Impact of pharmacological Interventions on insulin resistance in women with polycystic ovary syndrome: a systematic review and meta-analysis of randomised controlled trials

Running title: pharmacological interventions in PCOS

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Keywords: polycystic ovary syndrome, PCOS, FBG, FI, HOMA-IR, HOMA-B, pharmacological therapy.

PROSPERO registarion No: CRD42020178783

Abstract

Context: Polycystic ovary syndrome (PCOS) is a complex endocrine condition affecting women of reproductive age. It is characterised by insulin resistance and is a major cause of type 2 diabetes mellitus (T2DM).

Objective: To review the literature on the effect of different pharmacological interventions on insulin resistance in women with PCOS.

Data sources: We searched PubMed, MEDLINE, Scopus, Embase, Cochrane library and the Web of Science in April 2020 and updated in March 2021.

Study selection: The study follows the 2020 Preferred Reporting Items for Systematic reviews and Meta-Analyses (PRISMA).

Data extraction: Reviewers extracted data and assessed the risk of bias using the Cochrane risk of bias tool.

Data synthesis: 58 RCTs there were significant reductions in the fasting blood glucose (FBG) with metformin vs placebo (mean difference (MD): -0.16 mg/dL; 95% CI: -0.28, -0.04, I^2 = 0%, low grade evidence), and acarbose vs metformin (MD: -10.50 mg/dL; 95% CI: -15.76, -5.24, I^2 = 0%, low grade evidence). Significant reductions in fasting insulin (FI) in metformin vs placebo (MD: -2.20 pmol/L; 95% CI: -3.62, -0.77, I^2= 0%, moderate grade evidence) and with pioglitazone vs placebo (MD: -11.47 pmol/L; 95% CI: -20.20, -2.74, I^2= 35%, p = 0.01, very low-grade evidence). A significant reduction in HOMA-IR was seen with exenatide vs metformin(MD: -0.34; 95% CI: -0.65, -0.03, I^2= 0%, low grade evidence). No effect on HOMA-B was observed.

Conclusion: pharmacological interventions including metformin, acarbose, pioglitazone, and exenatide appeared to have significant effects on FBG, FI, HOMA-IR but not on HOMA-B.

Introduction

Polycystic ovary syndrome (PCOS) is a complex disease that affects women of reproductive age with a prevalence of up to 13 % [1,2]. It has been estimated that 50-70% of women with PCOS exhibit metabolic abnormalities, including insulin resistance, abnormal glucose tolerance and an increased risk of type 2 diabetes mellitus (T2DM)[3]. Insulin resistance is considered a result of a defect in insulin action, including insulin-mediated glucose transport and its signalling pathway[4]. However, further evidence suggests a bidirectional link between hyperinsulinemia and androgen production, with high insulin stimulating the ovarian androgen production[5]. Acanthosis nigricans is a velvety or brownish-black skin lesion commonly seen around the neck, and it is a common sign of insulin resistance. The majority of obese and lean women with PCOS have shown to have clinical evidence of acanthosis nigricans[6]. Moreover, hyperinsulinemia increases the risk of T2DM, and over 11% of overweight/obese women with PCOS develop diabetes[7]. Hyperinsulinemic glucose clamp is the standard method to determine the insulin sensitivity in which concomitant glucose and insulin are infused then followed by measuring the insulin and glucose levels. At the same time, homeostasis model assessment (HOMA) is used to determine insulin resistance (IR) and the pancreatic β-cell function[8].

Therapeutic approaches for PCOS are varied in their targets and effects and include both pharmacological and non-pharmacological interventions. Metformin, a widely used insulin sensitising agent, has been associated with a significant benefit in relation to glucose metabolism and metabolic syndrome[9]. A similar effect was also evident with thiazolidinediones (pioglitazone and rosiglitazone)[10]. However, the relative effectiveness of these therapeutic options remains elusive, with a significant gap in the available evidence; therefore, this review aimed to evaluate and analyse the available

evidence for the effectiveness of various pharmacological options for the treatment of insulin resistance in PCOS.

Methods

Protocol and registration

The protocol for the review was prospectively registered on PROSPERO (CRD42020178783) and was reported according to the Preferred Reporting Items for Systematic Reviews and Meta-analyses (PRISMA) statement[11].

This systematic review and meta-analysis is part of a major study that aims to understand the impact of various pharmacological therapies on different health outcomes in women with PCOS, including anthropometric outcomes, insulin resistance, and lipid profile. The first systematic review and meta-analysis study providing findings on the anthropometric outcomes has already been completed and submitted for a peer-reviewed journal. The present study provides findings on the impact of various pharmacological therapies and regimes on insulin resistance in women with PCOS.

Eligibility criteria

Only randomised controlled trials (RCTs) were included in the systematic review. RCTs were defined based on the PICO (population, intervention, comparator, and outcome). Eligibility criteria are presented in Table 1. In brief, only RCTs that recruited women aged ≥ 18 years and diagnosed with PCOS were eligible. RCTs that reported a comparison of at least one pharmacological agent with another pharmacological agent, a combination of pharmacological agents or a placebo were considered eligible to be included regardless of the design (open-labelled, double-blinded, parallel and crossover) and methodology.

Literature search

A systematic search for literature was conducted in six biomedical databases; PubMed, EMBASE, MEDLINE, Scopus, Cochrane Central Library and Web of Science in April 2020 and was updated in March 2021 (L.Ö). Search terms were selected by experts in the field of the subject (TS & MA) in close collaboration with a medical librarian specialised in systematic reviews (L.Ö). The search strategy was systematically developed in PubMed with the support of the MeSH (L.Ö). All search terms were searched in a combination of title, abstract and Medical Subject Headings (MeSH) to retrieve the best possible results. A filter for the English language was applied. All publication types and publication years were included in the search. The search strategy developed in PubMed were later repeated in all selected electronic databases and open access (Open Grey, ClinicalTrial.gov and Open thesis repository, EU clinical trial registry). The full search strategy, including results, notes, and search technical specifications for all information sourced, is available in supplementary material[91]. All records found in the literature search was uploaded to Covidence (www.covidence.org) [12] for automatic de-duplication and blinded screening. Full-text review and data extraction was subsequently performed. Selected references were then uploaded to the software EndNote for reference management[13]. The reference list of the final selected studies, as well as systematic reviews and meta-analyses located in the literature search, were also screened for additional undetected studies (MA & NS). Cabell's Predatory Report[14] was informed to verify the academic status of papers from open access journals included in the result.

Study selection

Titles and abstracts of the retrieved citations were screened and assessed for eligibility against the inclusion/exclusion criteria by two independent reviewers (M.A and N.S). The full-text assessment was undertaken and evaluated with the agreement of both reviewers. Any disagreements between reviewers about the inclusion were resolved by consensus, discussion or consultation with a third reviewer (T.S). Non-pharmacological interventions and observational studies were excluded. Where

duplicate publications for the same study on the same patients utilising the same intervention and measuring the same outcomes were identified, the most recent version of the study was selected—the study selection process presented in Figure 1 following the PRISMA guidelines[11].

Data extraction

From studies that were deemed eligible, two independent reviewers (M.A and N.S) extracted relevant information. The information extracted covered the country of the trial, year of publications, design of the intervention, type of the RCT and comparators, number of participants, duration of the trials, baseline characteristics of the participants, and outcomes reported. The summary of these findings is presented in Table 2. Out of all reported outcomes, in this review, we only analysed fasting blood glucose (FBG), fasting insulin (FI), HOMA-IR, and HOMA-B.

Risk of bias assessment in the included studies

The Cochrane collaboration's tool for assessing the risk of bias (RoB) was used as recommended by Higgins et al[15]. Six domains, including (selection bias, performance bias, detection bias, attrition bias, reporting bias and other bias) were assessed. Two independent reviewers (M.A and N.S) assessed the RoB for each study, and a third reviewer (S.T) mediated any conflict between reviewers. The recommendations from the Cochrane handbook[16] were followed, and any RoB was graded as either 'high RoB', 'low RoB', or 'unclear RoB' supplementary materials[17]. The proportion of studies regarded as either with 'high RoB', 'low RoB', or 'unclear RoB' for each specific RoB domain was calculated and reported in supplementary materials[17].

GRADE scoring

The strength of the evidence for each desired outcome fasting blood glucose (FBG), fasting insulin (FI), homeostatic model assessment of insulin resistance (HOMA-IR), homeostatic model assessment

of beta-cell (HOMA-B) was assessed using recommendations from the Grading of Recommendations, Assessments, Development and Evaluation (GRADE) system[18]. GRADEpro GDT software was used to grade the quality of each outcome and to produce "Summary of findings table" supplementary materials[17]**.** For each outcome, four points were assigned to begin with, and then we assessed factors reducing the quality of the evidence. Points were reduced in the presence of the following: the overall RoB for each comparison, inconsistency (significant statistical heterogeneity across the trial), indirectness of evidence (significant differences across the population, intervention, and outcomes), imprecision (sample size, the width, and the statistical significance of the confidence intervals). Based on these factors, we reported the overall GRADE scores for the quality of the outcome of each comparison; high (at least 4 points), moderate (3 points), low (2 points) and very low (1 point or less) quality.

Data analysis and evidence synthesis

The pooled effect estimate (mean difference) and its 95% confidence intervals (95% CIs) on the difference between the intervention and comparison group was quantified using the random-effects model[16]. The meta-analysis was performed if there were at least two effect estimates assuming that data for reported continuous outcome variable are normally distributed. Extremely skewed data or data reported as range were excluded from the meta-analysis. Mean, and standard deviation (SD) values for both post-intervention values and changes from baseline scores were combined for the meta-analysis. For data presented as standard error (SE), CIs, *p*-values and *t* values, the RevMan calculator was used when necessary to convert them to means and standard deviations (SD). Mean difference (MD) was used when the same continuous data presented using the same scales across the trials. For trials with more than one intervention arm on the same outcome, data from all arms were combined using the method recommended in the *Cochrane Handbook's* [16]. Post-intervention scores and data from crossover trials were used from the last point the trials were reported. For missing data, the authors were contacted, asking them to provide the missing information.

Meta-analysis was performed using the Review Manager software (RevMan 5.4, The Cochrane collaboration).

Assessment of heterogeneity

Heterogeneity for outcomes across the trials was assessed using the I-squared (I^2) test statistics. Heterogeneity was described as either not significant (I^2 0 - 40 %), moderate (I^2 30 - 60 %), substantial (I^2 50 -90 %) and considerable (I^2 75 -100 %) heterogenity[16]. For substantial heterogeneity, the source was investigated by removing the study that represented the largest weight from the analysis, and the I^2 was re-evaluated. If heterogeneity was still not resolved, subgroup analyses were performed.

