

AFFECTIVE AND PERCEIVED EXERTION RESPONSES DURING GRADED EXERCISE TEST IN FASTED AND NON-FASTED STATE: CYCLING VERSUS TREADMILL

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Abstract

This study assessed: 1) the effect of fasted and non-fasted states on the relationships between RPE and $\bar{V}O_2$, HR \bar{V}_E during treadmill and cycling GXT; 2) the effect of fasted and non-fasted states on the affective state during the cycling and treadmill GXTs. Ten Muslim male physical education students (22.3 ± 1.5 y) volunteered for the study. Each student performed two GXTs while fasting during Ramadan (one on the treadmill and one on the bike) and the same two GXTs while not fasting after Ramadan. The relationships between the RPE and \bar{V}_E , the RPE and $\bar{V}O_2$ and the RPE and HR were significantly higher ($P < 0.05$) in the non-fasted state compared to the fasted state ($R^2 = 0.946$ & $R^2 = 0.872$; $R^2 = 0.949$ & $R^2 = 0.866$; $R^2 = 0.949$ & $R^2 = 0.829$, respectively). There was no significant difference in the affective state between the fasted and non-fasted states ($P > 0.05$). RPE responses during the GXTs on treadmill and bike were affected during Ramadan fasting compared to a non-fasting state after Ramadan. This has very important implications especially when considering that there are numerous studies that have used sub-maximal RPE and $\bar{V}O_2$ to predict $\bar{V}O_{2max}$. This may be due to the lower glucose level during Ramadan fasting as indicated by the lower respiratory exchange ratio in the fasted compared to the non-fasted state. However, the GXTs on treadmill and bike during Ramadan fasting were felt to be as pleasant as when not fasting after Ramadan.

Keywords: Ramadan fast, GXT, RPE, Affective state, Treadmill, Cycling

Introduction

Specificity is one of the four exercise principles (Jackson et al., 1999; American College of Sports Medicine (ACSM), 2010). Specificity means that exercise adaptations and exercise responses are specific to the training

type (i.e., strength training versus cardiorespiratory training); exercise mode (i.e., leg cycling versus treadmill) and muscle mass (i.e., arms versus legs). Clausen et al. (1970) reported that leg training decreased the heart rate during leg exercise but not during arm exercise. Eston & Brodie (1986) reported significantly higher sub-maximal values of oxygen uptake, heart rate, rating of perceived exertion and pulmonary ventilation when arms and legs were trained at the same absolute sub-maximal exercise intensities. Al-Rahamneh & Al Kilani (2014) reported higher peak values for oxygen uptake, pulmonary ventilation, heart rate and respiratory exchange ratio during treadmill exercise compared to leg cycling while fasted and not-fasted states. These lower peak physiological values observed during arm cranking compared to leg cycling and during leg cycling compared to treadmill exercise can be attributed to the smaller muscle mass that is activated during arm exercise compared to leg cycling and during leg cycling compared to treadmill exercise (Åstrand et al., 2003; McArdle et al., 2007; ACSM, 2010).

The Borg 6-20 Rating of Perceived Exertion (RPE, Borg, 1998) has been used widely during the past three decades to complement exercise intensity monitoring alongside heart rate, oxygen uptake, heart rate reserve and oxygen uptake reserve (ACSM, 2010; Winter et al., 2007). Numerous studies have assessed the relationship between the RPE and the physiological indices of exercise intensity (e.g., Skinner et al., 1973; Borg et al., 1987; Hassmén, 1990; Faulkner & Eston, 2007; Al-Rahamneh et al., 2010; Al-Rahamneh et al., 2011). Very strong relationships between RPE and heart rate and between RPE oxygen uptake were reported during leg cycling (e.g., Skinner et al., 1973; Hassmén, 1990; Faulkner and Eston, 2007); treadmill exercise (e.g., Morris et al., 2010; Eston et al., 2012) and during arm cranking (e.g., Borg et al., 1987; Al-Rahamneh et al., 2010; Al-Rahamneh et al., 2011). These strong relationships were also evident during arm cranking in able-bodied and disabled individuals (Al-Rahamneh, 2010).

