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TRESEARCH

CARDIAC OUTPUT, BLOOD COMPOSITION AND LUNG FUNCTION IN WORKERS WITH DIFFERENT WORKLOADS UNDER OUT AND INDOOR CONDITIONS

Salah M. R[a] and Muna M.M[b]

[a]occupational health safety centre, Khartoum

[b]Institute of environmental studies, university of Khartoum

Corresponding Author: Muna, M.M

ABSTRACT

The present research work was carried with the objective to assess the impact of thermal environment (indoors/outdoors) on the health workers carrying different workloads (heavy, moderate, light) at indoor factories and outdoor in building construction. The number of each group with different workloads were done according to a certain formula adressing 18, 13, and 10 for heavy, moderate and light work respectively for outdoor workers, for indoor the numbers were 10, 15 and 23 respectively. The control number were 12 for each either outdoor or indoor, being selected from employees at the National Health Laboratory. Physiological measurements included: heamtocrit profile, blood electrolytes and blood metabolites, heart, pulse rates and lung function. For out and indoor groups pulse rate increased significantly (P <0.01) during and after work than before for heavy and moderate workloads subjects. Radial pulse rate was the highest during work for both heavy (~90 beats/min) and moderate (~85) work than before or after work for heavy (~84) and moderate work (~60). For light group work or control the changes were not significant and within the range of 78 - 82 beats/min for outdoor conditions. For indoor conditions, similar trends were observed where pulse rate was the highest during work for both heavy (~66) and moderate (~83) groups than before or after work for heavy (range~60) and moderate (range ~66) with significant differences (P <0.05) for both out and indoor groups. Systolic blood pressure before, during and after for subjects with different workloads for outdoor workers did not differ significantly for both outdoor and indoor groups and within the range of 113 - 123mmHg, while the diastolic blood pressure showed a range 74 - 84mmHg.

For outdoor study, 35% of the heavy workload group showed normal lung function, 21% showed mild restriction and moderate restriction, 7% moderate and 14% severe restriction. 50% of the group carrying moderate workload, suffered mild lung, and 25% showed normal lung function. 40% of the group carrying light work showed mild lung restriction and 30% normal lung function. 72% of the control group showed mild lung restriction and 18% showed moderate lung function. For indoor the heavy workload group; 33% showed mild restriction 44% moderate restriction and 11% severe restriction. 13% of the group carrying moderate workload showed normal function, 26% suffered mild lung, and 33% showed moderate restriction. 38% of the group carrying light work showed normal lung restriction, 15% mild and 46% moderate restriction

For haemogram profile, significant differences were only obtained for HCT and eosinophils where HCT was lower for outdoor group carrying moderate workload (38.98%) and for both moderate (41.67%) and light (45.12%) workload groups under indoor conditions. Eosinophils were significantly (P <0.01) higher in the moderate (7.17%) workload group under indoor which was above the normal range (1 - 6). Creatinine decreased significantly (P <0.05) with heavy workload at bot outdoor (0.83mg/dl) and indoor (0.93mg/dl). Creatinine (mg/dl) decreased significantly (P) with both heavy (0.85) and moderate (0.77) workload for outdoors. Same trend was obtained for indoors for both heavy (0.93) and moderate (0.88). urea, total protein and serum concentrations fell within the normal levels with no significant differences detected. Comparing creatine Phospho-Kinase (CPK) enzyme between outdoors and indoors, with heavy workload increased significantly (P <0.01) at outdoor (~540) than indoor (~227), for the moderate workload the differences were significant (P <0.01) with outdoor showing higher (412) levels that indoor (341), also for light workload outdoor conditions showed higher (190) than indoor (173). For electrolytes, K decreased significantly (P <0.01) with moderate (3.00mmol/l) workload while Ca increased significantly (P <0.01) with heavy (11.11mg/dl) for outdoors. For indoors K decreased significantly (P <0.01) heavy (3.03) workload

KEYWORDS: cardiac output, blood composition, lung function, working conditions

1. INTRODUCTION

It is well known that heat stress may represent an additional load on the cardiovascular system. This is evidenced by an elevated heart rate at the same work load in a hot environment versus a room temperature environment. The explanation is that, in the case of the heat stress, the circulating blood volume, in addition to having to transport oxygen, also has to serve as a cooling fluid. It therefore transports heat from the interior of the body to the skin where it is dissipated to the surrounding environment by conduction, convection, radiation and sweat evaporation. This requires an increase in speed of the blood circulation, i.e. the cardiac output (minute volume) has to be elevated. This can only be done by increasing the stroke volume

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of the heart and/or increasing the heart rate. Thus, the heart rate becomes an expression of the magnitude of the additional load exerted on the cardiovascular system when the body is exposed to a certain heat stress.

In a study of cardiac stress in glass bangle workers in India, exposed to radiant heat of 46°C and ambient temperatures of 38°C. Rastogi *et al*. (1990) observed a mean increase in pulse rate to 113 beats/min and a retarded recovery of the pulse rate after work. The authors recommended a series of revisions of the practices in the glass bangle industry in order to reduce the level of environmental heat and thermal radiation (Rodahl, 2003). There are three possible measures of the heart rate that can be used as an index of thermoregulatory strain. They are: the actual heart rate during or at the end of work; the increment in heart rate over a working period or day; and the time taken for the heart rate to return to its resting level after work (Brouha, 1967).

