Original Article

Exercise and lifestyle predictors of resting heart rate in healthy young adults

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ABSTRACT

Physical exercise is well-understood to provide significant health benefits, through physiological adaptations induced by the repeated exertion stress exercise imposes on our systems. Chief among these are cardiovascular adaptations to exercise, including adjustments of cardiac parameters such as stroke volume, heart rate, and maximal cardiac output. It is commonly assumed that aerobic forms of exercise provide greater cardiovascular benefits than do non-aerobic forms of exercise. To test this assumption, exercise habits and resting heart rate were examined in a large population of healthy young adults. 90% of subjects reported regular physical exercise, with aerobic exercise constituting 64% of all exercise hours. Subjects with a history of smoking exhibited higher resting heart rates than those with no smoking history, an effect which was due primarily to a reduction in exercise hours by smokers than due to a smoking habit itself. While both total exercise amount and aerobic exercise amount were significantly and negatively related to resting heart rate, total exercise amount was a better overall predictor of resting heart rate than was aerobic exercise amount. All forms of exercise were associated with cardiovascular health, with cardiovascular benefits accruing according to the amount of exercise performed, even in optimally healthy young adults. **Key words:** EXERCISE, AEROBIC, LIFESTYLE, RESTING HEART RATE

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INTRODUCTION

The health benefits of regular human exercise are well-understood, with regular physical exercise known to promote both physical and mental well-being (examples of recent reviews in [1-4]). Many of these health benefits are mediated by cardiovascular adaptations to a regular exercise program, such that physical exercise is an important component of many types of physical rehabilitation programs, including cardiac rehabilitation (recent examples in [5-7]).

Regular exercise promotes a wide variety of cardiac adaptations, including in alterations in cardiac excitability[8, 9], contractile force [10], stroke and end-diastolic volumes [11, 12], and diastolic efficiency [13]. These physiological responses to regular exercise increase cardiac peak function, permitting higher levels of physical work [5, 6, 11-13]. Exercise-induced cardiac adaptations also promote cardiac health under non-exercise conditions, as regular exercise reduces resting heart rate (examples in [14-17]) and resting blood pressure as well [18-20].

Because of the inter-relationships between physical exercise, resting heart rate, and overall health, resting heart rate is commonly assessed as an indicator of wellness. Indeed, resting heart rate is increasingly known to have valuable predictive utility in the assessment of a variety of cardiac diseases (recent examples in [21-23]).

Importantly, aerobic forms of exercise are commonly thought to be more effective in promoting cardiovascular health than are non-aerobic forms of exercise. However, while aerobic and anaerobic forms of exercise are commonly compared relative to biochemical [24-29] and hormonal [27, 28, 30, 31] markers of performance, direct comparisons of their relative contributions to cardiac health are surprisingly lacking.

To examine the importance of exercise form and extent to cardiac condition, I examined the association between exercise habits and resting heart rate in a large population of young adults, with consideration for general aspects of health and lifestyle . The specific goals of this study were to *(i)* test whether the commonly-assumed relationship between regular exercise and cardiac health was visible in resting heart rate alone, and *(ii)* assess the relative strengths of relationship between exercise and resting heart rate for aerobic and non-aerobic exercise. Study data also were used to evaluate *(iii)* the degree to which exercise amount is associated with reduced resting heart rates within a narrowly-defined and optimally healthy subject pool.

METHODS

Protection of human subjects

This study was approved by the Indiana University of Pennsylvania Institutional Review Board for the Protection of Human Subjects (IRB log #11-177). No individually-identifiable subject information was collected or evaluated.

Study subjects

Study subjects were drawn from an undergraduate laboratory class in Human Physiology at the Indiana University of Pennsylvania (Indiana, PA, U.S.A.). The majority of subjects were female. Although subject

ages were not tabulated, the vast majority of subjects was within the range expected of undergraduate college students (e.g., 18 – 25 years). A total of 724 subjects was evaluated.

Study environment

Study subjects were sampled during normal instructional hours (8am – 4pm). Prior to data collection, study subjects were seated and engaged in small group discussion of physiological topics for 10-20 min. Subjects received both written and verbal instructions of the procedure prior to data collection. Study subjects entered the data collection phase from a state of mental alertness, but of relative physical inactivity.

Estimation of subject resting heart rates

Subjects first remained seated and quiescent for a minimum of 2 min, after which they palpated their own wrists and monitored their heart rate for a period of 20 or 30 sec, via visual reference to nearby clocks. Subjects repeated this heart rate measure three times, in succession, and obtained an average value as their own estimate of their resting heart rate (BPM).

Evaluation of subject lifestyle

Following estimation of their own resting heart rate, subjects completed a brief questionnaire which assessed aspects of subject cardiopulmonary health and lifestyle fitness components (Table 1).

Table 1. Health and lifestyle variables scored for each study subject.