Subgroup analysis

Subgroup analysis was performed at different levels according to the nature, dosages, frequencies of administration (one/day (QD), twice/ day (BID) and trice/day (TDS)), and duration (weeks /months) of the pharmacological intervention.

Sensitivity analysis

The impact of each individual study on heterogeneity and the strength of the summary was assessed using sensitivity analysis. Small sample-sized trials and those with overall high RoB were removed from the analysis while observing their effects on the cumulative results. Thus, no significant effect was found, and hence no trial was removed from the meta-analysis.

Patient and Public Involvement

There was no direct patient or public involvement in this review.

Results

In total, 6,326 articles were identified from the database search, of which 3,186 were screened for eligibility based on titles and abstracts after removing duplicates. 814 full-text articles were retrieved for detailed assessment for eligibility, of which 58 RCTs were found eligible and included in the study (Figure1). Two studies[19,20] were eligible for inclusion but were excluded due to lack of outcomes of interest.

Scope of the included RCTs

The 58 RCTs were published until 2020, of which 35 RCTs (60.3%) [21-53] diagnosed PCOS based on the Rotterdam criteria 2003[54],54; nine (15.5%) RCTs [55-63] used the National Insatiate of Health 1990 (NIH, NICHD) criteria[64] while no diagnostic criteria were given for the rest of the RCTs (Table 2)**.**

Interventions and comparisons details

Sixteen (27.5%) RCTs assessed the effect of metformin compared with placebo [21,27,31,36,39,48,50,59,61,65-72]. Six (10%) RCTs evaluated metformin compared with pioglitazone[46,47,53,65,73,74]. Four (6.8%) RCTs assessed pioglitazone compared with placebo [22,55,75,76]. Eight (13.8%) RCTs examined rosiglitazone compared with metformin [23,35,38,41,51,57,63,77]. Three (5.2%) RCTs assessed liraglutide compared with liraglutide added to metformin[33,34,58].Two (3.4%) RCTs examined sitagliptin compared with placebo[25,30]. Two (3.4%) RCTs assessed exenatide compared with metformin [40,52]. Two (3.4%) RCTs compared orlistat with placebo[26,42]. Three (5.2%) RCTs examined acarbose with metformin [44,56,62]. Two (3.4%) RCTs compared saxagliptin with metformin [28,49]. Two (3.4%) RCTs compared simvastatin with metformin[60,78]. Two (3.4%) RCTs assessed metformin with N-Acetylcysteine (NAC)[32,43]. Two (3.4%) RCTs examined atorvastatin compared with placebo[45,79].Two (3.4%) RCTs assessed sitagliptin added to metformin compared with metformin alone[29,80]. Two (3.4%) RCTs examined acarbose compared with placebo[81,82].

Characteristics of the outcomes measured.

All RCTs were assessed outcomes at baseline and post-intervention**.** Forty-six (79.3%) RCTs reported changes in FBG[21,22,25-28,30-34,36,38-40,42-50,52,55,60,62,63,66-68,72-75,77-79]. Forty-eight (82.8%) RCTs reported FI [21-23,25-27,30-35,37-43,45-48,50-52,55-59,61-63,65,67-71,73-76,79].Thirty-seven (63.8%) RCTs reported the homeostatic model of insulin resistance (HOMA-IR)[22,24-31,33-35,39,40,42,47,49,50,52,53,57,58,63,65-67,69,74,75,77,80-84].Two(3.4%)RCTs reported the homeostatic model of β-cells (HOMA-B)[24,67].Table 2 presents more descriptive information on the included 58 RCTs.

R**isk of bias assessment**

The risk of bias (RoB) item for the included RCTs, and the overall RoB are presented in Figure 6 and 7 in the supplementary material[17]**.** One RCT was judged to have a high risk of selection bias due to an inappropriate method used to generate sequences[55]. Twenty-one RCTs were judged to have a high risk of performance bias due to lack of blinding the participants[26,27,29-31,33,34,38,40,41,47,49,52,53,58,65,73,74,83]. Nineteen RCTs were judged to have a high risk of detection bias due to lack of blinding outcome assessors[21,29-31,33,34,38,40,41,47,49,52,58,65,73,74,83]. Two RCTs were judged to have a high risk of selective reporting [35,78]. Low RoB was judged for the majority of domains among the included RCTs. However, an unclear RoB was also judged due to a lack of sufficient reporting.

Effects of interventions on the insulin resistance outcomes

The outcome of the meta-analyses on the effect of pharmaceutical medications compared with placebo presented in Figures 1-5 and compared with other medications was shown in Table 3.

Outcome: FBG

Metformin versus placebo

In one RCT, metformin 850 mg BID for six months was associated with insignificant reduction in the mean FBG (MD: -0.34 mg/dL; 95% CI: -0.77, 0.09). In eight RCTs and compared with placebo, metformin 1500 mg QD for three months was associated with a significant reduction in the mean FBG (MD: -0.17 mg/dL; 95% CI: -0.33, -0.01). In one RCT, metformin 1500 mg QD for six months was associated with an insignificant reduction in the mean FBG (MD: -3.83 mg/dL; 95% CI: -8.88, 1.22). In one RCT, metformin 2000 mg QD was associated with an insignificant reduction in the mean FBG (MD: -0.10 mg/dL; 95% CI: -0.31,0.11). Overall, regardless of the administered dosage and duration, metformin was associated with a significant reduction in the mean FBG (MD: -0.16 mg/dL; 95% CI: -0.28, -0.04, I^2 = 0%) in women who received metformin compared with women received placebo (Figure 2-A) (low grade of evidence, table 4, supplementary materials)[17].

Metformin versus Acarbose

In one RCT, Acarbose 100 mg QD for three months significantly reduced the mean FBG (MD: -10.30 mg/dL; 95% CI: -15.61, -4.99) compared with metformin. In one RCT Acarbose 300 mg QD for three months has insignificant effect on the mean FBG (MD: -20.80 mg/dL; 95% CI: -58.84, 17.24). However, in the two RCTs, regardless of the dosage, frequency, and duration, acarbose showed a significant reduction in the mean FBG (MD: -10.50 mg/dL; 95% CI: -15.76, -5.24, I^2 = 0%) (Table 3) (low grade evidence, table 4, supplementary materials)[17]**.**

Metformin versus Simvastatin

A significant reduction in the FBG level was also evident when metformin at various dosage was compared with Simvastatin 20 mg QD. In one RCT, metformin 1500 mg QD for three months has significantly reduced the mean FBG (MD: -2.79; 95% CI: -6.20, 0.26). In one RCT, metformin 1000 mg QD for six months has significantly reduced the mean FBG by 7.27 mg/dL (95% CI: -13.05, -1.49). Overall, regardless of the dosage and duration, metformin has significantly reduced the mean FBG

compared to simvastatin (MD: -4.43 mg/dL; 95% CI: -8.41, -0.44, I^2 = 38%) (Table 3) (very low-grade of evidence, table 4, supplementary materials)[17].

Metformin versus N-Acetylcysteine (NAC)

There was a significant favourable effect on the mean FBG when Metformin compared with NAC. In one RCT, metformin 1500 mg QD was compared with NAC 1800 mg QD for 12 weeks had a significant positive effect on the mean FBG level (MD: 5.10 mg/dL; 95% CI: -0.96, 11.16). One RCT, metformin 1500 mg QD, was compared with NAC 600 mg TDS for 24 weeks has a significant effect on the mean FBG level (MD: 3.41 mg/dL; 95% CI: 0.54, 6.28). Overall, metformin has significant positive effect on the mean FBG level (MD: 3.72 mg/dL; 95% CI: 1.13, 6.31, I^2 = 0%) compared with NAC (Table 3) (very low-grade of evidence, table 4, supplementary materials)[17].

The meta-analysis had also shown that there were no significant differences in the mean FBG when pioglitazone, sitagliptin, orlistat and atorvastatin were compared with placebo (Figure 4-B, C, D, E). Similarly, no significant effect in the mean FBG when metformin alone or in combination with liraglutide was compared with other medications (pioglitazone, rosiglitazone, liraglutide, exenatide and saxagliptin) (Table 3).

Outcome: FI

Metformin versus placebo

In five RCTs, metformin 850 mg BID for six months was associated with a significant reduction in the mean FI (MD: -7.10 pmol/L; 95% CI: -13.78, -0.42) compared with placebo. In six RCTs, metformin 1500 mg QD for three months was associated with an insignificant reduction in the mean FI (MD: -1.59 pmol/L; 95% CI: -4.48, 1.30). The pooled effect from one RCT, metformin 1500 mg QD for six months, has an insignificant effect on the mean FI (MD: 1.69 pmol/L; 95% CI: -3.09, 6.47). Additionally, in one RCT, metformin 2000 mg QD has shown no significant effect in the mean FI (MD: -1.20 pmol/L; 95%

CI: -3.79, 1.39). In one RCT, metformin 1500 mg QD for seven weeks has significantly reduced the mean FI (MD: -4.0 pmol/L; 95% CI: -6.53, -1.47). Overall, regardless of the dosage, duration and frequencies, metformin has significantly reduced the mean FI (MD: -2.20 pmol/L; 95% CI: -3.62, -0.77, I^2= 0%) (Figure 3-A) (moderate grade of evidence, table 4, supplementary material)[17].

Pioglitazone versus placebo

In three RCTs, pioglitazone 30 mg QD significantly reduced the mean by 16.76 pmol/L; 95% CI: -25.81, -7.72) compared with placebo. In one RCT, pioglitazone 45 mg QD has also significantly reduced the mean FI by 5.34 pmol/L; 95% CI: -14.54, -3.86). Overall, pioglitazone on various dosages has significantly reduced the mean FI by 11.47 pmol/L; 95% CI: -20.20, -2.74, I^2= 35%) (Figure 3-B) (very low-grade of evidence, Table 4, supplementary material)[17].

Metformin versus NAC

In one RCT, NAC 1800 mg QD has shown no significant effect in the mean FI when compared with Metformin 1500 mg QD for 12 weeks (MD: -1.20 pmol/L; 95% CI: -10.72, 8.32). One RCT compared NAC 600 mg QD with Metformin 1500 mg QD for 24 weeks showed a significant positive effect (MD: 1.51 pmol/L; 95% CI: 0.53, 2.49). Overall, metformin compared with NAC has a significant positive effect in the mean FI (MD: 1.48 pmol/L; 95% CI: 0.51, 2.46, I^2 = 0%) (Table 3) (low grade evidence, Table 4, supplementary material)[17].

