Artigo Original

REVISTA BRASILEIRA DE CIÊNCIA & MOVIMENTO
ISSN 0103-1716

Aerobic fitness and recovery type influence post-exercise heart rate in young women

Aptidão aeróbia e tipo de recuperação influenciam a frequência cardíaca pós-exercício em mulheres jovens

TRICOT GK, ARAÚJO JA, NOVELLI FI, ARSA G, CAMBRI LT. Aerobic fitness and type of recovery influence post-exercise heart rate recovery in young women. R. bras. Ci. e Mov 2019;27(2):18-27.

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***ABSTRACT*:** This study aimed to analyze both influence of aerobic fitness and active recovery in heart rate (HR) reduction after maximum exercise (i.e. maximum incremental test) in untrained young women. Seventeen women were evaluated (23.88 ± 4.85 years), divided by the medium of peak of consumption of oxygen (30.80 mL·kg-1·min-1), in higher or lower aerobic fitness obtained during a maximum incremental test performed on a cycle ergometer. The post-exercise recovery was performed actively and passively, on two randomly non-consecutive days. It was noticed that HR at 6th and from the 6th to 10th min after the passive and active recovery, respectively, was lower in the higher aerobic fitness group, beyond that, the values of %HR reduction from the 6th to 10th min at 6th min after passive and active recovery, respectively, were higher in the higher aerobic fitness group. After active recovery, HR in 8th and 9th min and %HR reduction of the 8th to 10th min were lower and higher, respectively ($p<0.05$) than passive recovery in the lower aerobic fitness group. In short, the aerobic fitness influenced HR reduction after maximum exercise in untrained young women, mainly, after passive recovery. Besides that, the active recovery showed benefits in HR reduction in lower aerobic fitness group.

Key Words: Autonomic cardiac modulation; Recovery; Maximum consumption of oxygen.

***RESUMO*:** O presente estudo teve como objetivo analisar a influência da aptidão aeróbia e recuperação ativa na redução da frequência cardíaca (FC) após o exercício máximo (teste incremental máximo) em mulheres jovens não treinadas. Foram avaliadas dezessete mulheres jovens (23,88 ± 4,85 anos), divididas pela mediana do consumo pico de oxigênio (30,80 $mL \cdot kg^{-1} \cdot min^{-1}$), em maior ou menor aptidão aeróbia obtida durante um teste incremental máximo. A recuperação pós-exercício foi realizada de forma ativa e passiva, em dois dias experimentais randomizados e não consecutivos. Foi observado que, a FC foi menor no grupo de maior aptidão aeróbia no 6º min após a recuperação passiva e do 6º ao 10º min após a recuperação ativa, além disso, os valores do percentual de redução da FC foram maiores no grupo de maior aptidão aeróbia do 6º ao 10º min e no 6º min após a recuperação passiva e ativa, respectivamente. Após a recuperação ativa, a FC no 8º e 9º min e o percentual de redução da FC do 8º ao 10º min foram menores e maiores, respectivamente ($p <0,05$) do que após a recuperação passiva no grupo com menor aptidão aeróbia. Em suma, a aptidão aeróbia influenciou na redução da FC pós-exercício máximo em mulheres jovens não treinadas, principalmente após a recuperação passiva. Além disso, a recuperação ativa auxiliou na redução da FC no grupo com menor aptidão aeróbia.

Palavras-chave: Modulação autonômica cardíaca; Recuperação; Consumo máximo de oxigênio.

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Recebido: 03/09/2018
Aceito: 10/12/2018

Introduction

Cardiovascular diseases are the main cause of death worldwide and it has had a progressive increase, mainly in young women[1]. In order to stratify cardiovascular alterations, is recommended that women be submitted to different laboratory protocols, e.g. maximal exercise effort, which represents the most common condition reproduced in a symptom-limited exercise test.

Besides that, an attenuated reduction of the heart rate (HR) after physical exercise is associated with lower aerobic fitness and the most cardiovascular risk[2-6]. In a general way, the HR recovery has been evaluated in several populations, as untrained young males[7], overweight[6,8], and normal weight physically active adults[9-13], as well as young and middle-aged men with different aerobic fitness levels[14]; healthy elderly[5,15,16] and/or with associated diseases[2-4,16].

It has been observed that women presented an autonomic balance in favor of parasympathetic modulation compared to men, regardless of the level of physical fitness[17], which has been justified by reproductive hormones[18]. In addition, a previous study showed that a higher aerobic fitness, in marathoner women, caused an accelerated HR recovery after a maximal incremental exercise test[19]. From this, small differences in aerobic fitness in untrained women may be important to improve the HR recovery. However, there are few studies singly evaluated untrained women without associated diseases[20,21], and mainly the recovery type influence. In this way, interventions that can accelerate the cardiac autonomic restoration in individual with lower aerobic fitness are essential and must be research.