A study at construction site in summer and its effects on health of workers concluded that in blood chemical data, electrolytes and blood urea nitrogen did not change, but blood sugar before work was significantly higher after work, and subjects' serum osmotic pressure increased after work, other subjects had a tendency to increase the blood pressure during work (Ikuharu *et al.*, 2006). Plasma electrolytes, total protein, and albumin concentrations were unaltered following heat acclimation, although the total plasma content of these constituents was elevated. A Study on extracellular fluid expansion concluded that acclimation-induced plasma volume (PV) expansion can be maintained following prolong heat acclimation (Mark *et al*., 2004). The rate of enzymatic reaction like any other chemical reaction increases with temperature. Creatine phosphokinase (CPK) is a very accurate measure of current muscle activity and, as such, it is the best indicator of the stresses associated with "today's" workout. Since CPK levels tend to rise and fall relatively quickly, this enzyme has become a good measure of training level and a recovery from increased work (Nannette *et al.*, 2004).

2. MATERIALS AND METHODS

2-1 AREA OF STUDY

The present study targeted workers carrying different workloads (light, moderate and heavy) under different thermal environments at Khartoum city. Selected outdoor workers were those working in an open area at ground floor, involved in cement mixing considered to carry out mild work; those in the second floor working under half-shaded roof were considered to perform moderate work, while those working on the third floor without roof were considered to perform heavy work. Indoor workers targeted those in textile and glassware industries. In the textile industry all were considered to carry heavy work. In the glassware industry workers were divided into three categories, as to carry light, moderate and heavy works.

For estimation of the sample size the following formula was used:

$$n = t^2PQ/d^2$$

where: n *= sample size*

t *= standard normal deviation (1.96)*

P *= proportion affected*

Q *= 1-P*

d *= degree of precision (0.05)*

For outdoor, 53 workers were selected and categorized as heavy (18), moderate (13), light (10) workers and 12 as control. For indoor 60 workers were also categorized as heavy (10), moderate (15), and light (23), workers with 12 controls

For indoor conditions, working hours was continuous for 8 hours with half an hour for breakfast and quarter of an hour for prayers. Work-rest regimen taken from wet-bulb globe temperature showed that for each hour workers carrying heavy loads must have 25% work and 75% rest throughout the day. For moderate, it is either 75% work or 25% rest (between 09 and 10 am), or 100% work and zero rest at 08:00 or 50% work and 50% rest (between 11 and 12:00) or 25% work and 75% rest for the rest of the day. For the light work group, it is 100% work till 09:00, 50:50 at 10:00 then 75:25 for the rest of the day. For the control it is 100 works and no rest for each hour throughout the day. For the outdoor groups, heavy work load group working hours and rest are the same. The control groups were selected from those working at the national health laboratory in Khartoum.

2-2 MEASUREMENTS OF THERMAL ENVIRONMENTS

Measurements of thermal environments were taken for workers for the two study areas (outdoors and indoors) the parameters included globe, dry and wet bulb temperatures, air temperature and humidity. For outdoors subjects with light workload at ground unshaded floor were exposed to high air temperature, high humidity and lower air velocity than those working in the second floor under half-shaded conditions. For heavy load workers were exposed to mild low temperature, less wind velocity and high humidity. The conditions were better for moderate work load group who were exposed to lower temperature, less wind velocity but higher humidity (Table 3.1.1).

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2.3 HEART RATE (BEATS/MIN)

The heart rate was checked by counting the radial pulse, before (rest), during (peak) and after work (recovery). Heart rate of recovery was checked also by counting the pulse rate immediately after stopping work in the second half of the first three minutes of recovery, as follows:

1st measurement -30 sec to 1 min

2nd measurement - 1½ to 2 min

3rd measurement - 2½ to 3min

The values obtained calculated according to (table 2.2).

Table 2.3. Heart rate recovery criteria

Heart rate recovery criteria pattern	P_3	Difference between P_1 and P_3
Satisfactory recovery	<90	-
High recovery (conditions may require further study)	90	10
No recovery (may indicate too much stress)	90	<10

Source (OSHA, 1999)

2.4 LUNG FUNCTION (SPIROMETRY TEST)

Measures of a series of parameters to human respiratory function were detected. It facilitates the total valuation of lung function of the subjects in the study. The valuation and interpretation of test results are given by comparing the measured parameters with specific 'normal' spirometry values (known as predicted values) which are calculated from subject data (age, height, weight, sex and ethnic group). Interpretation of the results for obstructive, restrictive diseases and normal spirometry was obtained by direct reading of internal software of the instrument used. After each test session the results are compared to the relevant predicted values and the percentage ratio between measured and predicted is shown for each parameter as follows:

% predicted = measured / predicted X100

FEV1% = FEV1/FVCX100

Where:

FEV1 = Volume expired in the first second of the test.

FVC = Forced vital capacity.

PEF = expiratory peak flow

(Instrument: MIR, Medical international research- Model spirolab11- Italy). (Seac, 2006).

2.5 BLOOD ANALYSIS

2.5.1. HAEMATOLOGICAL PARAMETERS

Blood samples were collected from each subject at 8.00 before starting of the work. and transferred into two vacationer tubes. EDTA-treated tubes for haematological investigations and plain tubes for serum analysis (John and Lewis, 1995) . Automated analyzer was used to determine the haematological parameters. Sysmex-Model KX-21 (medical electronics co.LTD) - Japan. Two transducer chambers for WBCs and HB and for RBCs and platelets.

2.5.1.1 HAEMOGLOBIN (HB)

Non cyanide haemoglobin method, which converts blood haemoglobin as the oxyhaemoglobin method (automated). In HB flow cells wavelength (555 nm) beam irradiated from the light emitting diode (LED) as applied to the sample is measured as absorbance, this absorbance is compared with that of the diluents alone that was measured before addition of the sample, thereby calculating HB value.

2.5.1.2 HAEMATOCRIT (HCT) (PCV)

The instrument calculates HCT from RBCs volume summation with whole blood volume.

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2.5.1.3 OTHER VALUES

MCV, MCH, MCHC calculated by the instrument from the basic values; RBCS, Platelets, HB and HCT.

