SUPPLEMENTARY FILE

Table S1. PRISMA STATEMENT

Section/topic	#	Checklist item	Reported on page #
TITLE			
Title	1	Identify the report as a systematic review, meta-analysis, or both.	1
ABSTRACT			
Structured summary	2	Provide a structured summary including, as applicable: background; objectives; data sources; study eligibility criteria, participants, and interventions; study appraisal and synthesis methods; results; limitations; conclusions and implications of key findings; systematic review registration number.	2
INTRODUCTION			
Rationale	3	Describe the rationale for the review in the context of what is already known.	4,5
Objectives	4	Provide an explicit statement of questions being addressed with reference to participants, interventions, comparisons, outcomes, and study design (PICOS).	5
METHODS			
Protocol and registration	5	Indicate if a review protocol exists, if and where it can be accessed (e.g., Web address), and, if available, provide registration information including registration number.	n/a
Eligibility criteria	6	Specify study characteristics (e.g., PICOS, length of follow-up) and report characteristics (e.g., years considered, language, publication status) used as criteria for eligibility, giving rationale.	5,6
Information sources	7	Describe all information sources (e.g., databases with dates of coverage, contact with study authors to identify additional studies) in the search and date last searched.	5
Search	8	Present full electronic search strategy for at least one database, including any limits used, such that it could be repeated.	Supplement File
Study selection	9	State the process for selecting studies (i.e., screening, eligibility, included in systematic review, and, if applicable, included in the meta-analysis).	5,6
Data collection process	10	Describe method of data extraction from reports (e.g., piloted forms, independently, in duplicate) and any processes for obtaining and confirming data from investigators.	6
Data items	11	List and define all variables for which data were sought (e.g., PICOS, funding sources) and any assumptions and simplifications made.	6
Risk of bias in individual studies	12	Describe methods used for assessing risk of bias of individual studies (including specification of whether this was done at the study or outcome level), and how this information is to be used in any data synthesis.	n/a
Summary measures	13	State the principal summary measures (e.g., risk ratio, difference in means).	7,8
Synthesis of results	14	Describe the methods of handling data and combining results of studies, if done, including measures of consistency (e.g., I^2) for each meta-analysis.	7,8
Risk of bias across studies	15	Specify any assessment of risk of bias that may affect the cumulative evidence (e.g., publication bias, selective reporting within studies).	7,8
Additional analyses	16	Describe methods of additional analyses (e.g., sensitivity or subgroup analyses, meta-regression), if done, indicating which were pre-specified.	7,8
RESULTS			
Study selection	17	Give numbers of studies screened, assessed for eligibility, and included in the review, with reasons for exclusions at each stage, ideally with a flow diagram.	9 & Fig 1
Study characteristics	18	For each study, present characteristics for which data were extracted (e.g., study size, PICOS, follow-up period) and provide the citations.	Table 1
Risk of bias within studies	19	Present data on risk of bias of each study and, if available, any outcome level assessment (see item 12).	n/a
Results of individual studies	20	For all outcomes considered (benefits or harms), present, for each study: (a) simple summary data for each intervention group (b) effect	Figs 2-6

		estimates and confidence intervals, ideally with a forest plot.	Table 2
Synthesis of results	21	Present results of each meta-analysis done, including confidence intervals and measures of consistency.	Figs 2-6 Table 2
Risk of bias across studies	22	Present results of any assessment of risk of bias across studies (see Item 15).	Supp Fig 1-5
Additional analysis	23	Give results of additional analyses, if done (e.g., sensitivity or subgroup analyses, meta-regression [see Item 16]).	Table 2
DISCUSSION			
Summary of evidence	24	Summarize the main findings including the strength of evidence for each main outcome; consider their relevance to key groups (e.g., healthcare providers, users, and policy makers).	15-19
Limitations	25	Discuss limitations at study and outcome level (e.g., risk of bias), and at review-level (e.g., incomplete retrieval of identified research, reporting bias).	19
Conclusions	26	Provide a general interpretation of the results in the context of other evidence, and implications for future research.	20
FUNDING			
Funding	27	Describe sources of funding for the systematic review and other support (e.g., supply of data); role of funders for the systematic review.	20

Table S1. Characteristics of the included studies

				Participants						
Author, year	**Country**	**Disease**	**Fasting and Exercise (Fasting)**	**BMI**	**Age**	**Gender**	**Modes of exercise**	**Intervention group**	**Duration of fasting in the month of Ramadan**	**Temperature**
Abdulrahman, (2006)	Iraq	None	15 (15)	NR	28	M	AE	Four sessions/week × 30 min with moderate exercise; 1 month	12 h	10-15 [C]
Attarzade Hosseini, (2013)	Iran	None	15 (11)	30.3	32.5	F	AE	Four sessions/week × 60 min at 50–65% HRmax; 1 month	NR	30-40 [C]
Attarzade Hosseini, (2014)	Iran	None	12 (10)	30.3	32.5	F	AE	Three sessions/week × 60 min at 50–65% HRmax; 1 month	16 h	NR
Attarzade Hosseini, (2015b)	Iran	None	25 (25)	23.06	20.69	Both	AE	Three sessions/week × 90 min at 60–75% HRmax; 1 month	NR	NR
Aziz, (2014)	Egypt	None	25 (25)	34.06	36.86	Both	AE	Three sessions/week × 30 min at 65–75% HRmax; 1 month	12 h	NR
Bhutani, (2013)	USA	None	18 (25)	35.0	43.5	Both	AE	**E-ADF**: Moderate-intensity programmed using exercise bikes and elliptical trainers. The length of the training was progressively increased by 5 minutes and 5% HRmax in weeks four, seven and ten and was combined with a fasting regime with controlled intake lasting four weeks in which the participants consumed 25% of their basic energy needs on the fasting day (24 h) and ate “ad libitum” on the normal diet day	NR	NR

