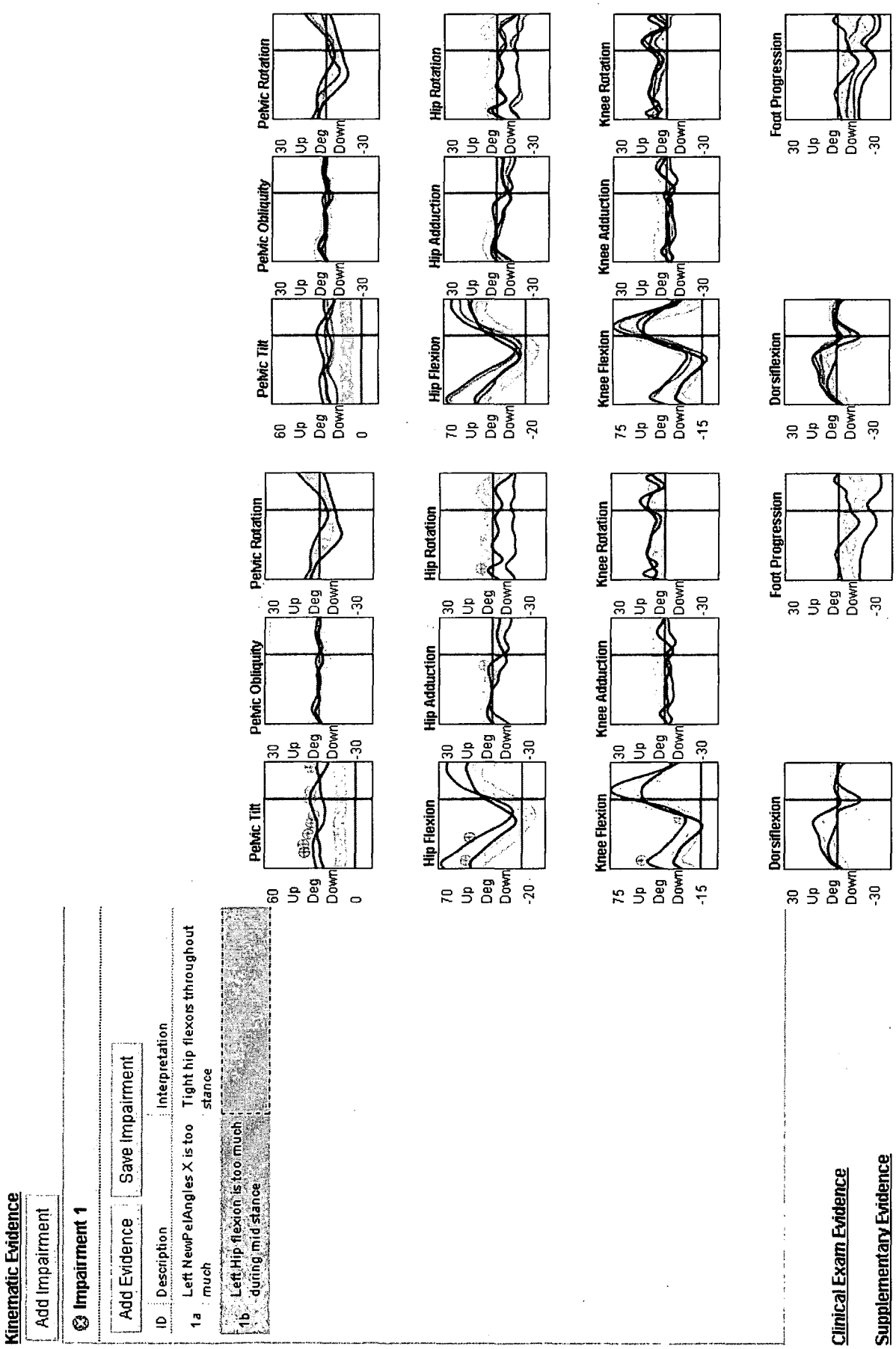

Kinematic Evidence
Add Impairment
Impairment 1
Add Evidence
Save Impairment
ID
Description
Interpretation
1a
Left NewPelAngles X is too much
Tight hip flexors throughout stance
1b
Left Hip flexion is too much during mid stance
Pelvic Tilt
Pelvic Obliquity
Pelvic Rotation
Hip Flexion
Hip Adduction
Hip Rotation
Knee Flexion
Knee Adduction
Knee Rotation
Dorsiflexion
Foot Progression
Up
Deg
Down
Clinical Exam Evidence
Supplementary Evidence

