Acute Effect of Exercise Intensity on Heart Rate Variability in Trained Thai Male

ผลเฉียบพลันของระดับความหนักของการออกกำลังกายต่อความแปรปรวนของอัตราการเต้นของหัวใจในชายไทยที่ได้รับการฝึก

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ABSTRACT

The objective of this study was to investigate the acute effect of exercise intensity on heart rate variability in trained Thai male. Ten trained Thai male aged 18-35 years old, randomly performed exercise on cycle ergometer at 25, 65 and 85% $\dot{V}O_{2,max}$. They spent 30 minutes for each intensity with at least 7 days apart and performed separately. Throughout the experiment, ECG was recorded in order to analyze HRV. The analysis of HRV used time domain (standard deviation of all normal-to-normal intervals; SDNN and the square root of the mean of the sum of the squares of differences between adjacent NN intervals; RMSSD) and frequency domain (low frequency; LF, high frequency; HF and LF/HF ratio). The results found that during exercise at moderate and high exercise intensities, SDNN, RMSSD, LF and HF value significantly decreased compared to low-exercise intensity. The results indicated that the increasing of exercise intensity affected on reduction in the parasympathetic during exercise in trained Thai male.

บทคัดย่อ

วัตถุประสงค์ของการศึกษาครั้งนี้เพื่อตรวจสอบผลเฉียบพลันของความหนักของการออกกำลังกายต่อความแปรปรวนของอัตราการเต้นของหัวใจในชายไทยที่ได้รับการฝึก กลุ่มตัวอย่างเป็นนักกีฬาชาย 10 คน อายุ 18-35 ปี ทำการออกกำลังกายด้วยจักรยานวัดงานที่ความหนัก 25, 65 และ 85 % ของอัตราการใช้ออกซิเจนสูงสุด เป็นเวลา 30 นาทีในแต่ละความหนัก ซึ่งในแต่ละความหนักจะสุ่มทำแยกกันห่างกันอย่างน้อย 7 วัน ตลอดการทดลองผู้วิจัยบันทึกอัตราการเต้นของหัวใจ และนำไปวิเคราะห์เพื่อดูค่าความแปรปรวนของอัตราการเต้นของหัวใจด้านเวลา (ค่า SDNN และ RMSSD) และความถี่ (LF, HF และ LF/HF) ผลการศึกษาพบว่า ขณะออกกำลังกายที่ความหนักปานกลางและความหนักสูง ค่า SDNN, RMSSD, LF และ HF ลดลงอย่างมีนัยสำคัญทางสถิติเมื่อเปรียบเทียบกับการออกกำลังกายที่ความหนักต่ำ ส่วนค่า LF/HF ไม่แตกต่างกัน จากผลการศึกษาสรุปได้ว่า การเพิ่มขึ้นของระดับความหนักในการออกกำลังกายมีผลลดการทำงานของระบบประสาทพาราซิมพาเธติก และเพิ่มการกระตุ้นการทำงานของระบบประสาทซิมพาเธติกขณะออกกำลังกายในกลุ่มชายไทยที่ได้รับการฝึกได้

Key Words: Exercise, Cardiac autonomic activity, Fitness status

คำสำคัญ: การออกกำลังกาย การทำงานของระบบประสาทอัตโนมัติที่ควบคุมการทำงานของหัวใจ สมรรถภาพทางกาย

