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Effects of Intermittent Fasting on Performance in U.S. Military Personnel While Operating OCONUS – A Review

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ABSTRACT

Linderman JK, O'Hara RB. Effects of Intermittent Fasting on Performance in U.S. Military Personnel While Operating OCONUS – A Review. **JEPonline** 2020;23(3):1-12. Fitness of highly trained military and special operations forces (SOF) exceeds that of the general population. In individuals with such levels of fitness, fasting decreases physical performance. The 30-day-period of Ramadan requires the observant to abstain from food or fluid from sunrise to sunset, ranging from 11 to 18 hrs a day. Ramadan Intermittent Fast (RIF) results in decreased lean body mass (LBM), muscle strength, and endurance. Hypohydration increases resting heart rate (HR) and decreases resting blood pressure, while sleep alterations may impair psychomotor task performance. Collectively, these changes appear to be more profound in fit individuals. The primary purpose of this review is to summarize and contrast research on RIF and fasting on human performance. The secondary purpose examines performance relevant to operational forces operating outside the continental U.S. (OCONUS). The Areas of focus include muscular strength, cardiovascular function and endurance, and neuromuscular function. A literature search ranging from 1975 to 2015 used PubMed identified 35 relevant sources. The data indicate that RIF results in a caloric deficit, reduction in sleep, and hypohydration that are associated with a decrease in LBM, strength, endurance capacity, and psychomotor function. Policies that require the observation of the RIF practices raise the potential for concern of personnel safety and mission success.

Key Words: Hypohydration, Psychomotor Function, Ramadan

INTRODUCTION

An article in Stars & Stripes (Hendrick Simoes, June 26, 2014) summarized guidelines for U.S. personnel serving in Bahrain and U.S. Central Command (CENTCOM) area of responsibility during Ramadan. Among these guidelines was the indication that "Eating, drinking, chewing, and smoking in public are civil offenses in some Islamic countries," leading some to interpret that the U.S. personnel were required to observe the daylight fast during Ramadan off-base. However, it is valid to question whether intermittent fasting affects the physical or cognitive performance of U.S. military personnel operating OCONUS, especially in extreme environments.

It is reasonable to speculate whether operational performance of U.S. military in these austere environments without food or drink during the daytime period of fasting could result in risk to personnel or to mission success. Whether the period of Ramadan and its associated 30-day fast affects performance, particularly in highly trained groups such as special operation forces (SOF) requires an identification and understanding of a number of potentially confounding variables. The 30-day Ramadan Intermittent Fast (RIF) requires the observant to abstain from any food or fluid from sunrise to sunset, but allows consumption after sunset until the ensuing sunrise. This form of daily intermittent fast differs considerably from other research on fasting that typically lasts 24 to 72 continuous hours.

Therefore, based upon differences in sunrise and sunset throughout the year in different geographical locations the duration of the fasting hours in a day can vary considerably over the course of 30 days. For example, Schmahl and colleagues reported significant health issues related to hypohydration in Muslim factory workers during 1983 when the daylight hours of Ramadan were ~17 hrs long (31). In his recent review, Shepard cited the lack of information regarding the duration of fasted hours during RIF in much of the literature currently available (32). Inconsistencies among studies regarding the potential impact of RIF on physical performance may in part be explained by the variability in the daylight hours of fasting among the studies.

This issue of hours fasted is linked to four contributing factors associated with RIF, which may affect physical performance of military personnel operating in the field undergoing RIF. The four factors are: (a) caloric deprivation; (b) hypohydration; (c) alterations in sleep patterns; and (e) decreased fitness level of the subjects. Previous reviews have produced conflicting results on human performance variables (2,10). In particular, a negative energy balance and sleep deprivation are cited as operational stressors related to diminished performance in SOF (28). Given these findings, the purpose of this review was to summarize and contrast the research on RIF and fasting on human performance (i.e., muscular strength, cardiovascular function, endurance, and neuromuscular function such as reaction time) that might have an influence on physical performance relevant to operational forces.

Contributing Factors that Decrease Physical Performance

Caloric Deprivation

In SOF, particularly those engaged in field operations, a decrease in caloric intake may impair physical work capacity and result in physical and/or mental fatigue. Previous research indicates that a fast of 24 to 36 hrs decreased physical work capacity up to 86% in young males who were highly fit (23,36). During SOF training and Sustained Special Operations (SUSOPS), subjects may incur a daily caloric deficit exceeding 3,000 $kcals \cdot d^{-1}$ (28). It is logical to assume that a prolonged fast would result in a decrease in caloric intake.

