Autogenous control of heart rate taking Deep Slow Breaths during exercise

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ABSTRACT: We investigated whether heart rate can be controlled consciously. This study examined the effect of 20 minutes of cycling exercise while being conscious about energy conservation on the heart rate. 21 healthy college students (9 men, 12 women) participated three exercise bouts. Exercise bouts were examined under the following three conditions: (a) known condition (participants having information about the exercise duration); (b) unknown condition (participants having no information about the exercise duration) and; (c) conserving energy condition (participants having information about the exercise duration and being conscious about energy conservation). Heart rate in the unknown condition was lower than that in the known condition (p < 0.05); further, it was lower in the conserving energy condition than in the known condition (p < 0.01). In contrast, the tidal volume of the conserving energy condition was higher than that in the known condition (p < 0.05). In addition, the respiratory rates in the unknown and conserving energy conditions were lower than that in the known condition (p < 0.01). Energy expenditure during exercise was lowest in the conserving energy condition. These results show the possibility of autogenous control of heart rate by taking deep slow breaths consciously during exercise.

KEY WORDS Breath control; Heart rate control; Cardiopulmonary exercise test; Exercise limit; Cardiac training

INTRODUCTION

Today, heart disease and stroke are important causes of mortality in Japan. In 2015, Heart disease is the 2nd and cerebrovascular diseases are the 4th leading cause of death in Japan [1]. Thus, exercise is important for the prevention and management of risk factor for these diseases. Moreover, assessing cardiorespiratory fitness is important as a vital sign in clinical practice [2]. In particular, aerobic training make a large contribution to decrease in Blood pressure which is one of the risk factor in stroke and heart diseases [3].

Generally, when we decide work intensity, we consider along the limit such as heart rate (HR), maximal oxygen intake (VO2max), and anaerobic threshold (AT) [4]. Further, the rating of perceived exertion (RPE) can use for deciding work intensity, because HR and RPE have a strong correlation [5] and scale 13 of RPE most often equals AT [6]. From the viewpoint of management of work intensity, in particular, in cardiac training, HR is an important and useful index for determining the level of work rate or exercise. From the viewpoint of recurrence prevention, there are many people who already have some disease with upper limitation against to increasing HR during exercise. Thus, it is important that people who need to exercise comply with the HR limit in order to prevent undesirable incidences [7, 8]. However, in medical practice, the HR of few patients exceeds the limit. Thus, therapists are sometimes forced to change the work rate or stop the exercise. With respect to these, HR is not only a target for exercise intensity, but also a limitation for safe exercise.
The HR is controlled by an autonomic nerve and its change relies on physical activities and physical performances. In addition, the mental situation influences the HR. Furthermore, HR as a cardiac function is mutually controlled with respiratory function and energy metabolism [9]. However, our conscious can control respiration for breathing and the motion of the four limbs and trunk for movement.

Eston et al. [10] and Baden et al. [11] investigated the effects of deception and the expected duration on HR and RPE in exercise testing. Result of these studies was that HR and VO2 were lower in condition which participants did not exercise duration. Their study suggests a subconscious attempt to conserve energy for lowering the HR. Thus, if we attempt to conserve energy consciously, HR could be lower.

We investigated whether HR can be changed unconsciously when we consciously attempt to conserve energy. In addition, we studied how respiratory function is changed unconsciously because of mutual control between HR and respiratory function. If respiratory function is changed, changing respiration under our conscious leads to conscious HR control. This could contribute to the continuation of exercise under HR limitation. Lastly, it will help people with low physical strength who need to exercise that expenditure of energy showed the lowest value by being sentient to conserve the energy. So, we investigated that a conscious attempt to conserve energy actually led to reduce energy expenditure.

METHODS
Participants
We enrolled 21 healthy college students (9 men and 12 women, age: 21.7 ± 0.5 years, weight : 54.4 ± 6.5 kg) after obtaining their written informed consent. The study protocol which was according to the Declaration of Helsinki was approved by the ethics committee of Teikyo Heisei University (approval number 28-079).

Determination of work rate at AT
Total 21 participants underwent the cardiopulmonary exercise testing in advance for determining AT using an expiration gas analyzer (cspot-1, Inter-Reha Inc) and a cycle ergometer (Aerobike 232CXL, Combi Inc). The exercise testing protocol includes 4-min rest, 3-min warm up, a ramp program with 20-W increase per minute, and a recovery period. Expiration was analyzed using a breath-by-breath system, and AT was determined using the V-slope technique.

Experimental bouts
All participants undertook 20 minutes exercise bouts which was single stage load at a work rate of AT minus 1 minute at 60 rpm pedaling following three conditions on separate days: (a) known condition: participants knew about the exercise duration; (b) unknown condition: participants were unaware about the exercise duration; and (c) conserving energy condition: participants knew about the exercise duration and attempted to conserve energy. Exercise bouts on condition (a) or condition (b) were in a randomized order. All participants exercised on condition (c) as the last bout. During the experimental exercise bout, HR and RPE were recorded at every minute. In addition, oxygen intake per weight (VO2/W), respiratory rate (RR), tidal volume (TV) and minute ventilation (VE) were recorded using an expiration gas analyzer and calculated to 1 minute on average.

