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Impact of Ramadan diurnal intermittent fasting on the metabolic syndrome components in healthy, non-athletic Muslim people aged over 15 years: a systematic review and meta-analysis

'Mo'ez Al-Islam' E. Faris[1]*, Haitham A. Jahrami[2,3], Joud Alsibai[1] and Asma A. Obaideen[1,4]

[1]*Department of Clinical Nutrition and Dietetics, College of Health Sciences/Research Institute of Medical and Health Sciences (RIMHS), University of Sharjah, Sharjah, United Arab Emirates*
[2]*Department of Rehabilitation Services, Periphery Hospitals, Ministry of Health, Manama, Bahrain*
[3]*Department of Psychiatry, College of Medicine and Medical Sciences, Arabian Gulf University, Manama, Bahrain*
[4]*Department of Clinical Nutrition, Faculty of Medicine and Health Sciences, University Putra Malaysia, 443400, Seri Kembangan, Malaysia*

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Abstract

Studies on the impact of Ramadan diurnal intermittent fasting (RDIF) on the metabolic syndrome (MetS) components among healthy Muslims observing Ramadan month have yielded contradictory results. This comprehensive meta-analysis aimed to obtain a more stable estimate of the effect size of fasting during Ramadan on the MetS components, examine variability among studies, assess the generalisability of reported results and perform subgroup analyses for associated factors. We searched the CINAHL, Cochrane, EBSCOhost, Google Scholar, ProQuest Medical, PubMed/MEDLINE, ScienceDirect, Scopus and Web of Science databases for relevant studies published from 1950 to March 2019. The MetS components analysed were: waist circumference (WC), systolic blood pressure (SBP), fasting plasma/serum glucose (FG), TAG, and HDL-cholesterol. We identified eighty-five studies (4326 participants in total) that were conducted in twenty-three countries between 1982 and 2019. RDIF-induced effect sizes for the MetS components were: small reductions in WC (no. of studies $K = 24$, N 1557, Hedges' $g = -0{\cdot}312$, 95 % CI $-0{\cdot}387$, $-0{\cdot}236$), SBP ($K = 22$, N 1172, Hedges' $g = -0{\cdot}239$, 95 % CI $-0{\cdot}372$, $-0{\cdot}106$), FG ($K = 51$, N 2318, Hedges' $g = -0{\cdot}101$, 95 % CI $-0{\cdot}260$, $0{\cdot}004$) and TAG ($K = 63$, N 2862, Hedges' $g = -0{\cdot}088$, 95 % CI $-0{\cdot}171$, $-0{\cdot}004$) and a small increase in HDL-cholesterol ($K = 57$, N 2771, Hedges' $g = 0{\cdot}150$, 95 % CI $0{\cdot}064$, $0{\cdot}236$). We concluded that among healthy people, RDIF shows small improvement in the five MetS components: WC, SBP, TAG, FG and HDL.

Key words: Energetic restriction: Intermittent fasting: The metabolic syndrome: Meta-analysis: Ramadan: Systematic review: Time-restricted feeding

The metabolic syndrome (MetS) is considered a multiplex risk factor for atherosclerotic CVD and type 2 diabetes(1). Major drivers of MetS are insulin resistance, atherogenic dyslipidaemia, prothrombotic state, elevated glucose, elevated blood pressure (BP), pro-inflammatory state and excess energy intake and concomitant obesity(2). Mounting evidence suggests that lifestyle interventions (e.g. intermittent fasting and energetic restriction(3) or a weight reducing diet(4)) and lifestyle modifications (e.g. physical exercise(5)) can reverse metabolic risk factors.

Ramadan is the ninth month of the Islamic lunar calendar during which healthy adult Muslims refrain from consuming food and drink from dawn to sunset. During Ramadan, the majority of Muslims throughout the world have two main meals, one immediately after sunset (*suhoor*) and the other just before dawn (*iftar*). During the night hours from sunset to dawn, people are allowed to eat and drink freely but may not consume any food or drink after dawn(6). Ramadan diurnal intermittent fasting (RDIF) represents a unique fasting pattern that involves consistent diurnal abstinence from food and drink, including water, for a fasting period of 12–18 h (depending on the season) over 29–30 d. In the last two decades, several published systematic reviews and meta-analyses(7–13) and original research studies have investigated the impact of RDIF on various health

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Abbreviations: BP, blood pressure; FG, fasting glucose; MetS, metabolic syndrome; RDIF, Ramadan diurnal intermittent fasting; SBP, systolic blood pressure; WC, waist circumference.

* **Corresponding author:** 'Mo'ez Al-Islam' E. Faris, fax +97165057515, email mfaris@sharjah.ac.ae; moezfaris@hotmail.com

outcomes, including risk factors for the MetS, such as body weight, body fat, lipid profile and inflammatory and oxidative stress states. The ultimate complications of the MetS, such as CVD, have also been well-investigated. However, no published works have discussed or systematically analysed the MetS components as a cluster of factors involved in the etiopathogenesis of the syndrome.

This systematic review and meta-analysis aimed to systematically summarise and analyse available scientific evidence and clarify the results of published studies regarding the impact of RDIF on the MetS components among non-diabetic, non-athletic, healthy people aged 15 years and older, who observed Ramadan fasting. The MetS components investigated in this review were elevated waist circumference (WC), elevated TAG, reduced HDL-cholesterol, elevated fasting glucose (FG) and elevated BP(14).

The results of this analysis will expand knowledge regarding the metabolic impacts of RDIF and help to contextualise existing knowledge by examining all similar studies. The analysis of all available valid evidence pertaining to the effect of RDIF on metabolic outcomes will provide the best estimates of effect(15). This analysis also aimed to clarify the variability between different observational and clinical studies on this topic(16). In addition, subgroup analyses for specific MetS components were performed to explore differences in findings among countries. The findings of the present review will help to determine the generalisability of the results of identified studies, direct future researchers towards knowledge gaps that need further examination using different research models (e.g. experimental interventional trials and animal models) and inform further subgroup analyses (as appropriate).

Materials and methods

This meta-analysis used the Preferred Reporting Items for Systematic Reviews and Meta-Analyses as a guideline for reporting the findings(17).

Database searches

Two authors (A. A. O. and M. E. F.) conducted an electronic search on the CINAHL, Cochrane, EBSCOhost, Google Scholar, ProQuest Medical, PubMed/MEDLINE, ScienceDirect, Scopus and Web of Science databases for relevant studies published from 1950 to March 2019. The search strategy included the keywords: ‘Ramadan fasting’ OR ‘Ramadan diurnal fasting’ OR ‘Ramadan intermittent fasting’ OR ‘Ramadan model of intermittent fasting’ OR ‘Ramadan fast’ OR ‘intermittent prolonged fasting during Ramadan’ AND ‘metabolic syndrome’ OR ‘cardiometabolic risk factors’ OR ‘body composition’ OR ‘anthropometrics’ OR ‘waist circumference’ OR ‘fasting glucose’ OR ‘lipid profile’ OR ‘blood lipids’ OR ‘TAG’ OR ‘HDL’ OR ‘blood pressure.’ Reference lists of identified studies were searched to find additional articles and reviews to ensure that all relevant publications were included in this review.

Inclusion criteria

We included observational and interventional clinical studies that examined the impact of RDIF on the MetS components. The principal criteria for study inclusion and outcomes were the MetS components as reported in the International Diabetes Federation Consensus Worldwide Definition of the Metabolic Syndrome(14). Specific inclusion criteria for study selection were: (1) publication date between 1950 and March 2019; (2) original research articles published in the English language; (3) studies that reported numerical values (e.g., arithmetic mean with/without standard deviation (SD)) for at least one MetS component (WC, FG, TAG, HDL and systolic BP (SBP)); (4) studies that assessed the impact of RDIF on healthy people as the target population in prospective observational studies or on healthy controls in case–control, semi-experimental and experimental/interventional studies. We focused on studies that examined the effect of RDIF on the MetS components; therefore, we included studies that examined these components at least twice: pre-fasting as the baseline (e.g. few days or 1–2 weeks before Ramadan month or the first few days of Ramadan month), and post-fasting (at least 2 weeks into Ramadan month or after completion of Ramadan month). It should be noted that Islamic laws pertaining to fasting specify that premenopausal women are exempt from fasting during menstruation days; therefore, these women are not expected to complete fasting for the whole month of Ramadan. A similar exemption applies to elderly people who may find it hard to complete the whole Ramadan month and may miss some fasting days.

In all of the included studies, fasting glucose/lipid parameters were obtained from venous blood sample collected after 8–12 h of overnight fast, for the assay of all standard biochemical parameters included in glucoses/lipids profile. For the purpose of data analyses, all parameters were unified to mmol/l rounded to two decimal places.

Exclusion criteria

Identified articles were assessed against specific exclusion criteria to eliminate potential methodological and quality issues: (1) studies that exclusively involved fasting children and adolescents <18 years of age; (2) studies that included patients with different diseases or conditions (including diabetes) who observed RDIF; (3) studies on the impact of RDIF on Muslim athletes that observed Ramadan fasting; (4) studies with no available full-text, even after contacting the authors; (5) studies that expressed changes in the MetS components using bar graphs and curves without reporting exact numerical values; (6) studies involving pregnant or lactating women who observed Ramadan fasting; (7) studies that reported post-Ramadan measurement after one or more months, as evidence suggests RDIF-induced biochemical variables disappear/return to pre-fasting levels after 1 month of Ramadan month cessation(18–20); (8) case reports, abstracts, review articles, editorials and non-English-language articles and (9) unpublished, non-peer-reviewed data. Articles that met any of these criteria were excluded from the present analysis (Fig. 1).

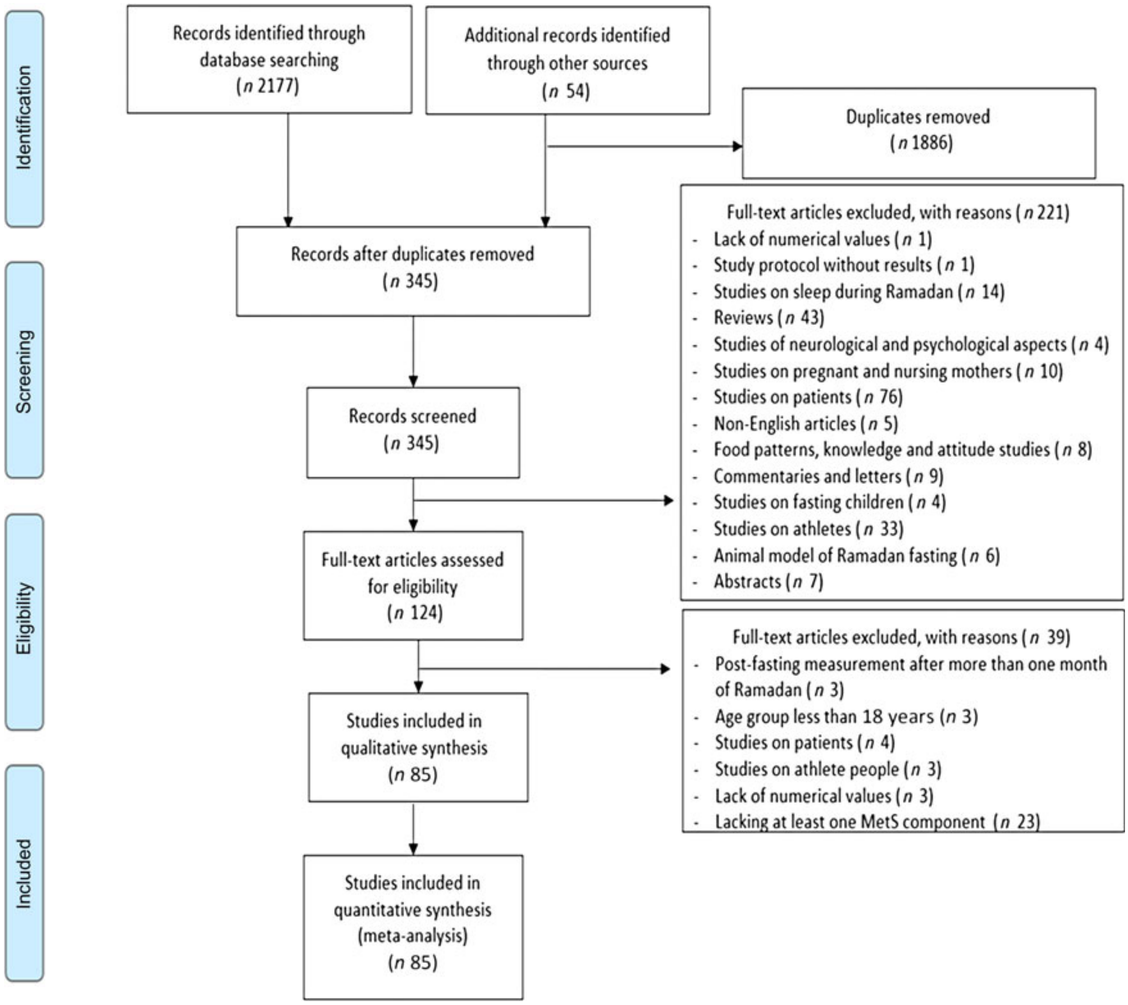


Fig. 1. Preferred Reporting Items for Systematic Reviews and Meta-Analyses flow chart for the selection of publications included in the systematic review and meta-analysis. MetS, metabolic syndrome.

Main outcomes and measures

The principal outcome of this review was to report the effect of RDIF on effect size changes in the MetS components (WC, FG, TAG, HDL and SBP). SBP was chosen as it is a major component of BP. Two authors (A. A. O. and M. E. F.) independently screened the titles and abstracts of identified studies to assess the studies for eligibility. The first step of screening was examining all titles and abstracts to exclude irrelevant publications. Two authors (M. E. F. and J. A.) performed this initial screening, which was validated by another author (A. A. O). Any conflicts in opinions regarding study eligibility were resolved through dialogue with a fourth author (H. A. J.) to reach consensus. To standardise data extraction, the review team systematically collected and coded data for study characteristics (e.g. title, year, country, sample size and participants' characteristics such as age, sex or proportion of males) and the main findings for the MetS components before and after RDIF.

Estimating fasting time length

Ramadan month as presented in the lunar calendar was matched with the Gregorian calendar using a time and date website (https://www.timeanddate.com/holidays/us/ramadan-begins). The daily length of fasting during Ramadan month was calculated using the sunrise and sunset times reported for that month for the city/country of each included study (https://www.timeanddate.com/sun/@8469718). Time points for Ramadan fasting are the call to prayer (*Athan*) for *Fajr* (abstinence or *Imsak* time, end of pre-fasting meal time or *suhoor*) and sunset or *Maghrib* (breakfast or *Iftar* meal time) prayer times. The sunrise prayer time is declared by *Fajr Athan* to be about mean of 80 min before the real sunrise time, as recorded in the Islamic calendar for prayer times. Therefore, the actual length of fasting time was calculated by adding 80 min to the time between the sunrise and sunset time points. Details of the pre-dawn *Fajr* and sunset *Maghrib* prayer time points on the Islamic calendar are available on the Islamic Finder website for

Sharjah city, United Arab Emirates (https://www.islamicfinder.org/world/united-arab-emirates/292672/sharjah-prayer-times/). This showed that the length of fasting time for a specific day (time between the *Fajr* and *Maghrib* prayer times) was 787 min (approximately 13 h), which was close to the length of fasting time calculated using the solar calendar (sunrise and sunset time points).

