Original Article

Cardiac strain comparison between workers with normal weight and overweight in the hot humid weather of the Persian Gulf region

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ABSTRACT

Background: In the hot weather, overweight and obesity are considered as significant risk factors for the incidence of cardiac strain in workers. This study is aimed at comparing the cardiac strain among overweight and normal-weighted workers, in the hot, humid conditions of the south of Iran. **Materials and Methods:** This cross-sectional study was conducted on 71 workers in the south of Iran, in the summer of 2010.The heart rate was measured at rest and at actual work. Cardiac strain based on the working heart rate (WHR), the relative cardiac cost (RCC), the net cardiac cost (NCC), the load relative cardiovascular (CVL), and heart rate reduction were analyzed in 35 normal weight people (BMI <25) and 36 people who were overweight (BMI >25), using descriptive statistics and t- tests. **Results:** In 42% of the total workers, the body mass index was more than 25. The average temperature of the two groups was not significantly different. The mean WHR in these two groups was 101 ± 20.3 and 112 ± 18.9, respectively (P = 0.026). Percentages that exceeded the acceptable limits in parameters of NCC, RCC, WHR, CVL, and the Brouha index, were significantly higher in overweight people than those in people with normal weight. **Conclusions:** Based on the study results, the severity of cardiac strain was higher in overweight workers when compared with normal weight workers. Hence, in order to decrease the cardiac strain, selecting overweight individuals for these jobs should be avoided, as also some vital intervention for losing weight, such as, nutrition education and encouraging them to increase their physical activity, should be implemented.

Key words: Body mass index, cardiac strain, heart rate, hot-wet climate, Persian Gulf

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INTRODUCTION

Having Gas and Petrochemical industries being constructed and developed in the Persian Gulf region, many workers have to do jobs with different intensities with regard to the nature of their work, in hot and humid weather. Among different workers, those who are working in the construction of buildings, installation of technical equipment, welding, and driving, are more exposed to the hot humid climate. Although the amount of physical activity demand has decreased with regard to technological progression in the construction industry, in many cases, Many duties were needed to moderate to severe physical

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activity However, if there are such conditions in the hot humid weather, this coincidence augments cardiac strain occurrence.

Performing the tasks in such situations results not only in the increase of blood supply required by large muscles, but also in being exposed to sultry weather and heat excretion through sweating. Evaporation of sweat also provides the potential of cardiac strain incidence.

The prevalence of overweight and obesity is increasing seriously in developing and industrial countries,[1] so much so, Esteghamati *et al*. have reported that obesity and overweight increased in Iran from 13.6 and 32.2 in 1999 to 19.6 and 35.8 in 2005, as well as, 22.3 and 36.3 in 2007.[2] Janghorbani *et al*. have pointed out the mean overweight and obesity among men to be 42.8 and 11.1%, respectively.[3] Furthermore, the prevalence of overweight and obesity among American adults has exceeded the previous 60%.[4]

The epidemic studies indicate that overweight and obesity are significant risk factors for some diseases such as diabetes, cardiovascular disease, cancer, and premature death. Furthermore, with regard to the fact that fat tissue is considered as a good thermal insulation and has less density than other tissues, so – the heat transfer coefficients for muscle and skin tissue are 95 and 85%, respectively, and for fat tissue, 36%. Although fat tissue plays a positive role in cold strain, it has a negative effect on heat strain. Fat tissue in obese people acts as heat insulation, besides, it increases energy consumption at the time of activity, and generally the level of physical fitness in such people is low. Moreover, in many people, a low level of physical fitness causes overweight, so they may have a higher heart rate at the time of physical activity. Overweight can be delineated by higher body mass index (BMI) as well as fat tissue percentage.

The reduction of performance in hot weather, in obese people, is due to the higher metabolism rate and a slower losing of heat load caused by low area/weight ratio,[5] which has a considerable influence on the capacity and appropriateness of the job.[6]

With regard to the high prevalence of obesity and overweight in adults and the workers' population, as well the fact that a high percentage of this population are exposed to hot weather and high humidity, simultaneously, in the Persian Gulf region, particularly in the hot seasons of the year, this question comes to the mind – does this coincidence of hot weather and high humidity augment the occurrence of cardiac strain among the workers? Thus, considering the limitation of relevant studies in such climate conditions, during the warm months in the Persian Gulf region, this study is aimed at determining the relationship between the severity of cardiac strain and overweight in the real field work carried out in the very hot and humid weather of the Persian Gulf region.

