A CLINICAL APPROACH TO THE STUDY OF HUMAN LOCOMOTION

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Abstract

The purpose of this paper is to focus attention on the clinical requirements of human locomotion studies, and to demonstrate from the results of a pilot study that technology has advanced sufficiently to exploit such studies to clinical advantage. A system to satisfy the clinician is being evolved at the Shriners Hospital in Winnipeg. Modern electronic data acquisition and digital processing equipment and techniques will be employed to handle the kinematic, temporal and EMG data.

Introduction

Over the past seventy years there have been several major studies of human locomotion. These valuable investigations have formed a basis of normal human gait, but were limited to a small number of subjects and an incomplete number of parameters. These compromises were forced on the investigators, mainly because of the tremendously high volume of data. However, modern technology has now advanced sufficiently to overcome this problem, and to permit exploitation of locomotion studies to clinical advantage.

The clinical objectives of the study are:

(a) to obtain a precise and complete definition of normal and abnormal gait.

(b) to extract the pertinent information which will aid in:

(i) the planning and assessment of tendon and muscle transfers.

(ii) the establishment of criteria for use in the design, development and assessment of new orthotic and prosthetic devices.

To achieve clinical success certain overriding criteria must be satisfied, which include:

(a) Active participation of clinical and rehabilitative staff.

(b) A quick turn-around between data collection, and the time it is available for clinical assessment.

(c) A minimum of time required to collect the data from the patient, who, for most natural gait, should be encumbered with a minimum of attachments.

System Description

The system under evolution at the Locomotion Laboratory at the Shriners Hospital, Winnipeg, is shown in Figure #1. It is to be noted that all data is to be recorded on magnetic tape prior to processing in a digital computer. As the patient proceeds along a walkway he is tracked by two TV cameras, one from the side, the other from the front. These two video signals are split, displayed on a monitor, and recorded on the video channel of the video tape recorder. Electromyographic signals, suitable conditioned, are frequency modulated on IRIG subcarrier and transmitted on a single FM transmitter. The received signal is demodulated and the total audio subcarrier signal is recorded on an audio channel of the video tape recorder. For quality control purposes, as the record is being taken, the EMG signals are separated by their respective subcarrier discriminators and displayed on a 12 channel monitor.

EMG Analysis

Detailed analysis of the function of the lower extremities in man is made possible by studying the precise activity of muscles and relating this activity in time with motions of the body and limb segments. Historically, the study of muscle activity was laborious and dependent on crude clinical evaluation. More recently, electromyography has been used to ascertain the precise phasic activity of individual muscles, muscle groups and gross degrees of activity in a muscle at a specific time.

Detailed investigation of human locomotion by Greenlaw (1) has shown the phasic and gross quantitative activity of 17 hip muscles in 15 human subjects using the technique of indwelling fine-wire electrodes and recorded on ultraviolet light sensitive paper. Activity of up to 10 muscles was recorded simultaneously. The mean activity in one group of muscles (abductors) about the hip joint in 15 subjects for one complete walking cycle is depicted in graphic form in Fig.#2. This information is further interpreted with respect to the per cent of the walking cycle in order to define the function of the muscles for the various periods of stance and swing phases of walking. However, this information must be correlated with the events of motion of the various corresponding skeletal segments to be of optimum clinical value, and it is the latter information that requires considerable improvement.

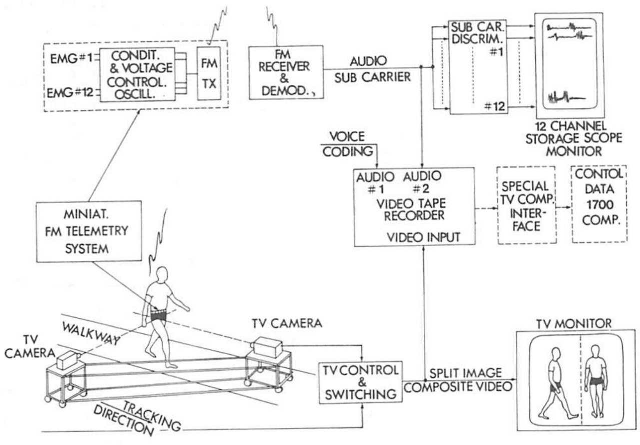
Kinematic and Temporal Factors

These measurements are concerned with the displacements, velocities, etc. associated with the motion of the segments of the lower extremity. Markers attached at suitable anatomical locations on the surface of the body define the position of the skeletal segments. Figure 3 illustrates the television recording of a subject on the walkway with reflective markers attached. The walkway consists of nothing more than a reflective background to give a spatial reference for calculation of absolute coordinates of motion in the forward (x) and vertical (y) directions.