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Introduction

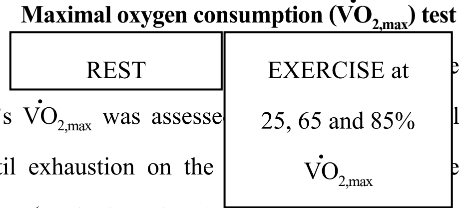
Autonomic nervous system (ANS) is a part of the peripheral nervous system that proceeds as a control system functioning mainly below the level of consciousness and controls visceral function (Van Der Velden, Hulsmann, 1999). Assessment of ANS function can be determined by heart rate variability (HRV) measurement (Routledge et al., 2010). Analysis of HRV has been promoted as a useful non-invasive method for evaluating function of the autonomic nervous system (Task Force of the European society of Cardiology and North American Society of Pacing and Electrophysiology, 1996). HRV is an indicator of the interaction between cardiac sympathetic and parasympathetic activity, which causes changes in the beat-to-beat intervals and changes in the frequency components of the heart rate (Kamath, Fallen, 1993; Park et al., 2009). It is widely accepted that during dynamic exercise, heart rate increases due to both an augmented sympathetic activity and a parasympathetic withdrawal (Bernardi, Piepoli, 2001). The autonomic responses to exercise vary depending on exercise intensity [Umetani et al.,1998; Ramaekers et al.,1998). A recent study has been showed that heavy exercise increases total power and LF power of HRV indicates highly increase in sympathetic activity (Rennie et al., 2003) which was positively related to the metabolic abnormalities (Licht et al., 2010). In contrast, regular aerobic exercise has beneficial effect on autonomic control of the heart (Hottenrott et al., 2006). It is often accompanied with an increase in HRV (Tuomainen et al., 2005), as a result of improved cardiovagal baroreflex sensitivity or via improvement in central regulation of the autonomic outflow (Monahan et al., 2000). The study done by Perini and coworkers found that only at low exercise intensities there was no change in the relative power of the three components of HRV with respect to rest. During exercise at the intensity above 30%$\dot{V}O_{2,max}$, a marked decrease in LF normalized (Perini et al., 1990). Cottin and coworkers found spectral analysis to confirm withdrawal of parasympathetic control during graded exercise load, as the power spectral density of the HF band significantly decreased with exercise loads. They also found that the LF power also decreased with exercise load (Cottin et al., 1999).

In addition, studies have shown that trained athletes have higher HRV compared to sedentary individuals, suggesting that exercise training can increase HRV in normal population (Tashita, Andrew, 2011). The studies in White population found that progressively greater reductions in cardiac vagal-related expression of HRV increase with increasing exercise intensity (Yamamoto et al., 1991). However, there were only few studies about effect of exercise intensity on HRV to exercise in trained Thai subjects. In addition, the information obtained from this study is important for our understanding of the impairment of ANS functions in trained Thai subjects. Therefore, the objective of this study was to investigate the acute effect of exercise intensity on HRV in trained Thai male.

Materials and methods

Subjects: Subjects were ten trained male. They were screened by health questionnaires, physical examination and blood chemistry before enrolling the study. Inclusion criteria were age 18-35 years old, performing regular exercise at least 5 days/week, for at least 3 years and having $\dot{V}O_{2,max}$ value equal or more than 50 ml/kg/min. Exclusion criteria were cardiovascular disease and hypertension, orthopedic problem, neuromuscular disorder, liver and kidney diseases and chronic infections. They were informed verbally and in writing before signing the consent form to participate in an experiment. A consent form approved by the Ethical Committee of Khon Kaen University in accordance with the 1964 Declaration of Helsinki. Before the experiment, subjects participated in a routine medical examination, anthropometric measurement (body mass index, height, weight, body composition), electrocardiography (ECG), routine blood chemistry (complete blood count,fasting blood glucose, liver function and renal test and lipid profile. Whole body composition (% body fat, fat mass and lean body mass) was directly measured by Dual- energy X-ray absorptiometry. Fat distribution was measured indirectly by measuring waist and hip circumference. The waist was measured at the midpoint between the lower rib margin and the iliac crest. Hips were measured at the trochanter level.

Maximal oxygen consumption ($\dot{V}O_{2,max}$) test



subject's $\dot{V}O_{2,max}$ was assesse… test until exhaustion on the … ergometer (Corival, Lode, The Netherlands). The first workload was 50-90 watts. The workload was increased every 3 min by 30-50 watts based on physical fitness until the subjects were fatigued. The criteria which were used to determine $\dot{V}O_{2,max}$ included a pedal rate less than 60 round per min, oxygen consumption reached a plateau with increase workload, a heart rate reached age-predicted maximum and a respiratory exchange ratio (RER) above 1.15. Expired air was collected and analyzed using a gas analysis system (PowerLab 8/30 AD Instrument, Australia). Heart rate was monitored with an oscilloscope monitor (Diascope type DS 521, Simonsen and Weel, Denmark) throughout the exercise test. The highest oxygen uptake obtained during the test was calculated for the $\dot{V}O_{2,max}$ value of the individual.

