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Effect of Ramadan Intermittent Fasting on Swimming Performance

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Abstract

During the holy month of Ramadan, Muslims fast (abstain from food and water) from dawn until dusk. In recent years, the proportion of Muslim athletes participating in global athletic events has risen dramatically: roughly 15% since 2010 (Roy, Hwa, Singh, Aziz, & Jin, 2011). As such, it is of particular interest to the sports science community to examine any possible adverse effects of Ramadan style intermittent fasting (RSIF) on athletic performance. This study explored the effects of RSIF on the glucose metabolism, hydration levels, circadian rhythm, and perceived fatigue of 14-16 year-old swimmers. Multiple fitness component tests were conducted in fed and fasted conditions using a within-subject design (n=8). Dehydration was investigated by recording participants' systolic blood pressure, resting heart rate, and muscular endurance using a sit-up test. Glycogen store depletion was assessed by measuring power through a standing broad jump, and strength using a grip dynamometer. Circadian rhythm disruption was explored using a reaction time device. Finally, perceived fatigue was measured through a self-reported 1-10 OMNI scale. Additionally, participants completed timed maximum effort 400-meter swims. On average, participants completed the 400-meter swim 3.4% slower in the fasted condition than in the fed condition. Moreover, statistical analysis of the fitness component data identified dehydration, sleep disturbance, and perceived fatigue as the primary detrimental factors. Interestingly, perceived fatigue data demonstrated a greater change between fasted and fed conditions compared to any other variable tested. These findings highlight the particular importance of mindset and arousal training for fasting athletes in the future.

1 Introduction

Fasting is described as the voluntary abstinence from all dietary intake for a set period of time (Patterson et al., 2015). Periodic fasting is practiced for a wide variety of reasons, including religious and cultural observances, as well as health-related benefits (Longo & Mattson, 2014). During the holy month of Ramadan, Muslims fast (including abstinence from water intake) from dawn to dusk, breaking their fast during hours of darkness (Longo & Mattson, 2014).

In recent years the proportion of Muslim athletes participating in global athletic events has risen tremendously: roughly 15% since 2010 (Roy et al., 2011). However, Ramadan is based on the Islamic Lunar calendar, which shifts across the Gregorian calendar over a 33-year cycle, making it difficult to plan major sporting events around this Islamic practice (Chaouachi, Leiper, Souissi, Coutts, & Chamari, 2009). Nevertheless, many Muslim athletes observed Ramadan during the 2016 football World Cup in Brazil, as well as during the 2012 London Olympics, which happened to coincide with Ramadan during those particular years (Rakhmonova, 2012). As such, it is of particular interest to the spots science community to examine any possible adverse effects Ramadan style intermittent fasting (RSIF) may have on athletic performance. This paper will investigate the effect of RSIF on the speed of male and female 14-16 year-old swimmers, across a 400 meters front crawl swim. A distance of 400 meters was selected because it allows for the activation of both anaerobic and aerobic energy systems, emulating most racing and training scenarios (Patel et al., 2017). Additionally, a secondary investigation will aim to pinpoint the specific factors that contribute to any change in performance, in order to determine whether exhaustion experienced while fasting is physiologically justified, or if psychological factors may have played a bigger role.

When it comes to the possible impairments to performance associated with RSIF, multiple aspects must be considered. The majority of comprehensive medical studies focus primarily on the effects RSIF on glucose metabolism, hydration levels, possible disruption to the circadian rhythm, as well as psychological factors on athletic performance (Chaouachi et al., 2009). Therefore, these are the primary aspects that will be discussed and tested within this investigation.

2 Literature Review

2.1 Effect of fasting on glucose and lipid metabolism

The human body is designed to maintain a constant internal environment within a set range, through a process called homeostasis (Palaparthi, 2017). These conditions include temperature, blood glucose levels (BGL), and blood pH, controlled via hormonal and neural mechanisms. During periods of fasting, dietary consumption of glucose is ceased. This causes a drop in BGL (Palaparthi, 2017). Through a homeostatic response, our bodies begin a set of chemical reactions to restore BGL to within the normal range (4-8 millimoles per dm^3) (Allott, 2014). First, a hormone called glucagon is secreted by alpha cells of the pancreas targeting liver and muscle cells, causing the hydrolysis of glycogen stores in liver and muscle cells to glucose, subsequently raising BGL (Allott, 2014). This process is called glycogenolysis. Glucagon is also responsible for lipolysis, stimulating the breakdown of fat stores, specifically triglycerides, to produce glucose (gluconeogenesis) (Petersen et al., 2017). Additionally, adrenaline is secreted in response to low BGL, which functions similarly to glucagon, by glycogenolysis and lipolysis. Hence, restoring BGL concentration (Petersen et al., 2017).