Finally, energy expenditure of during exercise is different on the basis of a participant’s weight and body fat [12]. Ainsworth et al. [13] were recommend estimation of the caloric cost using the below formula.

\[
\text{Energy expenditure (kcal)} = \text{Mets} \times \frac{\text{VO2/W(min)}}{3.5} \times \text{weight (kg)} \times \text{exercise duration (hour)}
\]

According to this formula, energy expenditure was calculated with the last 17 minutes average of VO2/W and compared among the three conditions.

Statistical analyses
Data were adopted from 4-min to 20-min (last 17 minutes) for statistical analyses because that physiological responses such as the oxygen intake becomes the plateau within three minutes in the work rate that is lower than AT [14, 15].

All statistical analyses were conducted using IBM SPSS statistics version 22. Data of HR, VO2/W, RPE, RR, VE and TV were analyzed using two-way repeated-measures analysis of variance (ANOVA). Energy expenditure over 17 minutes exercise was analyzed using one-way repeated-measures ANOVA. Post hoc test was performed using Bonferroni’s correction. When the assumption of sphericity was violated (P < 0.05), the Greenhouse-Geisser correction was used. The level of significance for all statistical analyses was set at P < 0.05. All values are presented as mean ± standard deviation.

STATISTICAL RESULTS
The average of VO2/W at AT minus 1 minute was 22.9 ± 3.7 ml/kg and 73.0± 11.3 W, respectively. The average of the HR of three conditions were 129.5 ±11.7 bpm in the known condition, 126.2 ±12.0 bpm in the unknown condition and 125.9 ±11.2 bpm in the conserving energy condition. The average of the TV in three conditions were 1675.0 ± 270.2 ml in the known condition, 1704.6 ±271.8 ml in the unknown condition and 1741.5 ±17.8 ml in the conserving energy condition. The average of the RR were 21.5 ± 3.4 rate in the known condition, 20.9 ± 3.3 rate in the unknown condition and 20.8 ± 3.3 rate in the conserving energy condition. The average of the VE were 35.6 ± 6.5 l in the known condition, 35.3 ± 6.5 l in the unknown condition and 35.9 ± 7.3 l in the
conserving energy condition. The average of the VO2/W were 26.5 ± 2.6 ml/kg in the known condition, 25.3 ± 2.1 ml/kg in the unknown condition and 25.2 ± 2.2 ml/kg in the conserving energy condition. The average of the RPE were 13.1 ± 2.0 in the known condition, 12.4 ± 2.3 in the unknown condition and 12.4 ± 2.0 in the conserving energy condition, respectively. Comparison among the three conditions over 17 minutes (4-min ~ 20-min) showed a significant main effect on the HR (F [1.489, 29.786] = 9.704, p < 0.01, ηp2 = 0.327), TV (F [1.628, 32.562] = 4.075, p < 0.01, ηp2 = 0.169), RR (F [1.394, 27.873] = 112.779, p < 0.01, ηp2 = 0.849), VO2/W (F [1.165, 23.304] = 64.798, p < 0.01, ηp2 = 0.764), and RPE (F [2, 40] = 15.764, p < 0.01, ηp2 = 0.441) respectively. The VE showed non-significant difference among three conditions. Concretely, the HR in the unknown condition was lower than that in the known condition (p < 0.05, 95%CI: -6.260 ~ -0.345) and that in the conserving energy condition was lower than that in the known condition (p < 0.01, 95%CI: -5.745 ~ -1.415) [Figure 1]. By contrast, from the perspective of breath, the TV of the conserving energy condition was higher than that in known condition (p < 0.05, 95%CI: 6.601 ~ 126.529) [Figure 2]. The RR of the unknown condition was lower than that in known condition (p < 0.01, 95%CI: -0.729 ~ -0.464) and conserving energy condition was lower than that in known condition (p < 0.01, 95%CI: -0.851 ~ -0.527) [Figure 3]. The VO2/W in the known condition was higher than that in both the unknown condition (p < 0.01, 95%CI: 0.828 ~ 1.630) and the conserving energy condition (p < 0.01, 95%CI: 0.934 ~ 1.768). Similarly, the RPE in the known condition was higher than that in both the unknown condition (p < 0.01, 95%CI: 0.282 ~ 1.012) and the conserving energy condition (p < 0.01, 95%CI: 0.311 ~ 0.966).

However, there were significant interaction effects between condition and time on VO2/W (F [5.971, 119.423] = 3.522, p < 0.01, ηp2 = 0.150), and RPE (F [7.525, 150.501] = 2.501, p < 0.05, ηp2 = 0.111). Thus, simple main effects for conditions were analyzed. There was a simple main effect between the known condition and the unknown condition in 4,7,14-min and between known condition and conserving energy condition in 4,5,6,7,8,10,14-min on VO2/W (p < 0.05) [Figure 4]. On the other hand, there was not any simple main effect on RPE [Figure 5].