The meta-analysis also showed no significant effect in the mean FI when sitagliptin, orlistat and atorvastatin were compared with placebo (Figure 3-C, D, E). Similarly, no significant effect was observed in the mean FI when metformin was used alone or in combination with liraglutide compared with other medications (liraglutide, pioglitazone, rosiglitazone, exenatide and acarbose) (Table 3).

Outcome: HOMA-IR

Exenatide versus Metformin

In one RCT, exenatide 10 µg BID compared with Metformin 1000 mg BID for 12 weeks showed insignificantly but the lower mean level of HOMA-IR (MD: -0.23; 95% CI: -0.83, 0.37). However, in one RCT comparing exenatide 10 µg BID with metformin 1000 mg BID for 24 weeks, a significant reduction in the mean HOMA-IR was observed (MD: -0.38; 95% CI: -0.74, -0.02). Overall, exenatide has significantly reduced the mean HOMA-IR (MD: -0.34; 95% CI: -0.65, -0.03, I^2= 0%) compared with metformin (Table 3) (low grade of evidence, Table 4, supplementary material)[17].

The meta-analysis showed no significant effect in the mean HOMA-IR when metformin, pioglitazone, sitagliptin, orlistat and acarbose were compared with placebo (Figure 4-A, B, C, D, E). Similarly, no significant effect in the mean HOMA-IR when metformin alone or in combination with liraglutide or sitagliptin compared with other medications (pioglitazone, rosiglitazone, liraglutide, orlistat, sitagliptin and saxagliptin) (Table 3).

Outcome: HOMA-B

Metformin versus placebo

One RCT compared metformin 850 mg BID for six months with placebo showed an insignificant effect on the mean HOMA-B (MD: 30.70; 95% CI: -66.18, 127.58). In one RCT, metformin 1500 mg for three months also showed an insignificant effect on the mean HOMA-B (MD: 39.73; 95% CI: -79.61, 159.07) compared with placebo. Overall, metformin was associated with an increased but insignificant effect in the mean HOMA-B level (MD: 34.29; 95% CI: -40.93, 109.50, I^2= 0%) compared with placebo (Figure 5)(low-grade evidence, Table 4, supplementary material)[17].

Discussion

Summary of the main findings

This systematic review summed up the current evidence supporting the effect of various pharmacological interventions on insulin resistance. To our knowledge, this is the first systematic review to report on the effect of various pharmacological interventions on insulin resistance in women with PCOS. When metformin was administered at various doses compared with placebo, there was a significant reduction in FBG and FI. This was also evident when metformin was compared with NAC, simvastatin and acarbose. On the other hand, exenatide significantly reduced HOMA-IR compared with metformin. The strength of evidence for these data ranged from very low to moderate, and therefore, care should be applied when interpreting these findings.

The insulin resistance outcomes

Metformin is a widely used drug that exerts its action by targeting various organs via multiple molecular mechanisms. Metformin acts on the liver to reduce hepatic glucose production by opposing the glucagon action and activating the activated protein kinase (AMPK), which also enhances insulin sensitivity by modulating lipid metabolism[85,86]. In the current systematic review, there were significant reductions in FBG and FI with metformin at various doses and when administered for both long and short duration compared with placebo. These results are in accord with what has been reported in a

non-randomised cohort study of 108 insulin resistant and obese women with PCOS who received Metformin 1500 mg QD for six months[87]. However, in a meta-analysis of RCTs evaluating the effects of metformin on the metabolic, hormonal, and clinical outcomes in women with PCOS, no effects on FBG, FI and HOMA-IR were found[88]. However, there was a significantly high level of heterogeneity amongst those studies. Furthermore, a recent systematic review and meta-analysis of RCTs evaluating the effect of metformin in overweight women with PCOS reported that although there was a significant effect on the anthropometric indices, no effect was seen on the parameters of insulin resistance[89]. Therefore, considering these previous findings, it appears that metformin alone has a variable effect on the parameters of insulin resistance in women with PCOS. In the present review, we reported a significant reduction in FI with pioglitazone compared with placebo and metformin. However, data from a meta-analysis assessed the effect of metformin versus thiazolidinediones in women with PCOS showed no changes in insulin sensitivity [90]. We also found a significant reduction in FBG when metformin was compared with NAC. However, a recent meta-analysis of RCTs that compared the efficacy of metformin versus NAC showed no significant changes in the parameters of insulin resistance[91]. This review did not establish any significant effect on HOMA-B with various pharmacological interventions used in the management of PCOS.

Strength and limitation of the review

The review followed a comprehensive and systematic search of the relevant databases and grey sources that only included RCTs and randomised crossover trials. Observational studies and non-randomised clinical trials were excluded to reduce the risk of bias.

To our knowledge, this is the most comprehensive and up-to-date systematic review and meta-analysis on the impact of pharmacological interventions on insulin resistance in women with PCOS.

However, there are limitations to this systematic review. We applied a language filter, and only trials reported in the English language were included, and therefore several clinical trials in foreign

languages may not have been retrieved. Assessing such trials requires sophisticated translation, which is challenging that could also affect the methodology of this review. Furthermore, only fully published trials were eligible, and publication bias was not performed. The majority of the trials were of smaller sample size, and the statistical power used to calculate sample size and to detect the meaningful differences between the groups were not fully reported. All the trials were of short duration and reported baseline and immediate post-intervention data. Therefore, the long-term effect of the different pharmacological interventions in women with PCOS is not clear.

The quality of the evidence

This systematic review acknowledges the poor quality of the included clinical trials, which is also reflected in the summary of evidence of the GRADE score. Due to the nature of the clinical trials, there was a significantly high level of heterogeneity as well as performance bias among the included studies. Although a simple logistical approach could have been taken by blinding the outcome assessors, there was a significantly high level of detection bias. Reporting and selection bias were inadequately reported amongst the trials, so the judgment of unclear risk of bias was made in nearly 75% of the included trials. Disproportionately, only 20% of the trials reported information of the method used to blind the participants and the outcome assessor and 49% were judged to have an unclear risk of attrition bias. Around 25% of the included trials had a high risk of performance and detection bias. For the insulin resistance outcomes, the grade of evidence was rated from very low to moderate due to the unclear or high risk of performance bias.

Relevance to clinical practice and future direction

Based on our findings, it is clear that there is a lack of robust clinical trials assessing the different pharmacological interventions in the management of PCOS. Furthermore, trials examining the clinical effectiveness of these interventions are of low or very low quality and therefore, the available data are not suitable to draw definite conclusions and recommendations for clinical practice. Furthermore,

these trials are of small sample sizes that clearly undermined the statistical power used to calculate the meaningful effects of the outcomes. Therefore, further clinical trials with robust design are needed to enable better-informed decisions, recommendations and draw guidelines for the various pharmacological interventions used in women with PCOS.

Conclusion

Treating insulin resistance in women with PCOS is of vital importance to reduce metabolic and reproductive abnormalities and to prevent the risk of developing T2DM and CVD. Data pooled in this meta-analysis showed that pharmacological interventions including metformin, pioglitazone, acarbose and exenatide reduce FBG, FI and HOMA-IR. However, some therapeutic agents have no effect on the parameters of insulin resistance. Even though data presented in this systematic review and meta-analysis are drawn mainly from clinical trials, caution should be taken when interpreting these results. We have rated the grade of evidence for the outcomes as very low, low, and moderate using the GRADE score. The majority of the interventions showed modest effects with wide confidence intervals that indicate significant uncertainties. Therefore, further clinical trials with rigorous methodology and sufficiently power are needed for each of these pharmacological interventions.

Acknowledgement

We thank Dr Gamila Hassan at the National Medical Library (UAEU) for her support with locating and uploading full-text papers to Covidence for screening.

Funding

This systematic review was completed as part of a self-funded PhD project for M.A, and no external fund was received.

Ethical approval

Not needed as no patients involved.

Conflict of interest

None to declare.

Availability of data

The datasets generated and analysed for this review are available upon compelling request to the authors.

Authors contributions

MA; designed the review, completed the databases searches, assessed the quality, extracted, collected, and analysed the data, written, revised, and edited the final manuscript. NS; assessed the quality, extracted, and collected the data, and revised and edited the final manuscript. HD; revised and edited the final manuscript. L. Ö; developed and performed the systematic search, assessed for predatory journals and revised and edited the final manuscript. RHA; contributed to the meta-analysis and participated in the critical discussion and revised and edited the final manuscript. SA; participated in the critical discussion and revised the final draft of the manuscript. TS; acted as a mediator for the assessment of the quality of the evidence, supervised the study, participated in the critical discussion, revised and edited the final manuscript.

