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Comparison of Heart Rate Variability during Playing Video Game and Cycle Exercise

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The purpose of the present study was to compare heart rate variabilities during playing a video game and physical exercise at the same heart rate (HR) level. Six healthy male subjects played the video game. The mean HR during playing the computer game was defined as the target HR. Then, subjects performed a bicycle exercise at the target HR. Electrocardiogram (ECG) was recored during experiment. R-R intervals were detected and resampled by 8Hz from ECG recordings. Power spectral densities were estimated by the direct method for last five minutes at rest, load and recovery. The low frequency (LF) powers (ms^2) were integrated from 0.04 to 0.15Hz and the high frequency (HF) powers were integrated from 0.15 to 0.5Hz. Natural logarithmic transformations of LF and HF powers were used to stabilize the skewness of raw data. The results of ANOVA showed a significant effect of periods ($p < 0.05$) and no significant effects of workloads and the interaction between the two factors. Significant differences in the ratio of LF and HF powers during playing the video game between at rest and load was observed. Significant differences in HF during mild levels of cycle exercise between at rest and load, and between at load and recovery was also observed. While during physical exercise, HR was thought to increase primarily due to the withdrawal of vagal nervous system activity, the contribution of sympathetic nervous system activity might be larger in the video game than in the cycle exercise.

Key words
Heart rate variability, Video game,
Cycle exercise

Introduction

The number of people in Japan using personal computers is increasing because of the rapid spread of information technology. According to a Japanese nationwide home child investigation (Japanese Ministry of Health, Labour and Welfare, 2006), 39.3% of children of less than 18 years in Japan play a video (computer) game or a personal computer for one hour or more a day.

Some studies have reported that heart rate (HR)[1,2] and blood pressure[3] increase with playing a video game. HR and blood pressure response to playing a video game is similar to the other mental task loads (Mental arithmetic, Stroop color words conflict test, star tracing, etc). These mental work loads alter heart rate variability (HRV) property. The low frequency (LF: 0.04-0.15 Hz) component of HRV is thought to reflect both sympathetic and parasympathetic nerve activity. It is also thought to be related to the baroreflex control. The high frequency (HF: 0.15-0.40 Hz) com-

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ponent of HRV is thought to reflect parasympathetic nerve activity. The ratio of LF and HF (LF/HF) is considered to mirror sympathovagal balance or to reflect the sympathetic modulations.[4] Several studies reported that mental task load reduced the power of both the LF and HF components of HRV.[5,6] There were few studies on the HRV during playing a video game. Frank and Boutcher[7] reported that there was no change of LF and HF components of HRV during playing a video game, although the HR increased.

Robinson et al.[8] suggested that at low to moderate intensities of physical exercise, the increase of HR is mediated primarily by a reduction of parasympathetic nervous system activity, and that sympathetic activity increases only after oxygen uptake exceeded 60 % of the maximum capacity. In general, sympathetic and parasympathetic nervous system activities are reciprocally organized. However, the magnitude of changes of these two activities was variable as mentioned above. It is unknown whether the contribution of these activities were the same or not when the same HRs were achieved at different conditions.

The purpose of the present study was to study the effects of video game on heart by comparing HRV during playing video game and cycle exercise at the same HR level.

Materials and Methods

Subject

Eight healthy male university students took part in this study. The mean and standard deviation of their age, height, and weight were 22.5 ± 0.5 yr, 171.1 ± 1.9 cm, and 60.1 ± 2.8 kg, respectively. None of the subjects was taking medication. All subjects were accustomed to the experiment of our laboratory. Before the experiment, the subjects gave their informed consent to participate in this experiment.

Protocol

Subjects were studied in the morning after a light breakfast. They were asked neither take beverages containing caffeine nor perform any intense exercise for 24 hours before the experiment.

On the first day, each subject maintained rest at the sitting position for ten minute, and played a fighting soccer game ("World Cup Soccer", Konami, Japan.) for eight minute, and recovered at the same position for ten minute. A pair of subjects fought in the game, and the pair of fighting was assigned at random. The mean HR during playing the video game was defined as the target HR.

On the second day, each subject performed three graded cycle exercise (30, 90, and 150 watts) with electrically braked cycle ergometer (STB-1400, Nihon-Koden, Japan). Mean HRs of the last five minute during the cycle exercise at different loads were measured. The target work load to achieve the target HR was calculated from the regression line of the physical exercise work loads and HRs.

