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Environmental variables and levels of exhaled carbon monoxide and carboxyhemoglobin in elderly people taking exercise

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Abstract *This article aims to analyze levels of exhaled carbon monoxide, carboxyhemoglobinand cardiopulmonary variables in old people practicing exercise in external environments, and correlate them with climate and pollution factors. Temporal ecological study with118 active elderly people in the city of Cuiabá, in the state of Mato Grosso, Brazil. Data were obtained on use of medication, smoking, anthropometric measurements, spirometry, peak flow, oxygen saturation, heart rate, exhaled carbon monoxide, carboxyhemoglobin, climate, number of farm fires and pollution. Correlations were found between on the one hand environmental temperature, relative humidity of the air and number of farmers' fires, and on the other hand levels of carbon monoxide exhaled and carboxyhemoglobin ($p < 0.05$).There was a correlation between heart rate and changes in environmental temperature, time of exposure to the sun and relative humidity ($p < 0.05$). In elderly people, environmental factors influence levels of exhaled carbon monoxide, carboxyhemoglobin and heart rate. There is thus a need for these to be monitored during exercise. The use of a carbon monoxide monitor to evaluate exposure to pollutants is suggested.*
Key words *Exercise, Environmental pollution, Elderly people*

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Introduction

Environmental pollution and climate changes have been described as responsible for influencing the health of the population, and causing damage to the cardiovascular and respiratory systems[1,2]. The attempt to understand the action of pollutants and the climate in human health has led to studies aiming to assess the risks to the population when submitted to short or long periods of exposure[3,4].

Sources that produce pollution include vehicles, industrial emissions and burning of biomass – the latter being more common in farming regions or regions of native surface biomass, such in the Brazilian *Cerrado* region[1,5]. The most important pollutants include carbon monoxide (CO), sulfur dioxide (SO_2), nitrogen dioxide (NO_2) and particulate matter ($PM_{2,5}$), also known as particle pollution. These can damage the organism when a person remains is continuously exposed to them in environments with concentrations above the tolerance threshold[6]; and depending on the local climate situation, these primary pollutants can suffer chemical changes giving rise to the formation of secondary pollutants, principally ozone, further exacerbating the quality of the air being breathed[6,7].

Climatic changes in themselves, in situations of high or low temperatures, associated with changes in the relative humidity of the air, have also been described as directly responsible for harming the respiratory and cardiovascular systems[8-10]. Thus, both environmental pollution and climate variations can jointly or in isolation influence human health, principally that of the populations that are more susceptible, such as the elderly and children[2,11].

Mato Grosso is a Brazilian state responsible for a high level of issuance of environmental pollution, generated by intentional burning of vegetation, which is intensified in the dry period[12]. The city of Cuiabá has a semi-humid tropical climate, with low wind speeds and high temperatures, and its own geomorphological characteristics that can make dispersion of pollutants less likely at times of atmospheric stability[13,14]. As a further cause of air pollution there is an old custom of burning domestic garbage; and in the last decade there has been an accentuated increase in the number of vehicles in use[15].

Since exercise is healthy, and with the trend to aging in the population, with a consequent increase in the number of elderly people, professionals have increasingly stimulated these individuals' to adopt training regimes as a resource to improve their quality of life[13,16,17]; but these individuals can become a group at risk by exposing themselves to adverse climate situations or to polluted environments. Having in mind the climate conditions of the city and the large numbers of fires in the dry period, this study aimed to ascertain the levels of exhaled carbon monoxide (COex) and carboxyhemoglobin (COHb), and cardiopulmonary changes in elderly people who practice exercise in external environments, and to assess the correlation with climatic variables, air pollution and fires.

Method

This was a temporal ecological observational study, involving 118healthy non-smoking residents of the city of Cuiabá, in the state of Mato Grosso, over the age of 60, of both genders, who practice exercise and participate in the "Healthy Longevity" (*Longevidade Saudável*) program of the Federal University of Mato Grosso (UFMT). This type of study considers a unit of time in a single location, with analysis by units of time – years, months or days[18].

