Journal of
Clinical Medicine

Article

The Effect of Bariatric Surgery on Circulating Levels of Monocyte Chemoattractant Protein-1: A Systematic Review and Meta-Analysis

Tannaz Jamialahmadi [1,2], Mitra Abbasifard [3,4,*], Željko Reiner [5], Prashant Kesharwani [6,7] and Amirhossein Sahebkar [1,8,9,*]

1 Applied Biomedical Research Center, Mashhad University of Medical Sciences, Mashhad, Iran
2 Surgical Oncology Research Center, Mashhad University of Medical Sciences, Mashhad, Iran
3 Immunology of Infectious Diseases Research Center, Research Institute of Basic Medical Sciences, Rafsanjan University of Medical Sciences, Rafsanjan, Iran
4 Department of Internal Medicine, Ali-Ibn Abi-Talib Hospital, School of Medicine, Rafsanjan University of Medical Sciences, Rafsanjan, Iran
5 Department of Internal Medicine, University Hospital Center Zagreb, 10000 Zagreb, Croatia
6 Department of Pharmaceutics, School of Pharmaceutical Education and Research, Jamia Hamdard, New Delhi 110062, India
7 Center for Transdisciplinary Research, Department of Pharmacology, Saveetha Dental College, Saveetha Institute of Medical and Technical Science, Chennai 602105, India
8 Biotechnology Research Center, Pharmaceutical Technology Institute, Mashhad University of Medical Sciences, Mashhad, Iran
9 Department of Biotechnology, School of Pharmacy, Mashhad University of Medical Sciences, Mashhad, Iran
* Correspondence: dr.mabbasifard@gmail.com (M.A.); amir_saheb2000@yahoo.com (A.S.)

Citation: Jamialahmadi, T.; Abbasifard, M.; Reiner, Ž.; Kesharwani, P.; Sahebkar, A. The Effect of Bariatric Surgery on Circulating Levels of Monocyte Chemoattractant Protein-1: A Systematic Review and Meta-Analysis. *J. Clin. Med.* **2022**, *11*, 7021. https://doi.org/10.3390/jcm11237021

Academic Editor: Alessandro Di Minno

Received: 6 October 2022
Accepted: 24 November 2022
Published: 28 November 2022

Abstract: Background: MCP-1 (monocyte chemoattractant protein) plays an important role in early phases of atherogenesis as well as in plaque destabilization, which causes cardiovascular events to play an important role in low-grade inflammation. Obesity, particularly extreme obesity, is a pivotal risk factor for atherosclerosis and many other diseases. In the early stages, bariatric surgery might stop or slow atherogenesis by suppressing inflammation, but also in later stages, preventing plaque destabilization. The aim of this meta-analysis was to provide an answer as to whether bariatric surgery has a significant effect on circulating MCP-1 level or not. **Methods**: A systematic literature search in PubMed, Scopus, Embase, and Web of Science was performed from inception to 1 January 2022. Meta-analysis was performed using Comprehensive Meta-Analysis (CMA) V2 software. In order to heterogeneity compensation of studies in terms of study design and treatment duration, the characteristics of the studied populations random-effects model and the generic inverse variance weighting method were used. To investigate the relationship with the estimated effect size, a random-effect meta-regression model was used. To assess the exitance of publication bias in the meta-analysis, the funnel plot, Begg's rank correlation, and Egger's weighted regression tests were used. **Results**: Meta-analysis of 25 studies with 927 subjects included demonstrated a significant decrease of MCP-1 concentration after bariatric surgery. The data of meta-regression did not indicate any association between the alterations in body mass index (BMI) and absolute difference in MCP-1 levels, but a linear relationship between the changes in MCP-1 and length of follow-up was proven. **Conclusions**: Bariatric surgery significantly decreases MCP-1 concentration, but there was no association between the changes in BMI and absolute difference in MCP-1 levels before and after the surgery.

Keywords: obesity; bariatric surgery; monocyte chemoattractant protein-1; atherosclerosis; meta-analysis; cardiovascular disease

1. Introduction

Obesity causes low-grade chronic inflammation, which is marked by abnormal cytokine production, increased synthesis of acute-phase reactants, and activation of pro-inflammatory signaling pathways [1]. In the adipose tissue of obese patients, the accumulation of macrophages causes macrophage-elicited inflammation and adipocyte-macrophage interaction, which are important processes in obesity. They occur due to hypertrophic adipocyte-derived MCP-1)/C-C chemokine receptor 2 (CCR2) pathway and participate in a vicious cycle that aggravates inflammation in the adipose tissue [2]. This is important, since it has to be stressed again that low grade inflammation is one of the main characteristics of atherogenesis.

