Effect of very vigorous physical activity on cardiac autonomic modulation in smokers and nonsmokers: an epidemiological study

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TO THE EDITOR:

Cardiac autonomic modulation (CAM) is an important component of cardiovascular health,[1] and its reduction has been associated with increased risk of death.[2] Smoking has been associated with low CAM, because nicotine has a negative effect on cardiac vagal control and, consequently, on parasympathetic modulation.[3] In contrast, engaging in physical activity (PA) is an important lifestyle habit that has been positively associated with high CAM, because PA improves vagal activity.[4] Nonetheless, it is not clear in the literature whether different intensities of PA could eliminate or at least mitigate the relationship between smoking and reduced CAM. Our hypothesis was that very vigorous PA would mitigate the effects of smoking on CAM.

This was a cross-sectional study, approved by the Research Ethics Committee of the *Universidade Estadual Paulista* (São Paulo State University) School of Science and Technology, located in the city of Presidente Prudente, Brazil (Reference no. 72191717.9.0000.5402). The sample size was calculated with the objective of achieving a correlation value of r = 0.24 between vigorous PA and heart rate variability (HRV) in an adult population,[5] a power of 80%, and an alpha error of 5%. To minimize multiple comparison biases and include adjustment for sex and age in the analysis, an additional 20 participants were included for each covariate, resulting in a minimum sample size of 207 subjects. The sample comprised residents of Santo Anastácio, a town located in the southeastern region of Brazil. Because the random sampling process was based on households and the proportionality of inhabitants in the 23 urban census tracts of Santo Anastácio was considered, all of those who were eligible in each selected household were evaluated. The detailed study protocol is available elsewhere.[6] If more than one person in a randomly selected household was eligible to participate in the study, they were also included in the study; therefore, the final sample comprised 258 adults (≥ 18 years of age), 150 of whom were women. Individuals who were on any medication to control HR or reported any pathophysiological or chronic condition were excluded from the study.

Participants were instructed not to consume stimulants or alcoholic beverages and to avoid physical exercise 12 h prior to HRV assessment.[7] The HRV indices were used in order to evaluate CAM. For this purpose, the beat-to-beat HR at rest was recorded with an HR monitor (Polar V800; Polar Electro OY, Kempele, Finland) for 30 min, with participants resting in the supine position and breathing spontaneously. For the analysis of CAM, 1,000 RR intervals (the time between two R waves) were selected, and HRV indices were obtained from the domains of time—root mean square of successive differences (RMSSD) and standard deviation of all normal-to-normal RR intervals (SDNN)—and frequency—low frequency: −0,04 Hz to 0,15 Hz; and high frequency: −0,15 Hz to 0,4 Hz in normalized units. In addition, we performed a quantitative analysis of the Poincaré plot, calculating the standard deviation perpendicular to the line of identity (SD1) and the standard deviation along the line of identity (SD2). The collection, processing, and analysis of data followed the standards described in the literature,[7] and indices were analyzed with the Kubios HRV Analysis software, version 2.0 (The Biomedical Signal and Medical Imaging Analysis Group, Department of Applied Physics, University of Kuopio, Finland).

Smoking status was assessed by the following questions: "Do you currently smoke?"; "How many days a week?"; and "How many cigarettes a day?." The intensity of PA was measured with a GT3X accelerometer (ActiGraph LLC, Pensacola, FL, USA) positioned on the right side of the participant, at waist level. Participants used the equipment for seven days (minimum of five days for at least 10 h daily in order to be included in the analysis). The cutoff point recommended by Sasaki et al.[8] was used in order to determine the intensity of PA—light intensity: < 2,690 counts/min (metabolic equivalent of task [MET] < 3.00); moderate intensity: 2,690-6,166 counts/min (MET = 3.00-5.99); vigorous intensity: 6,167-9,642 counts/min (MET = 6.00-8.99); and very vigorous intensity: > 9,642 counts/min (MET > 8.99).

The relationship between CAM and smoking was analyzed by multiple linear regression, the different intensities of PA being inserted one by one into the model (Table 1). The level of significance adopted was 5%.

The sample characteristics by smoking status revealed that the mean SDNN was lower in the smokers (n = 23) than in the nonsmokers (40.0 ± 21.6 ms vs. 50.8 ± 23.1 ms; p = 0.014), as was the mean SD1 (17.5 ± 15.9 ms vs. 26.7 ± 22.1 ms; p = 0.041) and the mean SD2 (50.1 ± 28.6 ms vs. 66.5 ± 27.6 ms; p = 0.007), whereas the mean low frequency index was higher among the smokers (68.2 ± 15.4 vs. 61.3 ± 17.6; p = 0.039), as was the mean number of minutes per day engaged in light PA (3,998.7 ± 905.2 vs. 3,645.0 ± 850.1; p = 0.047). No significant differences were found between smokers and nonsmokers regarding the mean age, RMSSD, high frequency index, moderate PA, vigorous PA, and very

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vigorous PA. Smokers reported smoking a mean of 13.4 ± 9.4 cigarettes/day, and the mean number of pack-years was 0.66.

