Correlation of Pedometric Measurement of Daily Physical Activity with Exercise Endurance by Oxygen Uptake Kinetics in Ambulatory Stroke Patients

JUNICHI KATOH1), MASAHITO MURAKAMI1), MASAO HIRAYAMA1), YASUO NAGATA1), MICHIKO HAYAKAWA2), TOSHIROU TANIZAKI2)

1)Department of Rehabilitation Medicine, Hyogo Rehabilitation Center Hospital
2)Department of Internal Medicine, Hyogo Rehabilitation Center, Akebono-Cho 1070, Nishi-Ku, Kobe City 651-2181, Japan. TEL +81-078-927-2727

Abstract. The purpose of this study was to investigate the relationship between daily physical activity and physical fitness in twenty ambulatory post-stroke patients. The pedometric measurement was made using a calorie counter in daily life at home and assessed to quantify the time constant (τ on) of oxygen uptake (V O2) and oxygen deficit with gas analysis using a bicycle ergometer. There were negative correlations between the amount of daily walking steps and τ on, as well as the oxygen deficit at the onset of exercise (τ on; r=–0.52, p<0.05, oxygen deficit; r=–0.61, p<0.01), and positive correlations between the amount of daily walking steps and peak VO2, as well as the maximal work load with gas analysis (peakVO2; r=0.61, p<0.01, maximal work load; r=0.69, p<0.01). These results suggest that gait performance of daily physical activity at home was generally related with exercise endurance in ambulatory post-stroke hemiplegia.

Key words: Stroke, Gait ability, Physical activity, Oxygen uptake kinetics, Exercise endurance

INTRODUCTION

Impaired walking function greatly contributes to functional disability after stroke, and improved walking function is the goal most often stated by hemiplegics. Post-stroke patients are known to have low endurance to exercise, which may decline further after discharge. Low endurance may compound the increased energy cost of movement associated with residual hemiparesis and may contribute to poor outcome rehabilitation1,2).

In clinical practice, the peak oxygen uptake (peak VO2) and the oxygen uptake (VO2) kinetics, which are the classic measures of overall cardiopulmonary fitness, are adequate parameters for determining the level of physical fitness of physical disabled persons3–5). Specifically, VO2 kinetics describe the rate at which the cardiorespiratory system is able to deliver oxygen to skeletal muscle with low level constant work rate at the beginning of exercise. The rise to steady state is described by a time constant, τ on, which is determined by fitting an exponential curve to VO2 kinetics data. A slow τ on is a marker of impaired oxygen delivery and/or extraction in patients with chronic heart diseases and cardiovascular diseases6,7).

The purposes of this investigation were to (1) measure the amount of walking steps in daily physical activity and (2) assess whether it was related to the exercise endurance described by VO2.
kinetics responses using not only the maximal exercise but also the submaximal exercise at a low level constant work rate in chronic stroke patients.

**MATERIALS AND METHODS**

**Subjects**

Twenty hemiparetic stroke patients (16 male and 4 female; 64 ± 9 years old) living in the community participated in this study. Their body mass index was 23.1 ± 1.8 kg/m² and the time interval from stroke onset to study was 22 ± 12 months. Subjects had mild to moderate hemiparesis, including both an upper and lower limb, which was documented on physical examination. Grades of the Brunnstrom’s stage of individual lower extremity were from III to V. Each patient was independent in indoor and/or outdoor gait with prosthesis.

**Pedometric analyses in daily physical activity**

In the present study, a compact ambulatory calorimeter (Kenz Life Corder, Suzuken Co, Nagoya, Japan) equipped with an acceleration sensor was used. It was designed to detect the acceleration rate along the vertical axis at the waist during body movements and automatically calculate walking steps and energy expenditure from the product of the acceleration rate and body weight. The number of walking steps and amount of energy expenditure during daily physical activities were measured continuously from the time it was put on at 7:30 a.m. (wear on) to the time it was taken off at 9:30 p.m. (wear off). To minimize day-to-day variation in daily gait, steps for 12 ± 4 consecutive days were obtained in this study. During the measurement period, subjects were instructed to continue their ordinary daily routine.

**Oxygen kinetics measurement during exercise testing system**

In this study we used a symptom-limited ramp exercise test with a load test system including an electromagnetically controlled cycle ergometer (Lode Corival WLP-400, Groningen, Netherlands). Some patients required assistance to start pedaling of the cycle ergometer, and some had to have a disabled hand fixed to the handle bar by an elastic bandage.