MATERIALS AND METHODS

This cross-sectional study was conducted on 71 (a total of 350) workers during two months, from June to September 2010, in the Persian Gulf region. The subjects were engaged in outdoor jobs at two sites of the petrochemical industrial complex that exposed them to heat stress. The subjects were selected by the simple random sampling method. Out of the 76 workers in the study; complete experiments were available from 71 workers. This study was approved by the Medical Ethics Committee of the Faculty of Medical Science at the Tarbiat Modares University, and all the subjects signed a consent form according to the Helsinki Declaration. The participants were medically screened for cardiovascular disease, respiratory disease, infectious disease, diabetes, hyperthyroidism, and no medicine use. All subjects were reminded of no drinking coffee and alcohol at the night before the testing day.

After resting for 30 minutes in a cool room (WBGT = 22.6 ± 1.9), heart rate at times 20, 25, and 30 minutes (as baseline) was measured with a heart rate monitor (Polar Electro RS100, Finland).[7,8] Then, without separating the measuring devices, the subject was asked to go and begin his work. If the work location was farther than 50 meters from the cool room, the subjects would be transported by car. After starting work, all through, the researcher measured and recorded the heart rate continuously. Simultaneous measurements of the heart rate, dry bulb temperature, wet bulb temperature, and globe temperature were carried out. The WBGT index at rest and work was also measured[9,10] with the WBGT meter (Cassella CEL).

After 60 minutes of heat exposure, the subject was made to stop work and sit on a footstool in the same work station, and the heart rate was measured at the last 30 seconds of each minute of the recovery period, that is, from 30 seconds to one minute (p_1) after stop of work, and from 2.5-3 minutes (p_3) and 4.5-5 minutes (p_5).[7,11] Assessment of heart rate recovery and reaching the normal rate was done by comparing P_1 and P_3; thus, if P_1-P_3 <10 and P_3 < 90 beats per minute (bpm), the heart rate reduction pattern was normal; if P_1-P_3 >10 and P_3 < 90 bpm, the duration of returning the heart rate to the normal pattern was long and conditions might require further analysis; and if P_1-P_3 <10 and P_3 > 90 bpm, it would show that returning to normal heart rate had not happened, and this 'no-recovery' pattern indicated too much strain.[8,12] To estimate the physical activities, the Persian version of the Rating Perceived Exertion of the Eston-Parfitt was used. In this study, all measurements were performed outdoors, from 9 to 12 PM and 3 to 6 AM. At the end of the measurements, the BMI and body surface area (BSA) were calculated, according to the equation, BMI = height (m)/weight^2 (Kg) and BSA = 0.20247* weight $^{0.425}$* height $^{0.725}$, respectively.[13,14]

The maximum heart rate (MHR) was estimated from equation 220 - age.[15] The Heart Rate Reserve (HRR) was calculated as the difference between the maximum heart rate and resting heart rate. The net cardiac cost (NCC) was calculated as the difference between the working heart rate (WHR) and resting heart rate (RHR). The relative cardiac cost (RCC) was obtained by expressing the net cardiac cost as the percentage of the heart rate reserve of the precipitants by using the following equation. RCC = NCC/HRR*100.[16,17]

The relative cardiovascular load (%CVL) was evaluated on the basis of HR as follows:

%CVL = 100 [(WHR - RHR)/HRmax (8 hours)], where HRmax (8 hours), was a maximum acceptable HR for a work shift of eight hours, that is, one-third (220 age) + RHR. The CVL evaluates the cardiovascular load or aerobic strain, and can be classified as follows: <30%CVL, acceptable level, no actions required; 30-60%CVL, moderate level, peak loads should be reduced within a period of weeks; 61-100%CVL, high level, peak loads should be reduced within a period of months; >100%CVL, intolerable high level, peak loads should be reduced immediately or work must be stopped.[18]

With regard to the fact that the heart rate is affected by physical activity, and to neutralize the effect of this; the heart rate was compared in two groups, with different BMIs, when sitting and in low mobility and high mobility standing postures. The physical activity was assessed through direct behavioral observation of the activity, by experienced observers.[19] The obtained data were analyzed with descriptive statistics, Pearson correlation, and *t*-tests, using SPSS-16. The significance level equal to 0.05 was considered.

