Cardio-respiratory responses to moderately heavy aerobic exercise during the Ramadan fasts

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ABSTRACT

Objective: The aim of this study was to quantify the magnitude of the cardiovascular and respiratory changes that occur during the month of Ramadan in response to moderately heavy aerobic physical exertion.

Methods: Eighteen sedentary Kuwaiti adult males were tested under thermo-neutral conditions during a spring-like month of Ramadan and one month thereafter.

Results: There were no significant changes in maximal exercise capacity, treadmill walking efficiency, percentage VO_2 max, in body weight and composition associated with Ramadan fasting or one month after. Cardiac (heart rate) and ventilatory responses to moderately intense bouts of sub-maximal aerobic exercise (70% of VO_2 max) were actually slightly (<5%) but significantly ($P<0.05$) reduced, while exercise systolic but not diastolic pressure increased slightly (6%) by the end of Ramadan.

Conclusions: Hormonal changes associated with dehydration or fasting, abstention from consumption of substances with negative inotropy and changes in circadian rhythms during Ramadan may be responsible for these mild changes in cardiorespiratory responses to exercise. Such changes had no negative effect on the physical aerobic performance of these subjects while exercising at moderately heavy intensity under thermally neutral conditions, during the month of Ramadan. Reduced ventilation during exercise may reflect a limited glycolytic capacity by the end of Ramadan.

Keywords: Ramadan fasting, heart rate, blood pressure, oxygen uptake, body composition, ventilation, exercise.

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Muslems abstain from food and drink from sunrise to sunset during the lenten month of Ramadan. This lunar month may fall in any season of the year and the effects of the daily fast are strongly influenced by climatic conditions being more severe in the summer than at other times in the year.[1] In Ramadan, daily living routines are markedly altered. These changes affect eating schedules, amount and types of foods eaten, the volume and timing of fluid ingestion, the sleeping patterns, the duration and intensity of physical labor and of recreational activities, the duration, intensity and type of ritual commitments.

Changes in work schedules and shortening of the duration of the work day for physical types of activities are usually implemented and affect the life and economies of hundreds of millions of people during a full month, year after year. It is implied that the changes that occur as a consequence of the daily fasts, impact significantly on the physical work capacity of the subjects, increases the effort required to perform a given task, impair physical performance, efficiency and endurance. It is not known however if Ramadan, when it occurs in a relatively thermo-

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neutral environment as when it happens in winter or spring in countries where air conditioning is readily available[1,2] has effects on the physiological responses to physical exercise that justify the drastic changes in duration and scheduling of physical work and of recreational physical activities that are common in Muslim countries during the month of Ramadan.

The aim of this study was to quantify the magnitude of the functional cardio-vascular and respiratory changes that occur during a spring month of Ramadan in response to moderately heavy aerobic physical exertion and to evaluate if they impinge significantly on the physical work capacity, on the efficiency, or on the effort required to perform a given physical activity.

Methods. Anthropometric changes and the cardiovascular and respiratory responses to maximal (progressive treadmill exercise test) and to moderately heavy sub-maximal aerobic exercise load (walking on the treadmill at 70% of VO_2 max) were studied in a group of 18 volunteers, sedentary, adult male Kuwaiti government office workers, followed longitudinally at the beginning (zero week), mid (second week) and end (fourth week) of the month of Ramadan and in a similar non-Ramadan testing period thereafter. None of the subjects participated regularly in recreational or health-related physical activity programs so that the cardiovascular and respiratory responses to the stress of moderately heavy physical exercise were expected to be maximized. Thus, for the first time we are following longitudinally the responses of the same group of sedentary subjects to exercise during the month of Ramadan and one month after the Ramadan fast. The tests were conducted during the Ramadan month (mid January to mid February) of 1996 and in April of the same year. At these times the ambient temperature and humidity in Kuwait were spring-like (15-25°C, 75-85% humidity). The measurements were conducted in a thermoneutral laboratory environment where temperature (25°C) and relative humidity (30%) were kept constant throughout the study period. Thus the extreme temperatures of Kuwait in the summer were avoided and never faced by the subjects in the course of this study. A consent form explaining in details the procedures and possible risks and benefits was obtained for each subject. The right to withdraw from the study at any time was clearly stated.

