Hemodynamic Responses to 3-minute Step Test in Sedentary Office Workers: A Case Study

Manita Chanpaibool, Chutima Jalayondeja*, Wattana Jalayondeja, Watesinee Kaewkhuntee
Faculty of Physical Therapy, Mahidol University, Thailand
*E-mail: chutima.jal@mahidol.ac.th

Abstract

Hemodynamic responses to exercise can be an indicator of cardiorespiratory fitness (CRF) which referred to a body's ability to supply adequate oxygen to all tissues. Behavioral factors including physical activity (PA) and sedentary behaviors (SB) influences on cardiometabolic risk factors that related to CF and hemodynamic responses. However, lack of study was conducted to measure the hemodynamic responses in those combined PA and SB. Therefore, the objective was to compare the hemodynamic responses between office workers who were in sedentary exercisers group (SEG) and couch potatoes group (CPG) at resting, exercise testing and recovery periods. A case study was conducted in office workers at Faculty of Physical Therapy, Mahidol University. The inclusion criteria were: age 20-40 years, body mass index (BMI) <30 kg/m^2 and sedentary time >8 hours/day. Demographic data were age, gender, weight, height, and job description. The sedentary time and PA were measured by questionnaire of Thai Physical Activity Guideline (TPAG). Sedentary participants were classified into SEG (with physically active) and CPG (with physical inactive). The hemodynamic responses were measured by a portable transthoracic bioimpedance cardiograph device (PhysioFlow Enduro, Paris, France). They were assessed at resting for 2 minutes, exercise testing using the 3-minute step test, and minute 1, 2 and 3 of recovery period. The Mann-Whitney U test was used for data analysis. Of total 22, 8 participants aged 26-36 years, BMI 18.81-29.06 kg/m^2, and sedentary times 8.5-14.0 hours/day. They were in SEG (n=5) and CPG (n=3). Similar pattern of hemodynamic responses were found in both groups at resting, exercise testing and recovery period. Significant difference of blood pressure (BP), heart rate (HR) and cardiac output (CO) (p<0.05) between SEG and CPG at exercise testing. At the recovery period, these parameters were not return to the resting period in CPG. In conclusion, PA was a dominant factor in combined behaviors and influenced on the hemodynamic responses to exercise. Therefore, encouraged PA in office workers who had sedentary time more than 8 hours per day was recommended.

Keywords: Cardiorespiratory fitness, Hemodynamic responses, Office worker, Physical activity, Sedentary behavior

Introduction

Cardiorespiratory fitness (CRF) is a body's ability to supply adequate oxygen to all tissues representing the function of heart, lungs and blood vessels or cardiovascular health. The maximum and sub-maximal exercise tests are a valuable tool for determining the CRF. Common exercise testing included of treadmill or stationary bicycling, 6-minute walk test and 3-minute step test. Hemodynamic response to exercise is a part of cardiovascular physiology that concerned with blood flow and blood pressure (2), and can be an indicator of CRF. The measurement of atrial blood pressure can be used to estimate cardiac hemodynamic responses including heart rate (HR), stroke volume (SV), cardiac output (CO), cardiac index (CI), and blood pressure (BP). Recently, two methods are used to assess cardiac hemodynamic responses comprised of invasive and non-invasive techniques. Although the measurement of invasive techniques was accurate, the non-invasive techniques such as impedance cardiograph demonstrated good correlation with invasive technique ($r=0.85-0.98$, $p\text{-value}<0.001$) (5), and it was simple to use to detect cardiac hemodynamic responses in clinic or field test. For example, Chantal's study in 2011 and Adriano's study in 2012 used impedance cardiograph to assess hemodynamic response during exercise in healthy and obese adults, and during 6-minute walk test in healthy and pulmonary hypertension patient, respectively (6-7).