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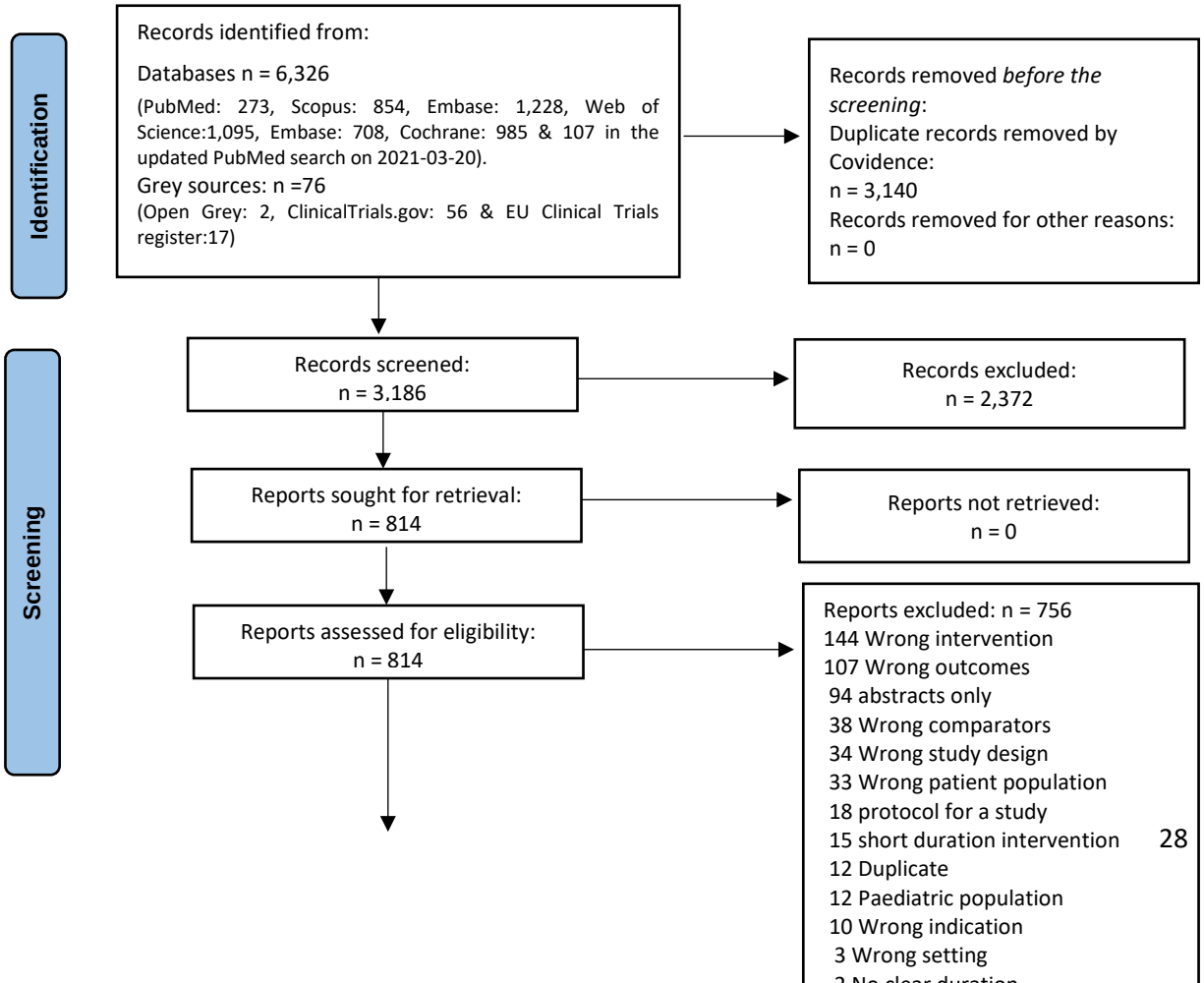
Table 1: The inclusion criteria for the included studies in this systematic review

Inclusion criteria 1. Study design: randomised controlled trials including (randomised open-label trials, double-blind controlled trials, crossover randomised trials, parallel randomised trials). 2. Patients population: adult females aged 18 and over with a diagnosis of PCOS based on a robust diagnostic criterion. 3. Comparators: reported pharmacological interventions compared to placebo or other pharmacological agents. 4. Outcomes: reported outcomes such as fasting blood glucose, fasting insulin, HOMA-IR, and HOMA-B. **Exclusion criteria** 1) Study design: case studies and animal studies. 2) Patients population: adolescents females, postmenopausal women, and women without PCOS. 3) Comparators: non-pharmacological interventions, pharmacological interventions versus dietary interventions, pharmacological interventions versus physical activities or surgery.

PCOS: polycystic ovary syndrome, **HOMA-IR**: homeostatic model assessment in the insulin resistance, **HOMA-B**: homeostatic Model assessment of beta-cell.

Figure 1: PRISMA flow diagram



Included

Studies included in review:
n = 58
Reports of included studies:
n = 58

Table 2: Characteristics of the studies included in the systematic review and meta-analysis

Author	Study design	Country	POCS diagnostic Criteria	Participants characteristics (PCOS)	Interventions	Durations	Outcomes
Amiri et al[21]	RCT	Iran	Rotterdam	Age:25.6±4.02 BMI: 28.9±5	Metf, Flu, Metf+ Flu, Placebo	6 months	FBG
Aroda et al[55]	RCT	USA	NIH	Age: 27.87 ±0.87 BMI: 36.29 ±1.34	Piog, Placebo	6 months	FBG,FI
Brettenthaler et al[22]	RCT	Switzerland	Rotterdam	Age: 30.2± 1.4 BMI: 29.4± 1.7	Piog, placebo	3 months	FBG, FI, HOMA-IR
Cetinkalp et al[23]	RCT	Turkey	Rotterdam	Age: N/A BMA:25.82±6.12	Met, Rosigl , ECA	4 months	FBG,FI, HOMA-IR
Cheng et al[24]	RCT	Australia	Rotterdam	Age: 26 ± 4 BMI:24.2±5.3	Metf, placebo	6 months	HOMA-IR, HOMA-B
Cho et al[65]	RCT	UK	Rotterdam	Age: 26·4 ± 1·5 BMI: 36·0 ± 1·2	Metf, Orlistat, Piog	12 weeks	HOMA-IR
Ciotta et al[81]	RCT	Italy	N/A	Age:20.5±0.6 BMI:22.7±0.34	Acarbose, Placebo	3 months	HOMA-IR
Devin et al[25]	RCT-cross over	USA	Rotterdam	Age:N/A BMI:N/A	Sitag, placebo	4 weeks	FBG
Diamanti-Kandarakis et al[26]	RCT	Greece	Rotterdam	Age: 27·52 ± 5·77 BMI: 35·43 ± 5·3	Orli, placebo	6 months	HOMA-IR
Eisenhardt et al[27]	RCT	Germany	Rotterdam	Age: 27.0 BMI: 28.9	Metf,Placebo	12 weeks	FBG.FI,HOMA-IR
Elkind-Hirsch et al[28]	RCT	USA	Rotterdam	Age: 28.2 ± 1.1 BMI: 39.9 ±1.5	Exen, Metf,Exen+Metf	24 weeks	FBG
Ferjan et al[30]	RCT	Slovenia	Rotterdam	Age: 34.3 ± 6.8 BMI: 36.3 ±5.2	Metf, Metf+Sitag	12 weeks	HOMA-IR
Ferjan et al[29]	RCT	Slovenia	Rotterdam	Age: 35.0 ± 7.2 BMI: 36.9 ± 5.5	Sitag, Placebo	12 weeks	HOMA-IR, HOMA-B, FBG
Gambineri et al[66]	RCT	Italy	N/A	Age: 27·1 ± 3·6 BMI: 37·6 ± 4·1	Plac, metfo, flut, metf + flut	6 months	FBG,FI,HOMA-IR
Glintborg et al[75]	RCT	USA	N/A	Age: 32 BMI: N/A	Piog, Placebo	16 weeks	FI, HOMA-IR
Glintborg et al[76]	RCT	USA	N/A	Age: 32 BMI: 32.2	Piog,Plcebo	16 weeks	FI
Hanjalic-Beck et al[56]	RCT	Germany	NIH	Age:N/A BMI:N/A	Metf, Acarbose	12 weeks	FBG,FI
Heidari et al[31]	RCT	USA	Rotterdam	Age: 32.47.5 BMI: 37.19.1	Metf, placebo	3 months	FBG, FI
Javanmanesh et al[32]	RCT	Iran	Rotterdam	Age: 29.75 ± 4.90 BMI: 29.05 ± 2.80	Metf, NAC	24 weeks	FBG,FI, HOMA-IR
Jayagopal et al[83]	RCT	UK	N/A	Age: 27 ±0.9 BMI: 36.7 ±3.3	Orlistat, Metf	3 months	FBG, FI

Table 2 continued…….

