Cardiovascular effects of smoking abstinence at rest and during submaximal exercise in young female smokers

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ABSTRACT

Objective: The objective of the present study was to verify the effect of tobacco smoking abstinence on cardiovascular responses to progressive submaximal physical exercise in sedentary female smokers. **Methods:** Systolic blood pressure (SBP), diastolic blood pressure (DBP) and heart rate (HR) were non-invasively measured in young non-smoking women (NSW, n = 7) and smoking women (SW, n = 7), with and without tobacco abstinence for 24 hours, at rest, during the accomplishment of a submaximal bicycle ergometric test and recovery period. **Results:** At rest, DBP and HR were higher in the SW group (76 ± 1 mmHg and 86 ± 5 bpm) when compared to the NSW group (68 ± 2 mmHg and 72 ± 2 bpm). After 24 hours of no tobacco use, the groups presented similar values. During exercise, SBP and HR increased in the studied groups. DBP was higher in the SW group (~15%) in relation to the NSW group in all periods of exercise training. In the abstinence period, DBP only increased in the last load of exercise. During recovery period, in basal condition and 24h-abstinence, both DBP and HR were higher in the SW group when compared to the NSW group. **Conclusion:** These results show that young female smokers present harmful consequences in hemodynamic parameters at rest and in response to submaximal exercise. These findings can be partly reverted by short-term abstinence from tobacco use.

Keywords: Ergometric test. Heart rate. Arterial pressure.

INTRODUCTION

According to the World Health Organization (WHO)[1] smoking is the main cause of inevitable death worldwide and it is considered one of the greatest challenges for public health of the modern world. Currently there are around 1 billion and 200 million smokers in the world, among them 200 million are women[2]. It is worth mentioning that concerning international trends of smoking prevalence, it is observed in the majority of countries a slow decrease of smoking prevalence among men, while for females the trend is increase in prevalence[1].

Tobacco has more than 4,720 chemical products, being nicotine the responsible for addiction, increase of heart rate (HR), blood pressure (BP)[3] and double product (DP)[4], which are alterations associated with the increase of cardiac work in smokers. Hollmann and Hettinger[5] have evidenced that by smoking a single cigarette the HR increases up to 10/20 beats/minutes and this increase may decrease after 15/45 minutes. Studies have shown that male and female non-smokers when smoke presented significant increase of HR and BP at rest; additionally, showing that a single cigarette may acutely increase these hemodynamic variables[6]. Moreover, higher HR and BP values are also observed in submaximal exercise; however, these increases have not been observed in maximal exercise[6].

It is also worth mentioning that smoking affects physical performance, especially in aerobic exercises. Studies consistently show that the oxygen maximal uptake and the anaerobic capacity are reduced in smokers from many age groups[7-9].

Despite the consensus that smoking represents a cardiovascular risk factor and reduces the functional capacity of smokers, the alterations of the cardiovascular function after a period of abstinence remain little studied. Moreover, the cardiorespiratory alterations induced by smoking have been predominantly studied in men. Therefore, the aim of the present study was to investigate the effect of 24h smoking abstinence in blood pressure and heart rate at rest, during progressive submaximal physical exercise as well as recovery of young female smokers.

MATERIALS AND METHODS

Fourteen healthy sedentary females who did not make use of contraceptive or any other kind of medication were selected. The women were divided into: smokers (FS, n = 7), with time of smoking of 7 ± 1.4 year, who smoked between 10 and 20 cigarettes, a day and non-smokers (FNS, n = 7). Body weight, height and body mass index (BMI) were similar between the studied groups (table 1). The experimental procedures were performed according to the regulations of the National Committee in Ethics in Research (Resolution CNS, 196/96). The procedures and evaluations were performed at the Laboratory of Human Movement of the São Judas Tadeu University of São Paulo – SP. All participants signed a clarified and free consent form.

