SKILL EVALUATION OF MOVEMENT BASED ON HUMAN LIMB ELECTRICAL IMPEDANCE

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INTRODUCTION

Some kinds of equipment for measurement of bio-dynamics in sports training and its related directions have been employed which are the goniometer, the electoromyography, the camera and the video camera (ADRIAN et al.,1989). Each piece of equipment has unique advantages, but there are some problems with relation to each piece of equipment. New measurement method have been expected. The purpose of this work is to propose a skill evaluation of tennis movement based on forearm electrical impedance and its measurement method. This method has the following characteristics: 1) It does not have spatial and temporal limitation for measurement. 2) The subject is scarcely restricted in movement. 3) The data processing can be handled easily and quickly. 4) Impedance waveforms intuitively show magnitude, form and stability of movement. This method uses a human body itself as a part of the sensor, and the change of bio-electrical impedance is measured in human movement (YAMAMOTO et al., 1992). We try to evaluate the pattern of movement using the pattern of impedance waveform and the stability of movement using the reproducibility of impedance waveform. It can be intuitively evaluated reproducibility and mobility of serve movement using waveform of forearm electrical impedance. Hence we made a trial about principal component analysis using 4 parameters of impedance waveform.

MATERIALS AND METHODS

(a) Impedance measuring system

Fig.1 shows a block diagram of impedance measuring system. The measurement method of impedance uses the four electrodes technique based on constant current (50kHz, 500μA) (GEDDES et al., 1989). Fig. 2 shows location of electrodes. The four electrodes technique is the method where four electrodes are put on in a line, constant current flows through the outside two electrodes (current electrodes: I^+, I^-)and the potential difference, which arises between the inside electrodes(potential electrodes: P^+, P^-), is detected(NAKAMURA et al.,1992a). We defined electrical impedance by measuring equivalent series resistence of human limb. The measured part is the middle of the forearm, whose length is H/3 with the impedance of Z where H is the length between the top of the olecranon and the processus styloideus. In order to standardize to the measured parts among subjects, the locations of electrodes are shown with H in Fig.1. All electrodes were attached to the skin surface of lateral aspect of the upper limb. Ag – AgCl electrodes of 10 mm dia. were used.

(b) Principle of bio-dynamics analysis

The human limb has a complicated structure which consists of bone, muscle, fat, blood and skin. A constant current of frequency 50 kHz flows almost through the tissues of muscle and blood whose resistivities are lower than the others (GEDDES et al., 1989). The human is approxi-

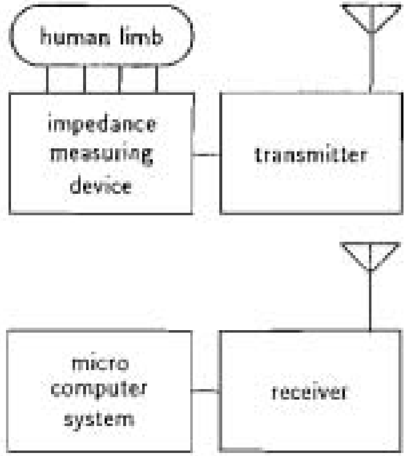


Fig.1 Impedance measuring system.

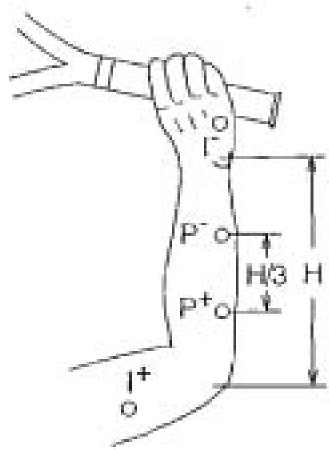


Fig.2 Location of electrode.

mated by the parallel conductor model which consists of tissues of muscle and blood. Taking the position that the changes in sectional area of muscular tissue and volume of blood cause the changes of impedance during some sorts of movement, we try to measure and analyse human movement through the changes of impedance(NAKAMURA et al.,1992b).

Bio-dynamics is characterized by magnitude of movement, form of movement and stability of movement. A summary of the magnitude of movement and the form of movement is defined as the movement pattern. It is very important to evaluate these exactly. We propose to analyse bio-dynamics using impedance characteristic, because human limb impedance varies with human movement. We try to evaluate the movement pattern using the pattern of impedance waveform (i.e. impedance pattern) and the stability of movement using the reproducibility of impedance waveform as shown in Table 1.

