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Waist circumference and altered metabolic indices are associated with increased resting pulse rate in middle-aged adults

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Availability of data and materials: data and materials are available from the corresponding author upon request.

Abstract

Metabolic indices significantly impact cardiovascular health. Research on the influence of metabolic indices on resting pulse rate in younger adults is needed. Utilizing the National Longitudinal Study of Adolescent to Adult Health (Add Health) Wave 5 Public-use biological data, we performed a multiple linear regression analysis to determine the predictive factors of resting pulse rate in adults aged 32-42 years. We controlled for sex, anthropometrics, lipid indices, diabetic status, blood pressure, and antihypertensive use. The total number of participants was 1839 (weighted n=1,390,763), the mean age was 38.1 [standard deviation (SD)=2.0] and the mean pulse rate was 75.2 (SD=11.6). Notably, body mass index did not exhibit a statistically significant relationship with resting pulse rate. Conversely, females presented a statistically significant higher pulse rate than males when adjusted for other variables [p<0.001; coefficient = 4.83; 95% confidence interval (CI): 3.54-6.13], as did individuals with increased waist circumference (p=0.023; coefficient = 2.62; 95% CI: 0.39-4.85). The data indicated a progressive rise in pulse rate correlating with elevated low-density lipoprotein and hemoglobin A1C levels, particularly among those with severe hypercholesterolemia (p=0.048, coefficient = 6.42; 95% CI: 0.12-12.71) and diabetes (p<0.001, coefficient = 7.11; 95% CI: 3.3-10.92). A significant increase was also observed in individuals with hypertension stage 1 and 2 [p<0.001 for both; coefficients = 2.98 (95% CI: 1.45-4.52) and 7.2 (95% CI: 5.28-9.12), respectively]. These findings underscore the necessity of considering metabolic indices in understanding the pathophysiology of elevated pulse rates in adults, thereby enhancing comprehension of cardiovascular tachyarrhythmias in younger adults.

Key words: resting heart rate, anthropometrics, HbA1C, dyslipidemia, hypertension.

Introduction

Pulse rate is modulated by a multitude of factors, which have been the subject of extensive research investigations. One cohort study demonstrated that resting heart rate (RHR) is influenced by sex, revealing that it tends to be elevated in females compared to males. The same research indicated that an increased body mass index (BMI), elevated glucose levels, heightened LDL cholesterol, and increased systolic blood pressure correlate with elevated RHR [1]. There exists a range of contentious factors as well. The previously mentioned study reported no significant relationship between aging and RHR, whereas another investigation presented an inverse association between age and RHR [2]. A retrospective analysis conducted among critically ill patients concluded that an escalation in body temperature correlates with an increase in HR for both males and females [3]. Furthermore, a meta-analysis and systematic review examining the impact of exercise on RHR concluded that both endurance training is effective in reducing RHR [4]. Additionally, another study found that HR significantly increases in response to psychological stressors as a result of marked neurohormonal effects [5,6].

The molecular mechanisms of such fluctuations in HR have been explored to a certain degree within the literature. Several studies have identified a connection between elevated RHR and systemic inflammation through mechanisms associated with autonomic dysregulation. Biomarkers indicative of endothelial dysfunction, such as von Willebrand factor and tissue plasminogen activator, were found to be critical in the context of cardiovascular disease and may be linked to RHR, while inflammatory markers including CRP and IL-6 have also been associated with the autonomic nervous system, suggesting that inflammation may exert an influence on HR [7,8]. Of note, increased systemic levels of inflammatory markers, such as hs-CRP, was linked to metabolic indices [9], which further highlights the importance of studying the effects of metabolic indices on RHR in middle-aged adults.

Many of the studies that looked into how metabolic and demographic factors affected HR were limited to older adults. After adjusting for potential confounders, the purpose of this study is to determine how metabolic indices impact RHR in young adults. The large sample size of this study would contribute significantly to the body of knowledge regarding the variables influencing RHR in young adults.

Materials and Methods

Study population

The National Longitudinal Study of Adolescent Health (Add Health) represents a longitudinal investigation involving a nationally representative cohort of adolescents enrolled in grades 7 through 12 across the United States during the period of 1994-1995, who have been longitudinally monitored throughout their adolescence and the transition into adulthood via four in-home interviews, with the overarching aim of examining the health status of adolescents. The most recent data wave (the fifth wave) was made publicly available in 2018. The participant pool for the fifth wave comprised all individuals who had initially participated in Wave I and were still residing in the study cohort during Wave 5 (ages 32-42), resulting in a total sample size of 19,828 individuals (Response rate: 71.8%). This participant pool was subsequently divided into three stratified random samples for the purpose of conducting survey design evaluations. The data sampling methodology employed by Add Health is predicated upon clustered sampling; a detailed exposition of the sampling process would be excessively intricate in this context. For additional details regarding the sampling methodology, interested readers are encouraged to consult the Add Health study [9].

