

A Review of the Effects of Ramadan Fasting and Regular Physical Activity on Metabolic Syndrome Indices

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ABSTRACT

Introduction: Metabolic syndrome constitutes a cluster of risk factors such as obesity, hyperglycemia, hypertension, and dyslipidemia, which increase the risk of cardiovascular diseases and type II diabetes mellitus. In this review article, we aimed to discuss the possible effects of fasting and regular physical activity on risk factors for cardiovascular diseases.

Methods: Online databases including Google Scholar, SID, PubMed, and MagIran were searched, using the following keywords: "training", "exercise", "physical activity", "fasting", "Ramadan", "metabolic syndrome", "fat percentage", "blood pressure", "blood sugar", "cholesterol", "triglyceride", and "low-density lipoprotein-cholesterol". All articles including research studies, review articles, descriptive and analytical studies, and cross-sectional research, published during 2006-2015, were reviewed. In case of any errors in the methodology of articles, they were removed from our analysis.

Results: Based on our literature review, inconsistent findings have been reported on risk factors for metabolic syndrome. However, the majority of conducted studies have suggested the positive effects of fasting on reducing the risk factors for metabolic syndrome.

Conclusion: Although fasting in different seasons of the year has no significant impacts on mental health or physical fitness, it can reduce the risk of various diseases such as cardiovascular diseases. Also, based on the conducted studies, if individuals adhere to a proper diet, avoid excessive eating, drink sufficient amounts of fluids, and keep a healthy level of physical activity, fasting can improve their physical health.

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Introduction

Metabolic syndrome constitutes a group of clinical and laboratory abnormalities, which are associated with the increased risk of cardiovascular diseases (CVDs) and diabetes mellitus (1). Metabolic syndrome is not a disease by itself, but rather a set of undesirable conditions, rooted in one's poor lifestyle; it is also associated with the increased prevalence of obesity (2).

The common symptoms of metabolic syndrome include excessive accumulation of fat, especially in the abdomen, high blood pressure, and high levels of triglyceride (TG), blood glucose, and low-density lipoprotein-cholesterol (LDL-C), which can increase the risk of CVDs and diabetes mellitus (3). American Heart Association and the National Heart, Lung, and Blood Institute have defined metabolic syndrome as consisting of at least three of the mentioned conditions (1, 4).

According to previous studies, heart attacks are three to five times more common among individuals with metabolic syndrome, compared to those with no such condition (5). Considering the significant increase in the global prevalence of obesity and type II diabetes among children and adolescents over the past 20 years and the strong correlation between childhood obesity and insulin resistance in early adulthood, it seems that cardiovascular risk factors can be found in children, similar to adults (6).

Although the management of metabolic syndrome risk factors is challenging, interventions such as lifestyle promotion and non-pharmacological methods can improve all aspects of this condition. During Ramadan, non-pharmacological methods can be applied, including daily regular exercise, which can result

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in weight loss (7), Low Blood Pressure (8), and balanced glucose level (9) and blood lipids (10). In fact, fasting, along with regular physical activity, is considered as an effective option for reducing metabolic syndrome risk factors (11). However, the evidence suggests that doing physical activities, during Ramadan, will facilitate body metabolism, and will also prevent fat accumulation in body; on the other hand, it has also been reported that fasting athletes face fewer digestive and blood sugar problems (12).

Ramadan with its particular characteristics causes lifestyle changes, e.g., alterations in water and food intake, dietary patterns, daily physical activity, and sleep cycle. The number of meals reduces in this month and patterns of food intake and sleep change (13). Although the secondary physiological changes during Ramadan have not been fully understood, changes in the number and timing of meals during the day seem to induce metabolic effects in the body.

Different studies have presented contradictory results on the effects of fasting on blood glucose level and insulin resistance among patients with type II diabetes and healthy individuals. In some studies, the positive effects of fasting on serum lipids and glucose level have been demonstrated (7, 14), whereas other studies have not indicated any changes in the levels of blood lipid and fasting blood sugar (15).

Evidence suggests that fasting affects the metabolic activity, body composition, blood components, and physical activity (16). Therefore, regular physical activity and proper diet by reducing obesity (especially abdominal obesity), increasing insulin sensitivity, decreasing blood pressure, and improving blood lipids can prevent metabolic syndrome (17). It seems that development of appropriate exercise programs, introduction of optimal nutritional patterns, changes in lifestyle, and increased quality of life can reduce the risk of CVDs. In this regard, Attarzadeh Hosseini et al. investigated the effects of Ramadan fasting and physical activity on blood hematological-biochemical parameters in active and inactive men and showed that high-density lipoprotein-cholesterol (HDL-C) significantly increased in both active and non-active fasting groups. Moreover, hematocrit level, red blood cell count, total cholesterol (TC), LDL, very-low-density lipoprotein (VLDL), LDL/HDL, and

TC/HDL significantly decreased after Ramadan fasting (10).

Additionally, Saada et al. showed that Ramadan fasting leads to an increase in HDL-C level, while decreasing the levels of serum TC, TG, LDL-C, and VLDL-C by the third week of Ramadan, compared to the non-fasting period (18). The conflicting findings on the effects of fasting on metabolic syndrome, insufficient evidence on the effects of sports activities in Ramadan, and the increased fasting time in summer have accentuated the need for evaluating fasting, accompanied with or without regular sports activities.