Participants									
Author, year	**Country**	**Disease**	**Fasting and Exercise (Fasting)**	**BMI**	**Age**	**Gender**	**Modes of exercise**	**Intervention group**	**Duration of fasting in the month of Ramadan**	**Temperature**
Cho, (2019)	Republic of Korea	None	9 (8)	27.9	34.00	Both	AE	(24 h). For the next eight weeks, the subjects continued not eating on the fasting days. 12 weeks **ADF**: Fasting regime with controlled intake lasting four weeks in which the participants consumed 25% of their basic energy needs on the fasting day (24 h) and ate "ad libitum" on the normal diet day (24 h). For the next eight weeks, the subjects continued not eating on the fasting days. **E-ADF**: Muscle-strengthening exercise (40 min, 3 times/week) and aerobic exercise (20 min, 2-3 times per week) combined with fasting, consisting of consuming 25% of the participants' recommended daily energy intake on each day of fasting (24 h) and eating "ad libitum" on each normal diet day (24 h). On the days of fasting, they had a meal between 12 noon and 2 p.m. to maintain the same times of fasting. 8 weeks. **ADF**: Consumption of 25% of the participants' recommended daily energy intake on each day of fasting (24 h) and eating "ad libitum" on each normal diet day (24 h). On the days of fasting, they had a meal between 12 noon and 2 p.m. to maintain the same times of fasting.	NR	NR
Haghdoost, (2009)	Iran	None	42 (51)	27.05	19.82	Both	AE	Three sessions/week × 45-60 min; 1 month	NR	NR
Maughan, (2008)	UK	None	59 (36)	22.3	18	M	AE	Players trained or played in competitive matches on a daily basis. In the last week before Ramadan, only one team trained in the morning, in the 2-week period prior to this, two of the teams trained in the morning and two in the afternoon. Training varied on a daily basis, but typically lasted about 60 min.	NR	28 [c]
Maughan, (2009)	UK	None	28 (14)	NR	17.5	M	AE	6-8 sessions/ week × 90 min; involving track running, swimming training; 1 month	NR	NR
Moazami, (2014)	Iran	Type 2 diabetes mellitus	9 (9)	35.23	45	M	AE	3-4 sessions/ week × 60 min; 4 weeks	NR	NR
Moradi, (2013)	Iran	None	12 (12)	23.64	25.93	M	AE	Three sessions/ week ×3200 meters run; 4 weeks	NR	NR
Moro, (2016)	Italy	None	17 (17)	NR	29.2	M	RT	**TRF:** 3 session/wk, 3 sets of 6–8 repetitions at 85–90 % 1-RM, 8 weeks + subjects consumed 100 % of their energy needs in an 8-h period of time each day, with their caloric intake divided into three meals consumed at 1 p.m., 4 p.m., and 8 p.m. The remaining 16 h per 24-h period made up the fasting period. TRF 2826 ± 412.3 kcal/day, carbohydrates 53.2 ± 1.4 %, fat 24.7 ± 3.1 %, protein 22.1 ± 2.6 %	NR	NR

Participants										
Author, year	**Country**	**Disease**	**Fasting and Exercise (Fasting)**	**BMI**	**Age**	**Gender**	**Modes of exercise**	**Intervention group**	**Duration of fasting in the month of Ramadan**	**Temperature**
Oh, (2018)	Republic of Korea	None	12 (13)	35.1	27.4	Both	RT	**ND:** Subjects in the ND group consumed 100 % of their energy needs divided into three meals consumed at 8 a.m., 1 p.m., and 8 p.m. ND 3007 ± 444.7 kcal/day, carbohydrates 54.7 ± 2.2 %, fat 23.9 ± 3.5 %, protein 21.4 ± 1.8 **E-ADCR:** Strength training and aerobic exercise three days per week combined with a nutritional strategy, consisting of three days of fasting with 25% recommended daily intake (the participants ate between 12 noon and 2 p.m.) and four days eating "ad libitum". 8 weeks. **ADCR**: Nutritional strategy, consisting of three days of fasting with 25% recommended daily intake (the participants ate between 12 noon and 2 p.m.) and four days eating "ad libitum".	NR	NR
Ramadan, (1999)	Kuwait	None	6 (7)	25.00	36.55	M	AE	3-5 sessions/ week × 30-60 min at 50-65% Vo2max; 1 month	11-14 h	20-25 C
Shirreffs, (2008)	UK	None	55 (37)	22.26	18.00	M	AE	60-70 min; 7 weeks	NR	25-28 C
Tan, (2021)	Singapore	None	15 (15)	23.75	37.5	Both	WAnT	Three sessions/ week ×≤80-min at moderate intensity (two to four WAnT bouts); 6 weeks	12 h	20-22 C
Tayebi, (2010)	Iran	None	10 (10)	NR	21.3	M	RT	3 sessions/ week × 90 min at weight-lifting training 1 month	NR	NR
Tayebi, (2018)	Iran	None	10 (10)	NR	21.3	M	RT	3 sessions/ week × 90 min at weight-lifting training 1 month	NR	NR
Trabelsi, (2011)	Tunisia	None	10 (8)	25.34	26.9	M	AE	3 sessions/ week × 45-50 min at jogging and swimming 1 month	15 h	30-35 C
Trabelsi, (2012)	Tunisia	None	9 (7)	26.00	25.00	M	RT	3 sessions/ week × 20-30 min (4-20 sets of 10 reps for the 4-6 exercises); 8 weeks	15 h	32-36 C
Trabelsi, (2013)	Tunisia	None	8 (8)	25.9	25.00	M	RT	Three sessions/ week × 20-30 min (20 sets of 10 reps for the 4-6 exercises); 8 weeks	15 h	34 C
Zorofi, (2013)	Iran	None	10 (10)	28.45	40.2	F	Y	60 min supervised training for the 7 exercises	NR	NR