Resting heart rate (BPM)[a]	Current heart medications (Y / N)[d,e]
Current or recent smoker (Y / N)[b]	Known cardiopulmonary condition (Y/N)[e,f]
Current student-athlete (Y / N)[c]	Aerobic exercise habit (hrs / wk)[g,h]
Gender (F / M	Total exercise habit (hrs / wk)[h,i]

Legend:

[a]Average of three subject self-made measurements; see Methods

[b]Any regular smoking within the last 6 months

[c]Membership on any official university sports team (excluding club sports or hobbies, as their hours of activity are non-obligatory and less-uniform)

[d]Current use of any medications with cardiac side effects

[e]Subjects often voluntarily reported the medical specifics of their conditions/medications

[f]Both chronic and acute conditions

[g]Hours per week specifically devoted to aerobic forms of exercise (including running, swimming, track, and others), on average over prior 6 months

[h]Specifically excluded incidental activities (such as walking to class, or climbing stairs) which were physical in nature but not done specifically for the sake of exercise.

[i]Hours per week specifically devoted to any form of exercise (aerobic and non-aerobic), on average over prior 6 months.

Data analyses

The cumulative data were tabulated (Microsoft Excel, Microsoft Corp., Redmond, WA). Subject data which was incomplete (missing one or more individual entries) was retained, with individual entries coded as

'missing' where necessary (e.g., no estimation procedures were used to extrapolate missing values). Statistical comparisons were conducted using IBM SPSS Statistics (ver. 22, IBM Corp.). Analyses for group differences were conducted using 2-sample t-tests (including assessment of the equality of variance among groups), or univariate and multivariate ANOVA. Correlations were assessed using Pearson's *r* values. The α criterion for statistical significance was set to a nominal level of 0.05. All comparisons were one-tailed, unless otherwise noted.

Criteria for select, 'healthy subject' data retention

The cumulative data were screened for subjects who reported cardiopulmonary health issues, the use of heart-related medications, or smoking histories. Subjects reporting any of the above (regardless of magnitude or form) were included in initial data analyses for tests associating these health and lifestyle variables with resting heart rate, but were then excluded from a subset of optimally-healthy subjects (n = 453) used for assessment of the relationship between exercise and resting heart rate (see Results).

RESULTS

Data were collected from a total of 724 subjects. Data first were evaluated to determine if subject self-reported smoking and medical histories were associated with resting heart rates which differed from the remainder of the subject pool. Then, a subset of the most-healthy subjects was retained for assessment of the degree to which subject exercise habits were associated with resting heart rate in a population of young adults of optimum health.

Direct and indirect effects of smoking on resting heart rate

Smokers (n = 79) had resting heart rates (75.5 ± 12.5 BPM) which were marginally greater than those of non-smokers (n = 630, 73.5 ± 11.0 BPM; t_{707} = 1.46, p = 0.07). To assess whether this effect was due to smoking itself or due to correlates of a lifestyle which includes smoking (such as reduced exercise [32, 33]), resting heart rates were compared between smokers and non-smokers separately for those groups which included exercise in their regular habits, and those who did not.

Among subjects who did not exercise, resting heart rates did not differ among smokers (n = 18) and non-smokers (n = 46; t = 0.97, NS). Likewise, resting heart rates did not differ between smokers (n = 47) and non-smokers (n = 406; t = 0.89, NS) among subjects who did exercise regularly. Among those subjects who did exercise, smokers averaged fewer hours of exercise per week than did non-smokers (6.1 vs 7.4 hrs/wk, t_{451} = 2.03, p = 0.022). In multivariate ANOVA, total amount of exercise (F_{32} = 1.68, p = 0.076) exerted a much stronger influence on resting heart rate than did a smoking habit (F_1 = 0.05, NS), suggesting that a reduced exercised correlate of a smoking lifestyle was the primary cause of the overall difference in resting heart rate between smokers and non-smokers.

No direct effect of cardiopulmonary health on resting heart rate in this subject pool

Students who reported either current heart medications (n = 17) or known cardiopulmonary conditions (n = 56) had resting heart rates which were slightly, but non-significantly, greater than students reporting neither heart medications or known cardiopulmonary conditions. Among those students who identified their cardiopulmonary conditions (n = 32), murmurs were the most commonly-reported condition (n = 13), followed by disorders of rhythm (n = 7), and asthma (n = 6).

Scrubbed data (eliminated smokers, anyone reporting heart meds or known conditions) (n = 453)
In order to most directly assess the influence of exercise on resting heart rates within a young and uniformly healthy population, a subset of the cumulative data was assembled from 453 subjects who reported no smoking history, no heart medications, and no cardiopulmonary conditions. This data subset from optimally-healthy subjects was retained for all subsequent analyses.