RESULTS

Individual and physiological characteristics when resting

The participants were working in jobs such as welding (n = 17), construction (n = 19), assembly of steel structures and components (n = 10), drivers and operators (n = 15), and supervisors (n = 10). The family of subjects was residing in the Fars province (21%), Chaharmahal Bakhtiari (20%), Khuzestan (18%), Bushehr (11%), Gilan (7%), Hamadan (4%), Central (4%), and eight other provinces (15%). The Body Mass Index was greater than 25 in 42% of the workers, based on the World Health Organization (WHO) criteria. They were classified into overweight or obesity groups.[20] The individual characteristics of workers in three postures, sitting, standing with low mobility, and standing with high mobility, in two groups of body mass index, are shown in Table 1. The mean maximum and minimum Body Mass Indices were 25 ± 4, 17.5 and 37 (kg/m^2), respectively. All of the three levels of working, the means of BMI, weight, and body surface area in the two body mass index groups were different (P > 0.001). The average of age and height in the two body mass index groups was not significantly different (Except age in the low mobility group). In the two groups with different BMI, the mean of Resting Heart Rate in the sitting posture (P = 0.021), Working Heart Rate (P = 0.002), and Heart Rate Reserve (P = 0.008) in the low mobility posture were significantly different.

The average resting heart rate in the normal weight and overweight groups were 70 ± 11.9 and 75 ± 9.6, respectively. Their means were not significantly different (P = 0.06). The average maximum heart rate in the normal weight and overweight groups were 190 ± 8.3 and 186 ± 8.4, respectively, the difference between their means was significant (P = 0.023).

The average heart rate in the normal weight and overweight groups were 120 ± 14.5 and 110 ± 10.0, respectively, the difference was significant (P = 0.002). The physiological strain indices in the normal weight and overweight groups, at different levels of activity, are presented in Table 2.

Heat stress in the workplace

The mean ± standard deviation of dry bulb temperature, wet bulb natural temperature, relative humidity, globe temperature, and the wet bulb globe temperature indices were 37.4 ± 3.0, 31.0 ± 2.0, 62 ± 12.8, 30.0 ± 3.9, and 33.3 ± 2.0, respectively. The value of the means at three levels of postures in the normal weight and overweight groups are shown in Table 3. The average of all temperatures and WBGT index at three levels of postures in the two BMI groups was not significantly different, and therefore, the heat stress was almost the same in all cases.

Cardiac strain parameters

The averages of the working heart rate in the normal weight and overweight groups were 101 ± 20.3 and 112 ± 18.9, respectively; the difference in the mean was significant (P = 0.026). The means of the net cardiac cost in the normal weight and overweight groups were 30.5 ± 17.6 and 36.3 ± 19.0, respectively, the difference in the mean was not significant.

Table 1: Physical and physiological characteristics of subjects in different BMI and posture groups

Variables	Sitting posture			Standing with low mobility			Standing with high mobility		
	BMI<25 *n*=9	BMI>25 *n*=7	*P* value	BMI<25 *n*=15	BMI>25 *n*=12	*P* value	BMI<25 *n*=11	BMI>25 *n*=8	*P* value
Age (years)	35.3 (9.9)	37.0 (5.3)	0.996	26.9 (7.1)	36.0 (9.4)	0.008	29.6 (8.0)	31.1 (9.1)	0.693
Height (cm)	170.0 (6.5)	174.0 (4.6)	0.162	171.3 (7.1)	171.0 (5.9)	0.919	170.0 (5.2)	171.0 (5.9)	0.667
Weight (kg)	63.0 (8.7)	90.6 (10.8)	<0.001	65.2 (7.0)	84.0 (9.8)	<0.001	64.0 (8.8)	84.8 (7.8)	<0.001
Body surface area (m^2)	1.73 (0.14)	2.05 (0.13)	<0.001	1.76 (0.12)	1.96 (0.13)	0.001	1.74 (0.12)	1.97 (0.12)	0.001
BMI (kg/m^2)	21.8 (2.1)	29.9 (3.4)	<0.001	22.2 (1.6)	28.7 (2.6)	<0.001	22.1 (2.5)	28.9 (1.5)	<0.001
RHR (bpm)	70.2 (4.8)	76.7 (5.1)	0.021	66.1 (12.8)	73.0 (12.9)	0.171	71.0 (11.5)	76.4 (6.3)	0.294
MHR (bpm)	185 (9.9)	183 (5.3)	0.696	193 (7.1)	184 (9.3)	0.008	190 (8.0)	189 (9.1)	0.693
HRR (bpm)	114.4 (10.8)	106.3 (8.2)	0.119	127 (11.9)	110.9 (12.0)	0.002	119 (13.8)	113 (7.7)	0.219

