Kobe University Repository : Kernel

PDF issue: 2026-11-23

Cardiorespiratory Fitness Evaluated by the Exercise Testing System in Hemiparetic Stroke Patients

Tsutou, Akimitsu ; Katoh, Junichi ; Hara, Yasuhisa ; Shimada, Tomoaki ; Shinohara, Hideki ; Yoneda, Toshihiko ; Takemasa, Seiichi ; Noyama,…

(Citation)
Bulletin of health sciences Kobe,14:1-9

(Issue Date)
1998-12-26

(Resource Type)
departmental bulletin paper

(Version)
Version of Record

(JaLCDOI)
https://doi.org/10.24546/00181744

(URL)
https://hdl.handle.net/20.500.14094/00181744

KOBE UNIVERSITY

Cardiorespiratory Fitness Evaluated by the Exercise Testing System in Hemiparetic Stroke Patients

Akimitsu Tsutou[1], Junichi Katoh[2], Yasuhisa Hara[2], Tomoaki Shimada[1], Hideki Shinohara[1], Toshihiko Yoneda[1], Seiichi Takemasa[1], Nozomi Noyama[3], Yoshiko Shimose[4], and Hiroshi Taniguchi[1]

Cardiorespiratory responses to the exercise testing system were examined in 43 hemiparetic stroke rehabilitation inpatients (Brunnstrom stage of individual lower extremity : Ⅲ~Ⅴ), aged 35 to 68 years (M = 53 years, SD = 12 years) and 16 healthy subjects, aged 33 to 67 (M = 49 years, SD = 9 years).
To evaluate physical fitness, a graded cycling exercise test using a bicycle ergometer was performed, monitoring gas exchange, ventilation and heart rate. The following results were obtained : 1) Percent maximal oxygen uptake (% $\dot{V}O_2$ max), peak oxygen uptake per unit body weight (peak $\dot{V}O_2$ / W.) and maximum load in patients were significantly lower than those in the control group, while percent heart rate did not have a significant difference between these two groups. 2) No statistically significant difference was observed between two groups on the percent vital capacity and forced expiratory volume at 1 second. 3) The oxygen uptake and $\dot{V}O_2$ / W. at the anaerobic threshold point in patients were significantly lower than those in the control group, while heart rate did not have a significant difference.
These results suggest that (1) physical fitness in patients is diminished partially due to reduced cardiac fitness, (2) heart rate in patients is more easily affected by the intensity of exercise, and (3) the attempts to improve low endurance might be necessary for the better recovery of hemiplegia.

Key Words
Hemiparetic stroke patients,
Rehabilitation,
Oxygen uptake,
Anaerobic threshold,
Physical fitness,
Low endurance.

Faculty of Health Sciences, Kobe University School of Medicine[1], Kobe, Department of Internal Medicine, Hyogo Rehabilitation Center Hospital[2], Kobe, First Department of Medical Technology, School of Medical Sciences, University of Occupational and Environmental Health[3], Kitakyusyu, and Department of Medical Rehabilitation, Ishikawa Hospital[4], Himeji, Japan.

Introduction

The cerebrovascular accidents, or strokes, often cause persistent neurological impairments those affect variable functional abilities. Traditional emphasis in the stroke rehabilitation has been on improving self-care abilities through muscle strength and coordination training[1].

On the one hand, each stroke inpatient usually has low endurance to daily admission life itself and / or exercise although it depends on the degree of impairment. The low endurance may compound the increased energy cost of movement and contribute to poor reha-

bilitation outcomes[1]. In addition, physically inactive behavior has been extensively linked with increased risk for disuse syndrome in post-stroke hemiplegic subjects[2]. And also, the lower level of physical fitness is associated with a higher risk of death from coronary heart disease and cardiovascular disease[3, 4].