For the choice of a month with dry climate, a prior analysis was made of records obtained by the Airforce Meteorological Command Network (REDEMET) over the period 2001 through 2012. Climatic data during the period of the study were supplied by reports from the Airforce Command, and the following averages established:

Average temperature of the day (Tmd°C); average temperature of the period (Tmp°C); average relative humidity of the day (URAmd%); average relative humidity of the period (URAmp%); average atmospheric pressure of the day (Pamd hPa); average atmospheric pressure of the period (Pamp hPa); average wind speed of the day (Velmd kt); and average wind speed of the period (Velmp kt). The period considered was late afternoon and early evening, the time of day when the subject took physical exercise.

Average data for agricultural fires per municipality per day (FQmd) and total of fires per day for the state (FQtot) were obtained from the National Space Research Institute (IMPE) and the Environmental Information System (SISAM) by online research referenced to the municipality of Cuiabá. Information on average daily environmental carbon monoxide (COmd ppb) and average particulate material$_{2,5}$per day (PMmd $\mu g/m^3$) was also obtained.

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To obtain the total number of fires (FQtot), the sum of fires produced by all the municipalities daily in the month in question (September) was used, considering the total of each day for the analysis, and for FQmd the sum of all the fires of the day divided by141 municipalities was used.

Individuals were included who did not present illnesses nor use medication, and did not have ventilation issues on the spirometry testing. Of the total of 153 subjects who practiced exercise, 35 were excluded (22.9%): of this total, 9 (5.8%) because they did not succeed in doing the spirometry test and/or had alterations in levels that indicated some breathing disturbance; 11 (7.2 %) were excluded because they reported an illness that justified non-participation; 12 (7.8%) due to their use of medication; and 3 (1.9%) because they refused to answer questions in the questionnaire.

After approval by the Ethics Committee of the Júlio Muller University Hospital (UFMT), under Opinion number 427.028, explanation on the objective of the survey and signature of the consent form, analysis of the lung function was made using a One-Flow spirometer (Clement Clark Ltda.),using the Brazilian Consensus of Spirometry[19] as a parameter. Reading of peripheral oxygen saturation ($SatO_2$) and heart beat frequency (heart rate) was then carried out with a Nonin-Onyx II 9550 pulse oximeter, standardizing use of the index finger and reading time of one minute, to establish stable parameters. Peak expiratory flow (PEF) was evaluated using the Clement Clark Ltda. portable flow meter with volume variation of 60-900 L/min, keeping the patient seated, with three explosive measurements of total lung capacity (TLC).The value adopted was that of the curve with the highest value provided that the individual measurements did not have a difference higher than 20L between them[19].Levels of COex and COHb were measured using a Micro-CO carbon monoxide monitor (Micro Medical S.A), using 6ppm as parameter for COex and 2.5% as parameter for COHb[20,21].

The data were collected in the period of afternoon to early evening at the same time of day, prior to exercise. A total of 584 measurements were made of each variable and the average data was obtained from the sum of all the individual daily analyses totaling 18 averages of measures carried out in the month, which represented the average levels of the population per day.

For statistical analysis the Minitab 6.0 and SPSS-PASW-18.0 software was used, with application of the Anderson-Darling test, the Student T-test, the Mann-Whitney and Kruskal-Wallis tests, and Pearson correlation when indicated. Multiple linear regression was carried out aiming to estimate the influence of the variables for climate and pollution on exhaled levels of COex and COHb, generating an equation based on the variables $PM_{2,5}$md, COmd, Tmp, URAmp, Pamp, Velmp andFQmd, for carbon monoxide (COex = 86.4-6,72PMmd-0.534COmd-1.31Tmp-0.172URAmp+0.067Pamp-102velmp+0.421FQmd)and for carboxyhemoglobin (COHb = 11.6-1.22PMmd-0.098COmd-0.236Tmp- 0.0292URAmp +0.0162Pamp-0.0206 velmp+0.0770 FQmd).