Physical activity (PA) was defined by WHO as any bodily movement produced by skeletal muscles that requires energy expenditure. Many studies were found PA had a direct relationship with cardiorespiratory health, and it improves CRF (8). From the study about the effect of PA on cardiac function and performance in woman of Djordje et al. in 2015, they found young-to-middle age adults with high-active PA group had higher stroke volume index and peak exercise cardiac index than low-active PA group ($P<0.05$) (9). Sedentary behaviors (SB) refer to any waking activity characterized by energy expenditure ≤ 1.5 metabolic equivalents and a sitting or reclining posture. Sedentary behavior times had an inverse association with CRF in child and adolescence (10). Thailand business's survey in 2014 reported that 83.2% of office workers sat for 8 to 10 hours a day and 8.8% of them spend longer than 10 hours for sitting (11). However, Thai physical activity situation from 2012-2014 by Institute for population and social research, Mahidol University found that 69.7% of working-age population have sufficient PA based on the global recommendation from WHO (12).

Behavioral risk factors including physical activity (PA) and sedentary behaviors influences on the CRF and hemodynamic responses. PA has been reported the benefit for health. Kishan and colleagues in 2016 (13) studied the effect of combined PA and SB on biomarkers of cardiometabolic health in English adults. The subjects were divided into 4 groups based on their

PA and sedentary statuses. First, 'Busy bees' for people who have physically active and low sedentary time. Second, 'Light movers' for people with physically inactive and low sedentary time. Next, 'Sedentary exercisers' for who have physically active with high sedentary times. Last, 'Couch potatoes' for who have physically inactive and high sedentary time. They found physically active was associated with better health even combined with high sedentary time, but HDL-cholesterol had a relationship with sedentary time more than physically activity.

However, lack of the study to identify the effect of combined PA and sedentary time on the cardiac hemodynamic responses and CRF in office workers. Therefore, the objective of this study was to compare the hemodynamic responses between office workers who were in sedentary exercisers group (SEG) and couch potatoes group (CPG) office workers at resting, exercise, and recovery periods.

Methods

A case study was conducted for determining the hemodynamic response in office workers at Faculty of Physical Therapy, Mahidol University. The inclusion criteria were age 20-40 years, the body mass index (BMI) less than 30 kg/m^2, and sitting time at work more than 8 hours per day. The participants were excluded if they had cardiovascular diseases, pregnant, and others condition that limited to exercise. They were recruited into this study using the convenient sampling technique. This study was approved by Mahidol University Institutional Review Board (COA no. MU-CIRB 2016/052.0804).

Demographics data collections were age, weight, height, BMI, job description, and sedentary time (hours per day). Physical activity (PA) recorded moderate to vigorous intensity of activity, frequency and duration of activity performance and sitting time during the last 7-days by the questionnaire of Thailand Physical Activity Guideline (TPAG). The participants were classified into six steps of TPAG: 0-1 referred to sedentary lifestyles, 2-3 referred to active lifestyles and 4-5 referred to vigorous lifestyles. The active lifestyles (step 2-3) were (a) they had at least 150 minutes/week of moderate PA or 75 minute/week of vigorous PA or combination according to the WHO recommendation for PA (8) and (b) they spend the calories expenditure of moderate to vigorous PA for 500 to 1000 kcal/week. All participants were divided into 2 groups using the six steps of TPAG for PA promotion (14). The sedentary exerciser group (SEG) referred to those who were in active and vigorous lifestyles of TPAG (step 2-5) while the couch potato group (CPG) referred to those who were in sedentary lifestyle (step 0-1).

Next, they were measured the cardiac hemodynamic responses comprising of heart rate (HR), stroke volume (SV), cardiac output (CO) and cardiac index (CI) using a portable transthoracic

bioimpedance cardiograph device (PhysioFlow Enduro, Paris, France). The blood pressure was measured using the digital sphygmomanometer (CARESCAPE V100 with DINAMAP technology). Participants were rested in sitting position for 2 minutes until hemodynamic parameters stable. After that, they were performed 3-minute step test. We used 30-cm box height and frequency of metronome is 96 beats per minute (24 step cycles per minute) (15). For the recovery periods, participants sat for 3 minutes and the data were recorded at minute1, 2 and 3 after exercise testing.