Body weight and height were measured using a beam balance (Physician Balance Beam Scale, Health-Matic, USA) with a height measuring scale. Skinfolds (chest, umbilical, thigh) were measured using a caliper (Lafayette Instruments). Exercise tests were carried out at 1-5 pm each day on a Quinton 65 treadmill. Maximal exercise test were carried out according to the progressive Bruce protocol. Heart rates were measured from pre-cordial lead ECG recordings (Quinton, Q5000, USA) at rest and during exercise. Blood pressure was measured at rest and during exercise using a sphygmomanometer and a stethoscope.

Ventilation and the composition of the expired gas were measured using appropriately calibrated flow and gas (CO_2 and O_2) meters (Quinton, Q-plex-1, USA). Calculations were computerized and results plotted on-line. Six repeated submaximal exercise tests were conducted at the same treadmill speed and grade for each subject, 3 at the Ramadan weeks 0, 2, 4 and 3 at post-Ramadan weeks 0, 2 and 4, after a one month interval. The tests were set-up to elicit about 70% of maximal aerobic effort (70% of VO_2max) in each case, so as to be able to induce comparable cardiovascular and respiratory responses to exercise in subjects that differed in body build, age and fitness levels.

Data was presented as means +/- one SEM. Differences between group means were considered statistically significant when, after a significant ANOVA, the paired or unpaired (as indicated) 2 tailed t-test between means had a $p<0.05$. To eliminate interindividual variability in the responses and to compare each subject's responses at the same absolute exercise load, the data for each subject was normalized to the values observed during the first test in each period.

Results. The average anthropometric (age, height, weight, skin-folds) and derived body composition parameters observed in this group of sedentary Kuwaiti adult male subjects are summarized in Table 1. A small (1 kg), not statistically significant decrease in average body weight occurred during Ramadan, most of it during the first 2 weeks, the body weight remaining stable thereafter (Figure 1). Skin-fold measurements of subcutaneous body fat failed to detect significant changes in body composition during the month of Ramadan (Table 1). During the 4-week non-Ramadan testing period, these same subjects showed no significant change in body weight nor in subcutaneous body fat folds (Table 1). This indicates that during Ramadan, on the average, in spite of the daily fasts, energy intake from sunset to sunrise was sufficient to maintain energy balance in this group of subjects.

During the maximal exercise tests the heart rates reached greater than 177 bpm and the respiratory exchange ratio exceeded 1.0 in all subjects tested. The maximal exercise tests revealed that the subjects were on the average moderately fit for their age (average VO_2 max = 3.29 $\pm$ 0.15 L/min; aerobic capacity 40.4 $\pm$ 1.6 ml/kg.min) and that their aerobic fitness level, the best objective measure of their physical work capacity, did not change significantly

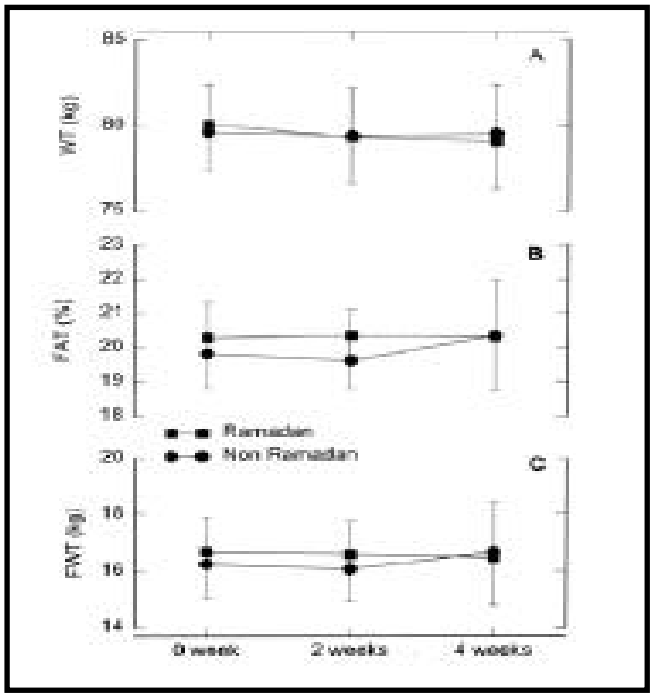

Figure 1 - Body weight, fat weight and percentage of fat during Ramadan and non-Ramadan testing periods.

