Cardiac Strain between Normal Weight and Overweight Workers in Hot/Humid Weather in the Persian Gulf

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Date of Submission: Jul 26, 2012

Date of Acceptance: Dec 23, 2012

How to cite this article: Dehghan H, Mortazavi SB, Jafari MJ, Maracy MR. Cardiac strain between normal weight and overweight workers in hot/humid weather in the persian gulf. Int J Prev Med 2013;4:1147-53.

ABSTRACT

Background: In hot weather, overweight and obesity are considered as significant risk factors for the incidence of cardiac strain in workers. This study was aimed to compare cardiac strain among overweight and normal-weight workers in hot, humid conditions in the south of Iran.

Methods: This cross-sectional study was conducted on 71 workers in the south of Iran in summer 2010. The heart rate was measured at rest and at actual work. Cardiac strain based on working heart rate (WHR), the relative cardiac cost (RCC), the net cardiac cost (NCC), load relative cardiovascular (CVL), and heart rate reduction was analyzed in 35 normal-weight people (body mass index (BMI) <25 kg/m^2) and 36 overweight people (BMI >25 kg/m^2) using descriptive statistics.

Results: In 42% of the total workers, BMI was >25 kg/m^2. The average of Wet Bulb Globe Temperature Index (WBGT Index) in the two groups was not significantly different. The mean WHR in the two groups was 101 ± 20.3 and 112 ± 18.9, respectively (P = 0.026). Percentages exceeded the acceptable limits in the parameters NCC, RCC, WHR, CVL, and Brouha index, which were significantly higher in overweight people than in those with normal weight.

Conclusions: Based on the study results, it is concluded that the severity of cardiac strain was higher in overweight workers compared with that in normal weight workers. Hence, in order to decrease the cardiac strain, selecting overweight individuals for these jobs should be avoided and also some vital intervention for losing weight should be implemented such as nutrition education and encouraging them regarding physical activity.

Keywords: Body mass index, cardiac strain, heart rate, hot-humid weather, Persian Gulf

Original Article

INTRODUCTION

With the development of gas and petrochemical industries in the Persian Gulf region, many workers are required to do jobs of different intensities in the hot and humid weather conditions. Among the different workers, those who work in the construction of buildings, installation of technical equipments, welding, and driving are more exposed to the hot and humid climate.[1] Although the amount of physical demand has been decreased due to the technological progression in construction industry and equipment installation, the task performed is severe or moderate physical activities in many cases. However, in hot humid weather conditions, this coincidence augments cardiac strain occurrence.

Doing tasks in hot conditions results in increased blood supply required by large muscles, also the exposure to sultry weather and heat excretion through sweating and evaporation of sweat increases the potential of cardiac strain incidence.

The prevalence of overweight and obesity is increasing at an alarming rate in developing and industrial countries.[2] 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 and 22.3% and 36.3% in 2007, respectively.[3] Janghorbani *et al.* have reported the mean overweight and obesity among men as 42.8% and 11.1%, respectively.[4]

The epidemiological studies indicate that overweight and obesity are important risk factors for some diseases such as diabetes, cardiovascular disease, cancer, and premature death. Furthermore, considering the fact that fat tissue is a good thermal insulator and has less density and blood vessels compared to other tissues, heat transfer coefficients for muscle and skin tissue are 95% and 85%, respectively. Also, for fat tissue, it is 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 a heat insulator. Besides this, it increases energy consumption at the time of activity. Generally, the level of physical fitness in such people is low. Moreover, in many people, low level of physical fitness causes overweight, which increases the 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 higher metabolism rate and slower loss 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 population,[7,8] as well as the fact that a high percentage of this population is exposed to hot weather and high humidity simultaneously in the south of Iran, particularly in the hot seasons of the year, the question that comes to mind is whether this coincidence, hot weather and high humidity, augments the occurrence of cardiac strain among workers. Thus, considering the limitation of relevant studies in such climatic conditions during the warm months in the Persian Gulf region, this study was aimed to determine the relationship between the severity of cardiac strain and overweight in the real field work carried out in very hot and humid weather in the south of Iran.

METHODS

This cross-sectional study was conducted on 71 (a total of 350) workers during 2 months, from June to September 2010 in the south of Iran. Subjects were engaged in outdoor jobs at two sites of petrochemical industrial complex that were exposed to heat stress. Subjects were selected by simple random sampling method. Out of the 76 workers in the study, complete experiments were available from 71 workers. The mean (standard deviation) of age, height, weight, and BMI were 31.6 (8.6) years, 171 (5.9) Cm, 73.5 (13.3) kg, and 25.0 (4.0) kg/m^2, respectively. Inclusion criteria were voluntary participation from workers, heat acclimatization, absence of diseases such as cardiovascular disease, respiratory disease, infectious disease, diabetes, and hyperthyroidism, and they were not under any medication. Therefore, participants were medically screened by physician; at the time of study, all subjects were healthy. This study was approved by the Medical Ethics Committee of the Faculty of Medical Science at the Tarbiat Modares University and all subjects signed a consent form in accordance with the Helsinki Declaration. After informing the individuals about the aim of the study, the parameters to be measured were tested. All subjects were instructed not to drink coffee or alcohol at the night before the day of testing.