The average glycogen store within the liver of a healthy 16-year-old male is 44g/kg (Adeva-Andany et al., 2016). In a 1.2 to 1.5 kg liver, this is about 60 grams of glycogen (Abdel-Misih & Bloomston, 2010). During the first stages of fasting, glycogen in the liver is converted to glucose and released to the blood at a rate of roughly 4 grams of glucose per hour (Murray & Rosenbloom, 2018). Short term fasting has little effect on the speed of metabolism, meaning there is still a need for oxidative metabolism to sustain energy requirements (Murray & Rosenbloom, 2018). Therefore, towards the end of a RSIF cycle (only 12-15 hours), glycogen stores within the liver are not yet completely depleted, suggesting that unavailability of glucose for cellular respiration is not a likely cause of impaired athletic performance. Additionally, this estimate does not take into consideration glycogen stored within muscle tissue, which may provide up to 5 more hours' worth of functional glucose in a 16 year old male (Jensen et al., 2011). While directly assessing participants BGL through blood tests would have been ideal, for practical purposes only fitness component tests were carried out. One quantitative feature linked to glycogen store depletion is a reduction in strength and power (Ortenblad, Westerblad, & Nielsen, 2013). Participants in this study completed strength and power testing. Strength was assessed using a forearm dynamometer to give grip strength, and power was gauged through a standing broad jump test.

2.2 Effect of dehydration on athletic performance

Water is a vital component to all metabolic functions within the body. It composes up to 90% of blood plasma volume, which provides a medium for chemical reactions, the transport of vital nutrients, hormones and dissolved respiratory gasses (Popkin, D'Anci, & Rosenberg, 2010). Therefore, even small fluctuations in water intake can have a profound effect on physiological functions, and thus athletic performance. Dehydration causes a decrease in overall blood plasma volume, decreasing blood pressure and impairing circulation (McCartney et al., 2017). Our bodies overcome this by increasing heart rate, increasing the strain on cardiac muscle, and subsequently increasing energy expenditure (Nuccio et al., 2017). Moreover, this decrease in blood plasma volume increases blood thickness and viscosity, impairing its ability to move through thin venules and capillaries near the surface of the skin efficiently. This leads to an elevated core body temperature during exercise (hyperthermia), as the body heat can no longer dissipate from the subcutaneous capillaries via radiation (McCartney et al., 2017). Hyperthermia is linked to reduced muscular endurance, as blood flow to and from the heart is slowed; this concern is magnified due to the desert climate of Saudi Arabia. The physiological presentation linked to dehydration is an elevated resting heart rate, relatively lower blood pressure (hypotension), and reduced muscular endurance (Nuccio et al., 2017). In this study, resting blood pressure and heart rate were taken before each trial, using a digital sphygmomanometer. Moreover, participants' muscular endurance was also measured, by counting the number of sit-ups completed in a minute.

2.3 Effect of fasting on circadian rhythm

Studies show the average reduction in nocturnal sleep time of 16-year-old Muslims during Ramadan is roughly 1 hour and 36 minutes compared to a pre-Ramadan baseline (BaHammam, Alaseem, Alzakri, & Sharif, 2013). A circadian rhythm is the body's internal clock, and adapts to the sleeping pattern of an individual's sleep-wake cycle (Potter et al., 2016). It controls things such as core body temperature, anti-diuretic hormone, and growth hormone secretions (BaHammam et al., 2013). During Ramadan, this sleep cycle is disrupted, as Muslims wake just before sunrise to have their final meal (Suhoor). This disruption, as well as a decrease in overall sleep time, is linked to a reduction in neuromuscular coordination, and impaired reaction time (Taheri & Arabameri, 2012). Furthermore, sleep disturbance associated with RSIF has also been the cause of increased fatigue and perceived exhaustion early in the day. Participants in this study completed a reaction time test before and during Ramadan.

2.4 Effect of RSIF on mental performance

Mental fatigue is not necessarily linked to muscular fatigue, but rather the mental deterioration associated with time spent awake (Schiphof-Godart et al., 2018). This deterioration can be alleviated by sleep. Therefore, there is a directly proportional relationship between the amount of time spent awake, and one's level of mental fatigue and perceived exhaustion (Schiphof-Godart et al., 2018). These temporary levels of mental impairment associated with sleep loss, manifest themselves as a disproportional decline in performance, that dietary restrictions linked to RSIF could not alone cause. Another possible adverse variable linked to performance is mental arousal. Elevated levels of perceived fatigue decrease motivation, leading to a reduction in effort. This suggests perceived fatigue may be a cause for athletes to subconsciously perform worse than physiologically able (Schiphof-Godart et al., 2018). In order to assess participants' perceived level of exhaustion, they completed a pictorial OMNI exhaustion scale.

3 Methodology

3.1 Research Question

How does Ramadan intermittent fasting affect the speed of 14-16 year-old swimmers, across a 400-meter front crawl swim?