FIGURE 12

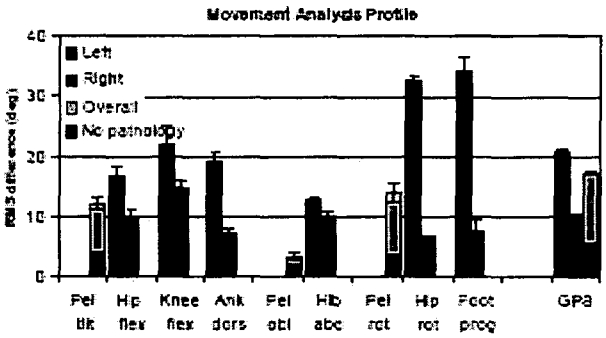
Gait Analysis Report: Joe Bloggs

Orientation:

Joe is an 8 year old boy with asymmetric diplegia, GMFCS II, FMS 555 who does not wear AFOs. His walking speed is 85% of normative data for his height. He has had no previous Botulinum Toxin or Surgery.

Joe exhibits abnormalities in the sagittal plane which are more pronounced on the left. He also has significant rotation issues on the left side.

Overall GPS is 17° with marked asymmetry between left and right sides.



Reason for referral:

Referring surgeon would like assessment with regard to single event multi-level surgery. Joe and Parents concerned he is up on his toes with increasing difficulty getting heel down.

Summary findings of gait analysis:

The gait analysis data suggest that the most likely contributors to Joe's gait pattern might be:

1. **Anteverted left femur**
2. **Tight left hip flexors**
3. **Tight left rectus femoris**
4. **Tight left triceps surae**
5. **Tight left hamstring**

And that important compensatory features might be:

1. **Right knee and ankle extension in mid-stance. This compensates for poor power generation during push-off and assists left foot clearance in swing.**

Other comments:

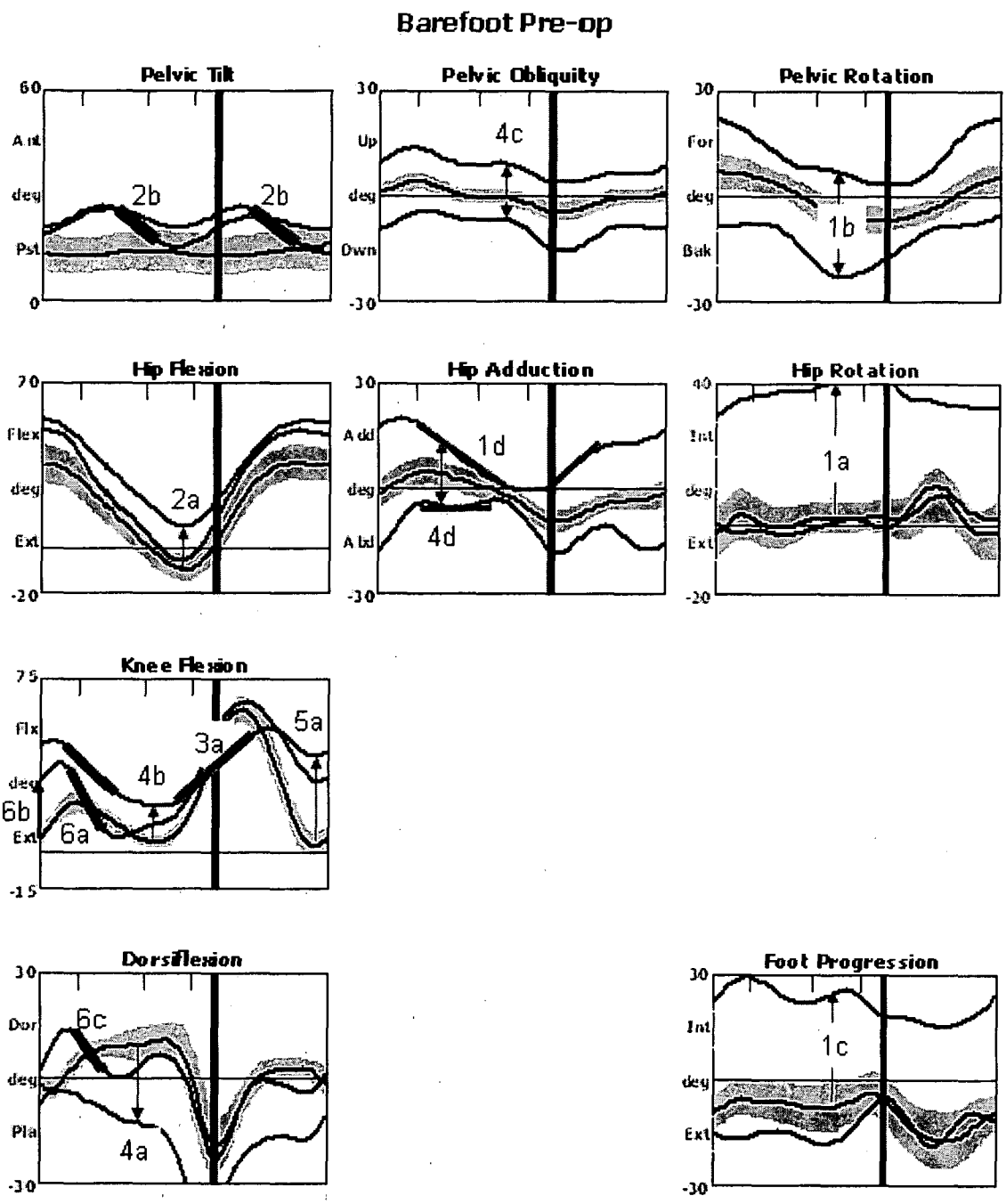
1. Hip radiology unremarkable.
2. Some evidence of tight hip adductors from clinical exam.
3. Joe refused to continue use of AFOs about six months prior to analysis.