It is also well-established that RPE is sensitive to some external factors such as sex, physical fitness level, exercise intensity, caffeine intake and glycogen level. For example, women report higher RPE values compared to men at a given exercise intensity (Faulkner and Eston, 2007), whilst less fit individuals usually report higher RPE values at a given exercise intensity compared to persons with higher fitness levels (Faulkner and Eston, 2007). Participants have also reported higher RPE values when exercising at higher intensity (Al-Rahamneh and Eston, 2011), whilst participants have reported lower RPE values when exercising under caffeine conditions compared to a placebo (Backhouse et al., 2011). Participants have also reported higher RPE values when exercising under a carbohydrate-depleted condition compared to a carbohydrate-replete condition (Noakes, 2004).

During Ramadan fasting, it is established that blood glucose level is lower (Gueye et al., 2004; Larijani et al., 2003) and it has also been reported that the level of physical fitness is lower during Ramadan fasting for Muslim participants (Hallak and Nomani, 1988). Furthermore, sleeping patterns are negatively affected by Ramadan fasting as a result of food intake being at different times (Roky et al., 2004; Ziaee et al., 2006). During Ramadan, Muslims only have two opportunities for food intake: one after sunset (called the Iftar time) and the second at dawn (the Sahur time). These changes in the timing of food intake and sleeping patterns might also affect cognition abilities (Maughan et al., 2008; Roky et al., 2000). It has also been demonstrated that alertness and mood decrease during Ramadan fasting (Roky et al., 2000). However, no studies have assessed the effect of Ramadan fasting on predicting the $\dot{V}O_2$ peak from sub-maximal $\dot{V}O_2$ and RPE values.

From observations at the same RPE level, the exercise felt good to some participants and bad to others (Hardy & Rejeski, 1989). Therefore, the aim of the current study was to assess the effect of the fasting state (i.e., fasting and non-fasting states) and exercise mode (i.e., leg cycling and treadmill exercise) on: i) the relationship between the RPE and heart rate, pulmonary ventilation and oxygen uptake; ii) the affective state; iii) the interaction between the fasting states and exercise mode on the affective state and the relationships between the RPE and physiological variables. I hypothesized that; i) the relationship between the RPE and physiological variables would be lower in Ramadan fasting compared to non-fasting; ii) the exercise would be felt more negative in fasting compared to non-fasting state.

Methods

Participants

Ten Muslim male physical education students (mean \pm SD, 22.3 \pm 1.5 y, 176.0 \pm 4.9 cm, fasting weight 83.8 \pm 17.0 kg, non-fasting weight 84.1 \pm 17.1 kg) from the Faculty of Physical Education and Sport Sciences at the Hashemite University provided informed consent to take part in the study. The inclusion criteria were: 1) being in good health and free of disease; 2) being physically active (i.e., > 3 hours per week); 3) engaging in fasting during Ramadan. This study was conducted in accordance with institutional ethics approval from the Faculty of Physical Education at the University of Jordan.

Procedures

The fasting data were collected during Ramadan, which is the ninth month of the lunar calendar, 2013 and the non-fasting data were collected in

the second 10 days of Shawwāl, which is the tenth month of the lunar calendar. This study involved a repeated measures design in which each student was required to attend the laboratory on four separate occasions. These included two fasted occasions during Ramadan. The study involved graded exercise tests (GXT) to exhaustion to measure peak oxygen uptake (i.e., one on the treadmill and one on the bike) and on two non-fasting occasions after Ramadan the participants performed the same graded exercise tests. The two GXTs, in Ramadan and after Ramadan, were conducted in a random and counterbalanced order. The treadmill GXTs employed a Bruce protocol (Bruce et al., 1973), in which the speed and incline were increased every 3 minutes until volitional exhaustion. In the cycling GXTs, the resistance was increased by 30 W every 3 minutes until volitional exhaustion.