3.2 Hypothesis

It is anticipated that RSIF will negatively impact athletic performance, meaning participants are expected to record slower times while fasting than not fasting. This prediction is based on the effects of RSIF outlined in the literature review, as well as a compilation of similar research (Chaouachi et al., 2009).

3.3 Null Hypothesis

There will be no statistically significant difference in performance between the fasting and non-fasting conditions.

3.4 Variables

Independent variable:	Unit:
Dietary intake: · Non-Fasting (Fed) · Fasting (RSIF)	
Dependent variable:	Unit:
Time taken to complete a 400-meter front crawl swim at maximum effort.	Seconds $\pm$0.5 seconds (measured using a digital stopwatch).

TABLE 1. Displaying independent variable (IV) and dependent variable (DV).

	Variable:	Why it must be controlled:	How it will be controlled:
1	Time of day participants are tested	If athletes are tested during variable times of day, the time spent fasting would fluctuate, leading to inaccurate results.	All participants were tested at 5 p.m. to allow the effects of RSIF to manifest themselves. Testing took roughly 45 minutes.

2	Distance swam	For the times recorded to be comparable between trials, the distance swam must be kept constant. Because different distances use different combinations of energy systems, decreasing the accuracy of results (Gastin, 2001).	400 meters will be swam in the same 25 meter pool in each trial (16 lengths).
3	Stroke swam	Different strokes require different levels of physical exertion, producing inaccurate results.	All participants swam front crawl, with a standard diving start for all trials.
4	Temperature of pool	Athletic performance is impaired at higher temperatures due to the body's inability to release heat effectively, causing the speed of participants to vary (Fortney & Vroman, 1985). Variable temperatures would lead to unreliable results.	The pool's internal heating system was set to 26 $\pm$0.5°C, to match the Olympic swimming pool standard (Khodaee et al., 2016).
5	Starting fitness level of participants	Athletes of different levels of fitness may cope with the side-effects of RSIF to varying degrees (Sedlock, 1994). This suggests fitter athletes are less affected by RSIF, decreasing the validity of the results.	The sample of participants selected were all part of the same competitive swimming team, who train with each other every day, and complete identical training sessions. Therefore, it was assumed that their fitness levels were equal.
6	Days of Ramadan participants were tested	As Ramadan progresses, the rate of metabolic activity adapts to the change in dietary intake (Chaouachi et al., 2009). This will cause a change in	All testing during Ramadan occurred on five consecutive days during the first week of Ramadan. This was done to minimize the

		the impact of RSIF on athletic performance, reducing the validity of the results.	metabolic adaptations that may occur during later stages of Ramadan.
7	Swimming gear worn by participants	Different gear (e.g. swimsuits or goggles) may enhance performance to varying degrees. This causes changes in performance to be partially attributed to the gear they wore, as opposed to whether or not they were fasting exclusively.	Participants were asked to wear the same shoes and clothes during preliminary testing. Also, they were asked to wear the same swimsuit, cap, and goggles across all trials.
8	Equipment used to test components of fitness	Different pieces of apparatus may have different degrees of error and uncertainty, making results obtained unreliable.	Identical equipment was used during preliminary fitness testing, such that uncertainty across trials remained constant.
9	Participants in the fasting and non-fasting group	Since athletes are of a range of ages (14-16), for their times to be used for comparative purposes, the same participants had to be tested in each condition, such that a percentage difference could be appreciated.	The same participants were tested in the fasting and non-fasting conditions.

TABLE 2. Displaying the controlled variables (CV), why they must be controlled and how they will be controlled.

3.5 Apparatus

Apparatus	Qty	Uncertainty	Relevance to investigation
Stopwatch	1	$\pm$0.5 seconds	Used to time the 400-meter swim, and 1 minute for sit-up test (muscular endurance)

10 Meter measuring tape	1	±0.5cm	To measure the distance jumped during the standing broad jump (power test)
Dynamometer (100 kg max)	1	±0.25kg	To measure forearm strength
iPad, using "Reaction time" application	1	±0.001ms	To measure reaction time
Digital sphygmomanometer	1	±0.01mm Hg	To measure blood pressure and resting heart rate

TABLE 3. Displaying apparatus used, quantities, uncertainties, and relevance to this investigation.

3.6 Outcome Measures

The aim of this investigation is to establish a relationship between the speed of a 400-meter front crawl swim by 14-16 year-old swimmers, and the effect of RSIF on athletic performance. This was done by measuring the time taken for participants to complete a 400-meter swim, while fasting and not fasting, and comparing the percentage change in time.

An additional aim of this study was to pinpoint the reason for any change in performance between the fasting and non-fasting condition. This was done by assessing the different known components linked to a decline in performance while fasting, outlined in the introduction, summarized in Table 4.