Data synthesis and statistical analyses

Combined means were computed when studies included subgroups (e.g. normal body weight, overweight, obese), with different means and SD reported for each subgroup. *P*-values for the combined subgroup means were calculated. All descriptive and inferential tests were performed using Stata software (Stata, M.P., 15.0.: StataCorp, 2017).

We performed a series of one-group (pre-post) meta-analyses using a pre- and post-means model, sample size and *P*-values (paired groups). Hedges' g was used to measure the effect size. Hedges' g is an important measure of corrected effect size that is sensitive to even small samples (<20). An effect size is a quantitative measure of the magnitude of a change between two groups or one group under two conditions, for example, before and after. Details on Hedges' g formula can be obtained from the original publication by Larry V. Hedges(21). An effect size of $\leq$0·2 was considered a small effect, an effect size approximately 0·5 a medium effect and an effect size approximately 0·8 a large effect. A Hedges' g value of one indicates the two groups differ by one SD, a g value of two indicates they differ by two SD, and so on. SD are equivalent to z-scores (1 SD = 1 z-score). In addition to Hedges' g, we used forest plots to graphically present the results and illustrate point estimates for effect sizes and 95 % CI.

Random effects modelling was used for all analyses. By using random effects modelling, we therefore assume that there is not only one true effect size, rather a distribution of true effect sizes. We therefore wanted in this project to estimate the mean of this distribution of true effect sizes. I^2 statistics were used to assess the heterogeneity between included studies, and τ^2 statistics were used to assess heterogeneity within studies.

Comprehensive Meta-Analysis version 2(22) was used for all analyses. To confirm that our meta-analysis findings were not driven by a single study, we conducted leave-one-out sensitivity analyses (sensitivity analysis) by iteratively eliminating one study at a time. Moderator analysis was performed using subgroup analyses for categorical variables (country) and meta-regression for integer or decimal variables (age, percentage of male participants and fasting time per d).

Computing I^2 and τ^2 statistics were particularly important to examine heterogeneity due to explainable causes, for example, timing of data collection before Ramadan month and post-fasting.

The algorithm used to estimate a random effects meta-regression model was obtained using methods of moments(23). β-coefficients and *P*-values resulting from modelling were reported. Graphical plots were used to visually aid the interpretation of the results. Funnel-plot-based analysis was used to detect publication bias, and the nonparametric trim and fill method was used to confirm the findings(24). Finally, subgroup analysis for each MetS component was performed to investigate differences among countries. We performed this analysis if three or more studies were available from any given country.

Critical appraisal of studies (quality assessment)

Two reviewers (M. E. F. and A. A. O.) independently assessed the methodological quality of studies using a standardised checklist consisting of six items in terms of sample size and sampling technique, standardisation of data collection, appropriateness of statistical analyses, quality of reporting results and generalisability. The appraisal scores range between 0 and 6, with scores of 0–2 corresponds to low quality, 3–4 medium quality and 5–6 high quality. Quality score was set for each study by consensus after discussion (see online Supplementary Material 2).

Results

Eighty-five studies with a total of 4326 participants were included in this meta-analysis. Details of the sample size, participants' sex and age, study design and major findings related to the MetS components for the included studies are shown in Table 1. All included studies used a pre-post design to report changes in the MetS components. Approximately 64 % of participants were male, and the median age was 31·5 years (range 15–80 years). The mean length of fasting during Ramadan across all studies was 828 (SD 90) min/d (range 668–1038 min).

Quality assessment of the analysed studies indicated that 15·3 % (13/85) were of low quality, while 84·7 % (72/85) were of medium quality.

Meta-analysis of the metabolic syndrome components

Table 2 summarises the number of studies (K), number of participants (N), participants' mean age, percentage of male participants and fasting time (min/d). Visual inspection of the funnel plots indicated no bias in any of the included studies (online Supplementary Fig. S1–S5). Meta-analytic pooling WC, FG, TAG, HDL and SBP was performed, and the results expressed as K, N, Hedges' g, 95 % CI and I^2: WC ($K = 24$, N 1557, Hedges' $g = -0·312$, 95 % CI −0·387, −0·236, $I^2 = 49$ %; Fig. 2); FG ($K = 51$, N 2318, Hedges' $g = -0·101$, 95 % CI −0·260, 0·004, $I^2 = 26·6$ %; Fig. 3); TAG ($K = 63$, N 2862, Hedges' $g = -0·088$, 95 % CI −0·171, −0·004, $I^2 = 78$ %; Fig. 4); HDL ($K = 57$, N 2771, Hedges' $g = 0·150$, 95 % CI 0·064, 0·236, $I^2 = 79$ %; Fig. 5) and SBP ($K = 22$, N 1172, Hedges' $g = -0·239$, 95 % CI −0·372, −0·106, $I^2 = 78$ %; Fig. 6). Sensitivity analyses were performed for the MetS components by removing one study at a time to determine if the pooled effect size for each component was arbitrary or influenced by a single study.

Moderator analysis for the metabolic syndrome components

Table 3 shows the results of the moderator analysis for each MetS component. We also performed subgroup analysis for specific MetS components for countries from which three or

Table 1. Characteristics and major findings of the included studies on the impact of Ramadan diurnal intermittent fasting on the metabolic syndrome components in healthy people aged 15 years and above

Study, publication year	Country	Sample size		Age (years)		Study design	Examined markers	Before Ramadan†		End of Ramadan†		Results (after Ramadan month compared with before)	Total quality score
		n	% Male	Mean	Range			Mean	SD	Mean	SD		
Fedail *et al.*, 1982(25)	Sudan	24	83·3	30	21–40	Prospective observational*	TAG	1·32 mmol/l	0·22	1·27 mmol/l	0·17	Non-significant decrease in TAG	4
Azizi & Rasouli, 1987(26)	Iran	9	100	35	23–54	Prospective observational*	FG	82 mg/dl	4·4	84 mg/dl	5·2	No significant change in FG	4
El Ati *et al.*, 1995(27)	Tunisia	16	0		25–39	Prospective observational*	TAG FG	0·68 mmol/l 4·86 mmol/l	0·05 0·39	0·66 mmol/l 5·21 mmol/l	0·07 0·62	No significant change in TAG or FG	4
Adlouni *et al.*, 1997(28)	Morocco	32	100		25–50	Prospective observational*	HDL TAG FG	0·91 mmol/l 1 mmol/l 5·1 mmol/l	0·21 0·42 0·5	1·04 mmol/l 0·7 mmol/l 4·38 mmol/l	0·08 0·28 0·39	Significant decrease in serum TAG and FG and a significant increase in HDL	4
Bilto, 1998(29)	Jordan	74	81		20–48	Prospective observational*	HDL TAG FG	1·3 mmol/l 1·35 mmol/l 5·4 mmol/l	0·33 0·68 2·21	1·07 mmol/l 0·82 mmol/l 4·73 mmol/l	0·19 0·33 0·5	HDL decreased significantly	4
Maislos *et al.*, 1998(30)	Israel	22	64	24	20–45	Prospective observational*	HDL TAG FG	0·91 mmol/l 1·3 mmol/l 4·27 mmol/l	0·28 0·7 0·66	1·13 mmol/l 1·3 mmol/l 4·44 mmol/l	0·27 1·1 0·33	Only HDL increased significantly	4
Mahboob *et al.*, 1999(31)	Iran	35	100	25	19–33	Prospective observational*	HDL TAG	49·53 mg/dl 83·5 mg/dl	7·48 30·64	51·35 mg/dl 76·54 mg/dl	11·71 17·59	No significant change in HDL or TAG	4
Akanji *et al.*, 2000(32)	Kuwait	49	NR	47·6	10·8	Prospective observational*	HDL TAG FG	1·16 mmol/l 2·7 mmol/l 5·59 mmol/l	0·32 1·5 1	1·13 mol/l 2·7 mmol/l 5·9 mmol/l	0·36 2·4 1·2	No significant change in HDL, TAG or FG	2
Asgary *et al.*, 2000(33)	Iran	46	100		30–60	Cross-sectional	TAG FG	209·8 mg/dl 92·57 mg/dl	71·65 33·73	193·00 mg/dl 90·22 mg/dl	57·15 22·09	TAG decreased significantly; FG decreased, but was not significant	4
Qujeq *et al.*, 2002(34)	Iran	83	69	34·25 (SD 9·8)	21–55	Prospective observational*	HDL	Male: 1·09 mmol/l Female: 1·13 mmol/l	0·11 0·12	Male: 1·74 mmol/l Female: 1·81 mmol/l	0·18 0·19	Statistically significant elevation in HDL	4
Ramadan, 2002(35)	Kuwait	16	100	NR		Prospective observational*	TAG FG	1·4 mmol/l 5 mmol/l	0·2 0·1	1·3 mmol/l 5·5 mmol/l	0·1 0·1	No significant changes in TAG and FG	2
Afrasiabi *et al.*, 2003(36)	Iran	16	100	NR		Prospective observational*	HDL TAG	43·2 mg/dl 235·7 mg/dl	2·2 36·9	45 mg/dl 171·1 mg/dl	2·1 25·9	Significant reduction in TAG	2
Fakhrzadeh *et al.*, 2003(37)	Iran	91	55	19·9 (SD 1·8)		Prospective observational*	WC HDL TAG FG SBP	Male: 74·2 cm Female: 81·2 cm Male: 39·9 mg/dl Female: 48·1 mg/dl Male: 118·6 mg/dl Female: 130 mg/dl Male: 87·5 mg/dl Female: 89·7 mg/dl Male: 117·7 mg/dl Female: 103·8 mg/dl	10·4 2 7·1 10·2 45·6 85·1 8·8 9·3 11·4 12·1	Male: 75 cm Female: 78·1 cm Male: 48·3 mg/dl Female: 62·9 mg/dl Male: 74·4 mg/dl Female: 105·2 mg/dl Male: 60·8 mg/dl Female: 65·7 mg/dl Male: 117·2 mg/dl Female: 103·7 mg/dl	6 12·5 7·2 18·3 1 64·7 6·5 18·4 10·6 11·2	Significant reduction in WC in women; FG decreased significantly in both men and women; Serum TAG decreased and HDL increased significantly	4
Kassab *et al.*, 2003(38)	Bahrain	44	0		18–45	Prospective observational*	WC TAG FG	Lean: 72·2 cm Obese: 93·1 cm Lean: 0·72 mmol/l Obese: 0·95 mmol/l Lean: 5·27 mmol/l Obese: 5·81 mmol/l	1 2·7 0·05 0·16 0·08 0·47	Lean: 71·5 cm Obese: 89·2 cm Lean: 0·77 mmol/l Obese: 1·04 mmol/l Lean: 5·06 mmol/l Obese: 5·84 mmol/l	1 2·5 0·03 0·21 0·15 0·61	No significant change in WC, TAG or FG	4
Larijani *et al.*, 2003(39)	Iran	115	58	21·2 (SD 4·3)	15–45	Prospective observational*	FG	88·4 mg/dl	9	62·9 mg/dl	7·7	Significant drop in FG	4

Table 1. *Continued*

Study, publication year	Country	Sample size		Age (years)		Study design	Examined markers	Before Ramadan†		End of Ramadan†		Results (after Ramadan month compared with before)	Total quality score
		n	% Male	Mean	Range			Mean	SD	Mean	SD		
Kassab *et al.*, 2004(40)	Bahrain	46	0	22 (SD 2)	18–45	Prospective observational*	WC	77·7 cm	1·6	75·8 cm	1·5	No significant change in WC, TAG or FG	4
							TAG	0·79 mmol/l	0·06	0·84 mmol/l	0·06		
							FG	5·41 mmol/l	0·14	5·27 mmol/l	0·2		
Rahman *et al.*, 2004(41)	Bangladesh	20	100	38·27 (SD 4·07)		Prospective observational*	HDL	38·14 mg/dl	7·4	46·71 mg/dl	14·33	SBP and FG significantly decreased; HDL increased significantly	4
							TAG	146·66 mg/dl	72·78	131·04 mg/dl	41·47		
							FG	105·3 mg/dl	14·1	85·6 mg/dl	12·4		
							SBP	124·3 mmHg	13·9	111·8 mmHg	10·8		
Yucel *et al.*, 2004(42)	Turkey	38	55	32·5 (SD 12·5)	20–45	Prospective	WC	83·29 cm	13·21	83·44 cm	12·82	No significant change in WC	4
Aksungar *et al.*, 2005(43)	Turkey	24	50		21–35	Prospective observational*	HDL	Male: 49 mg/dl	15·25	Male: 56 mg/dl	16·31	HDL increased significantly	4
								Female: 57·4 mg/dl	13·63	Female: 66·5 mg/dl	11·79		
							TAG	Male: 76·27 mg/dl	29·04	Male: 76·68 mg/dl	27·08		
								Female: 66·82 mg/dl	23·53	Female: 68·66 mg/dl	15·49		
Saleh *et al.*, 2005(44)	Kuwait	60	68		24–56	Prospective observational*	WC	Male: 94·68 cm	11·01	Male: 92 cm	10·7	WC significantly decreased in males and females	4
								Female: 89·76 cm	17·52	Female: 87·18 cm	17·53		
							HDL	Male: 1·02 mmol/l	0·33	Male: 1·04 mmol/l	0·37		
								Female: 1·27 mmol/l	0·34	Female: 1·32 mmol/l	0·36		
							TAG	Male: 1·33 mmol/l	0·6	Male: 1·54 mmol/l	1·19		
								Female: 1·38 mmol/l	0·96	Female: 1·19 mmol/l	0·8		
							FG	Male: 5·55 mmol/l	0·58	Male: 5·55 mmol/l	0·55		
								Female: 5·4 mmol/l	0·89	Female: 5·2 mmol/l	0·54		
Al-Numair, 2006(45)	Saudi Arabia	45	100		30–45	Prospective observational*	HDL	1·79 mmol/l	0·23	1·82 mmol/l	0·25	Significant decrease in FG and TAG; No significant change in serum HDL	4
							TAG	1·48 mmol/l	0·55	1·2 mmol/l	0·51		
							FG	4·91 mmol/l	0·5	4·51 mmol/l	0·52		
Dewanti *et al.*, 2006(46)	Indonesia	37	100	39 (SD 10)	17–62	Prospective observational*	SBP	134 mmHg	21	124 mmHg	17	SBP decreased significantly	2
Farshidfar *et al.*, 2006(47)	Iran	21	NR	NR		Pre-experimental	HDL	39·59 mg/dl	15·67	43·28 mg/dl	12·21	Significant decrease in FG and significant increase in HDL (on day 28 of Ramadan)	2
							TAG	65·37 mg/dl	36·76	68·34 mg/dl	19·85		
							FG	74·4 mg/dl	16·97	62·09 mg/dl	6·92		
Lamine *et al.*, 2006(48)	Tunisia	30	30	23·7 (SD 2·2)		Prospective observational*	HDL	1·1 mmol/l	0·4	1·3 mmol/l	0·4	Significant increase in HDL	4
							TAG	0·8 mmol/l	0·3	0·7 mmol/l	0·3		
							FG	5·4 mmol/l	0·6	6·3 mmol/l	0·6		
Ziaee *et al.*, 2006(49)	Iran	81	51	22·7 (SD 2·3)	20–35	Cohort	HDL	40 mg/dl	9·9	36·4 mg/dl	8·4	FG and HDL decreased significantly; No significant change in TAG	4
							TAG	66·6 mg/dl	35·7	69·7 mg/dl	4		
							FG	76·6 mg/dl	7·5	69·2 mg/dl	5·7		
Aksungar *et al.*, 2007(50)	Turkey	40	50		20–39	Case–control	HDL	Male: 88·64 mg/dl	44·49	Male: 91·64 mg/dl	67·89	HDL levels significantly increased in females	4
								Female: 69·44 mg/dl	26·98	Female: 64·88 mg/dl	35·13		
							TAG	Male: 46·82 mg/dl	7·69	Male: 50·67 mg/dl	7·07		
								Female: 48·51 mg/dl	11·68	Female: 56·46 mg/dl	8·07		
Furuncuoglu *et al.*, 2007(51)	Turkey	39	17·9	28 (SD 8·18)		Prospective observational*	HDL	45·7 mg/dl		43·9 mg/dl		TAG and FG decreased significantly; HDL did not change	4
							TAG	110 mg/dl		94 mg/dl			
							FG	83·9 mg/dl		73·6 mg/dl			