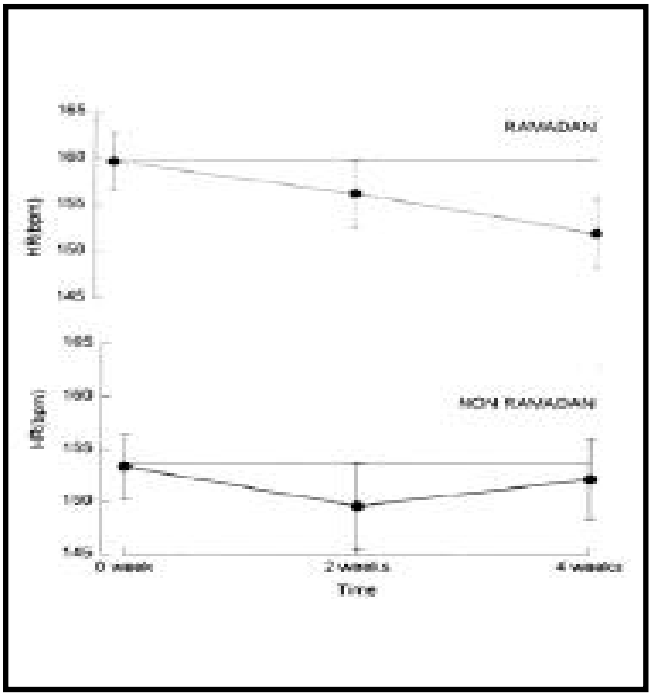

Figure 2A - Heart rates (beats per minute) during submaximal exercise during Ramadan and non-Ramadan testing periods.

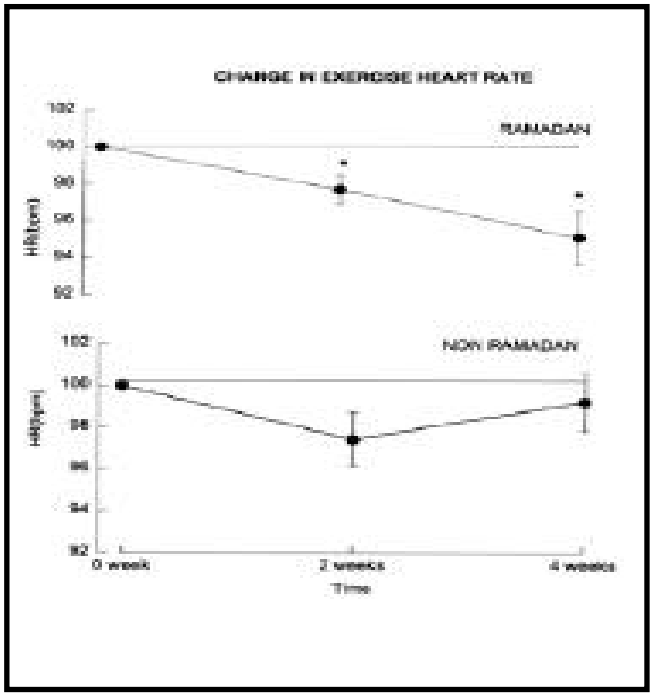

Figure 2B - Heart rates (% of control) during submaximal exercise; Ramadan and non-Ramadan testing periods.