RHR=Resting heart rate, MHR=Maximum heart rate, HRR=Heart rate reserve, BMI=Body mass index

The average of relative cardiac cost in the normal weight and overweight groups were 26.6 ± 15.1 and 32.4 ± 16.2, respectively, the difference was not significant ($P = 0.073$). The averages of the heart rate recovery indicator (P1 - P3) in the normal weight and overweight groups were 6.5 ± 6.9 and 6.6 ± 6.3, respectively; the difference was not significant.

According to the data in Table 3, all the three levels of activity, the average of working heart rate, the net cardiac cost, and the relative cardiac cost in the overweight group were higher, when compared with the normal weight group. However, the mean of the working heart rate was different statistically ($P = 0.042$). The data illustrated in Table 3 shows that the average of heart rate recovery after three and five minutes of resting in the overweight group, when compared with the normal weight group, tended to increase, but it was only statistically significant in the low mobility standing posture ($P = 0.015$).

The Pearson correlation between the BMI and RHR, NCC, RCC, and WHR, adjusted for age, and the WBGT index and activity intensity, was 0.25, 0.27, 0.31 ($P < 0.01$) and 0.37 ($P = 0.002$), respectively. Based on the data in Table 4, it can be seen that despite the adjusted WBGT index and activity intensity variables, the percentage of the cardiac strain indices are greater than the recommended limits in the overweight group.

DISCUSSION

In this cross-sectional study the level of cardiac strain among the workers exposed to very humid climatic conditions was higher among people who were overweight or obese than those with normal weight, particularly in the standing posture, with low/high activity. On the other hand, out of all the parameters showing cardiac strain, higher percentages had exceeded the acceptable limits in people who were overweight and obese than those with normal weight. Nevertheless all climatic parameters of the workplace were not significantly different for all activities in both groups [Table 3]. Moreover, the weather had been the same for all individuals. Therefore, based on the comparison between these groups, with the same activity, it could be concluded that the differences between the parameters representing cardiac strain were neither caused by climatic conditions nor the severity of activity, but were more influenced by the body mass index.

Table 2: Physical workload in two different BMI groups in relation to work posture

Variables (bpm)	Sitting posture			Standing with low mobility			Standing with high mobility		
	BMI<25 *n*=9	BMI>25 *n*=7	*P* value	BMI<25 *n*=15	BMI>25 *n*=12	*P* value	BMI<25 *n*=11	BMI>25 *n*=8	*P* value
WHR	85.2 (8.8)	98.1 (14.2)	0.042	97.1 (17.9)	108.9 (19.9)	0.119	108.0 (23.1)	126.6 (13.0)	0.03
NCC	15.0 (11.2)	21.4 (15.2)	0.345	31.1 (13.2)	35.8 (19.8)	0.462	37.3 (19.2)	50.3 (11.4)	0.108
RCC	13.1 (10.1)	20.1 (13.8)	0.258	24.5 (10.1)	31.6 (16.2)	0.174	31.8 (17.6)	45.0 (11.2)	0.082
P_3	79.1 (7.1)	86.1 (10.3)	0.127	78.3 (12.9)	93.9 (18.2)	0.015	92.3 (14.4)	98.8 (13.6)	0.337
P_5	78.3 (7.3)	84.6 (11.1)	0.198	75.9 (13.7)	90.0 (14.2)	0.015	90.5 (14.0)	95.3 (13.7)	0.468

WHR=Working heart rate, NCC=Net cardiac cost, RCC=Relative cardiac cost, BMI=Body mass index

Table 3: Heat stress in two different BMI groups in relation to work posture

Variables (°C)	Sitting posture			Standing with low mobility			Standing with high mobility		
	BMI<25 *n*=9	BMI>25 *n*=7	*P* value	BMI<25 *n*=15	BMI>25 *n*=12	*P* value	BMI<25 *n*=11	BMI>25 *n*=8	*P* value
Dry bulb temperature	37.1 (2.9)	36.8 (1.6)	0.816	37.8 (3.3)	36.4 (1.6)	0.193	36.9 (3.1)	37.4 (5.1)	0.794
Wet bulb temperature	30.4 (2.6)	30.6 (1.4)	0.611	30.7 (2.1)	31.1 (0.7)	0.535	32.5 (1.3)	30.8 (2.7)	0.0.09
Globe temperature	38.7 (4.0)	37.4 (2.7)	0.474	39.4 (4.1)	37.2 (1.6)	0.078	39.5 (3.1)	39.0 (6.4)	0.806
WBGT index	32.2 (2.7)	33.3 (1.0)	0.604	33.1 (2.2)	32.9 (0.8)	0.722	34.5 (1.5)	33.0 (3.2)	0.214