Table 1. *Continued*

Study, publication year	Country	Sample size		Age (years)		Study design	Examined markers	Before Ramadan†		End of Ramadan†		Results (after Ramadan month compared with before)	Total quality score
		n	% Male	Mean	Range			Mean	SD	Mean	SD		
Mansi, 2007[52]	Jordan	70	NR	21 (SD 1·6)		Cohort	HDL	36·13 mg/dl	6·42	48·86 mg/dl	12·34	SBP significantly decreased; HDL significantly increased	2
							TAG	148·54 mg/dl	54·72	139·36 mg/dl	52·29		
							FG	94·32 mg/dl	6·23	85·84 mg/dl	6·43		
							SBP	126·32 mmHg	17·46	112·4 mmHg	15		
Mansi & Amneh, 2007[53]	Jordan	42	100	21·3 (SD 1·6)		Prospective observational*	HDL	36·13 mg/dl	6·42	48·86 mg/dl	12·34	SBP significantly decreased; HDL significantly increased	4
							TAG	148·54 mg/dl	54·72	139·36 mg/dl	52·29		
							FG	88·4 mg/dl	9	62·9 mg/dl	7·7		
							SBP	126·32 mmHg	17·46	112·41 mmHg	15		
Salehi & Neghab, 2007[54]	Iran	28	100	23·4	20–26	Prospective observational*	TAG	195 mg/dl	31	197 mg/dl	19	Mean FG significantly decreased	4
							FG	81 mg/dl	23	69 mg/dl	8		
Shariatpanahi *et al.*, 2008[55]	Iran	55	100	34·1 (SD 8·9)	34–61	Prospective observational*	WC	94·81 cm	7·8	91·98 cm	7·7	HDL significantly increased; FG, WC and SBP significantly decreased	4
							HDL	42·87 mg/dl	5·45	46·24 mg/dl	5·5		
							TAG	210 mg/dl	139·6	232·78 mg/dl	108·87		
							FG	89·45 mg/dl	28·79	81·21 mg/dl	17·84		
							SBP	115 mmHg	13·57	108·93 mmHg	11·57		
Ibrahim *et al.*, 2008[56]	UAE	14	64		25–58	Prospective observational*	TAG	116·9 mg/dl	35·4	87·5 mg/dl	23·4	FG and TAG significantly decreased	4
							FG	109·3 mg/dl	6·6	96·4 mg/dl	11·4		
Al Hourani *et al.*, 2009[57]	Jordan	57	0	21·6 (SD 4·14)	18–29	Prospective observational*	HDL	59·3 mg/dl	9·5	62·3 mg/dl	14·6	No significant change in HDL or TAG	4
							TAG	88·3 mg/dl	62·5	65·4 mg/dl	20·8		
Lamri-Senhadji *et al.*, 2009[58]	Algeria	46	48	24 (SD 3)		Prospective	HDL	Male: 1·7 g/l	0·26	Male: 2·22 g/l	0·3	HDL was 1·4-fold higher in males and females	4
								Female: 2 g/l	0·42	Female: 2·7 g/l	0·2		
							TAG	Male: 0·72 g/l	0·36	Male: 0·69 g/l	0·36		
								Female: 0·67 g/l	0·26	Female: 0·93 g/l	0·5		
Sülü *et al.*, 2010[59]	Turkey	45	51·1	28·7	21–25	Prospective observational*	HDL	45 mg/dl	11·2	49·0 mg/dl	10·9	Significant increase in FG and HDL; Significant decrease in TAG	4
							TAG	142·9 mg/dl	61·1	105·8 mg/dl	57·1		
							FG	85·6 mg/dl	7·2	92·8 mg/dl	7·1		
Norouzy *et al.*, 2010[60]	Iran	240	66	40	18–70	Prospective cohort	WC	92·07 cm	11·1	90·71 cm	10·94	Significant reduction in WC	4
Barkia *et al.*, 2011[61]	Tunisia	25	76	42	22–55	Prospective observational*	HDL	1·0 mmol/l	0·2	1·0 mmol/l	0·3	No significant change in WC, TAG, HDL, SBP or FG	4
							TAG	1·1 mmol/l	0·5	1·1 mmol/l	0·3		
							FG	4·7 mmol/l	0·8	4·9 mmol/l	0·9		
Mohammed, 2011[62]	Iraq	56	100	48·4 (SD 7·15)		Prospective	HDL	0·8 mmol/l	0·2	0·9 mmol/l	0·7	Significant increase in HDL and decrease in TAG	4
							TAG	1·6 mmol/l	0·4	0·9 mmol/l	0·7		
							FG	5·3 mmol/l	0·15	4·2 mmol/l	0·3		
Ünalacak *et al.*, 2011[63]	Turkey	20	100	27·4 (SD 5·2)		Cross-sectional	HDL	Obese: 43 mg/dl	10	Obese: 43 mg/dl	6	Significant decrease in FG in obese group; SBP and TAG significantly reduced in obese and non-obese groups	4
								Normal: 45 mg/dl	5	Normal: 45 mg/dl	4		
							TAG	Obese: 151 mg/dl	41	Obese: 129 mg/dl	39		
								Normal: 120 mg/dl	59	Normal: 93 mg/dl	53		
							FG	Obese: 97·2 mg/dl	13·5	Obese: 93 mg/dl	7		
								Normal: 90·5 mg/dl	6·6	Normal: 89·2 mg/dl	5		
							SBP	Obese: 120 mmHg	8	Obese: 114 mmHg	8		
								Normal: 118 mmHg	8	Normal: 112 mmHg	8		
Faris *et al.*, 2012[18]	Jordan	50	42	32·7 (SD 9·5)	18–51	Cross-sectional	WC	83·62 cm	11·17	82·69 cm	10·34	SBP significantly decreased	4
							SBP	112·3 mmHg	10·01	104·4 mmHg	9·07		

Table 1. *Continued*

Study, publication year	Country	Sample size		Age (years)		Study design	Examined markers	Before Ramadan†		End of Ramadan†		Results (after Ramadan month compared with before)	Total quality score
		n	% Male	Mean	Range			Mean	SD	Mean	SD		
Shehab *et al.*, 2012(64)	UAE	60	65	43·2 (SD 9·4)		Prospective observational*	WC	Male: 96·9 cm	10·9	Male: 94·5 cm	11·1	Significant and beneficial change in SBP, WC, TAG and HDL	4
								Female: 79·6 cm	14·9	Female: 77·2 cm	15·1		
							HDL	Male: 0·8 mmol/l	0·2	Male: 0·8 mmol/l	0·3		
								Female: 0·9 mmol/l	0·4	Female: 0·9 mmol/l	0·4		
							TAG	Male: 1·2 mmol/l	1	Male: 1·1 mmol/l	1		
								Female: 0·7 mmol/l	0·5	Female: 1·2 mmol/l	1·2		
							SBP	Male: 124·1 mmHg	14·6	Male: 120·8 mmHg	13·8		
								Female: 117·6 mmHg	12·3	Female: 113·5 mmHg	11·2		
Sayedda *et al.*, 2013(65)	India	20	100	24·65 (SD 4·4)	19–32	Prospective observational*	WC	84·25 cm	5·44	82·15 cm	6·09	WC significantly decreased	4
Agoumi *et al.*, 2013(66)	Spain	55	40		18–70	Cohort	WC	101·63 cm	12·0	99·36 cm	11·24	WC decreased	4
Bahijri *et al.*, 2013(67)	Saudi Arabia	23	78	23·1 (SD 1·2)		Prospective observational*	HDL	1·2 mmol/l	0·05	1·1 mmol/l	0·03	Statistically significant decrease in HDL	4
							TAG	0·85 mmol/l	0·12	121 mmol/l	0·11		
							FG	5·33 mmol/l	0·07	5·62 mmol/l	0·11		
Haouari-Oukerro *et al.*, 2013(68)	Tunisia	38	100	20·8 (SD 1)	18–23	Prospective observational*	HDL	1·16 mmol/l	0·05	1·39 mmol/l	0·08	Significant increase in HDL; significant decrease in FG	4
							TAG	0·97 mmol/l	0·03	0·78 mmol/l	0·03		
							FG	4·94 mmol/l	0·11	4·55 mmol/l	0·39		
Hosseini *et al.*, 2013(69)	Iran	11	0		20–45	Semi-experimental	FG	87·2 mg/dl	5·1	83·3 mg/dl	7·9	No significant change in FG	4
Akrami *et al.*, 2013(70)	Iran	58	NR		20–40	Prospective observational*	HDL	52·1 mg/dl	4·64	50·85 mg/dl	5·96	Significant difference in FG and TAG levels	2
							TAG	151·55 mg/dl	94·6	125·6 mg/dl	64·8		
							FG	122·25 mg/dl	55	110·75 mg/dl	40·04		
Norouzy *et al.*, 2013(71)	Iran	240	66	40·1 (SD 0·7)	18–70	Prospective observational	WC	<35 years males: 92·9 cm	1·1	<35 years males: 91·6 cm	1·2	WC decreased significantly in most subjects except females aged 36–70 years	4
								35–70 years males: 96·4 cm	0·8	35–70 years males: 94·6 cm	0·8		
								<35 years females: 81·6 cm	1·6	<35 years females: 80·6 cm	1·5		
								35–70 years females: 90·5 cm	1·8	35–70 years females: 90·5 cm	1·9		
Pirsaheb *et al.*, 2013(72)	Iran	152	100	39·4 (SD 10·7)	21–63	Interventional cohort	HDL	44·7 mg/dl	7·9	45·59 mg/dl	9	TAG levels decreased significantly; SBP decreased significantly	4
							TAG	151·44 mg/dl	85·2	140·44 mg/dl	75·2		
							FG	126·96 mmHg	14·6	123·93 mmHg	15·2		
Rohin *et al.*, 2013(73)	Malaysia	46	30	33·04 (SD 4·6)	25–40	Prospective observational*	WC	Normal: 72·23 cm	6·39	Normal: 70·05 cm	5·67	WC significantly decreased in normal weight group	4
								Overweight: 82·13 cm	6·74	Overweight: 83·44 cm	2·03		
								Obese: 91·91 cm	6·37	Obese: 90·66 cm	7·85		
Rabiee *et al.*, 2014(74)	Iran	49	0		20–45	Cohort	HDL	Consuming downset meal: 49·35 mg/dl	7·4	Consuming downset meal: 48·9 mg/dl	12·15	Significant increase in TAG and significant decrease in HDL in fasting individuals	4
								Non-consuming downset meal: 49·85 mg/dl	11·25	Non-consuming downset meal: 49·1 mg/dl	9·6		
							TAG	Consuming downset meal: 96·9 mg/dl	49·7	Consuming downset meal: 112·45 mg/dl	65·65		
								Non-consuming downset meal: 111·85 mg/d	61·55	Non-consuming downset meal: 138·15 mg/dl	106·75		

Table 1. *Continued*

Study, publication year	Country	Sample size		Age (years)		Study design	Examined markers	Before Ramadan†		End of Ramadan†		Results (after Ramadan month compared with before)	Total quality score
		n	% Male	Mean	Range			Mean	SD	Mean	SD		
Akaberi *et al.*, 2014(75)	Iran	43	51·2		20–40	Prospective observational	HDL	33·10 mg/dl	6·53	42·49 mg/dl	8·44	HDL increased significantly	4
							TAG	113·33 mg/dl	49·74	111·87 mg/dl	59·55		
Akhtaruzzaman *et al.*, 2014(76)	Bangladesh	28	0		25–80	Prospective observational*	HDL	38·75 mg/dl	1·01	41·14 mg/dl	1·02	HDL significantly increased	4
							TAG	119·61 mg/dl	3·6	121·93 mg/dl	3·93		
AlNahari & Kouja, 2014(77)	Saudi Arabia	26	100	NR		Prospective observational*	HDL	1·1 mmol/l	0·04	1·12 mmol/l	0·03	Significant decrease in FG; Significant increase in TAG	2
							TAG	1·12 mmol/l	0·08	1·37 mmol/l	0·08		
							FG	5·57 mmol/l	0·07	5·23 mmol/l	0·15		
Celik *et al.*, 2014(78)	Turkey	42	100	35 (SD 8·9)		Prospective observational*	WC	95·4 cm	11·9	94·3 cm	11·4	Significant reduction in WC and increase in FG	4
							HDL	1·09 mmol/l	0·19	1·1 mmol/l	0·19		
							TAG	1·38 mmol/l	0·79	1·31 mmol/l	0·72		
							FG	74·2 mg/dl	12·67	84·2 mg/dl	10·71		
Feizollahzadeh *et al.*, 2014(79)	Iran	70	100	47·88	30–70	Prospective observational*	HDL	57·74 mg/dl	9·7	57·88 mg/dl	8·62	Significant increase in FG and TAG	4
							TAG	139·85 mg/dl	89·31	165·14 mg/dl	84·96		
							FG	96·7 mg/dl	17·29	106·6 mg/dl	24·7		
Hassan & Isawumi, 2014(80)	Nigeria	60	60	42·3 (SD 16·7)		Prospective observational*	WC	87·2 cm	12·387	81·78 cm	11·65	Significant decline in WC	4
Ismail & Haron, 2014(81)	Malaysia	31	NR	NR		Randomised trial	HDL	1·07 mmol/l	0·204	1·17 mmol/l	0·28	TAG decreased significantly; HDL increased significantly	2
							TAG	1·34 mmol/l	0·9	1·04 mmol/l	0·45		
McNeil *et al.*, 2014(82)	Canada	20	NR		20–35	Prospective observational*	WC	Normal weight: 82·6 cm	6·3	Normal weight: 83·3 cm	7·8	TAG increased significantly; FG decreased significantly	2
								Obese: 113·3 cm	10·8	Obese: 111·9 cm	11·2		
							HDL	Normal weight: 1·19 mmol/l	0·21	Normal weight: 1·17 mmol/l	0·21		
								Obese: 1·01 mmol/l	0·17	Obese: 1·10 mmol/l	0·17		
							TAG	Normal weight: 0·96 mmol/l	0·46	Normal weight: 0·77 mmol/l	0·16		
								Obese: 1·65 mmol/l	1·10	Obese: 1·35 mmol/l	0·83		
							FG	Normal weight: 4·6 mmol/l	0·3	Normal weight: 4·8 mmol/l	0·3		
								Obese: 5·0 mmol/l	0·7	Obese: 5·2 mmol/l	0·5		
Salahuddin & Javed, 2014(83)	India	30	NR		35–65	Case–control	SBP	121 mmHg	2·1	121 mmHg	0·7	No significant change in SBP	2
Pathan & Patil, 2015(84)	India	39	100		25–35	Prospective observational*	HDL	50·63 mg/dl	2·35	59·80 mg/dl	3·47	HDL significantly increased; TAG significantly decreased	4
							TAG	89·00 mg/dl	17·43	82·00 mg/dl	15·9		
Ara *et al.*, 2015(85)	India	60	100		24–28	Prospective observational	HDL	47·7 mg/dl	0·51	54·97 mg/dl	0·44	HDL significantly increased	4
Hosseini & Hejazi, 2015(86)	Iran	25	52	NR		Quasi-experimental	HDL	Male: 37·9 mg/dl	3·9	Male: 38·9 mg/dl	3·7	No significant change in HDL, TAG or FG	2
								Female: 41·58 mg/dl	6·08	Female: 37·45 mg/dl	4·39		
							TAG	Male: 97·1 mg/dl	57·4	Male: 107·3 mg/dl	52·5		
								Female: 88·54 mg/dl	52·58	Female: 112·6 mg/dl	56·39		
							FG	Male: 88·3 mg/dl	6·3	Male: 84·4 mg/dl	7·5		
								Female: 77·16 mg/dl	6·88	Female: 91·9 mg/dl	10·03		
López-Bueno *et al.*, 2015(87)	Spain	62	0	33·6 (SD 12·7)	18–61	Longitudinal	WC	90·1 cm	12·42	89·4 cm	12·4	No significant changes in WC	4