Moving averages were calculated, to smooth the oscillations of the temporal and pollutant variables. Temporal assessment was carried out, considering the month at two moments, approaching FQtot and COex for the purpose of understanding the performance of the variables.

Results

Of the subjects, 92 (79%) were female, with average age of 67.53 ± 5.07 years, weight 69.61 ± 10.42kg; average height 1.57 ± 0.08m and BMI 28.14 ± 4.10kg/m².All stated themselves to be non-smokers or former smokers, having ceased to smoke at least six months ago. The analysis of the data categorized by gender showed different averages for age and height ($p = 0.00$), and equal values of BMI among the subjects ($p = 0.62$), as shown in Table 1.

The overall average of COex was 2.69 ± 0.88ppm, and of COHb 0.43 ± 0.14, with exhaled levels showing no difference between males and females, nor between the fact of having or not having smoked ($p > 0.05$).

The overall average PEF found was 355.86 ± 17.15 L/min, with higher levels in the men ($p = 0.00$), with an average diminution of 16% for men and 4.5% for women, with no difference found between former smokers and non-smokers. Average $SatO_2$ was 96.45 ± 0.43% and average heart rate was 79.17 ± 3.06 bpm, the amounts being within the levels of normalcy, similar between the genders, and similar between ex-smokers and non-smokers ($p > 0.05$) (Table 1).

Analysis of the environment showed that in the reported month there were approximately 186 field fires for the city of Cuiabá, an average of 999.77 fires/day for the state, daily average environmental carbon monoxide (CO) emission lev-

Table 1. Distribution of anthropometric data and cardiopulmonary variables of the subjects by gender and smoking habits. Cuiabá, 2014.

	Male		Female		
	Average (SD)	IC (95%)	Average (SD)	IC (95%)	p-value
Age	71.28 ± 4.9	69.21-73.34	66.47 ± 4.6	65.22-67.42	0.00
Weight	76.69 ± 9.49	72.77-80.61	68.01 ± 9.66	66.01-70.06	0.00
Height	1.65 ± 0.07	1.62-1.68	1.56 ± 0.06	1.55-1.57	0.00
BMI	27.82 ± 2.62	26.79-28.95	28.29 ± 4.12	27.35-29.05	0.62
Heart rate	80.81 ± 15.40	74.45-87.16	78.74 ± 12.54	76.15-81.32	0.54
$SatO_2$	97.00 ± 1.85	96.23-97.76	96.00 ± 2.88	96.00-97.19	0.40
COex	3.21 ± 3.97	1.57-4.84	2.48 ± 3.20	1.82-3.14	0.40
COHb	0.51 ± 0.64	0.24-0.77	0.40 ± 0.51	0.29-0.50	0.43
PEF	429.79 ± 98.65	389.07-470.51	334.78 ± 63.23	321.74-347.82	0.00
	Former-smokers		**Non-smokers**		
Heart rate	78.16 ± 12.26	74.67-81.64	79.95 ± 13.89	76.58-83.31	0.46
$SatO_2$	97 ± 2.24	96.36-97.63	96 ± 3.03	95.26-96.73	0.39
COex	2.47 ± 3.40	1.50-3.43	2.82 ± 3.37	2.0-3.63	0.58
COHb	0.39 ± 0.54	0.23-0.54	0.45 ± 0.54	0.31-0.58	0.55
PEF	365.17 ± 89.23	339.79-390.55	345.52 ± 73.56	327.70-363.34	0.20

T-Student test; age: years; weight: kg; height: meters. BMI (body mass index): m/cm2; PEF (peak expiratory flow): L/min; $SatO_2$ (peripheral oxygen saturation): %; heart rate: bpm; COex (exhaled CO): ppm; COHb (carboxyhemoglobin): %.

els of 46.6 ppb and a daily average of 11.53 μg of particulate material per m^3 of air (Table 2).