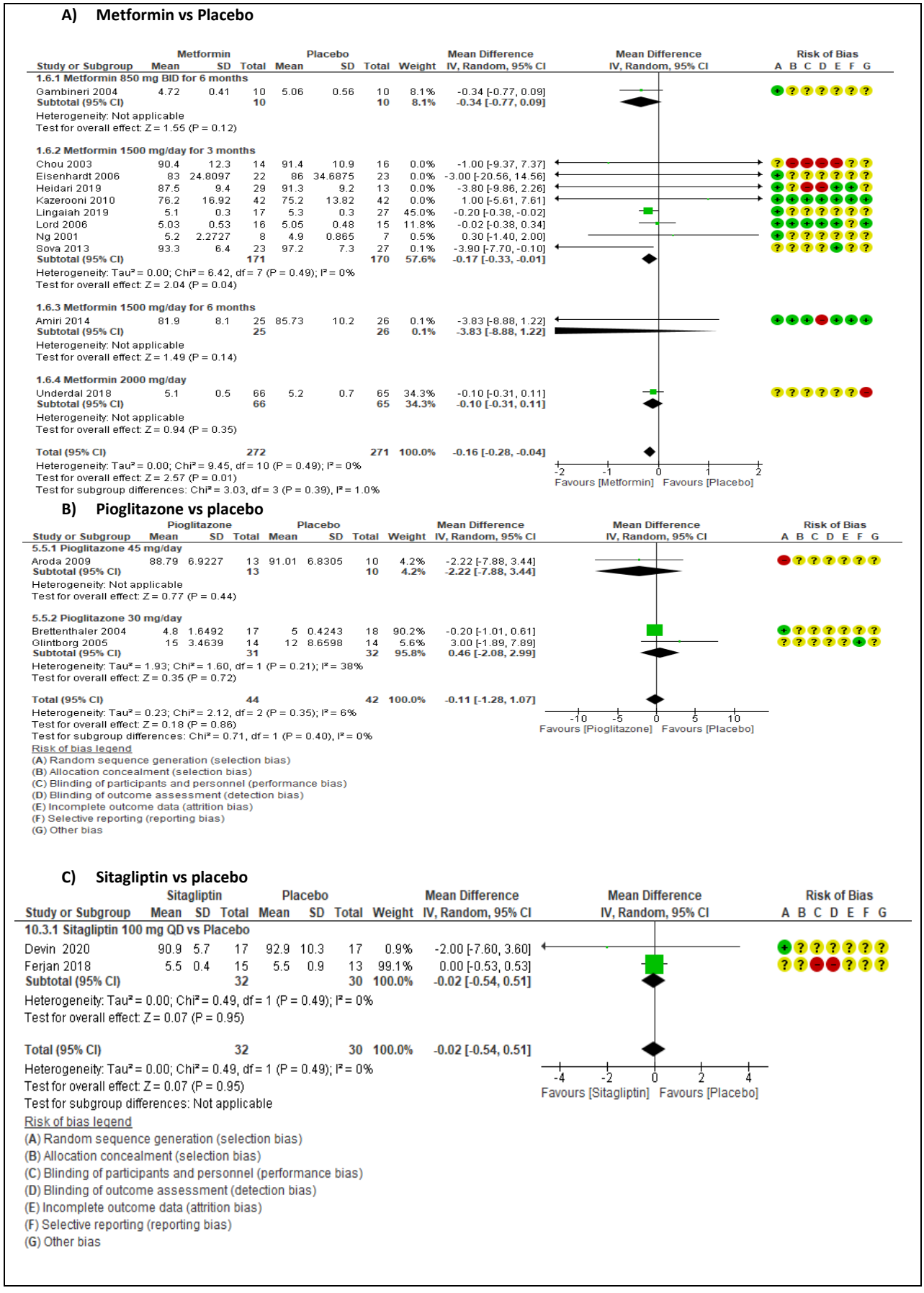
Jensterle et al[57]	RCT	Slovenia	NIH	Age: 27.6±7.2 BMI: 39.5±6.2	Metf, Rosi	6 months	FBG, FI
Jensterle et al[35]	RCT	Slovenia	Rotterdam	Age: 30.7 ± 7.9 BMI: 38.6 ± 6.0	Metfo, Rosi	6 months	FI, FBG, HOMA-IR
Jensterle et al[33]	RCT	Slovenia	Rotterdam	Age: 33.1 ± 6.1 BMI: 37.2±4.5	Met+Lira, Lira	12 weeks	FBG,FI, HOMA-IR
Jensterle et al[34]	RCT	Slovenia	Rotterdam	Age: 34.4 ± 6.5 BMI: 39.0 ± 4.9	Met+Lira,Lira	12 weeks	FI,FBG
Jensterle Sever et al[58]	RCT	Slovenia	NIH	Age: 31.3±7.1 BMI: 37.1±4.6	Lira,Metf, Lira+Metf	12 weeks	FBG,FI
Kazerooni et al[36]	RCT	Iran	Rotterdam	Age: 25.6± 4.32 BMI: 28.52± 1.61	Metf, simva,placebo	12 weeks	FI,FBG
Kocak et al[37]	RCT	Turkey	Rotterdam	Age: 26.2 ±3.7 BMI: 31.91± 5.38	Metf, Placebo	2 months	FI,FBG
Ladson[59]	RCT	USA	NIH	Age: 29±4.5 BMI: 38±7.8	Metfo, placebo	6 months	FBG, FI
Li et al[38]	RCT	China	Rotterdam	Age: 25.95± 4.36 BMI: 27.54 ±2.21	Rosi, metformin	6 months	FI,FBG
Lingaiah et al[39]	RCT	Finland	Rotterdam	Age: 27.6 ±4.0 BMI: 26.5 ±6.0	Metf, placebo	3 months	FI,FBG
Liu et al[40]	RCT	China	Rotterdam	Age: 27.69 ± 3.80 BMI: 28.29 ± 1.86	Metf, Exena	24 weeks	FI,FBG, HOMA-IR
Lord et al[67]	RCT	UK	N/A	Age: 27.76 ±4.89 BMI: 33.74± 6.74	Metf, placebo	3 months	FI,FBG, HOMA-IR
Mehrabian et al[60]	RCT	Iran	NIH	Age: 29.18±8.28 BMI: 29.83±4.1	Metf, flut, simva	6 months	FBG
Moghetti et al[61]	RCT	Italy	NICHD	Age: 23.9 6 1.2 BMI: 27.1 6 1.5	Metformin, placebo	6 months	FBG, FI
Mohiyiddeen et al[41]	RCT	UK	Rotterdam	Age: 29.0 ±1.0 BMI: 29.7 ±1.0	Metf,Rosig	3 months	FI,FBG
Moini et al[42]	RCT	Iran	Rotterdam	Age: 27.42 ± 3.31 BMI: 29.01 ± 2.09	Orlistat, placebo	3 months	FI,FBG
Naka et al[73]	RCT	Greece	N/A	Age: 23.3± 4.9 BMI: 28.7± 5.5	Metf,Piogl	6 months	FI,FBG
Navali et al[78]	RCT	Iran	N/A	Age:26.43±4.67 BMI:27.71±0.73	Metf, Simva	3 months	FI,FBG
Nemati et al[43]	RCT	Iran	Rotterdam	Age:N/A BMI: 36.3± 8.4	Metf, NAC	12 weeks	FBG,FI
Ng et al[68]	RCT	China	N/A	Age:30.5 BMI:N/A	Metf, placebo	3 months	FBG,FI
Ortega-González et al[74]	RCT	Mexico	N/A	Age: 28.8 ±0.9 BMI: 32.2 ±1.0	Metf, Piogl	6 months	FBG, FI

Table 2 continued…….

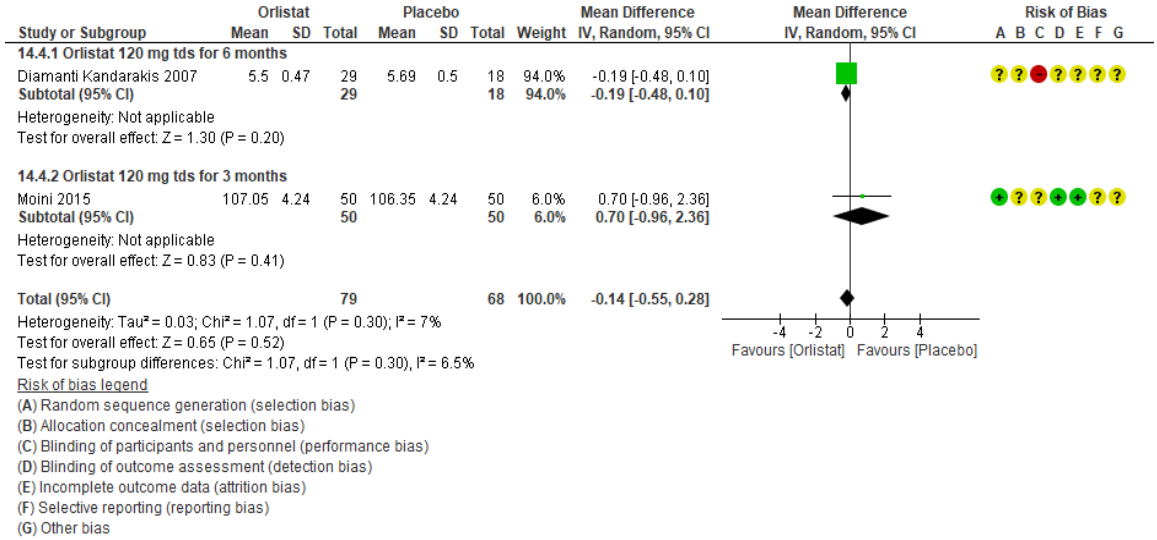
Paredes Palma et al[80]	RCT	Mixeco	N/A	Age:N/A BMI: N/A	Metf, Sitag	N/A	HOMA-IR
Penna et al[82]	RCT	Brazil	NA	Age: 26.69 ±1.46 BMI: 35.8± 2.60	Acarbose, Placebo	6 months	FI
Puurunen et al[79]	RCT	Finland	N/A	Age: 40.5 ±5.9 BMI: 30.4 ±8.6	Atorva, placebo	6 months	FI, HOMA-IR
Rezai et al[44]	RCT	Iran	Rotterdam	Age: 26.3±4 BMI: 26.9 ± 1.8	Metf, Acarbose	3 months	FBG
Sathyapalan et al[45]	RCT	UK	Rotterdam	Age: 27.7± 1.4 BMI: 33.20 ±1.4	Atorvas, placebo	12 weeks	HOMA-IR, FBG,FI
Shahebrahimi et al[46]	RCT	Iran	Rotterdam	Age: 27.5 ± 3.68 BMI: 27.71±4.36	Metf, piog	3 months	FBG
Sohrevardi et al[47]	RCT	Iran	Rotterdam	Age:N/A BMI: 27.5±3.6	Metf,piog, Metf+Piog	3 months	HOMA-IR, FBG, FI
Sönmez et al[62]	RCT	Turkey	NIH	Age: 26.13 ±5.08 BMI: 27 ±2.2	Metf, Acarbose	3 months	FBG,FI
Sova et al[48]	RCT	Finland	Rotterdam	Age: : 27.7 ±4.0 BMI: 27.5 ±6.2	Metf, placebo	3 months	FBG,FI
Steiner et al[63]	RCT	Germany	NIH	Age: 22.9±4.5 BMI: 27.4±6.0	Metf, Rosig	6 months	HOMA-IR, FBG,FI
Tao et al[49]	RCT	China	Rotterdam	Age: 30 ± 5 BMI: 27.2	Saxag, Metf	24 weeks	HOMA-IR
Trolle et al[69]	RCT	Denmark	N/A	Age: 31 BMI:32	Metf, placebo	6 months	FBG,FI,HOMA-IR
Underdal et al[50]	RCT	Denmark	Rotterdam	Age: 29.5 ±3.9 BMI: 28.7± 6.9	Metf, placebo	NA	FBG, FI
Vandermolen et al[71]	RCT	USA	N/A	Age: 29 6 ±1.2 BMI: 37.6 ± 4.3	Metf, Placebo	7 weeks	FBG,FI
Yarali et al[70]	RCT	Turkey	N/A	Age:29.7±5.6 BMI:28.6±4	Metf, placebo	6 weeks	FBG,FI
Yilmaz et al[51]	RCT	Turkey	Rotterdam	Age: 24.67+4.60 BMI: 27.12+6.18	Metf, Rosig	24 weeks	FBG,FI
Zheng et al[52]	RCT	China	Rotterdam	Age: 27.70 ± 3.41 BMI: 28.27 ± 4.85	Exena, Metf	12 weeks	FBG,FI
Ziaee et al[53]	RCT	Iran	Rotterdam	Age: 25.28±4.38 BMI: 26.13 ±3.03	Metf, piog	12 weeks	HOMA-IR

RCT: randomised clinical trial, **N/A**: not available, **FBG**: fasting blood glucose, **FI**: fasting insulin, **HOMA-IR:** homeostatic model of insulin resistance**,NIH**: national institute for health, **NICHD**:national inistitute of child health and development. **Metf:**metformin, **Saxa:** saxagliptin,**Piog**: pioglitazone, **Rosig**: rosiglitazone,**Atrova:** atorvastatin, **Simva**:simvastatin, **WHO:** world health organisation,**Lira**:liraglutide, **USA:** united state of America,**UK**: united kingdom, **HOMA-B:** homeostatic model of the beta cell.

