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Changes in Subjective and Objective Measures of Performance in Ramadan

H. Alabed, K. Abuzayan, and J. Waterhouse

Abstract—The Muslim faith requires individuals to fast between the hours of sunrise and sunset during the month of Ramadan. Our recent work has concentrated on some of the changes that take place *during the daytime* when fasting. A questionnaire was developed to assess subjective estimates of physical, mental and social activities, and fatigue. Four days were studied: in the weeks before and after Ramadan (control days) and during the first and last weeks of Ramadan (experimental days). On each of these four days, this questionnaire was given several times during the daytime and once after the fast had been broken and just before individuals retired at night.

During Ramadan, daytime mental, physical and social activities all decreased below control values but then increased to above-control values in the evening. The desires to perform physical and mental activities showed very similar patterns. That is, individuals tried to conserve energy during the daytime in preparation for the evenings when they ate and drank, often with friends. During Ramadan also, individuals were more fatigued in the daytime and napped more often than on control days. This extra fatigue probably reflected decreased sleep, individuals often having risen earlier (before sunrise, to prepare for fasting) and retired later (to enable recovery from the fast).

Some physiological measures and objective measures of performance (including the response to a bout of exercise) have also been investigated. Urine osmolality fell during the daytime on control days as subjects drank, but rose in Ramadan to reach values at sunset indicative of dehydration. Exercise performance was also compromised, particularly late in the afternoon when the fast had lasted several hours. Self-chosen exercise work-rates fell and a set amount of exercise felt more arduous. There were also changes in heart rate and lactate accumulation in the blood, indicative of greater cardiovascular and metabolic stress caused by the exercise in subjects who had been fasting. Daytime fasting in Ramadan produces widespread effects which probably reflect combined effects of sleep loss and restrictions to intakes of water and food.

Keywords—Drinking, Eating, Mental Performance, Physical Performance, Social Activity, Sleepiness.

I. INTRODUCTION

A previous pilot study (Alabed, 2010) [1]. Documented that one day of fasting during the daytime led to changes in human performance and physiology that closely reflected the changes seen in previous field studies of effects of Ramadan, [2]-[3]-[4].

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For example, urine osmolality showed evidence of the development of dehydration during the daytime and performance at a bout of exercise deteriorated. It was concluded that such results indicated that a laboratory-based experiment with a protocol that required daytime fasting for only a single day provided a useful tool for assessing some of the changes produced by fasting and changes of the sleep-wake cycle in the four weeks of Ramadan. By contrast, some of the measurements made in the previous laboratory-based pilot study [1] had indicated rather small changes due to fasting, including grip strength and the response of heart rate to a 5-min bout of exercise. It was suggested that such a lack of change in measures of objective performance might indicate that the measures used were not sufficiently sensitive to the effects of only one day of fasting. Another problem was that measurements were made only until the end of fasting (16:00 h), as a result of which any recuperation from effects of fasting could not be investigated. The aim of the present study has been to incorporate two improvements into this earlier design: additional objective measurements of performance and more frequent times of measurement. These times would span a wider portion of the waking period - four times per fasting period rather than three and a set of measurements after the end of the fast and before retiring - so bringing the protocol closer to that which has been used with previous field studies of Ramadan, [2]-[3]-[4]. It is hypothesised that, in comparison to the control days when there are no restraints on fluid and food intakes, daytime fasting will lead to dehydration and decrements in both subjective and objective measures of performance, and that these decrements will disappear or even reverse during the evening when recuperation from the fast takes place.

II. METHOD

A. Participants

The participants in this study eighteen male subjects, undergraduates at the University in Tripoli, with an age range of 18-21years, were recruited by word of mouth for the study. None of these was Muslim and so had no prior experience of fasting. The experiments were completed in July 2012 and had previously been approved by the University Ethics Committee.

B. Procedures

Subjects initially underwent a familiarisation session in which all aspects of the testing were explained, including the two conditions (fasting and non-fasting), and the dates on

which of the two conditions were to be performed. The various tests were described and subjects were required to practise them, to reduce learning effects during the main part of the experiment.

The main experiment (begun at least one week after the familiarisation session) was in two parts: a non-fasting (control) day and a fasting (intervention) day. The order in which the two experimental days took place was randomly selected by the experimenters, but the subjects knew of this order at least a week in advance. This arrangement gave them subjects the opportunity to eat/drink prior to sunrise (07:00 h) on the testing day and to go to bed/rise earlier if they wished to do so. No advice was given as to whether or not any extra food or fluid should be consumed before the fasting period. On the control (non-fasting) day, subjects were free to choose when to sleep, and what and when to eat and drink. On the fasting day, subjects were free to choose when to sleep and what to eat and drink before 07:00h and after 18:00 h; food and fluid intake were prohibited between 07:00 h and 18:00 h but subjects were free to nap if they choose to do so.

On each experimental day, subjects attended the laboratory at 09:00, 12:00, 15:00 and 18:00 h, to perform a series of tests and give a urine sample; they also answered the questionnaire again at home, when choosing to retire to bed at the end of the day. The tests and samples were given in the following order: questionnaire, urine sample, accuracy at throwing darts but an addition to this type of study), the Stroop test (new to this type of study), hand-grip strength, and vertical jumps. These tests are now described in more details.