Table 1. *Continued*

Study, publication year	Country	Sample size		Age (years)		Study design	Examined markers	Before Ramadan†		End of Ramadan†		Results (after Ramadan month compared with before)	Total quality score
		n	% Male	Mean	Range			Mean	SD	Mean	SD		
Shahsavan *et al.*, 2015[88]	Iran	89	57	34·97	20–50	Prospective observational*	HDL TAG SPB	42·76 mg/dl 123·07 mg/dl 116·4 mmHg	7·94 11	41·53 mg/dl 133·96 mg/dl 115·5 mmHg	6·98 10·1	Substantial decline in HDL	4
Suriani *et al.*, 2015[89]	Malaysia	84	0	39·8 (SD 10·3)		Prospective observational*	HDL TAG FG SBP	49·03 mg/dl 0·99 mmol/l 4·42 mmol/l 124·51 mmHg	13·9 0·4 0·87 18·14	34·36 mg/dl 0·89 mmol/l 4·24 mmol/l 123·27 mmHg	11·97 0·31 0·79 16·14	HDL, TAG and FG significantly reduced	4
Babaei *et al.*, 2016[90]	Iran	36	100	39·11 (SD 8·6)		Quasi-experimental	HDL TAG FG	51·78 mg/dl 162·72 mg/dl 75·78 mg/dl	12·27 94·23 8·46	49·81 mg/dl 144·22 mg/dl 80·06 mg/dl	12·14 67·06 9·26	Significant reduction in mean FG and TAG	4
BaHammam *et al.*, 2016[91]	Saudi Arabia	80	100	26·6 (SD 4·9)	20–35	Prospective observational*	FG	5·7mmol/l	0·4	5·8 mmol/l	0·5	No significant changes in FG	4
Esmaeilzadeh & Borne, 2016[92]	Belgium	14	100	42·4 (SD 1·5)		Prospective case–control	HDL TAG FG SBP	51·8 mg/dl 106·2 mg/dl 85·6 mg/dl 117 mmHg	4·2 20 1·3 3	47·5 mg/dl 119·6 mg/dl 93·4 mg/dl 104·3 mmHg	3·2 30·4 2·5 2·8	SBP decreased significantly; FG increased significantly	4
Ganjali *et al.*, 2016[93]	Iran	45	58	37·6 (SD 6·9)	25–58	Quasi-experimental	HDL TAG FG	Obese: 37·2 mg/dl Normal: 39·1 mg/dl Obese: 263 mg/dl Normal: 190 mg/dl Obese: 98·86 mg/dl Normal: 94·6 mg/dl	8·8 8·7 193·6 131·2 18·68 11·17	Obese: 41 mg/dl Normal: 40·1 mg/dl Obese: 255 mg/dl Normal: 163 mg/dl Obese: 93·68 mg/dl Normal: 85·69 mg/dl	6·1 7·9 177·4 97 11·66 7·32	FG significantly decreased in the normal weight group; HDL significantly increased in the obese group	4
Sezen *et al.*, 2016[94]	Turkey	70	100	37 (SD 7)		Prospective	SBP	120·2 mmHg	11·6	121·2 mmHg	10·2	No significant changes in SBP	4
Kiyani *et al.*, 2017[95]	Pakistan	80	62·5	20·5	18–24	Prospective observational*	HDL TAG FG	1·2 mmol/l 1·4 mmol/l 72·6 mg/dl	0·3 0·5 12·5	1·1 mmol/l 1·2 mmol/l 57·9 mg/dl	0·3 0·5 10·7	Significant decline in FG and TAG; Significant reduction in HDL	4
AbdulKareem *et al.*, 2017[96]	Iraq	12	25	37·5 (SD 10·8)	24–57	Case–control	HDL TAG FG	49·58 mg/dl 92 mg/dl 86·25 mg/dl	2·96 10·83 4·06	53·25 mg/dl 94·83 mg/dl 63·17 mg/dl	2·496 9·67 2·51	Significant decrease in FG and significant increase in HDL and TAG (healthy subjects)	4
Alsubheen *et al.*, 2017[97]	Canada	9	100	32·2 (SD 7·8)		Prospective observational*	SBP	120 mmHg	11	109 mmHg	12	Significant decrease in SBP	4
Bakki *et al.*, 2017[98]	Nigeria	75	62·6	25 (SD 2)	18–30	Cross-sectional	HDL TAG FG	1·4 mmol/l 1·2 mmol/l 4·0 mmol/l	0·3 0·4 0·5	1·3 mmol/l 1·2 mmol/l 4·7 mmol/l	0·2 0·3 0·9	No significant changes in TAG Significant increase in HDL Slight significant increase in FG	4
Khan *et al.*, 2017[99]	Pakistan	35	51	21·66 (SD 0·7)	21–23	Prospective observational*	WC HDL TAG FG SBP	79·9 cm 55·88 mg/dl 87·76 mg/dl 88·79 mg/dl 113·08 mmHg	10·18 13·73 37·87 9·1 10·52	79·74 cm 49·82 mg/dl 79·82 mg/dl 87·2 mg/dl 113·56 mmHg	10·33 10·09 34·54 6·35 9·5	Mean HDL decreased significantly	4
Malekmakan *et al.*, 2017[100]	Iran	93	52·7	37·2 (SD 7·9)	25–57	Semi-experimental study	WC SBP	89·1 cm 101·7 mmHg	11·1 12·9	87·5 cm 99·4 mmHg	11·1 12·7	WC and SBP significantly decreased	4

Table 1. *Continued*

Study, publication year	Country	Sample size		Age (years)		Study design	Examined markers	Before Ramadan†		End of Ramadan†		Results (after Ramadan month compared with before)	Total quality score
		n	% Male	Mean	Range			Mean	SD	Mean	SD		
Norouzy *et al.*, 2017(101)	Iran	12	50	54·6 (SD 4)		Prospective observational	SBP	119·5 mmHg	6	117·6 mmHg	9	No significant difference in SBP	4
Ongsara *et al.*, 2017(102)	Thailand	65	32	20·82 (SD 1·1)	19–24	Prospective observational	WC	Male: 79·83 cm	12·4	Male: 76·5 cm	10·84	No significant changes in WC, BP, TAG or HDL for either sex	4
								Female: 63·45 cm	6·66	Female: 65·44 cm	7		
							HDL	Male: 1·26 mmol/l	0·24	Male: 1·42 mmol/l	0·3		
								Female: 1·47 mmol/l	0·33	Female: 1·51 mmol/l	0·35		
							TAG	Male: 0·92 mmol/l	0·36	Male: 1·02 mmol/l	0·3		
								Female: 0·83 mmol/l	0·28	Female: 0·79 mmol/l	0·28		
							FG	Male: 5·34 mmol/l	0·51	Male: 5·27 mmol/l	0·41		
								Female: 4·83 mmol/l	0·38	Female: 4·9 mmol/l	0·41		
							SBP	Male: 126·76 mmHg	15·38	Male: 126·95 mmHg	14·54		
								Female: 107·14 mmHg	7·05	Female: 107·36 mmHg	9·86		
Mohammadzade *et al.*, 2017(103)	Iran	30	100	29·44 (SD 7·4)	20–35	Prospective observational	WC	96·48 cm	11·38	95·31 cm	10·62	No significant change in SBP; significantly decreased TAG and FG;·significantly increased HDL	4
							HDL	33·83 mg/dl	8·53	47·59 mg/dl	6·7		
							TAG	152·55 mg/dl	64·35	123·83 mg/dl	53·44		
							FG	98·58 mg/dl	7·04	81 mg/dl	4·97		
							SBP	124·7 mmHg	4	121·6 mmHg	6		
Abubakar *et al.*, 2018(104)	Pakistan	60	NR	34·3 (SD 8·6)		Prospective observational*	HDL	1·08 mmol/l	0·35	1·11 mmol/l	0·39	No significant change in TAG, HDL or FG	2
							TAG	1·33 mmol/l	0·75	1·45 mmol/l	0·99		
							FG	5·58 mmol/l	1·17	5·61 mmol/l	0·97		
Al-Barha & Aljaloud, 2018(105)	Saudi Arabia	44	100	27·7 (SD 5·8)	18–39	Quasi-experimental before/after study	WC	82·9 cm	10·9	81·8 cm	10·5	FG and SBP were slightly but significantly elevated	4
							FG	74·60 mg/dl		81·52 mg/dl			
							SBP	109·6 mmHg	9	111·8 mmHg	10·8		
Nachvak *et al.*, 2018(19)	Iran	152	100	39·35 (SD 11)	21–63	Observational	HDL	44·70 mg/dl	7·9	45·59 mg/dl	9	HDL levels increased significantly; significant decrease in TAG and FG	4
							TAG	151·44 mg/dl	85·2	140·44 mg/dl	75·2		
							FG	80·17 mg/dl	19·3	72·06 mg/dl	8·4		
Prasetya & Sepwarobol, 2018(106)	Thailand	27	100	24·3 (SD 3·7)	19–40	Prospective observational*	WC	81·82 cm	7·73	78·82 cm	7·96	Reductions in WC and HDL; no significant change in FG	4
							HDL	52·84 mg/dl	13·2	48·89 mg/dl	11·91		
							TAG	90·59 mg/dl	62·43	77·37 mg/dl	50·14		
							FG	4·83 mmol/l	0·36	4·87 mmol/l	0·35		
Rahbar *et al.*, 2019(107)	Iran	34	100	35 (SD 11)	16–64	Prospective observational*	WC	91·97 cm	11·71	91·45 cm	11·59	WC and TAG significantly decreased; HDL levels significantly increased	4
							HDL	43·79 mg/dl	5·49	48·38 mg/dl	9·39		
							TAG	143·56 mg/dl	47·64	120·33 mg/dl	42·67		

FG, fasting plasma/serum glucose; NR, not reported; SBP, systolic blood pressure; UAE, United Arab Emirates; WC, waist circumference.

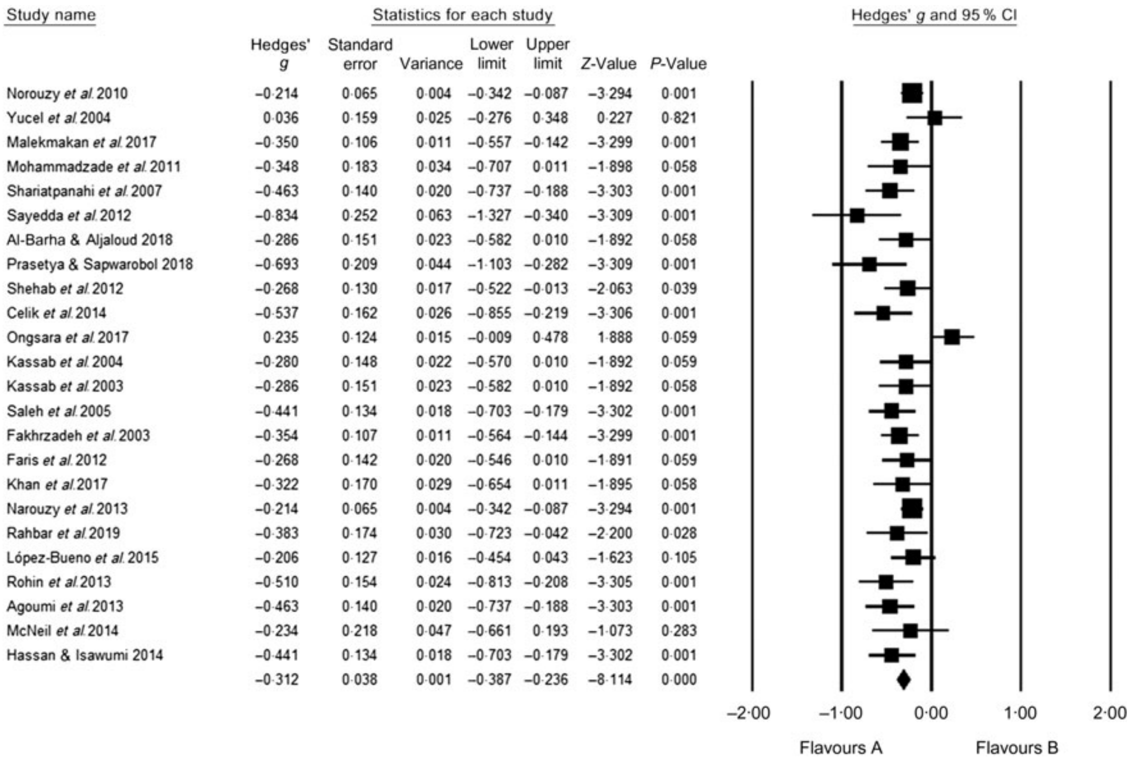
* Not reported by the study authors.