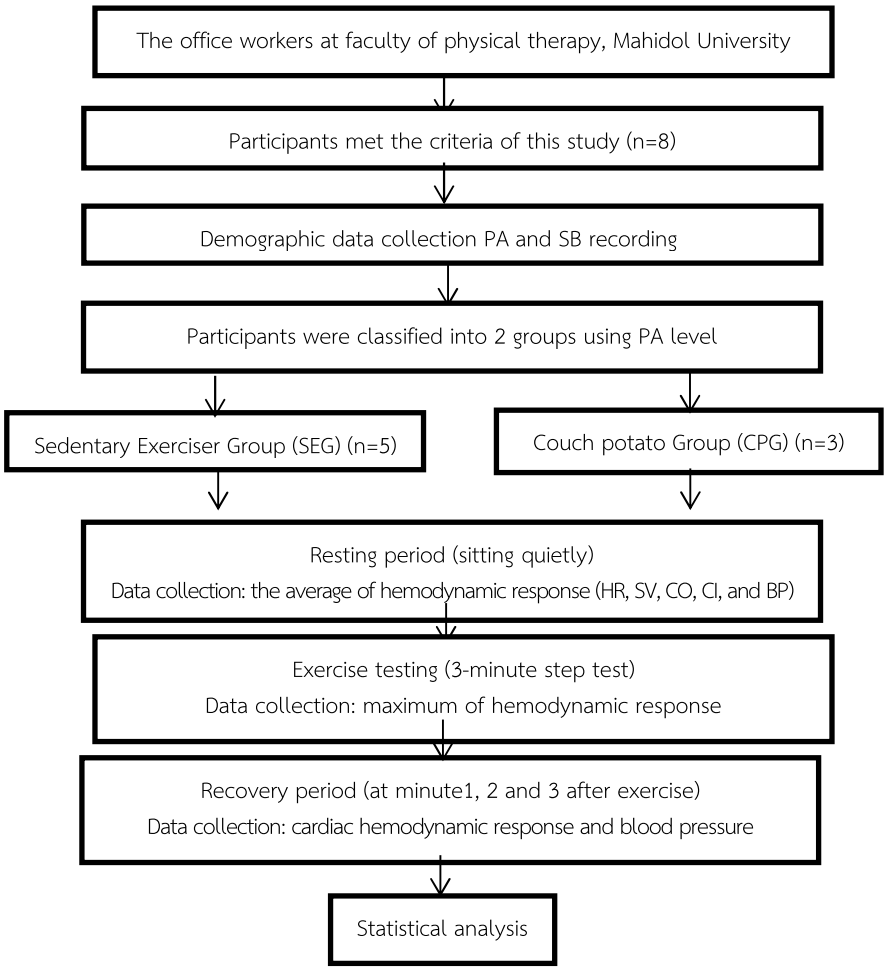

Figure 1 the study's protocol

PhysioFlow was collected data every 10 seconds. The blood flow parameters was collected 6 times; average of resting period (around 2 minute), peak in the last minute of testing period (exercise period), immediately after testing, and recovery period every minute (1 minute, 2 minute, and 3 minute). Before this study, we conduct validity and test-retest reliability test of protocol in 12 participants. The validity test of attach electrode followed PhysioFlow landmark was conduct under the supervision of an expert of PhysioFlow. An intraclass correlation coefficient for systolic blood pressure was 0.64-0.89, diastolic blood

pressure was 0.63-0.81, heart rate was 0.75-0.97, stroke volume was 0.75-0.91, cardiac output was 0.53-0.69, and cardiac index was 0.45-0.71.

Data were analyzed using SPSS® (version 21.0; Armonk, NY: IBM). The assumption of normal distribution was assessed by the Shapiro-Wilk test. Demographic data and the parameter of hemodynamic responses were described in median and range (min to max values). Hemodynamic parameters (heart rate, stroke volume, cardiac output, and cardiac index) change during each period was showed by table and line graph. The Mann-Whitney U test was used to compare all parameters between two groups. The P value was set at <0.05.