Table 1 shows that the SDNN and SD2 both had an inverse relationship with smoking. However, that relationship was mitigated after the insertion of very

Table 1. Relationship between cardiac autonomic modulation and smoking adjusted for different intensities of physical activity (N = 258).

Variable	Group		p
	Smoker (n = 23) Mean ± SD	Nonsmoker (n = 235) Mean ± SD	
Age, years	46.65 ± 14.99	41.96 ± 17.21	0.183
Weight, kg	76.14 ± 13.69	77.20 ± 16.10	0.747
Height, cm	165.57 ± 8.04	165.59 ± 9.96	0.928
BMI, kg/m²	27.12 ± 4.11	28.25 ± 5.35	0.348
Total counts per day	34,862.60 ± 13,274.11	41,352.77 ± 3,617.27	0.583
	ß	95% CI	p
RMSSD			
Model 1	−8.83	−20.33; 2.65	0.131
Model 2	−8.12	−19.69; 3.44	0.168
Model 3	−8.22	−19.81; 3.36	0.164
Model 4	−8.26	−19.88; 3.34	0.162
Model 5	−7.33	−18.77; 4.11	0.208
SDNN			
Model 1	−10.19	−18.96; −1.95	0.025
Model 2	−9.91	−18.83; −0.98	0.030
Model 3	−9.94	−18.89; −0.99	0.030
Model 4	−9.93	−18.89; −0.96	0.030
Model 5	−9.18	−18.00; −0.36	0.041
Low frequency			
Model 1	5.59	−1.26; 12.45	0.109
Model 2	4.93	1.95; 11.81	0.149
Model 3	5.04	−1.84; 11.92	0.151
Model 4	5.14	−1.71; 12.00	0.141
Model 5	5.06	−1.81; 11.94	0.149
High frequency			
Model 1	−4.53	−11.50; 2.43	0.201
Model 2	−3.84	−10.84; 3.11	0.280
Model 3	−3.97	−10.97; 3.01	0.264
Model 4	−4.07	−11.04; 2.88	0.250
Model 5	−3.98	−10.97; 3.00	0.263
SD1			
Model 1	−7.46	−16.17; 0.87	0.074
Model 2	−6.90	−15.46; 1.50	0.113
Model 3	−6.95	−15.53; 1.62	0.112
Model 4	−6.97	−15.57; 1.62	0.111
Model 5	−6.30	−14.78; 2.17	0.145
SD2			
Model 1	−13.49	−24.08; −2.90	0.013
Model 2	−13.72	−24.40; −3.05	0.012
Model 3	−13.73	−24.44; −3.02	0.012
Model 4	−13.70	−24.43; −2.97	0.012
Model 5	−12.86	−23.44; −2.27	0.017

RMSSD: root mean square of successive differences; SDNN: standard deviation of normal-to-normal intervals; SD1: Poincaré plot standard deviation perpendicular to the line of identity; and SD2: Poincaré plot standard deviation along the line of identity. Model 1: adjusted for sex and age; Model 2: model 1 + adjustment for light physical activity; Model 3: model 2 + adjustment for moderate physical activity; Model 4: model 3 + adjustment for vigorous physical activity; and Model 5: model 4 + adjustment for very vigorous physical activity.

vigorous PA in the statistical model (confirming our initial hypothesis).

The main finding of the present study was that smoking was inversely correlated with CAM, especially in relation to indices that reflect overall variability (SDNN and SD2). After inserting the different intensities of PA into the model (relationship between smoking and CAM), we found that very vigorous PA mitigated the effect of smoking on CAM.

Different hypotheses can explain the findings of the present study. One of the possible mechanisms is that vigorous and very vigorous PA could contribute to an increase in shear stress, promoting the release of nitric oxide and, consequently, an increase in parasympathetic activity.[9] Given the strong relationship between angiotensin and sympathetic modulation, which can be stimulated by the nicotine contained in cigarettes,[10] vigorous PA could also decrease angiotensin II levels, thus improving CAM.

Our study has some limitations. First, we did not employ other methods of assessing smoking status, such as determining the level of exhaled carbon monoxide. In addition, the cross-sectional design of the study precluded the assessment of causal relationships. However, the study has a number of strengths, including the randomized sampling process and the objective measurement of PA intensity by accelerometer. In terms of practical applications, our findings suggest that smokers who routinely engage in more vigorous PA may show improvement in CAM.

On the basis of our findings, we can conclude that very vigorous PA mitigates but does not eliminate the smoking-induced reduction in CAM in adult smokers. Smokers should be encouraged to perform vigorous PA in order to avoid a reduction in CAM.

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