Journal of Health and Medical Sciences

O., Taiwo E., and A., Thanni L. O. (2021), Exercise Modulation of Blood Pressure, Respiratory Rate and Pulse Rate in Undergraduate Students. In: *Journal of Health and Medical Sciences*, Vol.4, No.1, 59-66.

ISSN 2622-7258

DOI: 10.31014/aior.1994.04.01.156

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The Asian Institute of Research
Journal of Health and Medical Sciences
Vol.4, No.1, 2021: 59-66
ISSN 2622-7258

DOI: 10.31014/aior.1994.04.01.156

Exercise Modulation of Blood Pressure, Respiratory Rate and Pulse Rate in Undergraduate Students

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Abstract
Background: Physical Activity improves the functional capacity of the circulatory system with minimum myocardium stress. Objectives: This study was designed to assess exercise modulation and sex difference of blood pressure (BP), respiratory rate (RR) and pulse rate (PR) of selected undergraduate students. Design: This study involved 360 students selected using convenience sampling method, aged between 18 and 35 years. Lecturers and postgraduate students were exempted from the study. BP was measured using Sphygmomanometer before exercise and 30 minutes interval during exercise for two hours. Bicycle Ergometer was used as the exercise apparatus. Stop watch was used to measure PR and RR. Data were analyzed using descriptive statistics. Results: In total, 360 subjects, 180 males and 180 females, were included in the study. The mean SBP at baseline was 111.59 mmHg±0.35. It reduced to 96.99 mmHg±0.36 after 120 minutes of exercise (p=0.000). The mean DBP at baseline was 69.78mmHg±0.32. It reduced to 56.01mmHg±0.30 after 120 minutes of exercise (p=0.000). The mean Respiratory Rate (RR) at baseline was 15.91 cycles/ minute±0.11. It increased to 28.82 cycles/minute±0.21 after 120 minutes of exercise (p=0.000). The mean Rate Pulse Pressure (RPP) at baseline was 8322.35 mmHg. cycles/ minute±0.05 It increased to 12033.55mmHg.cycles/minute±0.21 after 120 minutes of exercise (p=0.000). Moreover, the male-female relationships showed that the SBP, DBP, RR and RPP were significantly lower in female than male subjects (p=0.000). Conclusions: Exercise reduces SBP and DBP. This reduction is greater among females.

Keywords: Sphygmomanometer, Blood Pressure Measurement, Pulse Rate, Respiratory Rate, Exercise.

Introduction

Physical activity (PA) is defined as any bodily movement produced by skeletal muscles that requires energy expenditure (WHO, 2019), provokes changes in the cardiovascular function of body with a positive effect on both the prevention of life-threatening CVD (WHO, 2019, Jakovljevic, 2018). Furthermore, PA has been linked to a reduced risk of several diseases, such as obesity, diabetes and metabolic syndrome. Nonetheless, it is not clear how much PA is required to reduce the risk of these diseases. A plethora of studies suggests that the increased level of PA significantly improves the functional capacity of the circulatory system by increasing stroke volume, cardiac output and enhancing blood and oxygen supply to active tissues (performance), with a minimum myocardium stress (economy) (Fletcher et al, 1996, ACSM, 2014).

The term "myocardial economy" describes the ability of the heart to meet the needs of the working tissues for blood and oxygen supply with the minimum of myocardium stress (Astrand et al, 2003, Leon et al, 1981). Heart rate (HR) and systolic blood pressure (SBP), are important prognostic factors of cardiovascular health; their lower rates are related to improved physical fitness (Shalnova et al, 1996, Cheng et al, 2003, Palatini et al, 2007) and decreased cardiovascular morbidity and mortality (Palatini et al, 2007, Perret-Guillaume et al, 2009, Kjeldsen et al,2001). The rate-pressure product (RPP = HR × SBP) is strongly and positively related to coronary blood flow and myocardial oxygen uptake (Astrand et al, 2003, Gobel etal, 1978, Czernin et al, 19956)· All of the above are positively related to myocardial oxygen demands and hence myocardial workload, being important non-invasive and inverse indicators of myocardial economy (Astrand et al, 2003, Fletcher et al,20016)·

There is limited data regarding the impact of PA on the myocardial function in students. Particularly, the effect of PA on the very important parameters of myocardial economy, such as HR, SBP, DBP< RR and RPP in students need to be further clarified. The purpose of this study was to investigate the effects of PA on myocardial economy in undergraduate students.