C. Measurements Made and Preparation of Results for Statistical Analysis

1. Questionnaires

Subjects were required to give information about their daily activities and feelings over the course of the day. The information was gained from a questionnaire which the subjects completed five times during each of the two days they were being investigated.

On the five occasions each day that they answered the questionnaire, subjects were asked to concentrate on their previous activities as follows: (1) at 09:00 h, activities after waking; (2) at 12:00 h, activities during the morning ; (3) at 15:00 h, activities during the early afternoon; (4) at 18:00 h, activities during the late afternoon; and (5) on retiring to bed (designated 24:00 h in the Fig.s), activities in the evening after breaking the fast.

For some of the variables (the reasons for drinking/not drinking and eating/not eating), the “fraction of possible occasions” was calculated for the group. This calculation was performed as follows. Suppose, for example, that only 12 of the 18 subjects drank on a particular occasion and that 8 of these gave the reason “Thirsty”. This means that the fraction of possible occasions that Thirsty was chosen was 8/12, that is, 0.67. Suppose, further, that, of the 6 who did not drink, 2 gave the reason “Too busy”. This means that the fraction of

possible occasions that Too busy was chosen was 2/6, that is, 0.33.

D. Physiological and Performance Tests

1. Urine Osmolality

This provides a measure of dehydration of the body. The urine sample was collected into a plastic pot and stored at 5°C until analysis. For the analysis, a 5 ml aliquot was taken and its osmolality measured (Osmocheck Pocket Pal OSMO, Vitech Scientific Ltd, Japan).

2. Throwing Darts

Throwing darts can be used as a model for investigating circadian and time-awake factors that influence motor performance, [5]-[6]. The subjects threw darts at a circular target (20 cm diameter) placed on the floor at a distance of 2.37 metres; the target consisted of 10 concentric rings of diameter 2 cm, 4 cm, 6 cm,.....20 cm. The subjects had 20 attempts to throw the dart as close to the target's centre as possible. After each throw the score for each dart was measured and then the dart was collected for the next throw. The score was determined as follows: a dart in the innermost ring scored 10 points, and darts in the other rings moving out from the centre scored 9, 8, 7...1 point, respectively. When a dart missed the target, the score was recorded as zero (a “miss”), regardless of the size of the miss.

In the analysis, the results from the first and last three darts were ignored (though the subjects did not know this when they were performing the test), due to possible effects of “getting my eye in” and “nearly finished”. The total score for the 14 darts, the number of misses, and the mean score per hit (ignoring the misses) were used as measures of throwing accuracy.

3. Stroop Test

The test used was the Colour-Word Stroop Test (CWST). It is a test that assesses working memory and attention. Therefore, it would be expected to show a daily rhythm peaking around noon, [7] - [8]. And, though it has not been used before in studies of Ramadan, might be expected to show deterioration due to restrictions of food and fluid intakes.

The test consisted of the subject viewing 20 separate cards. Each had a colour, “red”, “orange”, “green” or “brown” typed on it in one of these four colours. However, in many cases, the word was typed in a colour that was different from the meaning of the word – the word “orange” might be typed in green, for example. The participant was required to state the colour in which the word was typed, not the name of the colours itself. (In the example given, the correct answer would be “green” rather than “orange”). Incorrect answers had to be corrected by the subject. The total time taken to answer all 20 questions correctly was recorded on a stopwatch.

4. Hand Grip Strength

Only the dominant hand of each subject was investigated using a dynamometer (Handgrip Dynamometer TRK5106.

Jump MD, TAREK Scientific Instrument Score, Japan). The subject recorded grip strength on 3 occasions separated by 10-sec intervals, the maximum of the three values being recorded. This is a test of muscle strength using a comparatively small group of muscles.

5. Jump height

The jump test is a further example of a test of physical strength but, unlike grip strength, involves the integrated actions of several groups of muscles. Subjects performed 3 maximal vertical jumps using the “stand-and-reach” method, [9]. Subjects stood side-on to a wall and reached up with the right arm, which was next to the wall. Keeping the feet flat on the ground, the wall was marked by the tip of the fingertips, onto which chalk powder had been placed. The subjects then jumped vertically as high as possible using both arms and legs to assist in projecting the body upwards. The wall was touched at the highest point of the jump. The difference in distance between the standing height and the jump height was the height jumped. The best of three attempts was recorded.

After the vertical jump tests had been completed, subjects were free to leave the laboratory and continue their activities until the next visit to the laboratory. Subjects varied in their experience of having throwing darts before the experiment, but none of them had any previous experience with regard to answering the questionnaires or performing the other tests.