On the third day, each subject maintained rest at the sitting position for ten minute, and performed the cycle exercise with the target work load for eight minute, and recovered at the same position for ten minute.

During experiment, an electrocardiogram was monitored from the CM_5 lead and stored the magnetic-optical disc in the data recorder (DR-Ma2, TEAC, Japan). Their sampling rate was 1 kHz. The R-R intervals were detected by the custom computer program of our laboratory.

Data analysis

The Augmented Dickey-Fuller test were applied to the time series to test whether the time series data were stationary or not. All data showed significant stationarity. R-R intervals were resampled by 8Hz based on the integral pulse frequency modulation model.[9] Power spectral density was estimated by the direct

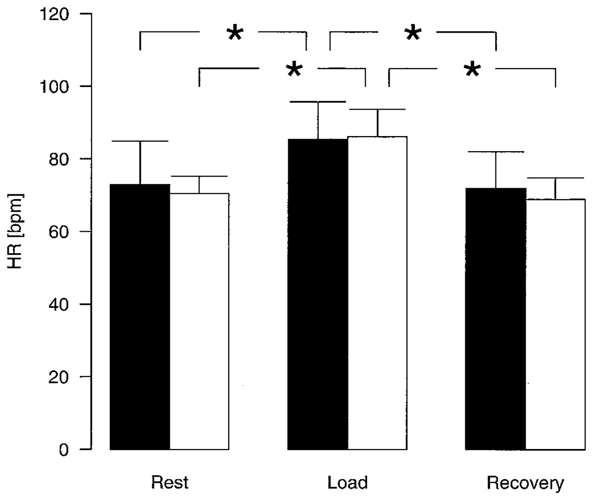

Fig. 1. HR at rest, load, and recovery. The black bar was a video game and the white one was cycle exercise (*;p < 0.05 by the Holm test).

method for last five minutes before, during and after work load. The powers were integrated in the low (LF; 0.04-0.15Hz) and the high (HF;0.15-0.5Hz) frequency bands[10]. Natural logarithmic transformation of LF and HF power (ms^2) was used to stabilize the skewness of the raw data.[11]

Statistical analysis

Results were presented as mean±standard deviation. Statistical analysis was performed by R ver2.2.1 statistical software.[12] The analysis of variance with repeated measures on two factors of workloads (playing a video game and cycle exercise) and periods (rest, during workload, and recovery) was performed. Pairwise comparisons were made using the Holm test. A probability level of less than 0.05 was considered significant.

Results

Table 1 showed the HR at rest and during playing a video game. HR increased during playing the video game in six of eight subjects, but it decreased in two. HR increases with mental tension, and conversely decreases

Table 1. Mean HR at rest and during playing video game

Subject	Rest (beats/min)	video game (beats/min)
A	76.1	95.5
B	69.1	80.4
C	54.9	74.7
D	91.7	99.7
E	75.2	86.2
F	71.2	75.9
G	72.4	69.5
H	90.0	81.6

with fatigue or being accustomed.[13,14] Two subjects whose HR decreased during playing the video game acquired 1st place and 2nd place in the game, indicating that the game seemed not to be a mental stress for them. Accordingly, the data of these two subjects were excluded from the following analysis.

Mean HRs at rest, load on, and recovery from mental work load condition were 72.9±11.9, 83.2±10.3, and 73.2±10.1 beats/min, respectively. The target HR and its work rate were 83.2±10.3 beats/min and 68±22 Watts, respectively. Mean HRs at rest, load on, and recovery from physical exercise work load condition were 70.5±4.8, 86.1±7.6, and 69.0 ±6.0 beats/min, respectively (Fig. 1). The results of ANOVA showed a significant effect of periods ($F=11.20$; $p < 0.05$) and no effects of work loads and the interaction of the two factors ($F=0.30$ and $F=0.15$). There were significant differences between rest and load, and between load and recovery in the both work load conditions($p < 0.05$ by the Holm test).

The LF power of HRV is thought to reflect both sympathetic and parasympathetic nerve activity. The HF power of HRV is thought to reflect parasympathetic nerve activity. The ratio of LF and HF powers is considered to mirror sympathovagal balance or to reflect the sympathetic nerve activity.

