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Original Article

The effects of Ramadan fasting on peak physiological function of active college-aged males during graded treadmill and cycling testing

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Abstract:
Aim: This study assessed the effect of Ramadan fasting on peak physiological markers of exercise intensity. Methods: Ten physical education students (22.3 ± 1.5 y, 176.0 ± 4.9 cm, 83.8 ± 17.0 kg) volunteered for the study. Each participant completed four graded exercise tests; two on the treadmill and two on the bike. Two graded exercise tests were conducted in Ramadan and two after Ramadan. Results: Peak oxygen uptake values were similar in Ramadan and after Ramadan for treadmill (59.6 ± 8.4 ml. kg.min^{-1} vs. 58.2 ± 12.3 ml. kg.min^{-1}, respectively) and cycling (52.1 ± 9.4 ml. kg.min^{-1} vs. 49.6 ± 11.5 ml. kg.min^{-1}, respectively). Similar findings were observed for power output, speed, heart rate and rating of perceived exertion. However, respiratory exchange ratio values were significantly lower ($P < 0.05$) in Ramadan compared to after Ramadan for cycling (0.95 ± 0.04 vs. 1.06 ± 0.09, respectively) and lower for treadmill (1.05 ± 0.05 vs. 1.09 ± 0.08, respectively). Ventilation values were significantly higher after Ramadan compared to Ramadan for both exercise modes. Conclusion: Although peak oxygen uptake and performance are not affected by Ramadan fasting for treadmill and cycling; respiratory exchange ratio and ventilation were lower during Ramadan compared to after Ramadan.
Key words: Ramadan, Peak Physiological Variables, Performance, Treadmill, Cycling

Introduction

Fasting during the holy month of Ramadan, the ninth month in the lunar calendar, is one of the five Islamic religion pillars. During the holy month of Ramadan, Muslims fast from the sunrise until the sunset. Muslims are allowed to eat and drink from the sunset (Iftar time) until the dawn time (Sahur time). Such changes in eating habits have an effect on sleeping patterns (Kirkendall, Leiper, Bartagi, Dvorak, & Zerguini, 2008; Roky, Houti, Moussamih, Qotbi, & Aadil, 2004) which may in turn be one cause of motor vehicle accidents that occur during Ramadan (Shanks, Ansari, & al-Kalai, 1994). Such changes in food intake habits may also affect body composition and body mass. For example, Maughan et al. (2008) observed a significant reduction in body mass in male football players in week two and week four of Ramadan compared to before Ramadan, but they did not observe significant differences in body fat.

Blood glucose level is lower during the day time of Ramadan while not exercising (Gueye, Samb, Seck, Cisse, & Martineaud, 2004). Stannard and Thompson, (2008) have indicated that low carbohydrate level during Ramadan fasting may affect physical work capacity, and Hallack and Nomani, (1988) have indicated that physical activity level is reduced for many Muslims during Ramadan. It has also been indicated that some physical fitness elements such as endurance capacity, agility and speed are significantly reduced at the end of Ramadan in professional football players (Zerguini, Kirkendall, Junge, & Dvorak, 2007).

Peak oxygen uptake is the highest volume of oxygen that an individual can transport, take up and use at the end of maximal exercise test (American College of Sports Medicine (ACSM, 2010); Åstrand, Rodahl, Dahl, & StrØmme, 2003). Most exercise physiologists consider peak oxygen uptake as the gold standard of cardiorespiratory fitness (ACSM, 2010; Åstrand et al., 2003). It is also a powerful predictor of mortality in patients with heart diseases and in all-cause mortality (Kavanagh et al., 2002). Peak oxygen uptake is affected by muscle mass that is involved in the exercise. Specifically, peak oxygen uptake is higher when a larger muscle mass is engaged in exercise. Accordingly, peak oxygen uptake is higher in running compared to leg cycling (Dunbar et al., 1992) and lower in arm cranking compared to leg cycling (Al-Rahamneh, 2010; Eston & Brodie, 1986). Some important sports competitions may take place in Ramadan. For example, the Olympic Games in 2010 in London took place from July 27th to August 12th and in the same year (2010) Ramadan took place from July 21st to August 20th. Therefore, some athletes and coaches might need to measure peak oxygen uptake, especially for aerobic sports such as marathon and long distances races. In addition, lay people may be encouraged to start exercising in Ramadan since they can easily control their diet in Ramadan. As such, physical

