THE FUNCTIONAL SIGNIFICANCE OF MOTION ANALYSIS

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Walking is a pattern of limb motion which advances the body along the desired path of progression. Motion analysis defines the quality of this function in both normal and abnormal situations. Thus, this technic would appear to be the basic gait measurement, yet few clinicians seek this information. Do their eyes tell them enough or are the gait measurements not presented in a meaningful manner? Experience says the latter is true. This seems paradoxical as most laboratories not only provide graphs of each joint's actions throughout the gait cycle but also include stick figure diagrams. What is lacking? It is the clinical interpretation of the gait measurements. Neither graphs nor diagrams speak in terms which can be applied directly to the patient. Only the few orthopedists who have added gait analysis to their specialty make the translation easily.

A functional interpretation of the motion data relates the patient's performance to the task required of the limb during walking. There are six distinct gait phases[3]. Each includes a specific pattern of motion (and muscle function) which must be accomplished if the person is to proceed in a normal manner. Deficits displayed by the patients represent either reduced joint motion or inappropriate muscle action. The motion analysis report must relate to these events.

For the events during stance, phase timing can be deduced from the person's foot support pattern. Each sequence represents a functional relationship between body weight alignment and the supporting limb. Floor contact begins the initial double stance period, a loading response interval when body weight is behind the supporting foot. Contralateral toe off signals the onset of single stance. This encompasses two gait phases: mid and terminal stance. During mid-stance the body weight line is basically vertical as it advances across the foot from heel to forefoot. In terminal stance the body falls forward of the supporting foot. Onset of this phase is designated by heel rise while the limb still is in single stance. Contralateral foot contact begins terminal double stance. Throughout this pre-swing phase the limb is rapidly unloaded and prepared for its forward swing. Following toe-off, the limb advances itself by three distinct patterns of action which divide the swing phase into three equal intervals. Initial, mid and terminal swing.

The significance of relating motion data to these functional phases can best be displayed in this short paper by two clinical examples.

A recent Boston study[1] of patients walking ability following total ankle arthroplasty included photographic motion analysis, stride measurements, determination of pain relief and muscle testing. The authors found the patient used the same 20^0 arc of ankle motion as did their normal subjects. Also, there was good pain relief. Two adverse findings were a gait velocity only 46% of normal and weak calf musculature.

Phasic analysis of the published motion data provided a logical basis for the patient's slow velocity. The critical findings were that their progress towards dorsiflexion continued well into the middle of terminal double stance (pre-swing phase) and only a zero degree position was reached. This was in marked contrast with the normal record which showed attainment of 10^0 dorsiflexion in terminal stance and subsequent reversal into plantar flexion during pre-swing. These differences are consistant with calf muscle weakness.

The relative plantar flexed posture the patient maintained throughout the early part of stance confirmed this interpretation. Floor contact was made with the ankle plantarflexed about 15^0, followed by another 10^0 in response to heel strike. Then the ankle progressed towards dorsiflexion in a manner similar to normal function but at a much slower rate. Hence throughout the entire stance period the ankle remained more plantar flexed than normal. By keeping the tibia angled posteriorly an unacceptable demand on the weak calf muscles was avoided but it also slowed the patient's rate of travel.

Hence the standard interpretation of the motion data noted that the artifical ankle joint provided the normal arc of motion used in walking. By adding a phasic interpretation the reason why the patient could not effectively use their newly acquired ankle mobility was identified. These findings also explained why a similar group of patients with ankle fusions walked better. Their average gait velocity was 73% normal[2].

A similar paradox can be found at the knee. Approximately half of the stroke patients who drag their toe at the onset of swing register by motion analysis an arc of knee flexion (45 to 50^0) which should have been sufficient to avoid this complication. This data conflict can be clarified by phasic interpretation of the knee's motion pattern.

The patient's peak knee flexion occurs in mid-swing rather than in the initial third of the phase. Thus, the needed arc of knee flexion is accomplished too late in the gait cycle to lift the trailing foot. The reason for this motion delay lies in their preceeding, pre-swing, gait phase. Either the knee still is fully extended or flexion is extremely limited. Without the passive arc usually attained at this time the amount of active knee flexion that accompanies hip flexion on the initiation of swing remains insufficient to avoid a toe drag.

This problem also is common in geriatric amputee patients. Often they fail to roll far enough forward over their prosthetic foot to stimulate pre-swing knee flexion. An overly stiff toe-break is a frequent cause of this problem.

The purpose of these two examples was to demonstrate the type of functional analysis that is needed to answer the clinicians questions. They seek not only a definition of how the patient performs but also why. This means that analysis of motion data must proceed as a sequence of orderly steps. First is to define the arcs of motion and the timing of their peaks. Secondly is to note the postures accomplished in each gait phase and relate these to normal performance. Third is to present these data in functional, i.e., clinical terms.

For timing accuracy the motion recording must be accomplished by some type of foot support identification system such as foot switches. Also, the analysist must have a clear understanding of the patterns of joint motion and muscle action which constitutes normal walking. Types of sbustitution introduced by the different fomrs of pathology also must be known. Interpretation of motion data thus is a comprehensive task.

REFERENCES

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