Meanwhile, maximal oxygen uptake ($\dot{V}O_2$ max.) is an index of cardiorespiratory fitness. It is, however, often difficult to measure it in cases of untrained healthy subjects and disabled ones. For this reason, the term peak $\dot{V}O_2$ (= maximum $\dot{V}O_2$) is usually used as an index of cardiorespiratory fitness. Peak $\dot{V}O_2$ refers to the highest value of oxygen consumption measured during the test[5]. And also, percent maximal oxygen uptake (% $\dot{V}O_2$ max. ; the ratio of peak $\dot{V}O_2$ divided by the expected maximal oxygen uptake[6, 7]) is often used. In healthy subjects, the intensity of moderate exercise expressed as % $\dot{V}O_2$ max. is thought to be approximately 50% or from 45 % to 60 %[8]. Lactic acid begins to accumulate and rise in an exponential fashion at about 55% of the healthy, untrained subject's maximal capacity for aerobic metabolism[8]. This pattern is essentially similar for the trained subjects except the threshold for lactate buildup, termed the anaerobic threshold (AT)[6], occurs at a higher percentage of the athlete's aerobic capacity[8]. However, little information is available on the responses to aerobic exercise and effects of aerobic exercise training in hemiparetic patients[9-11]. Moreover, limited data are available on the AT of subjects with physical disabilities[12, 13].

Anyhow, for above-mentioned reasons, it is very important to evaluate the physical fitness of hemiplegic stroke patient. The purpose of this investigation is to demonstrate one of the possible reasons of low endurance, and to describe the cardiorespiratory fitness, especially oxygen uptake ($\dot{V}O_2$) and $\dot{V}O_2$ per unit body weight ($\dot{V}O_2$ / W.) at the AT point, of hemiparetic stroke rehabilitation inpatients.

Materials and Methods

Subjects

Forty-three patients (31 male, 12 female) with a mean ± SD age of 53 ± 12 years (range 35 – 68) and sixteen healthy subjects (9 male, 7 female) with a mean ± SD age of 49 ± 9 years (range 33 – 67), participated in this study.

Each patient, who had had a hemispheric stroke about 3.5 months before this study, was medically stable, and was receiving a formal medical rehabilitation program at Hyogo Rehabilitation Center Hospital as an inpatient. Grades of the Brunnstrom stage[14] of individual lower extremity were from Ⅲ to Ⅴ. Each patient was independent in indoor gait by a prosthesis and / or indoor wheelchair handling. The type of cerebrovascular diseases and regional lesions were documented by a computed tomographic scan.

Subjects with brain stem lesions were so often suffering from impediments in balance that they were not included in the study.

Study Design

Exercise tests were performed in a humidity (45 ± 5 %) – and temperature (23 ± 1℃) – controlled laboratory and were conducted according to modified standard criteria of the American College of Sports Medicine[15].

Subjects, who consented the purpose of the exercise testing, were fully acclimated to the testing procedures by thorough explanations and were tested on a cycle ergometer (Lode Corival WLP–400, Groningen, Netherlands) with a load of 20 Watts/min. (ramp test[16]). The dynamic exercise was continued until individual's maximal effort was achieved. The electrocardiogram was monitored continuously with Fukuda ML–600 (Japan), and blood pressure was measured with an autoelectro–cardiometer (Colin STPB–780, Japan). The AT point was measured, and ventilator gas change was monitored with a respiromonitor (Minato RM–300 system, Japan). Respiratory functions were measured with an autospiror (Chest DISCOM–21, Japan). Exercise metabolic parameters such as $\dot{V}O_2$, heart rate (HR), and load were continuously determined during graded exercise tests using breath–by–breath respiration gas analysis assembly. Maximum values for exercise parameters were the maximum of average at every 30 seconds. Percent heart rate (%HR) was calculated as the ratio of the maximum HR divided by the expected maximal HR[6, 7]. Percentage of body fat (% Fat) was measured with an impedance fat meter (Selco SIF–891, Japan).