E. Statistical Analysis

The data were analysed by the Statistical Package of Social Science (SPSS) version 17 (SPSS Inc., Chicago, IL) for Windows. For most data, two-way ANOVA with repeated measures was used. The main factors were Day (2 levels: Controls vs. Fasting) and Time of Day (4 or 5 levels: 09:00, 12:00, 15:00, 18:00 h for all variables and also retiring time for the results from the questionnaires). When fractions of possible occasions were compared, the data were arcsine-transformed before ANOVA (a standard method used to make the data distributed normally). Greenhouse-Geiser corrections were used, and significant differences within the main factors were assessed using Bonferroni corrections. To compare nominal data (if subjects chose to eat or drink before sunrise, for example) the McNemar and Cochran tests were used. Correlations between variables were assessed using the method, [10]. A method which corrects for multiple pairs of values being obtained from each **subject**.

Exact P values are reported; significance was set as $P < 0.05$, though occasions where $0.05 < P < 0.10$ have been reported as “marginally significant” and results given as “0.000” by the computer output recorded as $P < 0.0005$.

III.RESULTS

A. Results from Questionnaires

Drinking

Comparisons between drinking and eating on the control and fasting days during the daytime were not made, since they were determined by the requirements of the protocol. However, it was possible to compare results before and after the period of fasting, to investigate preparations for, and recovery from, the period of fasting.

The number of subjects drinking or not drinking before 09:00h was compared on control and fasting days (Fig. 1). There was a significant increase in the number of subjects drinking before the day of fasting (13 out of 18, compared with only 6/18 on the control day, $P = 0.016$).

The reasons given for drinking are shown in Fig. 2. The four reasons were cited by different numbers of subjects on both control ($P = 0.010$) and fasting ($P < 0.0005$) days. “Thirsty” was cited most frequently on both types of day; “Preparation” was cited only on fasting days, even though this difference was not significant ($P = 0.25$) due to the small sample size.

There were too few occasions of “Not drinking” for statistical analysis of the reasons given to be performed. All subjects drank after 18:00 h on both days. The reasons given for drinking are shown in (Fig. 3). The four possible reasons were cited by different numbers of subjects on both control ($P < 0.0005$) and fasting ($P < 0.0005$) days. “Thirsty” was cited most frequently on both types of day; “Recover” was cited significantly more frequently on fasting days ($P = 0.002$).

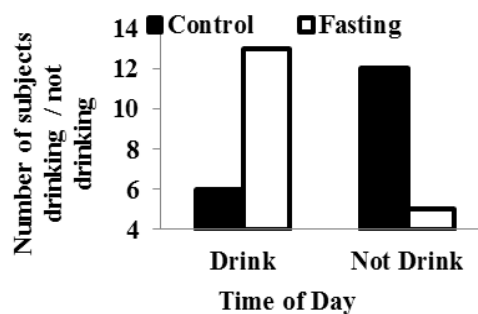


Fig. 1 Number of subjects drinking/not drinking before 09:00 h

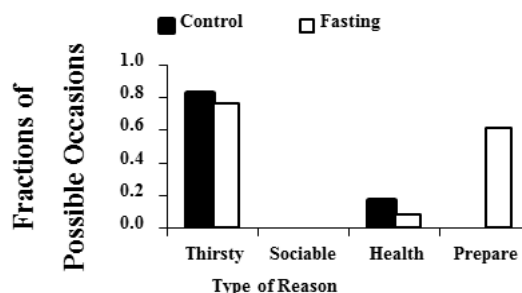


Fig. 2 Reasons for drinking before 09:00 h. For calculation of “Fraction of Possible Occasions”, see Methods

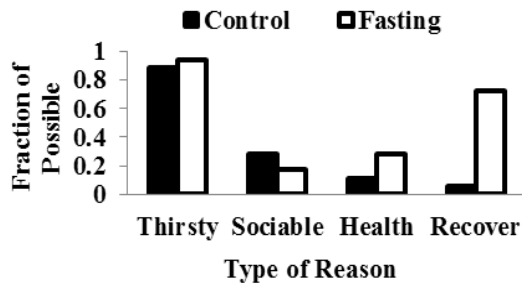


Fig. 3 Reasons for drinking after sunset (18:00 h). For calculation of “Fraction of Possible Occasions”, see Methods

1. Eating

The number of subjects eating or not eating before 09:00 h was compared on Control and Fasting days (Fig. 4). There was an increase in the number of subjects eating before 09:00 h on the day of fasting (12/18 compared with 7/18 on the Control day) but this difference was not significant ($P=0.125$)

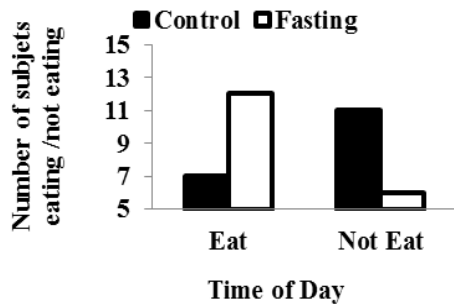


Fig. 4 Number of subjects eating/not eating before 09:00 h

The reasons given for eating are shown in Fig. 5. The four reasons were cited by significantly different numbers of subjects on both control ($P<0.0005$) and fasting ($P = 0.015$) days. “Hungry” was cited most frequently on both days; “Prepare” was cited only on fasting days, even though this difference was not significant ($P = 0.125$).

There were too few occasions of “Not eating” for statistical analysis of the reasons given to be performed.