Surgical recommendation (Prof H Kerr Graham):

Left derotation osteotomy, left psoas recession over brim of pelvis, left rectus femoris transfer (to gracilis), judicious left tendo-achilles lengthening (with soleal stripe if gastrocnemius still tight), left medial hamstring lengthening. No surgery required to right side but Botox to right calf and hamstrings might help in rehabilitation and gait re-training.

FIGURE 13a

Detailed Interpretation



Data Quality

Joe co-operated well in lab with both gait analysis and clinical exam.

Kinematic and kinetic traces all show good consistency. Representative trace chosen for analysis. No specific issues identified associated with marker placement or KAD alignments.

FIGURE 13b

Probable impairments

1. Left femur anteverted

Kinematic signs	1a	Left hip rotation internal throughout gait cycle.
	1b	Left pelvis back throughout gait cycle to compensate for internally rotated hip.
	1c	Internal foot progression throughout gait cycle (suggests pelvic positioning is not sufficient to compensate for hip rotation).
	1d	Pattern of hip adduction arising from need to flex and extend hip in direction of progression with pelvis held back on left.
Other evidence		Clinical exam. Left hip IR:50°, ER:0°, Anteversion 30°

2. Left hip flexors tight

Kinematic signs	2a	Left hip extension limited in late stance.
	2b	Left pelvis tilted anteriorly in mid stance. Tilting posteriorly in swing to improve step length.
Other evidence		Clinical exam. Left hip contracture: 10°

3. Left rectus femoris spasticity

Kinematic signs	3a	Knee flexion pattern through pre- and early swing.
Other evidence		Clinical exam. Left fast Duncan-Ely mildly positive. EMG: Over activity in Rectus Femoris throughout gait cycle.

4. Left triceps surae tight

Kinematic signs	4a	Left ankle plantarflexed throughout gait.
	4b	Left knee in late stance prevented from extending fully.
	4c	Left pelvis up throughout gait as consequence of functional leg length discrepancy from equinus ankle.
	4d	Left hip adducted, right hip abducted throughout gait.
Other evidence		Clinical exam. Left gastrocnemius range -10°, soleus range 0° Kinetics: Left ankle moment increased in early stance.

5. Left hamstrings tight

Kinematic signs	5a	Left Knee flexed in late swing and early stance.
Other evidence		Clinical exam. Popliteal angle: 60°, True popliteal: 45°, Dynamic 75° (but note that clinical exam of right hamstrings is similar)

Important compensations

1. Right knee and ankle extension in mid-stance

Kinematic signs	6a	Right knee extending rapidly in mid-stance
	6b	Right knee flexed at initial contact
	6c	Right ankle plantarflexion in mid-stance
Compensating for		This compensates for poor power generation during push-off and assists left foot clearance in swing
Other evidence		Kinetics: Vertical component of ground reaction shows increased first peak and decreased second peak. Kinetics: Knee, ankle and hip power generation in mid-stance.