The two fasting GXTs performed during Ramadan were conducted in the last 10 days of Ramadan in order for the students to become familiarized with fasting and to ensure that the effect of fasting had occurred. The two fasting GXTs were conducted in a random and counterbalanced order, and separated by 48 hours. Similarly, the two non-fasting GXTs were conducted in a randomized and counterbalanced order 10 days after the fast of Ramadan. These tests were also separated by 48 hours. The participants were requested to avoid moderate and vigorous exercise for 48 hours prior to the exercise tests.

On-line respiratory gas analysis was undertaken breath-by-breath during each exercise test via an automatic gas calibrator system (Quark PFT, Cosmed, Rome, Italy). The system was calibrated before each exercise test using a 3-L syringe for volume calibration and ambient air for gas calibration according to the manufacturer's guidelines. Heart rate (HR) was recorded continuously using a wireless chest strap telemetry system (Polar Electro T31, Kempele, Finland). The participants were asked to report their overall Rating of Perceived Exertion (RPE, Borg, 1998) during the last 20 seconds of each stage and upon completion of the exercise. The leg cycling GXT was terminated if the participant could not maintain the pedal cadence within 5 RPM for more than 20 consecutive seconds or if the participant reached volitional exhaustion.

Measurements

Borg 6-20 Rating of Perceived Exertion

The participants were familiarized with the Borg 6-20 RPE scale and were given standardized instructions on how to report their overall feelings of exertion (RPEo) prior to each exercise test (Borg, 1998). Any questions concerning the scale were answered before the exercise commenced. The

participants reported their RPEo upon completion of the exercise tests and in the remaining 20 seconds of each stage during the GXT.

Affective scale

The participants were asked to rate how good or bad the exercise felt using an 11-point bipolar scale with verbal anchors at +5 very good, +3 good, +1 fairly good, 0 neutral, -1 fairly bad, -3 bad and -5 very bad (Rejeski et al., 1987; Hardy and Rejeski, 1989). The participants reported how good or bad the exercise felt upon completion of the GXTs and during the last 20 seconds of each stage of the GXTs in both the fasted and non-fasted states.

Exercise tests

Treadmill exercise tests

The two GXTs on the treadmill were performed on a motorized treadmill (HP Cosmos, Traunstein, Germany). The Bruce protocol (Bruce, Kusami, & Hosmer, 1973), in which a continuous and incremental procedure is used, was started at a speed of 2.74 km h⁻¹ and a gradient of 10%, and the gradient was increased by 2% every 3 minutes in line with simultaneous increments at speeds of 2.74, 4.02, 5.47, 6.76, 8.05 and 8.85 km h⁻¹. The exercise test was terminated when the participants reached volitional exhaustion, although they were verbally encouraged to continue the exercise test. If the participant completed at least 1.5 minutes during the last stage, this was considered to be the peak speed and peak incline and the highest volume of oxygen uptake recorded during the last 30 seconds of each stage was considered to be the $\dot{V}O_{2peak}$.

Leg cycling

The two leg cycling GXTs were performed on a Monark bike (Monark, Ergomedic 894 E, Varberg, Sweden). A continuous and incremental procedure was employed. The pedal cadence was set at 60 revolutions per minute (rpm) and the resistance was increased by 30 W every 3 minutes (0.5 kg every 3 minutes). After warming up for 3 minutes at 0 W the exercise test commenced at 60 W and the resistance was increased by 30 W every 3 minutes. The test was terminated if the participant could not maintain a pedal cadence within 5 RPM for more than 20 consecutive seconds or if the participant reached volitional exhaustion. If the participant completed at least 1.5 minutes during the last stage this was considered to be the Peak Power Output (PO_{peak}) and the highest volume of oxygen uptake recorded during the last 30 seconds of each stage was considered as the $\dot{V}O_{2peak}$.