HR recovery can be influenced by the type of post-exercise recovery, which can be active[2,6,8,22] or passive[5,9,10,15]. Previously, it has been demonstrated that the use of post-exercise active recovery may be able to reduce hypotension, syncope, and arrhythmias[23,24] in this period, since the muscular pump action is not abruptly interrupted, contributing for better venous return and metabolites removal (i.e. blood lactate)[12,25-28]. A few studies examined the post-exercise active recovery influence in the HR recovery, and shown that had no benefit[11,12] in activity men. On the other hand, the active recovery caused delayed in post submaximal exercise HR recovery[27] and improved cardiac autonomic recovery after maximal exercise[29].

To the best of our knowledge, the influence of aerobic fitness and active recovery in the HR at initial instants after maximum exercise had been not investigated, mainly in untrained young adult women. Therefore, the aim of this study was to analyze the influence of the aerobic fitness level and active recovery in HR recovery after maximum exercise (i.e. maximum incremental test) in untrained young women. The hypothesis of this study was that a higher aerobic fitness influences higher HR reduction, independent of the recovery type and that there is a higher HR reduction after the active recovery.

Methods

Subjects

Seventeen young (23.88 ± 4.85 years old) untrained (not practicing regular physical exercises at least for four months) women were evaluated. The exclusion criteria were: smoking, using any continuous (e.g., anti-hypertensive, anti-diabetic, anti-depressive and anxiolytic agents) or casual medication use that could be possible use to interfere in the measure variables, osteoarticular problems, preexisting diseases, sudden death of first-degree relatives below 40 years-old, pregnancy, breastfeeding or on the first week of the follicular phase of the menstrual cycle.

The Ethics Committee in Human Research from the institution approved the study procedures (number 65485217.5.0000.5541) and all the participants signed an Informed Consent Term. All procedures beginning between 3 and 5 p. m., with an average temperature of 24.6 ± 1.0 °C and air humidity of 41.3 ± 5.0 %.

The participants performed three nonconsecutive visits to the laboratory, with 72 hours interval. The participants were divided by the median of aerobic fitness from the VO_{2peak} in two groups: higher (> 30.81 $mL \cdot kg^{-1} \cdot min^{-}$

^{1}) and lower ($\leq$ 30.80 mL·kg^{-1}·min^{-1}) aerobic fitness. To this was considered the VO_2 values obtained at first maximal incremental exercise realized at the second visit. Additionally, the participants performed two recovery types after maximal incremental exercise: passive or active, that were performed at the second and the third visit, according to the prior draw and balanced (Figure 1).

