Prosthetics and Orthotics International, 1988, 12, 46–49

A conductive walkway system for measurement of temporal and distance parameters of gait

C. RIGAS

Department of Medical Physics, University of Ioannina, Greece

Abstract

This work describes a system used in gait analysis studies. The system is based on a continuous conductive walkway, made of ordinary aluminium foil. It measures the length of each single step, as well as those temporal parameters of gait that relate to the position of the feet on or off the ground. The system is relatively simple and inexpensive to build and run. Data collection and reduction is not excessively time consuming and does not require particularly high training of the operator. In conjunction with a microcomputer the system could be suitable for routine testing in the clinical environment. The present setup has been tested and proved consistent and sufficiently accurate.

Introduction

A variety of gait analysis systems has been developed around the world. They can be classified according to the parameters they measure and the technique they use to measure the specific parameters. A detailed description of human locomotion calls for the employment of rather sophisticated systems. These systems are costly and require relatively high expert knowledge by the operator. On the other hand, more often than not, they are inconvenient, from the point of view of the patient, and time consuming, from the point of view of the data analyst. For these reasons such systems are restricted to the major gait analysis laboratories. Smaller units, particularly those attached to the clinical environment, have to adopt a compromise between the fullest possible gait picture on the one hand, and cost, work man-hours, and patient convenience on the other. Some of the systems that have been used in gait analysis so far do provide a useful compromise. One of them is the conductive walkway system, which records the temporal parameters of gait that relate to the position of the feet on or off the ground. Such a system was described by Drillis (1958) and later, in a developed version, by Gardner and Murray (1975). Basically it consists of a conductive walkway connected to one of the poles of a battery. Electrodes attached to the soles of the shoes are connected, through appropriate resistors, to the other pole. The system electrode-walkway works like an ON-OFF switch. The magnitude of the current through the circuit corresponds to the combination of electrodes that make contact with the walkway. A conductive walkway, split longitudinally, was also used by Cheung et al (1983). In their application the two sides of the walkway acted as the contacts of an ON-OFF switch. Electrodes placed at the soles of the shoes were short-circuited. Thus the circuit was ON only during the double support.

All systems based on the conductive walkway principle measure only temporal parameters of gait, such as cycle duration, duration of single and double support and duration of swing of each leg. In conjunction with a dual light beam/photocell system it can provide the mean step length.

The magnitude of each individual single step length is an important parameter of gait. In order to determine its value various methods can be used. Wall et al (1978) used a walkway consisting of a series of parallel conducting rods connected between resistors that formed a linear array. Electrodes positioned on the soles of the shoes short-circuited two adjacent rods and produced an electric signal proportional to the position of the shorting point along the walkway. An array of conducting strips was also

All correspondence to be addressed to Dr. C. Rigas, Department of Medical Physics, School of Medicine, University of Ioannina, Greece.

employed in a system developed by Gifford and Hutton (1980). Gabel et al (1979), described a walkway consisting of an array of flat linear pressure sensitive switches. Draganich et al (1980) produced a sheet transducer consisting of a matrix of 7168 switches. Their status (ON or OFF) defined the weight bearing pattern of the supporting foot. In principle this system could be used to measure step length.

The production of systems that can provide single step length, like those described above, imposes some difficulties, especially when long walkways are required. The purpose of this work was to produce a simpler system that could provide single step length, as well as the temporal parameters of gait that relate to the position of the feet on or off the ground.

System description

The system consists of a continuous conductive walkway, 22 m long, 1 m wide. The walkway is connected to one side of an electronic circuit. The other side of the circuit is connected to electrodes applied to the soles of the shoes. The system can be divided in two sub-systems having in common only the walkway. One of the sub-systems measures step length and the other the temporal parameters of gait.

In general terms the system can be described as follows: One end of a conductive walkway is raised to a potential voltage (V) relative to the other. Then electrodes positioned on the soles of the shoes measure the potential of the specific point of the walkway, where they make contact, relative to the end of the walkway. As the voltage gradient is nearly linear along the walkway (disregarding points close to its ends), the potential difference sensed by the electrodes is proportional to their distance along the long axis of the walkway. Instead of actually measuring the potential difference sensed by electrodes on the shoes, the signals from the electrodes are input to a differential amplifier. The amplifier is balanced when the distance of the electrodes along the long axis of the walkway is zero. Then when the electrodes are positioned anywhere along the walkway, the output from the differential amplifier is proportional to the distance of the electrodes along the axis of the walkway, or in other words proportional to the step length. A block diagram of the system is shown in Figure 1. The diagram shows both the sub-systems into which the whole system can be broken, the step length measuring system and the temporal parameters measuring system. The set-up basically consists of the conductive walkway, a generator, two