Results

Of total 22, 8 participants met our criteria in this study (5 SEG and 3 CPG). Demographics were presented in Table 1. They were 5 males and 3 females and their age ranged from 28 to 36 years. All demographics data were similar between SEG and CPG (P>0.05).

The results showed significant difference of HR, CO and systolic BP between two groups at exercise testing (3-minute step test) and recovery periods (p<0.05). Table 2 demonstrated the median and range (minimum to maximum values) of systolic and diastolic blood pressure (SBP and DHR), HR, SV, CO and CI in SEG and CPG. Figure 2 shows the change of hemodynamic responses and BP over the follow-up period. The hemodynamic responses patterns in both groups were similar as shown in Figure 2.

Table 1: Demographic data of all participants (n=8)

Participants (n=8)	SEG (n=5)			CPG (n=3)			*p*-value
	Median	Min	Max	Median	Min	Max	
Age (yrs)	32	30	32	28	26	36	0.445
Weight (kg)	57.0	44.6	92.6	72.9	66.6	82.5	0.267
Height (cm)	160	154	182	167	155	170	0.881
BMI (kg/m^2)	20.80	18.81	29.06	28.30	26.14	28.55	0.101
Sedentary times (hrs/day)	9.5	8.5	14.0	9.0	8.5	11.0	0.651
Physical activity (kcal/wk)	1138.9	178.6	6053.3	466.2	0	1712.4	0.297
At resting							
SBP (mmHg)	106	93	134	115	107	122	0.297
DBP (mmHg)	70	65	84	77	75	83	0.180
HR (bpm)	70.0	59.0	89.1	86.0	68.6	93.8	0.297
SV (ml)	83.82	63.14	87.50	83.58	72.64	83.70	0.456
CO (L/min)	5.37	4.44	7.17	6.26	5.77	7.89	0.297
CI (L/min/m^2)	3.16	2.48	4.73	3.41	2.87	4.55	0.655

The abbreviations: Min; minimum, Max; maximum, BMI; body mass index, SBP; systolic blood pressure, DBP; diastolic blood pressure

Table 2: Hemodynamic parameters measured during each period

Parameters		SEG			CPG		
		Median	Min	Max	Median	Min	Max
SBP/DBP (mmHg)	Resting	106/70	93/65	134/84	115/77	107/75	122/83
	Recovery						
	minute 0	148/80	117/68	151/90	162/87	121/68	191/93
	minute 1	129/79	116/67	152/88	166/85	131/77	188/86
	minute 2	116/68	106/64	139/82	161/84	131/74	170/92
	minute 3	114/63	93/62	128/84	155/79	129/76	162/84
Heart rate (bpm)	Resting	70.0	59.0	89.1	86.0	68.6	93.8
	Exercise	141.0	124.0	151.0	155.0	151.0	174.0
	Recovery						
	minute 0	140.0	124.0	151.0	151.0	148.0	174.0
	minute 1	90.0	84.0	117.0	136.0	120.0	144.0
	minute 2	80.0	73.0	108.0	118.0	107.0	121.0
	minute 3	77.0	65.0	106.0	105.0	103.0	116.0
Stroke volume (ml)	Resting	83.82	63.14	87.50	83.58	72.64	83.70
	Exercise	118.00	84.40	134.20	109.80	103.40	127.10
	Recovery						
	minute 0	101.90	84.40	134.20	93.80	90.50	118.20
	minute 1	101.60	80.10	116.50	102.00	94.50	115.50
	minute 2	86.70	75.80	114.00	104.00	81.00	112.30
	minute 3	97.90	71.50	109.10	102.90	82.80	104.60
Cardiac output (L/min)	Resting	5.37	4.44	7.17	6.26	5.77	7.89
	Exercise	16.60	11.50	17.60	18.60	15.90	19.10
	Recovery						
	minute 0	14.80	11.50	16.60	16.30	13.30	17.90
	minute 1	10.30	6.70	10.80	13.90	12.90	14.70
	minute 2	7.50	5.50	9.40	12.00	9.80	12.30
	minute 3	8.40	5.10	9.20	10.60	9.60	11.00
Cardiac index ($L/min/m^2$)	Resting	3.16	2.48	4.73	3.41	2.87	4.55
	Exercise	8.90	7.70	11.60	9.60	8.60	10.70
	Recovery						
	minute 0	8.80	7.70	9.60	9.00	7.20	9.40
	minute 1	5.60	4.80	7.10	7.00	7.00	8.50
	minute 2	4.20	3.90	5.70	6.00	5.30	7.10
	minute 3	3.90	3.50	5.80	5.30	5.20	6.30