2.6 ENZYME ANALYSES

Blood sample were obtained from the subjects for serum analysis using the automated machine-Selectra 'which consists of: computer, reagent rotor, cuvette rotor, sample disk, sample needle, wash, and waste bottle. (Instrument: Model - Selectra 'E'- E series clinical chemistry analyzer- 6-7240- Netherland).

2.6.1. CREATINE KINASE (CK)

The principle of the test depends on fact that Creatine Kinase (CK) catalyzes the phosphorylation of ADP, of Creatine phosphate, to form ATP and creatine. The catalytic concentration is determined from the rate of NADPH formation, measured at 340 nm by means of hexokinase (HK) and glucose-6-phosphate dehydrogenase (G6P-DH) coupled reaction. The measurement of the rate increase in NADPH liberated is directly proportional to the CK enzyme activity.

Creatine phosphate + ADP **CK** ⟶ Creatine + ATP ⟶ ATP + D-glucose

HK ADP + D-glucose-6-phosphate ⟶ D-glucose-6-phosphate +NADP G-6-PDH D-glucose-6-phosphate +NADPH+H^+

2.6.1.2 CREATININE

The principle of the test depends on that creatinine in the sample reacts with picrate in alkaline medium forming a colored complex. The colored intensity is proportional to the concentration of the reaction mixture serum was mixed with a mixture of picric acid and sodium hydroxide. The complex formation rate was measured in a short period to avoid interference.

2.6.2 UREA

Ureas, glutamate dehydrogenase method was used. Urea in the sample coupled in reaction described below, NADH that can be measured by spectrophotometry.

Urea + H2O ⟶ Urease ⟶ 2NH4 + CO2 + NADH+H^++ 2-OxOglutrate

NH4 ⟶ Glutamate +NAD ⟶ Glutamate dehydrogenase

2.6.3 TOTAL PROTEIN

Total serum protein was measured by colorimetric method. Determination of total protein in serum is based on the biuret reaction. The serum protein reacts with copper sulphate in the presence of sodium hydroxide (King and Wooton, 1965) by using Selectra 'E' instrument.

2.6.4 ALBUMIN

Bromocresol method was used. The measurement of serum albumin is based on its quantitative binding to the indicator 5, 5-di- purple, BCP. Albumin in the sample reacts with bromcresol green in acid medium forming a colored complex (Bartholomew and Delaney 1966), that can measure by Selectra 'E' instrument. (Reagent; 5x50 ml acetate buffer 100mmol/L, Bromocresol green 0.27 mmol/L, detergent ph 4.1).

2.6.5 ELECTROLYTES

2.6.5.1 CALCIUM

Serum calcium was determined by Arsenazo 111 method. Calcium in the sample reacts with arsenazo 111 forming a colored complex that can measured using Selectra 'E' instrument.

2.6.5.2 DETERMINATION OF NA^+ AND K^+

Flame photometer connected to gas cylinder and air pump. Measure 1.950 ml of distilled water in test tubes. Add 50 ml of sample of STD. Mix the sample and STD by vortex for ½minute. Open the pump in the flame photometer instrument. Open the gas cylinder. Switch on the flame photometer. Put distilled water in the nebulizer for 5 minute to maintain process and as blank to adjust the zero. Adjust the filter. Enter the standard in the instrument. Enter the samples after the STD and read the concentration.

2.7. STATISTICAL METHODS

Statistical analysis was conducted using package for social science (SPSS version 17). Association between qualitative variable was examined using chi- square test. Comparison of mean of quantitative variable between two groups was conducted using student T-test. Comparison of more than two groups was conducted using one way ANOVA. Correlation

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between quantitative variable was conducted using any regression of t-test. The test was considered significant which P-value was less than (0.05).

3. RESULTS

3.1 THERMAL ENVIRONMENT

For indoors, heavy load workers were exposed to high air temperature, lower air velocity but high humidity. The moderate workload groups were exposed to low air temperature, and higher wind velocity but lower humidity. The light work group experienced, less air temperature, air velocity and humidity (Tables, 3.1.2). The control group was exposed to lower air temperature, low air velocity but higher humidity compared to outdoor and indoor conditions (Table 3.1.3).

Table 3.1.1 Wet temperature (ºC), air velocity (m/s) and humidity (%) for outdoor

	Wet bulb temperature (°C)			**Air velocity m/s**			**Humidity %**		
	H	M	L	H	M	L	H	M	L
Mean	20.78	16.33	21.06	0.13	3.42	2.89	17.75	17.58	22.80
±SEM	0.41	0.61	0.34	0.03	0.57	0.36	1.44	2.14	0.80
±SD	1.23	1.83	1.01	0.8	1.71	1.07	4.32	6.41	2.39
Max	22	17	22.5	0.22	7.04	4.68	27.76	28.74	24.95
Min	19	15	19	0.02	1.23	1.31	12.93	11.30	17.42

Table 3.1.1 Wet temperature (ºC), air velocity (m/s) and humidity (%) for outdoor

	Wet bulb temperature (°C)			**Air velocity m/s**			**Humidity %**		
	H	M	L	H	M	L	H	M	L
Mean	23.3	20.11	21.44	0.42	0.54	0.42	33.08	17.76	20.84
±SEM	1.08	0.46	0.4	0.05	0.07	0.03	3.26	1.2	0.91
Max	27	22	23	0.61	0.92	0.56	51.89	21.44	24.17
Min	17	18	20	0.27	0.36	0.35	15.97	10.41	15.82

Table 3.1.3 Wet temperature (ºC), air velocity (m/s) and humidity (%) for control group

	Wet temperature (°C)	**Air velocity (m/s)**	**Humidity %**
Mean	21.28	1.18	35.97
±SEM	0.36	0.1	4.5
Max	22.5	1.52	54.87
Min	19	0.72	17.87

3.2 CARDIAC ASPECTS

3.2.1 RADIAL PULSE RATE

Comparisons among the different workloads for outdoor conditions, showed that for the heavy workloads the pulse rate was significantly (P<0.05) higher during work than before and after work, same was for the moderate work. Radial pulse rate was the highest during work for both heavy (~90 beats/min) and moderate (~85) work than before or after work for heavy (~84) and moderate work (~60). For light group work or control the changes were not significant and within the range of 78 - 82 beats/min for outdoor conditions (table 3.2.1.1).. For indoor conditions, similar trends were observed where pulse rate was the highest during work for both heavy (~66) and moderate (~83) groups than before or after work for heavy (range~60) and moderate (range ~66) (table 3.2.1.2) with significant differences (P <0.05) observed for both out and indoor groups.