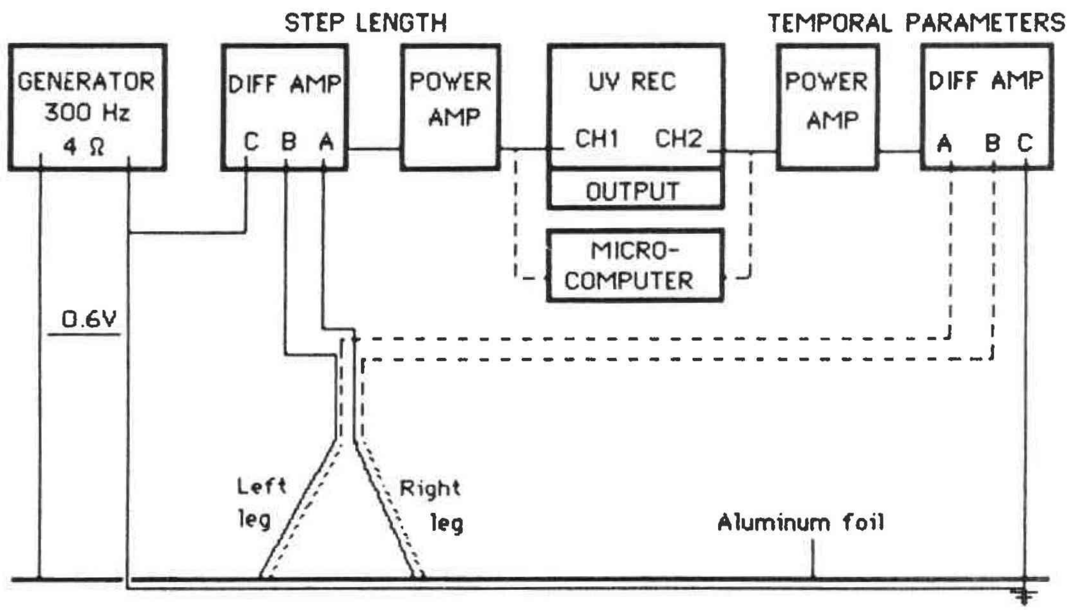

Fig. 1. Block diagram of the system.

sets of differential-power amplifiers and the U.V. recorder and/or, optionally, a microcomputer.

To achieve a good step length resolution a conductive walkway that will show sufficiently steep voltage gradient is required. To this end ordinary aluminium foil (kitchen foil) was used. It is thin enough (0.015 mm) to present appreciable resistance per unit length.

Current to the walkway was taken from a low impedance generator at 0.6V at the output and a frequency of 300 Hz.

The two differential amplifiers shown in Figure 1 work quite differently. The one measuring step length provides an output proportional to the step length when both the respective electrodes-one on each foot–make contact with the walkway. When only one foot is on the ground the differential amplifier saturates, a diode circuit is activated at the output of the power amplifier, and zero current is driven to CH1 of the U.V. recorder.

The differential amplifier associated with the measurement of the temporal parameters saturates and provides at its output a signal +V or −V according to which leg is on the ground. When both legs are on the ground it provides a signal oscillating at 300Hz between +V and −V, unless the distance of the corresponding sensing electrodes is less than 15cm. In that case (only possible in severely handicapped patients), the temporal parameters amplifier will function similarly to the step length amplifier and provide a signal proportional to the distance of the sensing points.

There are two sets of sensing electrodes on each shoe. The electrodes associated with the measurement of step length are two 5mm dia. thin copper discs fixed one at the heel and the other at the toe section of each shoe. They are short circuited. This configuration allows one specific point of one shoe to be related in distance with another specific point at the other shoe. The points related are the toes of the trailing leg and the heel of the forward. To get the actual step length one should add to the distance of the above points the distance of the two electrodes on the shoe (and probably correct roughly for the foot angle).

The electrodes associated with the measurement of the temporal parameters are formed from thin steel wire and attached to the soles of the shoes in a way that secures contact with the ground during the whole stance phase.