Method

A total of 360 students were randomly selected from the students' population of Olabisi Onabanjo University, Sagamu campus. At the baseline evaluation, health status was assessed. Students who are healthy and aged 18 to 35 years, with normal body weight (18.5<BMI<25 kg/m2) were eligible for the study. Our exclusion criteria were the following; metabolic diseases (such as diabetes mellitus or thyroid disease), physical disabilities, heart disorders, recent illness, and cardiac medications,

Before the day of their appointment, all participants were well informed about the research procedures and became familiar with the BP measurements and the test equipment (bicycle ergometer).

Measurements were conducted during morning hours, under the same conditions of temperature and humidity; all subjects abstained from coffee and alcohol, for at least 4 hours before the exercise procedure. Bicycle Ergometer was used for the exercise procedure. Stop watch was used to measure RR and PR.

Ethical Approval and Informed Consent

Ethical clearance for the study was obtained from the Health Research Ethics Committee (HREC) of Olabisi Onabanjo University Teaching Hospital (OOUTH), Sagamu (No HREC/OOU/0080). All participants (360) of this study signed an informed consent form, in accordance to the committee regulations, before completing a questionnaire and taking their anthropometric measurements. The use of proforma was adopted.

Data analysis

Data was expressed as means with ± standard deviation (SD). The normality of distribution for age, SBP, HR and RR was assessed with the Kolmogorov–Smirnov test. Multivariate analysis of variance (general linear model, full factorial – type III) – MANCOVA – was used to detect differences in HR, BP and RPP between parameters of PA. All HR, BP and RR values were considered as dependent variables. The level of significance was set as a p-value <0.05 throughout. Statistical analysis of the data was performed using the IBM SPSS version 19 software package (2010 SPSS Inc., Chicago, IL, USA).

Results

In total, 360 subjects, 180 males and 180 females, with the age group of 20 to 24 years constituted the highest age group were included in the study. All variables were normally distributed (table 1).

The mean SBP at baseline was 111.59mmHg±0.35. It reduced to 96.99mmHg±0.36 after 120 minutes of exercise.

The mean DBP at baseline was 69.78mmHg±0.32. It reduced to 56.01mmHg±0.30 after 120 minutes of exercise The mean Respiratory Rate (RR) at baseline was 15.91 cycles/ minute±0.11. It increased significantly to 28.82 cycles/minute±0.21 after 120 minutes of exercise. The mean Pulse Rate (PR) at baseline was 74.58 beat/minute±0.15. It increased to 124.07 beat/minute±0.90 after 120 minutes of exercise. RPP increased from 8322.35cycle mmHg/minute±0.25 at baseline to 12033.55±0.63 cycle mmHg±/minute after 120 minutes of exercise (p=0.000) (table 2).

In male, the mean SBP at baseline was 111.75mmHg±0.44. It reduced to 99.12mmHg±0.43 after 120 minutes of exercise. The mean DBP at baseline was 70.50mmHg±0.40. It reduced to 56.07mmHg±0.38 after 120 minutes of exercise.

The mean Respiratory Rate (RR) at baseline was 15.74 cycles/ minute±0.15. It increased to 28.96 cycles/minute±0.30 after 120 minutes of exercise. The mean Pulse Rate (PR) at baseline was 74.50 beats/minute±0.21. It increased to 127.43 beats/minute±1.29 after 120 minutes of exercise (p=0.000) (table 3).
In female subjects, the mean SBP at baseline was 111.42mmHg±0.56. It reduced to 91.85mmHg±0.58 after 120 minutes of exercise. The mean DBP at baseline was 69.06mmHg±0.50. It reduced to 55.95mmHg±0.44 after 120 minutes of exercise

The mean Respiratory Rate (RR) at baseline was 16.07 cycles/ minute±0.11. It increased to 28.68cycle/minute±0.31 after 120 minutes of exercise. The mean Pulse Rate (PP) at baseline was 74.66beats/minute±0.21. It increased to 120.71 beats/minute±1.20 after 120 minutes of exercise (p=0.000) (table 3).

