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Physical activity and resting pulse rate in older adults: findings from a randomized controlled trial

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Abstract

Background—Elevated resting pulse rate (RPR) is a well-recognized risk factor for adverse outcomes. Epidemiological evidence supports the beneficial effects of regular exercise for lowering RPR, but studies are mainly confined to persons younger than 65 years. We set out to evaluate the utility of a physical activity (PA) intervention for slowing RPR among older adults.

Methods—A total of 424 seniors (ages 70–89 years) were randomized to a moderate intensity PA intervention or an education-based “successful aging” (SA) health program. RPR was assessed at baseline, 6 months and 12 months. Longitudinal differences in RPR were evaluated between treatment groups using generalized estimating equation (GEE) models, reporting unstandardized beta coefficients (β) with robust standard errors (SE).

Results—Increased frequency and duration of aerobic training was observed for the PA group at 6 and 12 months as compared with the SA group ($P < 0.001$). In both groups, RPR remained unchanged over the course of the 12-month study period ($P = 0.67$). No significant improvement was observed (β [SE] = 0.58 [0.88], $P = 0.51$) for RPR when treatment groups were compared using the GEE method. Comparable results were found after omitting participants with a pacemaker, cardiac arrhythmia, or who were receiving beta-blockers.

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Conclusions—Twelve months of moderate intensity aerobic training did not improve RPR among older adults. Additional studies are needed to determine whether physical activity of longer duration and/or greater intensity can slow RPR in older persons.

In the United States, persons older than 65 years are frequently burdened with a high prevalence of cardiovascular disease (CVD), and this segment of the population is anticipated to double in size to almost 90 million over the next 3 decades.¹ This demographic imperative will have a profound effect on the nation's public health, social services, and health care system.² Thus, effective strategies to reduce the burden of CVD in this rapidly aging population are greatly needed.

Resting pulse rate (RPR), a surrogate of cardiorespiratory fitness, constitutes a promising and easy-to-measure predictor of CVD.³⁻⁶ Although not completely understood, possible mechanisms through which an elevated RPR may be directly associated with CVD risk include greater mechanical load imposed on the arterial wall,⁷ a compromised balance between myocardial oxygen demand and supply,⁸ and heightened inflammatory activity.⁹

Regular exercise has been shown to improve the cardiovascular profile by augmenting cardiorespiratory fitness.¹⁰ These beneficial effects may be mediated, in part, by reductions in the RPR, perhaps as a reflection of improved vagal activity.¹¹ Although the intermediary role of RPR in the relationship between physical fitness and CVD has been suggested in previous epidemiological studies,^{12, 13} these investigations have included relatively few persons older than 65 years.

As little is known about the effects of regular exercise on reducing RPR among older adults, we set out in the current study to evaluate the utility of structured physical activity (PA) in a randomized controlled trial of lifestyle interventions, in a population of community-dwelling older adults. Specifically, we evaluated whether a walking-based PA program lowered RPR, a distinct marker of cardiovascular status, in older persons.

Methods

LIFE-P Study Design

Details about the design, rationale and implementation of the Lifestyle Interventions and Independence for Elders-Pilot (LIFE-P) Study have been described elsewhere.¹⁴ In brief, LIFE-P was a single-masked, randomized controlled trial designed to evaluate the effects of PA on mobility limitations. The study was conducted at four field centers (The Cooper Institute, Dallas, TX; Stanford University, Palo Alto, CA; University of Pittsburgh, Pittsburgh, PA; and Wake Forest University, Winston-Salem, NC). Participants were 70-89 years of age, were at high-risk for mobility disability (defined as a score <10 on the short physical performance battery [SPPB]),¹⁵ were able to complete a 400-meter walk test in 15 minutes without the use of an assistive device, and led a sedentary lifestyle (defined as 20 minutes of regular physical activity per week during the prior month). Exclusion criteria included severe heart failure (New York Heart Association functional classifications III or IV), uncontrolled angina pectoris, severe pulmonary disease, chest pain or severe shortness of breath during the 400-meter walk test, severe arthritis, cancer requiring treatment in the