Considering the significance of fasting (especially accompanied with sports activities) and understanding the physiological conditions of fasting individuals during Ramadan, we aimed to investigate the effects of fasting and physical activity on different metabolic syndrome risk factors, including waist circumference (fat and overweight), lipid profile (HDL-C, LDL-C, and serum TG levels), blood pressure, fasting sugar level, and insulin resistance. Period of study should be expanded in these studies and consider alterations not only in Ramadan but also after this common time. Therefore, the purpose of this study was to investigate the effects of Ramadan Fasting and regular physical activity on metabolic syndrome indices.

Material and methods

Online databases including Google Scholar, SID, PubMed, and MagIran were searched, using the following keywords: "Training", "sports", "physical activity", "physical performance", "fasting", "Ramadan", "Islamic fasting", "Ramadan fasting", "metabolic syndrome", "fat percentage", "blood pressure", "triglyceride", "blood glucose", and "LDL-C". Articles including original studies, review articles, descriptive research, and cross-sectional studies, published during 2006-2015, were retrieved. Then, the full manuscripts of the articles and their methodologies were carefully examined. In case of any errors in the study methodology, the article was removed from our analysis. Shorthand form was designed to extract information, which consisted of information about subject, title, journal name, and author. As well as Studies that investigated among association between Ramadan fasting and physical activity are shown in table 1.

Table 1. Studies regarding the association between Ramadan fasting and physical activity

Author	Numbers/sex	Age (year)/ BMI (kg/m ²)	Design and aim	Duration of study	Result
A. The effects of fasting on body weight and body composition					
Khoshdel et al. (2015)(29)	39 healthy pregnant fasted women	Age: 26.9±6.4 BMI: 25±4.2	The effect of Ramadan fasting on lipid profile in pregnant women	Blood samples were taken at the 7th, 14th, and 28th days of Ramadan, as well as within the 2nd week after Ramadan	No significant changes in the weight or BMI of subjects
Zorofi et al. (2013)(23)	20 trained women	Age: 41.0±9.3 BMI: 28.89	Effect of Yoga Exercises on the Body Composition of Fasting Females	Exercise program included 4 weeks, two 60-min sessions per week	Decline in weight, BMI, subcutaneous fat, and waist-to-hip ratio
Attarzadeh Hosseini et al. (2013) (89)	22 healthy females: Fasting + exercise (n=11) and fasting + non exercise (n=15).	Age: 20-45 BMI: above 25	The Effect of Ramadan Fasting and Physical Activity on Body Composition, Serum Osmolarity Levels and Some Parameters of Electrolytes in Femal	Exercise program included 4 Sessions/week,60min/session. exercise with intensity of 50-65 HRR %	A significant weight loss, BMI, WHR, in two groups at the end of Ramadan. The mean of weight, BMI, WHR, body fat, protein, mineral and total water showed no difference between groups
Bassami et al. (2013) (50)	24 healthy men: fasting (n=12) and fasting plus endurance training (n=12)	Age:25.4±2.3	The combined effects of endurance training and fasting during Ramadan on fat and carbohydrate metabolism	The F+ET group performed three sessions of endurance training on the treadmill after Iftar	Weight and BMI did not significantly change during Ramadan in either of the groups, while body fat percentage reduced significantly during Ramadan in both groups
Nematy and colleagues (2012)(26)	38 males and 44 females	Age: 29–70	Effects of Ramadan fasting on cardiovascular risk factors: a prospective observational study	Blood samples were taken at the 7 d before and 2 first days of starting Ramadan and from the 27 th of Ramadan till 6 d after end of this month	A significant higher HDL-c and lower plasma TC, TG, LDL-c, VLDL-c, systolic blood pressure, body mass index and waist circumference after Ramadan
Navaei et al. (2011)(30)	10 obese males control group and 10 males with a normal BMI	Age: 27.4 ± 5.2	Effects of Ramadan fasting on biochemical and hematological parameters	Blood samples were taken before and after Ramadan	Decline in weight, BMI, insulin resistance, and glucose level
Sadiya et al. (2011)(11)	19 patients (14 females and 5 males)	Age: 37.1±12.5	The effects of Ramadan fasting on metabolic markers and body composition	Data was collected 1 week before and in the fourth week of Ramadan	Body weight, waist circumference, and glucose level decreased, while insulin concentration, homeostasis model assessment-insulin resistance and lipid concentration remained unchanged
B. The effects of fasting on serum TG and HDL-C levels					
Asemi et al. (2015)(90)	27 women	Age:18–40	Effects of Ramadan Fasting on Glucose Homeostasis, Lipid Profiles, in Women with Polycystic Ovary	Fasting blood samples were collected at the beginning of the study and after 29 days	Not changes in glucose hemostasis parameters, lipid profiles or total antioxidant capacity
Attarzadeh Hosseini et al. (2014) (91)	9 subjects	Age: 22.55±1.87	Fasting and regular physical activity and their impacts on body composition and blood hematological-biochemical parameters	The selected training program included participation in this exercise program, 90 min per session, 6 times per week for a period of one month	TC, LDL, HDL, TG: HDL and TC: HDL reduced at the end of Ramadan. However, HDL levels drastically increased during fasting
Attarzadeh Hosseini et al. (2013) (10)	26 healthy males: non-active fasting (n=13) and active fasting (n=13) groups	Age in experimental group: 19.38 ± 0.5 Age in control group: 21.07±1.55	The effects of ramadan fasting and physical activity on blood hematological-biochemical parameters.	The football training session was included 3 sessions per week, and each session lasted for 90 minutes	HDL-C increased significantly in both groups, TC, LDL, VLDL, LDL/HDL and TC/ HDL decreased significantly

Continuation of table 1.