† Results are transcribed from the original papers as reported. To convert from mg/dl to mmol/l, divide by 18. To convert mmol/l to mg/dl, multiply by 18.

Table 2. Characteristics and pooled analyses of included studies for each metabolic syndrome component

Component	*K**	*N*†	Number of countries	Mean age (years)	Overall % male	Fasting time (min/d)	Hedges' *g*	95 % CI
WC	24	1557	14	31·5	58·7	841	−0·312	−0·387, −0·236
FG	51	2318	19	30·3	66	817	−0·101	−0·260, 0·004
TAG	63	2862	21	31	67	820	−0·088	−0·171, −0·004
HDL	57	2771	19	31·5	66	830	0·150	0·064, 0·236
SBP	22	1172	13	33	63	876	−0·239	−0·372, −0·106

FG, fasting plasma glucose; SBP, systolic blood pressure; WC, waist circumference.
* *K*: denotes number of studies.
† *N*: denotes number of participants.



Study name	Hedges' *g*	Standard error	Variance	Lower limit	Upper limit	*Z*-Value	*P*-Value
Norouzy *et al.* 2010	−0·214	0·065	0·004	−0·342	−0·087	−3·294	0·001
Yucel *et al.* 2004	0·036	0·159	0·025	−0·276	0·348	0·227	0·821
Malekmakan *et al.* 2017	−0·350	0·106	0·011	−0·557	−0·142	−3·299	0·001
Mohammadzade *et al.* 2011	−0·348	0·183	0·034	−0·707	0·011	−1·898	0·058
Shariatpanahi *et al.* 2007	−0·463	0·140	0·020	−0·737	−0·188	−3·303	0·001
Sayedda *et al.* 2012	−0·834	0·252	0·063	−1·327	−0·340	−3·309	0·001
Al-Barha & Aljaloud 2018	−0·286	0·151	0·023	−0·582	0·010	−1·892	0·058
Prasetya & Sapwarobol 2018	−0·693	0·209	0·044	−1·103	−0·282	−3·309	0·001
Shehab *et al.* 2012	−0·268	0·130	0·017	−0·522	−0·013	−2·063	0·039
Celik *et al.* 2014	−0·537	0·162	0·026	−0·855	−0·219	−3·306	0·001
Ongsara *et al.* 2017	0·235	0·124	0·015	−0·009	0·478	1·888	0·059
Kassab *et al.* 2004	−0·280	0·148	0·022	−0·570	0·010	−1·892	0·059
Kassab *et al.* 2003	−0·286	0·151	0·023	−0·582	0·010	−1·892	0·058
Saleh *et al.* 2005	−0·441	0·134	0·018	−0·703	−0·179	−3·302	0·001
Fakhrzadeh *et al.* 2003	−0·354	0·107	0·011	−0·564	−0·144	−3·299	0·001
Faris *et al.* 2012	−0·268	0·142	0·020	−0·546	0·010	−1·891	0·059
Khan *et al.* 2017	−0·322	0·170	0·029	−0·654	0·011	−1·895	0·058
Narouzy *et al.* 2013	−0·214	0·065	0·004	−0·342	−0·087	−3·294	0·001
Rahbar *et al.* 2019	−0·383	0·174	0·030	−0·723	−0·042	−2·200	0·028
López-Bueno *et al.* 2015	−0·206	0·127	0·016	−0·454	0·043	−1·623	0·105
Rohin *et al.* 2013	−0·510	0·154	0·024	−0·813	−0·208	−3·305	0·001
Agoumi *et al.* 2013	−0·463	0·140	0·020	−0·737	−0·188	−3·303	0·001
McNeil *et al.* 2014	−0·234	0·218	0·047	−0·661	0·193	−1·073	0·283
Hassan & Isawumi 2014	−0·441	0·134	0·018	−0·703	−0·179	−3·302	0·001
	−0·312	0·038	0·001	−0·387	−0·236	−8·114	0·000

Fig. 2. According to Hedges' *g* value with 95 % CI, small (−0·312) significant reduction in waist circumference was induced by Ramadan fasting. Heterogeneity statistics: 95 % CI −0·387, −0·236, $I^2 = 49$ %. Hedges' *g* value is considered small when value = 0·2, medium = 0·5, large = 0·8.

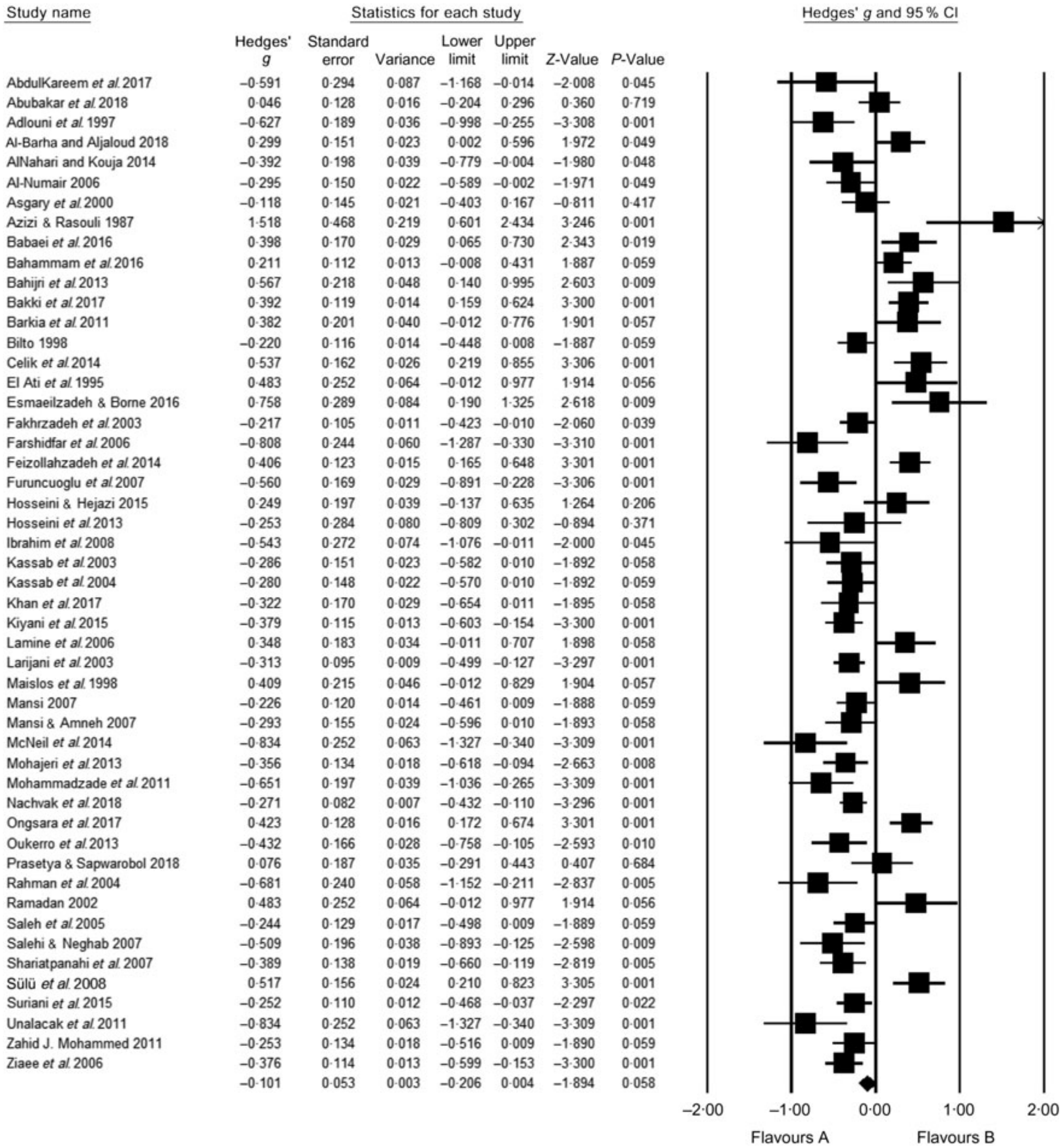
more studies were available to explore differences in findings among countries (Table 4).

Waist circumference

Age (online Supplementary Fig. S6) and fasting time/d (online Supplementary Fig. S7) were NS moderators for changes in WC. However, sex was significant in explaining variation in WC ($\beta = -0{\cdot}20$, $P = 0{\cdot}03$) (online Supplementary Fig. S8), suggesting that women experienced a larger change in WC than men during RDIF. Only Iran contributed three or more studies that measured WC change during RDIF ($K = 7$, N 783): Hedges' $g = -0{\cdot}275$, 95 % CI −0·346, −0·204, $I^2 = 0{\cdot}0$ %; online Supplementary Fig. S9).

Fasting glucose

Age ($\beta = 0{\cdot}005$, $P = 0{\cdot}05$; online Supplementary Fig. S10) and fasting time/d ($\beta = -0{\cdot}001$, $P = 0{\cdot}001$; online Supplementary Fig. S11) had significant impacts as moderators for changes in FG, whereas sex had no significant impact on FG changes during Ramadan fasting (online Supplementary Fig. S12). Six countries contributed three or more studies that measured FG changes during Ramadan month (online Supplementary Fig. S13): Iran ($K = 15$, N 828, Hedges' $g = -0{\cdot}173$, 95 % CI −0·348, 0·002, $I^2 = 81{\cdot}93$ %), Saudi Arabia ($K = 5$, N 218, Hedges' $g = 0{\cdot}075$, 95 % CI −0·240, 0·390, $I^2 = 80{\cdot}41$ %), Turkey ($K = 4$, N 146, Hedges' $g = -0{\cdot}069$, 95 % CI −0·735, 0·596, $I^2 = 93{\cdot}05$ %), Tunisia ($K = 4$, N 109, Hedges' $g = 0{\cdot}180$, 95 % CI −0·271, 0·630, $I^2 = 81{\cdot}6$ %), Jordan ($K = 3$, N 186, Hedges'



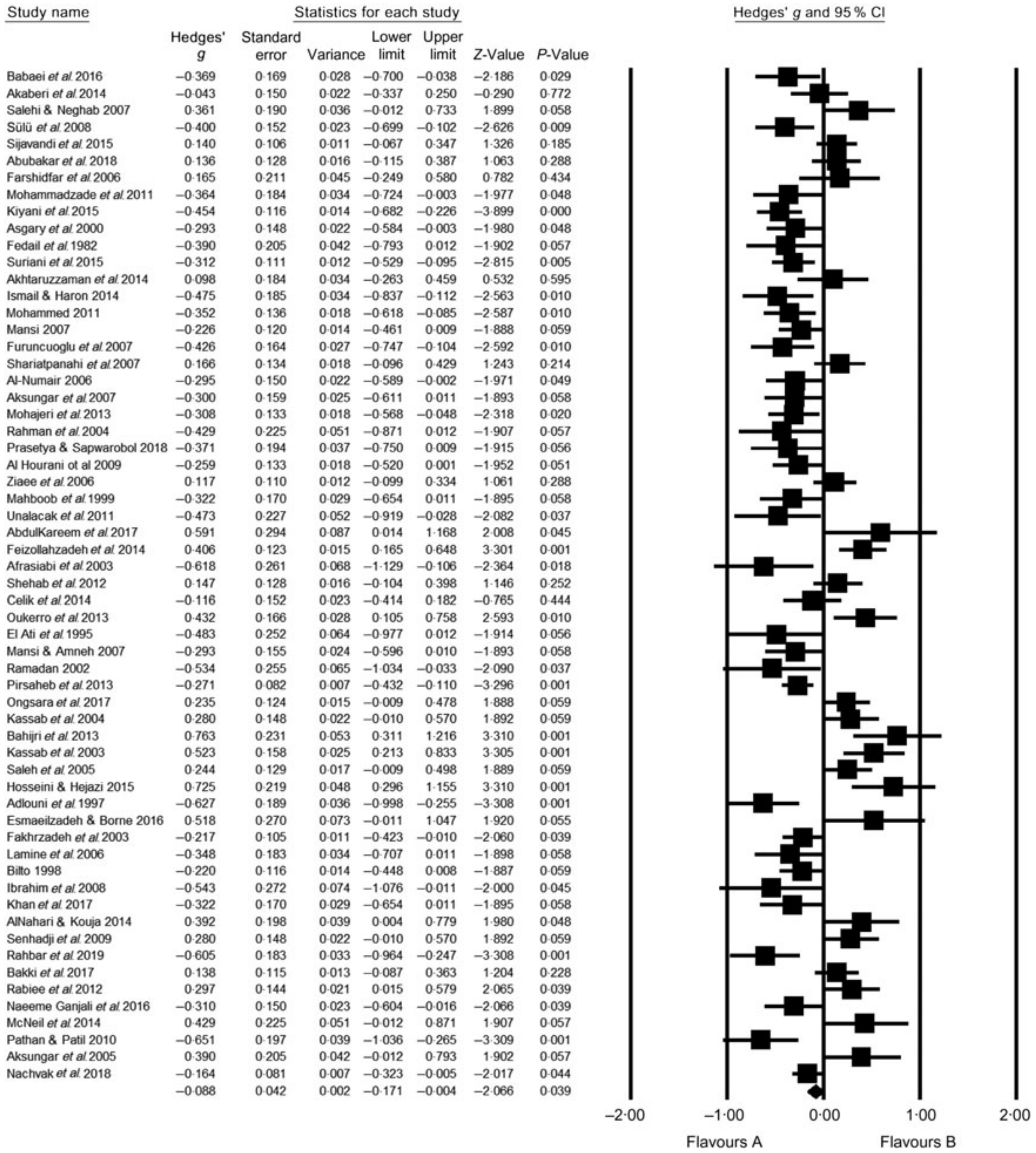
Study name	Hedges' *g*	Standard error	Variance	Lower limit	Upper limit	Z-Value	*P*-Value
AbdulKareem *et al.* 2017	–0·591	0·294	0·087	–1·168	–0·014	–2·008	0·045
Abubakar *et al.* 2018	0·046	0·128	0·016	–0·204	0·296	0·360	0·719
Adlouni *et al.* 1997	–0·627	0·189	0·036	–0·998	–0·255	–3·308	0·001
Al-Barha and Aljaloud 2018	0·299	0·151	0·023	0·002	0·596	1·972	0·049
AlNahari and Kouja 2014	–0·392	0·198	0·039	–0·779	–0·004	–1·980	0·048
Al-Numair 2006	–0·295	0·150	0·022	–0·589	–0·002	–1·971	0·049
Asgary *et al.* 2000	–0·118	0·145	0·021	–0·403	0·167	–0·811	0·417
Azizi & Rasouli 1987	1·518	0·468	0·219	0·601	2·434	3·246	0·001
Babaei *et al.* 2016	0·398	0·170	0·029	0·065	0·730	2·343	0·019
Bahammam *et al.* 2016	0·211	0·112	0·013	–0·008	0·431	1·887	0·059
Bahijri *et al.* 2013	0·567	0·218	0·048	0·140	0·995	2·603	0·009
Bakki *et al.* 2017	0·392	0·119	0·014	0·159	0·624	3·300	0·001
Barkia *et al.* 2011	0·382	0·201	0·040	–0·012	0·776	1·901	0·057
Bilto 1998	–0·220	0·116	0·014	–0·448	0·008	–1·887	0·059
Celik *et al.* 2014	0·537	0·162	0·026	0·219	0·855	3·306	0·001
El Ati *et al.* 1995	0·483	0·252	0·064	–0·012	0·977	1·914	0·056
Esmaeilzadeh & Borne 2016	0·758	0·289	0·084	0·190	1·325	2·618	0·009
Fakhrzadeh *et al.* 2003	–0·217	0·105	0·011	–0·423	–0·010	–2·060	0·039
Farshidfar *et al.* 2006	–0·808	0·244	0·060	–1·287	–0·330	–3·310	0·001
Feizollahzadeh *et al.* 2014	0·406	0·123	0·015	0·165	0·648	3·301	0·001
Furuncuoglu *et al.* 2007	–0·560	0·169	0·029	–0·891	–0·228	–3·306	0·001
Hosseini & Hejazi 2015	0·249	0·197	0·039	–0·137	0·635	1·264	0·206
Hosseini *et al.* 2013	–0·253	0·284	0·080	–0·809	0·302	–0·894	0·371
Ibrahim *et al.* 2008	–0·543	0·272	0·074	–1·076	–0·011	–2·000	0·045
Kassab *et al.* 2003	–0·286	0·151	0·023	–0·582	0·010	–1·892	0·058
Kassab *et al.* 2004	–0·280	0·148	0·022	–0·570	0·010	–1·892	0·059
Khan *et al.* 2017	–0·322	0·170	0·029	–0·654	0·011	–1·895	0·058
Kiyani *et al.* 2015	–0·379	0·115	0·013	–0·603	–0·154	–3·300	0·001
Lamine *et al.* 2006	0·348	0·183	0·034	–0·011	0·707	1·898	0·058
Larijani *et al.* 2003	–0·313	0·095	0·009	–0·499	–0·127	–3·297	0·001
Maislos *et al.* 1998	0·409	0·215	0·046	–0·012	0·829	1·904	0·057
Mansi 2007	–0·226	0·120	0·014	–0·461	0·009	–1·888	0·059
Mansi & Amneh 2007	–0·293	0·155	0·024	–0·596	0·010	–1·893	0·058
McNeil *et al.* 2014	–0·834	0·252	0·063	–1·327	–0·340	–3·309	0·001
Mohajeri *et al.* 2013	–0·356	0·134	0·018	–0·618	–0·094	–2·663	0·008
Mohammadzade *et al.* 2011	–0·651	0·197	0·039	–1·036	–0·265	–3·309	0·001
Nachvak *et al.* 2018	–0·271	0·082	0·007	–0·432	–0·110	–3·296	0·001
Ongsara *et al.* 2017	0·423	0·128	0·016	0·172	0·674	3·301	0·001
Oukerro *et al.* 2013	–0·432	0·166	0·028	–0·758	–0·105	–2·593	0·010
Prasetya & Sapwarobol 2018	0·076	0·187	0·035	–0·291	0·443	0·407	0·684
Rahman *et al.* 2004	–0·681	0·240	0·058	–1·152	–0·211	–2·837	0·005
Ramadan 2002	0·483	0·252	0·064	–0·012	0·977	1·914	0·056
Saleh *et al.* 2005	–0·244	0·129	0·017	–0·498	0·009	–1·889	0·059
Salehi & Neghab 2007	–0·509	0·196	0·038	–0·893	–0·125	–2·598	0·009
Shariatpanahi *et al.* 2007	–0·389	0·138	0·019	–0·660	–0·119	–2·819	0·005
Sülü *et al.* 2008	0·517	0·156	0·024	0·210	0·823	3·305	0·001
Suriani *et al.* 2015	–0·252	0·110	0·012	–0·468	–0·037	–2·297	0·022
Unalacak *et al.* 2011	–0·834	0·252	0·063	–1·327	–0·340	–3·309	0·001
Zahid J. Mohammed 2011	–0·253	0·134	0·018	–0·516	0·009	–1·890	0·059
Ziaee *et al.* 2006	–0·376	0·114	0·013	–0·599	–0·153	–3·300	0·001
	–0·101	0·053	0·003	–0·206	0·004	–1·894	0·058