Published data are inconsistent with regard to a decrease in daily caloric intake during Ramadan Intermittent Fast (RIF) (3,11,14,18,24,25,34). During RIF the average number of meals eaten is decreased from 3 per day to an average of 2 per day due to abstaining from the consumption of food and drink during the daylight hours (3). However, there are no restrictions on total caloric intake during RIF. Previous reports indicate that in either sedentary (18) or trained young males (11) RIF resulted in a caloric decrease up to 28% and was accompanied by significant weight loss. In contrast, Sweileh et al. (34) reported a significant increase in a 24 hr caloric intake following the 1st and 4th wks of RIF and no decrease in body mass. This conflict may again relate to the total hours of fasting during RIF and its variance by year and geography. In addition, Shepard (32) suggested that some individuals who observe RIF, particularly sedentary individuals, may use this time of fasting to improve body composition and induce a negative energy balance (32). Overall, researchers do not consistently provide conclusive support for a marked reduction in caloric intake during RIF. Therefore, it is important to consider this contrast in results of studies on RIF to those using conventional fasting paradigms to induce an acute decrease in caloric intake.

Hypohydration

Hypohydration or various levels of dehydration and loss of body water play a role in RIF. As with food, fluid consumption is also prohibited during the daylight hours of RIF. Swileh and colleagues (34) reported a significant decrease in water intake following the 1st (-0.82 L) and 4th wks (-0.73 L) of RIF. Studies (10-12) have most commonly assessed hypohydration using changes in body weight (35) and less commonly changes in hematocrit.

According to Leiper et al. (20), a review of a dozen studies indicates that the average change in body mass during RIF is an approximate loss of 2 kg or 3% of body mass (20). It is difficult to ascribe this change in body mass exclusively to hypohydration, since alterations in both fat mass and lean body mass have been reported (10,18,24,25,34). Determination of hydration is also subject to the time of day when body mass is measured. For example, Tian et al. (35) reported no effect of RIF on body mass in the morning. However, in the late afternoon (4:00 p.m.) body mass was decreased an estimated 1.3%, which was likely due to an abstinence from fluid intake.

Others have measured the % of red blood cells, hematocrit (HCT), where an increase in HCT would reflect a decrease in plasma volume indicative of hypohydration. Several researchers (10,11) have reported an increase in HCT following RIF. Similarly, Bigard and colleagues (10) reported an increase in hematocrit of 0.72% as well consistent with loss of plasma volume resulting in hemoconcentration.

Collectively, the findings regarding fluid intake, changes in body weight, as well as changes in HCT indicate a state of hypohydration. This may be of particular concern when military personnel such as SOF are operating in hyperthermic conditions during RIF as hypohydration has negative implications for tissue blood flow and blood pressure regulation.

Sleep Alteration

Potential alterations in sleep patterns during Ramadan have yielded conflicting results with regards to influencing physical performance and psychomotor performance (6,7,32,35). Shephard (32) summarized total sleep time and the onset of sleep in 10 articles. Six reported reductions in sleep ranging from 60 min to more than 120 $min \cdot d^{-1}$. In addition, bedtime was delayed between 60 min and nearly 200 min in 4 of the 10 articles. Sleep patterns, such as total time in REM (rapid eye movement) are also affected by Ramadan (6). It should be noted that data supporting alterations in sleep patterns on physical or psychomotor performance during RIF appear to be highly variable. For example, Tian et al. (35) reported a decrease in nocturnal sleep hours but an increase in daytime nap hours resulting in no reduction in total hours of sleep in the day.

However, in studies reporting marked reductions in physical work capacity, the investigators reported some alteration in sleep pattern. Aziz et al. (5) reported an average decrease in daily sleep of 3 hrs during RIF in 10 moderately trained men whose fitness level was in the 80th percentile according to ACSM. These subjects also reported a 17% decrease in alertness using a visual analog scale, and a 3.6% decrease in distance run during 30 min. The data appear to suggest that RIF independent of sleep alterations may affect physical performance, while significant alterations in sleep patterns result in greater reductions in physical performance and alertness.