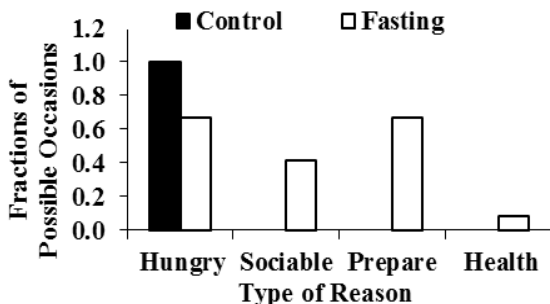


Fig. 5 Reasons for eating before sunrise. For calculation of “Fraction of Possible Occasions”, see Methods

The reasons given for eating after 18:00 h are shown in Fig. 6. The four reasons were cited by significantly different numbers of subjects on both control ($P<0.0005$) and fasting ($P<0.0005$) days. “Hungry” was cited most frequently on both days; “Recover” was cited significantly more frequently on fasting days ($P = 0.002$).

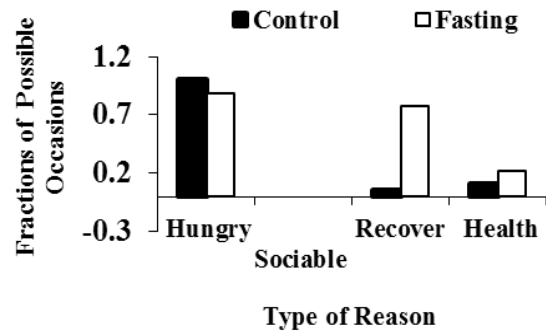


Fig. 6 Reasons for eating after sunset. For calculation of “Fraction of Possible Occasions”, see Methods

2. Physical Activity

Physical activity performed (Fig. 7) showed a significant difference between the times of day ($F_{3,2}, 54.7 = 8.3, P<0.0005$), this increasing throughout the day from the morning to the evening, with low values in the morning and a higher plateau for the rest of the day. There were no significant differences between control and fasting days ($F_{1,2} = 2.01, P = 0.17$) nor any significant interaction ($F_{3,3}, 56.6 = 1.5, P = 0.22$).

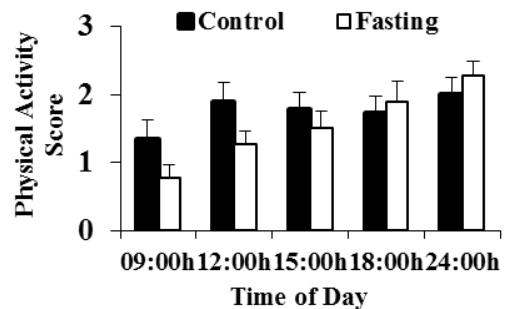


Fig. 7 Effect of time of day upon physical activity score on control and fasting days. Mean + SE

3. Mental Activity

With mental activity also (Fig. 8), there was a significant difference with time of day ($F_{2,9}, 50.9 = 12.9, P<0.0005$), with low values in the morning and a higher plateau for the rest of the day. There was no significant difference between control and fasting days ($F_{1,17} = 2.8, P = 0.12$) and no significant interaction between the two factors ($F_{2,8}, 46.8 = 0.99, P = 0.40$).

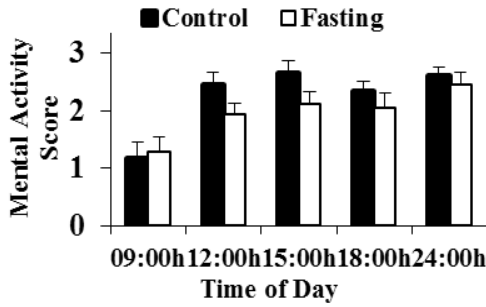


Fig. 8 Effect of time of day upon mental activity score on control and fasting days. Mean + SE

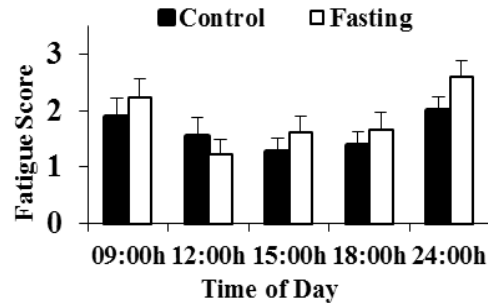


Fig. 10 Effect of time of day upon fatigue on control and fasting days. Mean + SE

4. Social Activity

Social activity done (Fig. 9) showed a significant difference between time of day and of social activity ($F_{2.4, 40.2} = 14.7$, $P < 0.0005$), increasing in the same way as physical activity. Again, there was no significant difference between control and fasting days ($F_{1, 17} = 0.07$, $P = 0.79$) and no significant interaction ($F_{3.1, 53.0} = 0.54$, $P = 0.66$).