Aspect of RSIF linked to a decline in athletic performance	Test	Results indicating a cause for decline in performance, compared to non-fasting control
Dehydration	Systolic blood pressure	Lower
	Resting heart rate	Higher
	Muscular endurance	Lower
Glycogen store depletion	Power	Lower
	Strength	Lower
Circadian rhythm disruption	Reaction time	Slower

Perceived psychological fatigue	OMNI scale	Higher

TABLE 4. Summarizing aspects linked to impaired performance during RSIF: a possible test, and a result suggesting a decline in performance.

3.7 Test types

*Note: An image and brief description of each test outlined below can be found in the appendix

- Blood pressure and resting heart rate: Digital sphygmomanometer (Appendix A)
- Muscular endurance: Number of sit-ups performed by participants in one minute (Appendix B)
- Power: Distance jumped from a standing upright position (Appendix C)
- Strength: Dynamometer (Appendix D)
- Reaction time: iPad application, measuring the time taken to react to a color change on the screen (Appendix E) (*Online Reaction Time Test*, 2019)
- Perceived fatigue: OMNI scale was used to assess participants' levels of perceived exhaustion on a scale of 1-10 (Appendix F)

3.8 Safety Considerations

All participants completed medical evaluation form (PAR-Q) (Appendix G). Because participants are minors (below the age of 18), they were required to have a parent's signature on a parental consent form (Appendix H). Participants completed the same 800 meter warm up and cool down before and after each trial respectively, to minimize the risk of injury. A trained lifeguard was present during all in-water testing, and a nurse was on call for the duration of all testing.

3.9 Procedure

This investigation was conducted in collaboration with the Stingrays Swim Club in Jeddah, Saudi Arabia. The athletes join the club at an average age of 8 years old. They train for 16 hours a week, and regularly compete at a national and international level. This study consisted of 8 participants: 4 males and 4 females. Participants were all within the age range of 14-16 years old. Candidates were chosen through opportunity sampling, as all members of the swim team that fit the age range participated. Participants were not made fully aware of the true intention of the study, to prevent them acting in a way that would support or go against the hypothesis (confirmation bias).

Testing took place over a two-week span: the week before the start of Ramadan, and the first week of Ramadan. Each participant completed 5 trials for both the fasting and non-fasting conditions on five consecutive days each week, to eliminate error and increase the validity of the investigation. The mean of the percentage change in performance was then graphed, with standard deviation used as error bars.

Pre-testing:

1. Participants were asked what number they would rate themselves on the perceived exhaustion OMNI scale (1-10)
2. Participants entered a quiet, temperature-controlled room, where their resting blood pressure and heart rate were taken using a sphygmomanometer in the upright position
3. Participants completed an 800-meter warm-up swim
4. Participants individually completed the reaction time test: time taken to tap an iPad screen after changing color
5. Standing broad jump test was carried out
6. Forearm grip test was carried out
7. Muscular endurance test was carried out

Main testing:

8. Participants completed a timed 400-meter swim from a dive start

Post testing:

9. All participants completed an 800-meter cool down swim

Repeat steps 1-9 on five consecutive days during the week before Ramadan, and the first week of Ramadan.

4 Data Collection and Processing

Raw data for the individual fitness components outlined in the test types can be found in Appendix I

4.1 Qualitative Observations

During the fasting condition, participants appeared visibly exhausted and lethargic before testing

Certain participants repeatedly complained about feeling fatigued and exhausted to other participants

4.2 Quantitative Observations

Non-Fasting							
Participants	Time taken to complete 400 meters/ seconds (±0.5 seconds)					Average time/ seconds	Standard deviation
	Trial 1	Trial 2	Trial 3	Trial 4	Trial 5		
1	276	279	280	274	276	277	2.19

2	318	322	321	320	321	320.4	1.36
3	308	308	307	306	310	307.8	1.33
4	304	306	304	303	305	304.4	1.02
5	311	306	307	310	306	308	2.10
6	289	289	288	285	290	288.2	1.72
7	311	314	309	307	309	310	2.37
8	291	290	287	292	286	289.2	2.32

TABLE 5: Processed data: averages and standard deviation for non-fasting participants.

Fasting							
Participant s	Time taken to complete 400 meters/ seconds ($\pm$0.5 seconds)					Average time/ seconds	Standard deviation
	Trial 1	Trial 2	Trial 3	Trial 4	Trial 5		
1	289	291	292	288	294	290.8	2.14
2	325	329	330	334	329	329.4	2.87
3	318	315	321	322	321	319.4	2.58
4	324	317	325	322	321	321.8	2.79
5	308	312	313	311	314	311.6	2.06
6	291	292	294	296	294	293.4	1.74
7	318	323	321	325	322	321.8	2.32
8	302	299	303	300	305	301.8	2.14

TABLE 6. Processed data: averages and standard deviation for fasting participants.