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For outdoor group, only those with moderate workload showed higher pulse rate after 30sec (~85) than after 2.5 min (~66) (P). All workload groups showed higher pulse rate ($P<0.05$) than the control after 30sec. After 2.5min, the moderate workload group showed the lowest ($P<0.05$) pulse rate (table 3.2.1.3). For indoor conditions, pulse rate did not differ significantly after 30sec or 2.5 min, however, it showed the lowest level after 30sec (~66) and 2.5 min (~62) which were nearly the same for the light group but higher than the control (~75) compared for the moderate group after 30sec (~83) and 2.5 min (~74) (table 3.2.1.4)

Table 3.2.1.1 Radial pulse before, during and after subjects work between groups for outdoor condition

Groups with different workloads	Pulse rate (beats/min) (±SEM)		
	Before work	During work	After work
Heavy group	81.33±3.67^{b}	90.22±4.42^{a}	87.22±4.49^{b}
Moderate group	62.50±2.23^{c}	85.67±3.84^{b}	61.17±6.06^{c}
Light group	82.20±1.91^{b}	83.10±2.26^{b}	82.60±2.87^{b}
Control group	84.64±0.90^{b}	78.56±2.73^{b}	76.70±2.83^{b}
P-value	.000	.226	.001

^{abc}Values within the same column and rows bearing different superscript vary significantly at $P<0.05$

Table 3.2.1.2 Radial pulse before, during and after subjects work between groups under indoor conditions

Groups with different workloads	Pulse rate (beats/min) (±SEM)		
	Before work	During work	After work
Heavy	59.00±3.21^{c}	66.20±3.61^{b}	61.11±2.08^{c}
Moderate	62.80±1.73^{c}	83.29±3.10^{a}	66.15±2.72^{b}
Light	64.45±1.22^{b}	69.68±2.19^{b}	65.44±1.69^{b}
Control	84.64±0.90^{a}	78.56±2.73^{a}	76.70±2.83^{a}
P-value	.000	.000	.001

^{abc}Values within the same column and rows, bearing different superscript vary significantly at $P<0.05$

Table 3.2.1.3. Radial pulse at the four locations after 30 sec and after 2.5 min for outdoor workers

Groups with different workloads	Pulse (P1) after 30 sec	Pulse (P2) after 2.5 min
Heavy	90.22±4.29^{a}	88.33±4.49^{a}
Moderate	85.67±3.67^{a}	66.83±4.46^{c}
Light	83.1±2.14^{a}	79.2±2.28^{a}
Control	77.7±3.17^{b}	73.29±3.47^{b}

Table 3.2.1.4 Radial pulse at the four locations after 30 sec and after 2.5 min for **i**ndoor workers

Groups with different workloads	Pulse (P1) after 30 sec	Pulse (P2) after 2.5 min
Heavy	66.2±3.42^{c}	62.0±3.3^{c}
Moderate	83.29±2.99^{a}	74.29±2.27^{b}
Light	69.68±2.13^{c}	65.89±1.76^{c}
Control	77.7±3.17^{b}	73.29±3.47^{b}

^{Abcd} Values within the same columns and rows bearing different superscript vary significantly at $P<0.05$

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3.2.2 SYSTOLIC AND DIASTOLIC BLOOD PRESSURE

Systolic blood pressure before, during and after for subjects with different workloads for outdoor workers did not differ significantly for the outdoor groups and within the range of 113 - 123mmHg for outdoor condition (Table 3.2.2.1), while the diastolic blood pressure showed a range 76 - 84mmHg (Table 3.2.2.2). For indoor conditions**,** systolic blood pressure did not differ significantly either with work duration or workload ranging between 113 and 121mmHg (Table 3.2.2.3). Same observations were obtained with diastolic blood pressure (81 - 74mmHg) (Table 3.2.2.4)

Table 3.2.2.1 Systolic blood pressure before, during and after for subjects with different workloads for outdoor workers

Group	**Systolic (mmHg)** (±SEM)		
	Before Work	**During Work**	**After Work**
Heavy	113.06±2.83	123.06±1.90	112.78±2.15
Moderate	119.23±1.86	121.54±3.12	119.17±1.93
Light	119.00±1.94	120.50±2.83	120.00±2.89
Control	117.08±2.78	121.67±1.12	120.00±0.62
P-Value	0.251	0.886	0.260

Table 3.2.2.2: Diastolic blood pressure before, during and after for subjects with different workloads for outdoor workers

Groups	**Diastolic (mmHg)** (±SEM)		
	Before Work	**During Work**	**After Work**
Heavy	75.83±1.53	84.17±1.95	76.94±2.40
Moderate	78.46±2.43	80.00±2.89	78.75±2.14
Light	80.50±1.89	81.50±2.59	81.00±2.67
Control	79.58±2.26[a]	81.67±1.28	80.42±0.42
P-Value	0.357	0.558	0.531

Table 3.2.2.3: Systolic blood pressure before, during and after for subjects with different workloads for indoor workers

Group	**Systolic (mmHg)** (±SEM)		
	Before work	**During work**	**After work**
Heavy	113.75±2.63	116.11±2.32	118.13±1.88
Moderate	122.67±2.28	119.00±1.00	119.23±1.86
Light	120.45±2.03	115.28±2.04	120.56±2.28
Control	117.08±2.78	121.67±1.12	120.00±0.62
P-Value	**.121**	**.050**	**.866**