In male the mean Rate Pressure Product (RPP) at baseline was 8325.38mmHg beats/ minute±0.09. It increased to 11738.85mmHg beats/minute±0.31 after 120 minutes of exercise. In female the mean Rate Pressure Product (RPP) at baseline was 8318.62mmHg.cycle/minute±0.12. It increased to 11087.21mmHg beats/minute±0.70 after 120 minutes of exercise (p=0.000) (table 3).

Finally, the male female relationships of both sexes were demonstrated in table 5. The SBP, DBP, RR, PR and RPP were significantly lower in female than male subjects (p=0.000)

Table1: Showing Age and Gender characteristics of the Participants.

Variable	Category	Frequency (n)	Percentage (%)
Gender	Male	180	50.0
	Female	180	50.0
Age	<20 years	113	31.4
	20-24 years	165	45.8
	25-29 years	73	20.3
	≥ 30 years	9	2.5

Table 2: Variability of vital parameters of all the subjects during study period

Variable	Baseline	30 mins	60 mins	90 mins	120 mins	P
SBP	111.59±0.35	108.04±0.45	104.53±0.41	99.31±0.39	96.99±0.36	0.000*
DBP	69.78±0.32	62.36±0.33	59.59±0.31	57.80±0.30	56.01±0.30	0.000*
RR	15.91±0.11	19.26±0.12	23.43±0.17	26.48±0.20	28.82±0.21	0.000*
Pulse	74.58±0.15	90.45±0.53	105.15±0.76	115.66±0.84	124.07±0.90	0.000*
RPP	8322.35+0.25	9772.22+0.49	10991.33+0.59	11486.20+0.62	12033.55+0.63	0.000*

Table 3: Variability of vital parameters of female and male subjects during study period

Variable	Baseline	30 mins	60 mins	90 mins	120 mins	P
SBP M	111.75±0.44	108.38±0.63	104.69±0.49	99.45±0.46	92.12±0.43	0.000*
F	111.42±0.56	107.69±0.63	104.38±0.66	99.16±0.63	91.85±0.58	0.000*
DBP M	70.50±0.40	62.59±0.46	59.65±0.40	57.86±0.39	56.07±0.38	0.000*
F	69.06±0.50	62.12±0.46	59.52±0.47	57.73±0.45	55.95±0.44	0.000*
RR M	15.74±0.15	19.35±0.17	23.55±0.24	26.61±0.27	28.96±0.30	0.000*
F	16.07±0.16	19.17±0.16	23.31±0.25	26.34±0.28	28.68±0.31	0.000*
Pulse M	74.50±0.21	90.20±0.76	107.99±1.09	118.79±1.20	127.43±1.29	0.000*
F	74.66±0.21	90.71±0.73	102.30±1.02	112.53±1.12	120.71±1.20	0.000*
RPP M	8325.38+0.09	9775.88+0.48	11305.47+0.53	11813.67+0.59	11738.85+0.55	0.000*
F	8318.62+0.12	9768.56+0.46	10678.07+0.67	11158’47+0.71	11087.21+0.70	0.000*

Discussion

We set out to evaluate whether PA is an effective physiological stimulus to improve myocardial function in healthy students. The results of the present study indicated that increased PA, from low to moderate level, significantly lowered DBP and SBP in both sexes. The RR and PR were found to increase in subjects with higher levels of PA, this association was however significant.