A significant increase in temperatures in the late afternoon was found (p = 0.00) to be associated with a lower relative humidity of the air (p = 0.00), with values reaching levels lower than those recommended for health. Also, analysis of the data showed low wind speed, with a slight increase at twilight (p = 0.03), but still remaining lower than the levels appropriate for a good dispersion of pollutants. No difference was observed in atmospheric pressure between the average for the day and the average for the late afternoon-early evening period (p = 0.05), as observed in Table 2.

The Pearson correlation analysis confirmed a positive relationship between levels of COex and COHb exhaled by the subjects, and FQtot and FQmd, respectively ($p < 0.05$) (Table 3).

The multiple regression model applied showed itself to be appropriate for COex (R^2 = 90.3%; p = 0.02) and for COHb (R^2 = 88.5%; p = 0.03) and analysis of the data showed that Tmp (p = 0.04);(p = 0.04), URAmp (p = 0.03); (p = 0.04), FQmd (p = 0.04); (p = 0.04) respectively, explained more than 88% of the alterations in COex gases exhaled and the levels of COHb.

In relation to the climate variables, COex and COHb also showed a positive linear regression with four-day moving average for Tmxd, but negative correlation when evaluated against URAmd ($p < 0.05$), indicating a possible relationship between the alterations found in the levels of gases exhaled by the subjects, and COHb, when the environmental variables changed (Table 3).

In the period it was also found that there was a linear relationship between the average temperature of the period (p = 0.00), average temperature of the day (p = 0.02), time of exposure to the sun (p = 0.03), average relative humidity of the period (p = 0.01), and changes in heart rate response (Table 3).

In the temporal assessment, separating the month of September into two consecutive periods (1st to 15th day; and 16thto 30th day), there was an increase, in the course of the month, in the average levels of carbon monoxide exhaled–Coex[(2.31 ± 0.83 and 3.06 ± 0.78 (p = 0.04))], and in the total number of fires in the day –FQtot [(549.33 ± 502.46 and 1,450.20 ± 801.70 (p = 0.00))]. The higher averages were for the period from the 16th to 30th day, for both variables, as shown in Graphics 1 and 2.

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Table 2. Distribution of cardiopulmonary variables, environmental pollutants and Climate data – average of daily measurements for September. Cuiabá, 2013.

Variables	n	Minimum	Maximum	Average	sd
COex (ppm)	18	1.22	4.23	2.69	0.88
COHb (%)	18	0.20	0.67	0.43	0.14
$SatO_2$ (%)	18	95.42	97.00	96.45	0.43
FC (bpm)	18	72.88	84.24	79.17	3.06
PF (L/min)	18	323.33	384.64	355.86	17.15
COmd (ppb)	30	40.80	46.50	43.60	1.23
PMmd (µg/m³)	30	11.30	12.10	11.53	0.27
Tmd (ºC)	30	20.20	31.60	27.28	3.42
Tmp (ºC)	30	22.20	37.40	32.6	4.70
URAmp (%)	30	17.00	73.00	33.67	14.53
URAmd (%)	30	34.00	78.00	48.47	11.89
Velmd (Kt)	30	2.60	11.00	5.68	2.36
Velmp (Kt)	30	2.30	14.00	7.21	3.10
Pamp (hPa)	30	984.90	996.50	989.28	2.91
Pamd (hPa)	39	987.10	998.10	990.74	2.68
FQmd	30	0.56	23.67	7.14	5.78
FQtot	30	79.00	3337.00	999.77	814.39