TABLE 1
Age (years), body weight (Kg), height (cm) and body mass index (Kg/m²)

	Age (years)	Body weight (Kg)	Height (cm)	BMI (Kg/m²)
Control	21 ± 0.7	66 ± 4	161 ± 0.02	26 ± 3
Smokers	21 ± 0.3	59 ± 3	166 ± 0.02	22 ± 2

Values represent mean ± mean standard deviation.

Systolic blood pressure (SBP) and diastolic blood pressure (DBP) and heart rate (HR) were non-invasively measured in the female non-smokers and smokers at rest, during performance of the submaximal test in ergometric bicycle and at recovery (5 min post-test). The double product (DP) was calculated through the product between the HR and SBP[10]. The female smoker group was submitted to these evaluations in two moments: without smoking abstinence and with 24 hour smoking abstinence.

The instruments used as reference standard for the measurement of the BP and HR in this study had been previously inspected by the INMETRO and were calibrated accordingly. The following

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have been used as conventional and validated methods: a Polar® frequency meter (model a1™) for HR measurement, which is well established within the evaluation and ergometric tests standards; an aneroid sphygmomanometer with armcuff, Missouri® (according to regulations from the British Society of Hypertension, 2004) and a stethoscope in perfect condition for BP measurement. All hemodynamic measurements were performed by the same evaluator and according to the Brazilian Society of Hypertension (2000) and the IV Brazilian Guidelines of Hypertension (2002) for the measurements at rest and according to the guidance from the American College Sports Medicine (2003) for the verification of BP and HR during exercise.

All measurements of the volunteers were performed at sitting position and the upper extremity was kept at heart level. After the measurements at rest the 14 women were submitted to an adapted submaximal ergometric test by Astrand (until 85% of maximal HR estimated by the formula: HR maximal = 220 – age), with load increment of 25 Watts at every 3 minutes. The BP and HR measurement was performed at the last minute of each load and all precaution was taken in order to avoid sound and motor interference during the test.

The software SPSS for *Windows* 12.0. was used for statistic analysis of the results. Means and means standard error (MSE) of the evaluated variables were calculated. The paired t-test and two-way ANOVA followed by the Student-Newman-Keuls test were applied for comparison between the obtained results by the indirect methods. The differences were considered significant for values of $p < 0.05$.

RESULTS

Table 2 presents the values of systolic blood pressure (SBP), diastolic blood pressure (DBP), heart rate (HR) and double product (DP) of the female non-smokers and smokers, without and with smoking abstinence, at rest. The DBP and HR were higher in the FS when compared with the FNS. After 24 hours without use of tobacco these measurements were normalized in the FS. The SBP and DP were similar between the studied groups at rest.

TABLE 2
Systolic blood pressure (SBP), diastolic blood pressure (DBP), heart rate (HR) and double product (DP) at rest

	SBP (mmHg)	DBP (mmHg)	HR (bpm)	DP (bpm.mmHg)
Non-smokers	107 ± 4	68 ± 2	72 ± 2	7769 ± 506
Smokers (without abstinence)	111 ± 2	76 ± 1*	86 ± 5*	9505 ± 519
Smokers (24hs abstinence)	109 ± 2	71 ± 2	79 ± 4	8621 ± 473

Values represent mean ± mean standard deviation. * $p < 0.05$ vs. female non-smokers (ONE-WAY ANOVA).

As can be observed in table 3, the SBP, HR and DP increased, while the DBP did not alter, with exercise load increment in the FNW and FS (without and with smoking abstinence). The FNS presented higher SBP and DP in the 9th minute (50 Watts) compared with the 6th minute (25 Watts) of the submaximal test, which was not observed in the FS. Moreover, the SBP was lower in the last workload (50 Watts) in the FS, with or without tobacco abstinence, compared with the FNS. The DBP was higher during all stages of the exercise in the FS when compared with the FNS. Nevertheless, after 24 hours of smoking abstinence, higher DBP was observed in the FS compared with the FNS only at the last stage of the submaximal test. Statistically significant differences were not observed in the HR and DP responses between groups at the different exercise intensities (table 3).