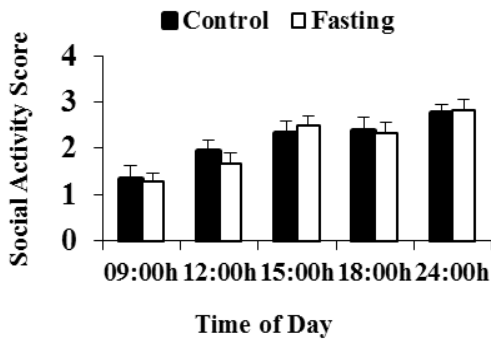


Fig. 9 Effect of time of day upon social activity score on control and fasting days. Mean + SE

5. Fatigue

Fig. 10 showed no significant difference between control and fasting days ($F_{1, 17} = 2.1$, $P = 0.16$). However, there was a significant difference between the times of day ($F_{2.8, 47.6} = 4.8$, $P = 0.006$) with fatigue falling during the morning and then rising throughout the afternoon and later into the evening. Fatigue was significantly lower on retiring. There was no significant interaction between the factors Day x Time of day ($F_{2.6, 44.9} = 1.10$, $P = 0.30$).

6. Amount of Physical Activity Wished for

The amount of physical activity that subjects wanted to perform showed a significant difference between control and fasting days ($F_{1, 17} = 5.5$, $P = 0.031$), lower values being associated with the fasting days (Fig. 11). There was also a significant effect of Time of day ($F_{3.1, 51.8} = 5.1$, $P = 0.004$), values being highest around noon and the early afternoon and then declining after this time. There was no significant interaction ($F_{3.1, 53.0} = 0.76$, $P = 0.52$).

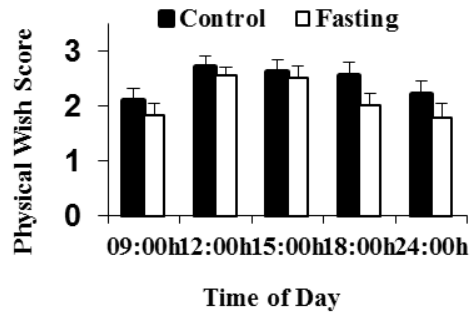


Fig. 11 Effect of time of day upon the desire to perform physical work on control and fasting days. Mean + SE

7. Amount of Mental Activity wished for

Subjects wanted to do less on fasting than control days ($F_{1, 17} = 2.1$, $P = 0.017$), Fig. 12. There was also a significant difference between the times of day ($F_{2.8, 47.2} = 7.5$, $P < 0.0005$), the profile being very similar to that of the desire to perform physical activity (Fig. 11). There was no significant interaction ($F_{3.5, 58.9} = 1.8$, $P = 0.15$).

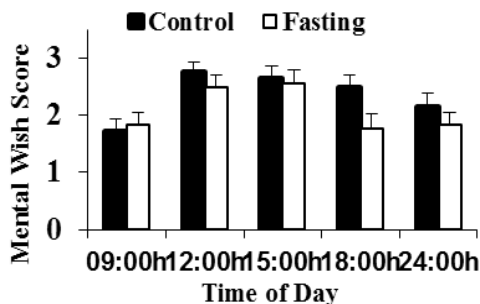


Fig. 12 Effect of time of day upon the desire to perform mental activity on control and fasting days. Mean +SE

8. Urine Osmolality

Fig. 13 shows mean urine osmolalities during the course of the control and fasting days. There were significant effects of Day ($F_{1, 17} = 30.7, P < 0.0005$), Time of day ($F_{2.3, 39.8} = 5.6, P = 0.005$) and a significant interaction between the Day x Time of day ($F_{2.5, 41.7} = 15.4, P < 0.0005$). The results show that the urine was fairly concentrated after waking from the night's sleep. Urine osmolality then fell during the daytime on the control days, when daytime fluid intake was allowed, but tended to increase further during the daytime on the fasting day.

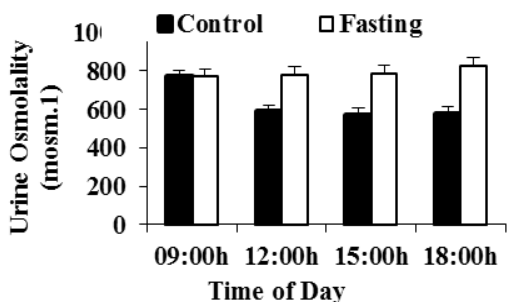


Fig. 13 Mean +SE of Urine Osmolality under non-fasting and fasting conditions

B. Hand Grip Strength

For grip strength of the dominant hand, there were a no significant effects of Day ($F_{1, 7} = 1.5, P = 0.23$), Time of day ($F_{2.6, 44.4} = 1.7, P = 0.19$) or interaction between Time x Day ($F_{2.4, 41.4} = 1.4, P = 0.27$) (Fig. 14).

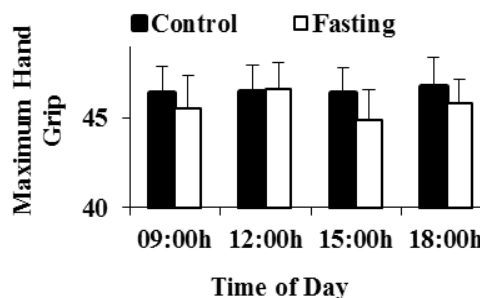


Fig. 14 Maximum hand grip strength (dominant hand). Mean + SE

C. Stroop Test

For the Stroop test, there was a no significant difference for Day ($F_{1, 17} = 2.5, P = 0.13$) but there was a highly significant effect of Time of day ($F_{2.0, 33.7} = 10.8, P < 0.0005$), with performance improving (time taken decreasing) as the day progressed (Fig. 15). There was no significant interaction between Time of day x Condition ($F_{2.4, 41.2} = 0.54, P = 0.62$).