Statistical analysis

Data are recorded as mean ± SD. Unpaired Student's t – test was used for statistical analyses of the data. Statistical significance was accepted where $P < 0.05$.

Results

The average body mass index (BMI) of patients was 23.5 ± 3.5 kg/m^2. Meanwhile, that of healthy subjects who were working in our hospital and volunteered for participation in this study was 22.6 ± 2.8 kg/m^2. There was no significant difference in the mean BMI between the stroke group and the control one. On the other hand, the average % Fat of male and female patients was 19.2 ± 2.1% and 24.5 ± 3.2%, respectively. Meanwhile, that of healthy male and female subjects was 18.1 ± 1.9% and 23.5 ±2.5%, respectively. There was no significant difference in the % Fat between these groups .

Medical characteristics of hemiparetic stroke patients are displayed in Table 1. Twenty–five subjects among all patients had the complication of hypertension. And , they had been treated with anti–hypertensive agents such as calcium channel blockers (n = 16), angiotensin–converting enzyme inhibitors (n = 10) and / or β–blockers (n = 3). Eight subjects had been suffered from type Ⅱ diabetes mellitus. Among these, two cases had been treated with insulin injection. And, remainder had been treated with antihyperglycemic agents. None of the patients reported symptoms of dizziness, fainting, or chest pain during the exercise testing. No abnormal findings of electrocardiogram were detected .

The physiological responses by the exercise are shown in Fig. 1. The %$\dot{V}O_2$ max , peak oxygen uptake per unit body weight (peak $\dot{V}O_2$ / W.) and maximum load (Load max.) in hemiparetic stroke patients were significantly lower than those in the control group ($P < 0.01$). Although the maximum heart rate responses were slightly suppressed by the presence of β–blockers (metoprolol tartrate 60 mg/day), the %HR did not have a significant difference between these two groups after all.

On the other hand, vital capacity (%

Table 1. Medical Characteristics of Hemiparetic Stroke Patients

Characteristics	Male	Female	Total number
Diseases			
cerebral hemmorrhage	14	5	19
cerebral infarction	17	7	24
Total number	N=31	N=12	N=43
Regions of illness			
right cerebrum	13	6	19
left cerebrum	18	6	24
Total number	N=31	N=12	N=43
Complications			
hypertension	19 /31	6 /12	25 /43
diabetes mellitus	5 /31	3 /12	8 /43
rheumatoid arthritis	0 /31	3 /12	3 /43

VC) and forced expiratory volume at one second (FEV 1.0%) had no significant differences between these two groups (Fig. 2). Their values were within normal limits.

The $\dot{V}O_2$ and $\dot{V}O_2$ / W. at the AT point in hemiparetic stroke patients were significantly lower than those in the control group ($P < 0.01$), although the heart rate at the AT point did not have a significant difference between these two groups (Fig. 3).

When the effect of β–blocker was examined in one case (Hemiparetic stroke patient, male, age of 59), there was little effect on the detection of the AT point. In the presence or absence of this drug, $\dot{V}O_2$ / W. was 9.7 ml/min./kg and 10.8 ml /min./kg , respectively.

With regard to the maximum responses of blood pressure (BP) to the exercise in all cases (n = 59), the systolic BP increased to be below 220, whereas the diastolic BP rose only slightly during the exercise in both groups.

Discussion

The exercise testing of physical strength has been now progressively spread in the area of rehabilitation medicine. Many researchers have investigated the aspect of exercise physiology of subjects not only with spinal cord injury but also with various types of disabilities which include cerebral palsy, dysvascular amputation, cerebrovascular accidents[11-13, 17-20]. And, low levels of fitness due to decon-