Natural logarithmic LF power at rest, load

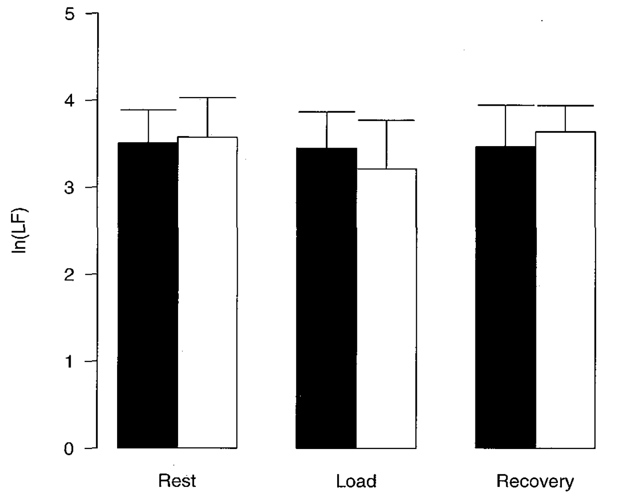

Fig. 2. Natural logarithmic LF power at rest, load, and recovery. The black bar was a video game and the white one was cycle exercise

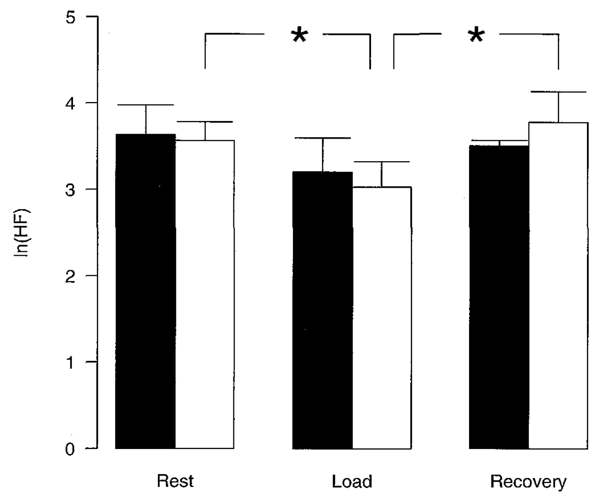

Fig. 3. Natural logarithmic HF power at rest, load, and recovery. The black bar was a video game and the white one was cycle

on, and recovery from mental work load condition were 3.505±0.378, 3.448±0.417, and 3.465 ±0.477 ln(ms^2), respectively. Natural logarithmic LF power at rest, load on, and recovery from physical exercise work load condition were 3.570±0.455, 3.211±0.558, and 3.636± 0.301 ln(ms^2), respectively (Fig.2). The results of ANOVA showed no effects of workloads, periods and the interaction of the two factors (F=0.00, F=0.96, and F=0.70, respectively).

Natural logarithmic HF power at rest, load on, and recovery from mental work load condition were 3.631±0.347, 3.201±0.397, and 3.505±0.062 ln(ms^2), respectively. Natural logarithmic HF power at rest, load on, and recovery from physical exercise work load condition were 3.566±0.215, 3.028±0.295, and 3.777±0.357 ln(ms^2), respectively(Fig.3). The results of ANOVA showed a significant effect of periods (F=11.35; $p < 0.05$) and no effects of work loads and the interaction of the two factors (F=0.01 and F=1.79). There were significant differences between rest and load, and between load and recovery in the physical exercise work load conditions ($p < 0.05$ by the Holm test).

The natural logarithmic formation of the ratio of LF and HF powers at rest, load on, and recovery from mental work load condition were -0.127±0.360, 0.247±0.204, and 0.040 ±0.425, respectively. Natural logarithmic LF/HF power spectra at rest, load on, and recovery from physical exercise work load condition were 0.004±0.480, 0.183±0.404, and -0.141±0.234, respectively (Fig. 4). The results of ANOVA showed a significant effect of periods (F=3.55; $p < 0.05$) and no effects of workloads and the interaction of the two factors (F=0.01 and F=0.35). There was significant difference between rest and load in the mental work load conditions ($p < 0.05$ by the Holm test).

Discussion

There was no significant difference in HR during playing a video game and cycle exercise. The same HR levels in the two conditions were validated. The work intensities of physical exercise were mild for all subjects, because the mean HR during physical exercise was 86.1 beats/min.