Table 3.2.2.4: Diastolic blood pressure before, during and after subjects work for subjects with different workloads for indoor workers

Group	**Diastolic (mmHg)** (±SEM)		
	Before work	**During work**	**After work**
Heavy	73.13±1.62[a]	77.22±2.90[a]	74.38±2.20[a]
Moderate	81.67±1.52[a]	79.33±0.83[a]	77.31±1.85[a]
Light	81.59±1.72[a]	76.94±2.33[b]	80.28±1.43[a]
Control	79.58±2.26[a]	81.67±1.28[b]	80.42±0.42[ab]
P-value	**0.32**	**.324**	**.053**

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3.3 LUNG FUNCTION

Percent of volume of air expired in the first second was taken as indicator of lung function. For outdoor study, 35% of the heavy workload group showed normal lung function, 21% showed mild restriction and moderate restriction, 7% moderate and 14% severe restriction. 50% of the group carrying moderate workload, suffered mild lung, and 25% showed normal lung function. 40% of the group carrying light work showed mild lung restriction and 30% normal lung function. 72% of the control group showed mild lung restriction and 18% showed moderate lung function (Table 3.3.1). For indoor the heavy workload group; 33% showed mild restriction 44% moderate restriction and 11% severe restriction. 13% of the group carrying moderate workload showed normal function, 26% suffered mild lung, and 33% showed moderate restriction. 38% of the group carrying light work showed normal lung restriction, 15% mild and 46% moderate restriction (table 3.3.2).

Table 3.3.1: Efficiency of lung function (FEV1/FVC %) for outdoor subjects with different workloads

		Workload groups				Total
		Control	Light	Moderate	Heavy	
Category	FEV1/FVC%	98.67 %	98.27 %	98.55%	95.94%	
N. S	Count	1	0	3	5	9
	% of Total	9.10%	0.00%	25.00%	35.70%	19.10%
MI.R	Count	8	3	6	3	20
	% of Total	72.70%	30.00%	50.00%	21.40%	42.60%
M.R	Count	2	4	2	3	11
	% of Total	18.20%	40.00%	16.70%	21.40%	23.40%
M.S. R	Count	0	3	0	1	4
	% of Total	0.00%	30.00%	0.00%	7.10%	8.50%
S. R	Count	0	0	1	2	3
	% of Total	0.00%	0.00%	8.30%	14.30%	6.40%
Total	Count	11	10	12	14	47
	% of Total	100%	100%	100%	100 %	100%

Table 3.3.2: Efficiency of lung function (FEV1/ FVC %) for indoor subjects with different workloads

		Workload groups				Total
		control	light	moderate	heavy	
category	FEV1/FVC %	98.67 %	94.87 %	91.02 %	95.72 %	
N.S	Count	1	5	2	0	8
	% of Total	9.1%	38.5%	13.3%	.0%	16.7%
MI.R	Count	8	2	4	3	17
	% of Total	72.7%	15.4%	26.7%	33.3%	35.4%
M.R	Count	2	6	5	4	17
	% of Total	18.2%	46.2%	33.3%	44.4%	35.4%
M.S.R	Count	0	0	2	1	3
	% of Total	.0%	.0%	13.3%	11.1%	6.3%
S.R	Count	0	0	2	1	3
	% of Total	.0%	.0%	13.3%	11.1%	6.3%
Total	Count	11	13	15	9	48
	% of Total	100.0%	100.0%	100.0%	100.0%	100.0%

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*FVC: Forced vital capacity * FEV1: Volume expired in the first second *FEV1%= FEV1/FVC X100

N.S = normal spirometry, MI.R = mild restriction, M.R = moderate restriction, M.S.R = moderate severe restriction, S.R = severe restriction

3.4 BLOOD PROFILE

3.4.1 HAEMATOLOGICAL VALUES

For outdoors, for subjects with different workloads and control showed all values including haematological, WBCs, MCH, MCHC, platelets and blood counts of WBCS neutrophils, lymphocytes and monocytes, showed no significant (P>0.05) differences. However, RBCs, HB, PCV, MCV HB, PCV, and blood counts of eosniphils showed significant (P<0.05) differences among groups. (Tables 3.4.1.1, 3.4.1.2, 3.4.1.3). All values were within the normal levels.

For indoors subjects and control with different workloads, no differences (P>0.05) were obtained for the levels of RBCS, HB, platelets and blood counts neutrophils and monocytes, while WBCS, HCT, MCH, MCHC, lymphocytes and eosnoiphils indicated significant (P<0.05) differences among the groups (tables 3.4.1.4, 3.4.1.5, 3.4.1.6).

3.4.2 CREATININE (MG/DL), TOTAL PROTEIN AND ALBUMIN (G/L)

Serum level of urea and creatinine (mg/dl), total protein and albumin (g/l) in the blood of subjects carrying different types of work and the control for outdoors was shown in table 3.4.2.1. It was shown that creatinine decreased significantly (P <0.01) with heavy and moderate workload but remained within the normal range for outdoor workers. For indoor workers, different workloads showed significant (P <0.01) decreases compared to the control (table 3.4.2.2)

3.4.3 CREATINE PHOSPHO- KINASE (CPK) ENZYME

Creatine phospho-kinase (CPK) levels were compared between different workers and the control at both study sites. It was shown that CPK level decreased significantly (P <0.01) with the decrease of workload in outdoor conditions which showed significant (P <0.01) higher values than indoor conditions except for the light workload. Heavy workload had the highest effect under outdoor conditions, while moderate workload had the highest effect under indoor conditions (table 3.4.3).

