Research Article

iMedPub Journals
www.imedpub.com

Health Science Journal
ISSN 1791-809X

2020
Vol. 14 No. 2: 712

DOI: 10.36648/1791-809X.14.2.712

# Impact of Physical Activity on Heart Rate, Blood Pressure and Rate-Pressure Product in Healthy Elderly

George Papathanasiou[1]*, Georgios Mitsiou[1], Magdalini Stamou[1], Sophia Stasi[1], Anastasia Mamali[2] and Effie Papageorgiou[3]

1 Department of Physiotherapy, Neuromuscular and Cardiovascular Study of Motion Lab, University of West Attica, Greece

2 National and Kapodistrian University of Athens, Greece

3 Vice Rector of University of West Attica, Athens, Greece

***Corresponding author:**
George Papathanasiou

papathanasiou.g@gmail.com

Director of Neuromuscular and Cardiovascular Study of Motion Lab, Department of Physiotherapy, University of West Attica, Ag. Spyridonos St., 12210 Athens, Greece

**Citation:** Papathanasiou G, Mitsiou G, Stamou M, Stasi S, Mamali A, et al. (2020) Impact of Physical Activity on Heart Rate, Blood Pressure and Rate-Pressure Product in Healthy Elderly. Health Sci J. 14 No. 2: 712.

## Abstract

**Objective:** Heart rate (HR), blood pressure (BP) and rate-pressure product (RPP) are important prognostic factors of cardiovascular health. They all related to myocardial $O_2$ uptake and hence myocardial work intensity, being important non-invasive and inverse indicators of myocardial economy. The study aimed to investigate the effect of physical activity (PA) on myocardial economy on healthy, elderly Greek individuals.

**Methods:** 106 participants were enrolled in the study, 37 men and 69 women. The resting HR, systolic BP (SBP) and RPP were determined and recorded according to the latest guidelines. The IPAQ-GR questionnaire was applied to evaluate the participants' level of PA.

**Results:** The HR and SBP were significantly associated with PA class. PA class was inversely associated with HR in men ($p$=0.023) and SBP in women ($p$=0.009). The RPP was lower in participants with moderate PA class, compared to those with low PA, yet the correlation was not statistically significant.

**Conclusion:** Increased PA, from low to moderate level, significantly lowered HR in men and SBP in women. The RPP was found lower in healthy elderly subjects with higher levels of PA, but this association was not significant. Future research must be carried out to clarify how PA of longer duration and/or higher intensity may affect myocardial function and cardiovascular responses in healthy elderly individuals.

**Keywords:** Blood pressure; Elderly; Heart rate; IPAQ; Myocardial economy; Physical activity; Rate-pressure product

**Received:** April 23, 2020, **Accepted:** April 27, 2020, **Published:** May 04, 2020

## Introduction

Ageing is associated with a significant increase in the prevalence of chronic degenerative disturbances [1]. The changes associated with progressive ageing make the elderly more susceptible to cardiovascular diseases (CVD), such as hypertension, heart failure, cardiac valvular disorders, and various types of arrhythmia [2]. Worldwide, it has been estimated that ischemic heart disease is the leading cause of global mortality [3], whereas CVD accounts for 45% of all deaths in Europe and 37% of all deaths in the European Union (EU) [4]. Overall CVD is estimated to cost the EU economy €210 billion a year [4]. In Greece, a state that tops the list of deaths due to ischemic heart disease and stroke [5], it is estimated that 48% of registered deaths are attributed to circulatory diseases.

Physical activity (PA), defined as any bodily movement produced by skeletal muscles that requires energy expenditure [6], provokes changes in the cardiovascular function of elderly with a positive effect on both the prevention and rehabilitation of life-threatening CVD [7,8]. 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) [9,10].

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 [10,11]. Heart rate (HR) and systolic blood pressure (SBP), are important prognostic factors of cardiovascular health; their lower rates are related to improved physical fitness [12-14] and decreased cardiovascular morbidity and mortality [15-17]. The rate-pressure product (RPP = HR × SBP) is strongly and positively related to coronary blood flow and myocardial $O_2$ uptake [11,18,19]. All of the above are positively related to myocardial $O_2$ demands and hence myocardial workload, being important non-invasive and inverse indicators of myocardial economy [11,20].