past 3 years, Parkinson's disease, other severe illnesses that may interfere with physical activity, life expectancy less than 12 months, and a Mini-Mental State Examination (MMSE) score <21.¹⁶ Temporary exclusion criteria included acute myocardial infarction (MI), deep venous thrombosis, pulmonary embolism, major arrhythmias or stroke within 6 months, recent major surgery, uncontrolled hypertension, uncontrolled diabetes, or ongoing lower extremity physical therapy. All participants provided written informed consent, and the review committees for each field site approved the study protocol. All aspects of this investigation were conducted in accordance with the principles expressed in the Declaration of Helsinki and is registered at <http://www.ClinicalTrials.gov> (registration # NCT00116194). Any sources of funding used to support this work are outlined in the appendix, and the authors are solely responsible for the design and conduct of this study, all study analyses, and drafting and editing of the paper.

Procedures

Participants were enrolled between April 2004 and February 2005 and were randomized to either a walking-based PA program or an education-based "successful aging" (SA) health program for a duration of 12 months. Of the 3,141 older persons initially screened by telephone, 213 (6.8%) were assigned to the PA group, and 211 (6.7%) were assigned to the SA group (Figure 1).

Physical Activity Treatment Group

The PA intervention included a combination of aerobic-walking, strength, balance, and flexibility exercises that were implemented in three phases: adoption (the first 2 months of intervention), transition (months 3–6), and maintenance (months 7–12). PA participants received a 45-minute induction session aimed at describing specific aspects of the intervention including safety. The adoption phase consisted of three supervised center-based exercise sessions (40–60 min) per week. During the subsequent transition phase, the number of center-based exercise sessions decreased (2/week) and a home-based intervention involving endurance, strengthening, and flexibility exercises was introduced (3/week). Finally, the maintenance phase consisted of the home-based intervention, along with optional once-to-twice per week center-based sessions and monthly telephone contacts.

Walking was the primary mode of exercise in this study, as it has been previously recommended by expert bodies, does not need to be center-based, and is widely acceptable and safe among older individuals.^{17, 18} According to the Surgeon General's recommendations, the target for the walking component was 150 minutes per week (over five or more days), achieved in a gradual and individualized fashion across the first 3 months of the trial.^{19, 20} For the walking component, moderate intensity exercise was promoted.²¹ The Borg scale²² was employed to regulate the intensity of exercise. Study participants were asked to walk at a perceived exertion of 13 (somewhat hard), and were discouraged from exercising at levels above 15 (hard) or below 11 (fairly light).

Successful Aging Treatment Group

A SA health education intervention was employed as the active control. Participants were required to attend small group sessions on a weekly basis for the first 26 weeks, and monthly

thereafter. The educational sessions were designed to increase awareness on a variety of health topics relevant to older adults including nutrition, how to effectively negotiate the health care system, medications, foot care, recommended preventive services at different ages, and how to travel safely. Basic educational information with regards to physical activity was also provided. Each session concluded with a short instructor-led program (5–10 minutes) of upper extremity stretching exercises.

LIFE-P Study Measures

Data collection occurred every six months during clinic visits. To ensure masking, study members were instructed not to discuss their intervention assignment during the assessments, which were conducted at locations separate from the intervention sites. Complete information about the LIFE-P assessments are provided in the main outcomes paper.²³ In brief, using a structured interview method, data were obtained on participants' age, sex, race, smoking status, income, chronic conditions, and medication use.

The Community Healthy Activities Model Program for Seniors (CHAMPS) self-report physical activity questionnaire was used to evaluate changes in physical activity over time. The CHAMPS questionnaire has been developed specifically to evaluate the frequency and duration of physical activity performed across an average week in the past month among older men and women. This measure has good psychometric properties and is sensitive to change.²⁴

Waist circumference (cm) was measured around the slimmest region between the ribs and iliac crest, or at the navel if no natural waistline was observed. RPR was recorded in duplicate via pulse palpitation of the radial artery over 30 seconds, after participants had been resting quietly for 5 minutes in the seated position. Blood pressure was determined twice using conventional auscultation and sphygmomanometry, with participants also having rested quietly for 5 minutes in the seated position. In the current analysis, the average of the RPR and blood pressure measures were used. As an index of myocardial oxygen consumption, rate pressure product (RPP) was calculated as the product of RPR and systolic blood pressure. Details of this hemodynamic parameter has been described previously.²⁵ Prior to assessing RPR and blood pressure in the morning, participants were instructed to remain fasting, not to consume alcohol or caffeine, and not to engage in strenuous physical activity.

