APPLICATION OF THREE DIMENSIONAL ACCELEROMETRY TO HUMAN MOTION ANALYSIS

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INTRODUCTION

Three dimensional measurement method is widely used in sports biomechanics research (Whittle, 1991). It records the movement by real time and is effective to reyroduce the movement. Goniometers, gyroscopes, and accelerometers are used for the appropriate parts of the body to measure directly (Morris, 1973). It is also an effective method to measure muscle activity (Winter, et al., 1993). In recent years, remote measurement devices which were small and light, were in practical use and various measurements have become possible in sport research. It is thought that the direct method is effective because it can quantify the characteristics of the movement easily, simply, and in a shot time compared with an indirect method (Egawa, et al., 1994).

This study was designed to investigate the application of the three dimensional accelerometry to human motion analysis, specifically trunk movements during normal gait using a simple model.

METHODOLOGY

To quantify the complex movement, tri-axial acceleration measurement of the human trunk was performed. Acceleration transducer (TA-513G, Nihon Kohden Inc.) with multi telemeter system (WEB-5000, Nihon Kohden Inc.) was used on the human trunk. The transmitter was attached to waist and data was transmitted to the receiver of this system. Normal subjects (5 males and 5 females, 21.2, 18.7 yr. respectively) performed trial walking ten times respectively. Subjects were instructed to start walking with right foot and to walk straight. Step length and duration was also measured simultaneously. The acceleration data was sampled at 200 Hz. Time series data was divided into one steps and normalized in order to obtain the average step pattern for each subject. Three dimension data was synthesized and the movement (acceleration amplitude) and angular changes were obtained from;

where α_{trunk} is the acceleration vector of human trunk, α_x, α_y, α_z is sagittal, lateral and vertical components of α_{trunk} respectively. θ_{hol} is the projection angle of α_{trunk} to the horizontal plane.

One-step length (L_{step}) was obtained from the acceleration data of one averaged walking cycle numeric integral calculus.

where $\alpha(t)$ is the time series data of acceleration of one averaged step.

Step length by kinematic measurements was compared with the result of the calculation. Repeated measures analysis of variance (ANOVA) and paired Student's T-test were used to compare means and the significance level was set at 5%.

RESULTS

The mean of one instructed step duration was the same at 0.53 sec in kinematic and accelerometric results. Mean step length was 76.7 cm in kinematic, and 81.8 cm in accelerometric. In free walking, mean step length was 77.4, 83.9 cm respectively. Numerical results tended to over estimate the kinematic parameters. However any statistical significant differences were shown between kinematic and accelerometric results ($p<.05$). When one step length of males and females was compared between kinematic and accelerometric, significant differences were not seen. The acceleration data was calculated to estimate the kinematic parameters such as angle and displacement of the trunk. Presenting the acceleration amplitude-phase curve on the horizontal plane of one averaged step, it was shown to reverse the swing phase of left and right foot (Figure 2). The direction of the movement of the trunk was indicated by the acceleration vector which was projected on the horizontal plane, and the walking phase was obtained from the vertical components of the acceleration waves (Figure 3).

DISCUSSION

Acceleration of the human body is not measured well directly, though it is a fundamental factor in biomechanics studies in sports (Morris, 1973). It was often pointed out that the measurement accuracy, noise problem, and enlargement of error by numerical integrating process of the measurement data were the main problems in accelerometry.

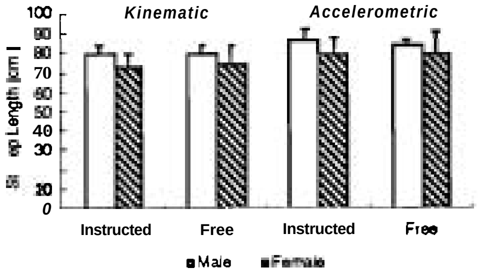

Figure 1. Comparison of step length between kinematic and accelerometric measurements in males and females

Movement information such as a force, direction, and moment of the body, is theoretically calculated by the accelerometry compared with the other kinetic and kinematic methods. Measuring human movements directly, creates error caused by the movement and artifacts due to the instruments (Cume, et al., **1992). A** small piezoelectric accelerometer improves