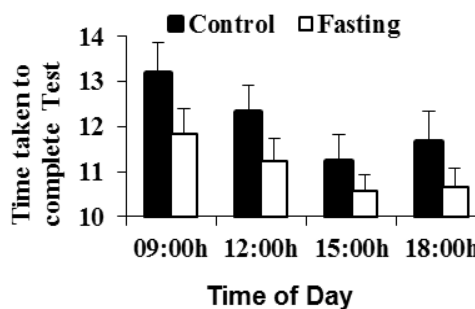


Fig. 15 Time taken to complete test. Mean + SE

D. Jump Height

Fig. 16 shows the results for jump height. There was no significant effect of Day ($F_{1, 17} = 1.4, P = 0.26$) but a significant effect of Time of day ($F_{2.5, 43.2} = 11.2, P < 0.0005$), performance improving throughout the daytime and evening. There was a significant interaction between the two factors ($F_{2.4, 40.1} = 4.9, P = 0.009$), the improvement during the daytime being less marked on the fasting day, particularly in the late afternoon.

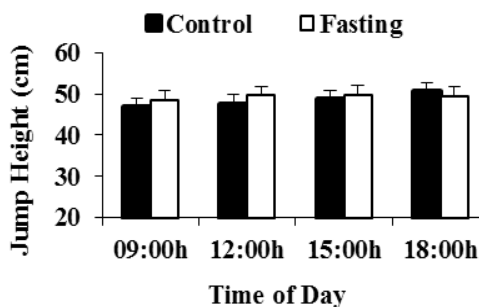


Fig. 16 Maximum height jumped. Mean + SE

E. Throwing Darts

Total Score for darts 4-17 (see Fig. 17) showed no significant effect of Day ($F_{1, 17} = 0.72, P = 0.41$). There was also no significant time-of-day effect ($F_{2.5, 41.9} = 0.93, P = 0.42$) but an interaction that was marginally significant ($F_{2.6, 44.8} = 2.3, P = 0.096$), because the scores fell towards the end of the day during fasting only.

The number of misses (“zero” scores) was also analysed (Fig. 18). Here also, there was no significant difference between Day ($F_{1, 17} = 0.06, P = 0.81$) or Time of day ($F_{2.2, 37.4} = 1.6, P = 0.21$). There was also no significant interaction ($F_{2.2, 38.2} = 1.12, P = 0.36$).

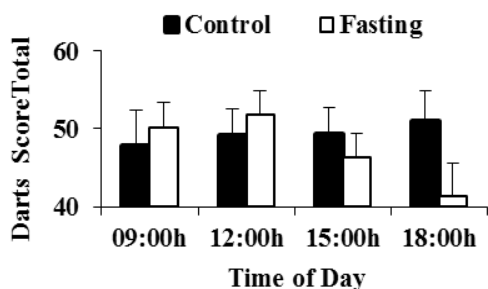


Fig. 17 The Mean +SE of total scores for darts 4-17. For calculation of Score, see text

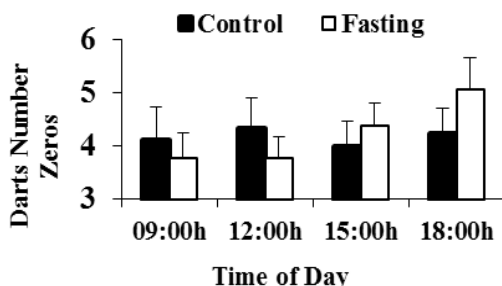


Fig. 18 The Mean +SE of mean number of zeros scored

As with the other estimates of performance at the task of throwing darts, Mean score per hit (see Fig. 19) showed no significant effect of Day ($F_{1,17} = 1.9, P = 0.19$), Time of day ($F_{2.5,42.3} = 0.58, P = 0.60$) or interaction between the two factors ($F_{2.6,44.9} = 1.7, P = 0.20$).

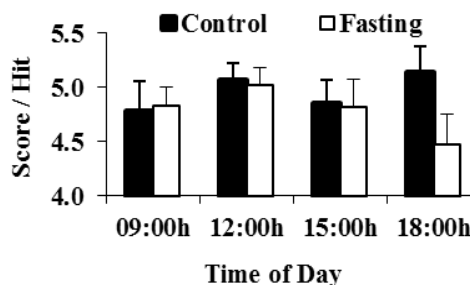


Fig. 19 The Mean +SE of Mean score per hit. For calculation of Score/Hit, see text

F. Correlations between the Variables

To calculate these, the three scores for physical, mental and social activities actually performed were combined (Score P), as were the two scores for the wished-for amounts of physical and mental activity (Score W). In the correlations, all pairs of values from the four times of day and both control and fasting days were used. That is, each subject gave 8 pairs of values (09:00, 12:00, 15:00 and 18:00 h for both control and fasting days). The correlation matrix is shown in Table I. As this Table indicates, the significant correlations were:

- Score P vs. Fatigue = -0.16; Score P vs. Score W = +0.39;
- Score P vs. Stroop test = -0.20.
- Fatigue vs. Score W = -0.62
- Score W vs. Urine = -0.18
- Darts total score vs. Darts number of zeros = -0.74
- Stroop test vs. Grip strength = -0.24; Stroop test vs. Jump height = -0.32

It will be noted that there were no significant correlations between performance at darts and the other variables.