Statistical Methods

Continuous variables were summarized as means $\pm$ SD and categorical variables were presented as counts (%) according to treatment groups. A repeated measures Analysis of Variance (ANOVA) was used to examine the mean change in RPR and RPP, as well as the frequency and duration of physical activity according to treatment groups at the 6-month and 12-month assessments. Each model included treatment and its error term (i.e., subject nested in treatment) to account for between-subject error, as well as the within-subject factor (i.e., time) to account for residual error. Violations in model sphericity and lack of compound symmetry were addressed by computing *P* values for conservative F-tests, reporting the Greenhouse-Geisser correction.

Longitudinal differences in RPR and RPP between treatment groups were evaluated using generalized estimating equation (GEE) models, reporting unstandardized beta coefficients (β) with robust standard errors (SE). In this model, the SA group served as the reference category. An unstructured covariance matrix was employed to account for the over-time correlation between repeated measures.

Several sensitivity checks were also performed using the GEE method. First, participants who had a pacemaker ($n=8$) were omitted from the analysis as such devices artificially regulate RPR. Second, participants with a cardiac arrhythmia ($n=72$) were omitted as this condition may influence RPR and lead to unreliable estimates. Third, participants who reported taking medication (i.e., beta-blockers [$n=140$], calcium channel blockers [$n=122$], diuretics [$n=158$], or statins [$n=145$]) that might have lowered RPR were also omitted. All statistical calculations were computed using STATA version 13.0 (StataCorp LP, College Station, Texas). Results were considered statistically significant at a two-tailed P -value of <0.05 .

Results

The mean age of the 424 study participants was 76.8 ± 4.2 years. Overall, 68.9% were women and 25.5% belonged to a racial/ethnic minority. Participant demographics according to the intervention groups are provided in Table 1. Both groups had similar characteristics, with the exception of diabetes, which was more prevalent in the PA group. Pairwise correlation revealed RPR was not significantly associated with other indices of physical performance and cardiorespiratory fitness, for example, SPPB ($r=0.03$, $P=0.33$) and 400-meter walk test ($r=0.002$, $P=0.93$).

Attendance during the follow-up assessments was excellent, with rates of 94.8% at 6 months and 94.0% at 12 months. In the PA group, attendance rates to the adoption and transition phases were 70.7% and 60.9%, respectively. During the maintenance phase, participants engaged in an average 3.6 walking sessions per week and walked an average 149 ± 201 minutes per week. Attendance rates in the SA group were 70% for weeks 1 to 26 and 73% for weeks 27 to 52. The frequency of moderate physical activity and the estimated number of minutes spent in such activities (as assessed by CHAMPS) were similar between treatment groups at baseline, but were significantly higher in the PA group compared with the SA group during follow-up (Table 2).

As shown in Table 3, mean RPR was similar between the PA and SA groups at baseline, and there were no significant differences in RPR between the two groups during follow-up. At 12 months, for example, RPR increased non-significantly by 0.58 beats/min in the PA group relative to the SA group (β [SE] = 0.58 [0.88], $P=0.51$). Comparable results were observed for RPP (Table 3). Specifically, over the course of the study, there was no significant decline (β [SE] = 38.0 [136.9], $P=0.78$) in RPP between treatment groups. Because mean RPR was relatively low to begin with, we repeated the analyses, focusing only on participants with a RPR ≥ 80 beats/min ($n=37$ for PA and $n=34$ for SA group), and found no significant improvement for the PA group relative to the SA group (β [SE] = 1.43 [0.98], $P=0.15$). Because diabetes was more prevalent in the PA group, it is possible that this condition may

have diminished the RPR response to exercise. Our results did not change, however, after participants with diabetes were omitted from the analysis (β [SE] = 0.69 [0.98], P =0.48). Lastly, the findings did not change appreciably for RPR after removing participants who had a pacemaker (β [SE] = 0.36 [0.90], P =0.69), a cardiac arrhythmia (β [SE] = 1.12 [0.98], P =0.25), or those who reported the use of beta-blockers (β [SE] = 0.70 [1.02], P =0.50), calcium channel blockers (β [SE] = 0.61 [1.01], P =0.55), diuretics (β [SE] = 0.80 [1.06], P =0.45), or statins (β [SE] = 1.71 [1.05], P =0.10).