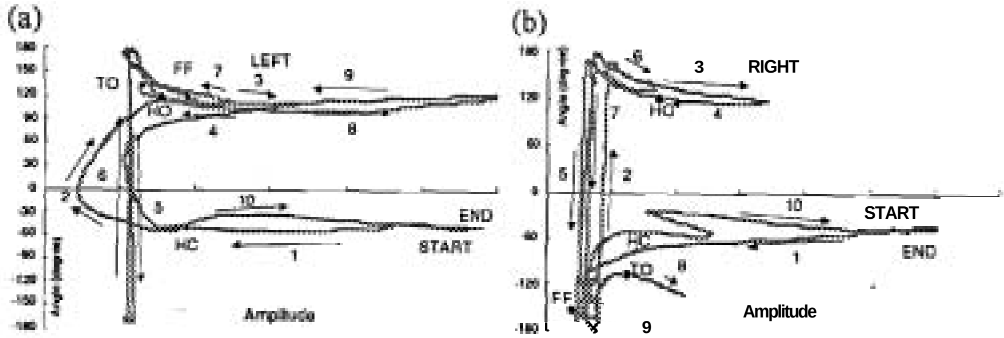

Figure 2. Amplitude-phase of trunk acceleration of one averaged step; (a) left and (b) right foot support; asymmetrical phase was from No. 8 to 9 arrows, i.e. after toe off (TO).

the noise during dynamic movements and is a sufficient instrument for practical use. However, appropriate processing of data is necessary to quantify human movements from acceleration (Evans, et al., **1991).** An excellent result was obtained in this study though the axis correction was not performed assuming the movement of accelerometer was not affected on tri-axial acceleration sensing. In the research of running and jumping, the movement of the accelerometer cannot be disregarded by the explosive movement of body. The method of correction of the axis is to measure the angular movements of the sensor by a gyroscope, or measure the movement by two accelerometer and correct by numerical calculation. It was possible to measure the movement with one acceleration sensor when the movement of the accelerometer was disregarded.

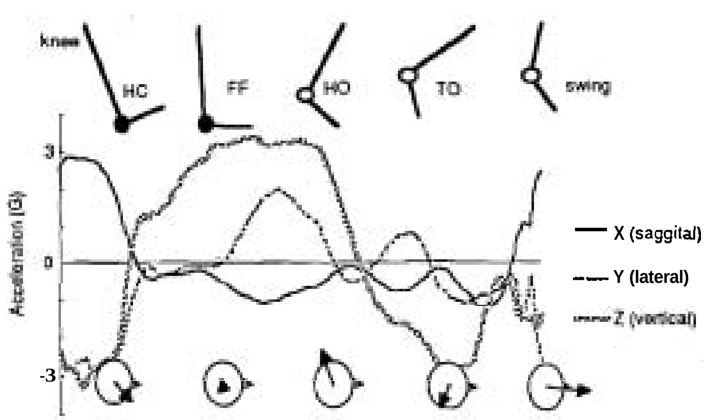

Figure 3. Estimating walking phase by three acceleration waves
Direction and amplitude indicate the trunk movement at heel contact (HC). foot flat (FF), heel off (HO), toe off (TO) and swing phase at right foot support. (1G=9.8m/s²)

A spatial description of the human body movement was possible because of the acceleration amplitude-phase curves on the horizontal plane shown in this research and the acceleration in the vertical direction. For further analysis, it is possible to measure with two sensors at one segment of the body when it is assumed to be a rigid body. It is concluded that this method using three-dimensional accelerometers is effective to describe human movements more easily and objectively. The practical application in sports biomechanics is expected because of the small, light and inexpensive method to measure free movement.

CONCLUSION

It was suggested that the acceleration measurement method was effective as an easy method of recording spatial movement. As for the explosive movements like running or jumping, it is necessary to quantity the characteristic of the movement by a simple index. Using three dimensional accelerometry, the detailed description of rotation and locomotion is possible. The direction and the amplitude of the movement were able to be obtained without restricting free movements of subjects. Moreover, a significant difference was not seen between kinematics and accelerometry in the distance factor. Therefore, the rhythmical movement was able to be shown in the walking movement as an acceleration wave. It is suggested that a more detailed analysis in various sports is completed to measure the acceleration of several segments of the body in addition to the trunk.

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