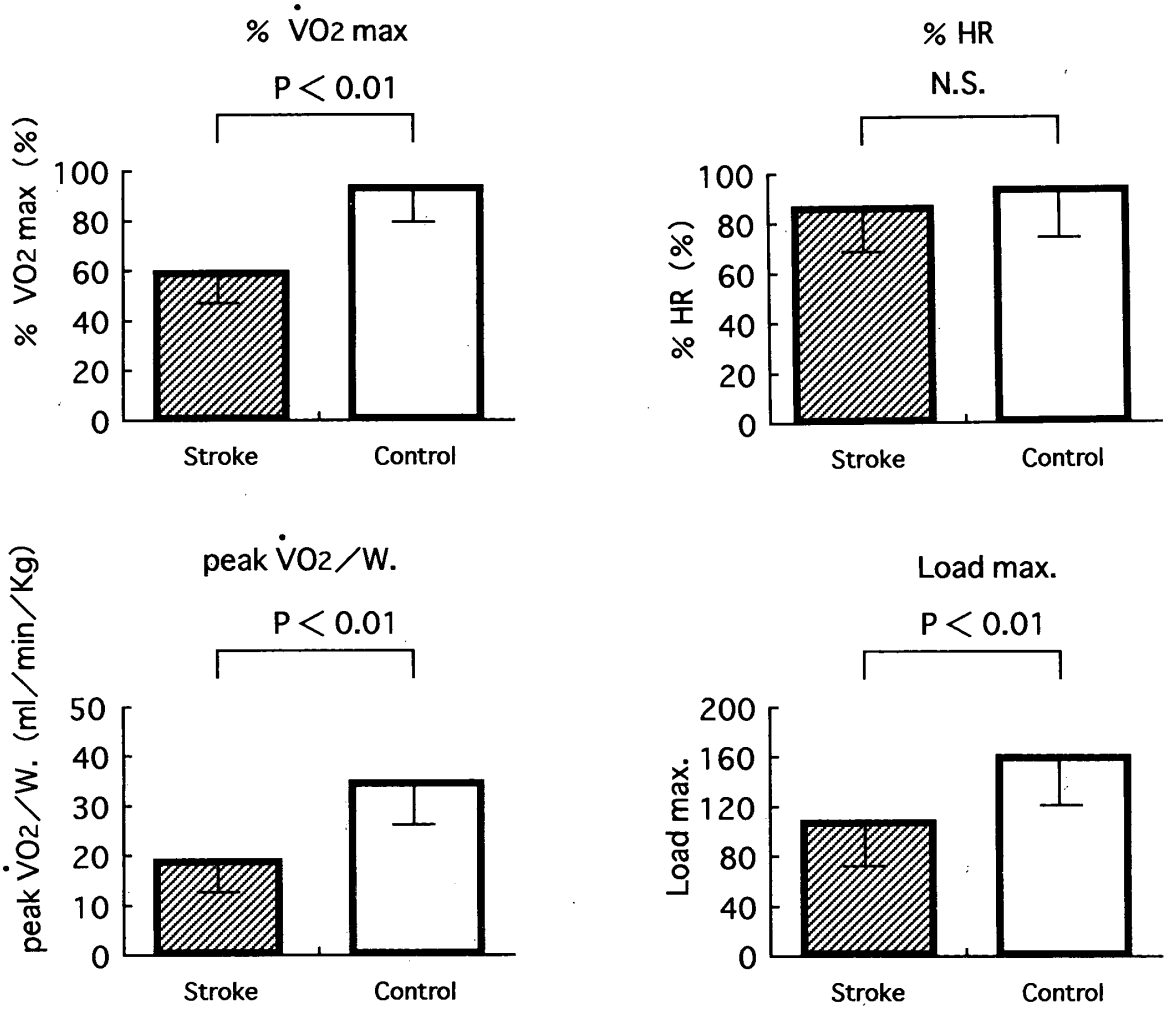


Figure 1. Physiological responses of physical exercise in stroke patients

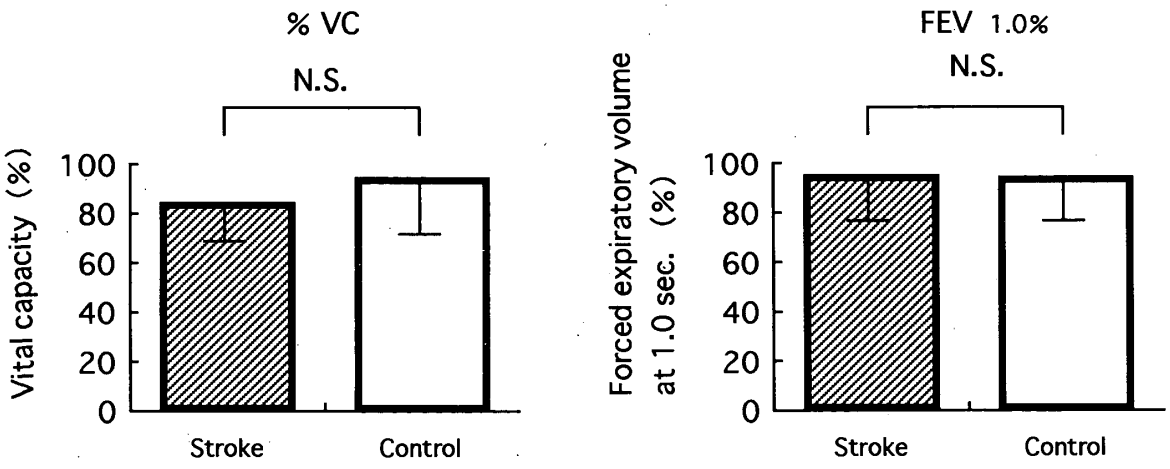


Figure 2. Respiratory responses of physical exercise in stroke patients

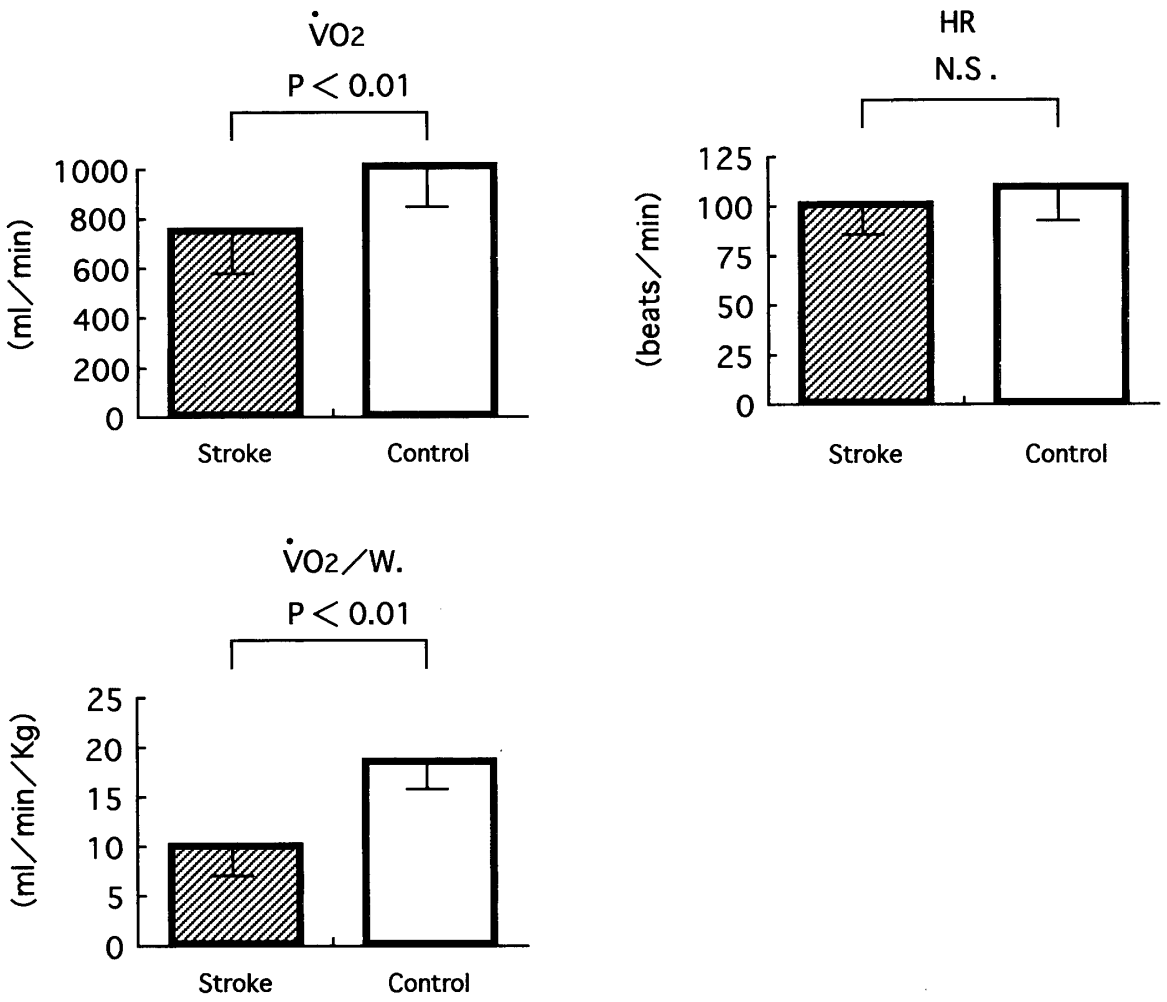


Figure 3. Physiological responses of physical exercise at anaerobic threshold (AT) in stroke patients

ditioning, associated with physical inactivity, have commonly been reported in the general population of individuals with physical disabilities, especially the paraplegics[21-23]. These studies have suggested that the low level of fitness may contribute to poor ability of exercise and poor rehabilitation outcomes. However, up to the present, the $\dot{V}O_2$ max. has been the most popular index among indices of fitness. This measurement