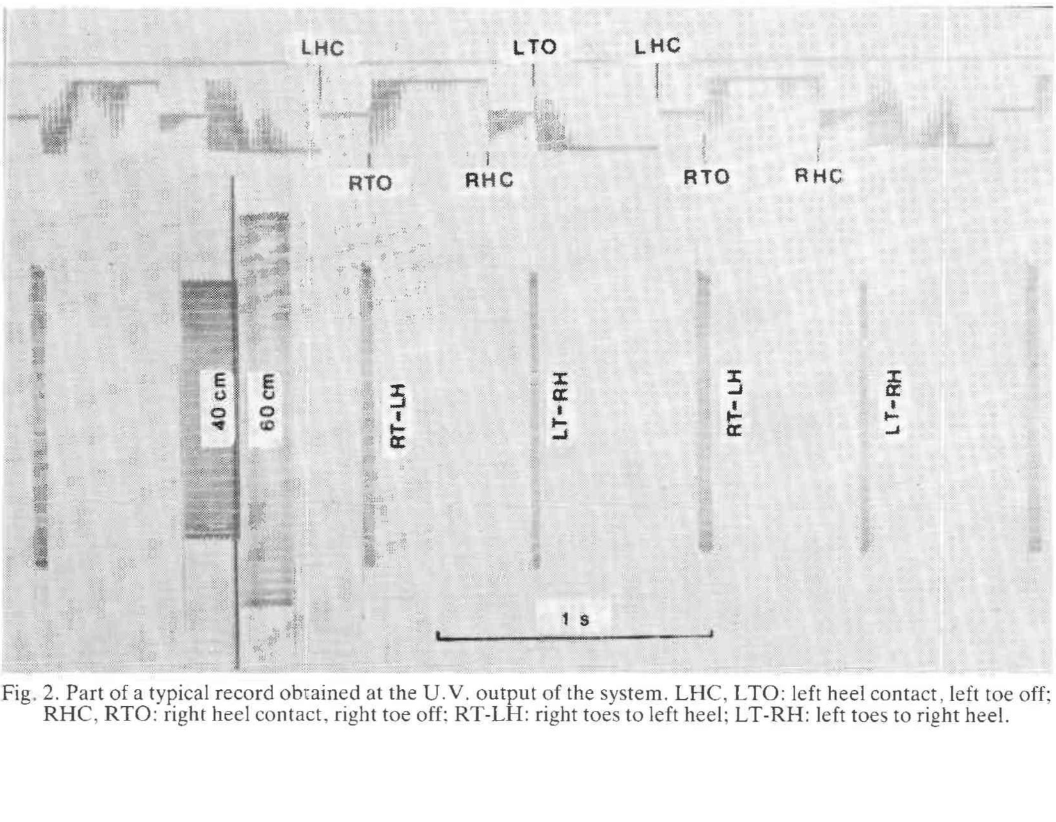

Fig. 2. Part of a typical record obtained at the U.V. output of the system. LHC, LTO: left heel contact, left toe off; RHC, RTO: right heel contact, right toe off; RT-LH: right toes to left heel; LT-RH: left toes to right heel.

Discussion

Part of a typical record of a gait analysis test using this technique is shown in Figure 2. Whether a particular step is a left or a right one can be inferred from the temporal parameters trace, obtained on the same record.

The step length sizes measured on the U.V. paper are entered into the microcomputer and analysed. The step length as measured by this method was compared with the step length measured physically on the walkway. The difference was typically smaller than 1cm.

The system reserves the merits of the conductive walkway systems that measured only temporal parameters of gait. It is rather simple and relatively inexpensive to build and run. It is simpler than other systems measuring step length since it does not require the construction of arrays of resistors, or matrices of switches. It can be made any practical length, without any appreciable extra cost. This is desirable, because it allows for a sufficient number of steps to be analysed and averaged. Routinely the author analyses and averages 20 consecutive steps for each run of a patient.

The aluminium foil that is used as the conductive walkway material is cheap, but is mechanically weak. Materials of higher resistivity can be selected for sufficient mechanical strength and high resistance per unit length.

REFERENCES

Cheung, C., Wall, J. C., Zelin, S. (1983). A microcomputer based system for measuring temporal asymmetry in amputee gait. *Prosthet. Orthot. Int.* **7,** 131–140.

Draganich, L. F., Andriacchi, T. P., Strongwater, A. M., Galante, J. O. (1980). Electronic measurement of instantaneous foot-floor contact patterns during gait. *J. Biomech.* **13,** 875–880.

Drillis, R. (1958). Objective recording and biomechanics of pathological gait. *Ann. N. Y. Acad. Sc.*, **74,** 86–109.

Gabel, R. H., Johnston, R. C., Crowninshield, R. D. (1979). A gait analyser/trainer system. *J. Biomech.* **12,** 543–549.

Gardner, G. M., Murray, M. P. (1975). A method of measuring the duration of foot-floor contact during walking. *Phys. Ther.* **55,** 751–756.

Gifford, G. E., Hutton, W. C. (1980). A microprocessor controlled system for evaluating treatments for disabilities affecting the lower limbs. *J. Biomed. Eng.* **2,** 45–48.

Wall, J. C., Charteris, J., Hoare, J. W. (1978). An automated on-line system for measuring the temporal patterns of foot/floor contact. *J. Med. Eng. Tech.* **2,** 4. 187–190.