SBP=systolic blood pressure; DBP= diastolic blood pressure

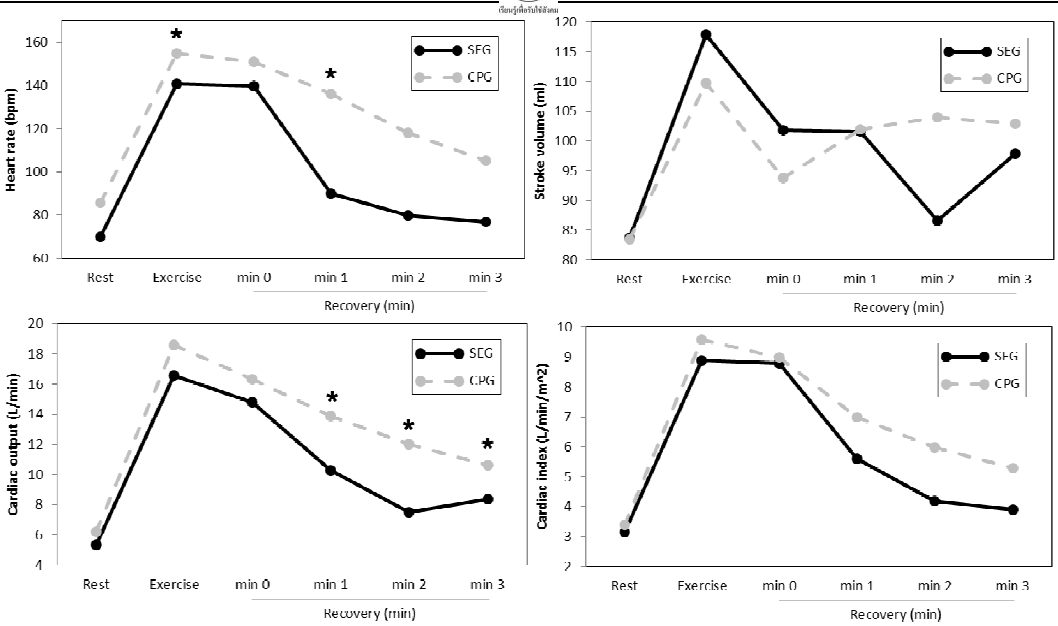

Figure 2 Graphs show hemodynamic change at resting, exercise testing, and recovery periods. * Significant difference between group at p-value<0.05.

Discussion

Our results demonstrated significant difference of hemodynamic responses (HR, CO and SBP) between SEG and CPG. The patterns of all parameters over the follow-up periods in both groups were similar. However, low values of hemodynamic responses were found in SEG resulting in the effect of sedentary behavior was compromised by PA. The BP, HR and CO of SEG was lower than CPG in the recovery period. However, Djordje and his colleagues reported that peak exercise HR didn't have a significant change between low active and high active group in the same age (p=0.16) while peak exercise cardiac index have a significant change between low and high active in young-to-middle adults (p<0.05) (9).