is often difficult in individuals with physical disabilities. Recently, according to the addition of index of fitness and the progress of mode of exercise testing, the contents of physical strength test have been greatly enriched. One of them is the adoption of the AT as an index of fitness of individuals with physical disabilities. As the AT point is theoretically detected under the submaximal exercise, validity and reliability of the AT point have been studied on the cases of cerebral palsy and paraplegia[12, 13]. In the present investigation, the study of the AT point was applied to the cases of hemiparetic stroke patients.

Patients investigated were moderately impaired hemiparetic stroke ones those were medically stable and well into the

long-term recovery phase after stroke. The indices of physical strength such as %$\dot{V}O_2$, $\dot{V}O_2$ / W. and maximum load in hemiparetic stroke patients were significantly lower than those in the control group (Fig. 1). And also, the aerobic capacity of hemiparetic stroke patients was less than that of healthy subjects, because the levels of $\dot{V}O_2$ and $\dot{V}O_2$ / W. at the AT point in patients were significantly lower than those in the control subjects (Fig. 3). On the other hand, % HR (Fig. 1) and HR at AT point (Fig. 3) did not have significant differences between these two groups. The%VC and FEV 1.0% had no significant differences between these two groups (Fig. 2). These results suggest that the physical fitness in hemiparetic stroke patients is diminished partially due to reduced cardiac function. And, these findings are likely related to low endurance.