Fitness Level

The most profound effects of RIF on performance appear to occur in subjects who are well trained or athletes, whose physical characteristics are most similar to well-trained SOF (28). As reviewed by Shephard (32), a majority of studies regarding the effects of RIF on performance have used young male subjects. Further, these subjects often appear to be at the lower levels of fitness, and the potential impact of RIF on physical performance is minimal. For example, Swileh et al. (34) reported no change in maximal oxygen consumption (VO_2 max) and the performance of a 1000 m time trail was unaffected by RIF. In their study, the subjects' body fat (~22%) characterized them as being poor in fitness, while their VO_2 max characterized them as poor to fair in fitness. In contrast, Brisswalter (13) reported that RIF decreased performance of ~5% in a 5000 m time trial in fit middle-distance runners. Both body fat percentage (~11%) and VO_2 max (>60 $mL \cdot kg^{-1} \cdot min^{-1}$) of these subjects placed their fitness in the top 1%, that is, in accordance with ACSM (29).

The lower limbs seem particularly affected in fit subjects during RIF. For example, lower limb strength (13) and vertical jump height (12) are decreased following RIF in trained males. The fitness levels of special operations forces (SOF) is reportedly very high (28), and the physical stress, particularly the daily energy expenditure of SOF training and SUSOPS may approach that of running 100 miles (21,28). Leg strength, power, and endurance are essential for SOF, particularly with regards to the load carried over distance during infiltration and exfiltration.

At present, the study by Bigard et al. (10) is the only study to investigate the effects of RIF in military personnel. They reported significant decrements to both the muscular system and the cardiovascular system that included a decrease in strength and an impaired orthostatic tolerance. Similarly, the fitness of SOF is reportedly comparable to that of elite athletes (28).

Given the apparent fitness levels of SOF, the effects of RIF on physical function may have a more profound effect in this specialized population.

RESULTS

Body Composition

Studies regarding changes in total body mass, fat mass, and lean body mass during RIF indicated conflicting results (10,18,24,25,34). Hallak et al. (18) reported approximately a 3% reduction in body mass at the end of RIF (18). Data from both Swileh et al. (34) and Hallak and colleagues (18) indicate that the decrease in body mass was due to the decrease in fat mass. Other reports, Chennaoui et al. (14), in particular, indicate little to no change in body mass during RIF.

However, it appears that fit subjects may be more likely to lose body mass and/or lean body mass (LBM) during RIF. Subjects in the study of Bouhlel et al. (11) were defined as fit by the authors, especially since the subjects were competitive sprinters and throwers. Yet, interestingly, although the subjects lost an average of 2 kg of body mass and body fat decreased from 12.5% to 11.7% following RIF, the estimates of LBM indicate that the subjects lost an average of 1.1 kg of LBM. In contrast, Bouhlel et al. (12) reported that a 1.8 kg loss in body mass was primarily due to decreased fat mass. In this case, the subjects were trained Rugby players. With ~80 kg body mass and a mean BMI of 25 $kg \cdot m^{-2}$, they were larger in size and body fat (~16%) when compared to the subjects in their later publication.

Bigard et al. (10) indicated that a 3% loss in body mass was primarily due to decreased LBM instead of fat mass. Their subjects had decrements in their muscle force and ability to sustain muscle force, which was likely associated with the decrease in LBM. It is also known that 3 to 8 days of special operation forces (SOF) training has been shown to decrease LBM as much as 4%. Given the rigors of SOF training and SUSOPS, any additive effect of RIF on LBM would probably have profound negative implications for muscle force and performance.

Strength and Power

Although Gutierrez et al. (17) reported that a 3-day fast had no effect on the isometric strength of their untrained male subjects, Brisswalter and colleagues (13) reported a 3.2% decrease in maximal voluntary isometric knee extensor strength following RIF in their trained middle distance runners. Interestingly, these subjects had no reported changes in body mass or body composition. Bouhlel et al. (11) reported that maximal power output of the arms and the legs was decreased 12% and 6.6%, respectively, in trained male subjects following RIF. In addition, the subjects lost an average of 2 kg in body mass, with approximately half of that loss accounted for by LBM. Collectively, the results suggest that fit subjects are more inclined to lose strength and the magnitude of decrease in strength is likely linked to the lost in LBM.