Haghdoost et al. (2009)(43)	93 students	Age 19-21	Interaction between physical activity and fasting on the serum lipid profile during Ramadan	Three practical sessions per week, each lasting 45-60 minutes	TG and FBS decreased in Fasting and physical activity groups. TC level dropped during and after Ramadan
Salehi et al. (2007)(44)	28 overweight male	Age 20-26	Effects of fasting and a medium calorie balanced diet during the holy month Ramadan on weight, BMI and some blood parameters of overweight males	Serum levels of glucose, cholesterol, triglyceride as well as weight and BMI were measured in all subjects one day before and after Ramadan.	A significant decrease in weight, BMI, glucose and cholesterol in subjects after Ramadan. while serum TG level did not change significantly
C. The effect of fasting on blood pressure					
Samad et al. (2015) (92)	70 individuals	Aged: 18-40	Effects of ramadan fasting on blood pressure in normotensive males	BP was taken one week before the start of Ramadan and on the 7th, 14th and 21st day of Ramadan	A significant drop in systolic And diastolic. Body mass index.
Paul et al. (2015) (93)	Fifty two (30 males and 22 females)	Age: 54.7±11.55	Effect of Ramadan Fasting on Anthropometric Measures and Metabolic Profiles among Type 2 Diabetic Subjects	Data collected one week before Ramadan (visit 1) and within last 3 days before the end of Ramadan (visit 2)	Weight decreased significantly. Blood pressure reduced but not significantly
Amirkalali sijavandi (2015) (66)	89 healthy subjects	Age:20-50	Effect of Ramadan Fasting on Blood Pressure and Lipid Profiles	Blood samples were drawn for the evaluation of lipid profile in the morning, and subjects' blood pressure was measured in the afternoon	Diastolic blood pressure in male subjects and systolic blood pressure in both genders remained unchanged whereas in females, diastolic blood pressure significantly decreased.
Alinezhad Namaghi et al. (2014)(65)	Six patients under hypertension treatment and 12 healthy individuals (control group)	Age: 45-75	Effects of Ramadan Fasting on Ambulatory Blood Pressure in Hypertensive Patients	Twenty-four-hour blood pressure monitoring was carried out during four periods: prior to Ramadan, during the first ten days and the last ten days of Ramadan, and one month after it.	A significant reduction in weight, a significant improvement was observed
Pirsaheb et al. (2013) (49)	160 subjects		Fasting consequences during Ramadan on lipid profile and dietary patterns	Data had been collected 1-7 days prior to Ramadan; the second phase was conducted 1-4 days prior to the end of Ramadan	Systolic blood pressure increased and diastolic blood pressure decreased during fasting period.
Kamal et al. (2012)(67)	30 subjects	Age: 20-30	The effect of Islamic fasting on the metabolism of human body	The blood was taken on four occasions—one week before Ramadan, 14th Ramadan, 26th Ramadan & 21 days after Ramadan	A significant decline in systolic blood pressure, while no significant changes were reported in diastolic blood pressure
Attarzadeh Hosseini et al. (2012)(68)	19 male students	Age: 19-25	The effect of Ramadan fasting and physical activity on anthropometrics, lipid profile and blood pressure of normal male students	Active fasting group performed 14 sessions of exercise training. Three sessions per week with an intensity of 50 to 75 percent heart rate reserve (HRR) for 45-60 minutes was performed	Fasting, with or without physical activity, does not cause any significant changes in heart rate at rest, diastolic and systolic blood pressure; mean arterial pressure.
Lotfi et al. (2010)(69)	Nine male resistance athletes	Age: 23 ± 3	The effect of Ramadan fasting and physical exercise on CNS activation, reaction time, blood pressure and heart rate	Experiments were performed on four separate sessions: 1) 1st week before Ramadan; 2) 1 week after the start of Ramadan; 3) during the 4th week of Ramadan; 4) 2 week after the end of Ramadan month.	Fasting and physical activity have no effects on weight or systolic blood pressure, while they caused a significant decline in diastolic blood pressure and heart rate by the end of the fasting period
Ural et al. (2008) (94)	45 treated patients with grade 2-3 hypertension (30 female, 15 male)	Age: 58±12	Effect of Ramadan fasting on ambulatory blood pressure in treated subjects	Twenty-four hours ambulatory blood pressure monitoring was performed during and 1 month after Ramadan	No significant difference was found between 24 h mean blood pressures in the two monitoring periods

Continuation of table 1.