Physical activity and heart rate

The PA-related low resting HR has been found to decrease the incidence of CVD and to be positively related to cardiovascular and all-cause mortality (Saxena et al, 2013, Mok et al, 2019). However, the effects of PA on HR in students have not been thoroughly studied yet. Similar to our findings were observed in sportive students, where increases in PA intensity were associated with higher HR variability (Buchheit et al,2004). Recent data has also indicated that moderate PA was associated with superior cardio-vagal baroreflex sensitivity reflecting the efficiency in regulating HR in older adults (O’Brien et al,2019). These results suggest that increased PA may be sufficient to affect the autonomic tone of adults, similar to exercise modalities that have been shown to do so (Karavirta et al, 2009, Ueno and Moritani, 2003). However, in contrast to our results, others have reported that in older adults, no statistically significant correlation was identified between resting HR and leisure-time PA (O’Hartaigh et al, 2014, Miranda et al, 2014).

Our findings indicated that the beneficial effect of PA on HR was stronger and significant for male compared to female. These results are in line with the study by Carter et al (Carter et al, 2015) who reported that men have lower HRs than women when performing exercise of similar intensity. Moreover, Rennie et al (Rennie et al, 2003) have found that increased level of moderate PA had significantly lowered resting HR in men, but not in women. However, these assessments were not conducted in older people. The PA-induced lower resting HR, as it was found in our male participants, may be related to increased stoke volume observed in exercising or physically active individuals (Rennie et al, 2003, Higginbotham et al, 1986, Chou et al 2019). Yet, it remains unclear why the above haemodynamic mechanism may hold true and explain the PA related HR decline in male, but not in female. The latter may be attributed to the sex-based differences in exercise-related tests such as VO2 norms, BP and lung diffusion capacity (Parker et al, 2010). It seems that when placed under increased cardiovascular demands, men respond by increasing vascular resistance, and consequently BP, whereas female respond by increasing HR, therefore presenting higher HRs following PA or exercise (Huxley, 2007).

Increased PA may provoke the physiological mechanisms that affect parasympathetic tone in healthy adults. Lower HR is, at least partially, the result of increased parasympathetic tone and may be related to the improvements in sympathetic control of vasomotor tone provoked by PA (Shin et al, 1997, Yataco et al, 1997). However, others have supported that the parasympathetic tone may be increased by high-intensity activity, such as jogging, while moderate activity is not (Schuit et al, 1999). Further studies are required to determine whether PA of vigorous-intensity would be more effective towards lowering HR in older adults of both sexes, compared with existing levels of PA in this population.

Physical activity and blood pressure

Blood pressure is directly proportional to the effect of cardiac output on the total peripheral vascular resistance and depends on the total blood volume and viscosity (Gori et al, 2015). PA has been associated with the prevention of increased BP, suggesting a mechanism which hypertensive patients can benefit. The results of the present study confirmed the benefits of PA in lowering BP in students, reported in a limited number of similar purpose studies. We found that BP was independently associated with increased PA, indicating that a dose-response relationship may exist between levels of PA and SBP; participants with a moderate PA profile had lower SBP compared with those with low PA. Similar findings were reported in the study by Hagberg et al. 1989 who reported that in 60-69 year old men and women SBP was marked lower after moderate exercise training (Hagberg et al, 1989). Physiological mechanisms such as systemic adaptation of the arterial wall, reduction of pro-oxidant levels and arterial stiffness, increases in central nitric oxide synthase activity and improvement in endothelial function may explain the effects of increased PA levels on BP, as it was found in our study.

Furthermore, we found that sex was significantly related to the SBP, indicating that routinely performed, increased PA was associated with lower SBP in females but not in male. This finding has also been supported by Reaven et al (Reaven et al, 1991) who indicated that in women, lower SBP and DBP were measured with low intensity, leisure-time PA, while further reductions were present with heavier PA. One possible explanation for the PA-induced lower SBP level in female may reside on the stimulation of their autonomic control. More specifically, sex-based differences in autonomic control of BP may underlie some of the differences observed in our study. We found that increased PA, from low to moderate level, seems to be adequate to affect autonomic control and provoke lower SBP levels in female, but not in male participants. Even more, although the relative contributions of potential mediators regarding MET energy cost and total workload of PA were qualitatively similar between sexes in this study, the beneficial effect of PA in BP was stronger for females compared to males. It has been supported that in male a higher level of PA, such as vigorous exercise, is required to affect autonomic control and provoke changes in BP (Cappio-Rivera et al, 2016). However, the tools used in the present study do not allow further speculation. On the other hand, previous studies have indicated that both sexes present equivocal results on BP levels following aerobic exercise (Cornelissen et al, 2010, Moreira etal, 2014).