Finally, the average of energy expenditure during exercise (4-min ~ 20-min) were 116.4 ± 14.8 kcal in the known condition, 111.1 ± 13.4 kcal in the unknown condition and 110.6 ± 13.3 kcal in conserving energy condition respectively. Comparison among the three conditions showed a significant effect (F [1.154, 23.071] = 64.238, p < 0.01, ηp2 = 0.763). Energy expenditure of known condition was higher than the both of unknown condition (p < 0.01, 95%CI: 3.586 ~ 7.807) and conserving energy condition (p < 0.01, 95%CI: 4.048 ~ 7.698) [Figure 6].

![Figure 1. One minute average of HR in the three conditions.](image-url)
known: condition that participants have information about the exercise duration. unknown: condition that participants have no information about the exercise duration. conserve: condition that participants have information about the exercise duration and attempt to conserve energy.

Figure 2. One minute average of TV in the three conditions.

Figure 3. One minute average of RR in three conditions.
known: condition that participants have information about the exercise duration.
unknown: condition that participants have no information about the exercise duration.
conserve: condition that participants have information about the exercise duration and attempt to conserve energy.
¶: Significant difference between the known condition and the unknown condition (p < 0.05), §: Significant difference between the known condition and the conserve condition (p < 0.05)

**Figure 4.** One minute average of VO2/W in three conditions.

**Figure 5.** One minute average of RPE in three conditions.
DISCUSSION

We investigated whether HR can be controlled when we consciously attempt to conserve the energy. The result were the HR in the unknown condition was lower than that in the known condition. Thus, participants had conserved energy subconsciously. This result was similar to that reported by Eston and Baden [10, 11]. In addition, the transition of HR in the conserving energy condition was similar to that in the unknown condition during experimental exercise bout. According to this result, the participant’s attempt to conserve energy change their HR.

In contrast, the study aimed to find how participants controlled their HR. Thus, we focused on breathing that influence on HR. As a result, TV changed much more and RR changed much less. Increase in the TV and decrease in the RR indicated that the breath has changed to deep and slow pattern from the normal breathing pattern. In this study, we did not give any instruction to the participants about breathing technique. Slow deep breath was natural reaction. Thus, we could be able to argue that the autogenous control of HR is possible to a certain degree using deep slow breathing technique.

The past study showed that slow deep breathing led to reduction in the blood pressure and HR because it influenced the sympathetic nervous system [16, 17]. In addition, the immediate effects of slow breathing exercise, such as yoga exercise have been reported [18]. Paprika et al. [19] investigated the relationship between slow breathing pattern and RR during yoga and the long-term effect in cardiovascular disease.

On the other hand, Taguchi et al. [20] showed that after physical training, the ventilatory patterns improved from abnormal short breath patterns. In addition, Pettersson et al. [21] showed that oxygenation improved by performing deep breathing exercise. Moreover, Garlando et al. [22] showed that simultaneous timing of breath and pedaling of cycling led to decreased oxygen intake. According to these studies, the breath pattern contributes to the change in HR and oxygen intake controlled by an autonomic nerve and these are mutually controlled.

From the viewpoint of RPE, the study by Denise et al. [23] showed that RPE changes are lower in the short run compared with the long run at the same speed. In this study, candidates controlled themselves by manipulating the attentional focus such as endpoint. This study suggested that RPE is strongly correlated with HR, while RPE was influenced by psychological factors. In the present study, there were significant interaction effects between condition and time and there was not any simple main effect among condition. Thus, it is difficult to conclude that RPE in the conserving energy condition was lower than that in the known condition. Finally, it will help people with low physical strength who need to exercise that conserving energy condition showed the lowest value by being sentient to conserve the energy.

CONCLUSIONS

According to the present results, the participants’ attempt to conserve energy changed their HR. In addition, the participants’ attempt to conserve energy changed their subconscious breathing; thus, subconscious deep slow pattern of breath contributed to lower the HR. Furthermore, the participants’ attempt to conserve energy actually led to reduce their energy expenditure. In medical practice and exercise conditions, there is some scope for lowering an individual’s HR to enable exercise within the safety limit of HR using deep slow breaths. In medical  

Figure 6. Energy expenditure in three conditions.

known: condition that participants have information about the exercise duration. unknown: condition that participants have no information about the exercise duration. conserve: condition that participants have information about the exercise duration and attempt to conserve energy. ✻: Significant difference (p < 0.01)
practice, in particular, exercise within the safety limit of HR were considered not only breathing but also pedaling cadences. In the present study, we did not focus on pedaling cadences. In the exercise boats, participants were forced to retain pedaling cadence at 60 rpm. It was likely that coordination of pedaling cadences and breathing rhythm influence on physiological responses. Lepers et al. [24] showed the effect of pedaling cadences on various physiological responses during exercise. Brisswalter et al. [25] suggested triathletes choose an energetically optimal cadence during prolonged exercise. On the other hand, Kohl et al. [26] showed coordination of pedaling and breathing rhythm was difficult for non-cyclists rather than racing cyclists. However, the Participants of the study in pedaling cadence were mostly athletes. Thus, we must investigate relation among pedaling cadence, breathing rhythm, and physiological responses, about non-athletes and people with low physical strength.

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