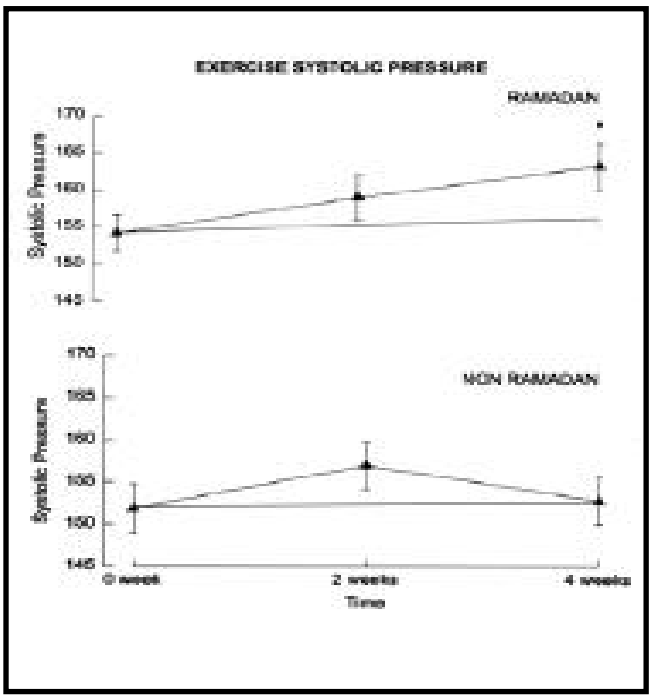

Figure 3A - Systolic pressure (mm Hg) during submaximal exercise during Ramadan and non-Ramadan testing periods.

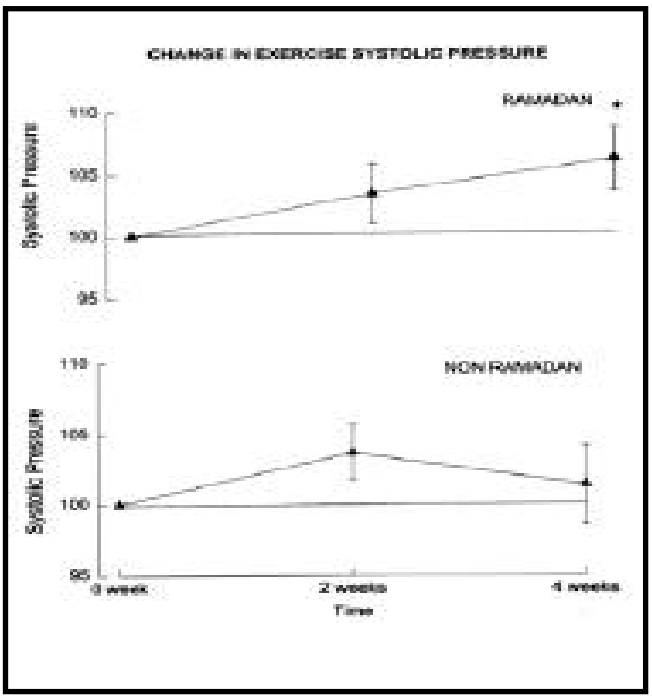

Figure 3B - Systolic pressure (% of control) during submaximal exercise during Ramadan and non-Ramadan testing periods.

during the month of Ramadan (Table 2).

The steady state sub-maximal exercise loads used during the tests were, on the average, at a VO_2 = 2.37 ± 0.12 L/min with a range of 1.7 to 3.3 L/min. These loads represented an average aerobic effort of 72 ± 2.3% of VO_2 max; the range of efforts varied however from 48 to 90% of VO_2 max. The average percentage of aerobic effort decreased insignificantly during the month of Ramadan (to 70.9% at 4 weeks, P< 0.5) and did not show any significant change during the similar non-Ramadan 4 week testing period of the same group of subjects (Table 2). The speed and percent grade used during the sub-maximal exercise tests, although variable from subject to subject, remained constant for each subject in all tests performed during and after Ramadan.

The average heart rate response to these sub-maximal aerobic exercise loads decreased progressively and significantly at the second and then at the fourth week of Ramadan (Figure 2A and 2B),

Table 1 - Body composition - Anthropometric measurements.

Test period	**Ramadan**		**Non Ramadan**	
Test week	**0**	**4**	**0**	**4**
Age (y)	35.00 ± 1.91			
Height (cm)	171.33 ± 1.68			
Weight (kg)	80.06 ± 2.70	79.06 ± 2.80	79.61 ± 2.77	79.50 ± 2.85
Skinfolds (mm)	67.62 ± 5.34	67.38 ± 5.59	65.59 ± 5.27	66.11 ± 5.49
Fat (%)	20.28 ± 1.48	20.30 ± 1.54	19.81 ± 1.48	20.33 ± 1.66
Fat (kg)	16.67 ± 1.65	13.36 ± 1.65	16.24 ± 1.64	16.67 ± 1.79
Values are mean ± 1 SE of 18 subjects				

Table 2 - Exercise responses.

