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2.6.1: Locomotion

QUANTIFYING THE STABILITY OF WALKING USING ACCELEROMETERS

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Abstract- **A dynamic analysis method is sought to measure the relative stability of walking, using a triaxial accelerometer. A performance parameter that can be calculated from the data from the accelerometer is defined; it should give a measure of the stability of the subject. It is based on the balancing forces as reflected in the power spectrum. Preliminary experiments have been done. The results suggest that the performance parameter can order different gait patterns in terms of relative stability.**

Further experiments are being set up to test the usefulness of the performance parameter in clinical applications and other parameters may be defined.

INTRODUCTION

At present, a diverse range of clinical tests are in use to measure a just as large number of parameters of gait. Although it is a problem for many people, especially elderly people, stability of gait is not among these parameters. Nowadays, clinicians determine this gait feature by observation. In this project, a dynamic analysis method is sought to give an objective measure of the relative stability of gait. The idea is to make the method as simple as possible so that it is suitable for use in clinical situations. This will be attempted by using only one triaxial accelerometer, accompanied by foot switches to record the different phases of the gait cycle.

Standing is statically stable. The body's center of mass (CoM) projection on the ground lies within the base of support enclosed by the feet. Walking, on the other hand, is a dynamically stable process. It can be seen as an interaction between the CoM projection on the ground and the center of pressure (CoP), the point of application of the ground reaction forces. The trajectory of the CoM is controlled by the movement of the CoP, as dictated by the placement of the feet by the neuromuscular system, resulting in a steady-state walking pattern[1][2].

In this paper, a performance parameter will be given that can be derived from the data of a single triaxial accelerometer, which we think will reflect the stability of walking. Further, a preliminary experiment is described with which the parameter was tested.

METHODS

A. Performance parameter

The balancing system can be seen as a control system with a feedback loop. The combined sensory input information is used to estimate the state (position and balance) of the body. This is compared to the expected state and actions will be carried out by the neuro-muscular system to diminish any differences between the estimated and expected states.

The accelerometer signal consists of a regular part associated with the steady-state walking pattern and an irregular part associated with the deviations from and the corrections back to steady-state, thus being a measure for the stability performance. In [3] this is called an intrinsic and extrinsic walking pattern, the former being the 'stereotyped' walking pattern and the latter caused by external disturbances.

In the frequency domain the regular signal consists of the fundamental frequency, equal to the stride frequency and its harmonics. The peaks in the spectrum lying in-between form the irregular signal. It is assumed that the power contained in these latter peaks is inversely proportional to the stability performance. By calculating the regular signal with a least squares method and subtracting it from the total and then calculating the area under the curve of the power spectrum of the resulting signal the performance parameter α can be found:

$$\alpha = \int \left(S_{\text{total signal}} - S_{\text{regular signal}}\right) df \qquad (1)$$

This can be calculated for the acceleration in the forward, lateral and vertical directions, thus giving three related values.

B. Subjects

Preliminary testing was carried out with two young subjects, one male and one female, having no history of balance disorders.

C. Experimental Setup

A triaxial accelerometer developed at the University of Twente [4] fixed on a motorcyclist belt was placed firmly around the subject's waist and hips, with the sensor placed approximately at the height of the body CoM. The accelerometer was as level as possible while standing. Footswitches were placed under heels and toes of both feet.

The signals from the accelerometer and footswitches were collected on a computer, sampling at 100 Hz. The accelerometer was connected to the computer by a 5 m long cable.

D. Protocol

For the preliminary test, subjects were asked to walk in two different ways. A normal walk and a narrow based walk. The last walk is chosen to challenge the balancing system and to simulate walking disorders.

For the normal walk, the subjects were asked to walk in their most natural and comfortable way as far as the cables would reach (about 10 meters). The subjects eyes were fixed straight ahead.

For the second walk, subjects were asked to place their feet in front of each other as if walking over a narrow line, thus forming a narrow walking base. They could choose their own walking speed and their eyes should be fixed straight ahead.

Both walks were repeated twice.

III. PRELIMINARY RESULTS

The results support the assumptions made above. Figure 1 gives the power spectrum for the acceleration signal in the forward direction, for both the total and the calculated irregular part of the signal for one subject. The irregular contents of the signal are clearly larger in case of the narrow based walk, as compared to the normal walk.

Table 1 gives the total area under the curves of the irregular power spectrum for all three directions for both the normal as the narrow based walk for one subject. For all directions the values for the narrow based walk are higher than for the normal walk.

IV. DISCUSSION

The preliminary results indicate that it is feasible to use the calculated parameter as a performance index for stability of walking. Further tests will be done, using a portable datalogger, so more strides can be recorded in one trial. In addition to the narrow based walk, other walks will be used for testing.

Other performance parameters will be defined as well. They could be based on the variance in the walking pattern and the principle of conservation of mechanical energy.

In the near future the experiments will be carried out and the data analyzed. If the results are as we expect, further experiments can be set up to test the method with people with balance disorders, such as Parkinson's disease, or amputees with a leg prosthesis.

V. REFERENCES

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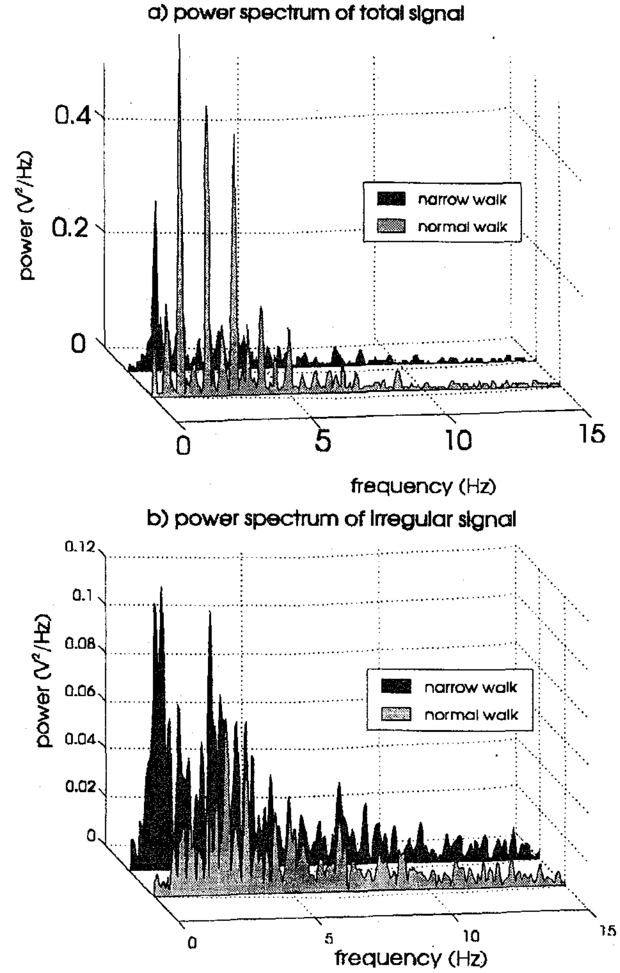

Figure 1: power spectrum for a) the signal as measured by the accelerometer and b) the calculated irregular signal. Both in the forward direction.

Table 1: area under the irregular power-spectrum curve.

walks\direction	*forward*	*lateral*	*vertical*
normal	0.377	0.556	0.442
narrow	0.883	0.906	0.862