Table 1 Evaluation method by impedance

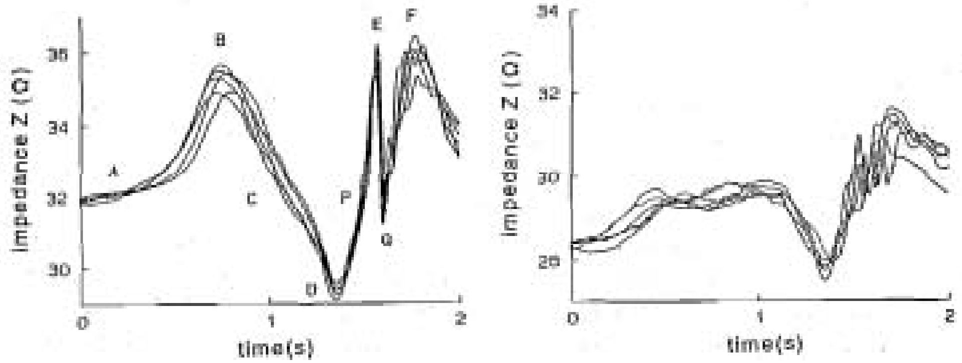
movement	impedance waveform
magnitude	pattern
form	
stability	reproducibility

RESULTS AND DISCUSSIONS

(a) Impedance waveform during serve

We measured six times in 9 subjects during a serve with and without a ball, the subjects were both skillful and beginner players. The superimposed *6* waveforms of are shown in Fig. **3.** The standard time point of superimposed waveforms is the time point of D in Fig. 3.

Z is influenced by flexion and extension of the elbow joint, ulnar flexion and palmer-flexion of the wrist joint and acceleration of the forearm. The movement of the wrist joint is very important before and after impact. A stands for ready position for the serve. B stands for flexion of the wrist joint after his toss up. The increase of Z from A to B is influenced by palmerflexion of the wrist joint. From B to D stands for the movement of the racket loop, the decrease of Z is caused by a release of palmerflexion. In particular, the variation of from C to P was influenced by flexion and extension of the elbow joint. From D to F stands for extension of the elbow joint, hitting the ball and follow-through. The quick change of Z during the time period between P and Q was caused by ulnar flexion of the wrist joint and promotion of muscular pump action before impact. The change of Z during the time period between Q and F was influenced by the change of blood volume during the swing.



(a) skillfull player (b) beginner player

Fig.3 Impedance waveform during tennis serve of skillfull and beginner player.

In waveforms of Z during serve with a ball and without a ball, each waveform of a skillful player was very similar to each other, but each waveform of a beginner player was not. Z of a skillful player varied more than that Z of a beginner player, because the movement of a skillful player is larger than that of a beginner player. This suggests that the wrist movement of a beginner player is not great enough. Thus impedance pattern represents the movement pattern of the movement of the serve. Reproducibility of impedance waveform represents a stability of movement of the serve which is high in the skillful player and low in the beginner player. In this method impedance waveform intuitively shows the whole image (magnitude, form, and stability) of movement.

(b) Principal component analysis

Four parameters which show reproducibility and mobility using waveform of impedance were defined. We made a trial about principal component analysis of Z during serve and got a scatter diagram of first - second principal component Z_1 and Z_2 about 9 subjects including skillful and

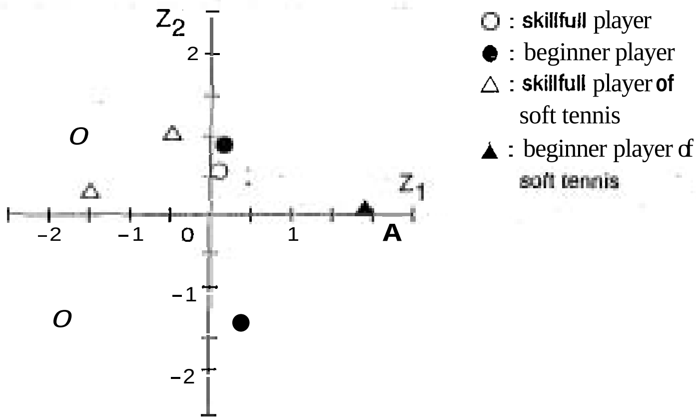


Fig.4 Diagram of first - second principal component.

beginner players. As shown scattering first principal component Z_1 in Fig.4, skillful players are almost negative area, and beginner players are positive area. The principal component analysis devided subjects into skillful and beginner players.

CONCLUSIONS

It was clear that the impedance waveform showed the movement pattern and the stability of movement of the serve from examining the results of skillful and beginner players. The advantages of this method are as follows. There is no spatial and temporal limitation for measurement. The subject is scarcely restricted in movement. Various data analysis can be applied through easy data processing. Although we must select appropriate locations of electrodes in each type of movement, this method can be expected to have applications for various sports. In processing the results of various subjects whose impedance level is different among the subjects, the standardization of the data for an accurate evaluation of movement is the matter for future study.

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