After resting for 30 min in a cool room (Wet Bulb Globe Temperature Index = 22.6 ± 1.9), body height was measured in the erect position without shoes to the nearest 0.1 cm using wall-mounted stadiometer. Body weight was measured in minimum clothing to the nearest 0.1 kg using a electronic personal scale (Hamilton SH 223 China), heart rate at 20, 25, and 30 min (as baseline) was measured by a heart rate monitor (Polar Electro RS100, Finland).[9-11] then, without removing the measuring devices, the subjects were asked to begin their work. If the work location was farther than 50 m from the cool room, the subjects were transported by car. After they started the work, the researcher measured and recorded the heart rate continuously. Simultaneous measurement of heart rate, dry bulb temperatures, wet bulb temperature, and globe temperature was carried out. WBGT index at rest and work was also measured[12,13] by Microtherm WBGT (Casella CEL U.K).

After 60 min of heat exposure, the subjects were asked to stop their work and sit on a footstool in the same work station for 5 min. Heart rate was measured at the last 30 sec of each minute of the recovery period, that is, from 30 sec to 1 min (P_1) after stopping work, and from 2.5 to 3 min (P_3) and from 4.5 to 5 min (P_5).[9,14] Assessment of heart rate recovery and reaching the normal rate was done in comparison with P_1 and P_3: 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 the heart rate returning to the normal pattern was long and conditions required further analysis; and if $P_1 - P_3 <10$ and $P_3 > 90$ bpm, it shows that heart rate returning to normal did not happen and this no recovery pattern indicates too much strain.[10,15] To estimate the effect of physical activities, the Persian version of Rating Perceived Exertion of the Eston–Parfitt was used. In this study, all measurements were performed outdoor from 9.00 AM to 12.00 PM and from 3.00 to 6.00 PM. At the end of measurements, BMI and body surface area (BSA) were calculated, according to the equations BMI = height (m)/weight^2 (kg) and BSA = 0.20247 × weight$^{0.425}$ × height$^{0.725}$, respectively.[16,17]

The maximum heart rate (MHR) was estimated from the formula 220 – age.[18] Heart rate reserve (HRR) was calculated as the difference between MHR and resting heart rate (RHR). Net cardiac cost (NCC) was calculated as the difference between working heart rate (WHR) and RHR. Relative cardiac cost (RCC) was obtained by expressing the NCC as the percentage of the HRR of the participants by using the following equation: RCC = NCC/HRR × 100.[19,20]

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

$$\% \text{CVL} = 100 ((\text{WHR} - \text{RHR})/\text{HRmax (8 hours)})$$

where, HRmax (8 hours) is the maximum acceptable HR for a work shift of 8 hours, that is, 1/3 (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.[21]

With regard to the fact that heart rate is affected by the activity intensity, to neutralize the effect of intense activity, heart rate was compared in two groups with different BMI in sitting, low mobility standing, and high mobility standing postures. 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 in resting

Participants were workers in jobs such as welding ($n = 17$), construction ($n = 19$), assembly of steel structures and components ($n = 10$), driving and operating ($n = 15$), or supervising ($n = 10$). BMI was greater than 25 kg/m^2 in 42% of workers, and based on World Health Organization criteria, were classified as overweight or obesity groups.[22] Individual characteristics of the workers in three postures, sitting, standing with low mobility, and standing with high mobility, in two groups based on BMI are shown in Table 1. The mean (SD), maximum, and minimum BMI was 25 (4), 17.5, and 37 kg/m^2, respectively. All the three levels of working, the means of BMI, weight, and BSA in the two BMI groups were significantly different ($P > 0.001$). In the average of age and height in the two BMI groups, there was no significant difference (except age in low mobility group). In the two groups with different BMI, the mean of RHR in sitting posture ($P = 0.021$), and

WHR (P = 0.002) and HRR (P = 0.008) in low mobility posture were significantly different.

The average (SD) of RHR 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 (SD) of MHR 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 (SD) of heart rate in the normal weight and overweight groups were 120 (14.5) and 110 (10.0), respectively, and 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 wet bulb globe temperature index were 37.4 ± 3.0, 31.0 ± 2.0, 62 ± 12.8, 30.0 ± 3.9, and 33.3 ± 2.0, respectively. The means at the 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 the 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 average (SD) of WHR in the normal weight and overweight groups were 101 (20.3) and 112 (18.9), respectively, and the difference in means was significant (P = 0.026). The means of NCC in the normal weight and overweight groups were 30.5 (17.6) and 36.3 (19.0), respectively, and the difference in means was not significant.