There is limited data regarding the impact of PA on the myocardial function of elderly adults. Particularly, the effect of PA on the very important parameters of myocardial economy, such as HR, SBP and RPP, of the elderly needs to be further clarified. The purpose of this study was to investigate the effects of PA on myocardial economy in Greek healthy elderly.

# Methods

## Study population

A total of 236 people were randomly selected from the population of the five Open Care Centers for the Elderly in Neo Iraklion, Athens, Greece. At the baseline evaluation, health status was assessed by internists and cardiologists, based on medical history, clinical and physical examination. Body mass index (BMI), health status, age and smoking seem to be potential confounders in the relation between PA and cardiac function [10]. Only healthy, non-smokers, aged 65 to 69 years of age, with normal body weight (18.5<BMI<25 kg/m$^2$) were eligible for the study. Our exclusion criteria were the following; metabolic diseases (such as diabetes or thyroid disease), physical disabilities, heart disorders, recent illness, and cardiac medications, such as β-blockers. Finally, 128 elderly met all the inclusive and exclusive criteria, of which106 subjects participated, whereas 22 (17.2%) either did not show up or returned non-valid questionnaires (**Table 1**).

**Table 1:** Personal characteristics of the study population (n=106).

| Variables | Total population (n=106) | Men (n=37) | Women (n=69) |
|---|---|---|---|
| Age (yrs) | 67.8 ± 1.6 | 68.7 ± 0.92 | 67.3 ± 1.69 |
| Height (cm) | 163.5 ± 0.09 | 171.9 ± 0.08 | 159.1 ± 0.06 |
| Weight (kg) | 64.6 ± 7.9 | 71.9 ± 7.37 | 60.8 ± 4.96 |
| BMI (kg/m$^2$) | 24.1 ± 1.1 | 24.3 ± 0.95 | 24.0 ± 1.21 |

BMI: Body Mass Index.
Values are presented as mean ± standard deviation.

All participants gave written informed consent prior to inclusion in the study. The study protocol was approved by the research committee of MSc "Cardiopulmonary Resuscitation" of the Medical School of the National and Kapodistrian University of Athens, Greece, and followed the principles of the Helsinki Declaration and its later amendments. In addition, written permission was obtained from the Organisation of Preschool Education and Social Welfare in Neo Iraklion, Athens, Greece (1603/May 28, 2014).

## Study protocol

Before the day of their appointment, all participants were well informed about the research procedures and became familiar with the lab and the test equipment (**Flow Diagram Figure 1**). All subjects filled in a standardized questionnaire recording their personal data and health-related information. In addition, they completed the IPAQ-GR to assess their PA level, after they had been given detailed instructions. The white coat effect [21] and masked hypertension [22] are major factors that have been found to affect the rates of HR and BP. These factors were limited by familiarising the subjects with the lab and the test equipment one day before the measurements. The HR, BP and RPP were then measured and recorded, as described elsewhere [23]. Tests and 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 tests.

## PA assessment

The PA level of the participants was evaluated using the Greek version of the short International Physical Activity Questionnaire (IPAQ-GR), which has been validated and proved reliable for the ages of 15-69 years [24,25]. Briefly, the IPAQ-Gr is a 7-item instrument consisting of six questions that subjects are asked to answer in order to record the number of days (frequency) and the number of minutes per day (duration) of their participation in all kinds of vigorous, moderate and walking PAs during the last seven days. The IPAQ-Gr is used to sum up vigorous, moderate, and walking PA class over the previous seven-day period and generate a total physical activity-score (PA-score), expressed in metabolic equivalent (MET)-minutes per week (MET·min·wk$^{-1}$). Prior to the IPAQ-Gr administration, the answering procedure was explained to the participants. Emphasis was given to the