Figure 2: Forest plot of comparisons on FBG

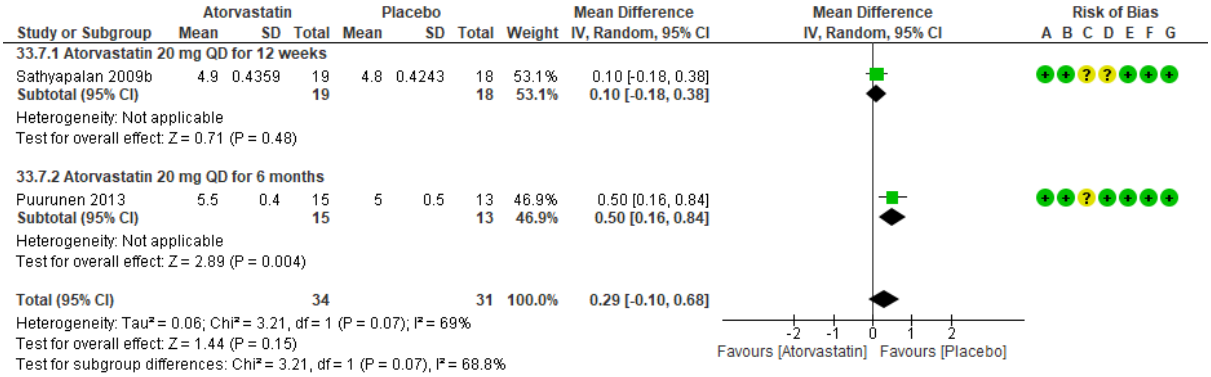


D) Orlistat vs placebo



Risk of bias legend
(A) Random sequence generation (selection bias)
(B) Allocation concealment (selection bias)
(C) Blinding of participants and personnel (performance bias)
(D) Blinding of outcome assessment (detection bias)
(E) Incomplete outcome data (attrition bias)
(F) Selective reporting (reporting bias)
(G) Other bias

E) Atorvastatin vs placebo



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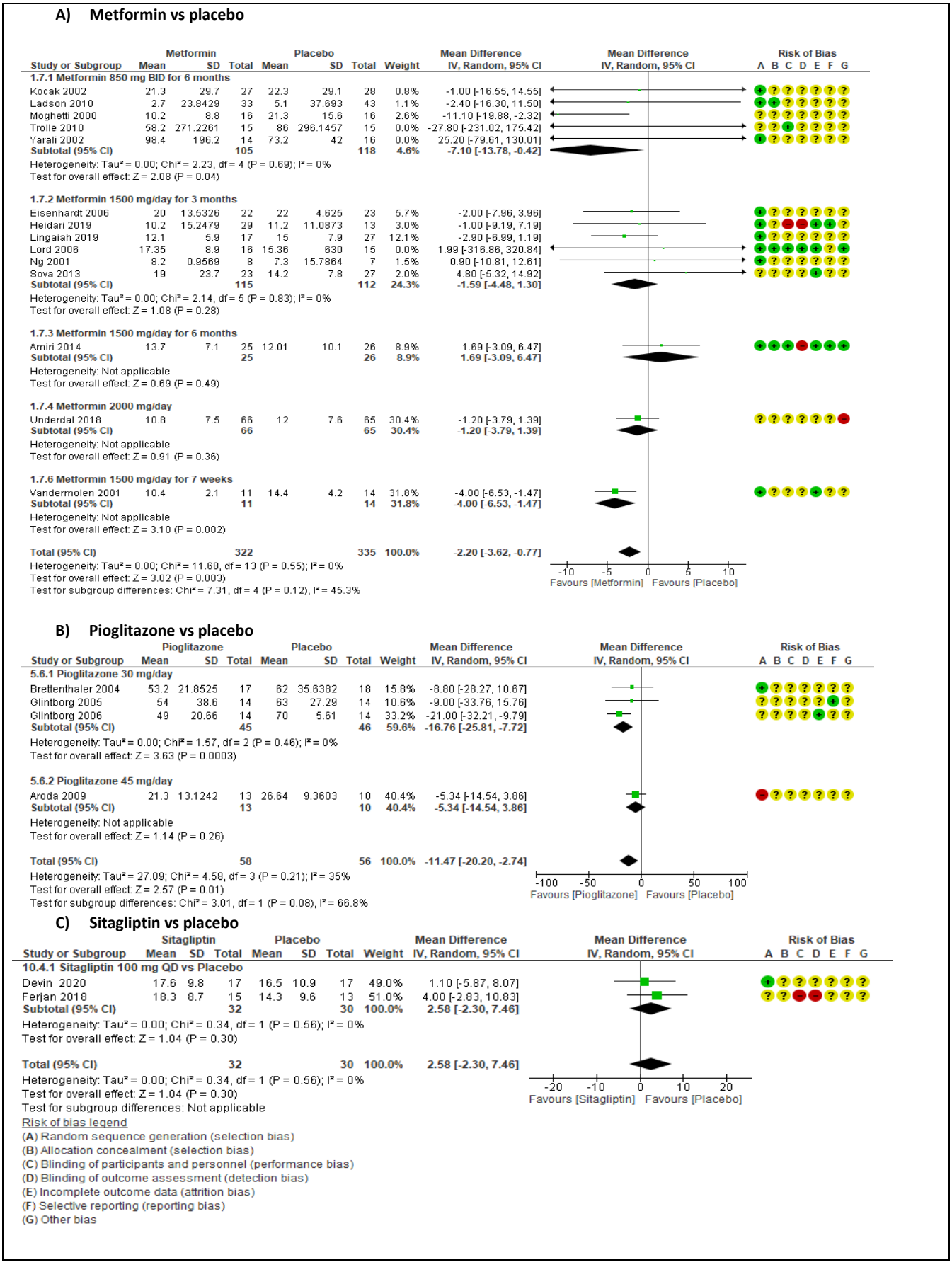
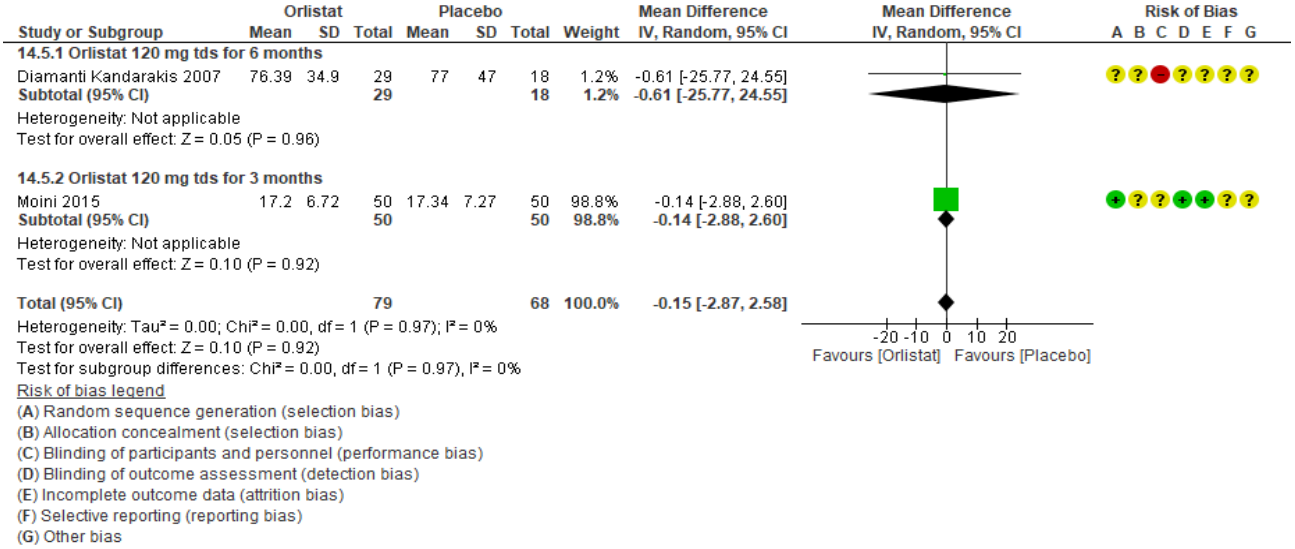
(D) Blinding of outcome assessment (detection bias)
(E) Incomplete outcome data (attrition bias)
(F) Selective reporting (reporting bias)
(G) Other bias

Figure 3: Forest plot of comparisons on FI

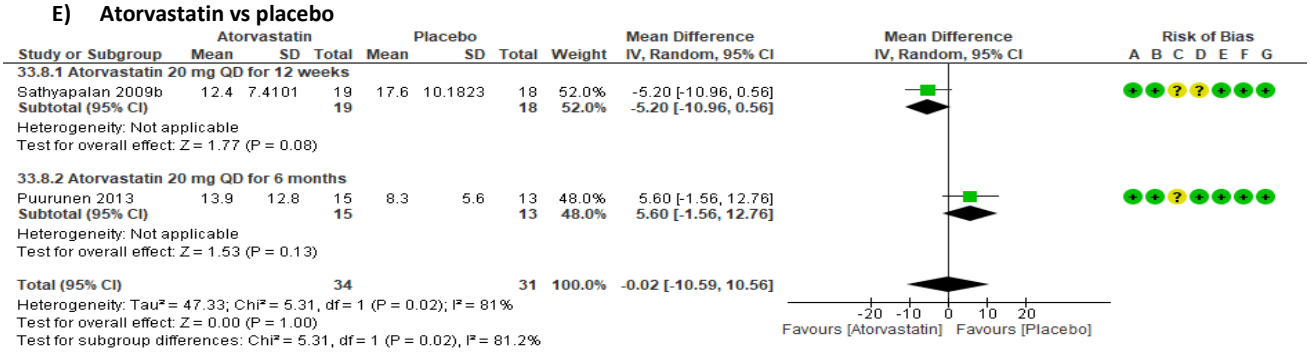


D) Orlistat vs placebo



Risk of bias legend
(A) Random sequence generation (selection bias)
(B) Allocation concealment (selection bias)
(C) Blinding of participants and personnel (performance bias)
(D) Blinding of outcome assessment (detection bias)
(E) Incomplete outcome data (attrition bias)
(F) Selective reporting (reporting bias)
(G) Other bias