Unexplained signs

None

FIGURE 13c

Term	Explanation	Defined by
Session	A specific occasion on which a specific individual attends for movement analysis.	Occasion (date and time) Individual
Trial	A specific episode of capturing movement analysis data. Typically several trials will be captured during a single session. This might include trials captured under different conditions (e.g. shod or bare-foot, with or without walking aids) and of different movements (e.g. walking, running, sit-to-stand).	Session Condition Movement
Parameter	A measurement specific to a session which does not vary over the course of a trial (e.g. age, bodymass, leg length)	Parameter name Session
Variable	A specific measurement which varies over the time course of a trial (e.g. joint angles and moments). Typically many variables will be captured for each trial.	Variable name Trial
Kinematics	Variables relating to movement of body parts (e.g. joint angles)	Variable name Trial
Kinetics	Variables relating to the forces or moments acting on body parts (e.g. joint moments)	Variable name Trial
Trace	The data describing how a variable changes over the course of a trail. The name reflects the fact that this will typically appear as a single line on a movement analysis graph.	Variable name Trial
Reference trace	The ensemble average of a number of traces (for a particular variable) used for comparative purposes. Often this will represent data from a population assumed to have no pathology affecting walking.	Variable name Trials

Table 1. General movement analysis terminology. (several terms used more loosely in general movement analysis are given these specific meanings in this document)

Term	Explanation	Defined by
Gait abnormality	A feature of a trace which differs from that of a reference trace representing a population assumed to have no pathology affecting walking.	
Impairment	A pathology of a patient which might give rise to one or more gait abnormalities.	
Variable difference score (VDS)	A summary statistic reflecting the difference between two traces (for the same variable). Often the second trace will be some reference trace and the variable score then represents the difference of a particular trace from that representing some reference population.	Variable name Trials
Movement analysis profile (MAP)	A set of two or more VDSs for the same trial. (This can be displayed in the form of a histogram. A histogram in a similar format can also be used to display the mean and standard deviations of a number of movement analysis profiles.)	Variable names Trial
Movement profile score (MPS)	A number being some combination of the variable scores comprising a particular movement analysis profile.	Trial

Table 2: Terminology developed to describe the invention

INTERNATIONAL SEARCH REPORT

International application No.
PCT/AU2009/000326

A. CLASSIFICATION OF SUBJECT MATTER

Int. Cl.

G06Q 50/00 (2006.01) ***A61B 5/11*** (2006.01) ***A61D 99/00*** (2006.01)

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
WPI, EPODOC , Google Scholar (gait, diagnose, animal, compare, differ, healthy)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2007/0000216 A1 (KATER et al.) 4 January 2007 – see whole document	1-56
X	US 2002/0055691 A1 (TESCH et al.) 9 May 2002 – see in particular the abstract and figures	1-56
A	WEISHAUPT et al. 'Assessment of gait irregularities in the horse: eye vs. gait analysis' Equine Veterinary Journal Suppl. 33 (2001) p135-140 – see whole document	1-56

☐ Further documents are listed in the continuation of Box C ☒ See patent family annex

* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier application or patent but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
02 April 2009	15 APR 2009
Name and mailing address of the ISA/AU AUSTRALIAN PATENT OFFICE PO BOX 200, WODEN ACT 2606, AUSTRALIA E-mail address: pct@ipaustralia.gov.au Facsimile No. +61 2 6283 7999	Authorized officer **TIM GILLETT** AUSTRALIAN PATENT OFFICE (ISO 9001 Quality Certified Service) Telephone No : +61 2 6222 3671

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.
PCT/AU2009/000326

This Annex lists the known "A" publication level patent family members relating to the patent documents cited in the above-mentioned international search report. The Australian Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

Patent Document Cited in Search Report		Patent Family Member					
US	2007000216	AU	2005265221	BR	PI0511360	CA	2572216
		CN	1980570	EP	1781087	MX	PA06014859
		WO	2006009959				
US	2002055691	AU	65117/01	AU	2005203075	CA	2410533
		EP	1284649	MX	PA02011927	NZ	522806
		US	6699207	US	2004158174	WO	0191640

Due to data integration issues this family listing may not include 10 digit Australian applications filed since May 2001.

END OF ANNEX