Physical activity and pulse-pressure and respiratory rate and Rate Pressure Product

Rate-pressure pressure is a valuable marker of cardiac function and an important index of myocardial economy (Astrand et al, 2003). To the best of our knowledge, the present study may be the first to examine the PA effects on RR in students. However, despite the fact that increased PA lowered SBP (in female) and HR (in male), as it was indicated by our findings, however statistical significance was observed in the increase of RR of both sexes. This may attributed to the fact that increased PA, from lower to moderate level, either didn't provoke any significant myocardial hemodynamic effects or didn't affect baroreflex control of blood vessels (Halliwill et al, 1996). In line with our results, Forjaz et al, 1998 found that in young normotensives exercise of moderate intensity lowered HR, however did not reduce RR.

It is well known that exercise intensity influences BP and HR responses. Therefore, it is possible that either exercise of higher intensity or vigorous PA may also have distinct effects on RR and PR, compared to leisure-time PA. Elsewhere, it has been reported that there is a dose-response relationship between PA intensity and cardiovascular benefits; high-intensity PA tends to lead to greater cardiovascular functional gains than low-intensity. (Alansare et al, 2018). This is further supported by Rennie et al, 2003 who suggested that parasympathetic tone may be increased by vigorous PA, compared to moderate PA, thus representing a possible mechanism by which PA reduces heart disease risk. It should be pointed out, though, that it is often not efficient to incorporate older adults in high intensity activities. Thus, vigorous activities are usually not advisable for sedentary older population (McPhee et al, 2016).

Besides intensity, total weekly energy expenditure during PA may be a crucial factor defining the dose-response relation between PA and RR and PR. The World Health Organization (WHO) suggests that older adults should perform at least 150 min of moderate-intensity PA per week (42), thus 600 MET.min.wk^{-1} (Shin et al, 1997). Therefore, although the WHO's PA weekly expenditure criteria should be recommended for people.

Strengths and Limitations

Among the strengths of the present study were the random selection of the subjects from a well-defined and homogeneous target population, the high participation rate and the double-blind design (neither the students, nor the examiner were aware of subjects' PA status). In addition, the control for any potential confounders and limiting factors, such as age, health status, BMI added statistical power to our results.

On the other hand, there are certain limitations that have to be mentioned. Due to the strict selection criteria, the size of the sample was limited. A larger number of subjects would have made the application of statistical findings more appropriate. It should be noted that we were not able to fully control for other confounding factors, such as coffee consumption, alcohol and eating habits. Finally, generalization of our results from a sample of healthy community of students would be ill-advised. Socioeconomic status, dietary habits and PA profile, as well as other factors, might differ between our participants and the general students population. In any case, longitudinal research is required to determine whether PA of longer duration and/or higher intensity may have even more strenuous results and significantly lower RR and PR thus improving myocardial function and enhance the prevention of cardiovascular diseases in healthy students.

Conclusion

In the present study, increased PA, from low to moderate level, was related to significantly lower HR in male and SBP in female. The RPP was found lower in healthy subjects with higher levels of PA, but this association was not significant. Further investigation is needed to determine the precise dose-response relationship between PA and RR and PR. Future research must be carried out to clarify how PA of longer duration and/or higher intensity may affect myocardial functions and cardiovascular responses in healthy individuals.

Conflicts of Interest

None of the authors had any conflict of interest in relation to this study.