3.5 SERUM ELECTROLYTE

Serum electrolyte measurements of sodium (Na), potassium (K) and calcium (Ca) for workers under outdoors, or indoors conditions carrying different workloads, have shown that, Na and Ca levels increased significantly (P <0.01) in the serum of the outdoors subjects carrying heavy workload, while K increased significantly with moderate workload (table 3.5.1). However, significant (P <0.01) differences were obtained only for K in the serum of indoor workers carrying heavy workload (table 3.5.2). All electrolyte levels fell within the normal range.

Table 3.4.1.1 TWBCS (10^3/µL), RBCS, (Million/µL), HB (g/dl), HCT (%) levels for subjects at outdoor and control

Group ↓	TWBCS (10^3/µL) (3.0 - 9.0)	RBCS (Million/µL) (3.8 - 5.5)	HB (g/dl) (13 - 17)	HCT (%) (40 - 50)
Heavy	5.60±0.37^{a}	4.87±0.07^{ab}	14.02±0.30^{b}	42.24±0.64^{b}
Moderate	4.91±0.33^{a}	4.78±0.06^{a}	13.55±0.23^{a}	38.98±1.12^{b}
Light	5.40±0.19^{a}	5.03±0.12^{b}	14.52±0.19^{b}	44.64±0.67^{b}
Control	5.33±0.34^{a}	5.07±0.05^{b}	14.42±0.21^{b}	43.86±0.53^{b}
***P-value**	**0.541**	**0.024**	**0.047**	**0.00**

Values are mean ±SEM, ^{abc}values significantly difference between the level of groups at (P<0.05) or (P<0.001), figures between brackets represent normal values

Table 3.4.1.2. MCV (fL), MCH (pg), MCHC (g/dl), Platelets(10^3/µL), levels or subjects at outdoor and control

Group ↓	MCV (fL) (80 - 100)	MCH (pg) (27 - 32)	MCHC (g/dl) (30 - 36)	Platelets(10^3/µL) (150 - 450)
Heavy	86.90±1.20^{a}	28.88±0.69^{a}	33.17±0.46^{a}	210.00±14.11^{a}
Moderate	83.59±0.67^{a}	28.36±0.40^{a}	33.94±0.37^{a}	208.30±20.42^{a}
Light	88.23±1.07^{b}	28.71±0.43^{a}	32.56±0.29^{a}	217.78±12.79^{a}
Control	86.54±0.86^{a}	28.47±0.37a	32.89±0.32^{a}	219.86±13.95^{a}
***P-value**	**0.028**	**0.888**	**0.122**	**0.937**

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Values are mean ±SEM, [abc]values significantly difference between the level of groups at (P<0.05) or (P<0.001) , figures between brackets represent normal values

Table 3.4.1.3. Percent neutrophils, lymphocytes, monocytes, eosinophils levels for subjects at outdoors and control

Group	Neutrophils (40 - 75 %)	Lymphocytes (20 - 45 %)	Monocytes (2 - 10 %)	Eosinophils (1 - 6 %)
Heavy	52.15±2.47[a]	39.39±1.47[a]	3.00±0.25[a]	6.23±1.73[a]
Moderate	46.82±1.68[a]	46.27±1.29[a]	4.00±0.45[a]	2.91±0.34[b]
Light	45.22±3.08[a]	43.22±2.71[a]	4.56±0.69[a]	7.00±1.86[a]
Control	50.21±2.79[a]	43.50±2.81[a]	3.79±0.24[a]	2.50±0.17[b]
***P-value**	**0.253**	**0.85**	**0.065**	**0.023**

Values are mean ±SEM, [abc]values significantly difference between the level of groups at (P<0.05) or (P<0.001), figures between brackets represent normal values.

Table 3.4.1.4 TWBCS (10^3/µL), RBCS, (Million/µL), HB (g/dl), HCT (%) for subjects at indoor and control

Group ↓	TWBCS (10^3/µL) (3.0-9.0)	RBCS (Million/µL) (3.8-5.5)	HB (g/dl) (13-17)	HCT (%) (40-50)
Heavy	7.46±0.88[a]	4.72±0.13[a]	14.08±0.41[a]	42.39±1.03[b]
Moderate	5.36±0.55 [b]	4.99±0.13[a]	14.95±0.26[a]	41.67±0.72[b]
Light	5.20±0.45[b]	5.12±0.09[a]	14.79±0.36[a]	45.12±0.68[a]
Control	5.33±0.34[b]	5.07±0.05[a]	14.42±0.21[a]	43.86±0.53[ab]
***P-value**	**0.028**	**0.059**	**0.310**	**0.006**

Values are mean ±SEM, [abc]values significantly difference between the level of groups at (P<0.05) or (P<0.001), Figures in parentheses indicate normal range

Table 3.3.1.5 MCV (fL), MCH (pg), MCHC (g/dl), Platelets(10^3/µL), levels for subjects at indoor and control

Group ↓	MCV (fL) 80-100	MCH (pg) 27-32	MCHC (g/dl) 30-36	PLATELETS (10^3/µL) 150-450
Heavy	89.30±1.09[a]	29.64±0.41[ab]	33.22±0.25[a]	209.22±14.29[a]
Moderate	84.61±1.09[b]	30.32±0.37[a]	35.85±0.19[b]	218.18±11.99[a]
Light	88.26±0.85[a]	28.56±0.33[b]	32.36±0.22[a]	206.63±8.61[a]
Control	86.54±0.86[a]	28.47±0.37[b]	32.89±0.32[a]	219.86±13.95[a]
P-value	**0.013**	**0.002**	**0.00**	**0.814**

Values are mean ±SEM, [abc]values significantly difference between the level of groups at (P<0.05) or (P<0.001), Figures in parentheses indicate normal range

Table 3.4.1.6. Percent neutrophils, lymphocytes, monocytes, eosinophils levels for subjects at indoors and control