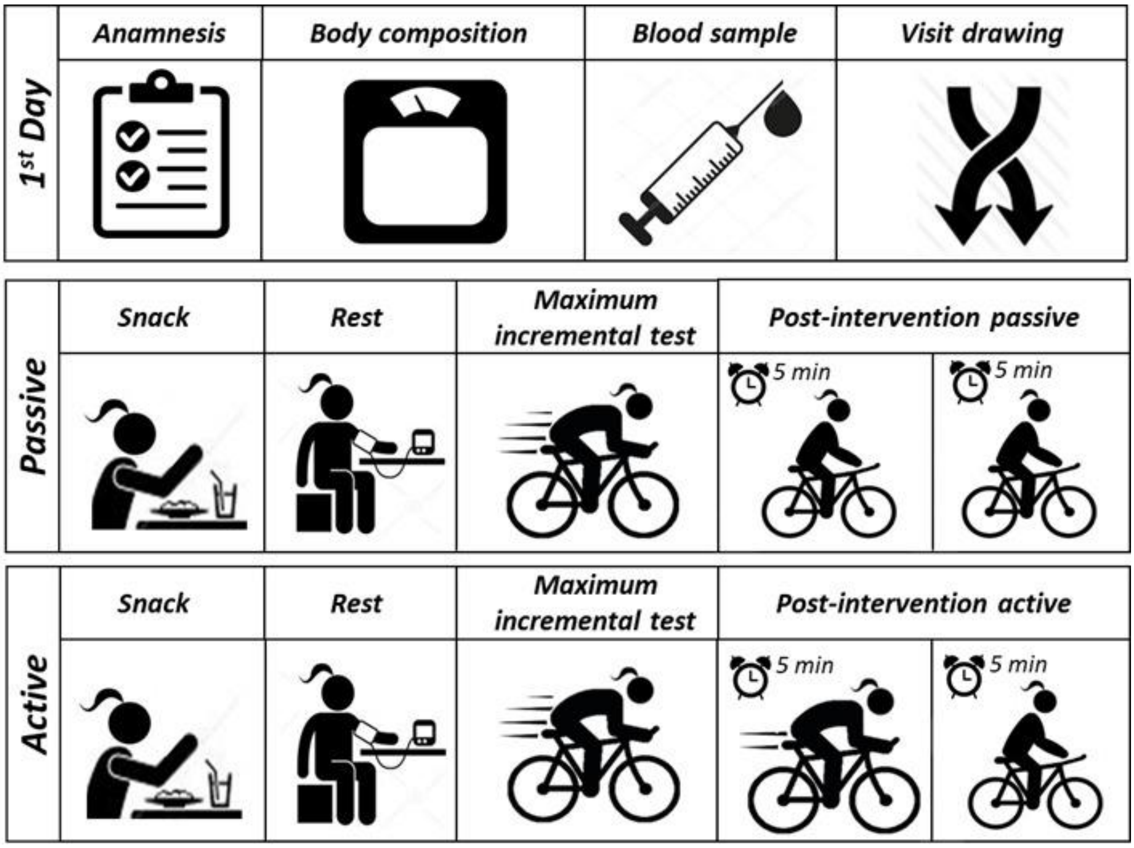

Figure 1. Experimental design.

Procedures

The participants were oriented not to practice hard physical activities and not drink stimulant or alcoholic beverages in the previous 24 hours to all evaluations. In the first visit, after 12 hours of fasting, venous blood was collected from the antecubital vein. The fasting glycemic and lipid profile (triglycerides and total cholesterol) were analyzed using specific reagents (ANALISA, Brazil) for serum dosage of each analyte, in the microplate's reader (KHB ST-360, Japan). None of the participants presented fasting glucose (> 100 mg dL^{-1}), triglycerides (> 150 mg dL^{-1}) and total cholesterol (> 200 mg dL^{-1}) elevated[30].

After that, the body composition measures collected were: body mass (CAMRY scale, Brazil) and height (SANNY stadiometer, Brazil) to determine the body mass index (BMI); abdominal circumference, obtained above the umbilical scar (CARDIOMED tape measure, Brazil). The body fat percentage (%BF) was measured through tetrapolar bioelectrical bioimpedance (MALTRON, BF 907) following the manufacturer instructions, and the participants were instructed not to drink any liquids and not urinate 30 min before the evaluation.

In the second and third visit, the participants consumed a standard snack (360.7 Kcal) two hours before the beginning of the procedures, composed by 73.2% carbohydrates (66g), 20.7% lipids (8.3g) and 6.1% proteins (5.5g).

The resting HR was measured during 15 continuous minutes, with the participants seated. The 10 final minutes of resting average were considered to determine the HR. After that, the blood pressure measured twice (Microlife BP3T0-A, Brazil), with two minutes of interval between each one. When a difference greater than 5% between the measurements was observed, it was performed a third one and calculated the average of the closest values. The measurement of blood pressure followed the procedures established by the VI Brazilian Guidelines of Hypertension[31].

Maximal incremental exercise protocol

In the second and third visit, the maximum incremental test in a cycle ergometer (INBRAMED, CG-04, Brazil) was performed, with initial workload of 30 W and addition of 15 W per minute, keeping a cadency of 60 rpm, until volitional exhaustion[32]. The rating of perceived exertion was monitored using the 15 points Borg's scale[33]. To consider test as maximum, three from four criteria would be attended: failure to maintain 60 rpm for more than 10 seconds; at least 90% maximum HR predicted by the age (220 – age); rating of perceived exertion higher than 17; respiratory exchange ratio higher than 1.1[28].

During the test, the expired gases were recorded every 10 seconds, analyzing the volumes of oxygen consumption (VO_2) and carbon dioxide (VCO_2) production. The aerobic fitness was determined by the peak of oxygen consumption (VO_{2peak}) obtained by the ergo spirometry (VO2000 MEDICAL GRAPHICS, USA), from the highest value measured in the final instants of the incremental test[34].

Recovery post-exercise

The recovery period was performed during 5 min in an active (15 W) or passive (seated on the cycloergometer) way, according to the prior and balanced draw. Then, the participants remained for more 5 min seated on the cycloergometer to evaluated the influence of type of recovery at HR (HR_6, HR_7, HR_8, HR_9, HR_{10}).

Data analyses

All HR data at rest, exercise and post-exercise were measured using a portable HR monitor (POLAR, RS800CX, Finland) with beat-to-beat records, by the R-R intervals. The data were treated in the Kubios HRV® program, with artefacts filtered in the software (moderate filter). The error percentage observed was lower than 2% in all evaluated.

When the last stage was not completed, the maximum workload was determined by the equation: $Workload_{max}$ = workload in W at the last complete stage + [(time (s) in the last stage/60s) x 15W][35].

HR was identified after maximun exercise, as well as, its reduction percentage (%HR), of each minute, in relation to HR_{peak}, identified at the end of exercise.

Statistical analyses

The normality and homogeneity of data were tested by Shapiro-Wilk and Levene tests, respectively. Descriptive statistic was used and the results were expressed by mean and standard deviation. Student's t-test was used to compare parametric data of anthropometric and body composition variables between the groups. ANOVA-Mixed of repeated measures with Bonferroni's Post-hoc were used to compare rest, exercise and post-exercise recovery variables between the groups. Pearson's correlations wes used to verify the correlations between variables. The significance level adopted was 5% ($p<0.05$).