It has been shown that MCP-1 (monocyte chemoattractant protein)—as a member of the CC chemokine subfamily—recruits immune cells to the peripheral tissues during inflammation. It plays a pivotal role in atherogenesis as well, particularly in the early phases of atherogenesis, since atherogenesis is also an inflammatory condition. Monocytes are recruited to the arterial wall by MCP-1 and experimental studies, suggested that inhibiting MCP-1 signaling could slow down atherosclerosis progression and atherosclerotic plaque destabilization, which causes cardiovascular events [3,4].

Bariatric surgery is a surgical treatment primarily for obese patients, which improves metabolic and inflammatory processes as well as cardiometabolic risk factors beyond weight loss [5–15]. The types of bariatric surgery are sleeve gastrectomy (SG), laparoscopic adjustable gastric band (LAGB), Roux-en-Y gastric bypass (RYGP), biliopancreatic diversion/duodenal switch (BPD/DS), and one anastomosis gastric bypass/mini gastric bypass (OAGB/MGB) [16]. In the early stages, bariatric surgery might prevent or slow atherogenesis by breaking the vicious circle between endothelial dysfunction and inflammation, but also in later stages, preventing plaque destabilization [17].

Despite many studies, there is still no clear answer whether bariatric surgery has a significant effect on circulating MCP-1 level or not. Therefore, the aim of this systematic review and meta-analysis was to provide the answer to this question.

2. Methods

2.1. Search Strategy

The 2009 preferred reporting items for systematic reviews and meta-analysis (PRISMA) guidelines were used to make this systematic review and meta-analysis [18]. From inception to 1 January 2022, Scopus, PubMed, Embase, Google scholar, and Web of Science were searched using the following keywords in titles and abstracts (including when used MESH terms): ("bariatric surgery" OR gastrectom* OR gastroplast* OR "Roux-en-Y" OR "gastric bypass" OR "biliopancreatic diversion" OR "duodenal switch" OR "gastrointestinal diversion" OR "weight loss surgery" OR gastroenterostom* OR "jejunoileal bypass" OR "obesity surgery" OR "weight-loss surgery" OR "sleeve surgery" OR "bariatric procedure" OR "metabolic surgery" OR "gastric band") AND ("monocyte chemoattractant protein-1" OR "MCP-1" OR MCP1 OR "MCP 1").

2.2. Study Selection

The eligibility criterion of the included studies was only peer-reviewed original publications written in English which reported MCP-1 concentration before and following bariatric surgery. All animal studies, abstract-only publications, non-English papers, duplicate research, reviews, case reports, meta-analyses, comments, letters, and studies without outcomes, and those with no surgical intervention were excluded.

2.3. Data Extraction

The titles and abstracts of the included publications were checked by two blinded authors independently (TJ and AS). The full texts of the chosen papers were gathered for a second review. In the case of the same organization and/or authors in same study, the larger study concerning the sample size was included. Any disagreement was reconciled with consensus and discussion. The extraction of following data was done: the identity of the first author and the design of the study, the year of publication, the type of surgery and length of follow-up, patients characteristics, and clinical outcomes.

Primary outcome: the effect of bariatric surgery on MCP-1 concentration.

Secondary outcome: the effect of body mass index (BMI) changes and length of follow-up on MCP-1 levels.

2.4. Quality Assessment

The Newcastle–Ottawa Scale was used to assess the quality of eligible studies. The scale is divided into three broad stratifications: selection (consists of four items), confounder (including one item), and exposure (contains two items), each with a maximum score of four, one, and two points [19,20].

2.5. Quantitative Data Synthesis

A meta-analysis was performed using comprehensive meta-analysis (CMA) V2 software [21]. For continuous outcomes, the weighted mean difference (WMD) with associated confidence intervals was presented. To calculate WMD means, standard deviations (SD) and sample sizes were needed. The mean and standard deviation values were calculated by the method described previously if the outcome measures were reported in median and interquartile range (or 95% confidence intervals [CI]). SD was determined using this formula: SD = SEM $\times$ sqrt (number of participants). Additionally, pooled standard deviation was used to deal with missing SD. The overall estimate of effect size was calculated using a random effects meta-analysis. A random-effects model (using DerSimonian-Laird method) and the general inverse variance weighting technique were employed to account for heterogeneity of publications in terms of study design, features of the populations and treatment duration [18]. To examine the effect of each study on the overall effect size, we conducted a sensitivity analysis using the leave-one-out strategy (i.e., exclusion of one study at a time to evaluate its impact on the overall result) [22].