TABLE I

CORRELATIONS BETWEEN THE VARIABLES USING THE METHOD,[10]. SIGNIFICANT ($P < 0.05$) VALUES GIVEN NUMERICALLY. VALUES IN BRACKETS INDICATE DIRECTION OF CORRELATION WHEN MARGINALLY SIGNIFICANT ($0.10 > P > 0.05$). BLANKS INDICATE THAT THE CORRELATIONS WERE NON-SIGNIFICANT ($P > 0.10$)

	Score Ph	Fatigue	Score W	Urine	Darts Total	Darts Zeros	Stroop	Grip strength	Jump Height
Score Ph	X	-0.16	0.39	(-)			-0.2	(+)	(+)
Fatigue	X	X	-0.62	(+)	(-)			(-)	(-)
Score W	X	X	X	-0.18	(+)	(-)	(-)	(+)	(+)
Urine	X	X	X	X	(-)	(+)		(-)	(-)
Darts Total	X	X	X	X	X	-0.74	(-)	(+)	(-)
Darts Zeros	X	X	X	X	X	X			(+)
Stroop	X	X	X	X	X	X	X	-0.24	-0.32
Grip strength	X	X	X	X	X	X	X	X	(+)

Jump height	X	X	X	X	X	X	X	X	X
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IV. DISCUSSION

Results show that there was clear evidence for changes during fasting to: drinking and eating habits, amounts of wished-for physical and mental activities, and hydration status of the body. By contrast, the changes observed in grip strength, performance at the Stroop test and jump tests, and the ability to throw darts accurately, were far less marked.

There was limited evidence to support the view that subjects made preparations before the time of fasting. More of them drank and ate before sunrise on the fasting than on the control day (Figs. 1 and 4). The most common reason cited for drinking or eating was “Thirsty” or “Hungry” but “Prepare” was tended to be cited almost as frequently before the day of fasting (Figs.2 and 5), After sunset, all subjects ate and drank. Again, thirst and hunger were cited most frequently but “Recover” was cited significantly more frequently after the day of fasting and almost as frequently as thirst or hunger (Figs.3 and 6).

These preparations for fasting and recovery from it afterwards agree with the work previously found in subjects during Ramadan, [11]-[2]-[3]-[4]. Whilst it can be argued that such preparations are intuitively likely, it must also be remembered that the fast lasted for one day only (unlike the case in Ramadan) and the subjects had no prior knowledge of the demands of Ramadan, none of them being Muslim. That is, as argued previously, [3]. Links between fluid and food intakes and the amount of drink or food ingested tend to break down in these circumstances. In this respect, there is some similarity with the intakes observed if the meal serves an important social function, when intakes might be greater than required, [12]-[13].

The subjects tended to show decreases in physical, mental and social activities in the daytime during fasting (Figs.7-9), Similar profiles were seen for the amounts of physical and mental activity that subjects wished to undertake (Figs.11, 12) but in these cases the differences were statistically significant. During the daytime, fatigue tended to be higher on the fasting day (Fig. 10). These results lend limited support to those found by us previously, [3]. Indicating that subjects “spare” themselves when fasting. Taken together, the results support the view that fasting in Ramadan has negative effects upon fatigue, partly due to the falls in glucose intake, and performance in general [14]-[15]-[16]-[17].

In the evening, the amounts of both physical and mental activity actually performed and the amounts wished for tended to increase towards, or even beyond, values on control days, even though, these increases were not as marked as those found previously, [2]-[3]. Any increase in physical and mental activities after the end of the fast is likely to reflect the social role played by food intake, [12]-[18]-[19]. The fact that it was not statistically significant in the present study (though there was still evidence that it was present) possibly indicates that

the effect is more marked in the Muslim community during the four weeks of Ramadan than in non-Muslim students performing only a single day of fasting.

Urine osmolality was quite high on waking on both days (Fig. 13), indicating the development of dehydration during sleep. The subsequent fall during the daytime on control days was due to the intake of fluids during the daytime. By contrast, urine osmolality (and dehydration) continued to rise during the daytime on the fasting day, as would be expected. Such results have been found previously in Ramadan, [20] - [4]. The observation that urine osmolality was not lower at 09:00h on the fasting day indicates that fluid intake before the start of the fasting period did not correct overnight dehydration. That is, even though subjects were more likely to drink before the start of the fasting period (see Fig. 1), the amount of fluid they drank was insufficient to correct any dehydration due to sleeping at night. This lack of successful preparation for the demands of daytime fasting can be compared with the extra fluid intake observed in Muslims in, [2]-[3]-[4]. There were no changes observed with grip strength (Fig. 14) ; no circadian rhythm was demonstrated on either day as well as no significant difference between the fasting and control days. It must be concluded either that this aspect of physical performance (maximal contraction of a limited muscle group) does not change with the amount of fasting undertaken in this study and/or that, as performed by these subjects in the conditions of the present experiment, the test was not sufficiently sensitive. Since other studies have shown a circadian rhythm of grip strength in subjects living normally, [9]. Lack of sensitivity as performed in the current study seems more likely.