This background is coded in binary format, which increases in the forward direction of motion along the length of a 35 foot walkway. It is intended to record data for a minimum of 5 strides. Temporal information of heel contact and toe off will be obtained from the foot markers.

Computer Processing of Data

The conversion and processing of the video data involves high data rates (about 1.5 million bits/sec) for about 10 seconds. This conversion is accomplished by specially designed television/computer interface to a CDC 1700 computer through a direct access (digital) channel. A typical image in the process of conversion is seen in Figure 4, where the sampling "window" depicts the area of the TV image being converted. A 118x212 matrix is being digitized with one bit intensity resolution at a field rate of 60/second. Computer programs have now been written to recognize the background and the markers, and to calculate the absolute coordinates of each marker



LOCOMOTION STUDIES DATA ACQUISITION SYSTEM

Figure #1

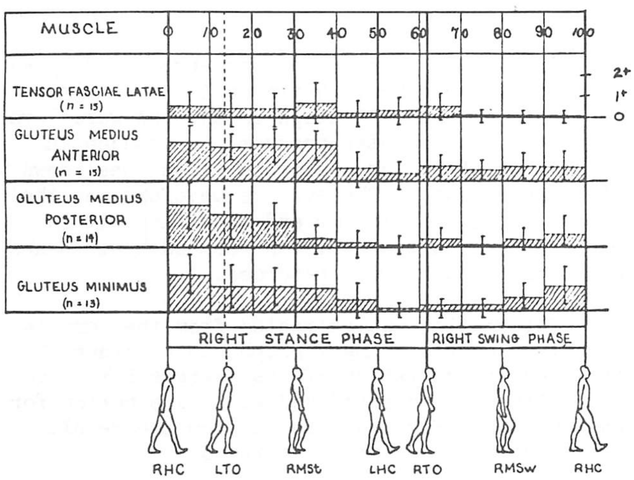


Figure #2 Phasic activity of abductor muscles during one walking cycle.

One sample of each channel of conditioned EMG will be taken each time a TV field is converted. It should be noted that the reduced data is still high in volume (about 30K-16 bit words for a 10 second run).

References

(1) Function of muscles above the hip during normal level walking; and electromyographic and biomechanical study. R. K. Greenlaw, Ph D. Thesis, Queens University 1970.

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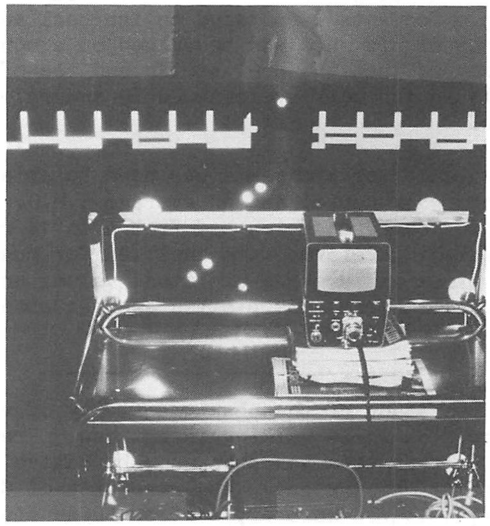

Figure #3 Subject on walkway during data collection.

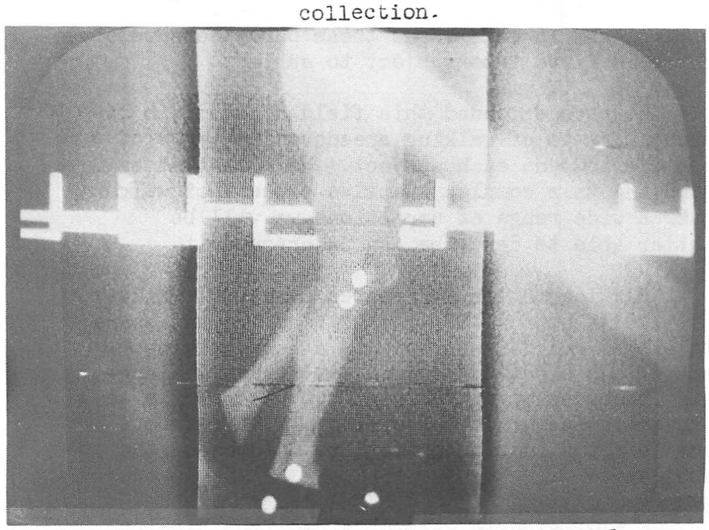

Figure #4 Sample "window" showing area of T V image being converted into digital format.