Data and statistical analysis

The data were checked for normality using the Shapiro-Wilk test (Field, 2009). Mauchly's test was used to confirm the assumptions of sphericity for repeated measures ANOVA (Field, 2009). Where this was not confirmed, the Greenhouse–Geisser correction factor was applied to correct the degrees of freedom (Field, 2009). All data were analyzed using the Statistical Package for Social Sciences (SPSS) for Windows, PC software, version 21. Alpha was set at $P < 0.05$.

Peak physiological and perceptual values

A series of two-way repeated measures analysis of variance (i.e., state; fasted and non-fasted; and exercise mode; treadmill and cycling) was used to assess the effect of fasting on the peak values for oxygen uptake, heart rate, ventilation, respiratory exchange ratio, and rating of perceived exertion and whether these values are affected by exercise mode.

Relationship between the RPE and physiological variables

The RPE values recorded during the last 20 seconds of each stage and at the end of the GXT were regressed against the corresponding mean \bar{V}_{O_2} , HR and \bar{V}_E in a linear regression analysis for each participant. Individual R^2 values were obtained for each participant to identify the relationship between the RPE and \bar{V}_{O_2} , HR and \bar{V}_E . All R^2 values calculated via the linear regression analyses were converted to Fisher Z_r values to approximate for the normality of the data distribution (Thomas et al., 2005). This is deemed appropriate because it has been indicated that a sampling distribution of high correlation coefficients may not be normally distributed (Thomas et al., 2005). A three-way repeated measure ANOVA (State, fasted and non-fasted; Relationship, RPE: \bar{V}_E , RPE: \bar{V}_{O_2} and RPE: HR; Exercise mode, cycling and treadmill) was used to assess the effect of fasting on the strength of the relationships between the RPE and the physiological indices of exercise intensity and to assess whether there was a significant interaction between exercise mode (cycling and treadmill) and fasting state (fasting and non-fasting) on these relationships.

Affective state

The participants were asked to report their affective state using the Hardy and Rejesci (1989) affective scale during the last 20 seconds of each stage and upon completion of the GXT. Three-way repeated measure ANOVA (Affective at: 20 %, 40 %, 60 %, 80 % and 100 % of the exercise time), (State: fasted and non-fasted) and (Exercise mode: cycling and treadmill) was used to assess the effect of fasting on the affective state

during exercise and whether there was an interaction between state and exercise mode on the affective values.

Results

Peak physiological and perceptual values

The peak values observed upon termination of the treadmill and cycling GXTs for oxygen uptake, heart rate, pulmonary ventilation, respiratory exchange ratio and rating of perceived exertion in the fasted and non-fasted states are presented in table 1.

Table 1: Peak values for oxygen uptake, heart rate, pulmonary ventilation, respiratory exchange ratio and rating of perceived exertion observed upon termination of the exercise test on the treadmill and the cycling ergometry in the fasted and non-fasted states. Values are mean \pm Standard deviation (SD). N = 10.

Fasting state\ Exercise mode	$\sqrt{V}O_2$ peak (ml.kg ⁻¹ .min ⁻¹)	HRmax (b.min ⁻¹)	\sqrt{V}_E (L.min ⁻¹)	RER	RPE	Time to exhaust ion (minute s)
Treadmill fasted	59.6 \pm 8.4*	188 \pm 9*	148 \pm 25 π	1.05 0.05*	17.6 \pm 2.1	13.0 \pm 1.9
Treadmill non- fasted	58.2 \pm 12.3*	189 \pm 10*	159 \pm 18	1.09 \pm 0.08*	18.4 \pm 1.4	12.8 \pm 1.6
Cycling fasted	52.1 \pm 9.4	182 \pm 9	140 \pm 19 π	0.95 \pm 0.04 π	18.2 \pm 1.8	17.8 \pm 2.0
Cycling non- fasted	49.6 \pm 11.5	183 \pm 8	150 \pm 19	1.06 \pm 0.09	18.3 \pm 1.7	17.8 \pm 2.9

