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(Citation)
Bulletin of allied medical sciences Kobe : BAMS (Kobe),13:1-9

(Issue Date)
1997-12-26

(Resource Type)
departmental bulletin paper

(Version)
Version of Record

(URL)
https://hdl.handle.net/20.500.14094/00188164

# Evaluation of Physical Fitness and Estimation of Daily Spent Calorie of the Disabled Inpatients by Exercise Testing System and Heart Rate Monitor (Pulse Watch)

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Cardiorespiratory responses to the exercise testing system were examined in 61 healthy volunteers and 359 disabled inpatients (incomplete hemiplegia, paraplegia and tetraplegia). In addition, using these data and a personal computer, we tried to make a program for calculating the oxygen uptake ($\dot{V}O_2$) and spent Calorie from the data of heart rate monitor (Pulse Watch).

The following results were obtained: 1) The correlation coefficients between $\dot{V}O_2$ and heart rate (HR) or load of healthy subjects by the bicycle ergometer, arm ergometer and treadmill were respectively higher than 0.90. 2) The peak $\dot{V}O_2$, peak oxygen uptake/body weight (peak$\dot{V}O_2$/W) and peak HR of patients were significantly lower than those of healthy subjects . 3) When the expected peak values were calculated according to Wasserman's protocol, the peak $\dot{V}O_2$/W and peak HR of patients were also significantly lower than those of the expected . 4) The anaerobic threshold (AT ) points of patients could be determined in approximate 76% of cases . The $\dot{V}O_2$ and $\dot{V}O_2$/W at the AT point were significantly lower. 5) The spent Calorie during the daytime of male thoracic or lumbar injury patients (mean $\pm$ SD age of 29 $\pm$ 3 years ) analyzed from the data of Pulse Watch was 2.71 Cal/min. on the average and the correlation coefficient between $\dot{V}O_2$ and HR was 0.96 $\pm$ 0.01 , although the former was significantly lower (1.78 Cal/min. on the average) and the latter was 0.82 $\pm$ 0.06 in male cervical injury patients (mean $\pm$ SD age of 28 $\pm$ 4 years ).

These results suggest that the physical fitness is diminished in disabled inpatients, and that the attempts to improve it might be necessary in the rehabilitation program. And also , Pulse Watch was suggested to be generally useful to estimate the $\dot{V}O_2$ and spent Calorie in disabled patients except those due to cervical injury .

## Key Words

Disabled patient,
Cardiorespiratory fitness,
Anaerobic threshold,
Exercise testing ,
Heart rate monitor (Pulse Watch),
Rehabilitation .

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## INTRODUCTION

The injuries of central nervous system often cause persistent neurological impairments that affect variable functional abilities. Traditional emphasis in medical rehabilitation has been on improving self-care abilities through muscle strength and coordination training.[1] Recently, the early rehabilitation to ensure better chance of recovery has been also emphasized.

But, though it depends on the degree of impairment, each inpatient usually seemed to have low endurance to daily admission life itself and exercise. The low endurance may compound the increased energy cost of movement and contribute to poor rehabilitation 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 even in clinically healthy men, independent of conventional coronary risk factors.[3,4]

Meanwhile, the maximum oxygen uptake is an index of cardiorespiratory fitness. It is, however, often difficult to measure it in the cases of untrained healthy subjects and disabled ones. For this reason, the peak oxygen uptake (peak$\dot{V}O_2$), which is shown when the subject could not complete the full duration of a particular work block any longer under the exercise testing, is often used as an index of cardiorespiratory fitness in not only healthy subjects but also disabled ones.

Anyhow, for above-mentioned reasons, it is very important to evaluate the physical fitness of disabled subjects, and to instruct each subject of the means of exercise training for the improvement of low endurance or low level of physical fitness. Though the role of aerobic exercise training in the functional recovery of patients after stroke has not been well documented, a few informations are available on the responses to aerobic exercise and effects of aerobic exercise training in hemiparetic patients.[5-7] Moreover, limited data are available on the anaerobic threshold of subjects with physical disabilities.[8,9]

