Original Article

Exercise intensity criteria for routine rehabilitation therapy for stroke patients

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Abstract. [Purpose] The aim of this study was to observe the relationships among heart rate, rate of perceived exertion, and oxygen consumption in stroke patients and the effectiveness of improving aerobic capacity during routine rehabilitation therapy. [Subjects and Methods] Thirty-six stroke patients participated in the study. A K4b^2 pulmonary function device was used to record heart rate (beats per minute), oxygen consumption (Equation Section (Next)ml·min^{-1}·kg^{-1}), and rate of perceived exertion. Results were recorded after completing the following activities continuously: (1) silent sitting, (2) sit-to-stand transfers, (3) hip extension while standing against a wall, (4) weight loading on the affected leg, (5) upward and downward leg movements on a stall bar, (6) walking up and down a flight of stairs, and (7) a 60-meter walk. Correlation analyses were performed to demonstrate the relationship of oxygen consumption with HR and RPE. [Results] Moderate correlation was found between HR and oxygen consumption, and low correlation was found between rate of perceived exertion and oxygen consumption. The routine rehabilitation therapy could reduce the accumulation of lactate. [Conclusion] HR is a better index than rate of perceived exertion in evaluating exercise intensity in stroke patients. The routine rehabilitation therapy can improve the aerobic capacity of stroke patients.
Key words: Stroke, Oxygen consumption, Heart rate

INTRODUCTION

Exercise intensity is important for both healthy adults and stroke patients. Oxygen consumption, metabolic equivalents, heart rate (HR), or rate of perceived exertion (RPE) are used to estimate exercise intensity. In healthy adults, HR is moderately related to oxygen consumption[1–3], and RPE is positively and linearly related to oxygen consumption and ventilatory capacity[4]. HR and RPE are typically used in assessing exercise intensity in healthy adults because they are practical and do not require special equipment. HR and RPE are also used in cardiac rehabilitation. Stroke patients have difficulties in completing a number of activities because of limb dysfunction. Moreover, mental stress, emotion fluctuation, and breath holding could accelerate HR, which may influence the accuracy of using HR as a parameter of exercise intensity. RPE is self-administered according to an individual's perception of physical exertion. It has been generally used in healthy adults, but evidence regarding its reliability for use among stroke patients is still currently in short

supply. Fatigue is common and contributes to poor stroke outcomes[5, 6]. Routine rehabilitation motions after stroke always include hip extension while standing against a wall, standing straight on the affected leg while the unaffected leg is raised up and down on a stall bar, climbing up and down a flight of stairs, etc. Whether the routine rehabilitation therapy can improve the aerobic capacity of stroke patients was also unknown. The primary purpose of this study was to observe the relationships among HR, RPE, and oxygen consumption during routine rehabilitation exercises in stroke patients to determine the optimum exercise intensity criteria. We also evaluated the effectiveness of routine rehabilitation therapy for improving the aerobic capacity after stroke.

SUBJECTS AND METHODS

Thirty-six stroke patients were recruited from inpatients of Sir Run Run Shaw Hospital. This study was conducted in accordance with the Declaration of Helsinki and with approval from the Ethics Committee of Zhejiang University. Written informed consent was obtained from all participants. Among the patients admitted for treatment at our university hospital department of rehabilitation, 36 consecutive hemiparetic stroke patients were recruited according to the following criteria: All subjects could walk at least 60 m independently without any aids. No specific requirements were imposed on the walking speed of the participants. All the participants had a mini-mental state examination (MMSE)

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score of 23 or higher. Patients with apraxia, severe cardiac diseases, or cognitive problems (MMSE score of <23) were excluded. None of the subjects were taking medicines, such as beta blockers, which could influence HR. The physical characteristics of the patients are presented in Table 1.