Test period	Ramadan		Non Ramadan	
Test week	**0**	**4**	**0**	**4**
VO_2 max (L/min)	3.29 ± 0.15		3.30 ± 0.16	
VO_2 max (ml/min.Kg)	40.44 ± 1.55		41.26 ± 1.80	
HR max (bpm)	187 ± 2.8		187 ± 3	
R max	1.18 ± 0.23		1.19 ± 0.21	
VO_2 submax (L/min)	2.37 ± 0.12	2.29 ± 0.13	2.32 ± 0.12	2.28 ± 0.12
VO_2 submax (% of max)	72.2 ± 2.3	70.9 ± 3.0	70.9 ± 2.5	69.9 ± 2.6
VE submax (L/min)	64.3 ± 3.6	61.0 ± 3.9	63.9 ± 3.7	64.3 ± 3.7
R submax	0.94 ± 0.01	0.93 ± 0.02	0.95 ± 3.02	0.97 ± 0.01
DP submax (mm Hg)	86.66 ± 1.81	87.00 ± 1.57	84.11 ± 1.76	83.44 ± 1.18
DP Rest (mm Hg)	83.85 ± 1.29	80.27 ± 1.37	82.44 ± 1.29	82.33 ± 1.54

Values are mean ± 1 SE of 18 subjects

Table 3 - Hematological constituents for Ramadan month.

Constituents	0 week	4 weeks
Hematocrit (Ratio)	46.54 ± 1.02	45.72 ± 1.0
Hemoglobin (g/dl)	16.07 ± 0.42	15.75 ± 0.36
Platelets 10^9/L	230.44 ±10.07	218.78 ± 11.94
Red blood cell Count x 10^{12}/L	5.54 ± 0.16	5,45 ± 0.14
White blood cell Count x 10^9/L	6.12 ± 0.48	5.77 + 0.39

Values are mean ± 1 SE of 18 subjects

Table 4 - Plasma constituents for Ramadan month.

Constituents	0 week	4 weeks
Chloride (mmol/l)	106.60 ± 0.51	108.78 ± 0.86*
Glucose (mmol/l)	5.01 ± 0.11	5.44 ± 0.10**

Values are mean ± 1 SE of 18 subjects, *Significantly different from control values at P<0.05, **Significantly different from control values at P<0.01.

but showed no significant change at the second or the fourth weeks of the non-Ramadan testing period (Figure 2A and 2B).

The steady state systolic pressure observed at similar sub-maximal exercise loads, increased progressively during the month of Ramadan, the increase reaching statistical significance by the fourth week of Ramadan (Figure 3A and 3B). During the non-Ramadan testing period of the same group of subjects, the sub-maximal exercise systolic pressure increased insignificantly at the second week test, and was unchanged at the fourth week test (Figure 3A and 3B). Diastolic pressure during exercise, systolic and diatolic pressures at rest, did not change during or after Ramadan (Table 2).

The respiratory ventilation during the bouts of sub-maximal aerobic exercise, decreased from an average of 64.3 to 61 L/min during the month of Ramadan (Table 2). When the percent changes in submaximal exercise ventilation that occurred in each subject from week 0 to week 4 of Ramadan were analyzed statistically, the small 5.3 ± 2.4% decrease observed reached statistical significance ($P<0.05$). This reflects the fact that the decrease in exercise VE during Ramadan was very consistent in all subjects. In the same group of 18 subjects, minute ventilation during similar sub-maximal exercise loads did not change significantly during the 4-week non-Ramadan

testing period (Table 2). The respiratory exchange ratio (R) during the submaximal exercise loads, did not significantly change during the Ramadan or the non-Ramadan testing periods (Table 2).

The hematocrit, blood hemoglobin concentration, red and white blood cell counts were unchanged during Ramadan (Table 3); no changes in these hematological variables were detected in the same group of subjects over a 4-week non-Ramadan testing period (Table 3). Significant increases in plasma chloride and fasting plasma glucose concentrations were detected during the Ramadan but not during the non-Ramadan testing period (Table 4).