The purpose in this investigation is to describe the cardiorespiratory fitness, especially not only peak $\dot{V}O_2/W$ but also $\dot{V}O_2/W$ at the AT point evaluated by the exercise testing system, of disabled inpatients. By the way, the ideal physical therapy is thought to be that patients are first examined their physical fitness by the gas analyzer, and thereafter, they are trained according to their physical conditions under the observation of optimum heart rate. If there was a compact machine that could quickly indicate $\dot{V}O_2/W$ and Calorie from the recorded heart rates in the heart rate monitor, it would make a great contribution to medical sciences and treatments. However, there is not such a compact and convenient machine at present that serves to know these three parameters simultaneously. But, it was possible to record the various data including the heart rate, $\dot{V}O_2$ and Calorie by our exercise testing system. So, using the data obtained from exercise testing, we tried to make a program of a per-

sonal computer for calculating the oxygen uptake ($\dot{V}O_2$) and spent Calorie from the data of Pulse Watch. The purpose in this investigation is to apply our program to a clinical use, too.

## MATERIALS AND METHODS

Sixty-one healthy volunteers (27 male, 34 female) with a mean ± SD age of 32 ± 6 years and 359 disabled inpatients (183 male, 176 female) with a mean ± SD age of 52 ± 5 years who had admitted recently to our Hyogo Rehabilitation Center Hospital participated in this study. Each stroke patient, who had had a hemispheric stroke about 3.5 months before this study, was medically stable, and was treated by a formal medical rehabilitation program at our hospital. Grades of the Brunnstrom stage[10] of individual lower extremity were from III to V. And also, nine out of 30 patients of spinal injury, who had received the injuries about 8 months ago, participated in the study of Pulse Watch. All patients were independent in indoor gait by a prosthesis and/or indoor wheelchair handling.

Exercise tests were performed in a humidity- and temperature-controlled laboratory and were conducted according to modified standard criteria of the American college of Sports Medicine.[11] Subjects were fully acclimated to the testing procedures by thorough explanations.

These 420 cases were analyzed in point of the cardiorespiratory fitness by various exercise testings. Load was increased by 5 to 20 watts/min. on the bicycle ergometer (WLP-400, Lode Corival Co.Ltd., Germany) or arm ergometer (WLP-300, Lode Corival Co.Ltd., Germany) until the maximal effort was achieved. In the case of treadmill (MAT 200, Fukuda Electronics Industry Co.Ltd., Japan), all subjects were evaluated by the condition of Bruce's protocol. Oxygen uptake ($\dot{V}O_2$:ml/min.), carbon dioxide output ($\dot{V}O_2$:ml/min.), volume of expired gas (VE:ml/min.) and anaerobic threshold (AT point)[12,13] were measured by the gas analyzer (Aeromonitor RM-300 system, Minato Co.Ltd., Japan) under the observation of electrocardiogram (electrocardiograph: ML-600, Fukuda Electronics Industry Co.Ltd., Japan), and blood pressure ( instrument : STPB-780, Colin Co.Ltd., Japan). Physical fitness was mainly evaluated by peak oxygen uptake per body weight (peak $\dot{V}O_2$/W : ml/min./Kg.) and peak heart rate (peak HR : beats/min.). Each maximal value for exercise parameters was the maximum of average at every 30 seconds .

The AT point was determined according to Wasserman's method.[12,13] At the same time, we calculated the expected peak oxygen uptake (exp $\dot{V}O_2$ : ml/min.), expected peak oxygen uptake/body weight (exp $\dot{V}O_2$/W : ml/min./Kg.) and expected peak heart rate (exp HR : beats/min.) according to Wasserman's protocol[14,15] which had been investigated in view of sex, age, height and body weight .

To estimate the $\dot{V}O_2$ and spent Calorie during the daytime, heart rates of each of twenty patients were monitored for about 8 hours in the daytime by the heart rate monitor (Pulse Watch, North Polar Co.Ltd.). After that, the data saved in Pulse Watch were used for the calculation

of the $\dot{V}O_2$ and spent Calorie by our original program. The program for analyzing heart rates was written using n88 basic. Data saved in Pulse Watch were translated into the personal computer through a interface ( RS232C cable). Heart rates were calculated for the estimation of the $\dot{V}O_2$ or Calorie by the recurrent expression between $\dot{V}O_2$ and heart rate or between Calorie and heart rate which had been obtained from previous exercise testing. If the calculated $\dot{V}O_2$ or Calorie was less than that of rest phase or greater than that of end point, the result was automatically changed into that of minimum or maximum value .