Experimental protocol

In the experiment, the subjects started the trial by resting in supine position for 30 minutes. Then, subjects moved to the cycle ergometer and performed exercise at the 25, 65 and 85% $\dot{V}O_{2,max}$ (referring to low, moderate and high exercise intensities) of each individual separately at least 7 days. Throughout the experiment, ECG was recorded in order to analyze HRV. Experimental procedure of this study is shown in Fig.1

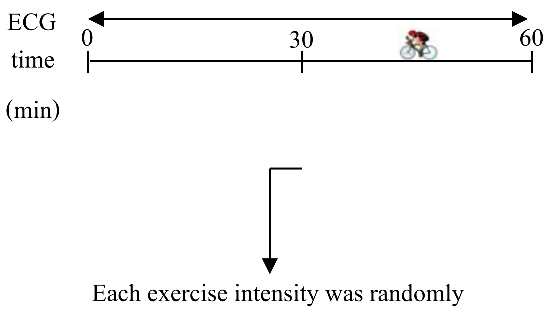


Figure 1 Experimental protocol

Heart rate variability measurement

HRV analyses were made using a PowerLab data acquisition systems (PowerLab 8/30 ADInstruments, Australia). Electrode placement was set under the middle left and right clavicles and left anterior lower rib reference by lead II ECG placement. EKG was used to analyze time domain (SDNN and RMSSD) and frequency domain (LF, HF and LF/HF ratio) of the HRV.

Statistical analyses

Data were expressed as mean and standard deviation (mean ±SD). A paired samples t test was used to assess the differences between before and during exercise in each exercise intensity. One-way ANOVA was used to evaluate the difference between exercise intensity. The level of significance was established at $p<0.05$ for all statistics.

Results

Table 1 showed mean age, body weight, height, BMI, waist and hip circumferences, W/H circumference ratio, percentage of body fat, fat mass, lean body mass and $\dot{V}O_{2,max}$. All subjects were non-obese and trained level of aerobic capacity.

Table 2 showed that they had normal fasting blood glucose, lipid profiles and liver and kidney functions.

Table 1 Anthropometric and physiological characteristics of subjects

	Mean ±S.D. (n=10)
Age (yr)	22 ±4.84
Body mass (kg)	61.1 ±4.79
Height (m)	1.7 ±0.03
BMI (kg/m^2)	20.7 ±1.50
Waist circumference (cm)	76.6 ±4.16
Hip circumference (cm)	88.9 ±5.15
W/H ratio	0.87 ±0.04
Body fat (%)	11.5 ±6.52
Fat mass (kg)	6.6 ±4.25
Lean body mass (kg)	50.6 ±4.29
$\dot{V}O_{2,max}$ (ml/kg/min)	54 ±5.33

BMI, body mass index; W/H, waist to hip circumference; $\dot{V}O_{2,max}$, maximal oxygen consumption

Table 2 Blood chemistry of subjects before enrolling the experiment

	Reference range	**Mean ±S.D. (n=10)**
Glucose (mg/dL)	70-110	78.2 ±7.13
Creatinine (mg/dL)	0.5-1.5	0.96 ±0.05
ALT (U/L)	4-36	19.7 ±5.03
Cholesterol(mg/dL)	127-262	192.5 ±34.66
TG (mg/dL)	< 200	76.4 ±53.66
HDL-C (mg/dL)	> 35	61.4 ±15.2
LDL-C (mg/dL)	< 150	123.9 ±29.5

ALT, alanine amino transferase; HDL-C, high density lipoprotein cholesterol; LDL-C; low density lipoprotein cholesterol

Table 3 HRV analysis at before exercise, immediately after exercise and after exercise at various intensities

	Exercise intensity					
	Low intensity		**Moderate intensity**		**High intensity**	
	Before Ex.	**During Ex.**	**Before Ex.**	**During Ex.**	**Before Ex.**	**During Ex.**
SDNN (ms)	95.45 ±50.45	42.44 ±26.44	97.82 ±36.39	10.85 ±5.69*#	100.83±22.14	13.50 ±12.50*#
RMSSD (ms)	99.23 ±84.21	40.64 ±38.75	80.83 ±43.62	10.52 ±9.14*#	91.06 ±43.02	8.18 ±8.52*#
LF (nu)	44.02 ±25.93	39.45 ±18.80	45.64 ±21.24	19.91 ±17.08#	48.81 ±19.98	13.81 ±9.47*#
HF (nu)	56.22 ±25.32	39.13 ±9.58	52.09 ±21.77	9.58 ±10.02*#	50.53 ±18.96	12.96 ±20.44*#
LF/HF ratio	2.23 ±3.94	2.09 ±3.57	1.22 ±1.02	2.90 ±3.16	1.42 ±1.27	3.57 ±3.94