The subjects were familiarized with the test before it started. Then, they performed the following activities while wearing the Cosmed k4b^2:

1) Sitting quietly for five minutes
2) Sit-to-stand transfers, 20 repetitions
3) Hip extension while standing against a wall, 10 repetitions
4) Standing straight on the affected leg while the unaffected leg was raised up and down on a stall bar, 20 repetitions
5) Standing straight on the unaffected leg while the affected leg was raised up and down on a 20-cm-high stall bar, 20 repetitions
6) Climbing up and down a flight of stairs with 10 steps, 20 repetitions
7) Walking 60 meters as quickly as possible

The training program consisted of routine rehabilitation therapy for after a stroke. The full training program should be completed within 30 min. All subjects performed the training 5 times a week for 4 weeks.

HR data and oxygen consumption per kilogram (VO$_2$/kg) were recorded continuously using the Cosmed k4b^2 (COSMED, s. r. l, Rome, Italy) according to the respiratory frequency[7, 8]. The corresponding RPE score[9, 10] (using the Borg scale) was also recorded after each activity. Venous blood samples were obtained just before and immediately after the training in weeks 1, 2, and 4 from the subjects' earlobes, and the lactate concentration was measured by a lactate analyzer[11].

The mean HR (beats per minute) and mean VO$_2$/kg (Equation Section (Next) ml·min^{-1}·kg^{-1}) of each subject were computed for each activity. Statistical analyses were performed using SPSS 11.0. The mean values were then pooled, and correlation analyses were performed to demonstrate the relationship of VO$_2$/kg with HR and RPE. Self-correlation analyses were also performed for the indices for each participant. Statistical comparisons of blood lactate concentrations between groups were done by one-way ANOVA analysis, with p values ≤0.05 were accepted as statistically significant. All analyses were carried out with the SPSS 21.0 software (Statistical Package for Social Sciences, IBM Corp., Armonk, NY, USA).

RESULTS

Examination of the relationship between HR (beats per minute) and VO$_2$/kg (ml·min^{-1}·kg^{-1}) revealed a correlation of r = 0.618 (p < 0.001), indicating moderate correlation and a significant difference. Therefore, HR can be used to estimate exercise intensity.

We found that the HR and oxygen consumption were related among the 36 subjects, among which 4 exhibited moderate correlation, while 31 exhibited strong correlation (r ranged from 0.657 to 0.968, p<0.05). Only one of the subjects did not exhibit a relationship between HR and oxygen

Table 1. Descriptive characteristics of subjects (n = 36)

Items	Contents
Gender (M/F)	20/16
Age (y)	54.3 ± 10.1 (42–74)
Height (cm)	168.8 ± 7.0 (150–180)
Weight (kg)	69.2 ± 11.4 (50–95)
Hemiplegic side (left/right)	20/16
Brain injury type (hemorrhage/infarction)	15/21
MMSE score	28.6 ± 2.0 (24–30)
NIHSS at enrollment	3.5±2.3
Fugl-Meyer score	61.9 ± 21.6 (20–92)

consumption.

There was a weak relationship (r=0.325, p<0.001) between RPE and VO$_2$/kg (ml·min^{-1}·kg^{-1}). Each RPE score corresponded to a wide range of VO$_2$/kg values. For example, when the RPE was 11, VO$_2$/kg ranged from 5.834 mL·min^{-1}·kg^{-1} to 14.143 mL·min^{-1}·kg^{-1}, and when the VO$_2$/kg was 10 mL·min^{-1}·kg^{-1}, RPE ranged from 9 to 14.

Examination of the lactate concentration demonstrated that each exercise session resulted in acute statistically significant enhancements in the blood lactate concentration. When pre-exercise measurements were compared with each other, no significant difference (F = 1.949, p = 0.148) was found. On the other hand, when post-exercise measurements were compared with each other, it was found that the post-exercise values for the 2nd and 4th weeks were significantly lower than that for the 1st week (1.96±0.44 vs. 2.43±0.45 mmol/L, p=0.001; 1.71±0.5 vs. 2.43±0.45 mmol/L, p = 0.001). Additionally, the post-exercise blood lactate concentration measured in the 4th week was lower compared with the post-exercise value in weeks 2 (1.71±0.5 vs. 1.96±0.44 mmol/L, p=0.026).