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fitness specialists might be interested in evaluating initial physical fitness level for lay people in Ramadan before starting their exercise programme. Therefore, the purpose of this study was to assess the effect of Ramadan fasting on peak oxygen uptake ($\dot{V}O_2peak$). The second purpose of this study was to assess whether measured $\dot{V}O_2peak$ values in Ramadan is affected by exercise mode (i.e., treadmill versus cycle ergometer).

Methods

Participants

Ten Muslim male physical education students (mean ± SD, 22.3 ± 1.5 y, 176.0 ± 4.9 cm, fasting weight 83.8 ± 17.0 kg, non-fasting weight 84.1 ± 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. Inclusion criteria were: 1, in good health and free of disease; 2, physically active (i.e., > 3 hours per week); 3, engage in fast Ramadan. This study was conducted in accordance with institutional ethics approval from the University of Jordan.

Procedures

Fasting data were collected in Ramadan 2013 and 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 and involved a graded exercise tests (GXT) to exhaustion to measure peak oxygen uptake (i.e., one on the treadmill and one on the bike) and two non-fasted occasions after Ramadan to perform the same two 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 the incline were increased every 3 minutes until volitional exhaustion. In the cycling GXTs, resistance was increased by 30 W every 3 min until volitional exhaustion.

The two fasting GXT in Ramadan were conducted in the last 10 days of Ramadan in order to get the students familiarized with fasting and to assure that the effect of fasting has happened. These two fasting GXT 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 counterbalance order 10 days after the fast of Ramadan. These tests were also separated by 48 h. Participants were requested to avoid moderate and vigorous exercise intensity in the 48 h prior the exercise tests.

On-line respiratory gas analysis occurred 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). Participants were asked to report their overall Rating of Perceived Exertion (RPE, Borg, 1998) during the last 20 seconds of each stage and at the 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.

Exercise tests

Treadmill exercise tests

The two GXTs on the treadmill were performed on motorized treadmill (HP Cosmos, Traunstein, Germany). The Bruce protocol (Bruce, Kusami, & Hosmer, 1973), in which a continuous and incremental procedure was used, started at a speed of 2.74 km h-1 and a gradient of 10%, increasing in gradient by 2% every 3 min in line with simultaneous increments in speed of 2.74, 4.02, 5.47, 6.76, 8.05 and 8.85 km h-1. The exercise test was terminated when 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 s of each stage was considered as the $\dot{V}O_2peak$.

Leg cycling

The two leg cycling GXTs were performed on Monark bike (Monark, Ergomedic 894 E, Varberg, Sweden). A continuous

and incremental procedure was employed. Pedal cadence was set at 60 revolutions per minute (rpm) and the resistance was increased by 30 W every 3 min (0.5 kg every 3 minutes). After warming up for 3 min at 0 W the exercise test commenced at 60 W and increased by 30 W every 3 min. The test was terminated if the participant could not maintain pedal cadence within 5 RPM for more than 20 consecutive seconds or if the participant reached volitional exhaustion. If the participant completed 1.5 minute at least during the last stage it was considered to be the Peak Power Output (POpeak) 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 analysis

Data were checked for normally using Shapiro-Wilk test (Field, 2009). A series of two way repeated measures analysis of variance (i.e., state; fasting and non fasting; and exercise mode; treadmill and bike) was used to assess the effect of fasting on peak values for oxygen uptake, heart rate, ventilation, respiratory exchange ratio, rating of perceived exertion and whether these values are affected by exercise mode. A series of paired sample t-test were used to assess the effect of fasting (i.e., Ramadan and after Ramadan) on peak power output during cycling, peak speed and peak incline during the treadmill exercise test. All data were analyzed using the Statistical Package for Social Sciences (SPSS) for Windows, PC software, version 16. Alpha was set at $P < 0.05$.