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

## RESULTS

In healthy subjects, the correlation coefficient between $\dot{V}O_2$ and HR in the bicycle ergometer (Load: 20watts/min.), arm ergometer (Load: 5watts/min.) and treadmill (Bruce's protocol) was $0.995 \pm 0.001$, $0.981 \pm 0.005$ and $0.948 \pm 0.030$, respectively. That between $\dot{V}O_2$ and Load in the bicycle ergometer and arm ergometer was $0.993 \pm 0.002$ and $0.962 \pm 0.012$, respectively. Hence, the data obtained from any of these loading machines were thought to be similar to those of others . And also, it was confirmed that the heart rate was remarkably related to $\dot{V}O_2$.

In the meantime, the following results were obtained by the bicycle ergometer, arm ergometer or treadmill as one of the exercise testings. According to the degrees of patients' impairments, the loading machine was selected. The mean peak $\dot{V}O_2$, peak $\dot{V}O_2/W$ and peak HR of both male and female patients were significantly lower than those of both male and female healthy subjects (Table 1.).

**Table 1.** Oxygen uptake and heart rate of healthy subjects and disabled patients by exercise testing system.

| | male | | female | |
|---|---|---|---|---|
| | healthy subjects (n= 27) | disabled patients (n= 183) | healthy subjects (n= 34) | disabled patients (n= 176) |
| peak $\dot{V}O_2$ (ml/min.) | 2526±105 | 1317±39 | 1764±97 | 1084±33 |
| | P<0.001 | | P<0.001 | |
| peak $\dot{V}O_2$/W (ml/min./kg) | 38.9±1.5 | 20.7±0.5 | 32.4±1.5 | 18.5±0.4 |
| | P<0.001 | | P<0.001 | |
| peak HR (beat/min.) | 176±3.9 | 142±2.1 | 171±3.0 | 137±1.9 |
| | P<0.001 | | P<0.001 | |

peak $\dot{V}O_2$ : peak oxygen uptake
peak $\dot{V}O_2/W$ : peak oxygen uptake/body weight
peak HR : peak heart rate
P<0.001 : healthy subjects vs. disabled patients

However, the number of healthy subjects was not enough and the range of ages and/or sex of healthy subjects was not matched strictly to that of patients. So, we compared the peak $\dot{V}O_2/W$ and peak HR of patients with the expected peak values which were calculated according to Wasserman's protocol[14)15)]. In the case of male patients, it became clear that the peak $\dot{V}O_2/W$ and peak HR were significantly lower than the expected peak values (Figure 1. Left column). Namely, the peak $\dot{V}O_2/W$ was $20.7 \pm 0.5$ and the expected peak value was $29.5 \pm 0.6$ ($P < 0.001$). The peak HR was $142 \pm 2.1$ and the expected peak value was $173 \pm 1.2$ ($P < 0.001$). In the case of female patients, it became clear that these two parameters were also significantly lower than the expected peak values (Figure 1. Right column). Namely, the peak $\dot{V}O_2/W$ was $18.5 \pm 0.4$ and the expected peak value was $23.2 \pm 0.4$ ($P < 0.001$). The peak HR was $137 \pm 1.9$ and the expected peak value was $163 \pm 1.1$ ($P < 0.001$).

By the way, the AT points of patients could be determined in approximate 76% of cases, although those of healthy subjects were all determined. Each patient whose AT point could not be determined was too weak physically to reach to the AT point. In those cases, the Brunnstrom stage of each hemiparetic