**Table 2:** Baseline data of the study population (n=106).

| Variables | Total population | Men (n=37) | Women (n=69) | Significance *p values* |
|---|---|---|---|---|
| HR (bmp) | 73.32 ± 8.8 | 70.53 ± 9.53 | 74.76 ± 8.22 | NS* |
| SBP (mmHg) | 135.79 ± 14.3 | 140.47 ± 11.29 | 133.38 ± 15.26 | 0.021* |
| DBP (mmHg) | 75.80 ± 9.9 | 74.12 ± 8.37 | 76.67 ± 10.61 | NS* |
| RPP | 9952 ± 1609 | 9913 ± 1625 | 9971 ± 1614 | NS* |
| PA (MET·min·wk$^{-1}$) | 762.2 ± 623.2 | 713.1 ± 579.2 | 787.5 ± 647.6 | NS* |
| PA (MET·min·wk$^{-1}$) | Total population | Low PA (n=47) | Moderate PA (n=59) | |
| | | 263 ± 213,3 | 1171.7 ± 545.3 | < 0.001** |

HR: Heart Rate; SBP: Systolic Blood Pressure; DBP: Diastolic Blood Pressure; RPP: Rate-Pressure Product; PA: Physical Activity; NS: Non-Significant.
Values are presented as mean ± standard deviation. None of the subjects was classified in high (vigorous) physical activity class.
(*): p - values for significant differences between men and women; (**): p - values for significant differences between physical activity of low PA and moderate PA class participants.