For data collection, after gaining consent from the participants and scheduling an in-home exam with them, different physical and lab measurements were done via in-home interviews by field examiners, which included blood sampling and anthropometric and BP measurements. All field examiners were trained and certified using a custom program specific to the Add Health protocol prior to in-home interviews. Electronic recording and transmitting of the collected data were done by using electronic devices (tablets) and special app (Add Health data collection application). These devices also contained job aids to guide examiners when completing the protocol. The reliability analysis of the home exam cardiovascular parameters was shown to be acceptable according to the Intra-class correlation analysis of a within race/ethnicity- and sex-stratified random sample of 112 Add Health Wave 5 respondents (range of estimates = 0.65-0.86) [10].

Study design

The variables that were gathered in the present cross-sectional investigation were exclusively derived from Wave 5, without the incorporation of any data from preceding waves.

Study variables

The independent variables identified for the purpose of predicting pulse rate in this investigation encompassed sex, waist circumference (classified according to NIH guidelines), BMI (classified according to NIH guidelines), blood pressure (classified according to AHA guidelines), levels of triglycerides and low-density lipoproteins (classified according to AHA guidelines), as well as HbA1c levels (classified according to ADA guidelines), in addition to recent use of antihypertensive drugs (within 4 weeks). The dependent variable was defined as the average pulse rate (continuous variable), which was computed as the mean of three separate readings for each participant. It is noteworthy that the design structure was integrated into our analytical model through the implementation of Design-Based analysis, which incorporated weighting and clustering variables throughout all analyses to ensure the calculation of reliable interval estimates. Importantly, the data underwent a weighting process prior to the procedure of statistical analysis, in accordance with the statistical analysis guidelines established by the Add Health Data.

Statistical analysis

To conduct the data analysis, descriptive statistics were employed to evaluate demographic characteristics. Both mean and standard deviation (SD) were utilized to characterize continuous variables, while frequencies and percentages were applied to nominal data. To evaluate the significance and strength of associations between independent variables and average pulse rate, multiple linear regression analysis was conducted. It is important to highlight that this model exhibited superior performance compared to alternative models, with an R^2 value of 0.140, thus validating the adequacy of our model. Wald statistics had also confirmed the adequacy of the model.

For the purposes of inferential statistics, a P-value threshold of 0.05 was used for significance, and coefficients were reported alongside 95% Confidence Intervals (95% Cl). Whenever deemed necessary, tabular representations were utilized to facilitate the illustration of results.

For data analysis, the AM Statistical Software for complex samples (Version 0.06.03) and PSPP software (Version 2.0.1) were used.

Ethical approval

The data was sent to us after requesting it via Add Health Data website, and consent was obtained to use it for research purposes. Please note that all presented results are based on weighted-data analyses, as they are representative for the population. The Add Health study was approved by the University of North Carolina Public Health-Nursing Institutional Review Board (Chapel Hill, NC).

Results

Upon conducting a thorough analysis of the weighted dataset, the subsequent findings were observed. A predominant proportion of the participants were males (55.6%), whereas females constituted 44.4%. The average age of the participants was 38.1 years (SD = 2.0). It is important to highlight that frequency distributions were generated for unnormalized weights-weighted data to accurately estimate population totals, in accordance with the Add Health Data guidelines. The weighted total is noted to be 1,390,763.

Considerable attention was devoted to delineating the frequency of each of the anthropometric and metabolic indices, as these variables are deemed independent predictors in our study. About 23% of the adult population exhibited a normal BMI, while 29.5% were categorized as overweight. Notably, 46.4% were classified as obese. For further details, refer to Table 1.

Regarding average pulse rate, the mean rate was 75.2 (SD = 11.6) which indicates a normal pulse rate (normal range: 60-100).

The results of the multiple linear regression analysis indicated that gender, waist circumference, blood pressure stage, LDL levels and HbA1c levels had a statistically significant impact on resting pulse rate. However, BMI didn’t have a statistically significant association with the pulse rate. Check Table 2. Of note, females presented a statistically significant higher pulse rate than males when adjusting for other variables (P < 0.001; Coefficient = 4.83; 95% Cl: 3.54-6.13), as did individuals with increased waist circumference (P = 0.023; Coefficient = 2.62; 95% Cl: 0.39-4.85). The data indicated a progressive rise in pulse rate correlating with elevated LDL and HbA1c levels, particularly among those with severe hypercholesterolemia (P = 0.048, Coefficient = 6.42; 95% Cl: 0.12-12.71) and diabetes (P < 0.001, Coefficient = 7.11; 95% Cl: 3.3-10.92). A significant increase was also observed in individuals with hypertension stage 1 and 2 (P < 0.001 for both; Coefficients = 2.98 (95% Cl: 1.45-4.52) and 7.2 (SE = 95% Cl: 5.28-9.12), respectively). Of note, triglyceride levels were excluded due to collinearity with LDL levels.