Source: Air Force Command environmental System (Sisam-Impe). Average by munipality/day; FQtot: daily average of total number of fires in the State. *Average for the period from 12:00 to 17:59 p.m; COex: exhaled carbon monoxide; COHb: carboxyhemoglobin; $SatO_2$: Peripheral oxygen saturation; FC: Heart rate; PEF: Peak expiratory flow; COmd: average environmental carbon monoxide/day; PMmd: particulate matter 2.5µ average/day; Tmd: average temperature/day; Tmp: average temperature/period; URAmp: average relative humidity/period; URAmd: average relative humidity/day; Velmd: average wind speed/day; Velmp: average wind speed/period; Pamp: average atmospheric pressure/period; Pamd: average atmospheric pressure/day; FQmd: daily average of number of fires per municipality; FQtot: total fires in the day.

Discussion

Carbon monoxide is the product of incomplete combustion of organic material. Due to its affinity with hemoglobin, when it links with hemoglobin it alters the blood's capacity to transport oxygen, modifying the oxyhemoglobin curve[22], causing a toxic action when inhaled.

In the present study the average levels of carbon monoxide exhaled by the subjects, although they varied daily, remained within the acceptable range, with an average of 2.69ppm, reaching values for carboxyhemoglobin of 0.43%, no difference being found between the genders nor between smokers and non-smokers[23].

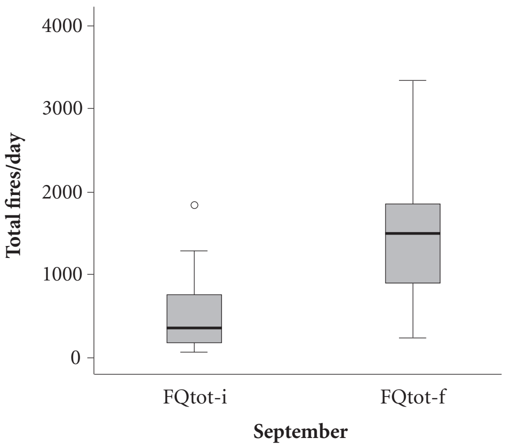
The values for COex and COHb found in the study are very close to those described by Santos et al.[20], who found an average of 2.5 ± 2.1ppm, and 0.43 ± 0.14% when evaluating individuals who were both non-smokers and former smokers. It is known that observation of the levels of COex and COHb in these individuals is important when planning external activities, since levels detected in the blood can be related to environmental exposure. Thus, prior identification of these gases by direct or indirect method constitutes a pair of biological indicators that can determine the risks of exposure[22].

The similarity between the values for exhaled CO found during the analyses in this study across the variables gender, age and smoking history has also been shown in other surveys, strengthening the conclusion that carbon monoxide levels do not change with individual characteristics[20,24].

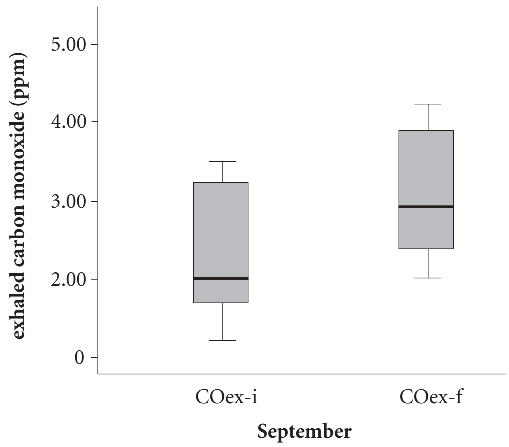
Table 3. Distribution of data: environmental variables, levels of exhaled gases and heart variables of the elderly subjects. Cuiabá, 2013.