Group ↓	Neutrophils (40 - 75 %)	Lymphocytes (20 - 45 %)	Monocytes (2 - 10 %)	Eosinophils (1 - 6 %)
Heavy	50.80±3.82[a]	32.70±3.32[b]	5.10±0.95[a]	10.40±4.17[a]
Moderate	50.33±2.39[a]	42.83±2.30[a]	3.67±0.23[b]	3.17±0.39[b]
Light	47.47±1.97[a]	40.88±1.73[a]	5.47±0.72[a]	6.18±1.56[a]
Control	50.21±2.79[a]	43.50±2.81[a]	3.79±0.24[b]	2.50±0.17[b]
P-value	**0.776**	**0.027**	**0.079**	**0.032**

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Values are mean ±SEM, abcvalues significantly difference between the level of groups at (P<0.05) or (P<0.001) , Figures in parentheses indicate normal range

Table 3..4.2.1 Serum level of urea and creatinine (mg/dl), total protein and albumin (g/l) in the blood of subjects carrying different types of work and the control for outdoors

Group ↓	Urea mg/dl (15-50)	Creatinine mg/dl (0.4-1.4)	Total protein g/dl (6.4-8.3)	Albumin g/dl (3.5-5)
Heavy	29.43±1.44[a]	0.85±0.04[a]	7.66±0.13[a]	4.14±0.08[a]
Moderate	28.22±2.63[a]	0.77±0.03[a]	7.72±0.20[a]	4.17±0.12[a]
Light	26.50±1.38[a]	1.19±0.08[b]	7.58±0.25[a]	3.93±0.12[a]
Control	23.85±2.06[a]	1.05±0.04[b]	7.35±0.15[a]	4.02±0.13[a]
P-value	**0.150**	**0.000**	**0.449**	**0.445**

Values are mean ±SEM· [abc]values significantly difference between the level of groups at (P<0.05) or (P<0.001), figures between brackets represent normal values

Table 3.4.2.2 Serum level of urea and creatinine (mg/dl), total protein and albumin (g/l) in the blood of subjects carrying different types of work and the control for indoors

Group ↓	Urea mg/dl (15 - 50)	Creatinine mg/dl (0.4 - 1.4)	Total protein g/l (6.4 - 8.3)	Albumin g/l (3.5 - 5)
Heavy	22.00±1.93	0.93±0.02[b]	7.12±0.18	4.27±0.09
Moderate	22.64±1.30	0.88±0.03[b]	7.45±0.10	4.00±0.05
Light	21.14±1.54	0.94±0.02[b]	6.77±0.17	3.96±0.09
Control	23.85±2.06	1.05±0.04[a]	7.35±0.15	4.02±0.13
P-value	**0.706**	**0.001**	**0.014**	**0.143**

Values are mean ±SEM, [abc]values significantly difference between the level of groups at (P<0.05) or (P<0.001), Figures in parentheses indicate normal range

Table 3.4.3. Serum level of Creatine Phospho Kinase (u/L)

Group ↓	**CPK (38-174) u/L**	
	Outdoors	**Indoors**
Heavy	540.71±74.63[a]	227.50±71.87[d]
Moderate	412.33±63.92[b]	341.55±66.00[c]
Light	190.67±36.21[e]	173.07±16.17[e]
Control	204.62±20.59[d]	204.62±20.59[d]
***P-value**	**0.00**	**0.061**

Values are means ±SEM *P <0.01. Figures in parentheses indicate normal range

Table 3.5.1: Serum level of sodium (Na, mmol/L), potassium (K, mmol/L) and calcium (Ca, mg/dL) for outdoors workers

Group	Na (135 - 145 mmol/l)	K (3.5 - 5.2 mmol/l)	Ca (8.6 - 10.3 mg/dl)
Heavy	140.29 ±1.64[a]	3.69 ±0.21[a]	11.11±0.20[a]
Moderate	134.33 ±1.71[b]	3.00 ±0.17[b]	8.68±0.69[b]
Light	138.33 ±1.57[b]	3.70 ±0.60[a]	9.25±0.23[b]
Control	135.50 ±1.49[b]	3.73 ±0.41[a]	9.51±0.17[b]
***P-value**	**0.05**	**0.021**	**0.000**

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Values are means ±SEM *P <0.01. Figures in parentheses indicate normal rang

Table 3.5.2: Serum level of sodium (Na, mmol/L), potassium (K, mmol/L) and calcium (Ca, mg/dL) for indoor workers

Group	Na (135 - 145 mmol/l)	K (3.5 - 5.2 mmol/l)	Ca (8.6 - 10.3 mg/dl)
Heavy	137.33±1.38[a]	3.03 ±0.10[b]	10.01±0.17[a]
Moderate	135.64 ±1.07[a]	3.32 ±0.07[a]	9.83±0.07[a]
Light	133.50 ±1.09[a]	3.22 ±0.06[a]	9.90±0.16[a]
Control	135.50 ±1.49[a]	3.75 ±0.16[a]	9.51±0.17[a]
***P-value**	**0.255**	**0.000**	**0.120**

Values are means ±SEM *P <0.01. Figures in parentheses indicate normal range

3.6 CORRELATIONS WITH THE THERMAL ENVIRONMENT

A significant positive correlation between pulse rate and air temperature were obtained for outdoor (P <0.01, $y = 0.2812x + 71.292$) and indoor (P <0.000, $y = 0.61x + 46.747$) workers.

Correlation/ regressions between Pulse rate and humidity were shown to be insignificant for both out and indoor workers, however, with radiant temperatures significant results were obtained for both outdoor (P <0.001, y = 0.6865x + 54.999) and indoor (P < 0.001, y = 0.1169x + 62.462).

Correlation/ regressions between systolic blood pressure (SBP) or diastolic (DBP) blood pressure and air temperature for outdoor and indoor workers were shown not to be significant (P >0.05). Same observations were obtained when SBP or DBP were regressed against humidity for out and indoor workers.