2.6. Meta-Regression

BMI change before and after the surgery, as well as follow-up duration, were the independent variables in a random-effect meta-regression model to explore the effect of these variables on effect size.

2.7. Subgroup Analysis

We classified the publications based on follow-up duration to illustrate the source of heterogeneity into <12 months and $\geq$12 months. Another sub-analysis was also performed, taking into consideration the two most prevalent types of surgery (LSG and RYGB).

2.8. Publication Bias

The "trim and fill" test was used to adjust the results when the funnel plot initially showed asymmetry. Then, Egger's and Begg's tests were applied to statistically evaluate publication bias. When a significant result occurred, the number of potentially missing studies required to make the *p*-value non-significant was calculated using the "fail-safe N" approach [23].

3. Results

The database search yielded 397 publications, 179 of which remained after exclusion of duplications. Overall, 154 studies were not included (29 publications were reviews, 61 publications were excluded for not fulfilling the inclusion criteria, 23 studies did not report enough data, and 41 were animal studies). As a result, 25 studies measuring circulating MCP-1 following bariatric surgery were analyzed (Table 1). The study selection procedure is presented in Figure 1.

Table 1. Characteristics of studies measuring MCP-1.

Study, Year, Country	Study Design	Follow-Up	Type of Surgery	Clinical Outcome: MCP-1 Level Change	Clinical Outcome: % BMI Change	Patients	No. of Patients
Salman 2021 [24]	Prospective study	12 months	LSG	Unchanged	−10.22 kg/m^2	Obese non-diabetic patients	61
Rizk 2021 [25]	Prospective longitudinal research	3 months	LSG	Significant reduction	−15.96 kg/m^2	Class III obesity subjects	24
Morales 2021 [26]	Prospective observational study	12 months	LSG, also known as RYGB	Significant reduction	−14.20 kg/m^2	Obese patients with CKD	30
Yan 2021 a [27] Yan 2021 b [27]	Prospective randomized study	1 month 3 months 6 months 12 months	RYGB LSG	Significant reduction Significant reduction after 6, also known as 12 months	−8.30 kg/m^2 (after 12 months) −8.80 kg/m^2 (after 12 months)	Overweight and obese patients with BMI > 28 kg/m^2 and type-2 diabetes	77 80
Bratti 2021 [28]	Prospective study	6 months	LSG, also known as RYGB	Unchanged	−15.47 kg/m^2	Severe obesity	40
Salman 2020 [29]	Prospective study	12 months	OAGB	Significant increase in MCP-1 level	−10.07 kg/m^2	Obese patients	62
Lambert 2018 [30]	Prospective study	1–2 months 12 months	BPD, also known as RYGB	Unchanged Significant reduction	−11.8 kg/m^2	Obese patients	109
Alsharidah 2018 [31]	Prospective study	3 months	Mixed	Significant reduction	−6.5 kg/m^2	Patients with NAFLD and obesity	51
Yadav 2017 [32]	Prospective study	6 months 12 months	RYGB	Significant reduction	−17 kg/m^2 (after 12 months)	Obese patients	37
van der Wielen 2017 [33]	Prospective study	12 months	Gastroplication	Unchanged	−6.4 kg/m^2	Morbidly obese patients	10
Sams 2016 a [34] Sams 2016 b [34]	Case-control study	2 weeks 6 months 2 weeks 6 months	RYGB LAGB	Unchanged	−12.7 kg/m^2 −4 kg/m^2	Obese patients	8 2
Kelly 2016 a Kelly 2016 b [35]	Longitudinal cohorts Longitudinal cohorts	6 months 12 months 6 months 12 months	LSG, also known as RYGB RYGB	Unchanged	−16.63 kg/m^2 −20.9 kg/m^2	Obese adolescents	39 13
Immonen 2014 a Immonen 2014 b [36]	Prospective study	6 months 6 months	LSG, also known as RYGB	Unchanged	−10 kg/m^2 −9.8 kg/m^2	Diabetic obese patients Non-diabetic obese patients	9 14
Gumbau 2014 [37]	Prospective study	1 day 5 days 1 month 6 months 12 months	LSG	Significant reduction after 12 months	−15.34 kg/m^2 (after 12 months)	Morbidly obese	20
Bachmayer 2013 [5]	Prospective observational study	10 ± 6 months	Mixed	Unchanged	−13.4 kg/m^2	Obese patients	21
Brinklov Thomsen 2013 a Brinklov Thomsen 2013 b [38]	Prospective cohort study	1 week 3 months 12 months 1 week 3 months 12 months	RYGB	Significant reduction	−30.52 kg/m^2 −29.86 kg/m^2	Obese patients without diabetes Obese patients with diabetes	10 10
Lima 2013 [39]	Prospective study	1 month 6 months 12 months	RYGB	Significant reduction	−16.4 kg/m^2	Premenopausal women with metabolic syndrome and grade III obesity	10
Monte 2012 [40]	Prospective study	6 months	RYGB	Significant reduction	−11.7 kg/m^2	Obese diabetic patients	15
Dalmas 2011 [41]	Case-control study	3 months 6 months 12 months	RYGB	Significant reduction after 3 and 12 months	−13.4 kg/m^2	Obese women	51
Schaller 2009 [42]	Prospective observational study	18 ± 3 months	RYGB, also known as LGB	Significant reduction	−13.1 kg/m^2	Morbidly obese patients	31
Hempen 2009 [43]	Case-control study	17.4 months	RYGB	Significant reduction	−13.2 kg/m^2	Obese patients	17
Swarbrick 2008 [44]	Prospective study	12 months	RYGB	Unchanged	−14.8 kg/m^2	Obese women	19
Catalán 2007 [1]	Case-control study	13 months	RYGB	Unchanged	−15.8 kg/m^2	Obese women	14
Fontana 2007 [45]	Case-control study	12 months	RYGB	Unchanged	−18.7 kg/m^2	Women with class III obesity	6
Schernthaner 2006 [46]	Prospective study	26.6 ± 11.5 months	VBG	Significant reduction	−12 kg/m^2	Obese patients	37