Fig. 3. According to Hedges' *g* value with 95 % CI, small (–0·101) significant reduction in fasting glucose was induced by Ramadan fasting. Heterogeneity statistics: 95 % CI –0·206, 0·004, $I^2 = 26·6\,\%$. Hedges' *g* value is considered small when value = 0·2, medium = 0·5, large = 0·8.

g = –0·239, 95 % CI –0·383, –0·095, $I^2 = 0·0\,\%$) and Pakistan (*K* = 3, *N* 175, Hedges' *g* = –0·215, 95 % CI –0·494, 0·064, $I^2 = 69·8\,\%$).

TAG

Sex (*β* = –0·14, *P* = 0·01; online Supplementary Fig. S14) and fasting time/d (*β* = –0·005, *P* = 0·01; online Supplementary Fig. S15) had significant impacts as moderators for changes in TAG during RDIF, but age (online Supplementary Fig. S16) had no significant impact on TAG changes (Table 3). These findings suggested that women experienced a larger change in TAG than men during Ramadan month and that longer fasting time/d was associated with a greater reduction in TAG at the end of Ramadan. Six countries contributed three or more studies that measured TAG change during RDIF (online Supplementary Fig. S17): Iran (*K* = 20, *N* 1156, Hedges' *g* = –0·073, 95 % CI –0·204, 0·058, $I^2 = 78·7\,\%$), Turkey (*K* = 6, *N* 210, Hedges' *g* = –0·229, 95 % CI –0·458, 0·001, $I^2 = 63·4\,\%$), Jordan (*K* = 4, *N* 243, Hedges' *g* = –0·244, 95 % CI –0·370, –0·117, $I^2 = 0·0\,\%$), Tunisia (*K* = 4, *N* 109, Hedges' *g* = –0·116, 95 % CI –0·706, 0·473, I^2 85·6 %), Pakistan (*K* = 3, *N* 175, Hedges' *g* = –0·212, 95 % CI –0·591, 0·168, $I^2 = 83·5\,\%$) and Saudi Arabia (*K* = 3, *N* 94, Hedges' *g* = 0·269, 95 % CI –0·366, 0·905, $I^2 = 88·5\,\%$).



Study name	Statistics for each study						
	Hedges' *g*	Standard error	Variance	Lower limit	Upper limit	*Z*-Value	*P*-Value
Babaei *et al.* 2016	−0·369	0·169	0·028	−0·700	−0·038	−2·186	0·029
Akaberi *et al.* 2014	−0·043	0·150	0·022	−0·337	0·250	−0·290	0·772
Salehi & Neghab 2007	0·361	0·190	0·036	−0·012	0·733	1·899	0·058
Sülü *et al.* 2008	−0·400	0·152	0·023	−0·699	−0·102	−2·626	0·009
Sijavandi *et al.* 2015	0·140	0·106	0·011	−0·067	0·347	1·326	0·185
Abubakar *et al.* 2018	0·136	0·128	0·016	−0·115	0·387	1·063	0·288
Farshidfar *et al.* 2006	0·165	0·211	0·045	−0·249	0·580	0·782	0·434
Mohammadzade *et al.* 2011	−0·364	0·184	0·034	−0·724	−0·003	−1·977	0·048
Kiyani *et al.* 2015	−0·454	0·116	0·014	−0·682	−0·226	−3·899	0·000
Asgary *et al.* 2000	−0·293	0·148	0·022	−0·584	−0·003	−1·980	0·048
Fedail *et al.* 1982	−0·390	0·205	0·042	−0·793	0·012	−1·902	0·057
Suriani *et al.* 2015	−0·312	0·111	0·012	−0·529	−0·095	−2·815	0·005
Akhtaruzzaman *et al.* 2014	0·098	0·184	0·034	−0·263	0·459	0·532	0·595
Ismail & Haron 2014	−0·475	0·185	0·034	−0·837	−0·112	−2·563	0·010
Mohammed 2011	−0·352	0·136	0·018	−0·618	−0·085	−2·587	0·010
Mansi 2007	−0·226	0·120	0·014	−0·461	0·009	−1·888	0·059
Furuncuoglu *et al.* 2007	−0·426	0·164	0·027	−0·747	−0·104	−2·592	0·010
Shariatpanahi *et al.* 2007	0·166	0·134	0·018	−0·096	0·429	1·243	0·214
Al-Numair 2006	−0·295	0·150	0·022	−0·589	−0·002	−1·971	0·049
Aksungar *et al.* 2007	−0·300	0·159	0·025	−0·611	0·011	−1·893	0·058
Mohajeri *et al.* 2013	−0·308	0·133	0·018	−0·568	−0·048	−2·318	0·020
Rahman *et al.* 2004	−0·429	0·225	0·051	−0·871	0·012	−1·907	0·057
Prasetya & Sapwarobol 2018	−0·371	0·194	0·037	−0·750	0·009	−1·915	0·056
Al Hourani ot al 2009	−0·259	0·133	0·018	−0·520	0·001	−1·952	0·051
Ziaee *et al.* 2006	0·117	0·110	0·012	−0·099	0·334	1·061	0·288
Mahboob *et al.* 1999	−0·322	0·170	0·029	−0·654	0·011	−1·895	0·058
Unalacak *et al.* 2011	−0·473	0·227	0·052	−0·919	−0·028	−2·082	0·037
AbdulKareem *et al.* 2017	0·591	0·294	0·087	0·014	1·168	2·008	0·045
Feizollahzadeh *et al.* 2014	0·406	0·123	0·015	0·165	0·648	3·301	0·001
Afrasiabi *et al.* 2003	−0·618	0·261	0·068	−1·129	−0·106	−2·364	0·018
Shehab *et al.* 2012	0·147	0·128	0·016	−0·104	0·398	1·146	0·252
Celik *et al.* 2014	−0·116	0·152	0·023	−0·414	0·182	−0·765	0·444
Oukerro *et al.* 2013	0·432	0·166	0·028	0·105	0·758	2·593	0·010
El Ati *et al.* 1995	−0·483	0·252	0·064	−0·977	0·012	−1·914	0·056
Mansi & Amneh 2007	−0·293	0·155	0·024	−0·596	0·010	−1·893	0·058
Ramadan 2002	−0·534	0·255	0·065	−1·034	−0·033	−2·090	0·037
Pirsaheb *et al.* 2013	−0·271	0·082	0·007	−0·432	−0·110	−3·296	0·001
Ongsara *et al.* 2017	0·235	0·124	0·015	−0·009	0·478	1·888	0·059
Kassab *et al.* 2004	0·280	0·148	0·022	−0·010	0·570	1·892	0·059
Bahijri *et al.* 2013	0·763	0·231	0·053	0·311	1·216	3·310	0·001
Kassab *et al.* 2003	0·523	0·158	0·025	0·213	0·833	3·305	0·001
Saleh *et al.* 2005	0·244	0·129	0·017	−0·009	0·498	1·889	0·059
Hosseini & Hejazi 2015	0·725	0·219	0·048	0·296	1·155	3·310	0·001
Adlouni *et al.* 1997	−0·627	0·189	0·036	−0·998	−0·255	−3·308	0·001
Esmaeilzadeh & Borne 2016	0·518	0·270	0·073	−0·011	1·047	1·920	0·055
Fakhrzadeh *et al.* 2003	−0·217	0·105	0·011	−0·423	−0·010	−2·060	0·039
Lamine *et al.* 2006	−0·348	0·183	0·034	−0·707	0·011	−1·898	0·058
Bilto 1998	−0·220	0·116	0·014	−0·448	0·008	−1·887	0·059
Ibrahim *et al.* 2008	−0·543	0·272	0·074	−1·076	−0·011	−2·000	0·045
Khan *et al.* 2017	−0·322	0·170	0·029	−0·654	0·011	−1·895	0·058
AlNahari & Kouja 2014	0·392	0·198	0·039	0·004	0·779	1·980	0·048
Senhadji *et al.* 2009	0·280	0·148	0·022	−0·010	0·570	1·892	0·059
Rahbar *et al.* 2019	−0·605	0·183	0·033	−0·964	−0·247	−3·308	0·001
Bakki *et al.* 2017	0·138	0·115	0·013	−0·087	0·363	1·204	0·228
Rabiee *et al.* 2012	0·297	0·144	0·021	0·015	0·579	2·065	0·039
Naeeme Ganjali *et al.* 2016	−0·310	0·150	0·023	−0·604	−0·016	−2·066	0·039
McNeil *et al.* 2014	0·429	0·225	0·051	−0·012	0·871	1·907	0·057
Pathan & Patil 2010	−0·651	0·197	0·039	−1·036	−0·265	−3·309	0·001
Aksungar *et al.* 2005	0·390	0·205	0·042	−0·012	0·793	1·902	0·057
Nachvak *et al.* 2018	−0·164	0·081	0·007	−0·323	−0·005	−2·017	0·044
	−0·088	0·042	0·002	−0·171	−0·004	−2·066	0·039