Health Science Journal
ISSN 1791-809X
2020
Vol. 14 No. 2: 712

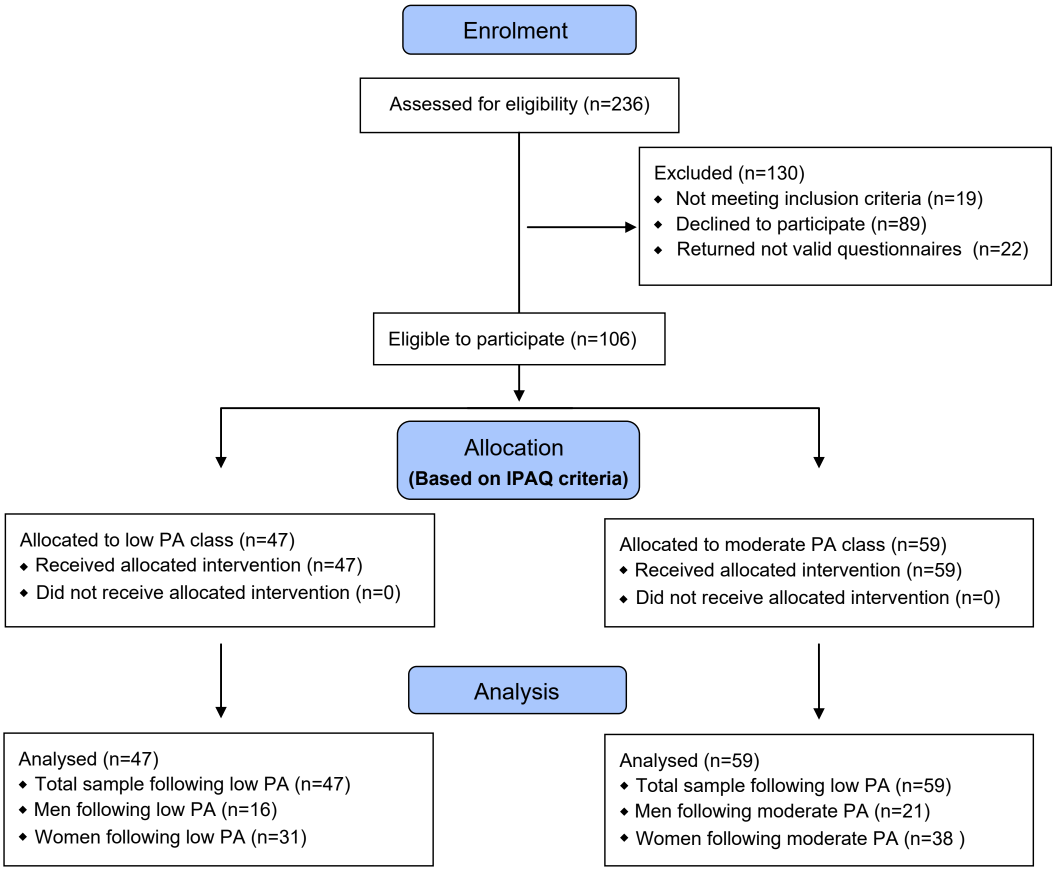


**Figure 1** Flow Diagram.
IPAQ: International Physical Activity Questionnaire; PA: Physical Activity

condition that only PAs that lasted at least 10 min should be recorded. Based on the IPAQ scoring procedure, PA status was classified into three categories (PA classes): 1) low PA class, insufficiently active subjects (total PA-score <600 MET·min·wk$^{-1}$); 2) moderate PA class; active subjects (total PA-score ≥600 MET.min.wk$^{-1}$ or vigorous PA-score ≥ 480 MET.min.wk$^{-1}$); and 3) high PA class, very active subjects engaging in health-enhancing PA (total PA-score ≥3000 MET·min·wk$^{-1}$ or vigorous PA-score ≥1500 MET·min·wk$^{-1}$) [24,25].

## Myocardial economy assessment

A reliable and valid monitor (Polar S810i Heart Rate Monitor) was used to measure HR, according to the manufacturer's instructions [26,27]. Resting HR was recorded in a supine position, after ten minutes of rest. The SBP was measured using an electronic sphygmomanometer (Omron 705IT, HEM-759-E) [28] with the subject in a seated position following ten minutes of rest, in accordance the European guidelines [29]. Three BP measurements were taken, at least 3 minutes apart from each other; the mean of the second and third measurement was recorded. The RPP was calculated as the product of HR x SBP [11]. During all measurements, the examiner was blinded to the participants' PA status and their PA class.

## Data analysis

Data was expressed as means with ± standard deviation (SD). The normality of distribution for age, BMI, SBP, HR and RPP 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 groups of PA class. PA class and sex were considered as independent variables and all HR, BP and RPP values were considered as dependent variables. Stepwise multiple regression analysis was used to determine which of the personal characteristics (age, sex, BMI, total weekly PA: independent variables) were significantly associated with each of the dependent variables. Age was related to diastolic BP values and was entered into the final MANCOVA model as a covariate. In order to examine the effects of PA on dependent variables, in both sexes, another multivariate analysis of variance (general linear model, full factorial – type III) was used for men and women, separately. 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, 106 subjects, 37 men and 69 women, with a mean age of 67.75 ± 1.60 years, were included in the study (**Table 1**). All variables were normally distributed. Baseline data for all independent (PA) and dependent (RPP, HR, SBP, DBP) variables are presented in **Table 2**. Age was significantly and directly associated with DBP ($p$=0.006), while sex had a significant association with SBP ($p$=0.021) (**Table 3**). Regarding participants' PA profile, 47 were found to have low PA (263 MET·min·wk$^{-1}$), 59 moderate PA (1171.7 MET·min·wk$^{-1}$), while none of the subjects was classified into high PA class (**Table 2**).

In our study, HR and SBP were independently associated with moderate PA class [F(1,34)=8.181; $p$<0.02 and F(1,75)=6.980; $p$=0.04, respectively] (data is not shown). When males and females were analysed separately PA class was indirectly associated with HR ($p$=0.023) in men and SBP ($p$=0.019) in women. Increased PA, from low to moderate level, significantly lowered HR in men and SBP in women (**Table 4**). No other significant differences in measures were found between participants with moderate vs. low PA class by multivariate analysis.

**Table 3:** Heart rate, systolic and diastolic blood pressure, rate-pressure product and physical activity in relation with age and sex (n=106).

| Variables | Age | Sex |
|---|---|---|
| HR (bmp) | NS | NS |
| SBP (mmHg) | NS | $p$ = 0.021 |
| DBP (mmHg) | $p$ = 0.006 | NS |
| RPP | NS | NS |
| PA (MET·min·wk$^{-1}$) | NS | NS |

HR: Heart Rate at rest; SBP: Systolic Blood Pressure at rest; DBP: Diastolic Blood Pressure at rest; RPP: Rate-Pressure Product; PA: Physical Activity; NS: Non significant
P: values for significance in the relation of dependent and independent (PA) variables with age and sex.