E) Atorvastatin vs placebo



Risk of bias legend
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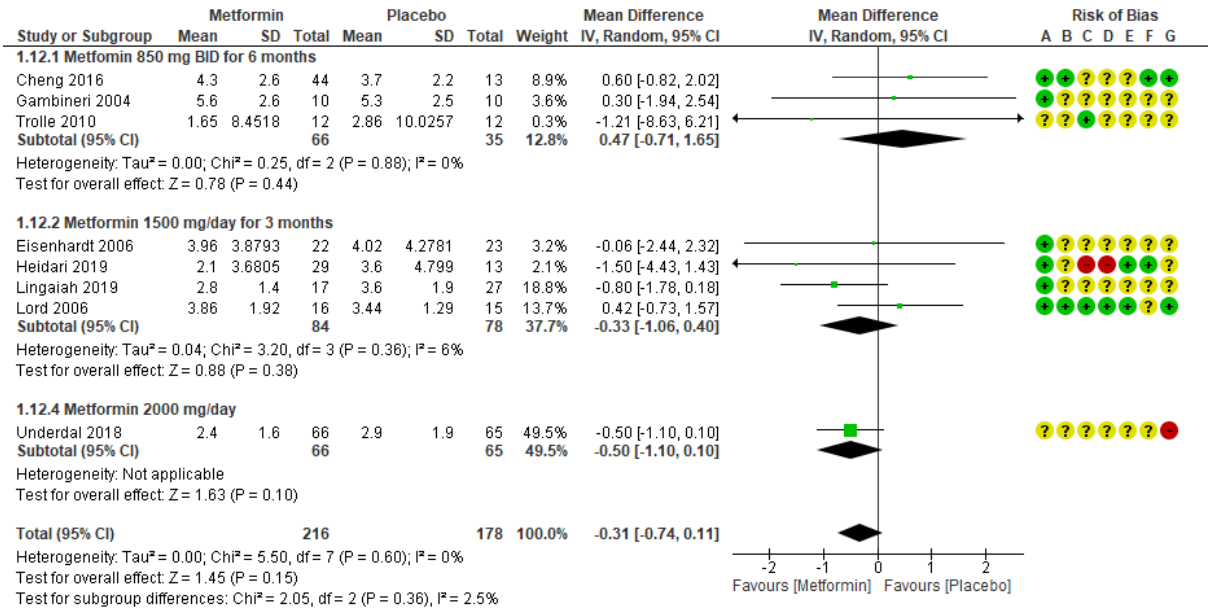
(D) Blinding of outcome assessment (detection bias)
(E) Incomplete outcome data (attrition bias)
(F) Selective reporting (reporting bias)
(G) Other bias

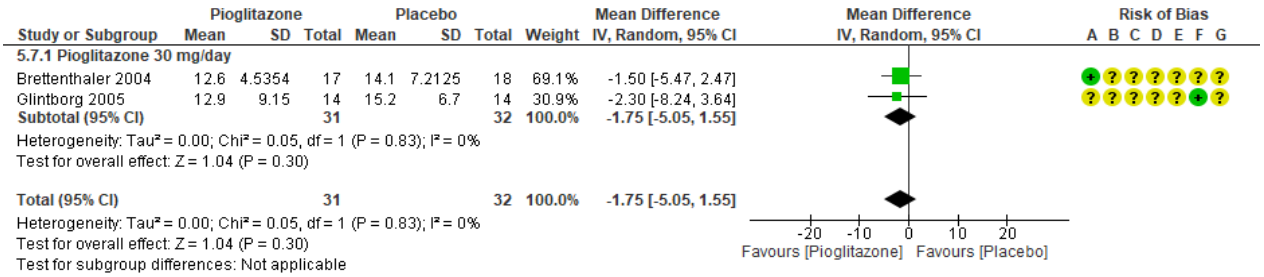
Figure 4: Forest plot of comparisons on HOMA-IR

A) Metformin vs placebo



Risk of bias legend
(A) Random sequence generation (selection bias)
(B) Allocation concealment (selection bias)
(C) Blinding of participants and personnel (performance bias)
(D) Blinding of outcome assessment (detection bias)
(E) Incomplete outcome data (attrition bias)
(F) Selective reporting (reporting bias)
(G) Other bias

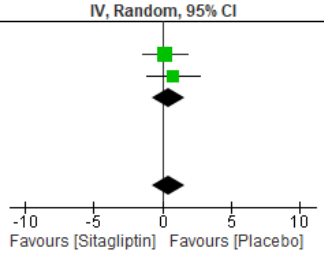
B) Pioglitazone vs placebo

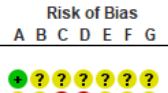


Risk of bias legend
(A) Random sequence generation (selection bias)
(B) Allocation concealment (selection bias)
(C) Blinding of participants and personnel (performance bias)
(D) Blinding of outcome assessment (detection bias)
(E) Incomplete outcome data (attrition bias)
(F) Selective reporting (reporting bias)
(G) Other bias

C) Sitagliptin vs placebo

Study or Subgroup	Sitagliptin Mean	SD	Total	Placebo Mean	SD	Total	Weight	Mean Difference IV, Random, 95% CI
10.2.1 Sitagliptin 100 mg QD vs Placebo								
Devin 2020	4.1	2.1	17	3.9	2.7	17	58.1%	0.20 [-1.43, 1.83]
Ferjan 2018	4.5	2.3	15	3.7	2.8	13	41.9%	0.80 [-1.12, 2.72]
Subtotal (95% CI)			**32**			**30**	**100.0%**	**0.45 [-0.79, 1.69]**
Heterogeneity: Tau² = 0.00; Chi² = 0.22, df = 1 (P = 0.64); I² = 0%								
Test for overall effect: Z = 0.71 (P = 0.48)								
Total (95% CI)			**32**			**30**	**100.0%**	**0.45 [-0.79, 1.69]**
Heterogeneity: Tau² = 0.00; Chi² = 0.22, df = 1 (P = 0.64); I² = 0%								
Test for overall effect: Z = 0.71 (P = 0.48)								
Test for subgroup differences: Not applicable								





Risk of bias legend
(A) Random sequence generation (selection bias)
(B) Allocation concealment (selection bias)
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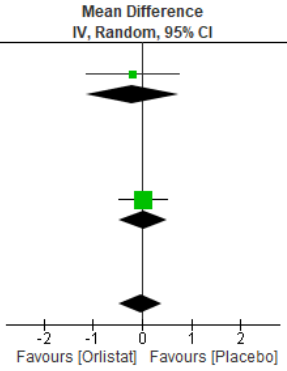
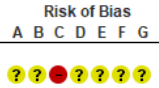
(D) Blinding of outcome assessment (detection bias)
(E) Incomplete outcome data (attrition bias)
(F) Selective reporting (reporting bias)
(G) Other bias

D) Orlistat vs placebo

Study or Subgroup	Orlistat Mean	SD	Total	Placebo Mean	SD	Total	Weight	Mean Difference IV, Random, 95% CI
14.3.1 Orlistat 120 mg tds for 6 months								
Diamanti Kandarakis 2007	2.67	1.23	29	2.87	1.79	18	22.0%	-0.20 [-1.14, 0.74]
Subtotal (95% CI)			**29**			**18**	**22.0%**	**-0.20 [-1.14, 0.74]**
Heterogeneity: Not applicable								
Test for overall effect: Z = 0.42 (P = 0.68)								
14.3.2 Orlistat 120 mg tds for 3 months								
Moini 2015	3.43	1.11	50	3.41	1.42	50	78.0%	0.02 [-0.48, 0.52]
Subtotal (95% CI)			**50**			**50**	**78.0%**	**0.02 [-0.48, 0.52]**
Heterogeneity: Not applicable								
Test for overall effect: Z = 0.08 (P = 0.94)								
Total (95% CI)			**79**			**68**	**100.0%**	**-0.03 [-0.47, 0.41]**
Heterogeneity: Tau² = 0.00; Chi² = 0.16, df = 1 (P = 0.69); I² = 0%								
Test for overall effect: Z = 0.13 (P = 0.90)								
Test for subgroup differences: Chi² = 0.16, df = 1 (P = 0.69), I² = 0%								





Risk of bias legend
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(B) Allocation concealment (selection bias)
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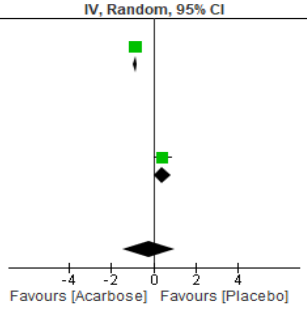
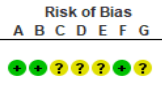
(D) Blinding of outcome assessment (detection bias)
(E) Incomplete outcome data (attrition bias)
(F) Selective reporting (reporting bias)
(G) Other bias

E) Acarbose vs placebo

Study or Subgroup	Acarbose Mean	SD	Total	Placebo Mean	SD	Total	Weight	Mean Difference IV, Random, 95% CI
15.2.1 Acarbose 300 mg QD for 3 months								
Ciotta 2001	0.66	0.1643	30	1.52	0.1549	15	51.2%	-0.86 [-0.96, -0.76]
Subtotal (95% CI)			**30**			**15**	**51.2%**	**-0.86 [-0.96, -0.76]**
Heterogeneity: Not applicable								
Test for overall effect: Z = 17.20 (P < 0.00001)								
15.2.2 Acarbose 150 mg QD for 6 months								
Penna 2005	1.54	0.45	13	1.12	0.59	14	48.8%	0.42 [0.03, 0.81]
Subtotal (95% CI)			**13**			**14**	**48.8%**	**0.42 [0.03, 0.81]**
Heterogeneity: Not applicable								
Test for overall effect: Z = 2.09 (P = 0.04)								
Total (95% CI)			**43**			**29**	**100.0%**	**-0.23 [-1.49, 1.02]**
Heterogeneity: Tau² = 0.80; Chi² = 38.16, df = 1 (P < 0.00001); I² = 97%								
Test for overall effect: Z = 0.37 (P = 0.71)								
Test for subgroup differences: Chi² = 38.16, df = 1 (P < 0.00001), I² = 97.4%								





Risk of bias legend
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(G) Other bias