Concerning physical performance of the evaluated women during the submaximal test, it was observed that 71% of the non-smoker evaluees (5 women) reached the load of 50 Watts. In the smoker group with smoking, 57% (4 women) reached the load of 50 Watts and 43% (3 women) stopped the physical test at the 25 Watts load. After the 24 hour smoking abstinence, two women who had interrupted the test at 25 Watts in smoking, reached the load of 50 Watts. Therefore, 86% of the female smokers without smoking stopped the exercise at the 50 Watts load and only one woman (14%) interrupted the test at load of 25 Watts.

TABLE 3
Systolic blood pressure (SBP), diastolic blood pressure (DBP), heart rate (HR) and double product (DP) during exercise

	SBP (mmHg)	DBP (mmHg)	HR (bpm)	DP (bpm.mmHg)
Non-smokers				
0 Watts – 3rd min.	131 ± 3	66 ± 2	130 ± 5	17190 ± 922
25 Watts – 6th min.	149 ± 4†	65 ± 2	152 ± 6†	22766 ± 1510†
50 Watts – 9th min.	161 ± 3†‡	62 ± 1	166 ± 3†	26778 ± 1001†‡
Smokers (without abstinence)				
0 Watts – 3rd min.	132 ± 2	75 ± 1*	139 ± 5	18471 ± 769
25 Watts – 6th min.	143 ± 2†	74 ± 1*	158 ± 4†	22496 ± 699†
50 Watts – 9th min.	151 ± 2*†	77 ± 1*	165 ± 4†	24869 ± 716†
Smokers (24hs abstinence)				
0 Watts – 3rd min.	128 ± 3	72 ± 2	132 ± 5	17047 ± 1034
25 Watts – 6th min.	140 ± 2†	72 ± 2	155 ± 5†	21715 ± 726†
50 Watts – 9th min.	148 ± 2*†	72 ± 2*	169 ± 3†	24879 ± 522†

Values represent mean ± mean standard deviation. * $p < 0.05$ vs. Female non-smokers the same stage; † $p < 0.05$ vs. 0 Watts (3rd min.) of the same group; ‡ $p < 0.05$ vs. 25 Watts (6th min.) of the same group (TWO-WAY ANOVA).

At recovery (5 minutes post-test), the SBP and DBP values were similar between the studied groups; however, the HR and DP were higher in the FS (with or without smoking) compared with the FNS (table 4).

TABLE 4
Systolic blood pressure (SBP), diastolic blood pressure (DBP), heart rate (HR) and double product (DP) in recovery

	SBP (mmHg)	DBP (mmHg)	HR (bpm)	DP (bpm.mmHg)
Non-smokers	110 ± 3	65 ± 3	89 ± 3	9790 ± 299
Smokers (without abstinence)	116 ± 3	73 ± 1	107 ± 4*	12459 ± 689*
Smokers (24hs abstinence)	115 ± 3	69 ± 2	103 ± 3*	11948 ± 609*

Values represent mean ± mean standard deviation. * $p < 0.05$ vs. female non-smokers (ONE-WAY ANOVA).

DISCUSSION

Smoking is a risk factor for women at any age. From the 300.000 deaths in women attributed to smoking in 1985, 21% were related with lung cancer, 18% with chronic obstructive disease and 41% with cardiovascular diseases (especially coronary disease and cerebral vascular accident)[11]. Therefore, the study of the hemodynamic alterations derived from smoking has been a recurrent topic of investigation. However, inconsistency in results has been observed between studies which evaluated the chronotropic and pressoric responses of smokers to exercise. Ideally, the exercise responses in smokers and non-smokers should be compared in subjects with similar age, physical activity level and body composition. Moreover, one should pay attention to studies which use samples of both genders, once it has been proved that women and men present important physiological differences. In the present study, the effect of smoking and 24-hour smoking abstinence in the BP and HR at rest, as well as in the pressoric and chronotropic responses to the submaximal effort test in young female smokers has been investigated. The results of the present study showed that young female smokers present higher DBP and HR compared with young non-smoker females at rest and that and that 24-h smoking abstinence may normalize these parameters. In addition to that, the pressoric response was altered during submaximal exercise in the FS, which was partly attenuated by smoking abstinence. At recovery higher HR and DP was observed in FS, with or without smoking abstinence, compared with the FNS.