Discussion

Metabolic indices and RHR

The study's results corroborate existing literature, reinforcing our conclusions. Severe hypercholesterolemia notably predicts an increase in RHR. A cross-sectional study on cardiovascular risk factors in the Chinese population established that dyslipidemia significantly influences elevated RHR [11]. Furthermore, obese youth exhibiting higher RHR demonstrated increased triglyceride and total cholesterol levels, suggesting a reciprocal relationship between dyslipidemia and increased RHR in this demographic [12].

The pathophysiology of this relationship is intricate and influenced by multiple factors. One investigation attributes this phenomenon to sympathovagal imbalance linked to dyslipidemia and other cardiovascular risks [13]. Another study determined that dyslipidemia leads to considerable endothelial dysfunction and heightened sympathetic drive, particularly in younger females [14]. Additionally, theories suggest that elevated triglyceride levels may result from catecholamine activity, promoting HDL synthesis and reducing LDL concentration via α1 stimulation [15].

Several studies have established a correlation between HbA1c levels and heart rate, indicating that elevated HbA1c in diabetic patients is associated with increased HR [16-18]. Further investigations elucidate the mechanisms underlying heart rate variability in diabetic individuals, attributing it to autonomic dysfunction induced by elevated glucose levels [19,20], thereby highlighting the interrelation between HbA1c and dyslipidemia regarding pulse rate [19,21].

Literature confirms a connection between HbA1c and dyslipidemia, as patients with higher HbA1c exhibit elevated LDL and triglyceride levels [22,23]. This phenomenon can be rationalized by the relationship between higher HbA1c and insulin resistance, which decreases LDL secretion suppression [24]. Consequently, these associations elucidate how dyslipidemia and poor HbA1c regulation may interchangeably affect pulse rate [25].

Our research indicated that waist circumference, not BMI, correlates with increased pulse rate. This correlation aligns with findings from another study assessing obese and control groups, where the obese group displayed a notable increase in mean HR related to high waist circumference [26]. Elevated waist circumference is indicative of visceral adiposity [27]. A study comparing BMI across groups with varying RHR found higher BMI in the group with high RHR, although this difference lacked statistical significance due to confounding variables causing this increase in HR [28]. The same research, based on regression analysis, indicated that BMI does not significantly predict RHR increase, necessitating further research into BMI's impact on sympathetic/parasympathetic balance [29].

Hypertension and RHR

Interestingly, our research found that both stages 1 and 2 hypertension were associated with significantly higher RHR. A previous study on adolescent of both genders demonstrated a relationship between elevated RHR and increased systolic and diastolic blood pressure even after controlling for potential confounders, such as general and abdominal obesity [30]. This was not the only study to show a significant association between hypertension and higher RHR [28,31]. Nevertheless, our study supports that it’s a two-way association. That is, increased RHR predicts hypertension, and vice versa.

Clinical implications

As seen, multiple factors contributed to the significant increase in RHR in young adults. Adequate management of the aforementioned medical factors plays a crucial role in the prevention of potential complications. Weight management can reduce arrhythmia risk and burden in obese individuals. Weight loss through lifestyle changes or bariatric surgery can improve arrhythmia outcomes, including reducing atrial fibrillation (AF) burden and symptom severity [32]. Cholesterol modulation through cholesterol-lowering therapy, such as the use of statins, shows promise as a therapeutic approach for cardiac arrhythmias. By reducing cholesterol levels in the membrane, these therapies may alter membrane properties and functions, potentially reducing the risk of arrhythmias [33]. Notably, ongoing Type 2 diabetes therapies aim to manage blood sugar levels and prevent complications. Metformin is linked to a lower risk of atrial fibrillation compared to untreated diabetic patients. Thiazolidinediones also reduce atrial fibrillation risk, potentially due to their anti-inflammatory effects. Dipeptidyl peptidase-4 (DPP-4) inhibitors, often used with metformin, further decrease atrial fibrillation incidence [34]. Additionally, evidence suggests that optimal blood pressure control and regression of LVH through antihypertensive treatment can help prevent cardiac arrhythmias like AF [35].