By the way, the role of aerobic exercise training in the functional recovery of patients after stroke has not been well documented. It has been, however, reported that improvement in sensorimotor function is significantly related to the improvement in aerobic capacity[11]. None of the patients reported symptoms of dizziness, fainting, or chest pain during the exercise testing, and the performance of exercise testing at AT point is not so hard. And yet, without the indices of the $\dot{V}O_2$ and $\dot{V}O_2$ / W. at the AT point, some investigators have reported that the exercise training benefits the stroke patients able to train at an intensity high enough to increase aerobic capacity[11, 20, 24]. By measuring the levels of the $\dot{V}O_2$ and $\dot{V}O_2$ / W. at the AT point, it might become possible to quantify the exact amount of exercise that a patient would be capable of handling. And also, it might become possible to suggest her or him a suitable plan to reach the individual's optimal fitness level. Hence positive attempts to search the AT point and to instruct each patient of aerobic exercise training might be necessary for the better recovery of hemiplegia. In any case, it has been clarified from the present investigation that the AT points in hemiparetic stroke patients are significantly lower than those in the healthy subjects. Heart rate at the AT point did not have a significant difference between these two groups. In the present study, the impairment of each patient investigated was relatively moderate in the subacute phase, and the Brunnstrom stage of each patient was relatively high. As the AT points of trained subjects are higher than those of untrained ones[8], the AT points of stroke patients whose grades of the Brunnstrom stage are from Ⅰ to Ⅱ are thought to be lower than those whose grades of Brunnstrom stage are from Ⅲ to Ⅵ. Hence the AT point might be thought to become the indices of physical strength, endurance performance and exercise intensity.

As for the reasons of low peak $\dot{V}O_2$ / W and low $\dot{V}O_2$ /W at the AT point in patients, precise mechanisms have not been clarified. It is well known that $\dot{V}O_2$ usually increases in proportion as quantity of muscles increases. So, $\dot{V}O_2$ / W is a popular index of physical fitness. Although several mechanisms for decreasd exercise capacity by the deconditioning have been reported[25-27], they are not cases of hemiplegic subjects but those of normal ones. Underlying mechanisms include the reduction of maximal stroke volume, cardiac output, oxygen uptake, muscle blood flow, red cell volume, capillarization and oxidative enzymes. In case of hemiplegic subject with impairment caused by damage of

central nervous system, different mechanisms might be present in peripheral nerves, blood vessels and muscles. In the present investigation, no obvious muscle atrophy was observed in each patient. And, each patient had been free from so–called bed–ridden status for at least 2 months. However, for example, metabolic disorders due to the bed–bound status and hemiparesis might be present in muscles.

Thus, the precise physiological significance of the AT point and the mechanism of decreased exercise capacity in individual hemiparetic stroke patient remain to be elucidated.

Acknowledgements

The authors would like to thank Mr. Yasuo Nagata (medical technologist) for providing the technical assistance during this study. This investigation was supported by research grants from Scientific Research Fund of the Hyogo Social Welfare Organization.

References

1. Duncan PW, Badke MB. Stroke rehabilitation : The recovery of motor control. Chicago, Year Book Medical Publishers, 1987
2. Fugl–Meyer AR. Post–stroke hemiplegia. Assessment of physical properties. Scand J Rehab Med. Suppl. No.7 : 85–93, 1980
3. Ekelund L–G, Haskell WL, Johnson JL, et al. Physical fitness as a predictor of cardiovascular mortality in asymptomatic North American Men. The lipid research clinics mortality follow–up study. N Eng J Med 319 : 1379–1384, 1988
4. Sandvik L, Erikssen J, Thaulow E, et al. Physical fitness as a predictor of mortality among healthy, middle–aged Norwegian men. N Engl J Med 328 : 533–537, 1993
5. McArdle WD, Katch FI, Katch VL. Chapter 11 : Individual differences and measurement of energy capacities. (In) Exercise physiology –energy, nutrition, and human performance–. Third edition. McArdle WD, Katch FI & Katch VL (Ed.) Philadelphia, Lea & Febiger. pp 123–144, 1991
6. Wasserman K, Hansen JE, Sue DY, et al. Principles of exercise testing and interpretation. Second edition. Lea & Febiger, Philadelphia : 119–120, 1994
7. Hansen JE, Sue DY, Wasserman K. Predicted values for clinical exercise testing. Am. Rev. Respir. Dis. 129 (Suppl.) : S 49–S 55, 1984
8. McArdle WD, Katch FI, Katch VL. Chapter 7 : Energy transfer in exercise. (In) Exercise physiology –energy, nutrition, and human performance–. Third edition. McArdle WD, Katch FI & Katch VL (Ed.) Philadelphia, Lea & Febiger. pp 123–144, 1991
9. Moldover JR, Daum MC, Downey JA. Cardiac stress testing of hemiparetic patients with a spine bicycle ergometer : preliminary study. Arch Phys Med Rehabil 65 : 470–476, 1984
10. Monga TN, Deforge DA, Williams J, et al. Cardiovascular responses to acute exercise in patients with cerebrovascular accidents. Arch Phys Med Rehabil 69 : 937–940, 1988
11. Potempa K, Lopez M, Braun LT, et al. Physiological outcomes of aerobic exercise training in hemiparetic stroke patients. Stroke 26 : 101–105, 1995
12. Bhambhani YN, Holland LJ, Steadward RD. Anaerobic threshold in wheelchair athletes with cerebral palsy : Validity and reliability. Arch Phys Med Rehabil 74 : 305–311, 1993
13. Lin KH, Lai JS, Kao MJ, et al. Anaerobic threshold and maximal oxygen consumption during arm cranking exercise in paraplegia. Arch Phys Med Rehabil 74 : 515–520, 1993