The increase of BP and HR derived from smoking has been attributed to the activation of the sympathetic nervous system with release of noradrenalin and adrenalin[12]. Moreover, Laustiola *et al.*[13] have shown activation of the renin-angiotensin-aldosterone system at rest as well as during exercise in monozygotic twins smokers when compared with their non-smoking pairs, suggesting hence that this could be a mechanism which would contribute to the typical artery vasoconstriction of chronic smokers. Nevertheless, other authors did not corroborate these findings[14]. Other mechanisms demonstrated and correlated with hemodynamic harm in smokers include the inhibition in the prostacyclins production by the endothelian cells; the platelets activation and vasopressin release[15-17].

Smoking causes increase in sympathetic activity which goes on during the 24 hours of the day[18]. Benowitz *et al.*[14] have demonstrated that healthy male smokers, for an average of 23 years, presented higher DBP and HR in the mean of the 24 hours when smoking than when they were submitted to 5 day-abstinence. Moreover, the DBP was only increased during the day (when the men smoked) and the HR was higher both during the day or night. In the work by these authors alterations in the SBP have not been observed. It is important to highlight that both the alterations observed in BP and HR in the study by Benowitz *et al.*[14], and the values of these variables were similar to the ones presented in the present study.

Hashizume *et al.*[19] while studying male and female smokers with similar age verified that after 6-7 days from smoking abstinence significant alterations have not been observed in the HR, SBP or DBP at rest in comparison to the period without abstinence. They have observed increase in pulse pressure and oxygen saturation though. Similarly, in the present work there were no differences in the HR and BP variables when the periods without and with smoking abstinence were compared in FS. However, higher DBP and HR were observed while smoking in FS when compared with the FNS group. Singh[20] demonstrated that male smokers increased the HR, SBP, DBP and DP after 2 cigarettes in an interval of 10 minutes when compared with the basal situation of 2 hours of smoking abstinence. In the present study, while smoking we found increase in only DBP and HR in women. Nevertheless, it should be highlighted that our experiments were performed in women younger (~21 years) than the male subjects reported in the study by Singh (~34 years)[20]. Moreover, the female responses to smoking may be differentiated. Smoking is associated with increase in the arterial intima-media thickness only in men[21], which may be concerned with the protection of circulating estrogens, which protect women from coronary disease at least until menopause[22].

The BP and HR evaluations during physical exercise performance, as well as after effort have been usually used as basis for physical training prescription and monitoring of the cardiovascular responses to physical activity, as well as for detection of symptoms and cardiorespiratory alterations which will only be observed when the body is submitted to overload. According to what has been demonstrated in other studies, in the present work, the responses to acute exercise were increase in SBP, HR and consequently cardiac work (DP = SBP x HR), besides the maintenance of DBP values in the female non-smokers group. During exercise the increase of SBP is due to increase of cardiac debt, a product of increase of the systolic volume and heart rate. The systolic volume increases due to the increase in the muscular bomb, ventilatory bomb and vasoconstriction, besides increase of contractibility derived from the cardiac sympathetic stimulation and the Frank-Starling mechanisms. The HR increases due to an increase of the sympathetic stimulation and a decrease of the vagal stimulation over the heart. However, the DBP in exercise tends to suffer slight alterations (maintenance, reduction or slight increase), derived from the post-load alterations. Healthy individuals usually present decrease of peripheral vascular resistance (and consequently of post-load) during exercise due to the muscular vasodilatation[23].