Many previous studies reported that heart rate (HR) was a prognostic factor for determining the occurrence of cardiovascular diseases (CVDs) and death. Cooney and colleagues in 2010 found that increase of 15 bpm of resting HR were increase the chance of cardiovascular diseases (CVDs) occurrences in both men and women (the hazard ratio 1.24 and 1.32, respectively) (3). HR is the primary outcome of our study and we found low of resting HR in SEG compared to CPG (the median of resting HR equal 70 for SEG and 86 for CPG). Therefore, our results indicated that SEG were less likely to have CVDs compared with CPG. The previous studies reported that the slow rate of HR recovery can be used as a prognosis tool for mortality in healthy population and patient with diabetes type 2, heart failure (16-21). Jouven and colleagues in 2005 found that decline of HR less than 25 bpm during the recovery periods were associated with increased risk of

death (relative risk = 2.20, 95%CI=1.02-4.74) (22). Our results demonstrated that decline of HR ranged from 34 to 51 in SEG and 12 to 31 in CPG at the recovery periods. These findings similar to the previous studies that found faster heart rate recovery in athletes or physically trained individuals when compared with sedentary individuals (23-25).

An unexpected finding in this study was an abnormal pattern of SV that demonstrated in two participants in the CPG. Contrast to the other participants, their SV declined after exercise testing immediately and then it's increased at minute 1 of recovery period. The SV is influenced by the contractility of heart and aortic pressure (26). During the exercise test, the adequate cardiac output to send oxygen throughout the body is essential. If cardiac muscles fiber cannot produce enough contractility, the body compensated by decreasing of SV and increasing of HR. Therefore, the abnormal pattern in two CPG participants may be caused by their cardiac muscles weakness. Another reason is the submaximal exercise testing such as the 3-minute step test could not provide the adequate intensity and time to enhance the maximum capacity of SV.

There were some limitations in our study. Small number of sample size might be effect to the generalization of our results. However, these findings could be the representative of the future study in the office workers for example, the observational study in the large and variation of population or the experimental study

Conclusion

In office workers, PA is a dominant factor that related to hemodynamic responses and can compromised the effect of sedentary behavior. Therefore the health benefits of PA regarding to the WHO recommendation should educate to the office workers who had high amount of sedentary time more than 8 hours per day.

Acknowledgments

We would like to thank all participants and research assistances from Faculty of Physical Therapy, Mahidol University for their invaluable help that made this study possible.

References

1. Nitaya Bhunthuwate, Hathaichanok chaiyawan. The campaign for World Heart Day 2015 [monograph on the imternet]. Bureau of Non Communicable Disease; 2015 [cited 20 Febuary 2017]. Available from: http://www.thaincd.com/document/hot%20news/ %E0%B8%A7%E0%B8%B1%E0%B8%99%E0%B8%AB%E0%B8%B1%E0%B8%A7%E0%B9%83%E0%B8%88%E0%B9%82%E0%B8%A5%E0%B8%81%202558.pdf.
2. International Hemodynamic Society.org [homepage on the internet]. [cited 2017 Feb 26]. Available from: http://www.hemodynamicsociety.org/hemodyn.html
3. Cooney MT, Vartiainen E, Laatikainen T, Juolevi A, Dudina A, Graham IM. Elevated resting heart rate is an independent risk factor for cardiovascular disease in healthy men and women. Am Heart J. 2010;159(4):612-9 e3.
4. Sesso HD, Stampfer MJ, Rosner B, Hennekens CH, Gaziano JM, Manson JE, et al. Systolic and diastolic blood pressure, pulse pressure, and mean arterial pressure as predictors of cardiovascular disease risk in Men. Hypertension. 2000;36(5):801-7.
5. Belardinelli R, Ciampani N, Costantini C, Blandini A, Purcaro A. Comparison of impedance cardiography with thermodilution and direct Fick methods for noninvasive measurement of stroke volume and cardiac output during incremental exercise in patients with ischemic cardiomyopathy. The American journal of cardiology. 1996;77(15):1293-301.
6. Chantal A. Vella, Diana Ontiveros, Raul Y. Zubia. Cardiac function and arteriovenous oxygen difference during exercise in obese adults.Eur J Appl Physiol. 2011 Jun; 111(6): 915–923.
7. Tonelli AR, Alkukhun L, Arelli V, et al. Value of Impedance Cardiography during Six-Minute Walk Test in Pulmonary Hypertension. Clinical and translational science. 2013;6(6):474-480.
8. World Health Organization. Global Recommendation on Physical Activity for Health, 2010. Switzerland; 2010.
9. Djordje G. Jakovljevic, Lida Papakonstantinou, Andrew M. Blamire et al. Effect of physical activity on age-related changes in cardiac function and performance in women. Circ Cardiovasc Imaging. 2015 Jan; 8(1)
10. Rute Santos, Jorge Mota, Anthony David Okely et al. The independent associations of sedentary behaviour and physical activity on cardiorespiratory fitness. Br J Sports Med. 2014 Oct; 48(20): 1508–1512.
11. Statistics Department 2, National Statistical Office Thailand. Summary Results of Trade, Business and Services Survey, 2014. Bangkok (Thailand): Bureau of Statistics Forecast, National Statistical Office Thailand; 2015.
12. Piyawat Katewongsa, Chutima Yousomboon, Kriangsak Teng-amnuay. Thai physical activity situation 2012-2014. Thailand:Institute for population and social research (Mahidol University) and Thai Health Promotion Foundation; 2014.