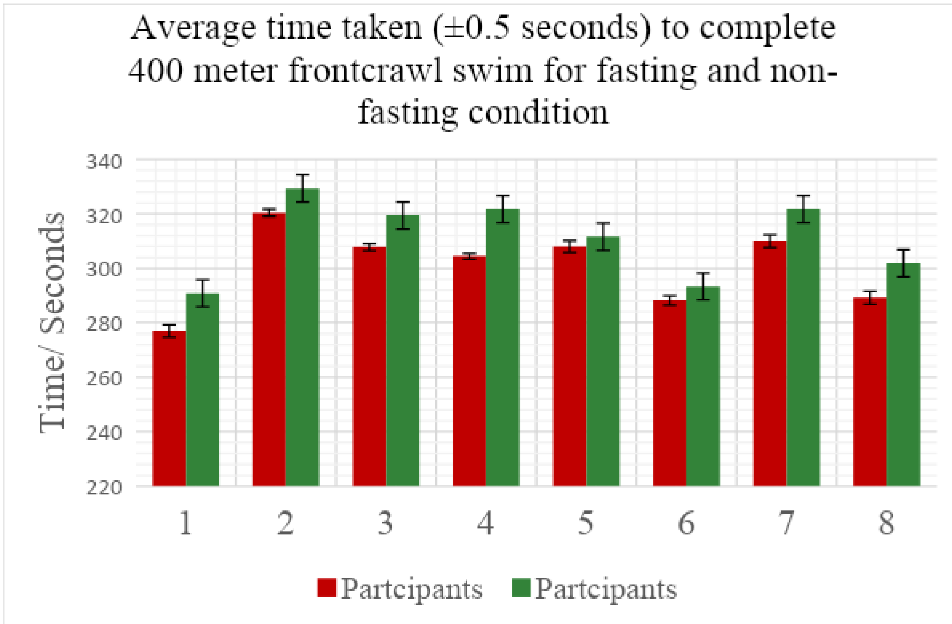

FIGURE 1. A bar chart displaying the average times of all participants while fasting and not fasting, with standard deviation as error bars.

The graph above demonstrates that while participants were not fasting, they completed the 400-meter front crawl swim in a faster time than when they were fasting. Also, the standard deviation is significantly narrower for the non-fasting group. The times of all participants were not averaged and collated, as although they started at similar fitness levels, the age range and mixed-sex make it difficult to compare results.

5 Analysis, Conclusion, and Evaluation

After collecting and analyzing data, a clear correlation can be seen between the participants' 400-meter swimming time, and whether or not they were fasting, demonstrated in Figure 1. A paired sample t-test, at significance level 0.05, was carried out on the percentage change in the time between the fasting and non-fasting conditions to determine if the difference was statistically significant. A paired sample was used because the same participants completed the experiment under both conditions. Additionally, a two tailed t-test was chosen because it tests the statistical significance in both directions, meaning my hypothesis will not bias the p value towards the expected direction. The t-test revealed that the difference between the times of the fasting and non-fasting groups are statistically significant, as the p value was less than 0.05 ($p = 0.000295$). This p value rejects the null hypothesis and suggests that RSIF negatively impacts the speed of 14-16 year-old participants across a 400 meter front crawl swim.

A secondary objective of this investigation was to determine which of the possible causes for a decline in performance, outlined in Table 4, was the primary reason participants recorded slower times while fasting than not fasting. To assess which possible detrimental factor played the largest role, a t-test was carried out on the results obtained from the individual sub-tests summarized in Table 4, to test their statistical significance. The results of these t-tests are summarized in Table 7.

Test	P value
Sit Ups (Muscular endurance)/ No. per minute	0.000317
Broad jump/ (Power)	0.0596
Grip test/ (Strength) Kg	0.684
Reaction time/ ms	0.00182
Perceived exhaustion/ Omni Scale (1-10)	0.00000830
Heart rate/ Beats per minute	0.000171
Blood pressure/ mm Hg	0.000215

TABLE 7. Table displaying tests carried out, and their p value after a paired sample t-test, where results suggesting statistical significance (below 0.05) are in green, and those with no statistical significance (above 0.05) are in red. (All values rounded to 3 significant figures) *Note: The t-test for blood pressure used the systolic pressures, as this is the value that indicates a decreased blood volume (Billington et al., 2018).