Short-Term Muscular Endurance

Muscular endurance is related to both muscle strength and local metabolic parameters. Short-term high intensity activities such as sprinting or repeated sprints and shuttle runs, as well as sustaining repetitive submaximal muscle contractions are dependent upon muscular endurance. Aloui et al. (1) reported significant changes in sprint performance by time of day, but no compelling effect of RIF on sprint speed. Similarly, Meckel (26) found little evidence that RIF decreased sprint velocity or performance of repeated sprints. In contrast, Bigard et al. (10) reported that endurance time at 35% and 70% of a MVC was decreased 28% and 22%, respectively, following RIF. The differences in the magnitude of change in muscular endurance in the Bigard et al. (10) study is likely due to the duration of given tests. For example, subjects can sustain 35% of an MVC for nearly 6 min (10), while a total of six 40 m sprints lasted approximately 45 sec (1).

Prolonged Endurance

Reports indicate no effect of the Ramadan fast or 3 continuous days of fasting on exercise capacity in the 3 to 4 min range (6,17,22). However, Loy et al. (23) reported that a 24-hr fast reduced cycling endurance between 26% and 63% at intensities of 79% and 86% of VO_2 max, respectively, in competitive male cyclists (VO_2 max, 50.5 $mL \cdot kg^{-1} \cdot min^{-1}$). Similarly, Zinker et al. (36) found that 36 hrs of fasting significantly impaired endurance (-38%) and altered glucose metabolism in fit (VO_2 max, 55 $mL \cdot kg^{-1} \cdot min^{-1}$) young (25.6 ± 1.7 yrs) males.

A direct comparison between 24- to 36-hr fast and RIF is difficult due to the intermittent nature of RIF and the variability in the hours fasted as described previously. However, a decrease in performance appears to be consistent. Aziz and colleagues (5) reported a 3.6% decrease in the distance run during 30 min in moderately trained males (VO_2 max, ~50 $mL \cdot kg^{-1} \cdot min^{-1}$). Also, Brisswalter et al. (13) reported that the average running velocity in fit (VO_2 max, >60 $mL \cdot kg^{-1} \cdot min^{-1}$) male middle distance runners was decreased ~5%.

For purposes of perspective, the 5% reduction in running velocity required 45 more seconds for the runners to complete a 5000 m run following RIF. Alternatively, the subjects would be nearly 250 m shy of the finish line compared to their performance prior to RIF. Interestingly, these investigations reported little if any decrease in body mass or VO_2 max that suggested the source of the decreased running velocity was more likely related to the decrease in strength discussed previously.

Although no data presently exist on the physical performance of SOF during RIF, the physical demands of SOF training in terms of energy expenditure is similar to running over 100 miles (21,28). A reduction in endurance by 5% would significantly delay arrival of an operator at a given location, such as a point of extraction. Further, the increase in time needed to cover a given distance would place the operator in the field for a longer period of time with the possibility of affecting mission completion and safety overall.

Cardiovascular Function

Measurements of cardiovascular function appear to be negatively impacted by RIF. Swileh et al. (34) reported no effect of RIF on maximal oxygen consumption (VO_2 max) in a group of 8 subjects characterized as poor to fair in fitness. Similarly, Brisswalter et al. (13) found no effect of RIF on VO_2 max in trained middle distance runners. In contrast, the speed that elicited the subjects' VO_2 max decreased 7.7%. The later finding indicates a decrease in efficiency evidenced by an increase in energy required to run the same speed.

Hypohydration is known to alter cardiovascular function by increasing heart rate (HR) in an attempt to maintain cardiac output (Q) due to the decrease in the filling of the heart (i.e., stroke volume, SV) where $Q = HR \times SV$. One of the primary determinants of blood pressure is Q. When Q is altered, it has an influence on the regulation of blood pressure. RIF reportedly results in a decrease in fluid intake as well as increased hematocrit (HCT) due to the loss of plasma volume.

Sweileh et al. (34) reported that HR and blood pressure at rest and during exercise are unaffected by RIF in untrained males. In spite of the increase in resting HR, systolic blood pressure (SBP) and diastolic blood pressure (DBP) are decreased in the supine position. Specifically, pulse pressure (SBP-DBP) is decreased 9 mmHg (-14.5%) following RIF.