Results

There were no significant differences in any anthropometrics and body composition variables between groups (Table 1).

Table 1: Anthropometric and body composition characteristics in lower and higher aerobic fitness groups.

	Lower aerobic fitness (n=8)	Higher aerobic fitness (n=9)	*p value*
Age (years)	25.28 ± 5.64	22.94 ± 5.64	0.370
Body mass (kg)	58.10 ± 7.55	56.83 ± 4.63	0.679
Height (m)	1.62 ± 0.07	1.63± 0.05	0.663
Body mass index (kg m^{-2})	22.23 ± 1.96	21.44 ± 1.76	0.399
Abdominal circumference (cm)	79.38 ± 6.45	75.11 ± 4.08	0.125
Body fat (%)	28.11 ± 3.66	25.36 ± 4.60	0.505

The incremental tests performed were considered maximum for all participants, once that all criteria were attended (Table 2), without difference between groups, refocusing that the both groups performed the post-exercise recovery period under similar conditions. Besides, lower values of absolute maximum workload and VO_{2peak} were observed in lower aerobic fitness group compared to higher aerobic fitness group (Table 2).

Table 2: Rest and exercise test variables.

	Passive		*p value*	Active		*p value*
	Lower aerobic fitness (n=8)	Higher aerobic fitness (n=9)		Lower aerobic fitness (n=8)	Higher aerobic fitness (n=9)	
Rest						
Systolic blood pressure (mmHg)	101.63 ± 8.19	105.61 ± 12.35	0.491	101.50 ± 10.42	107.72 ± 7.77	0.236
Diastolic blood pressure (mmHg)	65.63 ± 7.11	66.11 ± 8.43	0.900	65,38 ± 7,84	67.72 ± 8.52	0.637
Heart rate (bpm)	80.00 ± 17.91	71.6 ± 11.18	0.259	82.50 ± 16.72	71.17 ± 10.69	0.190
Exercise						
Peak heart rate (bpm)	191.88 ± 7.75	189.11 ± 5.06	0.392	191.88 ± 8.56	189.11 ± 5.16	0.426
Peak heart rate (%)	98.58 ± 4.36	96.03 ± 3.90	0.222	98.59 ± 4.88	96.00 ± 3.15	0.209
RPE	19.58 ± 0.35	20.00 ± 0.00	0.304	19.63 ± 1.06	19.78 ± 0.44	0.607
Respiratory exchange ratio	1.18 ± 0.05	1.21 ± 0.08	0.357	1.21 ± 0.08	1.17 ± 0.05	0.325
Peak workload (W)	138.28 ± 23.40†	167.61 ± 16.72	0.009	132.75 ± 22.62‡	171.36 ± 22.79	0.003
VO_{2peak} (mL kg^{-1} min^{-1})	29.37 ± 2.44†	36.38 ± 5.14	0.003	29.36 ± 1.79‡	37.52 ± 5.11	0.001

RPE: Rate of perceived exertion; VO_{2peak}: Peak oxygen consumption. † Difference between lower and higher aerobic fitness groups in passive recovery. ‡ Difference between lower and higher aerobic fitness groups in active recovery.

HR at 6^{th} min and from 6^{th} to 10^{th} min in passive and active recovery, respectively, was lower in the higher aerobic fitness group compared to lower aerobic fitness group (Figure 2). %HR reduction from 6^{th} to 10^{th} min and at 6^{th} min in passive and active recovery, respectively, was higher in higher aerobic fitness group compared to the lower aerobic fitness group (Table 3).