Unlike grip strength, jump height rose significantly as the day progressed (Fig. 16). In addition, control and fasting days differed, with the rise on the fasting day being less marked. This difference was most marked at 18:00 h when the effects of fluid restriction are likely to have been most marked. Research involving vertical jumps in conditions of fluid and food restriction is sparse. However, [21] investigated the effect of hydration state and found no significant differences in vertical jump height when dehydration was such as to cause 2.5% and 5% reductions in body mass. This result differs from the present one possibly because. Achieved these levels not only by prohibiting water intake but also by requiring the subjects to perform an exercise-induced heat stress trial on the previous day.

Considering physical performance in general, it has often been considered that muscle power is comparatively immune to effects of sleep loss and fasting [9]. However, motivation to perform activities and neural control of movement are both affected negatively by sleep loss and fasting [22]. And these factors might have contributed to the decline in jump height observed later in the day when fasting. Whatever the detailed explanations of the results, the present findings have clear

implications for those required to perform physically demanding tasks after an interval of fasting.

The Stroop test showed a clear circadian rhythm (Fig. 15) with performance improving (time taken to finish the test decreasing) until about 15:00 h. These results accord with those from other tests of mental performance which tend to peak slightly earlier than core temperature, [7]. The reason generally given to explain the earlier peak than for core temperature is that mental performance is negatively affected far more than is core temperature by increasing time awake, [23]. As a result, performance begins to fall any time from noon onwards as effects due to time awake increase. Mental performance is also adversely affected by sleep loss and by fasting, [23]. In the current study, performance was lower on the fasting day (Fig. 15) but not by amounts that were statistically significant. This lack of statistical significance might reflect sample size as well as insufficient sensitivity of the test as performed in the present experiment.

With the task of throwing darts, no statistically significant rhythms were found in any of the three methods used for scoring this task (total score, number of misses and score per hit, Figs. 17-19, respectively). This contrasts with previous work, [6]. Where rhythms peaking in the afternoon have been found. Also, there were no statistically significant effects of fasting. Nevertheless, inspection of Figs. 17-19 suggests that performance tended to improve during the course of the daytime on control days (total score, Fig. 17 and score/hit, Fig. 19) whereas, though performance rose in the first part of the fasting day (at 09:00 h and 12:00 h), it then deteriorated (at 15:00 h and 18:00 h). This deterioration in comparison with the control day is shown by the falls in total score (Fig. 17) and score/hit (Fig. 19), and by the increased number of misses (Fig. 18). Such differences are unlikely to be due to effects of time awake, which were almost identical on control and fasting days. Instead, the deterioration at the end of the daytime is more likely to reflect negative effects of fasting, [20]. And this interpretation brings the findings in agreement with those from the jump test, discussed above. The high variability in the results (contributing to the lack of statistical significance) might have arisen in part from a learning effect, subjects differing in their previous experience of throwing darts and, possibly, not having had enough practice during the familiarization session.

Whilst it is not possible to deduce causal links from correlations, the results from such analyses can be used to support or refute possible links that have been deduced from other studies of interactions between circadian rhythms and the effects of sleep loss and restricted food and fluid intakes. For example, the following possible scenarios can be devised by considering the results in Table I. If individuals are tired (Fatigue), they tend to perform less physical, mental and social activities (Score P) and wish to do less (Score W). And (2). If individuals are dehydrated (Urine osmolality), then one of the general effects of this is to feel less inclined to perform physical or mental tasks (Score W). Moreover, positive correlations between different performance tasks are to be

expected in this experiment, both tasks being affected by fasting. For example: (3).the less activities that have been undertaken (Score P), the poorer will performance be at some tests (Stroop test). And (4) Poorer performance at one task (Stroop test) is likely to be associated with poorer performance at other tasks (Grip strength and Jump height).

V. GENERAL CONCLUSION

The present results accord with the concept that fasting is associated with a general decline in many aspects of subjective and objective performance and the sense of well-being. Many of these negative effects disappear in the evening after the fast is broken. These conclusions have been drawn also from previous studies performed upon Muslims during Ramadan, [2]-[3]-[4] and in reviews of the field [20]-[24]. That is, there is evidence that many of the results obtained in comparatively arduous studies performed upon Muslims during the month of Ramadan can be duplicated in the present simpler protocol which involved non-Muslim subjects fasting for a single day only. What is clear from both protocols is that a day of fasting causes deterioration in many aspects of an individual's physiology, psychology and biochemistry, particularly as the length of fasting increases, and that this has obvious implications for the individual's performance under such circumstances.

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