The information in Table 7 can be used to determine which factor, of those outlined in Table 4, played the greatest role in participants decline in performance between the fasting and non-fasting condition. A p value of above 0.05 suggests there is no statically significant relationship between two variables, and that any trend observed may have been due to random error and chance (Witt & McGrain, 1985). Therefore, it can be concluded that both a decrease in power and strength were not contributing factors to the athletes' decrease in performance, as their p values were over 0.05. Additionally, as explained in the literature review, strength and power are both directly linked to the levels of depletion of the glycogen stores within the liver and muscles (Ortenblad, Westerblad, & Nielsen, 2013). This suggests that, as theorized, insufficient levels of glycogen within the liver and muscles due to a lack of consumption of carbohydrates does not cause a significant impact on performance due to RSIF. However, other tests did have a significant difference between the fasting and non-fasting condition: sit-up test, reaction time, perceived exhaustion, heart rate and blood pressure all had p values below 0.05. The sit-up test, heart rate, and blood pressure can all be used to examine hydration levels. Therefore, the results of this investigation point to dehydration as a significant contributing factor to the decline in athletic performance observed. Moreover, one indication of a disrupted circadian rhythm is a decline in reaction time. The experiment highlights a statistically significant increase in reaction time between the fasting and non-fasting condition. This suggests a disrupted circadian rhythm associated with RSIF was a detrimental factor causing participants to have a decrease in performance (Potter et al., 2016). Finally, psychological fatigue was examined using an OMNI scale, which demonstrated the most significant difference (smallest p value) between the fasting and non-fasting condition. Therefore, the results of this investigation identify psychological fatigue and mental exhaustion as the primary reason participants performed worse while fasting than non-fasting. The findings of this investigation are supported by a 2012 study which also identified psychological fatigue and perceived exhaustion as the most significant adverse effects of RSIF (Chaouachi et al., 2012).

During qualitative observations, it was noticed that several participants complained about how they were feeling (participants 1 and 3). These complaints may have created a more lethargic and negative atmosphere during testing, which may have caused athletes to conform to this new attitude, and overestimate their exhaustion levels that day. Additionally, while participants were not made aware of the true aim or hypothesis of the experiment, they would have likely been able to predict I was expecting a decline in performance, and may have modeled their behavior to suit that outcome. Furthermore, OMNI scales are self-reported, meaning participants could have provided a score that either sabotaged or suit the aim of the investigation. Therefore, while the OMNI scale results revealed the most significant difference using a t-test, this value may be inflated due to confirmation bias, and group persuasion. Another interesting observation, interpreted from the standard deviation, is that the results were far more variable while participants were fasting. This decrease in precision and increase in variability is likely due to athletes varying levels of effort across the five days, which fluctuated in response to their feelings of fatigue.

The literature surrounding the effect of RSIF on athletic performance is consistent with the findings of this study. Roky et al. attributed declines in performance to effects on mood and alertness (2000). Moreover, Zerguin et al. explored the effects of RSIF on professional soccer players and similarly concluded that the belief that RSIF is deleterious to performance made athletes less likely to perform at maximal effort (2007). Both Roky et al. and Zerguin et al. agree that the psychological impact of RSIF outweighed any physiological effects. Interestingly, neither study made note of the mood conformity among participants following the vocalization of complaints, as observed in this investigation. One result of this study that does not agree with the literature is the impact of RSIF on aerobic capacity. A meta-analysis by Abaïdia et al. found that RSIF can have a deleterious impact on specific athletic movements, such as repeated sprints, but attributed these to a decrease in power instead of a decline in aerobic capacity (2020).

The limitations of this study include the relatively small number of participants. For this reason, it was not possible to investigate sex differences in RSIF on swimming performance. Moreover, due to logistical constraints, the swimmers were not isolated during testing and so it is presumable that their attitudes were swayed due to other swimmers vocalizing their exhaustion. Finally, the age range of 14-16 coincides with puberty and the accompanying developmental changes which may have influenced the results.

Directions for future areas of study include: 1) Increasing the number of participants to improve statistical power and generalizability. 2) Investigating sex differences of RSIF on swimming performance. 3) Isolating athletes during testing to prevent any communication that could influence perceived exhaustion. 4) Monitoring participants' diets during the non-fasting condition, such that they can be accurately compared as a pre-Ramadan baseline.

The present study has highlighted the adverse effect of RSIF on Muslim high performing swimmers. Interestingly, while dehydration and disruptions to the circadian rhythm do impair athletic performance, this investigation suggests that mindset and arousal play a much greater role. Therefore, mindset and attitude training for athletes competing during Ramadan may prove effective to overcome these psychological barriers and improve athletic performance while practicing RSIF.