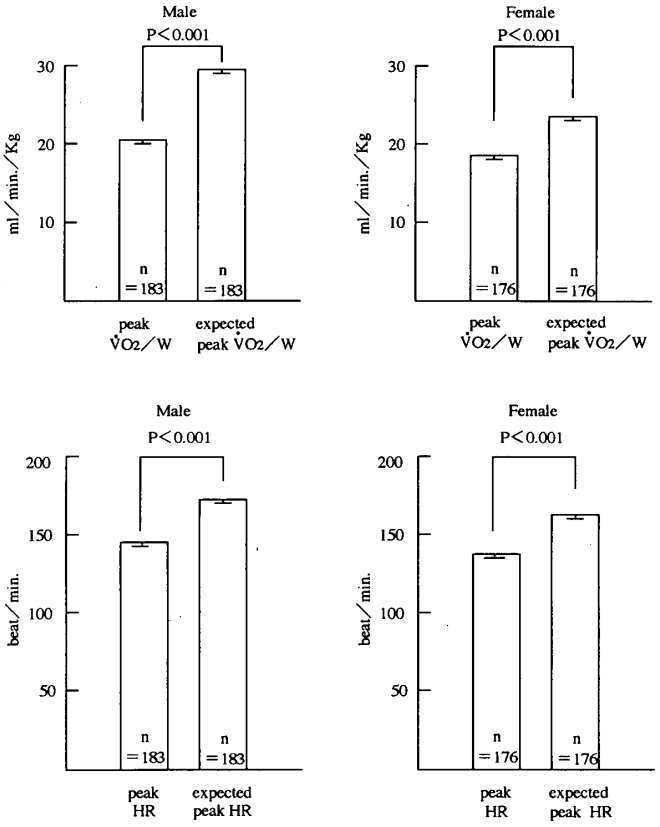


**Figure 1.** Comparison of peak $\dot{V}O_2/W$ with expected peak $\dot{V}O_2/W$ in disabled patients (Upper column), and Comparison of peakHR with expected peak HR in disabled patients (Lower column).

patient was generally low or the activities of daily livings of patients were relatively low . Anyhow, the mean $\dot{V}O_2$ and $\dot{V}O_2/W$ at the AT point of both male and female patients were significantly lower than those of both male and female healthy subjects. However, there was no significant difference between healthy subjects and patients in the mean HR at the AT point, although the mean value of patients was slightly low (Table 2.).

Next, we estimated the $\dot{V}O_2$ and spent Calorie of patients in the daytime. Individual heart rates of twenty patients was monitored by the attachment of Pulse Watch to the body for about 8 hours. The mean $\dot{V}O_2$ and spent Calorie of stroke hemiparetic patients in the daytime was about 435.0 ml/min. and 2.18 Cal/min., respectively. The correlation coefficient ($\dot{V}O_2$ vs. HR) was 0.90 ± 0.04. And, the former of thoracic or lumbar injury patients was about 542.0 ml/min. and 2.71 Cal/min., respectively. The latter was 0.96 ± 0.01. However, in the case of cervical injury, the former was about 335.0 ml/min. and 1.78 Cal/min., respectively. The latter was 0.82 ± 0.06 (Table 3.). Thus,

**Table 2.** Oxygen uptake and heart rate of healthy subjects and disabled patients at the AT point by exercise testing system.

| | male | | female | |
|---|---|---|---|---|
| | healthy subjects (n= 27) | disabled patients (n= 144) | healthy subjects (n= 34) | disabled patients (n= 133) |
| $\dot{V}O_2$ (ml/min.) | 1457±60 | 924±21 | 958±38 | 816±15 |
| | P<0.01 | | P<0.05 | |
| $\dot{V}O_2/W$ (ml/min./kg) | 22.4±0.9 | 14.5±0.3 | 18.1±0.8 | 13.6±0.2 |
| | P<0.01 | | P<0.01 | |
| HR (beat/min.) | 124±2.3 | 113±1.2 | 125±3.7 | 115±1.2 |
| | n s | | n s | |

$\dot{V}O_2$ : oxygen uptake
$\dot{V}O_2/W$ : oxygen uptake/body weight
HR : heart rate
P<0.01~0.05 : healthy subjects vs. disabled patients
n s : not significant

**Table 3.** Mean $\dot{V}O_2$ and spent Calorie of male disabled patients during the daytime calculated from the data of heart rate monitor (Pulse Watch).

| | | Age | $\dot{V}O_2$ (ml/min.) | Calorie (Calorie/min.) | Correlation Coefficient ($\dot{V}O_2$ vs. HR) |
|---|---|---|---|---|---|
| Stroke | (n=11) | 36±4 | 435.0±45.3 | 2.18±0.24 | 0.90±0.04 |
| Thoracic or Lumbar Injury | (n=5) | 29±3 | 542.0±85.5 | 2.71±0.43 | 0.96±0.01 |
| Cervical Injury | (n=4) | 28±4 | 335.0±70.1※ | 1.78±0.35※ | 0.82±0.06 |

※ : P<0.001 : cervical injury vs. thoratic or lumbar injury

our analytical method using Pulse Watch was suggested to be generally useful to estimate the $\dot{V}O_2$ and spent Calorie in disabled patients except those due to cervical injury.