D. The effects of fasting on fasting blood sugar level and insulin resistance

Moazami et al. (2013) (95)	18 obese men	Age: 40-50	Compare the effects of fasting during Ramadan (as a dietary pattern) and regular aerobic exercise on HSP70, lipid profile and insulin resistance indexes in non-active obese men	The first group just fasted, the fasting and exercise group in addition to fasting performed 27 sessions of exercise at an intensity of 50-70 % of their VO2max	Increased, Insulin resistance also decreased in both groups, a reduction that was significant in the fasting group
Afghari et al. (2012) (80)	49 fasting women	Age: 20-45	The short- and mid-term effects of fasting and downset meal pattern on dietary intake, anthropometric parameters, glycemic status, and lipid profile	Anthropometrical and biochemical parameters were measured three days before Ramadan, on the third day of Ramadan, and thirty days after the end of Ramadan	Serum glucose, cholesterol, and LDL-C levels were not significantly different between the two groups
Kalantary et al. (2007)(81)	17 subjects (5 males and 12 females)	Age: 32-65	The effect of fasting on blood sugar in Ramadan among seven non-insulin-dependent diabetes mellitus (NIDDM) patients	Blood was drawn for FBS before & during fasting month at 2 weeks interval	Fasting does not have any significant effects on fasting blood sugar in diabetic patients
Elnasri et al. (2006) (82)	55 adult diabetic patients (38 females and 17 males)	Age: 55.82± 16	Effects of Ramadan fasting on Blood levels of Glucose, Triglyceride and Cholesterol among type II diabetic patients	Three samples of blood were taken at three intervals (Before, during and after Ramadan)	Glucose, TG, and cholesterol levels increased during Ramadan, although these changes returned to the pre-fasting level

Results

A. The effects of fasting on body weight and body composition

Metabolic syndrome, also known as metabolic syndrome X or insulin resistance syndrome, is defined as a set of metabolic and hemodynamic abnormalities, which dependently or independently predict the occurrence of atherosclerosis and CVDs. Insulin resistance is among the main features and important identifiers of this condition (19).

Metabolic syndrome is also associated with visceral obesity, glucose intolerance, hyperinsulinemia, dyslipidemia, reduced HDL level, high blood pressure, and increased TG, free fatty acid, VLDL, and LDL concentrations. The co-occurrence of these conditions is much more threatening than their independent occurrence. In fact, mortality rate due to CVDs is higher in patients with metabolic syndrome (19).

Obesity is described as excessive accumulation of fat in the body. Individuals with abdominal obesity are at a higher risk of metabolic syndrome, compared to those with fat in the hip and thigh areas (20). Anthropometric measurements are performed to estimate the amount of subcutaneous fat in different parts of the body and the percentage of body fat.

Researchers have shown that body fat percentage is one of the factors, which can predict coronary artery diseases (CADs) in women and men. In fact, subcutaneous fat, especially in the central regions of the body, waist circumference, and waist-to-hip ratio may be stronger predictors of metabolic syndrome risk factors (21).

Visceral obesity is one of the indicators of metabolic syndrome, determined by measuring waist circumference. In case the calculated ratio is greater than 102 and 88 cm for men and women, respectively, the risk of metabolic syndrome increases (22). Abdominal obesity is considered as the main indicator of metabolic syndrome. It can induce the production of inflammatory markers, affect hormone production, and alter sugar and lipid metabolism, leading to increased mortality in humans. Therefore, it seems that nutrition and lifestyle changes can reduce the incidence of complications and risk of increased body fat percentage.

Many studies have been conducted on fasting and its positive effects on body weight and lipid profile (23). Fasting is an energy-restricted diet in which the body tends to consume more fat and less sugar. To do so, insulin secretion is reduced and level of hormones such as glucagon and

epinephrine increases until body cells are forced to use less sugar compounds and more fat (24).

Researchers have also demonstrated the positive effects of Ramadan fasting on reducing weight, body mass index (BMI), and body fat percentage. These studies have revealed the effective role of Ramadan fasting in reducing atherosclerosis (25-26). Previous research has reported a decline in body weight after a month of fasting (1.7-1.8 kg). It should be mentioned that weight loss greater than 3.8 kg or less than 1.2 kg and lack of BMI changes have been also reported during Ramadan fasting.

In another study, slight weight loss was reported by the end of Ramadan, which also occurred before this holy month. However, it seems that fasting during Ramadan is one of the effective factors in reducing body weight (within a year), without causing any harms to the body or imposing long-term regimens on the individual (27). In fact, fasting can be considered as a convenient and effective solution for weight loss.

With regard to body composition, energy metabolism at rest, and exercise during fasting, a previous study indicated reduced food intake, weight loss, fat loss, and decreased metabolism at rest (28). In fact, regular physical activity and fasting are among factors, which can prevent secondary disorders of lipid metabolism and metabolic syndrome by reducing the amount of fat, especially abdominal fat (17).

Zorofi et al. reported that yoga exercises during Ramadan among females led to a decline in weight, BMI, subcutaneous fat, and waist-to-hip ratio in the experimental group (23). In contrast, Khoshdel et al. observed no significant changes in the weight or BMI of subjects during fasting (29). Nematy and colleagues investigated the effects of Ramadan fasting on cardiovascular risk factors among 38 male and 44 female subjects, aged 29-70 years (mean: 54.0 ± 10 years). The results showed that a significant higher HDL-c, WBC, RBC and platelet count (PLT), and lower plasma cholesterol, triglycerides, LDL-c, VLDL-c, systolic blood pressure, body mass index and waist circumference after Ramadan. The changes in FBS, insulin, Homeostasis Model Assessment Insulin Resistance (HOMA-IR), hcy, hs-CRP and diastolic blood pressure before and after Ramadan were not significant (26).