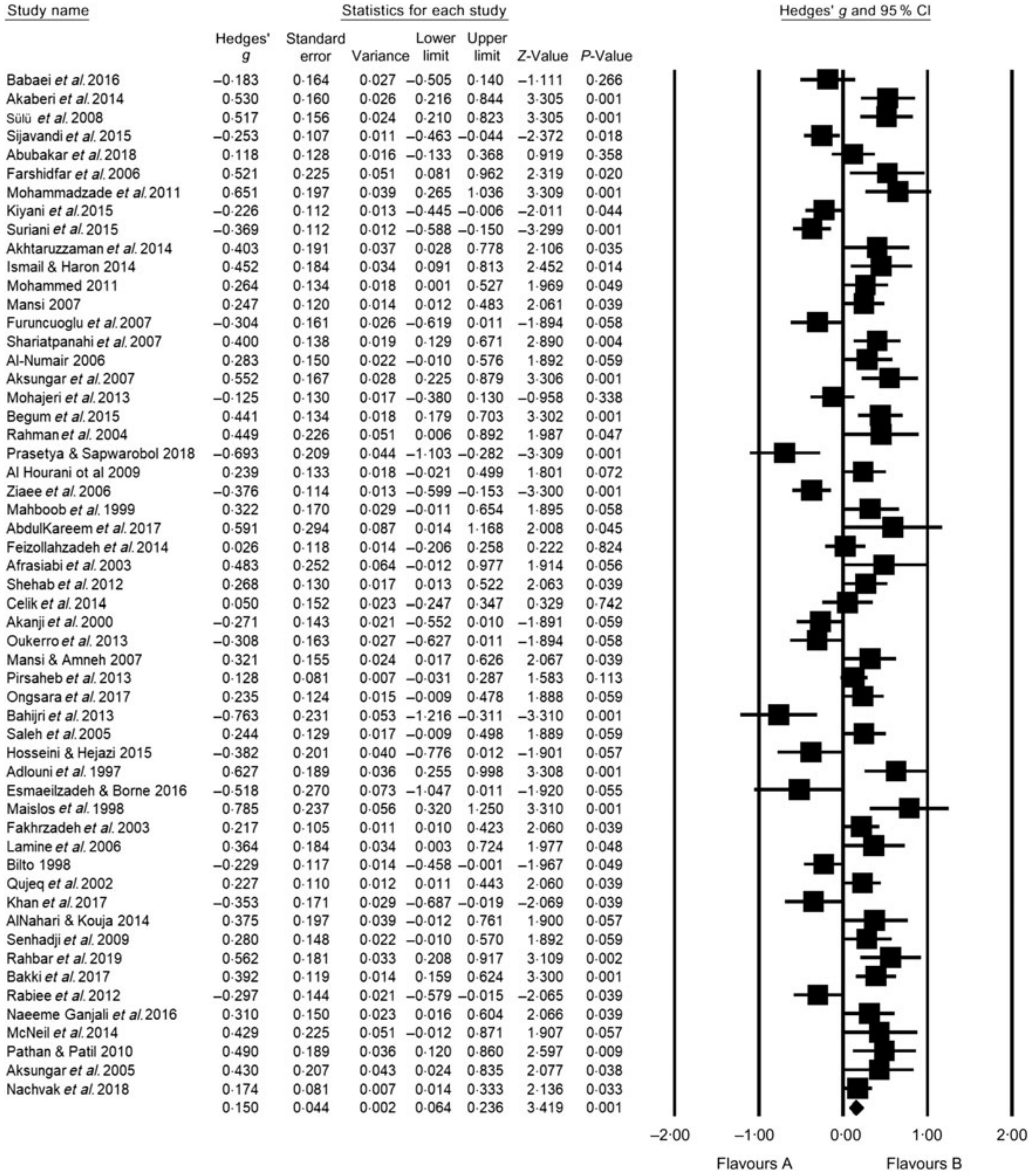
Fig. 4. According to Hedges' *g* value with 95 % CI, small (−0·088) significant reduction in serum TAG was induced by Ramadan fasting. Heterogeneity statistics: 95 % CI −0·171, −0·004, $I^2 = 78\,\%$. Hedges' *g* value is considered small when value = 0·2, medium = 0·5, large = 0·8.

HDL-cholesterol

Age (online Supplementary Fig. S18) and fasting time/d (online Supplementary Fig. S19) were NS moderators for RDIF-induced changes in HDL. However, sex was significant in explaining the variation in HDL ($\beta = 0{\cdot}15$, $P = 0{\cdot}005$; online Supplementary Fig. S20), which suggested that men experienced larger changes in HDL than women during Ramadan month. Five countries contributed three or more studies that measured HDL changes during Ramadan month (online Supplementary Fig. S21): Iran ($K = 19$, N 1165, Hedges' $g = 0{\cdot}135$, 95 % CI 0·002, 0·268, $I^2 = 79{\cdot}4\,\%$), Turkey ($K = 6$, N 210, Hedges' $g = 0{\cdot}244$, 95 % CI −0·087, 0·574, $I^2 = 80{\cdot}4\,\%$), Jordan ($K = 4$, N 243, Hedges' $g = 0{\cdot}137$, 95 % CI −0·124, 0·397, $I^2 = 76{\cdot}1\,\%$), Pakistan ($K = 3$, N 175, Hedges' $g = -0{\cdot}142$, 95 % CI −0·411, 0·126, $I^2 = 67{\cdot}6\,\%$) and Saudi Arabia ($K = 3$, N 94, Hedges' $g = -0{\cdot}019$, 95 % CI −0·655, 0·617, $I^2 = 88{\cdot}5\,\%$).

Systolic blood pressure

Age, sex and fasting time had no significant impact on SBP changes during RDIF (online Supplementary Figs. S22–S24). Two countries contributed three or more studies that measured SBP changes during RDIF (online Supplementary Fig. S25): Iran ($K = 7$, N 522, Hedges' $g = -0{\cdot}226$, 95 % CI −0·313,



Study name	Hedges' *g*	Standard error	Variance	Lower limit	Upper limit	*Z*-Value	*P*-Value
Babaei *et al.* 2016	−0·183	0·164	0·027	−0·505	0·140	−1·111	0·266
Akaberi *et al.* 2014	0·530	0·160	0·026	0·216	0·844	3·305	0·001
Sülü *et al.* 2008	0·517	0·156	0·024	0·210	0·823	3·305	0·001
Sijavandi *et al.* 2015	−0·253	0·107	0·011	−0·463	−0·044	−2·372	0·018
Abubakar *et al.* 2018	0·118	0·128	0·016	−0·133	0·368	0·919	0·358
Farshidfar *et al.* 2006	0·521	0·225	0·051	0·081	0·962	2·319	0·020
Mohammadzade *et al.* 2011	0·651	0·197	0·039	0·265	1·036	3·309	0·001
Kiyani *et al.* 2015	−0·226	0·112	0·013	−0·445	−0·006	−2·011	0·044
Suriani *et al.* 2015	−0·369	0·112	0·012	−0·588	−0·150	−3·299	0·001
Akhtaruzzaman *et al.* 2014	0·403	0·191	0·037	0·028	0·778	2·106	0·035
Ismail & Haron 2014	0·452	0·184	0·034	0·091	0·813	2·452	0·014
Mohammed 2011	0·264	0·134	0·018	0·001	0·527	1·969	0·049
Mansi 2007	0·247	0·120	0·014	0·012	0·483	2·061	0·039
Furuncuoglu *et al.* 2007	−0·304	0·161	0·026	−0·619	0·011	−1·894	0·058
Shariatpanahi *et al.* 2007	0·400	0·138	0·019	0·129	0·671	2·890	0·004
Al-Numair 2006	0·283	0·150	0·022	−0·010	0·576	1·892	0·059
Aksungar *et al.* 2007	0·552	0·167	0·028	0·225	0·879	3·306	0·001
Mohajeri *et al.* 2013	−0·125	0·130	0·017	−0·380	0·130	−0·958	0·338
Begum *et al.* 2015	0·441	0·134	0·018	0·179	0·703	3·302	0·001
Rahman *et al.* 2004	0·449	0·226	0·051	0·006	0·892	1·987	0·047
Prasetya & Sapwarobol 2018	−0·693	0·209	0·044	−1·103	−0·282	−3·309	0·001
Al Hourani ot al 2009	0·239	0·133	0·018	−0·021	0·499	1·801	0·072
Ziaee *et al.* 2006	−0·376	0·114	0·013	−0·599	−0·153	−3·300	0·001
Mahboob *et al.* 1999	0·322	0·170	0·029	−0·011	0·654	1·895	0·058
AbdulKareem *et al.* 2017	0·591	0·294	0·087	0·014	1·168	2·008	0·045
Feizollahzadeh *et al.* 2014	0·026	0·118	0·014	−0·206	0·258	0·222	0·824
Afrasiabi *et al.* 2003	0·483	0·252	0·064	−0·012	0·977	1·914	0·056
Shehab *et al.* 2012	0·268	0·130	0·017	0·013	0·522	2·063	0·039
Celik *et al.* 2014	0·050	0·152	0·023	−0·247	0·347	0·329	0·742
Akanji *et al.* 2000	−0·271	0·143	0·021	−0·552	0·010	−1·891	0·059
Oukerro *et al.* 2013	−0·308	0·163	0·027	−0·627	0·011	−1·894	0·058
Mansi & Amneh 2007	0·321	0·155	0·024	0·017	0·626	2·067	0·039
Pirsaheb *et al.* 2013	0·128	0·081	0·007	−0·031	0·287	1·583	0·113
Ongsara *et al.* 2017	0·235	0·124	0·015	−0·009	0·478	1·888	0·059
Bahijri *et al.* 2013	−0·763	0·231	0·053	−1·216	−0·311	−3·310	0·001
Saleh *et al.* 2005	0·244	0·129	0·017	−0·009	0·498	1·889	0·059
Hosseini & Hejazi 2015	−0·382	0·201	0·040	−0·776	0·012	−1·901	0·057
Adlouni *et al.* 1997	0·627	0·189	0·036	0·255	0·998	3·308	0·001
Esmaeilzadeh & Borne 2016	−0·518	0·270	0·073	−1·047	0·011	−1·920	0·055
Maislos *et al.* 1998	0·785	0·237	0·056	0·320	1·250	3·310	0·001
Fakhrzadeh *et al.* 2003	0·217	0·105	0·011	0·010	0·423	2·060	0·039
Lamine *et al.* 2006	0·364	0·184	0·034	0·003	0·724	1·977	0·048
Bilto 1998	−0·229	0·117	0·014	−0·458	−0·001	−1·967	0·049
Qujeq *et al.* 2002	0·227	0·110	0·012	0·011	0·443	2·060	0·039
Khan *et al.* 2017	−0·353	0·171	0·029	−0·687	−0·019	−2·069	0·039
AlNahari & Kouja 2014	0·375	0·197	0·039	−0·012	0·761	1·900	0·057
Senhadji *et al.* 2009	0·280	0·148	0·022	−0·010	0·570	1·892	0·059
Rahbar *et al.* 2019	0·562	0·181	0·033	0·208	0·917	3·109	0·002
Bakki *et al.* 2017	0·392	0·119	0·014	0·159	0·624	3·300	0·001
Rabiee *et al.* 2012	−0·297	0·144	0·021	−0·579	−0·015	−2·065	0·039
Naeeme Ganjali *et al.* 2016	0·310	0·150	0·023	0·016	0·604	2·066	0·039
McNeil *et al.* 2014	0·429	0·225	0·051	−0·012	0·871	1·907	0·057
Pathan & Patil 2010	0·490	0·189	0·036	0·120	0·860	2·597	0·009
Aksungar *et al.* 2005	0·430	0·207	0·043	0·024	0·835	2·077	0·038
Nachvak *et al.* 2018	0·174	0·081	0·007	0·014	0·333	2·136	0·033
	0·150	0·044	0·002	0·064	0·236	3·419	0·001

Fig. 5. According to Hedges' *g* value with 95 % CI, small (0·150) significant increment in serum HDL-cholesterol was induced by Ramadan fasting. Heterogeneity statistics: 95 % CI 0·0640, 0·236, $I^2 = 79$ %. Hedges' *g* value is considered small when value = 0·2, medium = 0·5, large = 0·8.

−0·138, $I^2 = 0{\cdot}0$ %) and Jordan ($K = 3$, N 162, Hedges' $g = -0{\cdot}342$, 95 % CI −0·501, −0·183, $I^2 = 0{\cdot}0$ %).

Discussion

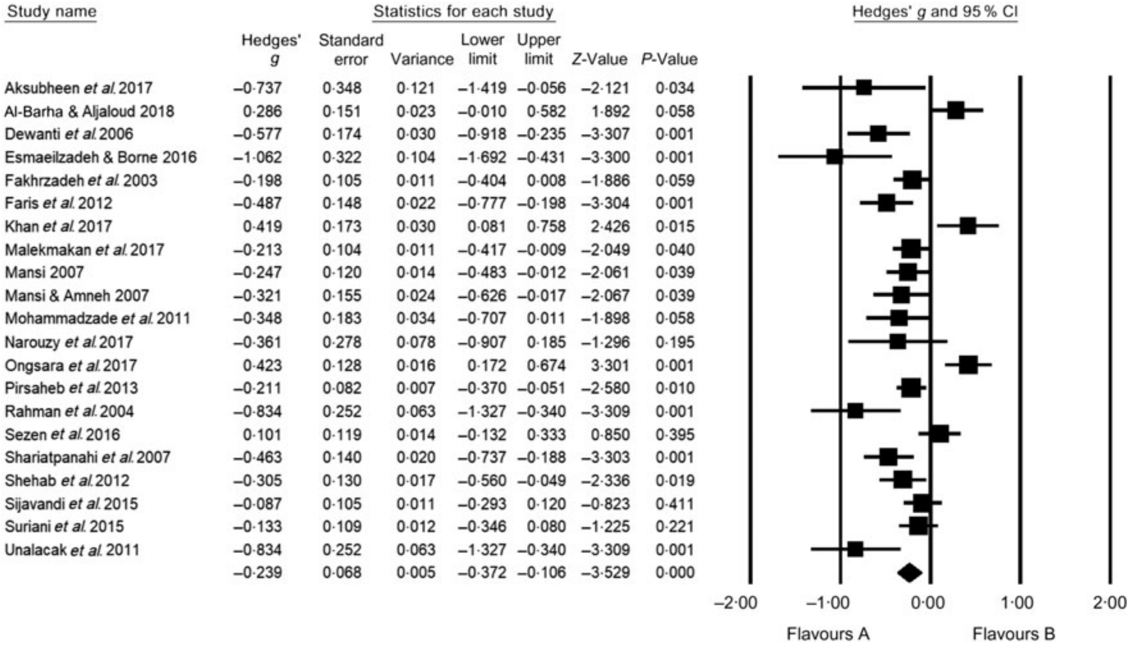
This systematic review and meta-analysis was the first to clarify the impact of RDIF on the cluster of the MetS components. We found that RDIF incurred small significant improvements in the MetS components; namely, decreased WC, TAG, FG, and SBP and increased HDL.

It is worth to emphasise that subjects included in the present analysis were normal, not patients. We excluded those studies on patients during Ramadan month, as shown in the exclusion section and depicted in Fig. 1 of Preferred Reporting Items for Systematic Reviews and Meta-Analyses. It is well-known and commonly seen that elderly Muslim people are very keen to fast during Ramadan, even those who are patients and excused not to observe Ramadan fasting(110). Providing that the authors of the used articles did not mention that elderly people interrupted their fasting during Ramadan, we cannot assume that fasting

Table 3. Overall Hedges' *g* values for the metabolic syndrome components and statistical values for the three moderators (age, sex and fasting time) at the end of Ramadan

							Moderators		
Component	K*	N†	I^2‡	τ^2§	Overall Hedges' g	95 % CI	Age	Sex (% Male)	Fasting time/d
WC	24	1557	49 %	$P = 0·001$	−0·32	−0·39, −0·24	$\beta = -0·002$, $P = 0·78$	$\beta = -0·20$, $P = 0·03$	$\beta = -0·001$, $P = 0·08$
FG	51	2318	26·6 %	$P = 0·001$	−0·10	−0·20, 0·004	$\beta = 0·005$, $P = 0·05$	$\beta = -0·10$, $P = 0·08$	$\beta = -0·001$, $P = 0·001$
TAG	63	2862	78 %	$P = 0·04$	−0·10	−0·12, 0·004	$\beta = 0·0004$, $P = 0·90$	$\beta = -0·14$, $P = 0·01$	$\beta = -0·005$, $P = 0·01$
HDL	57	2771	79 %	$P = 0·001$	0·15	0·07, 0·24	$\beta = -0·0003$, $P = 0·90$	$\beta = 0·15$, $P = 0·005$	$\beta = -0·002$, $P = 0·25$
SBP	22	1172	78 %	$P = 0·001$	−0·25	−0·38, −0·11	$\beta = -0·015$, $P = 0·064$	$\beta = -0·216$, $P = 0·20$	$\beta = 0·00005$, $P = 0·96$

FG, fasting plasma glucose; SBP, systolic blood pressure; WC, waist circumference.
* *K*: denotes number of studies.
† *N*: denotes number of participants.
‡ I^2 statistic describes the percentage of variation across studies due to heterogeneity rather than chance(108).
§ In a random-effects meta-analysis, the extent of variation among the effects observed in different studies (between-study variance) is referred to as τ^{2}(109).