LGB: laparoscopic gastric banding, LSG; laparoscopic sleeve gastrectomy, RYGB: Roux-en-Y gastric bypass, VBG: vertical banded gastroplasty surgery.

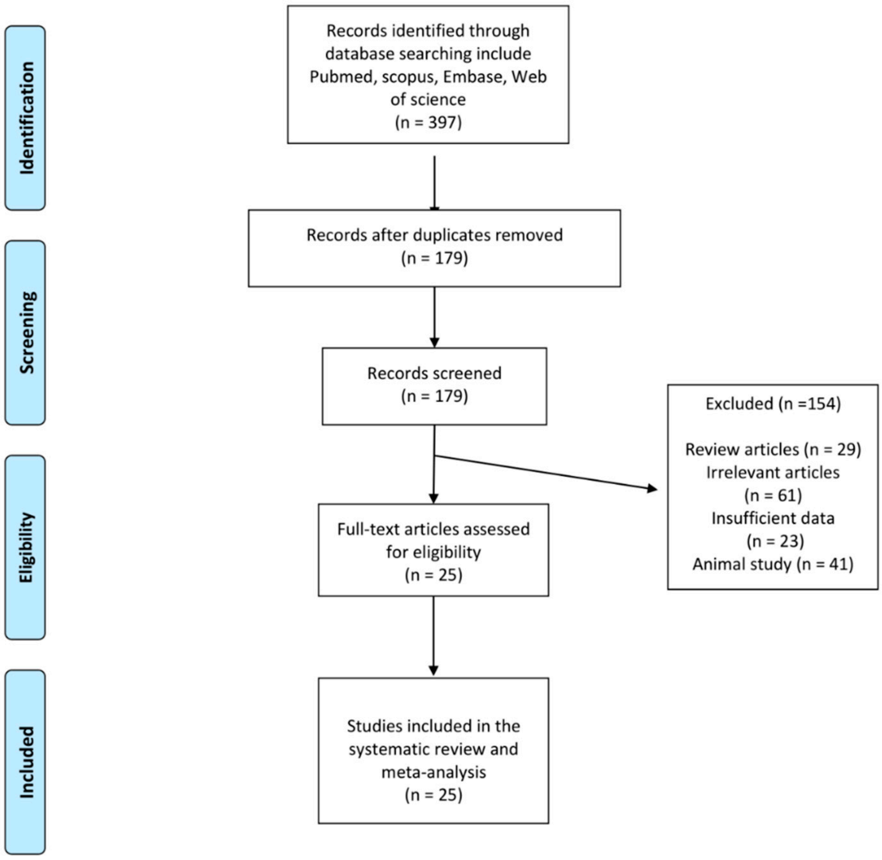


Figure 1. Flow chart of identified publications and those included into meta-analysis.