References

World Health Organization (2019) Global strategy on diet, physical activity and health.
World Health Organization (2019) Physical activity and older adults.
Jakovljevic DG (2018) Physical activity and cardiovascular aging: Physiological and molecular insights. Exp Gerontol 109: 67-74.
Fletcher GF, Balady G, Blair SN, Blumenthal J, Caspersen C, et al. (1996) Statement on exercise: benefits and recommendations for physical activity programs for all americans. A statement for health professionals by the committee on exercise and cardiac rehabilitation of the council on clinical cardiology. American Heart Association. Circulation 94: 857-862.
American College of Sports Medicine (2014) Guidelines for exercise testing and prescription (9th edn), Philadelphia: Lippincott Williams &Wilkins, USA.
Astrand PO, Rodahl K, Dahl HA, Stromme SB (2003) Body fluids, blood and circulation. In: Bahkre MS, ed. Textbook of work physiology. Physiological Basis of Exercise (2nd edn), Champagne, IL: Human Kinetics 2003.
Leon AS, Jacobs DR, DeBacker G, Taylor HL (1981) Relationship of physical characteristics and life habits to treadmill exercise capacity. Am J Epidemiol 113: 653-660.
Shalnova S, Shestov DB, Ekelud LG, Abernathy JR, Plavinskaya S, et al. (1996) Blood pressure response and heart rate response during exercise in men and women in the USA and Russia lipid research clinics prevalence study. Atherosclerosis 122: 47-57.
Cheng YJ, Macera CA, Addy CL, Sy FS, Wieland D, et al. (2003) Effects of physical activity on exercise tests and respiratory function. Br J Sports Med 37: 521-528.
10. Palatini P (2007) Heart rate as an independent risk factor for cardiovascular disease: current evidence and basic mechanisms. Drugs 67: 3-13.
Perret-Guillaume C, Joly L, Benetos A (2009) Heart rate as a risk factor for cardiovascular disease. Prog Cardiovasc Dis 52: 6-10.
Kjeldsen S, Mundal R, Sandvik L, Erikssen G, Thaulow E, et al. (2001) Supine and exercise systolic blood pressure predict cardiovascular death in middle-aged men. J Hypertens 19: 1343-1348