Discussion

Using a randomized controlled trial design, we set out to evaluate whether physical training offered a simple and inexpensive non-pharmacologic approach for reducing RPR. We found no beneficial effect of a physical activity intervention on lowering this putative marker of cardiovascular risk.

Prior epidemiological studies have documented a significant decline in RPR following completion of an aerobic training program in young-to-middle-aged adults.^{26, 27} Others, however, have reported no changes in RPR following exercise training in older adults.^{28, 29} The discrepancy in findings raise important questions concerning the utility of exercise regimens, along with their influence on the magnitude of change in RPR with advancing age. While younger persons may attain a meaningful reduction in RPR after a period of training, a comparable duration in training may exert little or no lowering effect on RPR in persons older than 70 years. Hence, further studies are required to determine whether aerobic training programs lasting longer than 12 months would be more effective for slowing RPR in older persons, compared with existing exercise strategies in this population.

The lack of an observed effect of walking on RPR raises additional questions about current guidelines regarding the specificity and/or intensity of physical activity in older humans, and whether these guidelines should be refined to account for the possible effects other modes of exercise may have on RPR.³⁰ Foremost, the capacity to perform more prolonged intensity exercise appears well preserved in older individuals – compelling evidence indicates that regular participation in endurance training may augment heart rate variability, as well as lowering resting and submaximal heart rate.³¹ For instance, six months of sustained submaximal aerobic exercise (e.g., between 50% and 85% heart rate reserve) consisting of walking, jogging, and bicycling 4-5 times per week, increased heart rate variability by 68% (from 31 ± 5 ms to 52 ± 8 ms) and lowered heart rate at rest by 9 beats/min.³² A strenuous aerobic intensity training intervention of combined treadmill walking/running uphill at 90-95% maximum heart rate significantly lowered RPR by 10 beats/min (from 69 to 59 beats/min) in a group of healthy sedentary seniors.³³ Donath and colleagues³⁴ observed a beneficial improvement in RPR among healthy older adults following completion of a stair climbing intervention. In that study, both one-step and two-step strategies significantly decreased RPR, with the latter approach revealing a more pronounced improvement.³⁴ The findings from these studies indicate that other modes of high intensity aerobic training may positively influence aging of the heart in older adults, perhaps offsetting some unhealthy processes such as impaired autonomic nervous system activity, endothelial dysfunction, and vascular stiffness.³⁵⁻³⁹

The present study had some limitations that warrant discussion. The PA group attendance rates at the adoption and transition phases were 70.7% and 60.9%, respectively. Maintaining adherence represents a challenge in long-term physical activity trials involving older adults,^{40, 41} and it is plausible, that the effect of exercise training on lowering RPR may have differed had the complete study sample adhered to the PA program. Despite the declining adherence rate, however, LIFE-P has had significant benefits on other health outcomes including functional performance and mobility disability.^{23, 42} Although we excluded participants who reported the use of beta-blockers, we were unable to account for other types of medications (i.e., calcium channel blockers and statins) that may have had potential heart rate-lowering effects. These unconsidered medications might have contributed, in part, to the relatively low baseline RPR, which may not have been amenable to further reduction from an exercise intervention. In LIFE-P, RPR was not a pre-determined outcome. Given the great expense of conducting high quality clinical trials, however, outcomes beyond those included in the original protocol are often evaluated. While some studies have assessed the efficacy of an exercise regimen for lowering the pulse rate in older adults,^{34, 43} the findings from these studies are difficult to interpret due to the number of discrepant factors involved such as the large heterogeneity in subjects' age, relatively small sample sizes, and differences in outcome measurement methods. Foremost, the current study extends the limited available literature on this topic as, to our knowledge, it represents the largest clinical trial to examine the efficacy of a moderate intensity exercise intervention for lowering RPR in older adults (n=424), includes a sufficient and representative age range (ages 70-89 years), and employed a standardized method of measurement for recording the RPR. Other strengths included a large representative sample of older community-dwelling adults, exceptional retention rate, and a single-masked design.