* Significant difference between leg cycling and treadmill exercise

π Significant difference between fasted and non-fasted states

Paired sample t-test showed no significant difference in body mass between fasting and non fasting state ($t_{(9)} = 0.51$, $P > 0.05$); therefore, relative not absolute peak oxygen uptake was used in the analysis. There was no significant difference in the peak oxygen uptake values between the fasting and non fasting states ($F_{(1,9)} = 2.309$, $P > 0.05$). The peak oxygen uptake values observed during the treadmill exercise test were significantly higher than those observed during the cycling exercise test ($F_{(1,9)} = 47.717$, $P < 0.05$). There was no significant interaction between fasting state (i.e., fasting and non fasting) and exercise mode (i.e., treadmill and cycling) on peak oxygen uptake values ($F_{(1,9)} = 0.247$, $P > 0.05$). There was no significant difference in the maximal heart rate between the fasted and non-fasted states ($F_{(1,9)} = 0.736$, $P > 0.05$). The maximal heart rate observed during the treadmill exercise test was significantly higher than that observed during the cycling exercise test ($F_{(1,9)} = 10.694$, $P < 0.05$). There was no significant interaction between fasted state (i.e., fasted and non-fasted) and exercise mode (i.e., treadmill and cycling) on the peak heart rate values ($F_{(1,9)}$

= 0.183, $P > 0.05$). The peak ventilation values were significantly higher while exercising in the non-fasted state compared to the fasted state ($F_{(1,9)} = 6.306$, $P < 0.05$). No significant difference was observed in the peak ventilation values between the treadmill exercise test and the cycling exercise test ($F_{(1,9)} = 3.118$, $P > 0.05$). There was no significant interaction between fasting state (i.e., fasted and non-fasted) and exercise mode (i.e., treadmill and cycling) on the peak ventilation values ($F_{(1,9)} = 0.013$, $P > 0.05$). There was no difference in the peak overall RPE values between the fasted and non-fasted states ($F_{(1,9)} = 3.488$, $P > 0.05$). There was no significant difference in the peak overall RPE values observed during the treadmill exercise test and the bike exercise test ($F_{(1,9)} = 0.413$, $P > 0.05$). There was no significant interaction between fasting state (i.e., fasting and non fasting) and exercise mode (i.e., treadmill and cycling) on the peak overall RPE values ($F_{(1,9)} = 0.612$, $P > 0.05$). The peak respiratory exchange ratio values were significantly higher while exercising in the non-fasted state after Ramadan ($F_{(1,9)} = 10.17$, $P < 0.05$). The peak respiratory exchange ratio values were also significantly higher in the treadmill exercise test compared to the cycling exercise test ($F_{(1,9)} = 22.31$, $P < 0.01$). There was a significant interaction between fasting state (i.e., fasting and non fasting) and exercise mode (i.e., treadmill and cycling) on the peak respiratory exchange ratio values ($F_{(1,9)} = 8.26$, $P < 0.05$). Post hoc analysis using a paired sample t-test with Bonferroni adjustment ($P = 0.025$) showed that the peak RER values were significantly higher in the non-fasted state after Ramadan compared to the fasted state in Ramadan for the cycling exercise test ($P = 0.002$). Time to exhaustion was similar between fasting and non-fasting state ($F_{(1,9)} = 0.262$, $P > 0.01$). Time to exhaustion was longer during cycling compared to treadmill ($F_{(1,9)} = 51.417$, $P < 0.001$). There was no significant interaction between fasting state (i.e., fasting and non fasting) and exercise mode (i.e., treadmill and cycling) on time to exhaustion ($F_{(1,9)} = 0.0145$, $P > 0.01$).

Relationship between the RPE and physiological variables

The relationships between the RPE and pulmonary ventilation and between the RPE and oxygen uptake and between the RPE and heart rate for both the treadmill and cycling GXTs in the fasted and non-fasted states are presented in table 2.