*Note: The control group received no training.
Abbreviations: IT, interval training; BT, badminton training; AT, Anaerobic training; WAnT, Wingate anaerobic cycle test; Y, Yoga; HRmax, Maximum heart rate; Vo2max, maximal oxygen consumption; NR, no report;

Table S2. Pooled estimates of blood hematological and insulin resistance within different subgroups

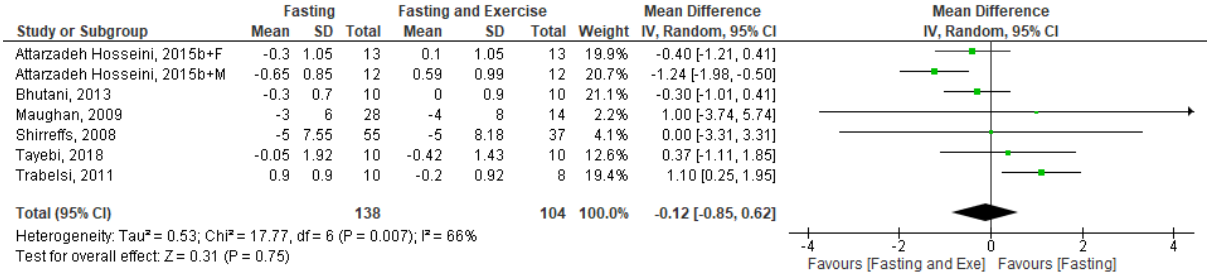
Markers	Moderators	No of arms	WMD (95% CI)	P-value	I^2	*p* (Heterogeneity)
Fasting versus Fasting + Exercise group						
Hemoglobin						
BMI classification	<25 kg/m²	3	-0.81 (-1.46, -0.16)	**0.00001**	21%	0.28
	25-29.9 kg/m²	1	1.10 (0.25, 1.95)	0.00001	-	-
	≥30 kg/m²	1	-0.30 (-1.01, 0.41)	0.41	-	-
Gender	Male	4	0.88 (0.17, 1.59)	**0.00001**	0%	0.80
	Both	3	-0.65 (-1.24, -0.06)	**0.00001**	47%	0.15
Hematocrit						
BMI classification	<25 kg/m²	3	-0.76 (-1.58, 0.05)	0.07	86%	< 0.001
	≥30 kg/m²	2	-1.43 (-3.73, 0.86)	0.22	60%	0.12
Gender	Male	5	-0.27 (-2.05, 1.51)	0.77	75%	< 0.001
	Both	3	-0.46 (-1.45, 0.53)	0.37	0%	0.67
Platelet						
BMI classification	<25 kg/m²	2	-10.49 (-33.07, 12.08)	0.36	0 %	0.38
	25-29.9 kg/m²	2	-6.31 (-35.43, 22.81)	0.67	0 %	0.40
Gender	Male	3	-6.93 (-33.77, 19.91)	0.61	0%	0.70
	Both	2	-10.49 (-33.07, 12.08)	0.36	0%	0.38
Red Blood Cell						
BMI classification	<25 kg/m²	2	-0.53 (-1.58, 0.52)	0.32	98%	< 0.001
Gender	Male	1	0.11 (-0.11, 0.33)	0.32	-	-
	Both	2	-0.53 (-1.58, 0.52)	0.32	98%	< 0.001
White Blood Cell						
BMI classification	<25 kg/m²	2	-0.91 (-2.00, 0.18)	0.10	35%	0.21
	≥30 kg/m²	1	-0.56 (-2.33, 1.21)	0.053	-	-
Gender	Male	1	-0.56 (-2.33, 1.21)	0.53	-	-
	Both	2	-0.91 (-2.00, 0.18)	0.10	35%	0.45
Fasting Insulin						
BMI classification	<25 kg/m²	1	-2.10 (-9.23, 5.03)	0.56	-	-
	25-29.9 kg/m²	1	-7.08 (-9.90, -4.26)	0.00001	-	-
	≥30 kg/m²	2	-4.63 (-10.52, 1.26)	0.12	0%	0.58
Gender	Male	1	-0.67 (-1.10, -0.24)	0.003	-	-
	Both	4	-6.11 (-8.51, -3.72)	**0.00001**	0%	0.53
Fasting Blood Glucose						
BMI classification	<25 kg/m²	5	0.36 (-0.61, 1.34)	0.47	59%	< 0.001
	25-29.9 kg/m²	4	-0.09 (-0.36, 0.17)	0.48	0%	0.83
	≥30 kg/m²	1	-3.10 (-8.14, 1.94)	0.23	-	-
Gender	Male	7	0.64 (-0.64, 1.92)	0.33	78%	< 0.001
	Both	4	-2.96 (-1.06, 6.97)	0.15	72%	< 0.001
HOMA-IR						
BMI classification	<25 kg/m²	1	-0.70 (-2.66, 1.26)	0.48	-	-
	25-29.9 kg/m²	1	-1.80 (-2.49, -1.11)	0.00001	-	-
	≥30 kg/m²	2	-1.45 (-3.11, 0.20)	0.08	0%	0.70

The bold value depicts statistical significance (p <0.05). WMD, weighted mean difference; CI, confidence interval; BMI, body mass index.