**Table 4**: Rate-pressure product, heart rate, systolic and diastolic blood pressure in relation with participants' physical activity (PAclass).

| Variables | Low PA | Moderate PA | Significance *p values** |
|---|---|---|---|
| **Men** (n=37) | (n=16) | (n=21) | |
| HR | 73.13 ± 11.64 | 68.47 ± 7.14 | 0.023 |
| SBP | 140.00 ± 12.01 | 140.84 ± 10.99 | NS |
| DBP | 73.93 ± 5.99 | 74.26 ± 10.02 | NS |
| RPP | 10241 ± 1929 | 9655 ± 1336 | NS |
| **Women** (n=69) | (n=31) | (n=38) | |
| HR | 73.93 ± 7.64 | 75.44 ± 8.71 | NS |
| SBP | 138.47 ± 14.40 | 129.14 ± 14.83 | 0.009 |
| DBP | 76.63 ± 10.88 | 76.69 ± 10.53 | NS |
| RPP | 10201 ± 1234 | 9779 ± 1868 | NS |
| **Total** (n=106) | (n=47) | (n=59) | |
| HR | 73.67 ± 9.04 | 73.04 ± 8.80 | NS |
| SBP | 138.98 ± 13.53 | 133.18 ± 14.65 | 0.044 |
| DBP | 75.73 ± 9.55 | 75.85 ± 10.33 | NS |
| RPP | 10215 ± 1479 | 9736 ± 1692 | NS |

PA: Physical Activity; HR: Heart Rate; SBP: Systolic Blood Pressure; DBP: Diastolic Blood Pressure; RPP: Rate-Pressure Product; NS: Non significant
Values are presented as mean ± standard deviation. None of the subjects was classified in high (vigorous) physical activity class.
(*): $p$ - values for significant differences between low and moderate PA class.

Our results indicated that PA was inversely related with the RPP; the later was lower in subjects with moderate PA level compared with those with low PA. However, when all 106 participants were included in multivariate analysis, the principal outcome yielded that there was no significant correlation between RPP and subjects' PA class (moderate or low) ($p$>0.05) (**Table 4**).

# Discussion

We set out to evaluate whether PA is an effective physiological stimulus to improve myocardial economy in healthy elderly individuals. The results of the present study indicated that increased PA, from low to moderate level, significantly lowered HR in men and SBP in women. The RPP was found lower in healthy elderly subjects with higher levels of PA, but this association was not 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 [30,31]. However, the effects of PA on HR of older adults have not been thoroughly studied yet. This is one of the few studies indicated that increased PA, from low to moderate level, lowered resting HR in healthy elderly. Similar to our findings were observed in sportive elderly, where increases in PA intensity were associated with higher HR variability [32]. 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 [33]. Moreover, increased PA has been shown to lower HR in other age groups such as young [34] and middle aged adults [35]. These results suggest that increased PA may be sufficient to affect the autonomic tone of the elderly, similar to exercise modalities that have been shown to do so [36,37]. 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 [38,39].

Our findings indicated that the beneficial effect of PA on HR was stronger and significant for men compared to women. These results are in line with the study by Carter et al. [40] who reported that men have lower HRs than women when performing exercise of similar intensity. Moreover, Rennie et al. [41] 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 elderly male participants, may be related to increased stoke volume observed in exercising or physically active individuals [42,43]. Yet, it remains unclear why the above haemodynamic mechanism may hold true and explain the PA-related HR decline in men, but not in women. The latter may be attributed to the sex-based differences in exercise-related tests such as $VO_2$ norms, BP and lung diffusion capacity [44]. It seems that when placed under increased cardiovascular demands, men respond by increasing vascular resistance, and consequently BP, whereas women respond by increasing HR, therefore presenting higher HRs following PA or exercise [45].