Conclusions

Numerous factors emerged as predictors of increased RHR among adults in our study. These factors encompass elevated waist circumference, diabetes, severe hypercholesterolemia, hypertension (stages 1 and 2), and female sex. However, BMI did not have a significant influence on pulse rate in our study. This finding should be interpreted with the understanding that our study consisted solely of individuals aged 32-42 years, suggesting that the notable influence of BMI observed in other studies may be attributable to different confounding factors. Our findings will contribute to a more comprehensive understanding of the pathophysiology underlying hypertension and cardiac tachyarrhythmias in young adults.

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Table 1. Metabolic and basic features of participants.

	N (Weighted N)	%
Classification of BMI (NIH)		
Underweight	15 (9680)	0.70
Normal	423 (319641)	23.30
Overweight	520 (404048)	29.50
Obesity stage I	383 (283838)	20.70
Obesity stage 2	246 (186868)	13.60
Obesity stage 3	223 (165154)	12.10
Total	1810 (1369228)	100
Classification of waist circumference (NIH)		
low risk: females <= 88 cm; males <= 102 cm	866 (670702)	48.50
high risk: females > 88 cm; males > 102 cm	962 (712305)	51.50
Total	1828 (1383007)	100
Classification of TG (AHA/ACC)		
Normal: TG is < 175 mg/dl	1317 (965878)	77.60
Moderate hypertriglyceridemia: TG is 175-499 mg/dl	317 (268002)	21.50
Severe hypertriglyceridemia: TG is >= 500 mg/dl	5 (3079)	0.20
Non-fasting: TG is >= 500 mg/dl	6 (7701)	0.60
Fasting status unknown: TG is >= 500 mg/dl	1 (166)	0.00
Total	1646 (1244825)	100
Classification of LDL-C (AHA/ACC)		
Normal: LDL-C is < 160 mg/dl	1552 (1175378)	94.60
Moderate hypercholesterolemia: LDL-C is 160-189 mg/dl	68 (46691)	3.80
Severe hypercholesterolemia: LDL-C is >= 190 mg/dl	22 (20050)	1.60
Total	1642 (1242119)	100
Classification of HbA1c (ADA)		
Normal: HbA1c (%) is <5.7	1427 (1075175)	87.20
Pre-Diabetes: HbA1c (%) is 5.7-6.4	135 (101861)	8.30
Diabetes: HbA1c (%) is >6.4	69 (55770)	4.50
Total	1631 (1232806)	100
Class of blood pressure (AHA/ACC)		
Normal	665 (488853)	36.60
Elevated blood pressure	218 (152230)	11.40
Hypertension stage 1	533 (420937)	31.50
Hypertension stage 2	343 (272429)	20.40
Hypertension crisis	3 (1358)	0.10
Total	1762 (1335806)	100
Antihypertensive use within the last 4 weeks		
Yes	224 (170100)	12.5
No	1580 (1194567)	87.5
Total	1804 (1364667)	100

Table 2. Factors affecting resting pulse rate among adults aged 32-42 years.

Parameter Name	Coefficient	Lower 95% CI	upper 95% CI	P
Constant	71.32	64.01	78.63	<0.001
BMI				
Underweight	Ref	Ref		
Normal	-2.98	-10.45	4.50	0.437
Overweight	-3.83	-11.42	3.76	0.324
Obesity stage I	-3.50	-11.20	4.20	0.375
Obesity stage 2	-4.70	-12.40	3.00	0.234
Obesity stage 3	-2.58	-10.22	5.05	0.508
Classification of LDL *				
Normal	Ref	Ref		
Moderate hypercholesterolemia	2.38	-0.80	5.57	0.145
Severe hypercholesterolemia	6.42	0.12	12.71	0.048
Diabetic status				
Normal	ref	Ref		
Pre-Diabetes	0.96	-1.40	3.32	0.425
Diabetes	7.11	3.30	10.92	<0.001
Blood pressure classification				
Normal	ref	Ref		
Elevated	1.17	-0.72	3.05	0.227
Hypertension stage 1	2.98	1.45	4.52	<0.001
Hypertension stage 2	7.20	5.28	9.12	<0.001
Waist circumference				
Low risk	Ref	Ref		
High risk	2.62	0.39	4.85	0.023
Sex				
Males	Ref	Ref		
Female	4.83	3.54	6.13	<0.001
Use of antihypertensive in last 4 weeks				
No antihypertensive use	Ref			
Used hypertensive	0.37	-1.87	2.61	0.748

*Triglycerides levels were excluded due to collinearity with LDL levels. Dependent variable: pulse rate.