14. Brunnstrom S. Motor testing procedure in hemiplegia. Phys Ther 46 : 357–375, 1966
15. American College of Sports Medicine : Guidelines for Exercise Testing and Prescription. 4 th ed. Philadelphia, Lea & Febiger, 1995
16. Davis JA, et al. Effect of ramp slope on determination of aerobic parameters from the ramp exercise test. Med Sci Sports Exerc 14 : 339–343, 1982
17. Bhambhani YN, Eriksson P, Steadward RD. Reliability of peak physiological responses during wheelchair ergometry in persons with spinal cord injury. Arch Phys Med Rehabil 72 : 559–562, 1991
18. Bhambhani YN, Holland LJ, Steadward RD. Maximal aerobic power in cerebral palsied wheelchair athletes : Validity and reliability. Arch Phys Med Rehabil 73 : 246–252, 1992
19. Davidoff GN, Lampman RN, Westbury L, et al. Exercise testing and training of persons with dysvascular amputation : Safety and efficacy of arm ergometry. Arch Phys Med Rehabil 73 : 334–338, 1992
20. Santiago MC, Coyle CP, Kinney WB. Aerobic exercise effect on individuals with physical disabilities. Arch Phys Med Rehabil 74 : 1192–1198, 1993
21. Jochheim KA, Strohkendle H. The value of particular sports of the wheelchair–disabled in maintaining health of the paraplegic. Paraplegia 11 : 173–178, 1973
22. Dearwater SP, LaPorte RE, Cauley JA, et al. Assessment of physical activity in inactive populations. Med Sci Sports Exerc 17 : 651–655, 1985
23. Glaser RM, Davis GM. Wheelchair dependent individuals. (In) Exercise in modern medicine. Franklin BA, Gordon S, Timmis GC (Ed.) Baltimore, Williams & Wilkins. pp 237–267, 1989
24. Coyle CP, Santiago MC. Aerobic exercise training and depressive symptomatology in adults with physical disabilities. Arch Phys Med Rehabil 76 : 647–652, 1995
25. Convertino VA, Hung J, Goldwater D, et al. Cardiovascular responses to exercise in middle–aged men after 10 days of bedrest. Circulation 65 : 134–140, 1982
26. Hung J, Goldwater D, Convertino VA, et al. Mechanisms for decreased exercise capacity after bed rest in normal middle–aged men. Am J Cardiol 51 : 344–348, 1983
27. Convertino VA, Bloomfield SA, Greenleaf JE. An overview of the issues : physiological effects of bed rest and restricted physical activity. Med Sci Sport Exerc 29 : 187–190, 1997