Figure 5: Forest plot of comparisons on HOMA-B

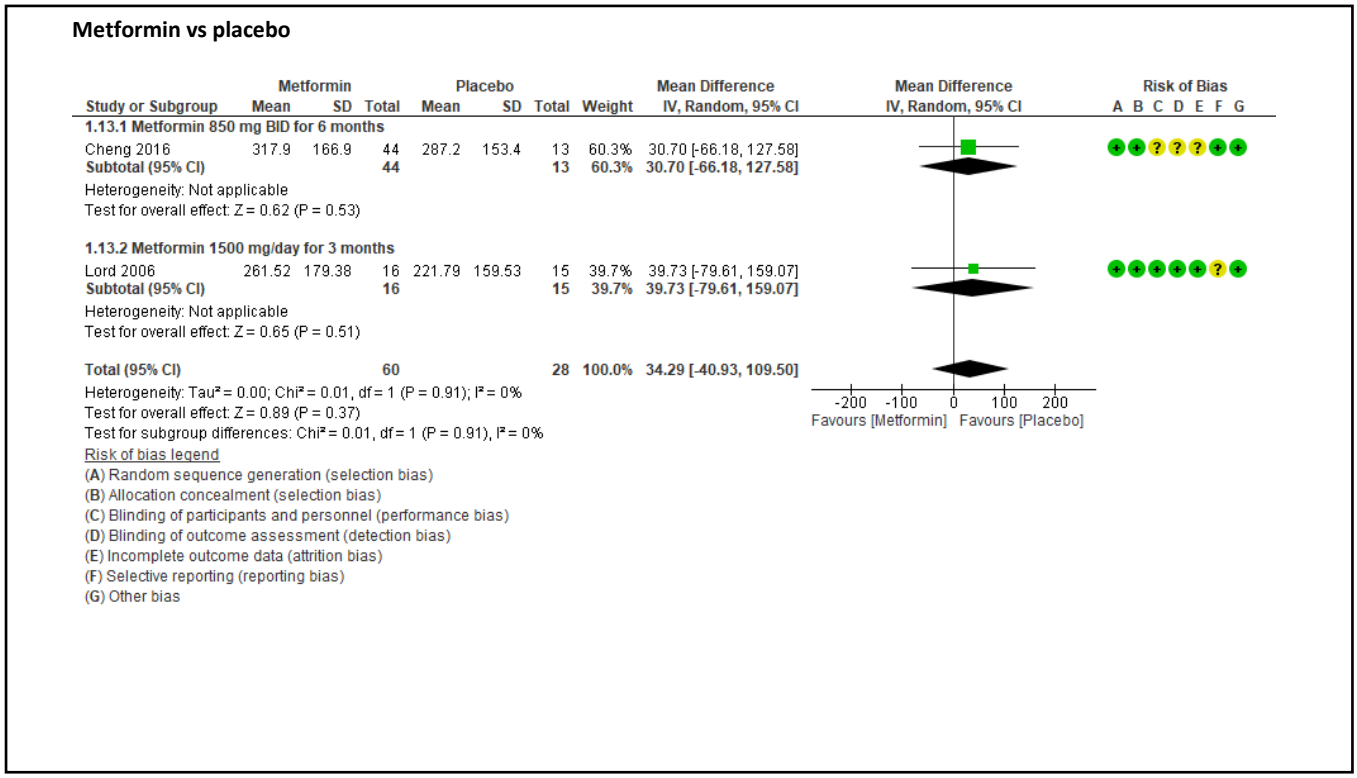

Table 3: summary pooled effect estimates of various medications on FBG, FI, HOMA-IR and HOMA-B in women with PCOS

Intervention	Comparison	No of women in the intervention arm	No of women in the control arm	No of RCTs	Pooled effect estimates	95% CI	I^2 (%)	I^2 (*p*-value)	Overall effect (*p*- value*)
Outcome: mean fasting blood glucose.									
Rosiglitazone 4 mg QD	Metformin 850 mg BID	61	65	4	-0.23	-0.75-0.30	17	0.31	0.40
Rosiglitazone 4 mg QD	Metformin 1500 mg QD	67	68	1	0.09	-0.36-0.54	-	-	0.69
Overall: Rosiglitazone versus Metformin		128	133	5	-0.09	-0.47-0.28	16	0.31	0.63
Metformin 850 mg BID for six months	Pioglitazone 45 mg QD	33	31	2	-0.57	-3.97-2.84	0.0	0.76	0.74
Metformin 1500 mg QD for three months	Pioglitazone 45 mg QD	76	75	3	0.10	-0.13-0.32	0.0	0.61	0.39
Overall: Metformin versus Pioglitazone		109	106	5	0.10	-0.13-0.32	0.0	0.87	0.40
Liraglutide 1.2 mg QD for 12 weeks	Liraglutide 1.2 mg QD with Metformin 1000 mg QD for 12 weeks	46	47	3	0.03	-0.19-0.25	0.0	0.52	0.79
Exenatide 10 µg BID	Metformin 1000 mg BID for 24 weeks	78	80	1	0.13	0.00-0.26	-	-	0.05
Exenatide 10 µg BID	Metformin 1000 mg BID for 12 weeks	31	32	1	-0.02	-0.13-0.09	-	-	0.71
Overall: Exenatide versus Metformin		109	112	2	0.05	-0.10-0.20	67	0.08	0.50
Acarbose 100 mg QD for Three months	Metformin	30	30	1	-10.30	-15.61-4.99	-	-	0.0001
Acarbose 300 mg QD for Three months	Metformin	15	15	1	-20.80	-58.84-17.24	-	-	0.28
Overall: Acarbose versus Metformin		45	45	2	-10.50	-15.67-5.24	0.0	0.59	<0.0001
Metformin 1500 mg QD for 3months	Simvastatin 20 mg for three months	100	100	1	-2.97	-6.20-0.26	-	-	0.07
Metformin 1000 mg QD	Simvastatin 20 mg for six months	34	34	1	-7.27	-13.05-1.49	-	-	0.01
Overall: Metformin versus Simvastatin		134	134	2	-4.43	-8.41-0.44	38	0.20	0.03
Metformin 1500 mg QD	NAC 1800 mg QD for 12 weeks	54	54	1	5.10	-0.96-11.16	-	-	0.10
Metformin 1500 mg QD	NAC 600 mg TDS for 24 weeks	48	46	1	3.41	0.54-6.28	-	-	0.02
Overall: Metformin versus NAC		102	100	2	3.72	1.13-6.31	0.0	0.62	0.005
Saxagliptin 5 mg QD	Metformin 2000 mg QD for 24 weeks	42	21	1	0.38	0.33-0.43	-	-	<0.0001
Saxagliptin 5 mg QD	Metformin 2000 mg QD for 16 weeks	22	12	1	-0.10	-0.55-0.35	-	-	0.66

Overall: Saxagliptin versus Metformin		64	33	2	0.19	-0.26-0.65	77	0.04	0.41
Outcome: mean fasting insulin									
Metformin 1500 mg BID	NAC 1800 mg QD for 12 weeks	54	54	1	-1.20	-10.71-8.32	-	-	0.80
Metformin 1500 mg QD	NAC 600 mg TDS for 24 weeks	48	46	1	1.51	0.53-2.49	-	-	0.003
Overall: Metformin versus NAC		102	100	2	1.48	0.51-2.46	0.0	0.58	0.003
Metformin 850 mg BID for six months	Pioglitazone	33	31	2	1.37	-1.11-3.86	0.0	0.33	0.28
Metformin 1500 mg QD for three months	Pioglitazone	114	140	4	0.28	-2.76-3.32	24	0.27	0.86
Overall: Metformin versus Pioglitazone		147	171	6	0.80	-1.07-2.67	5.0	0.38	0.40
Rosiglitazone 4 mg QD	Metformin 850 mg BID	91	93	4	-1.42	-3.11-0.27	0.0	0.54	0.10
Rosiglitazone 4 mg QD	Metformin 1000 mg QD	18	17	1	1.81	-4.65-8.27	-	-	0.58
Rosiglitazone 4 mg QD	Metformin 1500 mg QD	67	68	1	-0.20	-1.92-1.52	-	-	0.82
Rosiglitazone 4 mg QD	Metformin 2000 mg QD	14	47	1	-1.00	-6.44-4.44	-	-	0.72
Rosiglitazone versus Metformin		190	225	7	-0.74	-1.90-0.41	0.0	0.71	0.21
Liraglutide 1.2 mg QD for 12 weeks	Liraglutide 1.2 mg QD with Metformin 1000 mg QD for 12 weeks	46	47	3	-1.84	-6.04-2.35	0.0	0.38	0.39
Exenatide 10 ug BID	Metformin 1000 mg BID for 12 weeks	31	32	1	0.47	-1.89-2.83	-	-	0.70
Exenatide 10 ug BID	Metformin 1000 mg BID for 24 weeks	78	80	1	-0.25	-0.59-0.09	-	-	0.15
Exenatide versus Metformin		109	112	2	-0.24	-0.57-0.10	0.0	0.55	0.17
Acarbose 300 mg QD for three months	Metformin	44	42	2	0.86	-1.92-3.63	0.0	0.82	0.55
Outcome: mean HOMA-IR									
Exenatide 10 ug BID	Metformin 1000 mg BID for 12 weeks	31	32	1	-0.23	-0.83-0.37	-	-	0.45
Exenatide 10 ug BID	Metformin 1000 mg BID for 24 weeks	92	94	2	-0.38	-0.74-0.02	0.0	0.96	0.04

Overall: Exenatide versus Metformin		123	126	3	-0.34	-0.65-0.03	0.0	0.91	0.03
Metformin 850 mg BID for six months	Pioglitazone	18	17	1	0.01	-0.19-0.21	-	-	0.92
Metformin 1500 mg QD for three months	Pioglitazone	63	67	3	1.06	0.11-2.00	0.0	0.62	0.03
Overall: Metformin versus Pioglitazone		81	84	4	0.47	-0.33-1.28	45	0.14	0.25
Rosiglitazone 4 mg QD	Metformin 850 mg BID	61	65	4	-0.23	-0.75-0.30	17	0.31	0.40
Rosiglitazone 4 mg QD	Metformin 1500 mg QD	67	68	1	0.09	-0.36-0.54	-	-	0.96
Overall: Rosiglitazone versus Metformin		128	133	5	-0.09	-0.47-0.28	16	0.31	0.63
Liraglutide 1.2 mg QD	Liraglutide 1.2 mg with Metformin 1000 mg QD for 12 weeks	46	47	3	-0.37	-1.53-0.78	20	0.20	0.53
Orlistat 120 mg TDS	Metformin 1500 mg QD for three months	25	26	2	-0.19	-1.18-0.80	43	0.19	0.71
Sitagliptin 100 mg QD plus Metformin 850 mg BID	Metformin 850 mg BID	5	5	1	0.00	-3.61-3.61	-	-	1.00
Sitagliptin 100 mg QD plus Metformin 1000 mg BID	Metformin 1000 mg BID	12	12	1	-0.80	-2.13-0.53	-	-	0.24
Overall: Sitagliptin plus Metformin versus Metformin		17	17	2	-0.71	-1.95-0.54	0.0	0.68	0.27
Saxagliptin 5 mg QD	Metformin 2000 mg QD for 24 weeks	21	21	1	0.53	-0.08-1.14	-	-	0.09
Saxagliptin 5 mg QD	Metformin 2000 mg QD for 12 weeks	11	11	1	-1.50	-4.28-1.28	-	-	0.29
Overall: Saxagliptin versus Metformin		32	32	2	-0.01	-1.78-1.75	49	0.16	0.99

***RCT**: randomised control trials, **I^2:** heterogeneity, *The overall effect was significant at < 0.05, **CI:** confidence interval, **QD**: once a day, **BID:** Twice a day, **HOMA-IR:** the homeostatic model of insulin resistance.*