## DISCUSSION

Generally, physical fitness of athlete and/or healthy subject is evaluated by the $\dot{V}O_2$ at AT point and $\dot{V}O_2$ max. among the various data of the exercise testing.[16)17)] And, each of athletes is usually trained under the observation of suitable heart rate by the attachment of Pulse Watch to the body. For the appropriate program of medical rehabilitation to ensure better chance of recovery of disabled patients, the concept like this is also thought to be needful. However, most disabled patients are treated without the exercise testings and heart rate monitors during physical therapies. The reasons may be due to the difficulty of evaluation of physical fitness for some physical troubles, and the narrow spectrum of utilization of the data of heart rate monitor. Recently, the personal computer has developed to be so precise that many data can be calculated for certain purposes easily.[18)] In this study, we tried to search some equipments under the concept of easy using, operating several machines by one personal computer, and exchanging all data obtained from several machines by a interface. Our all devices of the gas analyzer, ECG analyzer, oxygen saturator (Pulse Oxymeter CSI 1502) and three loading machines could be controlled by one personal computer. And, the estimation of $\dot{V}O_2$ and spent Calorie from the data of Pulse Watch was possible by our technique described above.

The peak $\dot{V}O_2$, peak$\dot{V}O_2$/W and peak HR of patients were significantly lower than those of healthy subjects (Table 1.). As the $\dot{V}O_2$ depends on, at least, sex, age, height, body weight and body fat rate, it is very dangerous to evaluate the results obtained from these exercise testings simply.[14,15)] In the present investigation, we compared the obtained data with the expected peak values which were calculated according to Wasserman's protocol.[14,15)] In the cases of both male and female patients, it became clear that the peak $\dot{V}O_2$/W and peak HR were significantly lower than the expected peak values (Figure 1.). With regard to the expected peak HR, the expression of (220 − age) is generally used. The expected peak HR values of healthy subjects were slightly higher than the real values of healthy ones (n.s., data not shown). On the other hand, it is well known that the HR of athletes decreases. Hence, the peak HR is thought to be no absolute index for physical fitness. However, as the maximal oxygen pulse (peak $\dot{V}O_2$/HR ) means the stroke volume, we consider that the HR shows the ratio of physical fitness. Similarly, the results in Table 2. indicated that the mean $\dot{V}O_2$ and $\dot{V}O_2$/W at AT point of patients were lower than those of healthy subjects. Thus, it was suggested that the physical fitness is diminished in disabled inpatients. This reason was thought to be due to deconditioning, associated with physical inactivity[19-21)].

By the way, it could be easily understood that the low level of fit-

ness may contribute to poor ability of exercise and poor rehabilitation outcomes. Though the appropriate exercise training should be tried to prevent these evils, the role of aerobic exercise training in the functional recovery of patients has not been well documented. It has been, however, reported that improvement in sensorimotor function after stroke is significantly related to the improvement in aerobic capacity.[7] In addition, it was revealed from the present investigation that the load at the AT-adjacent point was free from any medical complication. Hence positive attempts to search the AT point and to instruct each patient of the means of aerobic exercise training for the improvement of physical fitness might be necessary for the better recovery of, at least, hemiparesis in the stroke rehabilitation program. 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. If the HR at the AT-adjacent point were observed during the physical therapy, each of patients could be treated more effectively and safely during a medical rehabilitation. With regard to the $\dot{V}O_2$ and spent Calorie during the daytime of male patients, the mean values of patients of cervical injury were significantly lower than those of stroke, thoracic or lumbar injury, and the relationship between $\dot{V}O_2$ and HR was not so good (Table 3.). The HR was thought to be no appropriate parameter of physical fitness in the case of cervical injury patient. One of the reasons was thought to be the arrhythmia due to autonomic imbalance. However, the calculation of HR into $\dot{V}O_2$ or Calorie by the present procedure was thought to be generally convenient and useful.

In conclusion, it was suggested from the present investigation that the physical fitness is diminished in disabled inpatients, and that the attempts to improve it might be necessary in the rehabilitation program. And also, Pulse Watch was suggested to be generally useful to estimate the $\dot{V}O_2$ and spent Calorie in disabled patients except those of cervical injury.

## ACKNOWLEDGMENTS

The authors would like to thank physical therapists and medical technologists in our hospital 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.

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