3.1. Quality Assessment of the Included Studies

Among 24 nonrandomized studies, all of the selected publications represented the exposed cohort, and ascertainment of exposure. All of them demonstrated that the outcome of interest was not present at the start of the study. Eventually, most of considered publications met the ascertainment of outcome criteria. Cochrane Collaboration's tool assessed the risk of bias in one randomized study. The quality of the included publications is assessed in Table 2.

Table 2. Quality assessment of the included studies in accordance with the Newcastle–Ottawa scale (for observational studies) and Cochrane Collaboration's tool (for randomized controlled trial).

Study	Selection				Comparability	Outcome		
	Representativeness of the Exposed Cohort	Selection of the Non-Exposed Cohort	Ascertainment of Exposure	Demonstration That Outcome of Interest Was Not Present at Start of Study	Comparability of Cohorts on the Basis of the Design or Analysis	Assessment of Outcome	Was Follow-Up Long Enough for Outcomes to Occur	Adequacy of Follow-Up of Cohorts
Salman 2021 [24]	*	-	*	*	-	*	*	*
Rizk 2021 [25]	*	*	*	*	-	*	-	-
Morales 2021 [26]	*	-	*	*	-	*	*	*
Yan 2021 [27]	*	-	*	*	-	*	*	*
Bratti 2021 [28]	*	*	*	*	*	*	*	*
Salman 2020 [29]	*	-	*	*	-	*	*	*
Lambert 2018 [30]	*	*	*	*	*	*	*	*
Alsharidah 2018 [31]	*	-	*	*	-	*	-	-
Yadav 2017 [32]	*	-	*	*	-	*	*	*
van der Wielen 2017 [33]	*	-	*	*	-	*	*	*
Sams 2016 [34]	*	-	*	*	-	*	*	*
Kelly 2016 [35]	*	-	*	*	-	*	*	*
Immonen 2014 [36]	*	*	*	*	*	*	*	*
Gumbau 2014 [37]	*	-	*	*	-	*	*	*
Bachmayer 2013 [5]	*	-	*	*	-	*	*	*
Thomsen 2013 [38]	*	-	*	*	-	*	*	*
Monte 2012 [40]	*	-	*	*	-	*	*	*
Dalmas 2011 [41]	*	*	*	*	*	*	*	*
Schaller 2009 [42]	*	-	*	*	-	*	*	*
Hempen 2009 [43]	*	-	*	*	-	*	*	*
Swarbrick 2008 [44]	*	-	*	*	-	*	*	*
Catalán 2007 [1]	*	-	*	*	-	*	*	*
Fontana 2007 [45]	*	*	*	*	*	*	*	*
Schernthaner 2006 [46]	*	*	*	*	*	*	*	*

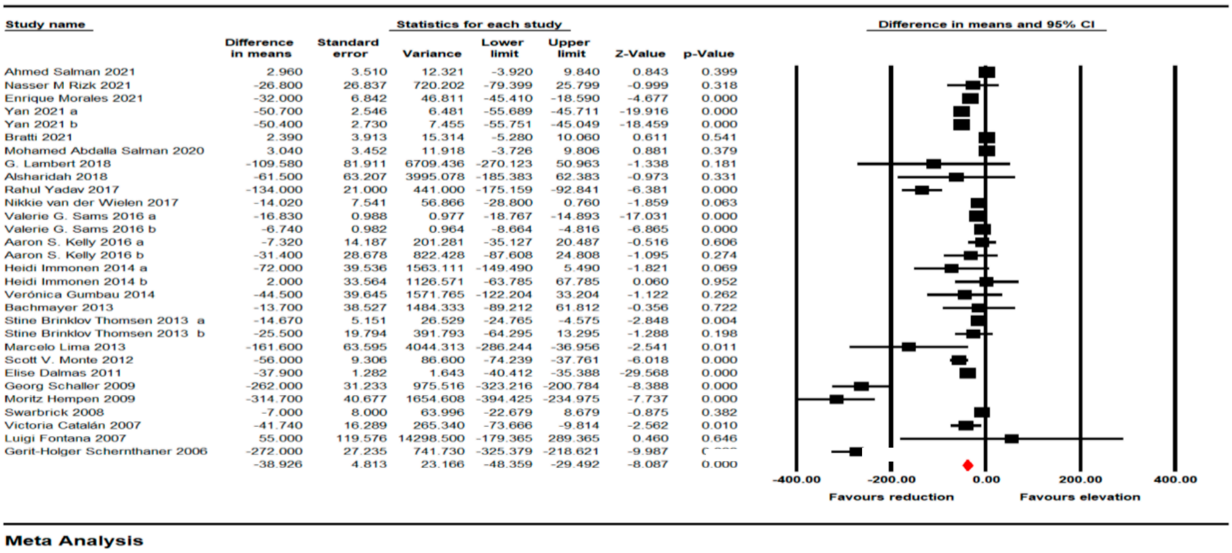
	Selection bias		Performance bias	detection bias	attrition bias	Reporting bias	other bias
	Random sequence generation	Allocation concealment					
Lima 2013 [39]	Unclear	high	low	Unclear	low	low	low