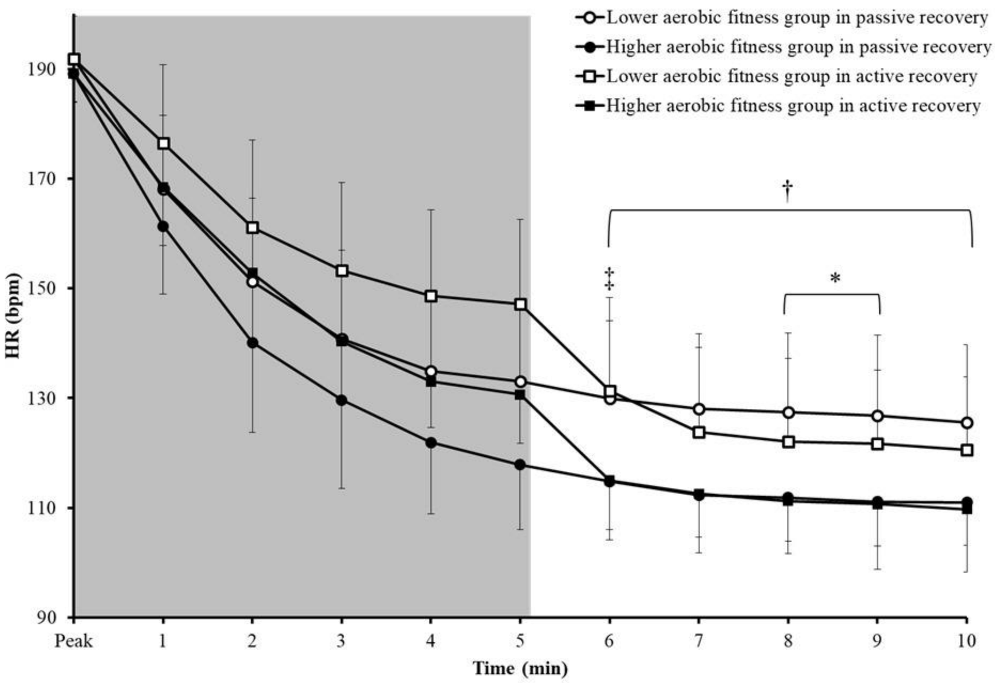

Figure 2. Heart rate (HR) at 1-10 min after maximal exercise test in the groups according to aerobic fitness and recovery type.
*Difference between passive and active recovery in lower aerobic fitness group; † Difference between lower and higher aerobic fitness groups after passive recovery; ‡ Difference between lower and higher aerobic fitness groups after active recovery.

Table 3: Percentage of heart rate (%HR) reduction during five minutes after recovery (passive or active) after maximum exercise in the groups according to aerobic fitness.

	Passive		**Active**	
	Lower aerobic fitness (n=8)	**Higher aerobic fitness (n=9)**	**Lower aerobic fitness (n=8)**	**Higher aerobic fitness (n=9)**
$\%HR_6$	32.46 ± 5.14†	39.35 ± 3.42	31.77 ± 6,54‡	39.25 ± 4.49
$\%HR_7$	33.43 ± 4.97†	40.63 ± 3.17	35.59 ± 5,79	40.53 ± 4.77
$\%HR_8$	33.71 ± 5.23†*	40.86 ± 3.49	36.51 ± 5,68	41.22 ± 4.17
$\%HR_9$	34.04 ± 5.36†*	41.27 ± 3.44	36.67 ± 4,76	41.55 ± 5.22
$\%HR_{10}$	34.68 ± 5.17†*	41.32 ± 2.51	37.26 ± 4,75	42.01 ± 5.07

† Difference between lower and higher aerobic fitness groups after passive recovery; ‡ Difference between lower and higher aerobic fitness groups after active recovery; * Difference between passive and active recovery in lower aerobic fitness group.

Aerobic fitness (VO_{2peak}) was associated with HR (r: -0.49 to - 0.51, $p < 0.05$) and %HR reduction (r: 0.50 to 0.53, $p < 0.05$) at the minutes 6, 7, 8 and 10 of passive recovery. There were no associations between aerobic fitness and HR in any moment after the active recovery.

After the active recovery, HR in 8th and 9th min and %HR reduction in 8th to 10th min, were lower and higher, respectively, compared to the passive recovery in the lower aerobic fitness group.

Discussion

In this study, the HR after maximum exercise was influenced by aerobic fitness, being evident that lower aerobic fitness delayed the HR reduction, mainly after passive recovery in untrained young women. Additionally, active recovery seems to show benefices only to the lower aerobic fitness group.

Considering the increase of cardiovascular problems in women, the HR assessment after maximal exercise, in passive or active recovery, is an important tool to evaluate cardiovascular reactivity in situations where the neural (central command) and peripheral mechanisms (metaboreflex, chemoreflex) of cardiovascular control, answer according to each stimulus[36,37].

To our knowledge, there is no study that has compared type of recovery in untrained populations, which represent the majority of beginners in physical training programs to health promotion, and often subjected to evaluation of current physical fitness.

HR was lower in higher aerobic fitness group in both recovery types, being evident that low aerobic fitness causes a delay in the HR reduction after maximal exercise. Previous studies showed that low aerobic fitness is related to lower HR reduction in recovery after exercise in different populations[4,6,8,10,14]. It is possible to observe that higher aerobic fitness group had moderate values of maximum workload and peak oxygen consumption, compared to literature, which corresponds to the untrained condition of the participants[38,39].

Araújo *et al*.[8] observed that young untrained men with higher aerobic fitness presented lower resting and HR during active recovery in the 1st, 2nd, 3rd min after maximum exercise compared to their pairs with lower aerobic fitness. In the same way, higher aerobic fitness level causes an accelerated HR reduction in the recovery, in men and women trained and sedentary in middle-aged[15], so as, marathoners women[19]. In our study, the aerobic fitness (VO_{2peak}) was positively associated with HR and %HR reduction in the minutes 6, 7, 8 and 10 of passive recovery.

In the present study, the HR was lower during passive recovery compared to active recovery, regardless aerobic fitness. This is probably due to the cessation of the central command of the motor cortex and the mechanoreceptor stimulus reduction, which cause the parasympathetic activity increase and the sympathetic activity reduction, after the interruption of the physical exercise[40].