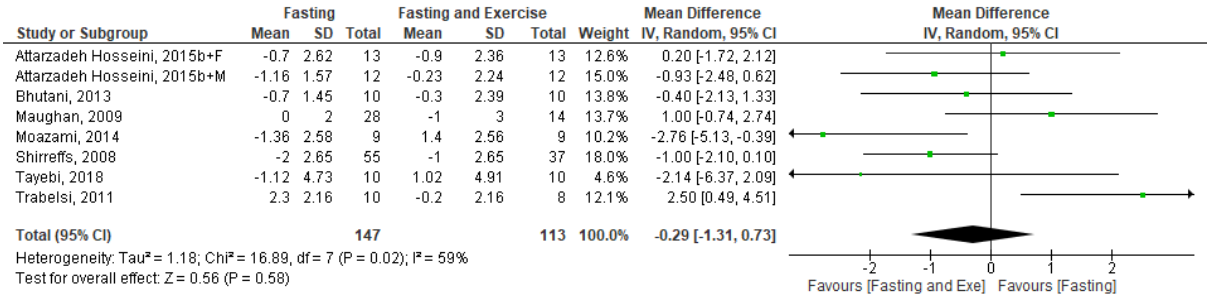
Table S3. Study quality assessment of included studies by the tool for the assessment of study quality in exercise (TESTEX)

Study Random	Eligibility criteria specified	Randomization specified	Allocation concealment	Group similar at baseline	Blinding of assessor	Outcome measures assessed in 85% of patients #	Intention-to-treat analysis	Between-group statistical comparisons were reported*	Point measures and measures of variability for all reported outcome measures	Activity monitoring in control group	Relative exercise intensity remained constant	Exercise volume and energy expenditure	Overall TESTEX (/15)
Abdulrahman, 2006	1	0	1	0	0	1	0	2	1	0	0	1	7
Attarzade Hosseini, 2015	1	0	1	1	0	1	0	2	1	0	1	1	9
Attarzade Hosseini, 2013	1	0	1	1	0	1	0	2	1	0	1	1	9
Attarzade Hosseini, 2014	1	0	1	1	0	2	0	2	1	0	1	1	10
Aziz, 2014	1	0	0	1	0	1	0	2	1	0	1	1	8
Bhutani, 2013	1	1	0	1	0	2	1	2	1	1	1	0	11
Cho, 2019	1	1	1	1	1	1	1	2	1	1	0	1	12
Haghdoost, 2009	1	0	1	1	1	2	0	2	1	0	0	1	10
Maughan, 2008	1	0	0	1	0	1	0	2	1	0	0	1	7
Maughan, 2009	1	0	0	1	1	1	0	2	1	0	0	1	8
Moazami, 2014	1	0	0	1	0	1	0	2	1	0	0	1	7
Moradi, 2013	1	0	0	1	0	1	0	2	1	0	0	1	7
Moro, 2016	1	1	0	1	1	1	0	2	1	1	1	1	11
Oh, 2018	1	1	1	1	1	1	1	2	1	1	0	1	12
Ramadan, 1999	1	1	0	1	0	1	1	2	1	0	1	1	10
Shirreffs, 2008	1	0	0	1	0	1	0	2	1	0	0	1	7
Tan, 2021	1	1	0	1	0	1	0	2	1	0	1	1	9
Tayebi, 2010	1	0	0	1	0	1	0	2	1	0	0	1	7
Tayebi, 2018	1	0	0	1	0	1	0	2	1	0	0	1	7
Trabelsi, 2011	1	0	0	1	0	1	0	2	1	0	0	1	7
Trabelsi, 2012	1	0	0	1	0	1	0	2	1	1	1	1	9
Trabelsi, 2013	1	0	0	1	0	1	0	2	1	1	1	1	9
Zorofi, 2013	1	0	0	1	0	2	0	2	1	1	0	1	9

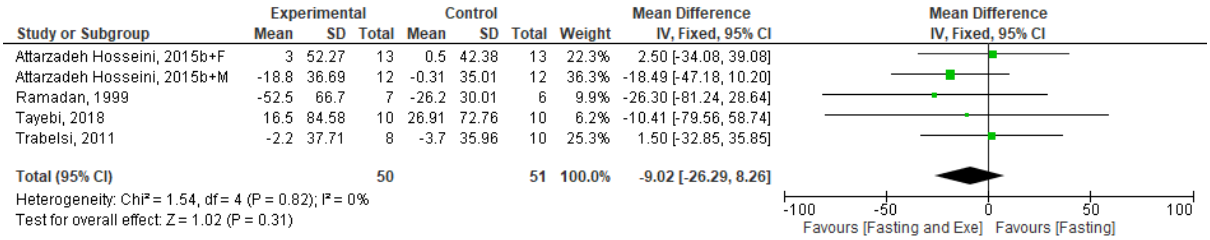
Total out of 15 points.
Three points possible – 1 point if adherence >85%, 1 point if adverse events reported, 1 point if exercise attendance is reported.
* Two points possible – 1 point if primary outcome is reported, 1 point if all other outcome reported.



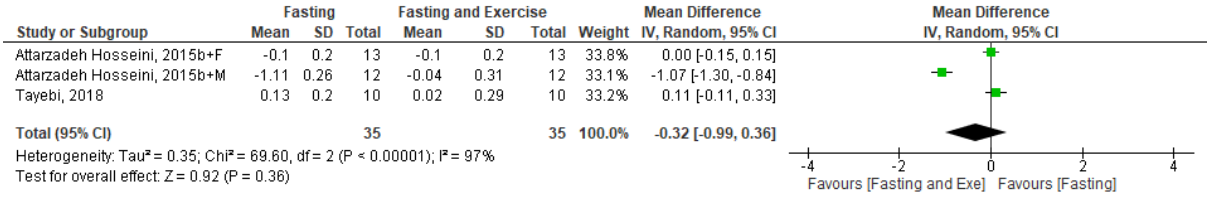
Supplementary Figure S1: Forest plot showing study precision against the mean difference effect estimate with 95% confidence interval for Hemoglobin.