While the risk of developing CVD tends to advance with aging,² it is noteworthy that certain factors associated with this disease are often modifiable by practicing healthy behaviors used to promote and preserve wellbeing later in life. Although we were unable to establish a beneficial effect of physical activity on lowering RPR, our findings should not be used to discourage others who wish to examine the impact of exercise training on slowing RPR, particularly in seniors. The current lack of evidence in older adults emphasizes the pressing need for additional studies to further clarify the role of physical activity on attenuating RPR, an easy-to-obtain and affordable predictor of cardiovascular risk.

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Appendix

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Figure 1.
Flow diagram of the study participants. SPPB = short physical performance battery.

Table 1

Study characteristics according to intervention groups

Characteristics	Physical activity n=213	Successful aging n=211
Age 80 years, n (%)	53 (24.9)	62 (29.4)
Female gender, n (%)	146 (68.5)	146 (69.2)
Race, n (%)		
White	160 (75.1)	155 (73.5)
African American/Black	37 (17.4)	40 (19.0)
Other	16 (7.5)	16 (7.6)
Income (USD), n (%)		
<15,000	39 (18.3)	28 (13.3)
15,000 - <50,000	101 (47.4)	91 (43.1)
50,000	40 (18.8)	55 (26.1)
Other	33 (15.5)	37 (17.5)
Current smoker, n (%)	7 (3.3)	7 (3.3)
Waist circumference (cm)	101.9±15.5	99.8±14.3
Blood pressure (mm Hg)		
Systolic	130±17	130±17
Diastolic	69±9	70±10
Prevalent diseases, n (%)		
Hypertension	148 (69.5)	145 (68.7)
Diabetes	58 (27.2)	34 (16.1)
Myocardial infarction	24 (11.3)	15 (7.1)
Congestive heart failure	11 (5.2)	13 (6.2)
Stroke	8 (3.8)	12 (5.7)
Arrhythmia	39 (18.3)	33 (15.6)
Pacemaker	5 (2.4)	3 (1.4)
Cardiovascular medications, n (%)		
Beta-blockers	72 (33.8)	68 (32.2)
Calcium channel blockers	65 (30.5)	57 (27.0)
Diuretics	83 (39.0)	75 (35.6)
Statins	80 (37.6)	65 (30.8)
SPPB score	7.6±1.5	7.5±1.4
400 m walk speed, m/s	0.86±0.18	0.85±0.18

Values reported as means ± SD or counts with proportions.

SPPB = short physical performance battery.

Table 2

Frequency and duration spent in moderate physical activity per week according to intervention group

Group	Baseline	6 Months	12 Months
Frequency of moderate physical activity per week			
Successful aging	2.8 ± 3.5	3.1 ± 4.0	3.1 ± 3.9
Physical activity	2.7 ± 4.0	5.6 ± 4.7	4.5 ± 4.6
	<i>P</i> =0.81	<i>P</i> <0.001	<i>P</i> <0.001
Minutes of moderate physical activity per week			
Successful aging	116.2 ± 171.2	135.2 ± 204.6	124.5 ± 170.0
Physical activity	120.2 ± 195.9	220.9 ± 240.2	184.7 ± 197.6
	<i>P</i> =0.82	<i>P</i> <0.001	<i>P</i> <0.001

Values reported as means ± SD.

P values reporting Greenhouse-Geisser correction are shown for between-group differences.

Table 3

Mean resting pulse rate and rate pressure product according to intervention groups

Group	Baseline	6 Months	12 Months
Resting pulse rate (beats/min)			
Successful aging	68 ± 10	66 ± 9	66 ± 10
Physical activity	69 ± 12	67 ± 11	66 ± 11
	<i>P</i> =0.08	<i>P</i> =0.27	<i>P</i> =0.67
Rate pressure product (resting pulse rate • systolic blood pressure)			
Successful aging	8,969 ± 1,682	8,646 ± 1,537	8,504 ± 1,702
Physical activity	9,091 ± 1,828	8,691 ± 1,720	8,466 ± 1,703
	<i>P</i> =0.33	<i>P</i> =0.59	<i>P</i> =0.65

Values reported as means ± SD.

P values reporting Greenhouse-Geisser correction are shown for between-group differences.