The active recovery after physical exercise is recommended because can minimize the hypotension in the initial recovery instants and cardiac autonomic imbalance, once that the muscular pump action is not suddenly interrupted, helping the venous response[27,28], besides to accelerate accumulated metabolites during exercise[12]. However, there was no influence of the active recovery in hemodynamics and cardiac autonomic responses post-exercise, during a period of 30 min after recovery, in young men physically active, once there were no benefits in the parasympathetic activity[11,12]. Additionally, there were no differences in HR during the active and passive recovery in physically active young people of both sexes in the 5 initial minutes[7] similar in this study, because there were no benefits of active recovery in the higher aerobic fitness group.

The active recovery seems to have benefices only at the very low aerobic fitness as the lower aerobic fitness group of present study, in which after the active recovery, HR in 8th and 9th min and the %HR reduction from 8th to 10th min, were lower and higher, respectively compared to the passive recovery. Similar results were found after 7 and 27 min of active recovery post submaximal exercise[29]. We assumed that this maybe be due the accelerate lactate removal related to the higher aerobic fitness[41], limiting a possible positive effect of the active recovery in the higher aerobic fitness group, or the low intensity used in active recovery (8.77% maximal workload), was insufficient to promote benefits in women with greater aerobic fitness. It was recently found that recovery (20 min) at 50% and 25% of maximal potency reduced lactate concentrations by 43% and 15%, respectively[42]. Additionally, Hoshi, Vanderlei [(9)] reported that at first, lactate returns to baseline values, allowing sympathetic-vagal reorganization and subsequently, vagal activity is restored.

The differences among the reported studies can be a result of the exercise (treadmill and cycle ergometer) and post-exercise recovery type and duration (i.e. 5, 10 and 15 min), population and aerobic fitness level, which in turn, cause changes in cardiac autonomic modulation after exercise, being difficult to generalize these results.

There is a clinical implication in HR post-exercise monitoring once it is useful to detect previous cardiovascular function alterations, such as arrhythmias and post-exercise parasympathetic activity reduction[43], being able to prevent cardiovascular risks in young untrained women.

Given that, HR after passive recovery was similar to active recovery in the higher aerobic fitness group. It is reasonable to assume that young women with moderate peak oxygen consumption values, as the women evaluated in this study (higher aerobic fitness group) could use passive recovery after physical exercise aiming to diminish the time spent in an exercise session and consequently could be an alternative to improve the adherence to physically active lifestyle[44]. On the other hand, our findings are suggestive that the active recovery must be recommended to lower aerobic fitness people to accelerate the HR recovery, and promote a better cardiac autonomic control and post-exercise cardio-protector effect[29]. Additionally, changing the lifestyle is recommended, focusing on aerobic fitness increase.

In this study, the menstrual cycle of the participants was not monitored, what constitutes one of the limitations, as well as the lack of menstrual cycle regularity control, hormonal levels and post-exercise recovery lactate evaluation. However, previous study, there were no significant differences in the HR reduction and in women's cardiac autonomic control in the luteal and follicular phase of the menstrual cycle[21]. The blood pressure post-exercise is not measured, so we cannot assess to the possibility of hypotension and/or syncope symptom in passive recovery. However, Soares, Oliveira[11] did not find any difference in blood pressure responses after aerobic exercise after passive or active recovery in active men.

In summary, the HR recovery after maximum exercise in untrained young women was influenced by aerobic fitness, mainly after passive recovery. Besides that, the active recovery presented benefits in HR reduction in lower aerobic fitness group. Future researches involving clinical populations should be addressed to observe whether responses are similar.

Acknowledgments

The authors thank volunteers for participation. This study was supported by Fundação de Amparo à Pesquisa do Estado de Mato Grosso (FAPEMAT - process 151411/2014), Conselho Nacional de Desenvolvimento Científico e Tecnológico (CNPq - process 443361/2014-2), Pró-Reitoria de Pesquisa (PROPeq), and Fundação de Amparo à Pesquisa do Estado de Mato Grosso (FAPEMAT/CAPES) with a granting the scholarships in graduated.

References

1. Mosca L, Benjamin EJ, Berra K, Bezanson JL, Dolor RJ, Lloyd-Jones DM, *et al*. Effectiveness-based guidelines for the prevention of cardiovascular disease in women—2011 update: a guideline from the American Heart Association. Circulation. 2011:CIR. 0b013e31820faaf8.

2. Nishime EO, Cole CR, Blackstone EH, Pashkow FJ, Lauer MS. Heart rate recovery and treadmill exercise score as predictors of mortality in patients referred for exercise ECG. JAMA. 2000; 284(11): 1392-8.

3. Savonen KP, Kiviniemi V, Laaksonen DE, Lakka TA, Laukkanen JA, Tuomainen TP, *et al*. Two-minute heart rate recovery after cycle ergometer exercise and all-cause mortality in middle-aged men. J Intern Med. 2011; 270(6): 589-96.