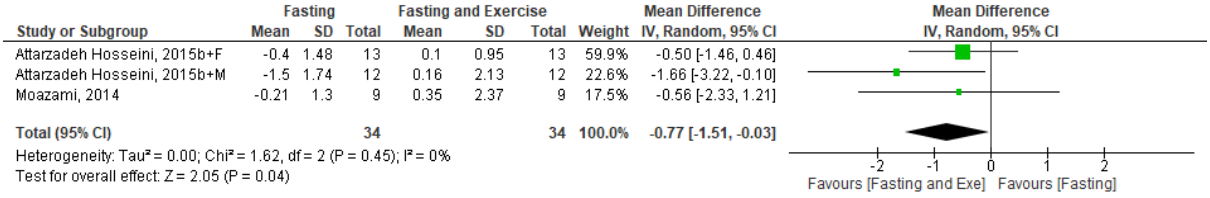
Supplementary Figure S2: Forest plot showing study precision against the mean difference effect estimate with 95% confidence interval for Hematocrit.



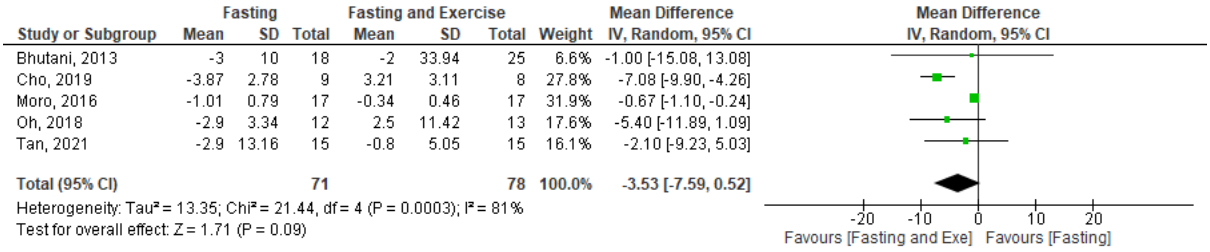
Supplementary Figure S3: Forest plot showing study precision against the mean difference effect estimate with 95% confidence interval for Platelet.



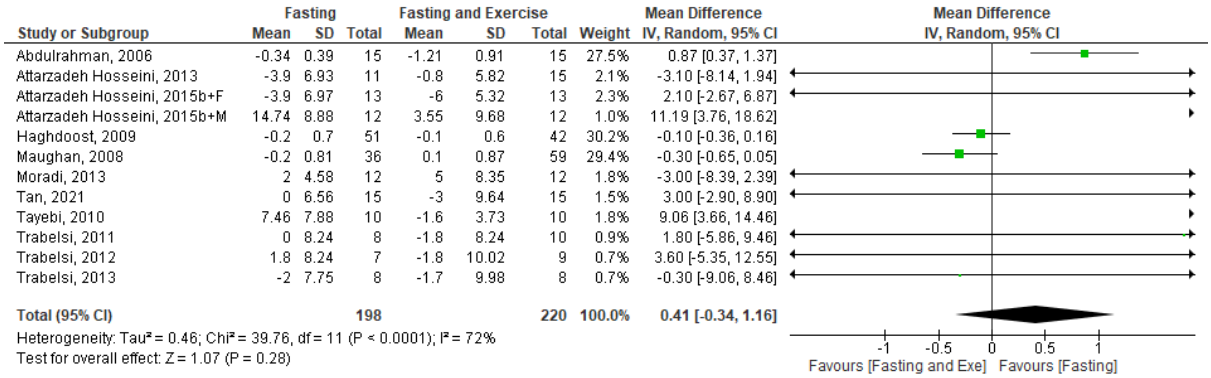
Supplementary Figure S4: Forest plot showing study precision against the mean difference effect estimate with 95% confidence interval for red blood cell.



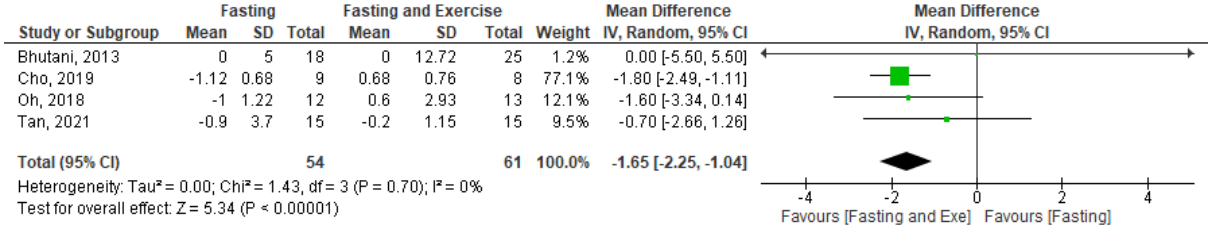
Supplementary Figure S5: Forest plot showing study precision against the mean difference effect estimate with 95% confidence interval for white blood cell.



Supplementary Figure S6: Forest plot showing study precision against the mean difference effect estimate with 95% confidence interval for fasting insulin levels.