Table 2: The relationships between the RPE and physiological variables during the treadmill and cycling GXTs in the fasted and non-fasted states when the Fisher Zr values were reconverted to R^2

State/ Relationships	RPE and $\sqrt{V_E}$	RPE and $\sqrt{V_{O_2}}$	RPE and HR
Fasted Treadmill	0.940 ^o	0.866	0.829
Non-fasted treadmill	0.973* ^o	0.927*	0.919*
Fasted cycling	0.872	0.944 ^π	0.927 ^π
Non-fasted cycling	0.918*	0.970* ^π	0.978* ^π

*Significant difference between fasted and non-fasted states

^π Significantly higher than treadmill GXT ^o Significantly higher than cycling GXT

There was no significant difference in these relationships between the RPE and the physiological indices of exercise intensity ($F_{(1,244, 11.195)} = 0.388$, $P > 0.05$). The relationships between the RPE and physiological markers were significantly higher during the non-fasted state compared to the fasted state ($F_{(1, 9)} = 48.480$, $P < 0.05$). There was no significant difference between the treadmill and leg cycling in these relationships ($F_{(1, 9)} = 2.871$, $P > 0.05$). There was no significant interaction in these relationships between the RPE and physiological markers and state ($F_{(1,274, 11.466)} = 0.899$, $P > 0.05$). There was no significant interaction between state and exercise mode on the relationships between the RPE and the physiological markers ($F_{(1, 9)} = 0.018$, $P > 0.05$). There was no significant interaction in the relationships between the RPE and physiological markers and state and exercise mode ($F_{(1,247, 11.224)} = 0.534$, $P > 0.05$). However, there was a significant interaction in the relationships between the RPE and physiological markers and exercise mode ($F_{(2, 18)} = 71.549$, $P < 0.05$). Post hoc analysis using Tukey HSD showed that the relationship between the RPE and pulmonary ventilation was significantly higher during the treadmill GXT compared to the cycling GXT ($P < 0.05$). Tukey HSD also showed that the relationships between the RPE and oxygen uptake and between the RPE and heart rate were significantly higher during the leg cycling GXT compared to the treadmill GXT ($P < 0.05$).

Affective state

A three way repeated measure ANOVA showed that the affective state decreased across time ($F_{(1,941, 17.469)} = 60.401$, $P < 0.05$). There was no significant difference in the affective state between the fasted and non-fasted states ($F_{(1, 9)} = 0.768$, $P > 0.05$). The affective state was lower during cycling compared to the treadmill GXT ($F_{(1, 9)} = 5.258$, $P < 0.05$). There was no significant interaction between the affective state and fasting state ($F_{(4, 36)} = 2.328$, $P > 0.05$). There was no significant interaction between exercise mode and fasting state on the affective state ($F_{(1, 9)} = 1.400$, $P > 0.05$). There was no significant interaction between affective state and exercise

mode and fasting state ($F_{(4, 36)} = 0.253, P > 0.05$). However, there was a significant interaction between time and exercise mode on the affective state ($F_{(4, 36)} = 2.998, P < 0.05$). Post hoc analysis using Tukey HSD showed that the affective state was lower during cycling at 40%, 60% and 80% of the exercise time compared to the treadmill ($P < 0.05$). The affective state during the cycling and treadmill GXTs at 20%, 40%, 60%, 80% and 100% of exercise time in the fasted and non-fasted states is depicted in **table 3**.

Table 3: shows the mean values for the affective state observed at 20%, 40%, 60%, 80% and 100% of exercise time for both the treadmill and cycling in the fasted and non-fasted states

Time/States	Affect at 20%	Affect at 40%	Affect at 60%	Affect at 80%	Affect at 100%
Fasted Treadmill	4.2 ± 1.0	3.2 ± 1.0	3.0 ± 1.7	1.2 ± 2.1	-1.8 ± 2.0
Non-fasted treadmill	3.8 ± 1.4	3.4 ± 1.4	2.3 ± 1.4	0.1 ± 1.1	-2.5 ± 1.5
Fasted cycling	3.6 ± 0.7	2.3 ± 1.6*	1.4 ± 2.0*	0.1 ± 1.9*	-2.3 ± 2.2
Non-fasted cycling	3.8 ± 1.2	2.7 ± 1.4*	1.4 ± 2.1*	-0.1 ± 2.4*	-2.1 ± 2.0