There are few investigations which relate physical performance with smoking; however, it is known that smoking adds limitations to exercising[24], especially aerobic ones[25]. Studies also show that the aerobic and anaerobic power is reduced in smokers from many ages[7,26]. Hirsch *et al.*[27] demonstrated that the $\dot{V}O2max$ and anaerobic threshold were acutely reduced in apparently healthy smokers immediately after smoking, comparing to five hours after smoking, due to the carbon monoxide as well as the high level of nicotine.

Concerning physical performance of the evaluated women in this study, it was observed that after 24 hours of smoking abstinence two FS reached a higher exercise load compared with the test without smoking abstinence, which also means a higher time of submaximal test. It is important to mention that tests with and without smoking abstinence were randomly performed, that is to say, some women performed the test with smoking first while others performed the submaximal test in smoking abstinence first. Therefore, the performance improvement cannot be attributed to occasional adaptations to cycle ergometric bicycle or hemodynamic evaluations performed. Actually, McDonough and Moffart[28] concluded that smoking induces increase in the blood carbon monoxide content, which may reduce the exercise tolerance and decrease the maximal aerobic capacity. Moreover, these authors demonstrated that smoking may also harm the glucose metabolism during exercise. These two factors could contribute to an early fatigue in smokers compared with non-smokers. Hashizume *et al.*[19] showed increase in the time of exercise and reduction of HR in all stages of exercise, without alteration of oxygen maximal uptake in male smokers after an abstinence time of 6 to 7 days. In the present work, the highest load reached in the submaximal test and consequently the highest exercise time, in two SW in abstinence, despite not having induced a statistically significant difference in the exercise mean time of SW, suggest an improvement after abstinence similar to the one observed in males in abstinence in the study by Hashizume *et al.*[19]. Contrary to this study with men, no alterations in the chronotropic response to exercise in FS after abstinence were observed, probably due to the fact that these women present HR responses similar to the FNS and/or because the abstinence time was much shorter in the present study. Within this context, Kobayashi *et al.*[29] demonstrated similar chronotropic responses between healthy male smokers and non-smokers in all submaximal or maximal exercise levels.

The SBP increased in the FS during the submaximal test; however, in the last exercise load, the SBP was lower in the FS, with or without smoking abstinence, comparing with the FNS. This finding could be interpreted as a difficulty from the FS in keeping the demand. Considering that the HR values were similar during the different workloads between the studied groups, the lower SBP in the FS could be attributed to the reduction of the systolic volume derived from the post-load increase and/or harm in the cardiac contractibility. Smoking abstinence delayed the DBP increase during submaximal exercise, suggesting lower vasoconstrictor tonus, or higher vasodilatator, after this short abstinence period. Nonetheless, the DBP was increased in 50 Watts in the FS, with or without abstinence, which could suggest a post-load increase. Besides that, long term smoking in healthy subjects has been associated with changes in the myocardial perfusion induced by the interaction between endothelial and autonomic dysfunction. Thus, the oxygen supply may be reduced due to the coronary vasoconstriction[30] as well as by the changes in the aortic elastic properties[31], alterations which adversely affect the myocardial performance[32]. However, it is worth mentioning that Behr *et al.*[33] did not observed significant alterations in the cardiac function during submaximal exercise in young male smokers.

During the recovery period the SBP and DBP were similar between groups; however, the HR and consequently the DP were higher in this period in the FS compared with the FNS. Young male smokers also HR return slower than the basal levels after exercise[29]. This reduction at HR recovery may be related with the chronotropic and inothropic effects of the catecholamines recruited by the exposition to nicotine in smokers[34].

The results of the present study demonstrate that young healthy female smokers present harm in hemodynamic parameters at rest as well as at submaximal exercise response, which may be partly reverted by the short-term smoking abstinence. Further studies are needed in order to confirm the physiological mechanisms involved in such dysfunctions especially in women, which will enable the search for more accurate pharmacological or not interventions in the combat of smoking adverse effects in women.

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