Influence of gender
As has been reported previously [34, 35], resting heart rate differed strongly between genders. Males (n = 124, 70.2 ± 9.4 BPM) exhibited heart rates which were both less in magnitude ($t_{258} = 3.69$, $p < 0.001$) and less variable (Levene's test for equality of variances: $F = 4.22$, $p = 0.04$) than those of females (n = 329, 74.0 ± 11.0 BPM).

Resting heart rate is strongly influenced by exercise habit in young adults
Exercise was a significant aspect of subjects' lifestyles, with 90% of subjects reporting regular weekly exercise. Among those students who regularly exercised, the time devoted to exercise varied widely (range: 1 – 30 hrs/wk, mean = 7.4). Students who exercised (n = 407) had lower resting heart rates (72.3 ±10.5 BPM) than students who reported no regular exercise (n = 46, 79.0 ± 11.0 BPM; $t_{451} = 4.10$, $p < 0.001$).

In addition to the importance of exercise (vs. none), the amount of exercise also contributed strongly to resting heart rate. The resting heart rates of student-athletes (n = 39, 66.7 ± 12.3 BPM) were significantly lower than those of non-athletes (n = 414, 73.6 ± 10.4 BPM; $t_{451} = 3.89$, $p < 0.001$), as athletes averaged twice as much exercise per week than did non-team member subjects (13.4 vs 6.7 hrs / wk, $t_{43} = 7.08$, $p < 0.001$).

Students who exercised regularly overwhelmingly included aerobic forms of exercise in their activities, with hours spent in aerobic exercise comprising 64% of all exercise hours, on average (range: 0 – 100%). Only 25 subjects reported that all of their regular exercise was non-aerobic, while 112 subjects reported that all of their weekly exercise was aerobic in form. As such, the number of hours spent in aerobic exercise was strongly correlated with the total hours of exercise (n = 453, Pearson $r = 0.79$, $p < 0.001$).

To assess the importance of exercise form on resting heart rates, subjects were grouped according to whether their exercise was primarily anaerobic (< 1/3 of exercise hours were aerobic; n = 68), primarily aerobic (> 2/3 of exercise hours were aerobic; n = 211), or mixed (aerobic exercise hours between 1/3 and 2/3 of total exercise hours; n = 127). All forms of exercise were associated with relatively lower resting heart rates, as resting heart rate did not differ among subjects who exercise was primarily aerobic, primarily anaerobic, or mixed ($F_{2,403} = 1.64$, NS).

Both aerobic exercise hrs/wk (n = 453, $r = -0.21$) and total exercise hrs /wk ($r = -0.29$) were strongly, and negatively, correlated with resting heart rate (both $p < 0.001$; Figure 1). Excluding subjects whose exercise habits were at the extremes of those sampled (total exercise <1 or >20 hrs / wk) did not change the form or the significance of this relationship (for total exercise: n = 399, Pearson $r = -0.21$, $p < 0.001$). Linear regression of the relationship between exercise amount and resting heart rate (Figure 1) suggests that resting heart rate was reduced by ca. 0.65 BPM for every hour of exercise per week. Polynomial or exponential regression analyses did not provide explanatory power any greater than that of linear regression (*pers. obs.*).

In summary, these analyses suggest that *(i)* all forms of exercise are associated with lower resting heart rate in healthy young adults, *(ii)* total exercise amount was a better predictor of resting heart rate than was aerobic exercise amount, and *(iii)* even within a young and healthy subject pool, fitness benefits accrue according to the total amount of exercise performed.