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 [46,47]. However, others have supported that the parasympathetic tone may be increased by high-intensity activity, such as jogging, while moderate activity is not [48]. 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 [49]. 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 the elderly, 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. who reported that in 60-69 year old men and women SBP was marked lower after moderate exercise training [50]. 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 older women but not in men. This finding has also been supported by Reaven et al. [51] who indicated that in elderly 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 women 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 women compared to men. It has been supported that in men a higher level of PA, such as vigorous exercise, is required to affect autonomic control and provoke changes in BP [52]. 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 [53,54].

## Physical activity and rate-pressure product

Rate-pressure product is a valuable marker of cardiac function and an important index of myocardial economy [11]. To the best of our knowledge, the present study may be the first to examine the PA effects on RPP in the elderly. However, despite the fact that increased PA lowered SBP (in women) and HR (in men), as it was indicated by our findings, no statistical significance was observed in the reduction of RPP 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 [55]. In line with our results, Forjaz et al. [56] found that in young normotensives exercise of moderate intensity lowered HR, however did not reduce RPP.

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 RPP, compared to leisure-time PA. Furthermore, it has been shown that intensity seems to be a significant factor in affecting the impact of exercise on RPP [56]. 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 Pas [57]. This is further supported by Rennie et al. [41] 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 [58].

Besides intensity, total weekly energy expenditure during PA may be a crucial factor defining the dose-response relation between PA and RPP. The World Health Organization (WHO) suggests that older adults should perform at least 150 min of moderate-intensity PA per week [59], thus 600 MET.min.wk$^{-1}$ [24]. In our study, 45% of the participants performed low PA. This is attributed to the lifestyle and the daily habits of our participants; all subjects were members of Open Care Centers and did not participate in any organized scheduled exercise programme. However, the rest 55% of our participants performed moderate PA (≥ 600 MET.min.wk$^{-1}$). Therefore, although the WHO's PA weekly expenditure criteria were met from our moderate PA participants, there weren't any significant RPP reductions recorded. Probably, healthy elderly individuals may require an even higher amount of total weekly PA energy expenditure for their RPP to be reduced.

## 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 single-blind design (neither the physicians, 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, smoking and white coat effect 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, generalisation of our results from a sample of healthy community dwelling subjects to all Greek elderly would be ill-advised. Socioeconomic status, dietary habits and PA profile, as well as other factors, might differ between our participants and the general 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 RPP, thus improving myocardial economy and enhance the prevention of cardiovascular diseases in healthy elderly.

## Conclusion

In the present study, increased PA, from low to moderate level, was related to significantly lower HR in men and SBP in women. The RPP was found lower in healthy elderly 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 RPP. Future research must be carried out to clarify how PA of longer duration and/or higher intensity may affect myocardial economy and cardiovascular responses in healthy elderly individuals.

## Conflicts of Interest

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

## References

1 Franceschi C, Garagnani P, Morsiani C, Conte M, Santoro A, et al. (2018) The continuum of aging and age-related diseases: common mechanisms but different rates. Front Med (Lausanne) 5: 61.

2 North BJ, Sinclair DA (2012) Aging and cardiovascular disease. The intersection between aging and cardiovascular disease. Circ Res 110: 1097-1108.

3 Pagidipati NJ, Gaziano TA (2013) Estimating deaths from cardiovascular disease: a review of global methodologies of mortality measurement. Circulation 127: 749-756.

4 Wilkins E, Wilson L, Wickramasinghe K, Bhatnagar P, Leal J, et al. (2017) European cardiovascular disease Statistics 2017. European Heart Network, Brussels.

5 Michas G, Karvelas G, Trikas A (2018) Cardiovascular disease in Greece; the latest evidence on risk factors. Hellenic J Cardiol pp: S1109-9666(18)30342-7.

6 World Health Organization (2019) Global strategy on diet, physical activity and health.

7 World Health Organization (2019) Physical activity and older adults.

8 Jakovljevic DG (2018) Physical activity and cardiovascular aging: Physiological and molecular insights. Exp Gerontol 109: 67-74.

9 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.

10 American College of Sports Medicine (2014) Guidelines for exercise testing and prescription (9th edn), Philadelphia: Lippincott Williams &Wilkins, USA.

11 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.

12 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.

13 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.

14 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.

15 Palatini P (2007) Heart rate as an independent risk factor for cardiovascular disease: current evidence and basic mechanisms. Drugs 67: 3-13.

