ABSTRACT

In the case of patients having lower back pain, it is known that by using shoe insole therapy, stability of walking is increased and lower back pain is lessen ed. In this study, Synchronized System of Accelerometers was used. The time series data of accelerometer in the two directions (X, Y) on each pelvis and knees were measured while the subjects were walking. Analyses on the response of step signals add to the system shows that in the case of the subjects wearing shoe insole, walking stability is increased more than without insoles. And the relative power contribution shows dynamic time-spatial relationship of both the knee and pelvis.

KEY WORDS

Step response, Relative power contribution, Insole, Stability, Rehabilitation.

1. INTRODUCTION

The sequential movements of the knee and pelvis cooperate with and influence each other while walking. It is very important to evaluate the bio-feedback control relationship of each part movement on therapeutic effects in rehabilitation medicine. In the case of patients having lower back pain, their rhythm of pelvises and knees is unstable while walking, but it is known that by using shoe insole therapy, stability of their walking is increased and lower back pain is lessened [1]. In this study, Synchronized System of Accelerometers (SSA) was used [2]. The time series data of accelerometer in the two directions (X, Y) on each part (pelvis and knees) were measured while the subjects were walking. This study presents an approach utilizing multivariate autoregressive model for feedback system analysis [3]. Analyses on the response of step signals add to the system shows that in the case of the subjects wearing shoe insole, walking stability is increased more than in the case of without insoles [4]. And the relative power contribution (RPC) shows dynamic time-spatial relationship of both the knee and pelvis.

2. METHOD

2.1 Synchronized System of Accelerometers (SSA) and Dynamic shoe insoles (Fig.1, 2)

The Synchronized System of Accelerometers (SSA) is for walking analysis. In this study, SSA was used. It consists of two acceleration sensors connected on a small, easily wearable personal computer (WPC) of a wristwatch type. While walking, the WPC is worn on the subject’s wrist, the sensors are fixed to the subject’s left pelvis and right and left knees, and the batteries are inserted into the subject’s waist pouch. When a switch is turned on, the serial time counts and accelerations in the two axes of the subject’s left pelvis and right knee are recorded into the WPC.

The subjects were having lower back pain and walking stability was measured while the subjects were walking with wearing shoe insole and without shoe insole.

Fig.1 SSA
2.2 Step response and RPC by AR modeling

Multivariate AR modeling is given as follows:

\[ x_i(s) = \sum_{j=1}^{K} \sum_{m=1}^{M} a_{ij}(m)x_j(s-m) + u_i(s) \]  

(1)

The system given by (1) is a feedback system within which \( x_i(s) \) is connected to \( x_j(s) \) by an element having \( a_{ij}(f) \) and each \( x_i(s) \) has its own noise source \( u_i(s) \).

When AR coefficient is obtained, we add the step signals in the term of noise. Then we have the step response of every variable.

The frequency response function \( a_{ij}(f) \) of \( x_i(s) \) to the input \( x_j(s) \) is given by \( a_{ij}(f) \).

\[ a_{ij}(f) = \sum_{m=1}^{M} a_{ij}(m)e^{-j2\pi fm} \]  

(2)

\( x_i(s) \) can be expressed as a sum of the influences of \( u_i(s) \)'s.

The power spectral density function \( p_{ij}(f) \) of \( x_i(s) \) can be expressed as a sum of the power contributions from each \( u_i(s) \). If we denote the power spectral density function of \( u_i(s) \) by \( p(u_i)(f) \), then, as the influence of \( x_i(s) \) on \( x_j(s) \) is generated by the frequency response function \( b_{ij}(f) \) of \( x_i(s) \) to the input \( u_i(s) \), we get

\[ p_{ij}(f) = \sum_{j=1}^{K} |b_{ij}(f)|^2 p(u_j)(f) \]  

(3)

If we define \( q_{ij}(f) \) by

\[ q_{ij}(f) = |b_{ij}(f)|^2 p(u_j)(f) \]  

(4)

this represents the contribution of \( u_j(s) \) to the power spectral density of \( x_i(s) \) at the frequency \( f \). The relative contribution is given by

\[ r_{ij}(f) = \frac{q_{ij}(f)}{p_{ij}(f)} \]  

(5)

and the cumulative relative power contribution is given by

\[ R_{ij}(f) = \sum_{k=1}^{i} r_{ik}(f) \]  

(6)

3. RESULT AND DISCUSSION

3.1 Step response analysis

In the case of the subjects having lower back pain on the left side and wearing shoe insole, the response of the right knee to step signals added to the left pelvis converge from transition characteristic to a stationary characteristic clearly (Fig.3) in the Y direction. In the case of the subjects without shoe insole, the wave fell into disorder. It was observed that in walking the case of subjects wearing shoe insole, the stability was more increased than without shoe insole. Also in the X direction (Fig.4), in the case of subjects wearing shoe insole, diminishing vibration curve was clearly defined. It was analyzed that in the case of the subjects having lower back pain on the left side and wearing shoe insole, the stability of the right knee was so increased and the stability of walking was also improved.

3.2 RPC analysis

While the subjects were walking, in the case of having lower back pain wearing shoe insole, the RPC of both knees in the X Y directions was larger than without shoe insole to the movement of the side having lower back pain. It was
observed that patients’ pain was eased and was it was possible to analyze the ratio of reducing burden quantitatively (Fig.5, 6).

4. CONCLUSION

Using analysis of the response on step signals, it was presented that walking stability on patients having lower back pain were improved in the case of wearing shoe insole. And the analysis of RPC, the relationship of the joint during walking was provides. And the ratio of improvement on walking stability was showed quantitatively. Thus, we can obtain a better analysis of the original data and measure quantitatively the relationship between different variables. These analyses can help make a more effective plan of kinesithrapy in rehabilitation for the improvement of each patient.

REFERENCES