Discussion. The changes observed in the cardio-respiratory responses to sub-maximal exercise during the month of Ramadan were small but significant reductions in heart rate and ventilation and an increase in systolic but not in diastolic blood pressure. There were no significant changes in maximal exercise capacity, percentage of VO_2 max, treadmill walking efficiency, in body weight and in body composition (skinfolds) associated with Ramadan fasting.

The decrease in submaximal exercise heart rate may be consequent to a reduction in the intensity of the effort performed. However there were no significant changes in VO_2 max or in the percentage of VO_2 max at which the subjects worked during the submaximal exercise bouts used during the Ramadan and the non-Ramadan testing periods, and the speed and grade at which the subjects walked were the same throughout the Ramadan and non-Ramadan tests. This also indicates that the efficiency of walking on the treadmill was unchanged in the consecutive tests and that familiarity of the subjects with walking on the treadmill was not a factor accounting for the decrease in exercise heart rate. The lower heart rate while walking at 70% of VO_2 max noted during Ramadan may be interpreted to reflect an improvement in the physical condition of the subjects rather than any deleterious effect of the Ramadan fast. However, we have found it to occur independently of the initial physical condition and of the habitual level of physical activity of the subjects and has been previously described by us to be also present in physically active adult male subjects.[2] It is thus that it is not due to a "training" effect. We cannot discard possible cardiac effects of avoiding certain substances (such as cigarettes) or of volume regulatory hormones such as antidiuretic hormone,[3] which increase in concentration in the plasma as a consequence of the dehydration that progressively develops during the Ramadan fast.[4] This dehydration becomes more severe as the month of Ramadan progresses, as indicated by increases in the urine and the plasma osmolarities,[4] as well as by increases in plasma sodium[5] and in plasma chloride (Table 4) concentrations.

A significant increase in sub-maximal exercise systolic pressure was observed during the Ramadan period in the absence of changes in exercise or in resting diastolic blood pressures, and in too short a time to be due to changes in arterial elasticity. It occurs in the absence of changes in sub-maximal exercise effort (70% of VO_2 max). The increase in systolic pressure is thus likely to represent an increase in pulse pressure due to a larger stroke volume.

An increase in stroke volume during exercise may be secondary to a positive inotropic effect of hormones such as angiotensin II[6] and glucagon,[7] which increase in plasma concentration during dehydration[8] and fasting.[9] Alternatively it may be secondary to increases in central blood volume due to redistribution of blood from periphery to central reservoirs[10] during the prolonged period of consecutive daily abstentions from fluids, salt and other foods. Hormonal changes (eg glucagon) with consequences on cardiac chrono and inotropism may also result from the changes in eating, activity and sleep circadian patterns that occur during the month of Ramadan. It is also possible that substance(s) avoided during Ramadan (such as cigarettes) have a negative inotropic influence.

The slightly reduced (5%) ventilatory response to 70% aerobic effort that was detected by the fourth week of Ramadan may reflect a lower acid stimulus to ventilation secondary to reduced production of lactic acid by muscles where the glycogen reserves might be low.[9] This may limit performance of anaerobic efforts by the end of Ramadan.

In conclusion, the present study indicates that the responses of these sedentary, "white collar" subjects to moderately intense bouts of sub-maximal aerobic exercise is not markedly affected by the daily fasts that occur during the month of Ramadan. There are no significant changes in maximal exercise capacity, in body composition, nor in the efficiency of treadmill walking at a defined grade and speed during the Ramadan testing period. We have previously shown that there are no differences in the physiological responses to moderate sub-maximal aerobic exercise between sedentary and physically active subjects and thus that no training effects are involved.[2,11]

The direction and magnitude of the observed changes in cardio-respiratory responses to exercise is such that they should have no negative impact on, and may rather be of benefit to, the ability to perform aerobically either at work or recreationally, at least when the Ramadan fasts occur in a relatively neutral thermal environment. Such changes are likely to be different and more severe when the month of Ramadan occurs during the summer and more extreme warm temperatures and humidity or both are present. The cardio-vascular responses to exercise

may be particularly altered during peregrinations when exposure to heat, long periods of immobility, crowding and increases in physical activity will reinforce the effects of deprivation of fluids, salt and food. Reduced ventilation during heavy exercise by the end of Ramadan may reflect a limited glycolytic capacity that may interfere with anaerobic efforts.

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