*Significant difference between cycling and treadmill in the affective state

Discussion

The primary aim of this study was to assess the effect of Ramadan fasting on the relationship between the RPE and \bar{V}_{O_2} , HR and \bar{V}_E . This study also assessed the effect of Ramadan fasting on the affective state. Finally, this study assessed whether there was an interaction in the relationships between the RPE and physiological markers of exercise intensity and state (fasted and non-fasted) and exercise mode (treadmill and cycling) and the interaction between the affective state and state (fasted and non-fasted) and exercise mode (treadmill and cycling). To the best of my knowledge this is the first study that has investigated the effect of Ramadan fasting on the relationships between the RPE and \bar{V}_{O_2} , HR and \bar{V}_E and its effect on the affective state during treadmill and cycling GXTs. I found that that \bar{V}_{O_2} peak, HRmax and maximal RPE are not affected by the fasted state (Table 1). However, the peak pulmonary ventilation values were significantly lower and the peak respiratory exchange ratio values were lower during the fasted state compared to the non-fasted state. The relationships between the RPE and \bar{V}_{O_2} , HR and \bar{V}_E were significantly higher in the non-fasting state compared to the fasted state (Table 2). It was found that the fasted state did not affect how pleasant or unpleasant the exercise felt (Table 3).

Peak values in fasted and non-fasted state

There were no significant differences in the peak values for heart rate, oxygen uptake and rating of perceived exertion. The findings of a

similar peak oxygen uptake, heart rate and rating of perceived exertion are not surprising, as these variables are dependent on the work rate being performed, which was similar in both the fasted and non-fasted states. More details regarding the peak power output, peak speed and peak incline can be observed in Al-Rahamneh & Al Kilani (2014). These findings are not surprising as the exercise tests in Ramadan were conducted in the morning after 6-7 hours of fasting to avoid severe hunger and thirst during the middle and end of the day. However, the peak respiratory exchange ratio values and peak pulmonary ventilation values were significantly lower in the fasted state during Ramadan compared to the non-fasted state. This could be attributed to the lower glucose levels found in the body while fasting in Ramadan; there is greater oxidation of fat than carbohydrate. Thus, is it possible that had testing occurred later in the day, the relationships found in the current study would have been significantly different? Gueye et al. (2004) showed a lower blood glucose level while resting during fasting. The lower fasted RER values are in agreement with Stannard & Thompson (2008), who observed lower RER values in the fasted state than the pre-fasted state, especially when the participants were exercising at 45 % of their $\dot{V}O_2\text{max}$. Lower peak RER values in a fasted compared to a non-fasted state were accompanied by lower pulmonary ventilation values. RER values above 1.10 are used as secondary criteria for achieving $\dot{V}O_2\text{peak}$. Therefore, if lower RER values are observed in the fasted state, it might be falsely declared that the subject has not reached their $\dot{V}O_2\text{peak}$.

The higher peak values for oxygen uptake, heart rate, pulmonary ventilation and respiratory exchange ratio during treadmill exercise compared to leg cycling are very expected. These differences in these peak values between the two modes of exercise are due to the larger muscle mass that are activated during treadmill exercise compared to leg cycling (Åstrand et al., 2003; McArdle et al., 2007; ACSM, 2010).

