1. Introduction

Associated with the increasing the elderly populations, many developed country have several problems including the burden of medical cost. At the same time, it is vital to initiate strategies for healthy elderly to keep them from illness and extend their healthy years. It has been demonstrated that improving aerobic capacity through regular exercise habits is effective against all these problems (ACSM, 1998a; 1998b; Kiyonaga, et al., 1985; Motoyama, et al., 1995; 1998; Nishida, et al., 2001; Sunami, et al., 1999). Therefore, we must develop exercise programs that can determine aerobic capacity and measure its improvement, as soon as possible. What is particularly needed is a method of creating practical exercise prescriptions for elderly at health promotion fields.

Exercise at lactate threshold (LT) is known to have positive effects on physical function and also on many illnesses, such as high cholesterol, high blood pressure, and diabetes (Kiyonaga, et al., 1985; Motoyama, et al., 1995; 1998; Nishida, et al., 2001; Sunami, et al., 1999). Because exercise at LT intensity places little burden on the heart and also permits measurement during sub-maximal exercise, it allows for highly precise development of safe and effective exercise prescriptions for patients with heart disease as well as the patients with lifestyle-related diseases (Brubaker, et al., 1997; Kumahara, et al., 1997; Makoto Ayabe, et al., 2005).
Table 1  Characteristics of subjects.

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<thead>
<tr>
<th></th>
<th>Exercise Group</th>
<th>Control Group</th>
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<tr>
<td></td>
<td>Men (n=8)</td>
<td>Women (n=12)</td>
</tr>
<tr>
<td>Age (yr.)</td>
<td>71.1 ± 3.5</td>
<td>72.1 ± 5.4</td>
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<tr>
<td></td>
<td>(66.0 - 76.0)</td>
<td>(65.0 - 80.0)</td>
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<tr>
<td>Height (cm)</td>
<td>168.0 ± 5.7</td>
<td>151.2 ± 5.0</td>
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<td>(155.8 - 175.1)</td>
<td>(143.9 - 159.2)</td>
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<tr>
<td>Weight (kg)</td>
<td>69.2 ± 5.3</td>
<td>51.8 ± 8.0</td>
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<tr>
<td></td>
<td>(64.8 - 81.0)</td>
<td>(39.5 - 64.3)</td>
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<tr>
<td></td>
<td>mean ±standard deviation (max-min)</td>
<td>mean ±standard deviation (max-min)</td>
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2003; Tanaka, et al., 1997). Thus, LT has been considered as the most effective exercise intensity for the exercise prescription.

In order to determine LT directly, we, however, must determine the exercise intensity (oxygen uptake) where blood lactate increases acceleratory from resting level, after the frequent blood sampling (Beaver, et al., 1985; Beaver, et al., 1986), so its use at health promotion fields has proven difficult. On the other hand, % of maximal heart rate and heart reserve are commonly used at health promotion fields as a simple method of evaluating exercise intensity (ACSM, 1998a; 1998b). The American College of Sports Medicine recommends 55-90% of maximal heart rate or 40-85% of heart rate reserve as the beneficial intensity for health (ACSM, 1998a; 1998b). Although such exercise prescription using heart rate have the advantage of being easy to develop for large numbers of subjects, the metabolic stress may differ among individuals for exercise intensities drawn up on the basis of heart rate, consequently the exercise at these intensities do not guarantee the desirable health benefits for all individuals (Fabre, et al., 1997; Gaskill, et al., 2001; Vallet, et al., 1997). Also similar procedures based on the rating perceived exertion (RPE) or the fixed blood lactate concentration have been developed, but as of yet, none of these has achieved a consensus (Bosquet, et al., 2002; Dickstein, et al., 1990; Shigematsu, et al., 2004; Tokmadikis, et al., 1998, Yoshida, et al., 1987).

Therefore, in present investigation as a basic research toward the development of a simple method of creating exercise prescriptions for elderly, studied the alterations in heart rate, blood lactate concentration, RPE at LT in older individuals.

2. Methods

2.1. Subjects

Subjects were 37 elderly (71 ± 4 years), divided into an exercise group (8 males, 12 females) and a control group (10 males, 7 females). Age, height and weight of subjects are shown in Table 1. One feature of the subjects is that there were no significant observable differences between the exercise group and the control group.