Navaei et al. reported that Ramadan fasting causes a decline in weight, BMI, insulin resistance, and glucose level (30). Additionally, Sadiya et al. evaluated the effects of Ramadan fasting on metabolic markers and body composition among 19 patients (14 females and 5 males). In their study, body weight, waist circumference, and glucose level decreased, while insulin concentration, homeostasis model assessment-insulin resistance (HOMA-IR) index, and lipid concentration remained unchanged (11).

Several studies have shown that regular physical activity causes a regular decline in total body fat and subcutaneous fat thickness in most parts of the body (31). In fact, regular exercise increases the expression of lipolytic enzymes, beta oxidation, Krebs cycle, and the electron transport chain and elevates the density of mitochondria and fat instead of carbohydrates for energy production (32).

The decline in weight and BMI can be enhanced by increasing the basal metabolic energy in the body. As exercise becomes part of one's daily activities, the basal metabolic rate gradually increases; in fact, the body burns more fat and consumes more calories even after the end of exercise. Blood flow in the tissues increases during exercise, while insulin release is decreased. In fact, when the insulin level is reduced in the blood, the body can better release the stored fat. In addition, reduced insulin secretion can prevent the conversion of sugar to fat and stored body fat in adipose tissue (33); eventually, the reduced amount of fat leads to weight loss and reduced BMI.

The discrepancy between the reported findings could be related to factors such as metabolic changes (induced by different dietary habits), type of consumed foodstuffs, physical activity level, and weather conditions. It should be noted that reduced number of meals during Ramadan may also change the body composition. One of the reasons for this state is increased release of fatty acids from adipose tissues and increased gluconeogenesis (34). Gluconeogenesis usually starts 4 to 6 hours after the last meal and reaches its maximum level of activity via liver glycogen depletion. Also, Glucogenic amino acids and fatty acids by lipolysis can providing needed required energy; overall, these factors can enhance weight loss and reduce BMI (35).

B. The effects of fasting on serum TG and HDL-C levels

Obesity, as one of the risk factors for metabolic syndrome, occurs as a result of changes in dietary habits and sedentary lifestyle. This condition increases the risk of diseases such as atherosclerosis (21). Obesity is associated with increased LDL-C and TG levels, reduced HDL-C concentration, and probably increased risk of high blood pressure and diabetes mellitus. In addition, overweight and obesity cause damage to the muscles and joints and increase the risk of some cancers (36). The rise in LDL-C level is directly associated with an increased risk of CAD. On the other hand, obesity plays a very effective role in increasing the level of LDL-C. In fact, an increase in BMI from 20 to 30 kg/m² causes a 10-20 mg increase in LDL-C level (37).

TG is a lipid structure, which plays an important role in the human body. TG is involved in insulation and energy storage in fatty tissues and is formed by combining glycerol with three fatty acid molecules(38). Normal TG level is defined as < 150 mg/dL, while serum TG level > 150 mg/dL, accompanied by HDL-C level < 40 mg/dL in men and < 50 mg/dL in women, increases the risk of metabolic syndrome (39).

Reports on the effects of Ramadan fasting on lipid profile have been diverse, which may be due to changes in diet, physical activity, weight, and cultural indices. In this regard, in a previous study, positive changes occurred in blood lipids due to changes in fat intake, caused by adherence to a particular program during Ramadan. These changes in blood lipids might even persist for one month after the end of Ramadan (40).

In some studies, serum TG level has been reported to increase during Ramadan, which may be due to increased carbohydrate consumption during this month (36). Also, in the early stages of weight loss, an increase in TG level has been observed, which may be caused by the use of fat storage in the body. Moreover, lifestyle changes may help reduce TG concentration. The decline in energy intake due to physical activity during Ramadan can reduce TG and lead to weight loss, which has beneficial effects on blood lipids (41). However, reduced physical activity during Ramadan leads to the increased level of blood lipids (42). Therefore, fasting during Ramadan, along with regular physical activity, could be a solution for reducing serum TG level (16).

Haghdoost et al. in a study on 93 students (divided into two groups with regular physical activity after Ramadan and physical activity during Ramadan), who followed a physical training course, showed that fasting and physical activity decreased body weight by 1.2 kg. Moreover, TG and fasting blood sugar (by 7 mg/dL) concentrations decreased during Ramadan; this decline was observed in both groups. Also, cholesterol level considerably dropped during and after Ramadan for those who concurrently engaged in physical activity and fasting (-12.24 and -8.4 mg/dL, respectively) (43).

Salehi et al. reported that fasting resulted in a significant decline in mean weight and BMI. Similarly, the mean glucose and cholesterol levels significantly decreased in subjects after Ramadan, while serum TG level did not change significantly (44). Additionally, Gumaa et al. reported that one month of Ramadan fasting caused a linear increase in uric acid level. This increase was positively correlated with the elevated serum TG level, but not cholesterol or phospholipid levels. TG increased at a faster rate than uric acid, implying that the increase in uric acid was secondary to that of lipid (42).

TG is the most important source of energy in endurance physical activities. Lipoprotein lipase causes the release of free fatty acids from TG in order to provide the energy during aerobic exercises. Therefore, there is a significant correlation between the activity of lipoprotein lipase enzymes and consumption of serum TG. It can be concluded that after aerobic exercises (increased lipoprotein lipase activity), the amount of serum TG required for energy production decreases (45). However, in other studies, cholesterol level during Ramadan fasting remained unchanged (36) or declined (46).