Relationship between the RPE and physiological variables

All *R* squared values between the RPE and HR, RPE and $\dot{V}O_2$, RPE and \dot{V}_E were ≥ 0.829 during the GXT while fasting in Ramadan and during the non-fasting GXT after Ramadan. The very strong linear relationships between the RPE and physiological indices of exercise intensity are in agreement with previous research during leg cycling (Skinner et al., 1973; Faulkner and Eston, 2007), arm cranking (Borg et al., 1987; Al-Rahamneh et al., 2010; Al-Rahamneh et al., 2011) and treadmill exercise (Morris et al., 2010; Eston et al., 2012). These findings are not surprising since the exercising person appraises his/her overall rating of perceived exertion based on the input from the working muscles and cardio respiratory system (Borg,

1998). In fact, the Borg 6-20 RPE scale was constructed to correlate with HR values (Borg, 1998). In general, each RPE unit is equal to 10 beats of the heart. The relationships between the RPE and physiological markers were significantly lower during the fasted state compared to the non-fasted state for the treadmill and cycling. The strong relationships between the RPE and physiological variables in the fasted and non-fasted states during the GXTs are in disagreement with Leiper et al. (2008). These authors reported similar RPE values before, during and after Ramadan training in football players, although these players reported higher subjective ratings of tiredness before training during Ramadan compared to before and after Ramadan training.

The stronger relationships between the RPE and HR, RPE and $\dot{V}O_2$, RPE and \dot{V}_E during non-fasting compared to fasting state might be due to the fact that these exercise tests were conducted during the last 10 days of Ramadan. Therefore most the effect of Ramadan had already occurred, which in turn may have affected the RPE responses during these GXTs as well as the relationships between the RPE and physiological markers of exercise intensity. This may in turn affect the prediction of peak oxygen uptake from sub-maximal RPE and $\dot{V}O_2$ while fasted compared to non-fasted state.

Affective state

How good/pleasant or bad/unpleasant the exercise feels is an important factor in determining participation in physical activity and exercise adherence. Williams et al. (2008) reported that a shift of one unit in the feeling scale was connected with a 38 minute increase in physical activity per week at six months and a 41 minute increase in physical activity per week at 12 months. William et al. (2008) & (2012) also reported that a decrease of one unit on the affect scale is accompanied by a 15-29 minute reduction in physical activity in the later 6 months. Exercise intensity and physical fitness level therefore affect how good and/or bad exercise feels. For example, participants reported that the exercise felt more negative at 90 % $\dot{V}O_2$ max compared to 60 % $\dot{V}O_2$ max (Parfitt et al., 1994). Additionally, the exercise felt more negative for less active participants at both 60 % $\dot{V}O_2$ max and 90 % $\dot{V}O_2$ max (Parfitt et al., 1994).

In the current study, the higher the exercise intensity the less pleasurable the exercise felt (Table 3); this is in accordance with Parfitt et al. (1994). There was no significant difference in the affective state during the fasted state during Ramadan and the non-fasted state after Ramadan. This means that exercising while fasting during Ramadan does not feel more negative or less pleasurable compared to the non-fasted state after Ramadan. This is important, as individuals do not feel exercise more negatively whilst

fasting especially when considering that this was a maximal exercise test. Therefore, Muslims can perform maximal exercise tests while fasting in Ramadan without feeling that the exercise is more negative or less pleasant.

Conclusion

Peak values for oxygen uptake, heart rate and rating of perceived exertion are not affected by Ramadan fasting for either the treadmill or cycling exercise modes. The pulmonary ventilation and respiratory exchange ratio were significantly lower during Ramadan fasting compared to not fasting after Ramadan. The relationships between the RPE and pulmonary ventilation, heart rate and oxygen uptake were significantly lower during Ramadan fasting compared to not fasting after Ramadan. The relationships between the RPE and heart rate and oxygen uptake were higher in the cycling compared to the treadmill. The relationship between the RPE and ventilation was higher in the treadmill compared to the cycling. The fasted state did not affect how bad or good the GXT felt. However, the treadmill mode of exercise felt better than the cycling exercise mode. Finally, GXTs can be performed while fasting in Ramadan without affecting peak oxygen uptake and maximal heart rate and without affecting our exercising mood (affective state). However, the RPE responses may be affected. Therefore, researchers should be aware of that when predicting peak oxygen uptake from sub-maximal RPE and $\dot{V}O_2$ values. Researchers and coaches should also be aware of lower RER values in Ramadan fasting, which is a normal response to the lower glucose level during fasting.

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