Further, subjects were sought through a newspaper advertising supplement. All participants were apparently healthy, independently living, and were free from any disability in the bench stepping exercise. None of the subjects was involved in any special training regimen before participating in this research, and they continued to maintain their usual lifestyles throughout the period of the research.
Additionally, after an explanation of the study design and requirements, each participant read and signed a consent form. The ethic committee in graduate School of Education, Hokkaido University as well as the Medical School of Fukuoka University, approved all procedures of present investigation.

2.2. Graded exercise test and determination of heart rate corresponding to LT, RPE, blood lactate concentration and metabolic equivalents

All the subjects performed submaximal bench stepping tests before and after the 12-week exercise intervention. Stepping test was the graded stepping rate method, using a step of 20 cm in height. The stepping frequency increased 2.5 times/min/stage. Furthermore the stepping frequency at the first stage was 10 or 15 times/min in the baseline step test, and was determined individually according to the LT levels in the post training measurement. Metabolic equivalents (METs) assumed from the height of the step and the stepping frequency were 3-4 METs at the first stage and 0.5 METs for the load increase rate (ASCM, 2000). Exercise duration was 4 min/stage; 2 min rest period was established between stages. We measured blood lactate concentration and heart rate at rest, heart rate for 30 sec before the end of each load, and blood lactate and RPE immediately at the end of each load. In order determined blood lactate concentration, a 5μl of blood sample from earlobe was analyzed by means of a portable lactate analyzer (Lactate Pro, Arkray, Japan; Pyne et al., 2000). Further, in this research, we took any blood lactate concentration less than 0.8 mmol/l, which cannot be measured by the Lactate Pro, to be 0.7 mmol/l. Also, heart rate was measured with a heart rate recorder, Accurex Plus (Polar Electric, Finland), and RPE was measured by the Borg scale. The termination criteria of the present exercise test was 15 of RPE or 4 mmol/l of blood lactate concentration. Furthermore the test was finished when subjects could not maintain the prescribed stepping frequency. LT was determined by the method of Beaver et al. (1985). Briefly, we separated pre-LT and post-LT visually from the graph of the independent variable log-exercise intensity and the dependent variable log-blood lactate, taking the intersection of the regression equations for each as METs at LT. Thereafter, heart rate, RPE and blood lactate concentration at LT were calculated.

2.3. Training program

The participants in the exercise group performed the bench stepping exercise at their home over a period of 12 weeks. Training intensity was LT, duration was 20-30 min/day, and frequency was 7 days/week.

2.4. Statistics

Numerical values in the paper are shown in mean and standard deviation. We used unpaired t-test to determine the differences between the two groups. The significance of the changes in heart rate, RPE and blood lactate concentration after the intervention was determined by the two-way repeated ANOVA. The relationship of two variables was analyzed by Pearson’ correlation coefficient (r). For all analysis, p<0.05 was set at statistically significant.

3. Results

Table 2 shows METs, heart rate, blood lactate concentration and RPE corresponding to LT before and after training. METs and heart rate corresponding to LT in the exercise group showed significant improvement after training. In addition, the change in heart rate was 6.4 ± 10.1 beats/min (6.7 ±10.3%); it was in the range of -12 beats/min to 30 beats/min (-10.9 to 30.6). Also, for the 4 subjects whose heart rate worsened, the increase in LT was less than 0.5 METs. On the other hand, no significant differences were observed pre- and post-training in blood lactate concentration and RPE corresponding to LT in the exercise group. In addition, no significant differences were observed for any values in the control group after training.

Significant correlation was observed between METs and heart rate at LT before and after the intervention, respectively (r = 0.371, .549, p<0.01, n = 37). Additionally, the intervention induced changes in METs and heart rate at LT were significantly associated (r = 0.570-.733, p<0.05). We show in Figure 1 the relationship with %heart rate reserve, where the highest correlation was obtained (r = 0.733, p<0.001). Further, as seen in Figure 2, a significant correlation between pre-training heart rate corresponding to LT and its change was observed (r = 0.595, p<0.001).
Training Effects on Lacatate Threshold

Table 2  Metabolic equivalents, lactate accumulation, heart rate and rating perceive of exertion at lactate threshold before and after training