4. Kokkinos P, Myers J, Doumas M, Faselis C, Pittaras A, Manolis A, *et al*. Heart rate recovery, exercise capacity, and mortality risk in male veterans. Eur J Prev Cardiol. 2012; 19(2): 177-84.

5. Dhoble A, Lahr BD, Allison TG, Kopecky SL. Cardiopulmonary fitness and heart rate recovery as predictors of mortality in a referral population. J Am Heart Assoc. 2014; 3(2): e000559.

6. Araújo JAd, Tricot GK, Arsa G, Queiroz MG, Santos KMd, Dias ARL, *et al*. Blood pressure and cardiac autonomic modulation at rest, during exercise and recovery time in the young overweight. Motriz. Rev. Ed. Fis 2016; 22(1): 27-34.

7. Takahashi T, Hayano J, Okada A, Saitoh T, Kamiya A. Effects of the muscle pump and body posture on cardiovascular responses during recovery from cycle exercise. Eur J Appl Physiol. 2005; 94(5-6): 576-83.

8. de Araújo JA, Queiroz MG, Novelli FI, Tricot GK, Dias ARL, Arsa G, *et al*. Aerobic fitness influences rest and heart rate recovery on young men regardless of body mass index. Sport Sci Health. 2017; 13: 217-23.

9. Hoshi RA, Vanderlei LCM, Godoy MF, Bastos FdN, Netto J, Pastre CM. Temporal sequence of recovery-related events following maximal exercise assessed by heart rate variability and blood lactate concentration. Clin Physiol Funct Imaging. 2017; 37(5):536-543.

10. Fernandes TC, Adam F, Costa VP, Silva AEL, De-Oliveira FR. Frequência cardíaca de recuperação como índice de aptidão aeróbia. J Phys Educ. 2005; 16(2): 129-37.

11. Soares AH, Oliveira TP, Cavalcante BR, Farah BQ, Lima AH, Cucato GG, *et al*. Effects of active recovery on autonomic and haemodynamic responses after aerobic exercise. Clin Physiol Funct Imaging. 2015; 37: 62-7.

12. Bastos F, Vanderlei L, Nakamura F, Bertollo M, Godoy M, Hoshi R, *et al*. Effects of cold water immersion and active recovery on post-exercise heart rate variability. Int J Sports Med. 2012; 33(11): 873-9.

13. Oliveira TP, Alvarenga Mattos R, Silva RBF, Rezende RA, Lima JRP. Absence of parasympathetic reactivation after maximal exercise. Clin Physiol Funct Imaging. 2013; 33(2): 143-9.

14. Trevizani GA, Benchimol-Barbosa PR, Nadal J. Efeitos da idade e da aptidão aeróbica na recuperação da frequência cardíaca em homens adultos. Arq Bras Cardiol. 2012; 99(3): 802-10.

15. Danieli A, Lusa L, Potočnik N, Meglič B, Grad A, Bajrović FF. Resting heart rate variability and heart rate recovery after submaximal exercise. Clin Auton Res. 2014; 24(2): 53-61.

16. Sung J, Choi Y-H, Park JB. Metabolic syndrome is associated with delayed heart rate recovery after exercise. J Korean Med Sci. 2006; 21(4): 621-6.

17. Dutra SG, Pereira AP, Tezini GC, Mazon JH, Martins-Pinge MC, Souza HC. Cardiac autonomic modulation is determined by gender and is independent of aerobic physical capacity in healthy subjects. PLoS One. 2013; 8(10): e77092.

18. Du XJ, Dart AM, Riemersma RA. Sex differences in the parasympathetic nerve control of rat heart. Clin Exp Pharmacol Physiol. 1994; 21(6): 485-93.

19. Du N, Bai S, Oguri K, Kato Y, Matsumoto I, Kawase H, *et al*. Heart rate recovery after exercise and neural regulation of heart rate variability in 30-40 year old female marathon runners. Journal of sports science & medicine. 2005; 4(1): 9.

20. Shane Journeay W, Reardon FD, McInnis NH, Kenny GP. Nonthermoregulatory control of cutaneous vascular conductance and sweating during recovery from dynamic exercise in women. J Appl Physiol. 2005; 99(5): 1816-21.

21. Yazar S, Yazıcı M. Impact of menstrual cycle on cardiac autonomic function assessed by heart rate variability and heart rate recovery. Med Princ Pract. 2016; 25(4): 374-7.

22. Prado D, Silva A, Trombetta I, Ribeiro M, Guazzelli I, Matos L, *et al*. Exercise training associated with diet improves heart rate recovery and cardiac autonomic nervous system activity in obese children. Int J Sports Med. 2010; 31(12): 860-5.

23. Skaug E-A, Madssen E, Aspenes ST, Wisløff U, Ellingsen Ø. Cardiovascular risk factors have larger impact on endothelial function in self-reported healthy women than men in the HUNT3 Fitness study. PloS One. 2014; 9(7): e101371.