DISCUSSION

The objective of this research was to observe the relationships among HR, RPE, and oxygen consumption of stroke patients and the effectiveness in improving aerobic capacity during routine rehabilitation therapy. Correlations between HR and VO$_2$/kg in healthy persons and athletes have been extensively reported. However, only a few studies have been reported that involved persons with limb dysfunction. Moreover, only one report involved children with hemiplegic cerebral palsy (CP). Examination of individual data revealed that most children displayed an unmatched pattern of response between oxygen consumption and HR. Thus, caution should be observed when using HR for estimating walking energy expenditure in children with CP[12].

Homogeneity is difficult to achieve because of individual variations in type, position, area of brain injury, and limb functions. Heterogeneous study populations related to stroke outcomes are commonly encountered in the literature, which multiply the variability encountered in routine clinical practice[7, 13, 14].

Moderate correlation between HR and oxygen consumption was observed in the present investigation (r = 0.618, p < 0.001). Considering the heterogeneity of the subjects, an individual analysis of each subject's HR and oxygen consumption was performed aside from the overall evaluation. Strong correlations were found among the 17 subjects. Only one subject who did not exhibit an HR–RPE correlation was the oldest among the subjects (74 years old) and had a 10-year history of hypertension. The results could have been affected by the presence of an unknown cardiorespiratory disease. Masahito found that that low-intensity endurance training improves the energy efficiency of oxygen uptake kinetics and improves the physical fitness of ambulatory hemiparetic stroke patients[15]. Eduard[4] reported that RPE exhibits positive linear correlations with oxygen consumption, ventilatory capacity, and HR. The validity coefficients derived from various regression models ranged from r = 0.67 to 0.88 (p < 0.05). Eduard used RPE and HR to evaluate exercise safety for the elderly, but the relationship between RPE and HR and their relationships with oxygen consumption were not analyzed. RPE and HR were correlated with oxygen consumption in the study of Haykowsky on endurance training[16]. However, the correlation found in the present study was weak (r = 0.325). Hemiplegic patients usually have difficulties in motor control. The local fatigue in the affected limbs that occurs after mild activity is usually confused with general fatigue. When such a patient felt tired and stopped exercising, the cardiorespiratory function did not improve. Thus, we conducted a talking-test to determine RPE using a subjective parameter[4], which involved talking to the subject during the whole duration of the activity and evaluating the exertion extent based on the smoothness of speech and breath depth of the subject.

Lactate is the anaerobic oxidation metabolite of glucose. Aerobic glucose metabolism to lactate may be a preferred way to rapidly produce significant amounts of energy. Therefore, stimulating increased aerobic glucose metabolism has been shown to increase lactate levels in the absence of tissue hypoxia[17, 18]. Aerobic exercise can improve lactate metabolism. Aerobic training was safe and did not cause any overload symptoms in spinal cord injury patients[19]. Generally speaking, the intensity of routine rehabilitation therapy after a stroke is low. However, our study found that the routine rehabilitation therapy can reduce the accumulation of lactic acid. It also indicated that the routine rehabilitation therapy can improve the aerobic capacity of stroke patients.

This study shows that HR and oxygen consumption are moderately correlated in stroke patients. However, the weak correlation between RPE and oxygen consumption indicates that among stroke patients, HR is a better exercise intensity parameter than RPE. The routine rehabilitation therapy can improve the aerobic capacity of stroke patients.

We acknowledge some limitations in this study. The small patient sample size was characterized by a wide range of residual impairment severity. The time elapsed since the onset of stroke also varied widely for each patient. Enlarging the sample size and using stratification analysis could help to describe the correlation between HR and exercise intensity among stroke patients more accurately.

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