<table>
<thead>
<tr>
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<th>Training Group (n=20)</th>
<th>Control Group (n=17)</th>
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<tr>
<td></td>
<td>Before</td>
<td>After</td>
</tr>
<tr>
<td>LT(METs)</td>
<td>4.4 ± 0.6 (3.5 - 5.8)</td>
<td>5.3 ± 0.6 (4.2 - 6.6)</td>
</tr>
<tr>
<td>LA(mmol/l)</td>
<td>1.1 ± 0.2 (0.7 - 1.3)</td>
<td>1.2 ± 0.2 (0.8 - 1.5)</td>
</tr>
<tr>
<td>HR(bpm)</td>
<td>109.0 ± 16.1 (83.0 - 136.5)</td>
<td>115.4 ± 13.9# (95.0 - 144.3)</td>
</tr>
<tr>
<td>%HRmax(%)</td>
<td>73.4 ± 10.9 (53.9 - 90.1)</td>
<td>77.8 ± 9.1# (63.3 - 93.1)</td>
</tr>
<tr>
<td>%HRR(%)</td>
<td>48.7 ± 17.9 (23.8 - 82.1)</td>
<td>55.8 ± 16.8# (25.3 - 81.2)</td>
</tr>
<tr>
<td>RPE</td>
<td>12.1 ± 2.1 (7.2 - 17.3)</td>
<td>12.3 ± 2.5 (7.7 - 15.9)</td>
</tr>
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</table>

mean±standard deviation (max-min)
#significantly difference between baseline level and that at after training (p<0.01).
LT; lactate threshold; ΔLA : The increase of lactate accumulation from resting level to that at LT; %HRmax; (Heart rate at LT) × Δ(220 - age) × 100 ; %HRR : (heart rate at LT - heart rate at rest) × (220 - age - heart rate at rest) × 100.

4. Discussion

The physical activity at appropriate intensity elicits numerous health benefits (ASCM 1998a; 1998b). However, exercise at excessive intensity gives rise to unnecessary stress on the body, causing various kinds of damage. Before the participation in a exercise program, therefore, the desirable excise intensity should be determined individually. This research was undertaken with the aim of clarifying the results of exercise training corresponding to the already confirmed safe and effective measurements of heart rate, RPE and blood lactate concentration corresponding to LT. Results revealed that, in elderly, heart rate at LT improved in conjunction with improvements in aerobic capacity through exercise, and that the lower the pre-training level the more striking was the amount of improvement. However, no change was observed pre- and post-training for RPE or blood lactate concentration corresponding to LT. These results show that using blood lactate is the best for a safe and effective exercise prescription, but that RPE is a better substitute than heart rate.

Improvements in LT and ventilation threshold (VT) due to exercise are greater than improvements in maximal oxygen uptake, consequently the exercise training increased the relative oxygenuptake at VT and LT (Fabre, et al., 1997; Vallet, et al., 1997). In contrast, the relationship between the relative value of oxygen uptake and the absolute value of heart rate did not change significantly (Skinner, 2003). As the result of the exercise intervention, heart rate at LT increased significantly with the improvement of the aerobic capacity (Jones and Carter, 2000). In elderly, there is no consensus concerning the effects of the exercise interventions on heart rate corresponding to LT (VT) (Amaidi, et al., 1998; Fabre, et al., 1997; Poulin, et al., 1992; Takeshima, et al., 1993). But Takeshima et al. (1993), who observed significant improvement in aerobic capacity, have observed higher values for heart rate at LT. These results indicate the likelihood that improvement in aerobic capacity in elderly due to exercise does raise heart rate.

However, according to Figure 1, for subjects whose heart rate at LT exceeded 130 beats/min, we can infer that heart rate will change little through exercise. In previous researches that also did not observe changes in heart rate at LT pre- and post-training (Amaidi, et al., 1998; Fabre, et al., 1997), average heart rate at LT before training was 129 beats/min. In addition, 130 beats/min is 87%
of the assumed maximal heart rate for the 70-year average age of the subjects in present study; this corresponds to the exercise intensity recommended for the long-term exercise practitioner and/or individuals with higher fitness level (ACSM 1998a; 1998b). Furthermore, as seen in Figure 3, post-training LT (5.3 ± 1.3 METs) and METs corresponding to 85%maximal heart rate (5.8 ± 1.6 METs) did not differ significantly. Similarly, Gaskill (2001) has reported post-training VT approaching pre-training 75%maximal oxygen uptake (85%maximal heart rate). All this demonstrates a convergence heart rate at LT around 85%maximal heart rate as a result of improved aerobic capacity, so that perhaps an exercise intensity program based on heart rate could have served as a substitute for LT in physically fit elderly or in those who were in the mid to late stages of the training.