24. Antelmi I, Chuang EY, Grupi CJ, Latorre MdRDdO, Mansur AJ. Recuperação da frequência cardíaca após teste de esforço em esteira ergométrica e variabilidade da frequência cardíaca em 24 horas em indivíduos sadios. Arq Bras Cardiol. 2008; 90(6): 413-8.

25. Mota MR, Dantas RAE, Oliveira-Silva I, Sales MM, Sotero RDC, Venancio PEM, *et al*. Effect of self-paced active recovery and passive recovery on blood lactate removal following a 200 m freestyle swimming trial. Open Access J Sports Med. 2017; 8: 155-60.

26. Spierer DK, Goldsmith R, Baran DA, Hryniewicz K, Katz SD. Effects of active vs. passive recovery on work performed during serial supramaximal exercise tests. Int J Sports Med. 2004; 25(2): 109-14.

27. Carter R, Watenpaugh DE, Wasmund WL, Wasmund SL, Smith ML. Muscle pump and central command during recovery from exercise in humans. J Appl Physiol 1999; 87(4): 1463-9.

28. Medicine ACoS. Diretrizes do ACSM para os Testes de Esforço e sua Prescrição. Outras Condições Clínicas que Influenciam a Prescrição do Exercício. 7. ed. Rio de Janeiro: Guanabara Koogan; 2007.

29. Takahashi T, Miyamoto Y. Influence of light physical activity on cardiac responses during recovery from exercise in humans. Eur J Appl Physiol Occup Physiol. 1998; 77(4): 305-11.

30. Federation ID. IDF diabetes atlas: International Diabetes Federation, Executive Office; 2011.

31. SBC S. SBN. Sociedade Brasileira de Cardiologia, Sociedade Brasileira de Hipertensão, Sociedade Brasileira de

Nefrologia: VI Diretrizes Brasileiras de Hipertensão Arterial. Arq Bras Cardiol. 2010; 1(1): 1-51.

32. Cambri LT, Novelli FI, Sales MM, Queiroz MG, Dias ARL, dos Santos KM, *et al*. Heart rate inflection point estimates the anaerobic threshold in overweight and obese young adults. Sport Sci Health. 2016; 12(3): 397-405.

33. Borg GA. Psychophysical bases of perceived exertion. Med Sci Sports Exerc. 1982; 14(5): 377-81.

34. Howley ET, Bassett DR, Welch HG. Criteria for maximal oxygen uptake: review and commentary. Med Sci Sports Exerc. 1995; 27(9): 1292-301.

35. Kuipers H, Verstappen F, Keizer H, Geurten P, Van Kranenburg G. Variability of aerobic performance in the laboratory and its physiologic correlates. Int J Sports Med. 1985; 6(04): 197-201.

36. Michael S, Graham KS, Davis GM. Cardiac autonomic responses during exercise and post-exercise recovery using heart rate variability and systolic time intervals—a review. Front Physiol. 2017; 8: 301.

37. Peçanha T, Silva‐Júnior ND, Forjaz CLdM. Heart rate recovery: autonomic determinants, methods of assessment and association with mortality and cardiovascular diseases. Clin Physiol Funct Imaging. 2014; 34(5): 327-39.

38. Dutra SG, Pereira APM, Tezini GC, Mazon JH, Martins-Pinge MC, Souza HC. Cardiac autonomic modulation is determined by gender and is independent of aerobic physical capacity in healthy subjects. PloS One. 2013; 8(10): e77092.

39. Couto PG, Rodrigues AP, Ferreira Júnior AJ, Silva SF, De Oliveira FR. Pontos de transição da frequência cardíaca em teste progressivo máximo. Motriz, Rev. Ed. Fis. 2013; 19(2): 261-8.

40. O'Leary DS. Autonomic mechanisms of muscle metaboreflex control of heart rate. J Appl Physiol. 1993; 74(4): 1748-54.

41. de Aguiar RA, Cruz RS, Turnes T, Pereira KL, Caputo F. Relationships between VO2 and blood lactate responses after all-out running exercise. Appl Physiol Nutr Metab. 2015; 40(3): 263-8.

42. Riganas C, Papadopoulou Z, Psichas N, Skoufas D, Gissis I, Sampanis M, *et al*. The rate of lactate removal after maximal exercise: the effect of intensity during active recovery. J Sports Med Phys Fitness. 2015; 55(10): 1058-63.

43. Smith LL, Kukielka M, Billman GE. Heart rate recovery after exercise: a predictor of ventricular fibrillation susceptibility after myocardial infarction. Am J Physiol Heart Circ Physiol. 2005; 288(4):H1763-9.

44. Ashton LM, Hutchesson MJ, Rollo ME, Morgan PJ, Collins CE. Motivators and barriers to engaging in healthy eating and physical activity. Am J Mens Health. 2017; 11(2): 330-43.