	FC		COHb		COex	
	r	p-value	r	p-value	r	p-value
FQ tot (ppb)	-0.205	0.415	0.492	0.037*	0.475	0.037*
FQmd (ppb)	-0.205	0.415	0.492	0.037*	0.475	0.037*
URAmd (%)	-0.319	0.197	-0.509	0.031*	-0.519	0.031*
URAmp (%)	-0.546	0.019*	-0.322	0.193	-0.341	0.193
Insol (h)	0.492	0.038*	0.015	0.954	0.017	0.954
Tmp (ºC)	0.672	0.002**	0.046	0.855	0.083	0.855
Tmd (ºC)	0.542	0.020*	0.048	0.850	0.091	0.850
Tmxd-move 4 (ºC)	-0.198	0.446	0.570	0.017*	0.579	0.017*

Pearson correlation: significant variables: * $p < 0.05$; ** $p < 0.01$.
FQtot: total fires/day; FQmd: average number of fires in municipality/day, URAmd: average relative humidity/day; PMmxd: particulate matter 2.5µ maximum/day; PMmd: particulate matter 2.5µ average/day; Insol: sun exposure time; Tmd: average temperature/day; Tmp: average temperature/period; URAmp: average relative humidity/period; Tmxd-move4: moving average of maximum temperature/day; COex: exhaled carbon monoxide; COHb: carboxyhemoglobin; FC: heart rate



Graphic 1. Average levels of total FQ1day according temporal distribution. Cuiabá, september 2013.



Graphic 2. Average levels of exhaled carbon monoxide by the elderly according temporal distribution. Cuiabá, september 2013.

Although COex levels of the subjects were found to be within the levels of normality[21], there was a variation in daily measurements with a significant increase toward the end of the month, coinciding with increases in numbers of fires, as shown by the temporal analysis for COex and fires.

Since there was no influence of the individual variables on gases exhaled, the alterations found in the subjects maybe associated with higher environmental emission of CO coming from the fires which increased in this period, associated with the concentrations of pollutants emitted by vehicles, exacerbated by the local climate conditions.

The fact that strengthens the possibility of influence of pollutants on the levels exhaled is that the group of subjects in this study comprised active individuals, with exclusion of those who used medication, who presented some type of acute illness or some treatment for chronic illness that might increase endogenous production that might in turn alter levels of COex[20,25].

Further, the participants in the present study live in an urban center, being subject to greater action of pollutants, high temperatures and low relative humidity. In these locations, drier and hotter periods can alter the local atmosphere, creating situations of atmospheric stability that are an obstacle to dispersion of pollutants – which have a tendency to accumulate in lower regions – causing the population to be more exposed[26,27].

Associated with this factor, the city of Cuiabá is located in a depression that favors concentration of pollution during fires, with winds tending to blow toward the urban region, increasing the possibility of concentration of pollution in the more central regions[26].

Winds also favor transport of environmental CO from distant fires, and this factor could increase the levels of CO in the air in populated regions by up to 70% [28].

Levels of CO in the organism can be increased by direct inhalation of the environmental gases or by oxidative stress due to exposure to various pollutants[25,29,30]; the alterations found in the subjects of this survey might be the result of either or both of these factors.

The figures for temperature, fires and relative humidity and those for exhalation of gases by the subjects suggests inter-dependence between the two.

It is difficult to separate the action of the climate and of pollution in the air breathed, since there is a relationship between the two and these factors finish up exercising an additive effect in the response of the respiratory and cardiovascular apparatus to aggressions[31-33].

The association of climatic factors with heat and pollution by environmental CO has also been described as responsible for risk of acute episodes of infarct of the myocardium and cephalic vascular accident, principally in old people. Thus caution is recommended in physical exercise and exposure to the sun on days of high temperatures and high concentrations of CO in the air[34].

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This is in line with the findings of this study on the relationships between climate and levels of COex, and indicates the existence of a greater risk of practicing exercise by elderly people in the dry period in external environments, since in this period there is an increase in the occurrence of forest fires, associated with high temperatures. Also exercise increases lung ventilation, leading to greater inhalation of pollutants, with negative effects on transport of oxygen[23,35,36].