Results

Shapiro-Wilk test showed that data were normally distributed. There was no significant difference in peak oxygen uptake values between fasting and non fasting state ($F_{(1,9)} = 2.31$, $P > 0.05$). Peak oxygen uptake values observed during treadmill exercise test were significantly higher compared to the cycling exercise test ($F_{(1,9)} = 47.72$, $P < 0.05$). 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 ($F_{(1,9)} = 0.25$, $P > 0.05$).

Table 1: Peak values for oxygen uptake, heart rate, ventilation, respiratory exchange ratio and rating of perceived exertion observed at the termination of the exercise test on the treadmill and the bike in the fasted and non-fasted state. Values are mean ± Standard deviation (SD). N = 10.

Fasting state\ Exercise mode	$\dot{V}O_2$peak (ml.kg^{-1}.min^{-1})	HRmax (b.min^{-1})	$\dot{V}_E$ (L.min^{-1})	RER	$\dot{V}CO_2$peak (L.min^{-1})	$\dot{V}_E/\dot{V}O_2$ (L.min^{-1})	$\dot{V}_E/\dot{V}CO_2$ (L.min^{-1})	RPE
Treadmill fasting	59.6 ± 8.4*	188 ± 9*	148 ± 25*	1.05 ± 0.05*	5017 ± 814*	31 ± 3*π	30 ± 3*π	17.6 ± 2.1
Treadmill non-fasting	58.2 ± 12.3*	189 ± 10*	159 ± 18*	1.09 ± 0.08*	5031 ± 590*	34 ± 4*	32 ± 3	18.4 ± 1.4
Cycle fasting	52.1 ± 9.4	182 ± 9	140 ± 19	0.95 ± 0.04π	3974 ± 340	33 ± 5π	35 ± 4*π	18.2 ± 1.8
Cycle non fasting	49.6 ± 11.5	183 ± 8	150 ± 19	1.06 ± 0.09	4049 ± 567	38 ± 7	37 ± 4	18.3 ± 1.7

* Significant difference between leg cycling and treadmill exercise
π Significant difference between fasted and non-fasted state

There was no significant difference in maximal heart rate between fasted and non-fasted state ($F_{(1,9)} = 0.74$, $P > 0.05$). Maximal heart rate observed during the treadmill exercise test was significantly higher compared to the cycling exercise test ($F_{(1,9)} = 10.69$, $P < 0.05$). There was no significant interaction between fasted state (i.e., fasted and non-fasted) and exercise mode (i.e., treadmill and cycling) on peak heart rate values ($F_{(1,9)} = 0.18$, $P > 0.05$).

Peak ventilation values were significantly higher while exercising in the non-fasted state compared to fasted state ($F_{(1,9)} = 6.31$, $P < 0.05$). No significant difference was observed in peak ventilation values between treadmill exercise test and the cycling exercise test ($F_{(1,9)} = 3.12$, $P > 0.05$). There was no significant interaction between fasting state (i.e., fasted and non-fasted) and exercise mode (i.e., treadmill and cycling) on peak ventilation values ($F_{(1,9)} = 0.01$, $P > 0.05$).

Table 2: Peak physical values (i.e., power output, speed, incline and time). Values are mean ± Standard deviation (SD). N = 10.

Fasting state\ exercise mode	PO (W)	Speed (Km)	Incline (%)	Time (min: s)
Treadmill fasting	-	7.1 ± 0.9	16.6 ± 1.4	13.2 ± 1.52
Treadmill non fasting	-	7.1 ± 0.9	16.6 ± 1.4	12.46 ± 1.37
Bike fasting	207 ± 22	-	-	17.49 ± 1.57
Bike non fasting	210 ± 28	-	-	17.46 ± 2.53

Peak respiratory exchange ratio values were significantly higher while exercising in the non-fasted state after Ramadan ($F_{(1,9)} = 10.17$, $P < 0.05$). 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 peak respiratory exchange ratio values ($F_{(1,9)} = 8.26$, $P < 0.05$). Post hock analysis using paired sample t-test with Bonferroni adjustment ($P = 0.025$) showed that 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 ($P = 0.002$).