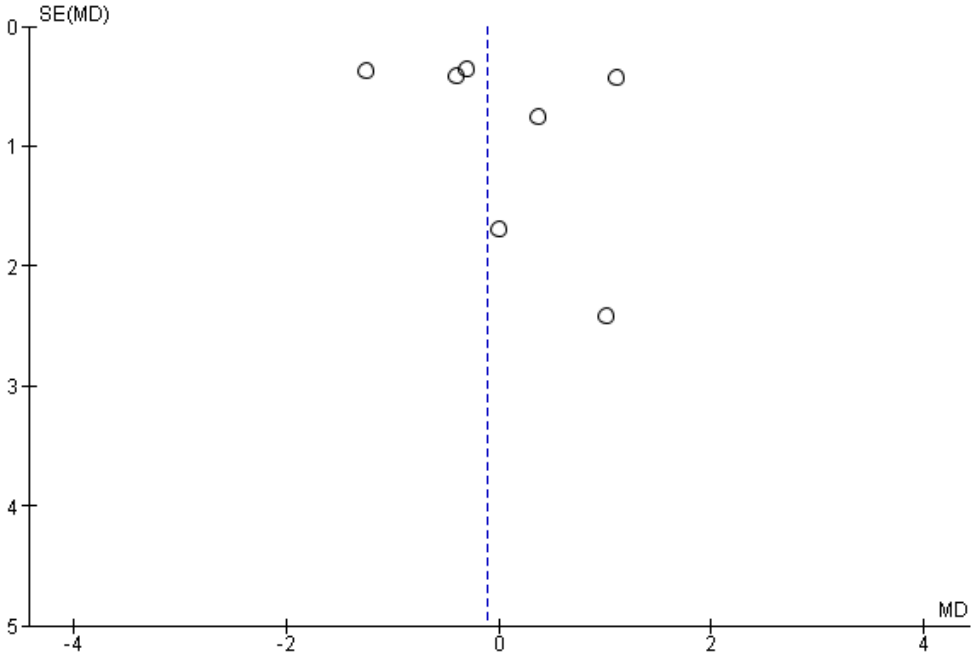


Supplementary Figure S7: Forest plot showing study precision against the mean difference effect estimate with 95% confidence interval for fasting blood glucose.

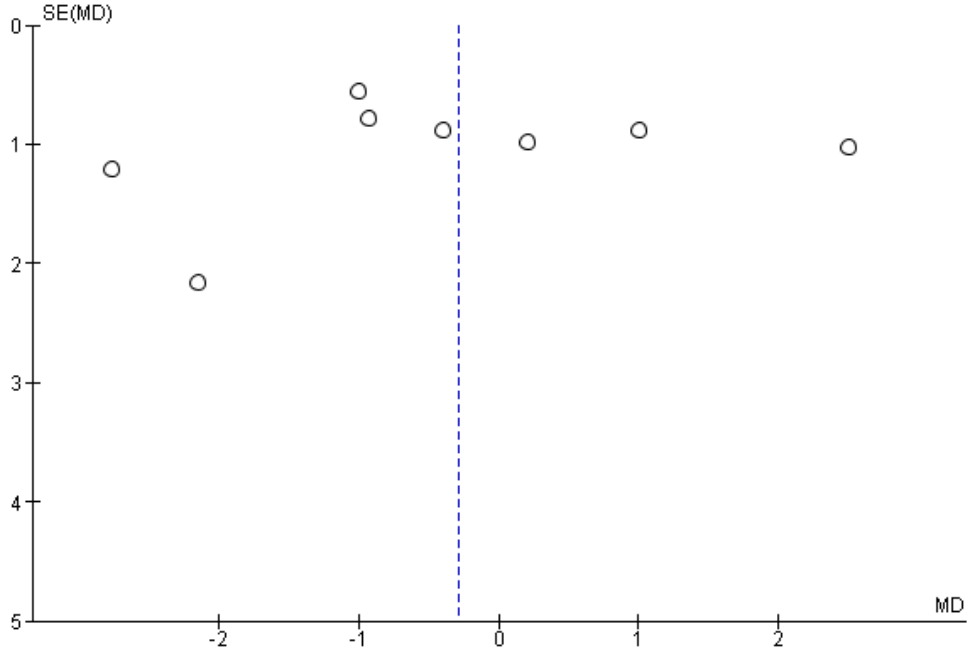


Supplementary Figure S8: Forest plot showing study precision against the mean difference effect estimate with 95% confidence interval for HOMA-IR.