Study name	Hedges' *g*	Standard error	Variance	Lower limit	Upper limit	*Z*-Value	*P*-Value
Aksubheen *et al.* 2017	−0·737	0·348	0·121	−1·419	−0·056	−2·121	0·034
Al-Barha & Aljaloud 2018	0·286	0·151	0·023	−0·010	0·582	1·892	0·058
Dewanti *et al.* 2006	−0·577	0·174	0·030	−0·918	−0·235	−3·307	0·001
Esmaeilzadeh & Borne 2016	−1·062	0·322	0·104	−1·692	−0·431	−3·300	0·001
Fakhrzadeh *et al.* 2003	−0·198	0·105	0·011	−0·404	0·008	−1·886	0·059
Faris *et al.* 2012	−0·487	0·148	0·022	−0·777	−0·198	−3·304	0·001
Khan *et al.* 2017	0·419	0·173	0·030	0·081	0·758	2·426	0·015
Malekmakan *et al.* 2017	−0·213	0·104	0·011	−0·417	−0·009	−2·049	0·040
Mansi 2007	−0·247	0·120	0·014	−0·483	−0·012	−2·061	0·039
Mansi & Amneh 2007	−0·321	0·155	0·024	−0·626	−0·017	−2·067	0·039
Mohammadzade *et al.* 2011	−0·348	0·183	0·034	−0·707	0·011	−1·898	0·058
Narouzy *et al.* 2017	−0·361	0·278	0·078	−0·907	0·185	−1·296	0·195
Ongsara *et al.* 2017	0·423	0·128	0·016	0·172	0·674	3·301	0·001
Pirsaheb *et al.* 2013	−0·211	0·082	0·007	−0·370	−0·051	−2·580	0·010
Rahman *et al.* 2004	−0·834	0·252	0·063	−1·327	−0·340	−3·309	0·001
Sezen *et al.* 2016	0·101	0·119	0·014	−0·132	0·333	0·850	0·395
Shariatpanahi *et al.* 2007	−0·463	0·140	0·020	−0·737	−0·188	−3·303	0·001
Shehab *et al.* 2012	−0·305	0·130	0·017	−0·560	−0·049	−2·336	0·019
Sijavandi *et al.* 2015	−0·087	0·105	0·011	−0·293	0·120	−0·823	0·411
Suriani *et al.* 2015	−0·133	0·109	0·012	−0·346	0·080	−1·225	0·221
Unalacak *et al.* 2011	−0·834	0·252	0·063	−1·327	−0·340	−3·309	0·001
	−0·239	0·068	0·005	−0·372	−0·106	−3·529	0·000

Fig. 6. According to Hedges' *g* value with 95 % CI, small (−0·239) significant reduction in systolic blood pressure was induced by Ramadan fasting. Heterogeneity statistics: 95 % CI −0·372, −0·106, $I^2 = 78$ %. Hedges' *g* value is considered small when value = 0·2, medium = 0·5, large = 0·8.

days were reduced. Further, it is expected that differences may be existing in lipid profile changes between pre- and post-menopause women included in the present analysis, as supported by the published literature(111,112). However, such differences cannot be inferred from the present analysis and need to be executed in a special sub-group analysis.

The RDIF model is a widely known and well-studied model of religion-based intermittent fasting. Intermittent fasting is associated with improved human health(113–116). The results of this meta-analysis expanded existing knowledge and confirmed that practicing RDIF had positive health impacts. RDIF had a beneficial effect on abdominal obesity, serum lipids, glucose metabolism and BP levels; all of which are the MetS components and risk factors for the development of insulin resistance, diabetes and CVD. The beneficial impact of RDIF on health is further reinforced by its ability to induce and activate antioxidant and anti-inflammatory mechanisms(8,18).

The small reduction in WC shown in our results was consistent with (and may partially explain) the significant small RDIF-induced reduction in inflammatory markers including IL-6, TNF-α and *hs*-C-reactive protein and the oxidative stress marker malondialdehyde shown in a recent meta-analysis(8).

Table 4. Characteristics of studies included in each of the metabolic syndrome components reviewed and analysed by countries with three or more studies

Component	Country	*K**	*N*†	I^2‡	Hedges' *g*	95 % CI
WC	Iran	7	783	0·000	−0·275	−0·348, 0·002
FG	Iran	15	828	81·865	−0·173	−0·348, 0·002
	Saudi Arabia	5	218	80·395	0·075	−0·240, 0·390
	Turkey	4	146	93·036	−0·069	−0·735, 0·596
	Tunisia	4	109	81·565	0·180	−0·271, 0·630
	Pakistan	3	175	69·743	−0·215	−0·494, 0·064
	Jordan	3	186	0·000	−0·239	−0·383, −0·095
TAG	Iran	20	1156	78·652	−0·073	−0·204, 0·058
	Turkey	6	210	63·288	−0·229	−0·458, 0·001
	Jordan	4	243	0·000	−0·244	−0·370, −0·117
	Pakistan	3	175	83·488	−0·212	−0·591, 0·168
	Tunisia	4	109	85·646	−0·116	−0·706, 0·473
	Saudi Arabia	3	94	88·524	0·269	−0·366, 0·905
HDL	Jordan	4	243	76·175	0·137	−0·124, 0·397
	Iran	19	1165	79·422	0·135	0·002, 0·268
	Turkey	5	210	80·481	0·244	−0·087, 0·574
	Pakistan	3	175	67·711	−0·142	−0·411, 0·126
	Saudi Arabia	3	94	88·510	−0·019	−0·655, 0·617
SBP	Iran	7	522	0·000	−0·226	−0·313, −0·138
	Jordan	3	162	0·000	−0·342	−0·501, −0·183

FG, fasting plasma glucose; SBP, systolic blood pressure; WC, waist circumference.

* *K*: denotes number of studies.

† *N*: denotes number of participants.

‡ I^2 statistic describes the percentage of variation across studies due to heterogeneity rather than chance(108).

The presence of the MetS has also been associated with lower plasma adiponectin levels(117), indicating adipose tissue dysfunction and a two- to four-times increased risk for developing CVD and type 2 diabetes(118). Similarly, several reports have indicated RDIF was associated with variable increments in adiponectin levels in fasting people(119–121). Recently, we found that RDIF was associated with significant reduction in visceral fat surface area (measured by MRI) in fifty-seven overweight/obese participants, concomitant with significant reductions proinflammatory cytokines (IL-6 and TNF-α), and a significant increase in the anti-inflammatory cytokine IL-10(122). In addition, Fernando *et al.* conducted a systematic review and meta-analysis on the impact of RDIF on body fatness. They found a significant reduction in fat percentage between pre- and post-Ramadan in people with overweight or obesity (−1·46, 95 % CI −2·57, −0·35 %, $P = 0·010$) compared with fasting subjects with normal weight(9). This implied that RDIF incurs a pronounced protective effect against the MetS in people at risk for obesity.

In the present meta-analysis, there was a small but significant RDIF-induced reduction in serum TAG in healthy people, which may contribute to lowering the risk for atherogenesis. This plausible effect is supported by other reports that showed an anti-RDIF-induced atherogenic effect in ameliorating LDL-cholesterol and apo B, and improving anti-atherogenic apo A levels in subjects with normal weight(107,123,124) and a small significant increase in HDL levels at the end of Ramadan. Other anti-atherogenic impacts for RDIF include: significant improvements in blood coagulation parameters(125), along with significant reductions in total cholesterol(84,85,95,107), very LDL(57,58,61,125), LDL:HDL and cholesterol:HDL ratios(123,126) and atherogenic index ((total cholesterol – HDL-cholesterol)/HDL-cholesterol)(43).

RDIF was also shown to improve endothelial function(127) by increasing nitric oxide production (important for normal endothelium)(128) and improving the heat shock protein HSP70, which has been shown to possess atheroprotective and endothelial-improving effects(126). Interestingly, the RDIF-induced cardioprotective effect extended for about 1 month after Ramadan month cessation(27,124). This indicated that RDIF has an annual short-term transient protective function against developing CVD. Finally, the small but significant reductions in the inflammatory (*hs*-C-reactive protein, TNF-α and IL-6) and oxidative stress (malondialdehyde) markers induced by RDIF reported in a recent meta-analysis(8) support the cardioprotective effect of Ramadan fasting. These markers have been shown to be involved in the etiopathogenesis of atherosclerosis and other CVD(129–131). The potential for RDIF to improve antioxidants was supported by our recent findings that the relative gene expressions in obese subjects were significantly increased for three antioxidant genes (superoxide dismutase, *SOD2*; mitochondrial transcription factor A, *TFAM*; and nuclear factor erythroid 2-related factor 2, *Nrf2*) at the end of Ramadan, with percent increases of 90·5 %, 54·1 % and 411·5 % for these genes, respectively(132). However, the protective effect of RDIF against CVD does not appear to be substantiated by rigorous scientific evidence available to date. This suggests that more controlled research is warranted.

A decreased level of HDL-cholesterol is a basic component in the diagnosis and definition of the MetS(2). In epidemiological studies, this abnormality has been closely associated with a higher risk for atherosclerotic CVD. Despite debate as to whether low HDL is involved in the pathogenesis of CVD, there is agreement that low HDL-cholesterol is a marker for increased risk for CVD(2,133). In the present review, the presence of small but significant increments in HDL at the end of RDIF was an added RDIF-induced protective factor against CVD, as dyslipidemia and its cumulative metabolic derangements are all involved in the etiopathogenesis of the MetS and its complications.

Several mechanisms have been suggested to explain the relationship between hypertension and the MetS. These include the release of angiotensinogen from adipose tissue, expansion of intravascular volume, enhanced renal reabsorption of sodium (possibly due to insulin resistance), activations of the renin-angiotensin-aldosterone system and sympathetic nervous system and insulin resistance. Current consensus is that these factors act in conjunction to raise BP(2). Consistent with the reduction in SBP, several reports indicated there was reduction in diastolic BP after RDIF(8,92,100,102).

Insulin resistance with fatty acid flux is an accepted hypothesised mechanism for the underlying pathophysiology of the MetS, with low-grade chronic inflammation and oxidative stress being mechanisms that accompany the MetS(134). A recent systematic review and meta-analysis revealed RDIF had a positive effect on lowering inflammatory and oxidative stress markers(8), with emphasis on IL-6 and TNF-α as the pro-inflammatory markers most involved in the pathogenesis of the MetS(134). Several reports indicated RDIF was associated with variable changes in serum insulin and insulin resistance (presented as homeostatic model assessment of insulin resistance levels). Although several reports indicated a lack of significant changes in serum insulin and insulin resistance during RDIF(37,78,135,136), other studies reported significant changes during RDIF(67–69,106). However, considerable variations in insulin and insulin resistance measurements imply that behavioural, dietary, and lifestyle factors affect these measurements, including quantity and quality of foods consumed, duration of fasting time, body weight and health status before fasting, differences in physical activity levels and differences in circadian rhythm and hormonal changes during RDIF.

The heterogeneity of the studies included in this meta-analysis regarding the MetS components could be attributed to various effects and confounding factors and perhaps explained by inconsistencies in the designs, procedures and interpretation of results of studies conducted during Ramadan. It is believed that a critical violation performed by many fasting people during Ramadan is skipping the predawn meal (*suhoor*), which may contribute to a significant daily energetic deficit and is likely to promote metabolic derangements, increased postprandial insulin levels and fat oxidation and induce confounding in the results(53).

Assuming that Ramadan fasting represents a form of time-restricted feeding as reported by Patterson & Sears(114), our findings were consistent with other research on human and animal intermittent energy restriction and time-restricted feeding. There is a growing evidence base demonstrating short-to-medium term benefits of time-restricted feeding on glucose and lipid homeostasis, even in the absence of significant total daily energetic restriction (reduction in 25–40 % of total daily energetic intake). The majority of published research conducted during Ramadan revealed a lack of significant changes in total daily energetic intake during Ramadan compared with pre-fasting energetic intake(18,97,137,138). By combining studies on RDIF, the present meta-analysis analysed a large sample, thereby increasing the power of the studies in showing the effects of RDIF. However, this meta-analysis had some limitations. In most included studies that evaluated the impact of RDIF on body weight, lipids and other metabolic profiles, there was no information as to whether participants consumed a predawn breakfast. During RDIF, subjects are at postprandial state if blood parameters are measured in the morning because of the predawn meal (*suhoor*). Several studies focused on RDIF did not report whether baseline laboratory parameters measured after an overnight fast before the initiation of Ramadan fasting were compared with laboratory parameters measured a couple of hours before the fast was broken at sunset, which would be the equivalent of an overnight fast. More importantly, the assessment of several key biomarkers of glucose and lipid metabolism and various hormones (including leptin, melatonin, ghrelin, cortisol and adiponectin) exhibits circadian rhythm and requires 24-h blood monitoring with multiple time points(139). Measurement of these parameters at only one or a few time points may to lead to biased outcomes and potentially provide false data on increased/decreased levels, depending on the measurement time.

Dawn-to-sunset Ramadan fasting starts at dawn and ends at sunset. Therefore, fasting people have two major meals a day: breakfast before dawn and dinner after sunset, and may eat *ad libitum* from sunset until dawn. In general, it is a common practice for Ramadan fasters to work and fast during the daytime, have dinner, sleep and wake 1 h before dawn to eat and restart fasting at dawn. Most studies on RDIF did not provide explicit dietary information about the frequency of meals between sunset and dawn, meal content during night hours and sleeping times(97,140). Furthermore, some study subjects may secretly break their fast and further confound the desired adaptive response. No information on compliance monitoring with fasting was available for any of the included studies. Well-designed clinical trials that evaluate the impact of dawn-to-sunset fasting on BMI and key metabolic parameters before, during and after fasting would provide important information about health maintenance(97).

Conclusions

It can be concluded from the reviewed and analysed the MetS components that RDIF showed small reductions in components associated with increased risk for and severity of the MetS (WC, SBP, TAG and FG), with a concomitant increase in anti-atherogenic HDL-cholesterol. These beneficial effects were also associated with variable improvements in other covariates involved in the etiopathogenesis factors, such as reduction in diastolic BP. The heterogeneity in the findings of the reviewed studies offers a picture of the varying dietary and lifestyle behaviours practiced during Ramadan month, along with variations in the duration of fasting and climatic and geographical conditions surrounding fasting people in different countries.

Ethical statement

This article does not contain any studies with human participants performed by any of the authors. For this type of study formal consent was not required

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The authors have no conflicts of interest to declare.

Supplementary materials

To view supplementary material for this article, please visit https://doi.org/10.1017/S000711451900254X

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