An increase has been observed in the level of HDL-C after Ramadan, which could be an important finding (40). According to a previous study, exercise less than the maximum power among professional athletes increased fat oxidation during Ramadan (47). Changes in blood lipid level may be associated with the amount of food consumption among people who consume great meals during the day (48). The reduced energy consumption during Ramadan is related to the reduced levels of TC, LDL-C, and plasma TG, which act as cardiovascular risk factors (29, 49).

Researchers have suggested that between physical activity and Ramadan has similar effects on triglycerides of fat tissue and transfers it into the blood circulation until this energy source, available for metabolically active tissues, is consumed. In such cases, biochemical pathways are involved in mobilizing and burning fat to increase the amount of free fatty acids. In fact, short periods of fasting, e.g., Ramadan fasting, activate regular tissue access to fat intake (50).

Endurance exercises increase the lipase lipoprotein level. This enzyme has been shown to play an important role in transforming VLDL to HDL. Aerobic exercise has been also shown to increase the level of lecithin-cholesterol acyltransferase (LCAT), which esterifies cholesterol to HDL in the muscles and may be a cause of increased HDL concentration (33, 51).

After some physical exercises, HDL-C, similar to TG, increases in terms of density (almost after a day of activity) and disappearance (almost after three days of activity). The interplay between these contradictory changes can possibly increase lipoprotein lipase activity, expedite glyceride decomposition in VLDL, and remove lipoprotein particles, thus making an additional layer of fat (including free cholesterol and phospholipids) to be transferred to HDL-C. In addition, physical exercise can lead to the formation of LCAT enzymes, which feed HDL-C particles (33).

LCAT is synthesized in the liver, is secreted in the plasma, and most of it connects to HDL. This enzyme helps form cholesteryl ester transfer protein (CETP) and facilitates the transfer of CETP to VLDL (sometimes to LDL-C). Also, LCAT, along with apolipoprotein A (co-factor), changes free cholesterol. Lack of this enzyme may be triggered by genetic malfunction or lack of apolipoprotein A; moreover, LCAT enzymes reduce CETP and HDL-C.

Chylomicrons including cholesterol, cholesteryl ester, phospholipids, and apoproteins are all first absorbed by the liver via endocytosis and are then separated. Therefore, fatty acids, derived from foodstuffs or produced in the liver via synthesis, transform into TG, compact into VLDL particles (along with cholesterol and cholesteryl ester), and finally empty into the blood stream (33).

C. The effect of fasting on blood pressure

Many studies have been conducted on the relationship between metabolic syndrome and cardiovascular risk factors such as diabetes, hypertension, dyslipidemia, obesity, and physical inactivity (52). Hypertension or high blood pressure is a medical condition, in which the pressure on vessel walls and blood flow is higher than the normal level. In fact, high blood pressure exerts extra pressure on the heart to pump and circulate blood (53).

Normal systolic and diastolic pressures at rest are defined as 120 and 80 mmHg, respectively. When systolic pressure is ≤ 130 mmHg and diastolic blood pressure is ≤ 85 mmHg in patients with metabolic syndrome, they are considered to be pathologically sick (54). In fact, metabolic changes are among factors, which regulate the blood pressure; however, there are still controversies in this area.

Some researchers believe that insulin resistance and hyperinsulinemia are more common among individuals with high blood pressure; however, all individuals with high blood pressure are not resistant to insulin (55). On the other hand, some studies have not confirmed the relationship between blood pressure and insulin resistance (56). Various mechanisms such as the involvement of autonomic nervous system, renal access to sodium, and vasoconstrictors, contribute to this process (57).

Saeidi reported that metabolic syndrome is more prevalent among hypertensive patients, compared to normotensive patients (93.3% vs. 62.7%). The mean systolic and diastolic blood pressures were higher in patients with metabolic syndrome, compared to those without this condition (58). Moreover, the results of a previous study indicated that abstinence from eating during Ramadan leads to high blood pressure (or its exacerbation) (59).

Changes in sleep patterns during Ramadan can also affect blood pressure. For instance, sleeping during the day reduces blood pressure more than night sleep (60). Changes in the time of drug use in Ramadan and salt intake may also facilitate blood pressure changes during Ramadan. However, Ramadan fasting normally reduces blood pressure in healthy individuals (61). In some studies, fasting not only controlled blood pressure in hypertensive patients, but also made no interference in the

medical treatment (62). Also, in some studies, decline and improvement in systolic and diastolic blood pressures have been reported, respectively (63).

Loss of body fluids, dehydration, and electrolyte imbalance depend on the season in which Ramadan falls (64). Overall, metabolic syndrome is associated with genetic factors, lifestyle, and hypertension, although conflicting results have been reported in this regard. Alinezhad Namaghi et al. investigated the effects of Ramadan fasting on 24-hour ambulatory blood pressure and heart rate and indicated a significant decline in subjects' weight during the third period of the experiment. Also, a significant improvement was observed in the heart rate during the second and third periods in the experimental group. Moreover, no high-risk variations in blood pressure or heart rate were observed among the subjects (65).

Amirkalali Sijavandi et al. investigated the effects of Ramadan fasting on blood pressure and lipid profile in 89 healthy subjects, aged 20-50 years. A week after Ramadan, body weight and BMI decreased in both genders, compared to a week before Ramadan ($P < 0.001$). Diastolic blood pressure in male subjects and systolic blood pressure in both genders remained unchanged, whereas diastolic blood pressure significantly decreased in females (66).