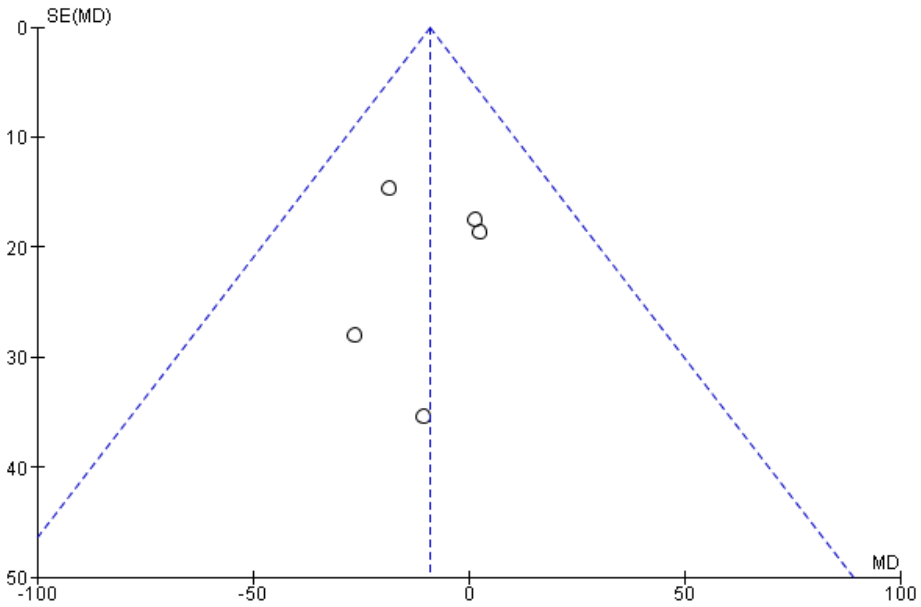
EGGER PLOTS



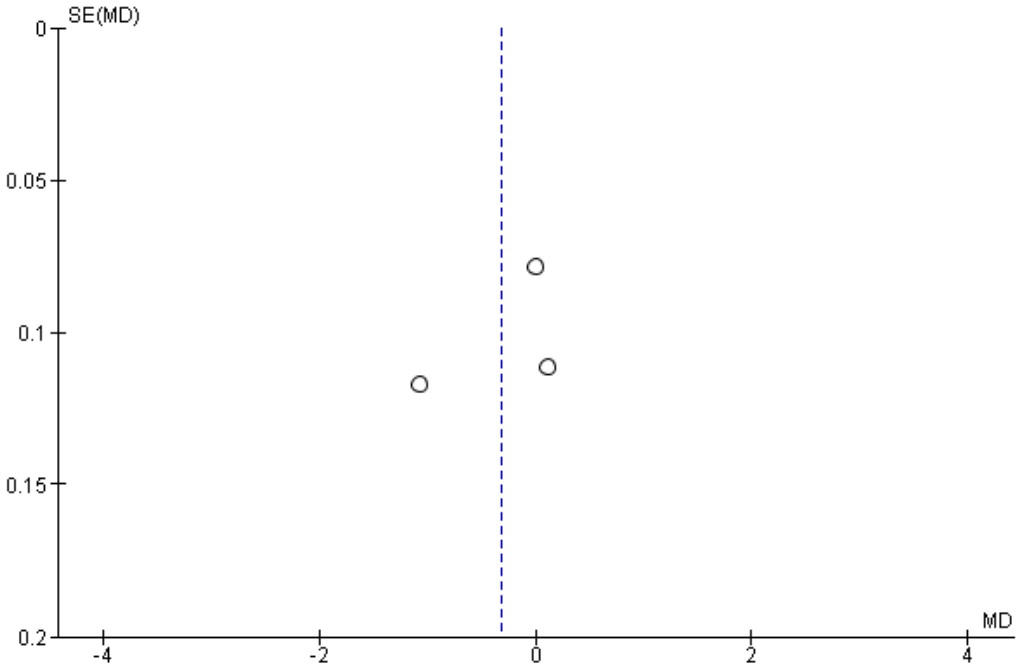
Supplementary Figure S1. Funnel plot showing study precision against the mean difference effect estimate with 95% confidence interval for Hemoglobin. SE, standard error; MD, mean difference



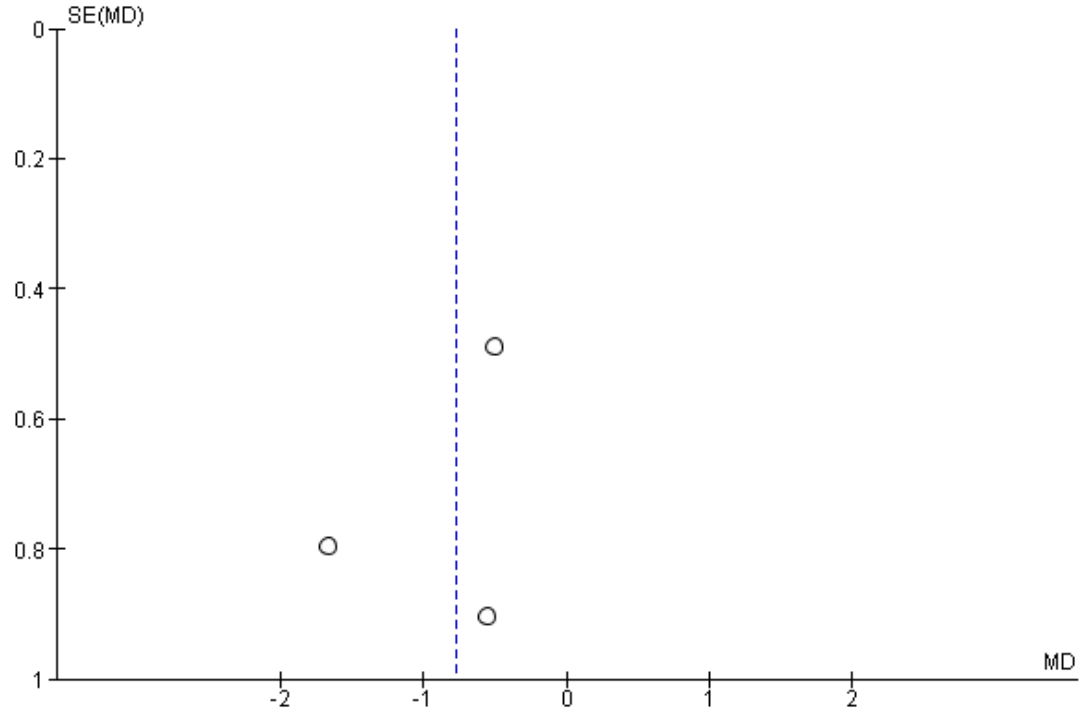
Supplementary Figure S2. Funnel plot showing study precision against the mean difference effect estimate with 95% confidence interval for Hematocrit. SE, standard error; MD, mean difference



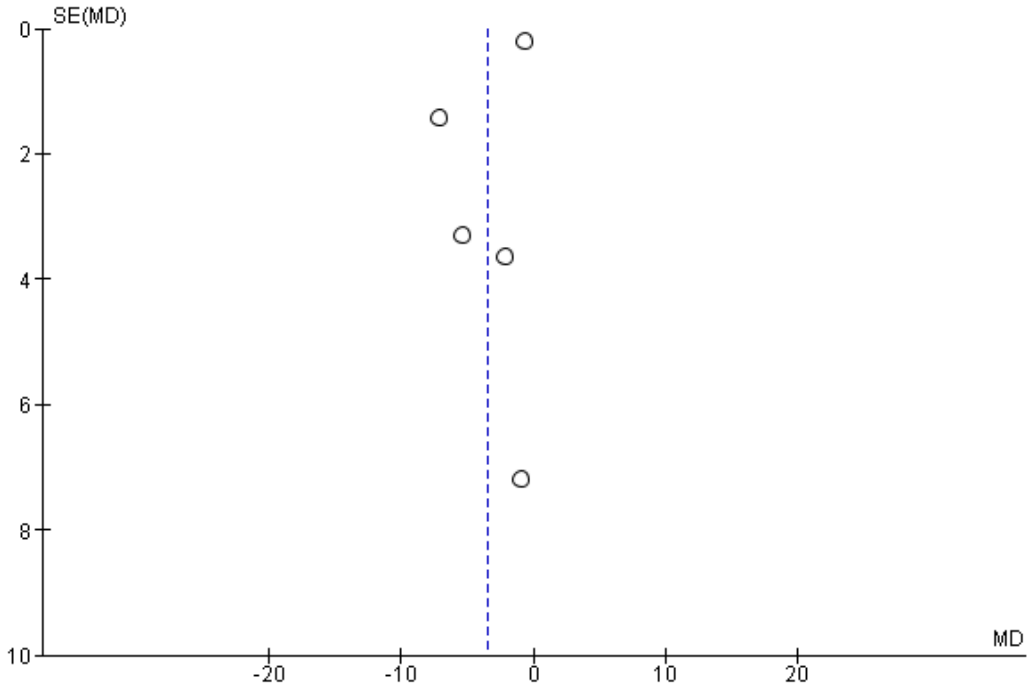
Supplementary Figure S3. Funnel plot showing study precision against the mean difference effect estimate with 95% confidence interval for Platelet. SE, standard error; MD, mean difference