Data are expressed as mean ± S.D.; n=10; Ex.; exercise

* Significantly different from rest before exercise ($p<0.05$)

Significantly different from during exercise at low-exercise intensity ($p<0.05$)

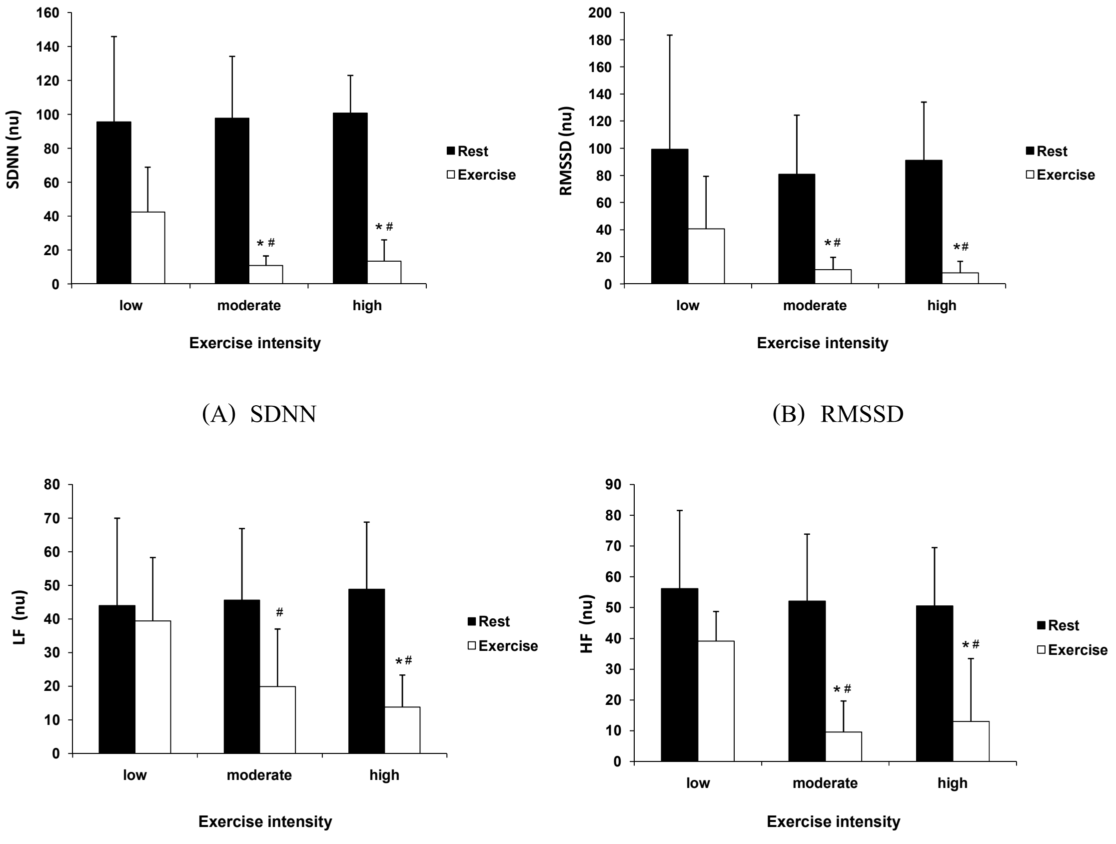
The results of the time domain analysis showed that HRV, SDNN and RMSSD values during exercise at moderate and high exercise intensity were significantly decreased compared with rest before exercise ($p<0.05$). Moreover, during exercise at moderate and high exercise intensities, there were significantly decreases in SDNN and RMSSD values compared with during exercise at low exercise intensity ($p<0.05$) (Table 3, Fig.2 (A) and (B)).

The frequency domain analysis, LF value during exercise at high exercise intensity was significantly decreased compared with rest before exercise while HF value during exercise at moderate and high exercise intensities were significantly decreased compared with rest before exercise ($p<0.05$). Moreover, during exercise at moderate and high exercise intensities, there were significantly decreases in LF and HF values compared with during exercise at low intensity ($p<0.05$) (Table 3, Fig. 2 (C) and (D)). However, there was no significant difference in ratio of LF/HF value within and between exercise intensity.