Pirsaheb et al. determined the effects of fasting during Ramadan on lifestyle and lipid profile among 160 healthy subjects. Based on the findings, systolic blood pressure increased, while diastolic blood pressure decreased during the fasting period (49). Moreover, Kamal et al. reported a significant decline in systolic blood pressure, while no significant changes were reported in diastolic blood pressure (67). Also, Attarzadeh Hosseini et al. revealed that fasting, with or without physical activity, does not cause any significant changes in heart rate at rest, diastolic and systolic blood pressure, mean arterial pressure, or myocardial oxygen consumption (68).

Lotfi et al. evaluated the effects of Ramadan fasting and physical exercise on central nervous system activation, reaction time, blood pressure, and heart rate among nine male resistance athletes, aged 23 ± 3 years. They concluded that fasting and physical activity have no effects on

weight or systolic blood pressure, while they caused a significant decline in diastolic blood pressure and heart rate by the end of the fasting period (69).

Regulated blood pressure has a close relationship with the ability of the kidneys to excrete excess sodium and adjust the sodium level, extracellular fluid volume, and blood volume. A healthy person's body regulates the sodium content on its own, and excess sodium is excreted without causing hypertension. However, many external factors, including renal diseases reduce this potential. Subsequently, due to excessive salt intake, the kidney is not able to excrete sodium, resulting in increased blood volume, extracellular fluid, and blood pressure (70).

Complete abstinence from eating for about 14-15 hours per day during Ramadan reduces the blood sodium level, resulting in lower blood pressure, compared to the pre-Ramadan period. Therefore, if possible, non-drug methods should be principally applied to control blood pressure. Based on previous studies, weight is the best predictor of systolic and diastolic blood pressures; in fact, the subsequent changes in body weight can alter blood pressure (71).

Except for the abovementioned factors, there are other parameters, which may change during Ramadan fasting and affect blood pressure; therefore, one of the signs on blood pressure is vascular resistance increases during Ramadan fasting (72). This study indicated that dehydration is caused by increased resistance by the renin-angiotensin system. Also, increased vascular resistance can lead to elevated blood pressure and persist until the end of Ramadan.

In contrast, few studies indicated reduced metabolism among individuals who fasted on the first day of Ramadan; this is considered as an adaptive response of the body to hunger and thirst (28). Decreased metabolism can lead to low blood pressure on the first days of fasting. Probably, two factors could explain the changes in blood pressure, i.e., changes in the circadian rhythm and dietary patterns (73). Stress and anxiety increase blood pressure (74), while mental health plays the opposite role (75). In fact, mental and spiritual effects of fasting in Ramadan can lower blood pressure.

D. The effects of fasting on fasting blood sugar level and insulin resistance

One of the most influential determinants of type II diabetes is metabolic syndrome (76). Accordingly, fasting and regular physical activity can promote diabetes management. The risk of fasting is much lower if patients with type II diabetes control their disease by considering their nutritional status and physical activity. However, overeating in Sahar (pre-dawn meal) and Iftar (evening meal) may lead to increased sugar level after eating. Also, energy intake divided to two or three smaller meals from Iftar to Sahar can be effective in preventing increased blood sugar (77).

In order to prevent the abnormal drop in blood sugar, daily exercise programs should be changed in terms of intensity and duration during Ramadan. Physical fitness and physical activity are factors, which reduce the rate of obesity, particularly abdominal obesity, increase insulin sensitivity, lower blood pressure, and improve blood lipid profile, resulting in the prevention of atherosclerosis.

It seems that changes in dietary patterns and lifestyle during Ramadan can lead to the reduced risk of atherosclerosis, followed by the reduced risk of CVDs (78). Studies on the effects of fasting on cardiovascular risk factors have reported contradictory results. Joshaghan et al. investigated the nutritional effects of fasting on CVDs and showed that two factors contribute to health improvement or deterioration, i.e., age and balance or imbalance between insulin level and blood sugar (79).

Also, Bassami et al. investigated the combined effects of endurance training and fasting during Ramadan on fat and carbohydrate metabolism. In their study, 24 healthy men (age: 25.4 ± 2.3 years) were randomly allocated to two groups: fasting ($n=12$) and fasting plus endurance training ($n=12$). Based on the findings, weight and BMI did not significantly change during Ramadan in either of the groups, while body fat percentage reduced significantly during Ramadan in both groups (50).

In the mentioned study, fat oxidation, carbohydrate oxidation, and levels of insulin, glucose, glycerol, and non-esterified free fatty acids changed in the first week of Ramadan more pronouncedly in the fasting plus endurance training group, whereas in the fasting group,

these changes were more prevalent during the second half of Ramadan; however, the changes did not vary significantly between the two groups (50).

Moreover, Afghari et al. assessed the short- and mid-term effects of fasting and downset meal pattern on dietary intake, anthropometric parameters, glycemic status, and lipid profile of 49 fasting women, aged 20-45 years. They concluded that body weight and BMI among women, who consumed nocturnal meals, were significantly different from those who did not consume the downset meal. There were significant differences in energy, carbohydrate level, fat intake, serum TG level, HDL-C, and physical activity between the three specified periods. However, serum glucose, cholesterol, and LDL-C levels were not significantly different between the two groups (80).