WBGT=Wet-bulb globe temperature, BMI=Body mass index

Table 4: Percentage of subjects exceeding the recommended limits of cardiac strain

Cardiac strain parameters	Accepted limits	Sitting posture		Standing with low mobility		Standing with high mobility		*P* value
		BMI<25 *n*=9%	BMI>25 *n*=7%	BMI<25 *n*=15%	BMI>25 *n*=12%	BMI<25 *n*=11%	BMI>25 *n*=8%	
WHR	More than 110 bpm	0	29	40	50	55	88	<0.001
RCC	More than 30%	11	14	40	67	55	88	<0.001
RCC	More than 50%	0	14	0	17	18	38	<0.001
CVL	Between 30 and 50%	11	29	53	17	0	25	<0.001
CVL	More than 60%	11	24	27	58	64	75	<0.001
NCC	30 bpm	11	14	53	67	64	100	<0.001
Brouha's index	P_1-P_3<10 P_3>90	11	14	20	42	46	75	<0.001

WHR=Working heart rate, RCC=Relative cardiac cost, CVL=Relative cardiovascular load, NCC=Net cardiac cost

There are some reasons for this, first of all, for doing a certain job compared to normal weight, overweight and obesity cause an increase in the metabolism of work as well as make the rate of heat conduction to central parts of the body lower, due to a decrease in the surface area to mass ratio, as fat tissue heat capacity (0.2 W/m.°C) is less than that of muscular tissue (0.5-0.6 w/m. °C).[21,22] The specific heat capacity of adipose tissue is less than that of fat-free mass (2.97 $kJ\cdot g^{-1}\cdot°C^{-1}$ v. 3.64 $kJ\cdot g^{-1}\cdot°C^{-1}$), which means that a given amount of heat storage per unit body mass will cause a greater increase in average tissue temperature in a person with higher body-fat mass. In addition, the thermal conductivity of fatty tissue is lower than that of other tissues in the body[23] also, the peripheral blood flow (skin) in thin people is less than that in people with obesity, at the time of working.[24]

Hence, the potential of heat accumulation enhances in the central parts of the body in those with obesity or overweight, which itself leads to an increase in heart rate, in order to speed up the peripheral blood flow. This mechanism leads to an increase in BMI, which is a risk factor in job-disease incidence caused by the hot weather at the workplace,[25,26] so the significant correlation between heart rate at rest and relative obesity in young and middle-aged men has been reported in a sitting posture, which in in line with the result of this study. Besides, a significant correlation has been reported at the time of activity between the body fat content and heart rate increase in experimental conditions.[27]

Pin and Chung studied 218 soldiers, who suffered from thermal disorders, with 537 soldiers as the control group, who had been controlled with regard to age and gender. In this study they reported that the odd ratio in obese people (BMI > 27) for the occurrence of thermal disorders was 3.53.[28] Under experimental conditions also, it was reported that the body weight, BMI, body fat percent, and a decline in the surface area to mass ratio, were significantly related to cardiac strain increase (deep body temperature and heart rate).[29-32]

In the evaluation of the relation between BMI and thermal fatigue, studied by Bate and Donoghue, they reported that with an increase in BMI, the risk of thermal fatigue occurrence would be obviously increased, so that the odd ratios for BMI < 27, 27 < BMI < 32 and BMI > 32, were 1.0, 2.94, and 3.63, respectively.[26]

CONCLUSION

According to the study results, the intensity of cardiac strain among the workers who were overweight or obese, was significantly higher than in those with normal weight. Therefore, in order to control the workers' cardiac strain, employing people with a BMI of more than 25 for such positions should be withheld, when monitoring people before employment.

Furthermore, it is proposed that to decline the intensity of cardiac strain in those employed, who are overweight, implementation of some essential interventions, such as, nutrition education and regular physical activity encouragement seems essential.

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