A significant (P <0.01) negative correlation was obtained between air temperatures and lung function for both outdoor ($y = -0.3315x + 109.51$) and indoor ($y = -0.5118x + 113.5$) groups which meant that lung function efficiency decreased with increase of dry temperature.

5. DISCUSSION

5.1CARDIAC OUTPUT

Radial pulse rate, was found to increase significantly during than before workload and were higher with heavy workload than moderate and light workload with retarded recovery. This could be related with the increase in body temperature and exposure to high radiant energy (38 – 42ºC) as the increase in pulse rate was strongly correlated with both air and radiant temperature. Furthermore, significant negative correlation was obtained between air temperatures and lung function for both outdoor and indoor groups which meant that lung function efficiency decreased with increase of dry temperature. Similar observations were obtained in India working in glass bangle exposed to radiant heat of 46°C and ambient temperatures of 38°C (Rastogi *et al*., 1990). Similarly, it was shown that a rise in the temperature of the blood by less than 1°C activates peripheral and hypothalamic heat receptors that signal the hypothalamic thermoregulatory center, and the efferent response from this center increases the delivery of heated blood to the surface of the body. Active sympathetic cutaneous vasodilatations then increase blood flow in the skin by up to 8 liters per minute. Furthermore, an elevated blood temperature also causes tachycardia, increases cardiac output, and increases minute ventilation (Abderrezak and James, 2002). As blood is shunted from the central circulation to the muscles and skin to facilitate heat dissipation, visceral perfusion is reduced, particularly in the intestines and kidneys.

In this study, systolic, diastolic blood and pulse rates showed that their levels increased during exercise but returned to normal levels after exercise in all workers under different environments. It was shown that, the ability of a worker to tolerate heat stress requires integrity of cardiac, pulmonary, and renal function, the sweating mechanism, the body's fluid and electrolyte balances, and the central nervous system's heat-regulatory mechanism. Impairment or diminution of any of these functions may interfere with the worker's capacity to acclimatize to the heat or to perform strenuous work in the heat once acclimatized (NIOSH, 2002).

5.2 HAEMATOLOGICAL VALUES, CREATINE PHOSPHO-KINASE (CPK) ENZYME, ELECTROLYTES

The regulation of temperature is one of the primary functions of the blood. Adjustments of blood flow modify heat flow between the body core and shell and the rate of heat loss to the environment. Peripheral vasodilatation or vasoconstriction under warm and cold conditions affects the volume and distribution of blood. Haematocreit levels showed heamodilution in workers carrying mild workload under out-and indoor conditions. However, other workloads showed heamoconstration

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although all levels were within the normal range. Similarly, conflicting results in man showing either haemoconcentration (Malamud *et al*., 1946) or haemodilution (Austain and Berry, 1956). However, Haematocreit level is extremely important during exercise and becomes more crucial as the duration of exercise increases (Moran *et al*., 1999). In this study, sodium level was found to increase with the increase in workload which could be related to dehydration and elevated body temperature. Similarly, it was pointed that hematocrit values and sodium (Na+) levels might increase due to dehydration (Moran *et al*., 1999). In this study, elevated calcium levels were obtained in heavy workload subjects under out-and outdoor conditions. Within this line it was observed that hypocalcemia and hypomagnesaemia may occur as a result of increased loss of calcium and magnesium in urine and/or sweat (Moran *et al*., 1999). Furthermore, hypokalemia is found in the early stages of extended heat stress and may later develop to hyperkalemia as a result of acidosis (Moran *et al*., 1999).

In this study, total protein and albumin levels did not change significantly. Similar findings were obtained in heat acclimated subjects (Mark *et al*., 2004). Urea levels were not altered with different workloads, similarly, Khogoly *et al* (1983) did not report an increase in blood urea level in hyperthermic subjects. On the other hand, it was stated that blood urea level usually increases under heat stress (Malamud *et al*., 1946).

It was pointed out that an increase in core temperature and exercise stress, recruit leukocytes into peripheral circulation, with potentiating the response during a second bout of exercise (Severs *et al*., 2004). In this study, neutrophils, lymphocytes, monocytes, eosinophils did not change significantly within the different workload and were within the normal range. However, eosinophils level concentration increased significantly with heavy work load under indoor conditions. This could be related the effect intermittent exercise bouts and return to baseline. It was shown that the response could be exacerbated when exercise is done at 40°C and so there is synergism between heat and exercise exposure (Severs *et al*., 2004).

Creatine phospho-kinase (CPK) level increased significantly for subjects carry heavy and moderate workloads working under out- or indoors conditions compared with those carrying light work. This could be related to muscle work which increase with the increase in exercise. Similarly, it was pointed out that CPK is a very accurate measure of current muscle activity and, as such, it is the best indicator of the stresses associated workout (Kachmar and Moss, 1982).

CONCLUSIONS AND RECOMMENDATIONS

For indoor and outdoor workers with different workloads, pulse rate, systolic and diastolic blood pressures were higher during than before or after work. HCT and eosinophils levels were lower for outdoor group carrying moderate workload and for both moderate and light workload groups under indoor conditions. Eosinophils were higher in the heavy workload group under indoor conditions only. Creatinine decreased with heavy and moderate workload. Positive correlations were obtained between air or radiant heat were obtained between pulse rate and SBP or DBP and air temperature. While negative correlations were obtained between air temperatures and lung function.

It is recommended that, periodic clinical examination of the workers for the prevention, discovery and treatment, check of heart rate, count the radial pulse for 30 seconds at the beginning of the rest period. If the heart rate exceeds 110 beats per minute, shorten the next work period by one third and maintain the same rest period. Occupational health services covering all workers should be established. Education and training are vital components of safe, healthy working environments. The suitable personal protective equipment should be available for all workers.

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