Each test began with 3 min of resting baseline measurement. After the constant load work exercise at 20 W for 3 min, incremental loading of 10 W/min was started. The electrocardiogram and heart rate were monitored continuously with Fukuda ML-600 (Japan). On the stage of constant load, τ on and O₂ deficit were calculated from actual VO₂ changes using a statistical program, which was used to fit a single exponential data curve from the onset of exercise to the end of the steady-state exercise. Exercise metabolic parameters such as VO₂ and work rate were continuously determined during the graded exercise test using a breath-by-breath respiration gas analysis assembly with a gas analyzer (Minato RM-300, Japan). Peak VO₂ and maximal work load were measured as parameters of endurance abilities, forcing individually to maximal effort exercise on the incremental load.

**Statistical analysis**

Data are shown as mean ± SD. Linear regression analysis was used to correlate data which were considered statistically significant at p<0.05.

**RESULTS**

The number of walking steps and amount of exercise energy expenditure, which was measured by a calorie counter in daily physical activity with ambulatory hemiplegia, were 4,346 ± 2,933 steps/day and 112 ± 82 kcal/day. τ on and oxygen deficit with gas analysis using a bicycle ergometer were 29 ± 6 seconds and 239 ± 71 ml, respectively. Peak VO₂ and maximal work load were 16.6 ± 4.8 ml/min/kg and 79 ± 35 watts, respectively. The relationships between the daily walking steps and VO₂ kinetics at the onset of exercise is shown in Fig. 1. There were negative correlations between the amount of daily walking steps and τ on, as well as the oxygen deficit at the onset of exercise (τ on ; r=−0.52, p<0.05, oxygen deficit; r=−0.61, p<0.01). The relationships between the daily walking steps and VO₂ kinetics at the ramp exercise test are shown in Fig. 2. There were positive correlations between the amount of daily walking steps and the peak VO₂, as well as the maximal work load (peak VO₂; r=0.61, p<0.01, maximal work load; r=0.69, p<0.01).

**DISCUSSION**

Elevated energy requirements of hemiparetic gait are of particular concern among the elderly, for
whom advancing age and residual neurological deficits promote a sedentary life-style leading to declining cardiovascular fitness, disuse atrophy and weakness\textsuperscript{11,12}). The evaluation of physical fitness and physical activities are important for patients with physical disabilities\textsuperscript{3}). The number of walking steps by post-stroke patients obtained in our study was similar to those of previous studies\textsuperscript{13,14)}.

In clinical practice, the assessment of physical fitness is useful for advising patients about their lifestyle and designing a rehabilitation program for maintaining physical activities. It has been commonly reported that adults with physical disabilities, including those with hemiplegia, improve their physical fitness after aerobic exercise training\textsuperscript{15,16}). Oxygen uptake is the classic measure of overall cardiorespiratory fitness and peak VO\textsubscript{2} describes the highest oxygen uptake obtained by an individual for a given form of exercise despite increased effort and work. In contrast, the oxygen uptake kinetics show the efficiency of the cardiorespiratory response to an imposed work demand. Specifically, oxygen uptake kinetics describe the rate at which the cardiorespiratory system is able to deliver oxygen to skeletal muscle and the rate at which oxygen is consumed by skeletal muscle at the beginning of exercise\textsuperscript{17,18}). We have little information regarding whether the effect of endurance training on oxygen uptake kinetics is influenced at the onset of submaximal exercise.

In the present study, it was firstly demonstrated that the exercise endurance in hemiparetic stroke patients is correlated with oxygen uptake kinetics.
such as \( \tau \) on and \( O_2 \) deficit at the onset of exercise. The rise to steady state is described by a time constant \( \tau \) on, which is determined by fitting an exponential curve to oxygen uptake kinetics data. A slow \( \tau \) on is a marker of impaired oxygen delivery and/or extraction. Oxygen uptake kinetics is influenced by a combination of cardiovascular and peripheral factors. Recent study has been directed at determining whether cardiac output, arteriovenous oxygen difference, aspects of skeletal muscle metabolism, or a combination factors play a role in exercise. The present study showed that the number of daily walking steps was negatively related to \( \tau \) on, as well as the oxygen deficit at the onset of exercise, and was positively correlated with peak \( V_O^2 \), as well as the maximal work load with gas analysis.

These results suggest that the gait performance of daily physical activity at home is generally related with exercise endurance in ambulatory post-stroke hemiplegia. The investigation also showed that the number of walking steps in daily physical activity was related to the exercise endurance by \( V_O^2 \) kinetics responses using not only maximal exercise but also submaximal exercise at a low level constant work rate in chronic stroke patients.

REFERENCES