The average (SD) of RCC in the normal weight and overweight groups were 26.6 (15.1) and 32.4 (16.2), respectively, and the difference was not significant (P = 0.073). The average (SD) of heart rate recovery indicator ($P_1 - P_3$) in the normal weight and overweight groups were 6.5 (6.9) and 6.6 (6.3), respectively, and the difference 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

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

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
WHR (bpm)	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 (bpm)	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 (bpm)	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 (bpm)	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 (bpm)	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

According to the data in Table 4, all the three levels of activity and the average of WHR, the NCC, and the RCC in the overweight group compared with those in the normal weight group were higher. But the mean of WHR was statistically different ($P = 0.042$). The data illustrated in Table 3 show that the average of heart rate recovery after 3 and 5 min of resting in the overweight group compared with that in the normal weight group tended to increase, but it was statistically significant only in the low mobility standing posture ($P = 0.015$).

The Pearson correlation between BMI and RHR, NCC, RCC, and WHR, adjusted for age, 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 cardiac strain indices was higher than the recommended limits in the overweight group.

DISCUSSION

In this cross-sectional study, the level of cardiac strain among workers exposed to very humid climatic conditions was found to be higher among overweight or obese people than in those with normal weight, particularly in standing posture with low/high activity. On the other hand, out of all parameters showing cardiac strain, higher activity exceeded the acceptable limits in overweight and obese people than in those with normal weight [Table 4]. Nevertheless, all the climatic parameters of the workplace were not significantly different for all activities in both the groups. Moreover, the weather has been the same for all individuals. Therefore, based on the comparison between the two groups with the same activity, it can be concluded that the differences between the parameters representing cardiac strain were caused by neither the climatic conditions nor the severity of activity, but were more influenced by BMI.

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

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
Dry bulb temperature (°C)	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 (°C)	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 (°C)	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 (°C)	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 index=Wet bulb globe temperature index, 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	>110 bpm	0	29	40	50	55	88	<0.001
RCC	>30%	11	14	40	67	55	88	<0.001
RCC	>50%	0	14	0	17	18	38	<0.001
CVL	30-50%	11	29	53	17	0	25	<0.001
CVL	>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, BMI=Body mass index, bpm=Beats per minute

There are some reasons for this. First of all, for doing a certain job, compared to the normal weight, overweight and obesity increases the metabolism of work as well as makes the rate of heat conduction of central parts of the body lower due to the decrease in the surface area to mass ratio since the fat tissue heat capacity (0.2 W/m °C) is lesser than that of the muscular tissue (0.5-0.6 W/m °C).[23,24] Furthermore, considering that fat tissue possesses lesser heat capacity (0.4 kcal/kg °C) than the whole body (0.82 kcal/kg °C), saving certain amount of heat in the body enhances the temperature of fat tissue.[25] Also, peripheral blood flow (skin) in thin people is lesser than in obese people at the time of working.[26]

Hence, the potential of heat accumulation enhances in the central parts of the body in obese or overweight people, which itself leads to heart rate increase in order to speed up the peripheral blood flow and this mechanism might have led to increased BMI as a risk factor in job disease incidence caused by hot weather of the workplace.[27,28] A significant correlation between heart rate at rest and relative obesity in young and middle-aged men has been reported in sitting posture, which aligns 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.[29]

Pin and Chung studied 218 soldiers who suffered from thermal disorders and 537 soldiers as the control group with regard to age and gender. In this study, they reported that the odd ratio in obese people (BMI > 27 kg/m^2) for the occurrence of thermal disorders was 3.53.[30] Under the experimental conditions, it was also reported that body weight, BMI, body fat percent, and a decline in the surface area to mass ratio were significantly related with cardiac strain increase (deep body temperature and heart rate).[31-34]

In the evaluation of the relation between BMI and thermal fatigue, Bate and Donoghue reported that, with increasing BMI, the risk of thermal fatigue occurrence was obviously increased, as the odd ratios for BMI < 27, 27 < BMI < 32, and BMI > 32 were 1.0, 2.94, and 3.63, respectively.[28]

CONCLUSIONS

According to the study results, the intensity of cardiac strain among overweight or obese workers was significantly higher than it was in those with normal weight. Therefore, in order to control workers' cardiac strain, employing people with BMI more than 25 kg/m^2 in hot humid conditions should be avoided while monitoring people before employment.

Furthermore, it is proposed that to decline the intensity of cardiac strain among overweight employees, implementation of some essential interventions such as nutrition education and regular physical activity encouragement seems to be essential.

ACKNOWLEDGMENTS

This research was supported in part by the National Iranian Petrochemical Company. The authors are grateful to Mr. Ardalan Soleimanian; the Head of Occupational Health Laboratory of Tarbiat Modares University, Mr. Jahangiri, the Occupational Health Supervisor of National Petrochemical Company, for their help.

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Source of Support: Nil, **Conflict of Interest:** None declared.