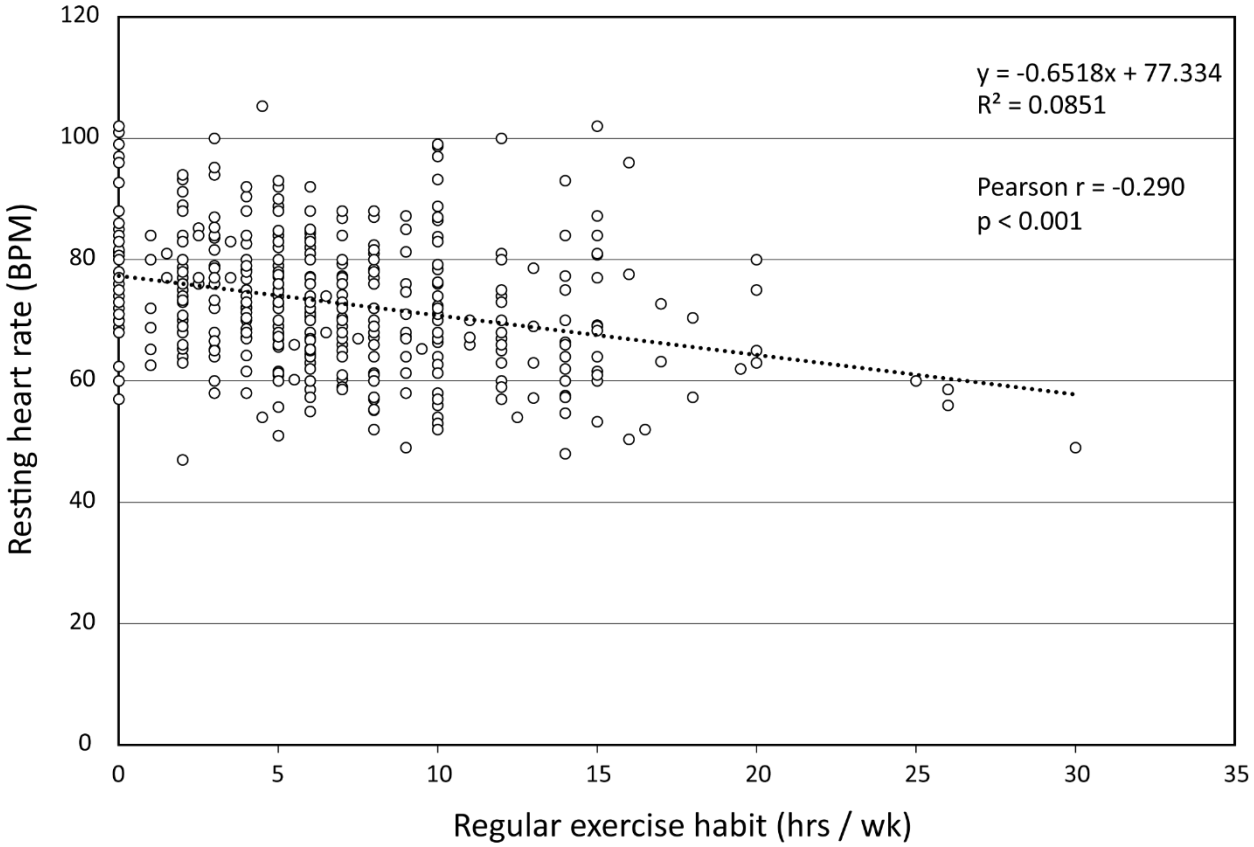

Figure 1. Among healthy young adults (n = 453), regular exercise was strongly associated with reduced resting heart rate relative to non-exercisers. Across all subjects, the total amount of regular exercise was strongly, and negatively, correlated with resting heart rate. Inset text depicts linear regression parameters relating total exercise amount to resting heart rate, as well as Pearson evaluation of their correlation.

DISCUSSION

While regular exercise is recommended to all as part of a healthy lifestyle [24, 36-41], the extent to which already-healthy young adults might benefit from regular exercise is less clear. Here, within a population of young adults of reported excellent health, regular exercise is associated with lower resting heart rate, a useful indicator of overall cardiovascular health.

The extent of exercise was significantly correlated with the degree to which resting heart rate was reduced relative to non-exercisers. While many studies have examined the health benefits of exercise versus none, relatively few have consider the incremental benefits of increasing amounts of exercise. As has been reported

for body fat and mass loss [42-44], symptoms of both metabolic syndrome [45] and depression [46], blood plasma lipoproteins [47], and blood pressure [48], the present data confirm that the cardiovascular benefits of exercise accrue in direct proportion to the amount of regular exercise performed.

The notion that aerobic exercise is more-strongly associated with cardiovascular health than are non-aerobic forms of exercise was not supported by this study. Both aerobic exercise amount and total exercise amount were significantly related to resting heart rate, with resting heart rate more strongly correlated with total, than with aerobic, exercise amount (Pearson $r = -0.290$ vs. -0.209, both $p < 0.001$). This may reflect the physiological benefits of all forms of regular exercise, or could be due to the fact that all forms of exercise are at least partially aerobic in form.

A lifestyle which included smoking was associated with a reduced amount of regular exercise, and this reduced amount of regular exercise was associated with more of the variance in resting heart rate than was a smoking habit itself. While the extent of smoking history was not examined for these subjects, it seems unlikely that any of these subjects had accumulated multiple years of an intense smoking habit (*pers. obs.*). This subject pool is perhaps typical of a university student population, being of relatively uniform age, excellent general health, and with a predominance of healthy habits.

CONCLUSIONS

While aerobic exercise is understood to promote cardiovascular health, lesser attention has been paid to the cardiovascular benefits afforded by non-aerobic forms of exercise. In a population of healthy, young adults, exercise was a routine component of regular lifestyles, with a majority of the exercise performed being aerobic in nature. All forms of exercise were associated with relatively low resting heart rates, with total exercise amount being a slightly better predictor of resting heart rate than was aerobic exercise amount. A smoking habit was associated with relatively higher resting heart rates, an effect that was due to reduced exercise among smokers than to the consequences of smoking itself in this population.

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