The impact of RIF on cardiovascular function appears to be related to hypohydration that results from the decrease in fluid intake. In addition, the decrease in muscular strength likely plays a role in the impaired orthostatic tolerance. As with other systems such as endurance or strength, more compelling indicators of diminished capacity are evidenced in fit individuals.

Psychomotor Function

Alterations in sleep are theorized to impair wakefulness and, therefore, psychomotor tasks requiring the integration of the central nervous and the musculoskeletal systems. Chennaoui and colleagues (14) found that RIF reduced sleep time by 32 $min \cdot d^{-1}$ and subjects reported a 46% increase in fatigue using the Profile of Mood States questionnaire. Similarly, Tian et al. (35) reported alterations in sleep, specifically a decrease in night time sleep and an increase in daytime naps during RIF with reductions in psychomotor function and processing speed. Roky et al. (30) reported decreases in alertness and mood, with reported increases in mean reaction time. Both Tian et al. (35) and Chennaoui et al. (14) studied young (20 to 25 yrs of age) competitive athletes who maintained a weekly training volume of 8 to 9 $hrs \cdot wk^{-1}$. In contrast, BaHammam et al. (6) reported no effect of RIF on drowsiness or vigilance, but the subjects were older (36.3 ± 4.5) and indicators of fitness such as BMI (≥25) indicated they were overweight and likely less fit.

As with many of the studies on caloric intake during RIF, considerable differences exist in the literature regarding sleep alterations during RIF and its influence on psychomotor function and perception of fatigue and wakefulness (15). However, those studies performed in either fit individuals or those reporting significant decreases in total sleep more consistently reported a decrease in physical and or psychomotor function. In addition, sleep deprivation is common to SOF training and during SUSOPS (28). Any additive effect of RIF and sleep deprivation associated with SOF activities would likely have a cumulative impact.

CONCLUSIONS

In spite of considerable heterogeneity among the results of RIF on physical and cognitive performance, a review of the literature indicates that fit to highly fit individuals are likely to have decreased physical or psychomotor performance as a function of observing RIF. Muscle force and endurance are consistently decreased in fit individuals including well-trained athletes and elite military forces. The decrease in muscle force and endurance appears more pronounced when the subjects experience a decrease in LBM, which is again more likely to occur in the fit individuals. In addition, diminished cardiovascular function is most likely associated with hypohydration and may affect the regulation of blood pressure. Special Operations Forces exhibit fitness well above that of the average individual, and it is likely that this level of fitness is requisite for optimal performance of their missions. However, these individuals are also more susceptible for decreased performance during RIF.

Recommendations
Individuals who voluntarily fast during Ramadan accept any decrements in physical and/or psychomotor performance as part of their religious devotion. The Department of Defense recognizes protection of religious freedom for U.S. service members as articulated in DODI 1300.17. However, U.S. military commanders are authorized, based upon location, to provide Operating Instructions (OIs) to aid service members in understanding religious and cultural customs during Ramadan while OCONUS in CENTCOM countries. Therefore, OIs may require U.S. personnel to observe RIF off-base in deference to the religious laws and customs of CENTCOM countries. This leads to the potential for U.S. military personnel to operate off base during Ramadan in CENTCOM countries where temperatures exceed 100° without sufficient fluid replacement and energy intake during daylight hours with potential risk to the safety and performance of U.S. military personnel.

Dehydration is likely to occur in military personnel operating in CENTCOM countries due to the environmental conditions of those areas and abstaining from fluid during RIF. An acute decrease in bodyweight of ≥2% reflects a level of dehydration that may affect physical work capacity and cardiovascular function (16). Therefore, rehydration should continue until the subjects have <2% loss in body mass before returning to operational missions. The two primary concerns regarding nutrition for operational forces are sufficient carbohydrates to restore liver and muscle glycogen stores, as well as an increase in protein intake to minimize loss of LBM. Additionally, various countermeasures may be used to mitigate decrements in performance (28).

Future Directions
Although the research that is presently available indicates that RIF affects physical and psychomotor performance, particularly in fit individuals, little data are available using military subjects. Research is needed to understand the relative impact of each of the individual contributing factors presently identified: (a) caloric restriction; (b) hypohydration; and (c) sleep alterations. Because the effects of RIF appear to be cumulative, it is also important to understand a dose response relationship of the contributing factors to ascertain a threshold at which performance may be affected.

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