There was no significant difference in peak carbon dioxide values ($\dot{V}CO_2$peak) between fasted and non-fasted state ($F_{(1,9)} = 0.10$, $P > 0.05$). Peak $\dot{V}CO_2$ values were higher during treadmill exercise test compared to the cycling exercise test ($F_{(1,9)} = 50.38$, $P < 0.001$). There was no significant interaction between fasting condition (i.e., fasted and non-fasted) and exercise mode (i.e., treadmill and cycling) on peak $\dot{V}CO_2$ values ($F_{(1,9)} = 0.06$, $P > 0.05$).

Peak values for $\dot{V}_E/\dot{V}O_2$ were significantly higher during non fasted compared to fasted state ($F_{(1,9)} = 10.09$, $P < 0.05$). The $\dot{V}_E/\dot{V}O_2$ ratio was also significantly higher during leg cycling compared to treadmill exercise ($F_{(1,9)} = 11.30$, $P < 0.01$). There was no significant interaction between fasted and non-fasted state and exercise mode on peak $\dot{V}_E\backslash\dot{V}O_2$ values ($F_{(1,9)} = 1.95$, $P > 0.05$).

Peak values for $\dot{V}_E/\dot{V}CO_2$ were significantly higher during non-fasted compared to fasted state ($F_{(1,9)} = 35.59$, $P < 0.001$).Peak values for $\dot{V}_E/\dot{V}CO_2$ were also significantly higher during leg cycling compared to treadmill exercise ($F_{(1,9)} = 24.93$, $P < 0.01$). There was no significant interaction between fasting and non fasting state and exercise mode on peak $\dot{V}_E\backslash\dot{V}CO_2$ values ($F_{(1,9)} = 0.04$, $P > 0.05$).

There was no difference in peak overall RPE values between fasted and non-fasted state ($F_{(1,9)} = 3.49$, $P > 0.05$). There was no significant difference in peak overall RPE values observed during treadmill exercise test and the bike exercise test ($F_{(1,9)} = 0.41$, $P > 0.05$). There was no significant interaction between fasting state (i.e., fasting and non fasting) and exercise mode (i.e., treadmill and cycling) on peak overall RPE values ($F_{(1,9)} = 0.61$, $P > 0.05$).

Paired sample t-test showed no significant difference in peak power output during leg cycling in Ramadan fasting and after Ramadan ($t_{(9)} = 0.56$, $P > 0.05$). Paired sample t-tests also showed no significant difference in peak speed ($P > 0.05$) and peak incline ($p > 0.05$) during treadmill exercise in Ramadan fasting and after fasting.

Discussion

The effect of Ramadan fasting on physiological and clinical variables has been an area of research interest for many years (Hallack & Nomani, 1988; Kirkendall et al., 2008; Maughan et al., 2008; Roky et al., 2004; Shanks et al., 1994). However, no research has assessed the effect of Ramadan fasting on peak oxygen uptake while walking/running on treadmill and cycling. Therefore, the aim of the current study was to assess the effect of Ramadan fasting during two different exercise modes on peak oxygen uptake. In accordance with previous research (Bergh, Kanstrup, & Ekblom, 1976; Dunbar et al., 1992) peak values for oxygen uptake, heart rate, pulmonary ventilation and respiratory exchange ratio during the treadmill exercise were higher compared to during leg cycling. These differences are generally attributed to the large muscle mass that is activated in treadmill exercise compared to leg cycling (McArdle, Katch, & Katch, 2007). However, no significant differences were observed in peak values for rating of perceived exertion between treadmill exercise and leg cycling. These findings of the RPE are in accordance with previous research during treadmill exercise mode (Eston et al., 2012), leg cycling (Al-Rahamneh, 2011) and arm cranking (Al-Rahamneh, 2011). These similar peak RPE values are not surprising as participants reach their peak RPE values at the end of the exercise regardless of the exercise mode and muscle mass that is activated during exercise.

