CLINICAL GAIT ANALYZER

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ABSTRACT

This report describes the development of a clinical gait analyzer designed to measure the patient's velocity and single limb support time. The unit can be used in any environment that has at least a 10 m. walkway.

The memory unit has been designed and a prototype is ready for testing. A preliminary design of the calculator-display unit has been completed. Gait tests with 33 normal subjects were conducted to establish a normal single limb support time (single stance time) velocity curve.

DEVELOPMENT OF A GAIT ANALYZER

Measurement of gait provides an objective correlation between functional capacity and physical impairment. In amputees the significance in walking ability of the level of amputation and a vascular etiology for the impairment has been clearly demonstrated. The technique also has been used to define the functional level of patients at the time of their total hip replacement surgery and their postoperative gains.

To obtain this information the patient is outfitted with a pair of insole foot switches and then asked to walk along measured walkway while a timed recording is made. Both customary and fast gait are recorded.

Each insole contains a cluster of contact closing switches in the areas of the heel, first and fifth metatarsal heads, and the great toe. Their output is electronically coded to indicate which areas of the foot are contacting the ground. The normal sequence (heel, heel and fifth, flat foot, and forefoot) is displayed as a staircase. Unusual support patterns (fifth or first only or heel and first) are identified as half steps. A 16 m. walkway provides a starting and stopping area at each end of the middle 6 m. segment that is defined by photoelectric cells. This middle interval is used for data analysis. All data are transmitted via telemetry to the recording system. The output is a printed record of the two foot-switch patterns and the photoelectric signals designating the 6 m. area.
These records are interpreted by manual measurement of the stance and swing intervals and their subdivisions. With appropriate calculation one can identify velocity, cadence, stride length, gait cycle duration, single stance, double stance, swing-stance ratio, and the pattern of foot support. Correlation of these data with the clinical course of patients with total hip joint replacement has indicated some factors are more representative than others.

Velocity is the product of cadence and stride length. With only infrequent exception all three factors have been found to change in the same direction as the patient's status changes. So velocity can be considered representative of this group of data and indicative of his general mobility.

Double stance time, while denoting a period of weight exchange, fails to identify the relative contribution of the two limbs. In contrast, single stance is an interval of total weight acceptance and hence a clinically important period. However, its absolute duration is not meaningful as the very slow walker who seemingly only briefly stands on his limb may use as much time as a speedier person with a proportionally much longer stance interval. When single stance time is correlated with the person's velocity, it has clinical significance.

Swing-stance ratio also was found not to be representative of pathology. In patients with unilateral hip disease, that limb maintains a virtually normal ratio while the sound side may alter its swing and stance times drastically to accommodate for contralateral impairment. Patients having bilateral disease may display normal ratios even though all intervals are prolonged. For these reasons single stance time as a percent of normal for the measured velocity has been selected as a clinical index of the limb's weight-bearing tolerance.

The limitation to adoption of this system in the clinics has been the chore of making the manual measurements and calculations. This act is too foreign to the routine working of the clinical staff. Hence the current objective is to develop a gait calculator. A gait analyzer (clinical gait analyzer) is being designed to automatically identify the patient's velocity and percent of normal single stance time.

The clinical gait analyzer will consist of a memory unit, which stores the data obtained from the patient, and a calculator display unit, which calculates the patient's velocity and percent of single stance time, displaying the results.

The memory unit will be a small electronic package worn on the belt of the patient (Fig. 1). Data will be fed into the memory unit from foot switches worn by the patient and from a switch operated by the person running the test. The operator's switch will identify the beginning and end of a measured walkway for purposes of determining the patient's average velocity.
FIGURE 1.—Artist's concept of patient walking with clinical gait analyzer (memory unit).

FIGURE 2.—Block diagram of clinical gait analyzer (memory unit).
The left and right foot switch data will be obtained by detecting the absence of any foot-switch closures which indicates the limb is in swing phase. This gives a measure of single stance time since swing equals contralateral single stance. These data will be fed into signal processing logic circuits (Fig. 2) which delay the data 100 ms. to eliminate unwanted short duration (less than 100 ms.) artifact signals. These might occur as a result of a sticking foot switch or a tow scuff during swing phase. The processed foot-switch signals will be fed simultaneously into three logic circuits, a stride counter, a run error detector, and a single stance control. The single stance control logic circuits will restrict the recordings to those obtained from the first three strides that follow the “start of run” signal.

The stride counter will count the strides and control the single stance control logic. If three strides are completed prior to the end of the run, the stride count complete indicator will come on. If this indicator does not come on, the person conducting the test knows the single stance data is invalid due to an insufficient number of strides being completed during the test.

The run error detecting logic will determine whether a proper step sequence has occurred. Specifically, left initial stance must follow right terminal stance and conversely, right initial stance must follow left terminal stance. If this sequence does not occur, the run is invalid due to an improper step sequence, and an indicator will come on. Situations which would cause this condition are hopping, resting on the swing side during swing, a long toe scuff during swing, a broken foot-switch wire, etc.

The start-stop run control logic will allow data to be recorded only during the time the patient is walking through the measured walkway. The clock will generate pulses at a fixed repetition rate. These pulses will be counted and stored in the memories providing a measure of the single stance times and the velocity.

The calculator display unit (Fig. 3) will have a memory into which are stored the single stance times for normals as a function of velocity. When the memory unit is plugged into the calculator display unit and the velocity button is pushed, the patient’s velocity will be fed into the calculator and a normal single stance time will be selected for that velocity from the stored data. The patient’s average single stance time for three strides will be calculated and the ratio of this value to the normal single stance time will be computed and displayed (as a percentage) on the digital display.
FIGURE 3.—Artist's concept of clinical gait analyzer.