HRV has been categorised mainly into LF and HF components according to its frequency bands.[10] HF is equivalent to the well-

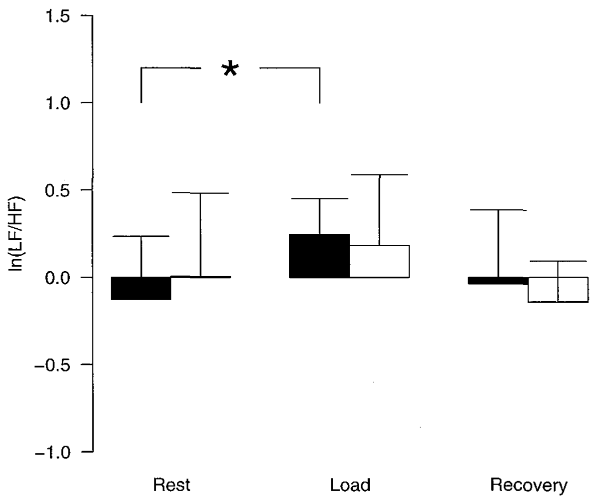

Fig. 4. Natural logarithmic formation of the ratio in the LF and HF power at rest, load,and recovery. The black bar was a video game and the white one was cycle exercise(*;p < 0.05 by the Holm test).

known respiratory sinus arrhythmia and is considered to represent vagal control of HR. LF is jointly contributed by both vagal and sympathetic nerves. LF/HF is considered to mirror sympathovagal balance or to reflect the sympathetic modulations.[4] Because it is easily accessible and noninvasive, frequency-domain analysis of HRV has gained its popularity with broad applications as a functional indicator of the autonomic nervous system.

Arai et al.[15] reported a reduced HF but no change in LF/HF during incremental physical exercise until exhaustion. Yamamoto et al.[16] found that HF decreased progressively from rest to a work rate equivalent to 60 % of ventilaroty threshold. Our results showed that HF decreased but LF/HF did not change during mild cycle exercise as well as previous researches. These results suggested that during mild levels of physical exercise HR was increased primarily by withdrawal of vagal activity.[8,17]

There were no significant differences of LF, HF, and LF/HF between playing the video game and cycle exercise in the present study. However, there was significant difference of LF/HF during playing the video game between at rest and load, although there was significant difference of HF during cycle exercise between at rest and load, and between at load and recovery. Many studies showed that HR increased during playing a video game,[1,2,7,18] but only Frank et al. reported its HRV property.[7] They found that LF and HF did not change in a video game (Tetris), but they did not mention about LF/HF. They explained that the game might be less visually and audibly stimulating than modern video games, and thus subjects might find this task less arousing.

Video games are kinds of mental task such as mental arithmetic, Stroop test, star tracing, and so on.[2] Several studies reported that mental task using mental arithmetic or Stroop test reduced the power of both the LF and HF of HRV components.[5,6,14] Reduced LF power was thought to be the result of a defensive cardiovascular system reaction associated with attention demanding information processing.[19] The principle subcomponent of the HF component is the respiratory sinus arrhythmia, the power of which depends on the stability of respiratory rhythm.[20] Therefore, it was advantageous to control respiration rhythm to a periodic predetermined frequency to eliminate the respiration effect from assessments of parasympathetic nerve activity. However, it was not practical to do so because this would induce extra stress on the subjects.

In contrast, Vuksanovi'c and Gal[21] reported that there was no significant changes of LF, HF, and LF/HF during mental arithmetic in 23 subjects. They noticed that HF increased in 13 and decreased in 10 subjects. LF unchanged and LF/HF increase in the group of an HF increase, and LF and LF/HF unchanged in the one of an HF decrease. In our data, HF tended to decrease, LF unchanged, and LF/HF increased significantly. These data were similar to the above-mentioned data. LF power did not change significantly indicating that slower cardiovascular rhythms maintain their activity during short-term regulation of HR.[20] Shapiro et al.[22] selected five subjects from the lowest quartile of distribution of hostility scores and five from the highest quartile of hostility from screening pooled 48 men. They found the high hostility group had a larger HR increase and decline in HF power in the mental arithmetic condition, whereas the low hostility group did not have significant cardiac or autonomic reactivity. The trait hostility of subjects might reflect HF power during playing the video game.

In summary, significant difference of LF/HF during playing the video game between at rest and load was observed, although HF during mild levels of cycle exercise between at rest and load, and between at load and recovery was also observed. During physical exercise HR was thought to increase primarily by withdrawal of vagal nervous system activity. The contribution of sympathetic nervous system activity might be larger in the video game than in the cycle exercise.

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