Also, RPE and blood lactate concentration at LT did not change as a result of the exercise intervention. Therefore, a safe and effective exercise prescription suited to the individual would preferably use blood lactate concentration and RPE might serve as a substitute. But special care must be taken with

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**Figure 1** The relationship between the magnitude of change of lactate threshold and the magnitude of change of percent heart rate reserve at lactate threshold.

- ΔLT: The magnitude of change of lactate threshold, from base line level to that at after training
- Δ%HRR@LT: The magnitude of change of %HRR (percent heart rate reserve at LT) from base line level to that at after training.

\[ y = 14.926x - 6.860 \\
\text{r}=0.733, \ p<0.01 \\
\text{n}=20 \]

**Figure 2** The relationship between the magnitude of change and the baseline level for the heart rate at lactate threshold.

- HR@LT: Heart rate at LT(Lactate Threshold)
- ΔHR@LT: The magnitude of change of HR(percent heart rate reserve at LT) from base line level to that at after training.

\[ y = -0.381x + 48.313 \\
\text{r}=0.595, \ p<0.01 \\
\text{n}=20 \]
Training Effects on Lactate Threshold

Figure 3  The METs at lactate threshold and 85%HRmax before and after exercise training. METs; metabolic equivalents: LT; lactate threshold.
*Significantly lower than METs at 85%HRmax in baseline and METs at LT in the post training ($p<0.01$).

people with illnesses or elderly in regard to exercise prescriptions based on RPE. Whaley et al. (1997) have shown that RPE corresponding to this heart rate is significantly lower in patients with heart disease than in healthy individuals. Similarly, Kunitomi et al. (2000) have reported that RPE corresponding to VT in Type II diabetes patients in their sixties is significantly lower than it is in healthy elderly the same age. One interesting fact is that this difference in RPE corresponding to VT between Type II diabetes patients and healthy people was limited to those in their sixties; it was not observed in those in their forties or fifties. In any case, RPE corresponding to the same intensity may be lower in the physically unfit, such as those with illnesses or elderly, than in healthy people. Further, it has been demonstrated that the validity of the RPE assessment seemed questionable in older individuals, because lower levels of aerobic capacity decreased the cognitive performance (Van Boxtel et al., 1997).

Present investigation assumed maximal heart rate to be age subtracted from 220. Maximal heart rate estimated from age has been frequently not validate in elderly. (Sidney and Shephard, 1977), so that the %maximal heart rate at LT and %heart rate reserve show lower values than actual maximal heart rates in previous researchers (Fabre, et al., 1997). On the other hand, there have been reports of results even lower than those of this research, with heart rates corresponding to LT or VT in sufferers of lifestyle illnesses or those at risk as low as 30% of that predicted for age (Kunimoto, et al., 2000; Shono, et al., 2003). Thus, the presently used heart rate at LT, as a result of the method of calculation, in addition to such physical characteristics as age or illness, does not yet permit of standardization. Taking into consideration safety of measurement and labor, real measurement of maximal heart rate at the health promotional fields is very difficult. Thus in future, in order to develop a practical assumption method for heart rate at LT, we will have to collect in advance hard data corresponding to age, fitness and state of health.

In summary, this research was conducted with the aim of clarifying the longitudinal changes in heart rate, RPE and blood lactate concentration corresponding to LT in elderly. The results show that in regard to a safe and effective exercise prescription suited to the individual, a program based on blood lactate concentration is preferable, but we think that using RPE as a substitute is more applicable than heart rate. Particularly for beginners and those with low levels of fitness, the exercise prescription should be made based on the metabolic stress level, such as LT or VT. In the past, difficulty in measuring prevented common use of LT, but today, easy methods of determining LT have been developed, so that it can be used on the fields at very little cost (Ayabe, et al., 2003, 2004). On the other hand, for those who have been in training for a long
period or for the physically fit, exercise programs based on heart rate or RPE can yield sufficiently safe and effective results as substitute methods for LT. We conclude from the above that in regard to the methods for creating exercise prescriptions for elderly, LT, %maximal heart rate, %maximal heart reserve, RPE, etc., diverse exercise prescription systems suited to individual characteristics (fitness, state of health, etc.) may be practical. Thus, we must develop a graded exercise test based on the heart rate, RPE or blood lactate concentration, respectively, as well as the application criteria of these procedures.

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References


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