Moreover, Kalantary, who investigated the effect of fasting on blood sugar in Ramadan among seven non-insulin-dependent diabetes mellitus (NIDDM) patients (5 males and 12 females), aged 32-65 years, concluded that fasting does not have any significant effects on fasting blood sugar in diabetic patients (81). Also, Elnasri et al. reported that glucose, TG, and cholesterol levels increased during Ramadan, although these changes returned to the pre-fasting level among 55 adult diabetic patients (38 females and 17 males) after the end of this month (82).

The mentioned study confirmed the decline in blood glucose level, which this state one of the strong indicator of effects of fasting to reduce of blood glucose. In prolonged starving, plasma glucose concentration decreased to the lowest level, while after a week of starvation, its level again began to rise. Continued starvation for more than three weeks resulted in increased fasting sugar level, while after a week of starvation, its level started to increase again.

Under normal conditions, glycogenolysis can maintain the normal range of plasma glucose level for a period of 12-13 days, while in long-term starvation, it is able to keep plasma glucose level in the normal range for 2-10 days. After this period, the body begins to break down fat stores; this state could be one of the important factors involved in reduced plasma glucose level (16).

In addition, exercise can elevate skeletal muscle response to insulin through increased expression or activity of proteins, involved in metabolism and insulin signaling. In fact, moderate aerobic exercise increases the activity of glycogen synthase; also, it can increase GLUT4 oxidation. Lipid oxidation is a key factor in improving insulin function.

Exercise leads to increased consumption of fat storage in the muscles and promotes the capacity for fat oxidation (83). Training can affect the use of carbohydrates during exercise. A few weeks of aerobic training can increase the use of fats, which in turn maintains this action muscle glycogens and blood glucose; this process ultimately reduces glycogen after exercise. In fact, the level of physical fitness is associated with reduced lipid oxidation and carbohydrate oxidation at all exercise intensities (84)

Discussion

Based on our literature review, previous studies have reported contradictory findings on the risk factors for metabolic syndrome, including waist circumference (obesity and overweight), lipid profile (HDL-C, LDL, and serum TG levels), hypertension, fasting sugar level, and insulin resistance.

It should be noted that making comparisons between the conducted studies is difficult. Some of the effective factors include differences in weather conditions, seasons in which Ramadan falls, periods of fasting, number of participants, diets, intensity and duration of exercises, and study populations (in terms of age, gender, and race). It seems that season is one of the factors, which can affect the obtained findings. Ramadan is one of the lunar months, with 11 days less than the solar year; therefore, we experience different periods of fasting in different seasons (11 to 17 hours) (18).

Another important factor is the diet of participants during Ramadan. The type and amount of energy intake, as well as sleep pattern and daily physical activity, change during Ramadan fasting (85). These changes could affect the biochemistry of blood, urine, blood pressure, and especially blood sugar level. Based on a previous study, 78.2% of the subjects consumed more high-fat foods in Iftar meals, while 40.1% of the participants slept less during

this period (86).

Also, one of the factors affecting the changes in body weight during Ramadan is the alteration in energy intake. The different amount of food consumed during Ramadan, compared to other days of the year, can affect body weight. On the other hand, an increase in daily calorie intake can lead to weight gain and vice versa. For instance, consumption of sweets and fatty foods is common in Ramadan and can lead to weight gain.

Another factor is the change in body energy, which is consumed during daily activities. Reduced physical activity in Ramadan partly reduces the need for energy. Therefore, if energy intake remains unchanged and level of physical activity reduces, weight gain is inevitable.

Change in the amount of body fluids is another effective factor in weight loss/gain. If water intake is insufficient during Ramadan, especially if Ramadan falls in a warm month of the year, body weight may temporarily reduce as a result of excessive sweating and loss of body water. Therefore, factors affecting weight changes during Ramadan include changes in energy intake, energy expenditure, and body water.

Among physiological effects, fasting can change blood pressure during Ramadan. According to previous studies, the reduced number of meals consumed during this month (in comparison with three meals) results in an increase in systolic and diastolic blood pressure (7 ml and 3 ml, respectively) (34). This increase may be related to the role of circadian rhythm in blood pressure regulation (87). In overweight individuals, decreased number of meals was associated with reduced energy intake, blood pressure, and heart rate (88). Therefore, it seems that reduced energy intake has a strong correlation with the number of meals or meal time.

In different studies, fasting in different seasons had no adverse effects on physical or mental health of healthy fasting people, and the risk of various diseases such as CVDs reduced during Ramadan fasting. Studies have also shown that adherence to a proper diet, abstinence from overeating from dusk till dawn, adequate fluid intake, physical activity, and avoidance of heat exhaustion can result in the effectiveness of Ramadan fasting and promotion of physical health.

In addition, since regular physical activity improves the metabolic function and cardiovascular, respiratory, and musculoskeletal systems in the body, interruption in performing physical exercise during this month can significantly reduce the performance of these systems; therefore, abandoning exercise programs during fasting is not recommended. However, it seems that changes in diet, exercise methods, and exercise timing are required in many cases.

Conclusion

It can be concluded that fasting has different impacts on different individuals. These variations highly depend on daily nutritional habits and the season that Ramadan occurs in.

Most literature examined the effect of Ramadan fasting on traditional cardiovascular risk factor. However, it is better to investigate new cardiovascular risk factor in studies. Moreover, the sample size used in the study is limited. It is better to examine the impact of Ramadan fasting together with regular physical activity using a bigger sample size.

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