Discussion

HRV analysis can provide a non-invasive method of evaluating autonomic neural balance of the heart in various physiological situations. The SDNN estimates overall of HRV power and represents a general measurement of autonomic nervous system balance (Evrengul et al., 2006). The RMSSD represents the short-term parasympathetic component of HRV (Risk et al., 2001). The LF reflects a combination of both parasympathetic and sympathetic modulations whereas the HF is a marker of parasympathetic activity. The LF/HF ratio is thought to reflect the interplay between the parasympathetic and sympathetic branches of the ANS (Liao et al., 1997).

The main finding of this study was that SDNN, RMSSD, LF and HF values during exercise at moderate and high exercise intensities were decreased when compared with during exercise at low exercise intensity. Thus, the results indicated that the increasing of exercise intensity to moderate and high resulted in reduction in the parasympathetic during exercise in trained Thai male.



(A) SDNN (B) RMSSD

(C) LF (D) HF

Figure 2 SDNN (A), RMSSD (B), LF (C) and HF (D) values at rest before exercise and during exercise at various intensities

Data are expressed as mean ± S.D.; n=10

[*] Significantly different from rest before exercise ($p<0.05$)

[#] Significantly different from during exercise at low-intensity exercise ($p<0.05$)

The studies in white population, the sympathovagal balance changes in response to different intensities of aerobic training, as evidenced by changes in HRV parameter, including significant changes LF, HF and total power of the frequency domain. In addition, as exercise intensity increased over time, the LF/HF ratio increased with exercise intensity, reflecting and increase in the sympathetic tone (increased LF nu) and decreased in the parasympathetic Tone (decreased HF nu). Thus, they indicate that exercise and increasing exercise intensities results in detectable changes in HRV measure, reflecting the relative input of the autonomic system the body makes in response (Hottenrott et al., 2006; Pichon et al., 2004; Bojan et al., 2013).

Our results are in consistent with previous studies, which showed that an exercise decreased HRV in normal subjects (Arai et al., 1989; Marinmaki et al., 2008). The effect of exercise is remarkable in both HF power and LF power of HRV. Both HF and LF power diminished with onset of exercise in healthy subjects. This suggests a strong withdrawal of the parasympathetic activity of the cardiac autonomic activity during exercise (Chen et al., 2008). Early studies in spectral analysis of HRV data during exercise seemed to indicate that HF power decreased during exercise. However, these studies also showed that total power declining in the same period. Thus studies quantifying HF and LF power in normalized units, allow a better appreciation of the fractional distribution of HRV energy, are more illuminating. Normalized HF power, which is generally thought to be an indicator of vagal activity, would be expected to diminish during exercise. Rather, it increases gradually during exercise, whereas normalized LF power, which is thought to reflect sympathetic activity, decreases during exercise (Hagerman et al., 1996; Pichon et al., 2004). In the study of Kannankeril and Goldberger (2002) electrophysiology of the heart was measured during moderate exercise. It was found that the vagal activity of the heart was withdrawn but still measurable during moderate-intensity exercise. This study showed that even though the vagal activity diminished, it was still measurable in normal subjects during moderate-intensity exercise. In addition, two other studies suggested that sympathetic influence (measured by LF and LF/HF) was increased during graded exercise in healthy subjects (Lucini et al., 2004; Saito, Nakamura, 1995). These results were indirect conflict with studies indicating significant suppression of both sympathetic and parasympathetic cardiac control during graded exercise measured by the LF and HF of the spectrum of HRV (Pichon et al., 2004; Kamath et al., 1991). Moreover, Yamamoto and coworker reported that decreased parasympathetic activity (HF) and unchanged sympathetic activity (LF/HF) up to 100% of the predetermined ventilatory threshold (Yamamoto et al., 1991). However, Perini and Veicsteinas concluded that changes in HF and LF power and LF/HF ratio observed during exercise do not reflect the decrease in vagal activity and the activation of the sympathetic at increasing load (Perini and Veicsteinas, 2003).

Conclusions

Heart rate variability measures, Short-term recordings are easy to perform and are suitable for both clinical and physiological research for used to monitor autonomic function. Our study showed that the acute exercise with increasing exercise intensity affected on reduction in the parasympathetic during exercise in trained Thai male. It is apparent that with increasing intensity of exercise, cardiac vagal withdrawal became greater and the sympathoadrenal system is activated. However, it gives no information on the possible effects of exercise training at various exercise intensities and gender difference. Therefore, further investigate may advance exercise prescription training and comparison for male and female to affects on HRV.

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