Gobel FL, Nordstrom LA, Nelson RR, Jorgensen CR, Wang Y (1978) The rate-pressure product as an index of myocardial oxygen consumption during exercise in patients with angina pectoris. Circulation 57: 549-556.
Czernin J, Sun K, Brunken R, Böttcher M, Phelps M, et al. (1995) Effect of acute and long-term smoking on myocardial blood flow and flow reserve. Circulation 91: 2891-2897.
Fletcher GF, Balady GJ, Amsterdam EA, Chaitman B, Eckel R, et al. (2001) Exercise standards for testing and training: a statement for healthcare professionals from the American Heart Association. Circulation 104: 1694-1740.
Saxena A, Minton D, Lee DC, Sui X, Fayad R, et al. (2013) Protective role of resting heart rate on all-cause and cardiovascular disease mortality. Mayo Clin Proc 88: 1420-1426.
Mok A, Khaw KT, Luben R, Wareham N, Brage S (2019) Physical activity trajectories and mortality: population based cohort study. BMJ 365: l2323.
Buchheit M, Simon C, Viola AU, Doutreleau S, Piquard F, et al. (2004) Heart rate variability in sportive elderly: relationship with daily physical activity. Med Sci Sports Exerc 36: 601-605.
O'Brien MW, Johns JA, Dorey TW, Frayne RJ, Fowles JR, et al. (2019) Meeting international aerobic physical activity guidelines is associated with enhanced cardiovagal baroreflex sensitivity in healthy older adults. Clin Auton Res 30: 139-148.
Karavirta L, Tulppo MP, Laaksonen DE (2009) Heart rate dynamics after combined endurance and strength training in older men. Med Sci Sports Exerc 41: 1436-1443.
Ueno LM, Moritani T (2003) Effects of long-term exercise training on cardiac autonomic nervous activities and baroreflex sensitivity. Eur J Appl Physiol 89: 109-114.
O'Hartaigh B, Pahor M, Buford TW, Dodson JA, Forman DE, et al. (2014) Physical activity and resting pulse rate in older adults: findings from a randomized controlled trial. Am Heart J 168: 597-604.
Miranda LS, Sattelmair J, Chaves P, Duncan G, Siscovick DS, et al. (2014) Physical activity and heart rate variability in older adults: The Cardiovascular Health Study. Circulation 129: 2100–2110.
Carter R, Hinojosa-Laborde C, Convertino VA (2015) Sex comparisons in muscle sympathetic nerve activity and arterial pressure oscillations during progressive central hypovolemia. Physiol Rep 3: e12420.
Rennie KL, Hemingway H, Kumari M, Brunner E, Malik M, et al. (2003) Effects of moderate and vigorous physical activity on heart rate variability in a british study of civil servants. Am J Epidemiol 158: 135-143.
Higginbotham MB, Morris KG, Williams RS, McHale PA, Coleman RE, et al. (1986) Regulation of stroke volume during submaximal and maximal upright exercise in normal man. Circ Res 58: 281-291.
Chou TH, Akins JD, Crawford CK, Allen JR, Coyle EF (2019) Low stroke volume during exercise with hot skin is due to elevated heart rate. Med Sci Sports Exerc 51: 2025-2032.
Parker BA, Kalasky MJ, Proctor DN (2010) Evidence for sex differences in cardiovascular aging and adaptive responses to physical activity. Eur J Appl Physiol 110: 235-246.
Huxley VH (2007) Sex and the cardiovascular system: the intriguing tale of how women and men regulate cardiovascular function differently. Adv Physiol Educ 31: 17-22.
Shin K, Minamitani H, Onishi S, Yamazaki H, Lee M (1997) Autonomic differences between athletes and nonathletes: spectral analysis approach. Med Sci Sports Exerc 29: 1482–1490.
Yataco AR, Fleisher LA, Katzel LI (1997) Heart rate variability and cardiovascular fitness in senior athletes. Am J Cardiol 80: 1389-1391.
Schuit AJ, van Amelsvoort LG, Verheij TC, Rijneke RD, Maan AC, et al. (1999) Exercise training and heart rate variability in older people. Med Sci Sports Exerc 31: 816-821
Gori T, Wild PS, Schnabel R, Schulz A, Pfeiffer N, et al. (2015) The distribution of whole blood viscosity, its determinants and relationship with arterial blood pressure in the community: cross-sectional analysis from the gutenberg health study. Ther Adv Cardiovasc Dis 9: 354-365.
Hagberg JM, Montain SJ, Martin WH, Ehsani AA (1989) Effect of exercise training in 60- to 69-year-old persons with essential hypertension. Am J Cardiol 64: 348-353.
Reaven PD, Barrett-Connor E, Edelstein S (1991) Relation between leisure-time physical activity and blood pressure in older women. Circulation 83: 559-565.
Carpio-Rivera E, Moncada-Jiménez J, Salazar-Rojas W, Solera-Herrera A (2016) Acute effects of exercise on blood pressure: a meta-analytic investigation. Arq Bras Cardiol 106: 422-433.
Cornelissen VA, Verheyden B, Aubert AE, Fagard RH (2010) Effects of aerobic training intensity on resting, exercise and post-exercise blood pressure, heart rate and heart-rate variability. J Hum Hypertens 24: 175-182.
Moreira S, Lima RM, Silva KE, Simoes HG (2014) Combined exercise circuit session acutely attenuates stress-induced blood pressure reactivity in healthy adults. Braz J Phys Ther 18: 38-46.
Halliwill JR, Taylor JA, Eckberg DL (1996) Impaired sympathetic vascular regulation in humans after acute dynamic exercise. J Physiol 495: 279-288.
Forjaz CL, Matsudaira Y, Rodrigues FB, Nunes N, Negrão CE (1998) Post-exercise changes in blood pressure, heart rate and rate pressure product at different exercise intensities in normotensive humans. Braz J Med Biol Res 31: 1247-1255.

Alansare A, Alford K, Lee S, Church T, Jung HC (2018) The effects of high-intensity interval training vs. moderate-intensity continuous training on heart rate variability in physically inactive adults. Int J Environ Res Public Health 15: E1508.

McPhee JS, French DP, Jackson D, Nazroo J, Pendleton N, et al. (2016) Physical activity in older age: perspectives for healthy ageing and frailty. Biogerontology 17: 567-580.