It should also be taken into consideration that the obtaining of the environmental data in this study relating to the emissions of pollutants was not made by monitoring on at ground level but from satellite data that estimate levels of pollutants well above the level of the ground, and it is possible that concentrations at ground level were underestimated.

As well as the association between climate and pollution, variations in environmental temperature have been described as an important cause of death from cardiovascular and respiratory disease in children and old people[37]. Cardiovascular mortality takes place when the body exceeds the thermoregulatory threshold generating changes in heart rate, viscosity of the blood, change in coagulability of the blood, reduction in cerebral perfusion and attenuation in vasomotor responses[38].

In the present study there was a positive relationship between heart rate and time of exposure to the sun and environmental temperature, and a negative one with relative humidity. The influence of climate in elderly individuals can cause an increased cardiac load, especially on days that are hotter with lower relative humidity, exposing the heart to greater work during exercise[39,40].

Elderly individuals have lower homeostatic responses to the control of body temperature, and this is a factor that can cause hyperthermia when exposed to high temperatures and a greater predisposition to dehydration when associated with low relative humidity[40,41]. Also, for efficient cooling of the body in hotter periods there is a need to increase the distribution of the flow of blood to cover a larger area of the surface of the body, causing a greater load on the heart which is often debilitated by the process of aging[40,41].

Thus, in spite of the physiological responses being efficient, situations of high environmental temperatures and low relative humidity associated with intense muscular work and lack of acclimatization of the organism can lead the elderly individual to heat stress, causing a range of factors from simpler alterations such as syncope and edemas to more serious conditions such as dehydration and hyperthermia[40]. Reinforcing the influence of the temperature in the cardiovascular response, a study carried out in Boston in 2000 through 2008 found a lower variability in heart rate in elderly people with high temperatures[42].

As well as influencing the cardiovascular responses, high environmental temperatures have also been cited as a factor responsible for an increased number of hospitalizations, increase of mortality and morbidity in elderly individuals for various pathologies[43-45]. Temperatures above 30ºC have been associated with increases in cases of ischemic cardiovascular diseases and respiratory diseases such as asthma and bronchitis[46].

As well as high temperatures, damage can be caused to the bronchial tubes in periods of dry climate by the great quantity of dust and materials suspended in the air such as pollens and other inhalable particles. Thus, greater exposure to suspended particles due to lower humidity may explain the findings of reduced PEF found in the elderly people in this study[2,8,43,47].

Low humidity of the air can cause various health problems to the elderly population, such as nosebleeds, irritation in the eyes, drying of the skin, acute respiratory insufficiency, irritations of the respiratory system, drying of the mucous tissues, all of which can be exacerbated by pollutants[48].

Thus, based on the research studied and the results presented that the period of late afternoon / early evening was the time at which there were higher environmental temperatures and lower relative humidity, it is shown that the practice of exercise for these individuals should be avoided in this period, since the elderly person's difficulty in thermoregulation, ease of dehydration and lower perspiration, associated with higher environmental temperature, can lead to various events including cephalic vascular accidents and respiratory diseases[34,49].

The data of this study shows that alterations in FC, COex and COHb were related to environmental exposure, confirming that the elderly population is at risk of damage to health during the practice of exercise in the periods of fires and dry climate in the city of Cuiabá, MT. Thus, when exercising in external environments, elderly people should be monitored by professionals giving greater attention to climate conditions and pollution; the use of a portable monoxide monitor is suggested.

This study brings to light a process of potential illness in elderly individuals exercising in external environments in the city of Cuiabá, MT. Exposure to high temperatures and pollutants could be reduced by: more effective health supervision action; greater attention; and training of exercise professionals, minimizing risks to the health of the elderly population.

Collaborations

MA Salicio: drafting the text and data analysis; VAM Mana: Critical revision of the article; WCR Fett: Critical revision of the article; LT Gomes: Statistical analysis of the data; C Botelho: Version approval to be published.

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