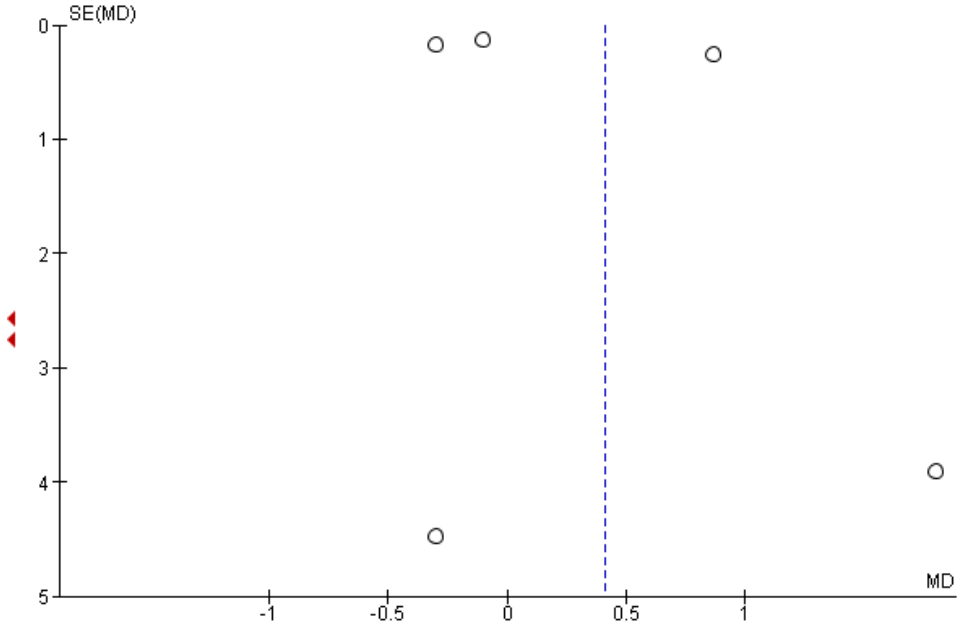
Supplementary Figure S4. Funnel plot showing study precision against the mean difference effect estimate with 95% confidence interval for red blood cell. SE, standard error; MD, mean difference



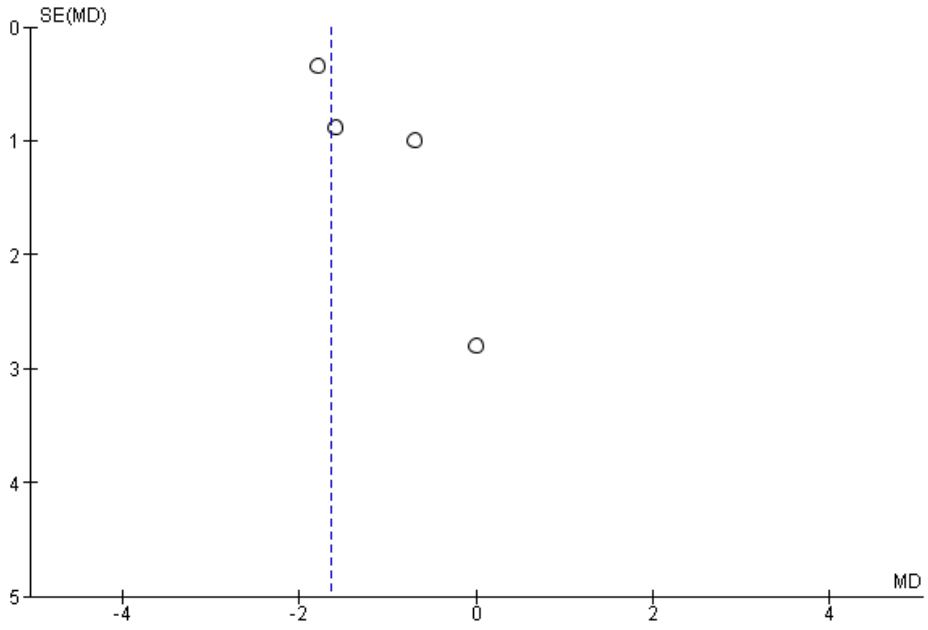
Supplementary Figure S5. Funnel plot showing study precision against the mean difference effect estimate with 95% confidence interval for white blood cell. SE, standard error; MD, mean difference



Supplementary Figure S6. Funnel plot showing study precision against the mean difference effect estimate with 95% confidence interval for fasting insulin. SE, standard error; MD, mean difference



Supplementary Figure S7. Funnel plot showing study precision against the mean difference effect estimate with 95% confidence interval for fasting blood sugar. SE, standard error; MD, mean difference



Supplementary Figure S8. Funnel plot showing study precision against the mean difference effect estimate with 95% confidence interval for HOMA-IR. SE, standard error; MD, mean difference