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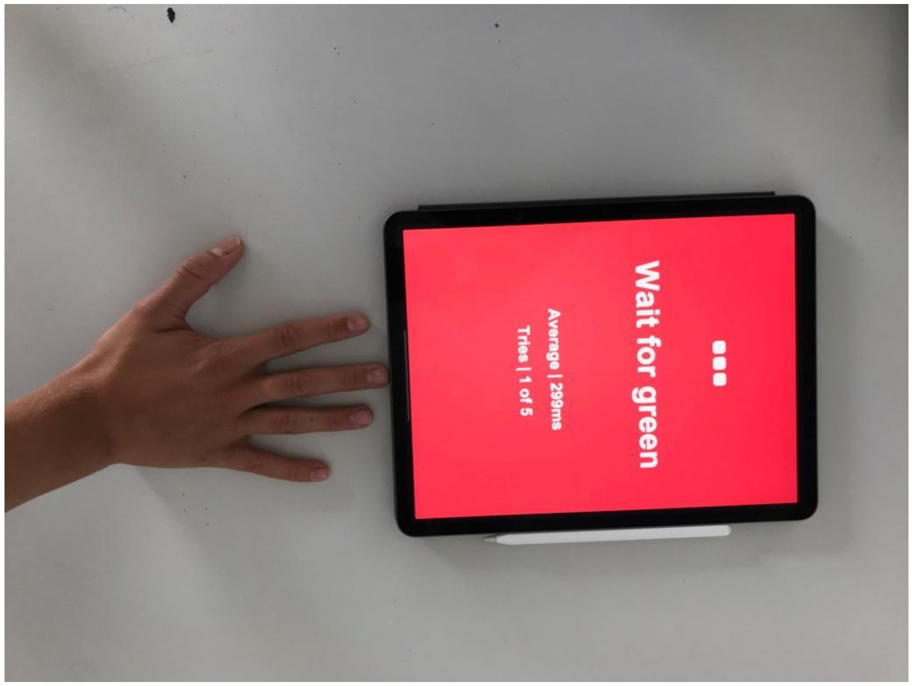
Appendix

APPENDIX A. Blood pressure and heart rate being taken in an upright position using digital sphygmomanometer within a temperature-controlled room

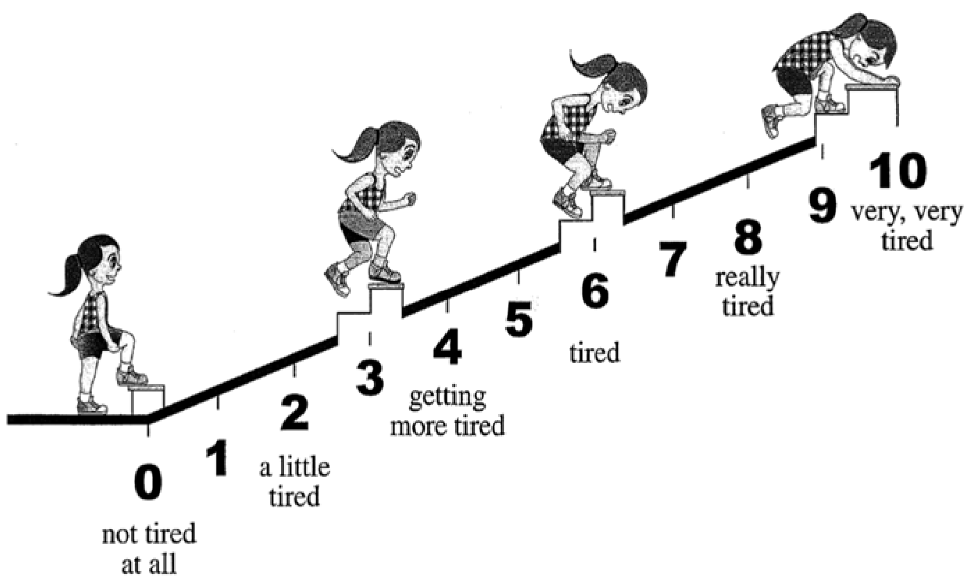
APPENDIX B. Muscular endurance test: participants completing as many sit-ups as possible in one minute (elbow to knee contact must be made, as shown in image)

APPENDIX C. Participant jumping as far as possible from a standing position, and distance being measured using measuring tape (standing broad jump)

APPENDIX D. Participant using dynamometer at right angle to measure strength, pressing down for 5 seconds at maximum effort.



Appendix E. Participant using "reaction time" app on iPad, touching the screen as fast as possible once the color turns green. The middle finger must be touching the bottom edge of the iPad at the start, as shown in image.



Appendix F. Perceived exhaustion OMNI scale. Participants were asked to rate themselves from 1-10.

Blood pressure/ mm Hg											
Non-Fasting						Fasting					
Participant	Trial 1	Trial 2	Trial 3	Trial 4	Trial 5	Trial 1	Trial 2	Trial 3	Trial 4	Trial 5	Participant
1	132 / 66	134 / 66	133 / 64	132 / 70	132 / 65	125 / 65	129 / 64	128 / 62	125 / 63	125 / 62	1
2	138 / 86	130 / 76	130 / 84	129 / 90	128 / 91	119 / 70	125 / 81	117 / 86	125 / 71	117 / 60	2
3	116 / 68	121 / 67	115 / 59	125 / 63	123 / 70	112 / 73	114 / 76	116 / 72	117 / 65	112 / 61	3
4	119 / 69	119 / 73	127 / 71	122 / 70	126 / 62	115 / 75	121 / 70	110 / 72	110 / 68	116 / 67	4
5	120 / 78	120 / 75	121 / 74	127 / 75	121 / 74	113 / 77	113 / 78	107 / 78	114 / 73	117 / 77	5
6	114 / 71	117 / 70	113 / 65	127 / 76	117 / 72	115 / 70	110 / 71	107 / 68	109 / 69	113 / 69	6
7	106 / 63	105 /60	115 /59	110 /60	112 / 61	94/ 55	96/ 54	95/ 59	97/ 61	96/ 62	7
8	122 /64	123 / 70	124 / 72	120 /65	126 / 66	115 / 60	117 /64	112 / 61	112 /63	114 / 64	8