13. Bakrania K, Edwardson CL, Bodicoat DH, Esliger DW, Gill JM, Kazi A, et al. Associations of mutually exclusive categories of physical activity and sedentary time with markers of cardiometabolic health in English adults: a cross-sectional analysis of the Health Survey for England. BMC public health. 2016;16(1):25.
14. Chutima Jalayondeja. Thai Physical Activity Guideline (TPAG). 1st ed. Nakhon Pathom: Faculty of Physical Therapy, Mahidol University; 2015.
15. Supitr Samahito et al. Standard fitness test for Thai population age 19-59 years. Bangkok: Department of Physical Education; 2013.
16. Lipinski MJ, Vetrovec GW, Froelicher VF. Importance of the first two minutes of heart rate recovery after exercise treadmill testing in predicting mortality and the presence of coronary artery disease in men. Am J Cardiol (2004); 93: 445–449.
17. Chacko KM, Bauer TA, Dale RA, Dixon JA, Schrier RW, Estacio RO. Heart rate recovery predicts mortality and cardiovascular events in patients with type 2 diabetes. Med Sci Sports Exerc (2008); 40: 288–295.
18. Arena R, Myers J, Abella J, Peberdy MA, Bensimhon D, Chase P, et al. The prognostic value of the heart rate response during exercise and recovery in patients with heart failure: influence of beta-blockade. Int J Cardiol (2010a); 138: 166–173.
19. Sung J, Choi YH, Park JB. Metabolic syndrome is associated with delayed heart rate recovery after exercise. J Korean Med Sci (2006); 21: 621–626.
20. Erdogan D, Gonul E, Icli A, Yucel H, Arslan A, Akcay S, et al. Effects of normal blood pressure, prehypertension, and hypertension on autonomic nervous system function. Int J Cardiol (2011); 151: 50–53.
21. Dimkpa U, Oji JO. Association of heart rate recovery after exercise with indices of obesity in healthy, non-obese adults. Eur J Appl Physiol (2010); 108: 695–699.
22. Jouven X, Empana JP, Schwartz PJ, Desnos M, Courbon D, Ducimetiere P. Heart-rate profile during exercise as a predictor of sudden death. N Engl J Med (2005); 352: 1951–1958.
23. Darr KC, Bassett DR, Morgan BJ, Thomas DP. Effects of age and training status on heart rate recovery after peak exercise. Am J Physiol (1988); 254: H340–H343.
24. Imai K, Sato H, Hori M, Kusuoka H, Ozaki H, Yokoyama H, et al. Vagally mediated heart rate recovery after exercise is accelerated in athletes but blunted in patients with chronic heart failure. J Am Coll Cardiol (1994); 24: 1529–1535.
25. Trevizani GA, Benchimol-Barbosa PR, Nadal J. Effects of age and aerobic fitness on heart rate recovery in adult men. Arq Bras Cardiol (2012); 99: 802–810.
26. J Rodney Levick. An Introduction to Cardiovascular Physiology. 5th ed. Great Britain: Hodder Arnold; 2010.