16 Perret-Guillaume C, Joly L, Benetos A (2009) Heart rate as a risk factor for cardiovascular disease. Prog Cardiovasc Dis 52: 6-10.

17 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

18 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.

19 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.

20 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.

21 Strandberg TE, Salomaa V (2000) White coat effect, blood pressure and mortality in men: prospective cohort study. Eur Heart J 21: 1714-1718.

22 Papadopoulos DP, Makris TK (2007) Masked hypertension definition, impact, outcomes: a critical review. J Clin Hypertens (Greenwich) 9: 956-963.

23 Papathanasiou G, Georgakopoulos D, Georgoudis G, Spyropoulos P, Perrea D, et al. (2007) Effects of chronic smoking on exercise tolerance and on heart rate - systolic blood pressure product in young healthy adults. Eur J Cardiovasc Prev Rehabil 14: 646–652.

24 Papathanasiou G, Georgoudis G, Papandreou M, Spyropoulos P, Georgakopoulos D, et al. (2009) Reliability measures of the short International Physical Activity Questionnaire (IPAQ) in Greek young adults. Hellenic J Cardiol 50: 283-294.

25 Papathanasiou G, Georgoudis G, Georgakopoulos D, Katsouras C, Kalfakakou V, et al. (2010) Criterion-related validity of the short

International Physical Activity Questionnaire against exercise capacity in young adults. Eur J Cardiovasc Prev Rehabil 17: 380-386.

26 Gamelin FX, Berthoin S, Bosquet L (2006) Validity of the polar S810 heart rate monitor to measure R-R intervals at rest. Med Sci Sports Exerc 38: 887-893.

27 Vanderlei LC, Silva RA, Pastre CM, Azevedo FM, Godoy MF (2008) Comparison of the Polar S810i monitor and the ECG for the analysis of heart rate variability in the time and frequency domains. Braz J Med Biol Res 41: 854-859.

28 Coleman A, Freeman P, Steel S, Shennan A (2006) Validation of the Omron 705IT (HEM-759-E) oscillometric blood pressure monitoring device according to the British Hypertension Society protocol. Blood Press Monit 11: 27-32.

29 Pickering TG, Hall JE, Appel LJ, Falkner BE, Graves J, et al. (2005) Recommendations for blood pressure measurement in humans and experimental animals: part 1: blood pressure measurement in humans: A statement for professionals from the Subcommittee of Professional and Public Education of the American Heart Association Council on high blood pressure research. Hypertension 45: 142-161.

30 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.

31 Mok A, Khaw KT, Luben R, Wareham N, Brage S (2019) Physical activity trajectories and mortality: population based cohort study. BMJ 365: l2323.

32 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.

33 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.

34 Melo RC, Santos MD, Silva E, Quitério RJ, Moreno MA, et al. (2005) Effects of age and physical activity on the autonomic control of heart rate in healthy men. Braz J Med Biol Res 38: 1331-1338.

35 Reimers AK, Knapp G, Reimers CD (2018) Effects of exercise on the resting heart rate: a systematic review and meta-analysis of interventional studies. J Clin Med 7: E503

36 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.

37 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.

38 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.

39 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.

40 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.

41 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.

42 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.

43 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.

44 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.

45 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.

46 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.

47 Yataco AR, Fleisher LA, Katzel LI (1997) Heart rate variability and cardiovascular fitness in senior athletes. Am J Cardiol 80: 1389-1391.

48 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

49 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.

50 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.

51 Reaven PD, Barrett-Connor E, Edelstein S (1991) Relation between leisure-time physical activity and blood pressure in older women. Circulation 83: 559-565.

52 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.

53 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.

54 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.

55 Halliwill JR, Taylor JA, Eckberg DL (1996) Impaired sympathetic vascular regulation in humans after acute dynamic exercise. J Physiol 495: 279-288.

56 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.

57 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.

58 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.

59 Marques A, Sarmento H, Martins J, Saboga-Nunes L (2015) Prevalence of physical activity in european adults - Compliance with the world health organization's physical activity guidelines. Prev Med 81: 333-338.