Similar peak power outputs were observed during leg cycling in Ramadan fasting and after Ramadan. Similar peak speed and peak incline were observed while walking\running on treadmill in Ramadan and after Ramadan. As peak physical variables (i.e., power output, speed and incline) were similar during Ramadan and after Ramadan, peak values for oxygen uptake and heart rate were similar for walking\running on treadmill and leg cycling in Ramadan and after Ramadan. These findings of similar peak oxygen uptake and heart rate are not surprising since it is well established that oxygen uptake and heart rate are increased in proportion to the work load being performed (ACSM, 2010; Åstrand et al., 2003; Bergh et al., 1976; McArdle et al., 2007). The similar work rate during fasted and non-fasted sate might be attributed to the time of the exercise tests as these exercise tests were performed while fasted in Ramadan in the morning where participants did not experience severe hunger or thirst which might in turn affect the results of the exercise tests. Similar peak values for RPE were observed in Ramadan and after Ramadan for both exercise modes.

All participants reached a plateau in oxygen uptake during cycling and treadmill exercise and reached 87% and above of their estimated maximal heart rate using the equation described by Tanaka, Monahan, and Seals, (2001) during leg cycling and walking/running on treadmill. These are two indicators of reaching peak oxygen uptake (Winter et al., 2007). In addition, the BASES exercise testing guidelines (2007) uses the respiratory exchange ratio of 1.15 or above as an indicator of determining that participants have reached their peak oxygen uptake. The peak RER values during leg cycling and treadmill were lower than 1.15. During Ramadan's fasting the peak RER values were lower in treadmill exercise compared to non fasting condition. During leg cycling the peak RER values were significantly lower in Ramadan compared to peak RER values that observed after Ramadan. The peak RER values were significantly higher in treadmill compared to leg cycling. These findings of lower peak RER values in Ramadan are not surprising as these exercise tests were conducted after 6 hours and 30 minutes of fasting. Gueye et al. (2004) showed lower blood glucose level while resting during Ramadan. The lower peak RER values are in agreement with Stannard and Thompson (2008), who observed lower RER values exercising at 45% of $\dot{V}O_2$max. The lower peak RER values observed during Ramadan were accompanied by lower peak values for pulmonary ventilation. The higher values of pulmonary ventilation during non-fasted exercise tests might be attributed to the clearance of elevated carbon dioxide level in the blood as a result of dissolving lactic acid which resulted from producing energy anaerobically towards the end of the exercise (ACSM, 2010; Åstrand et al., 2003; McArdle et al., 2007).

Peak oxygen uptake and performance were not affected during Ramadan. That was evident of similar peak oxygen uptake and maximal heart rate during leg cycling and treadmill exercise. Supporting that, the ventilatory equivalent for oxygen uptake was higher during the exercise after Ramadan compared to Ramadan for both exercise modes (Table 1). In accordance with previous research (Bergh et al., 1976) $\dot{V}_E\backslash\dot{V}O_2$ was higher for leg cycling compared to treadmill exercise (Table 1). The ventilatory equivalent for carbon dioxide was also higher while exercising after Ramadan compared to exercising in Ramadan for both exercise modes.

Conclusion

In conclusion, peak oxygen uptake and heart rate can be measured accurately while fasting in Ramadan regardless of the exercise mode, although it should be noted that these values are lower for cycling compared to treadmill exercise, independently of fasting state. However, peak RER values were significantly lower during the fasted state for both cycling and treadmill exercise. Nevertheless, participants reached similar peak RPE values for both forms of exercise during and after Ramadan. It should be noted that these exercise tests were conducted after 10 am in the morning 6 hours and 30 min after the period of fasting.

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