Heart rate/ Beats per minute											
Non-Fasting						Fasting					
Participant	Trial 1	Trial 2	Trial 3	Trial 4	Trial 5	Trial 1	Trial 2	Trial 3	Trial 4	Trial 5	Participant
1	57	60	60	64	58	65	64	67	69	67	1
2	69	64	65	67	62	70	74	76	70	84	2
3	57	68	58	66	65	66	66	65	67	67	3
4	84	88	82	84	81	92	86	93	89	90	4
5	57	65	65	54	62	66	69	68	69	64	5
6	52	56	57	58	60	57	56	60	60	60	6
7	70	73	68	75	69	78	75	76	77	76	7
8	69	72	69	70	70	76	74	77	79	76	8

Strength/ (Grip test) Kg											
Non-Fasting						Fasting					
Participant	Trial 1	Trial 2	Trial 3	Trial 4	Trial 5	Trial 1	Trial 2	Trial 3	Trial 4	Trial 5	Participant
1	42	39	39	40	40	37	40	38	37	38	1
2	29	28	26	26	28	26	24	27	24	28	2
3	35	36	36	34	37	33	37	34	35	36	3
4	40	38	41	34	36	40	40	39	42	39	4
5	26	29	24	29	28	23	23	22	22	22	5
6	30	32	34	30	35	30	31	30	29	30	6
7	19	18	21	20	22	18	19	18	20	20	7
8	34	29	31	34	32	30	27	29	31	30	8

Perceived exhaustion/ Omni Scale											
Non-Fasting						Fasting					
Participant	Trial 1	Trial 2	Trial 3	Trial 4	Trial 5	Trial 1	Trial 2	Trial 3	Trial 4	Trial 5	Participant
1	3	2	3	3	4	4	5	6	5	6	1
2	4	4	3	2	3	3	5	5	6	5	2
3	3	3	4	2	2	4	7	5	6	6	3
4	3	2	4	2	3	7	5	7	4	6	4
5	2	2	3	2	3	5	6	6	7	6	5
6	2	3	3	2	2	6	7	5	5	7	6
7	3	2	2	1	2	5	7	6	4	5	7
8	1	2	2	2	3	6	4	4	5	6	8

Power/ (Broad jump) cm											
Non-Fasting						Fasting					
Participant	Trial 1	Trial 2	Trial 3	Trial 4	Trial 5	Trial 1	Trial 2	Trial 3	Trial 4	Trial 5	Participant
1	246	239	245	244	250	240	239	237	235	235	1
2	171	172	173	182	181	175	174	180	173	176	2
3	207	210	220	219	218	220	222	218	217	219	3
4	192	205	214	203	207	210	215	217	209	211	4
5	176	173	170	178	182	180	182	183	185	178	5
6	190	195	200	203	199	204	197	207	196	206	6
7	1.58	1.56	1.55	1.68	1.67	1.50	1.54	1.53	1.56	1.51	7
8	1.70	1.72	1.80	1.84	1.75	1.71	1.73	1.64	1.67	1.75	8

Reaction time/ ms											
Non-Fasting						Fasting					
Participant	Trial 1	Trial 2	Trial 3	Trial 4	Trial 5	Trial 1	Trial 2	Trial 3	Trial 4	Trial 5	Participant
1	258	270	265	268	261	303	319	321	298	296	1
2	290	284	278	286	272	274	270	315	287	317	2
3	234	239	224	221	229	226	235	247	243	251	3
4	250	246	251	241	260	270	303	277	284	289	4
5	258	263	251	248	242	286	271	290	286	293	5
6	257	261	252	247	246	270	262	291	282	263	6
7	274	271	275	267	266	275	281	284	279	288	7
8	286	274	273	269	270	288	293	283	291	284	8

Sit Ups/ (Muscular endurance) No. Per minute	
Non-Fasting	Fasting

Participant	Trial 1	Trial 2	Trial 3	Trial 4	Trial 5	Trial 1	Trial 2	Trial 3	Trial 4	Trial 5	Participant
1	55	52	54	54	55	51	49	48	51	47	1
2	46	51	47	50	54	46	44	43	44	45	2
3	57	52	54	55	57	42	47	48	50	49	3
4	46	51	49	50	51	41	44	45	43	44	4
5	44	47	45	44	47	43	40	41	39	39	5
6	55	54	57	54	53	49	45	46	47	45	6
7	44	47	46	45	44	38	40	43	37	36	7
8	49	52	50	47	53	44	43	47	41	44	8

APPENDIX G. Raw data for individual tests outlined in Table 4