3.2. Primary Outcome

Effect of Bariatric Surgery on MCP-1 Concentration

A total of 25 trials, including 927 individuals, confirmed a significant reduction in MCP following bariatric surgery (WMD: −38.926, 95% CI: −48.359, −29.492, $p < 0.001$) (Figure 2A). The reduction of MCP-1 concentration was robust in the leave-one-out sensitivity analysis (Figure 2B).

A.



B.

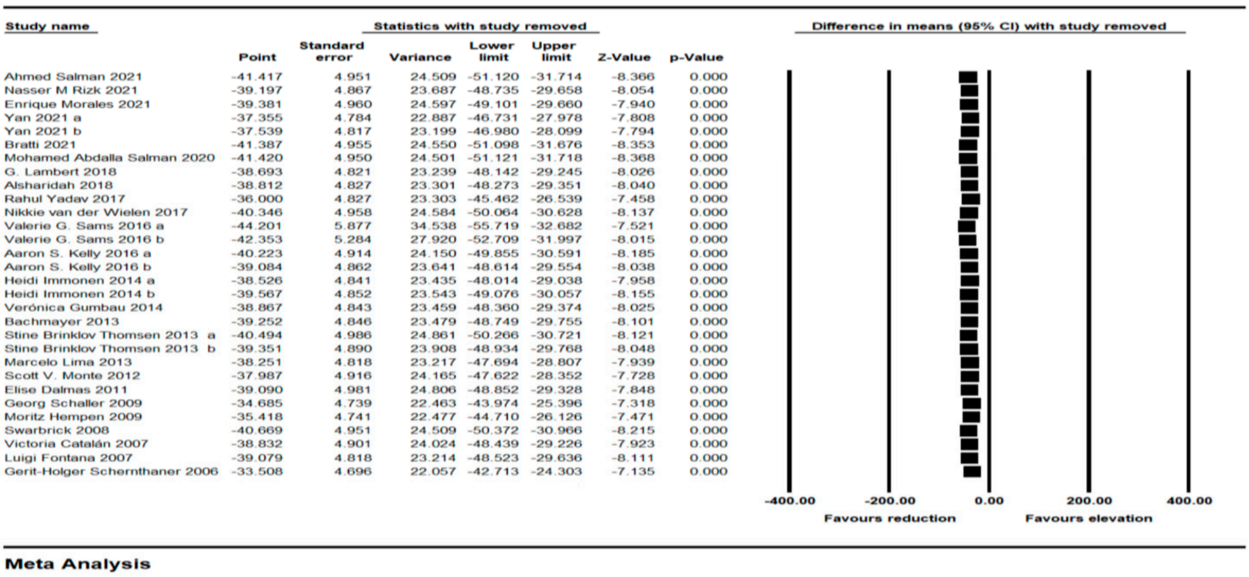


Figure 2. (**A**) Forest plots representing standardized mean difference and 95% confidence intervals (CIs) for the effect of bariatric surgery on MCP-1; (**B**) Leave-one-out sensitivity analysis for the effect of bariatric surgery on MCP-1.

3.3. Secondary Outcomes

Meta-Regression

The results of meta-regression, which were used to assess the effect of various variables on the reduction of post-surgery circulating MCP-1, did not show any association between the changes in body mass index (BMI) and absolute difference in MCP-1 levels (slope: 2.378;

95% CI: 0.470, 5.226; $p = 0.101$). The results showed a linear relationship between the changes in MCP-1 and length of follow-up (slope: −8.814; 95% CI: −11.068, −6.559; $p < 0.001$) (Figure 3A,B).

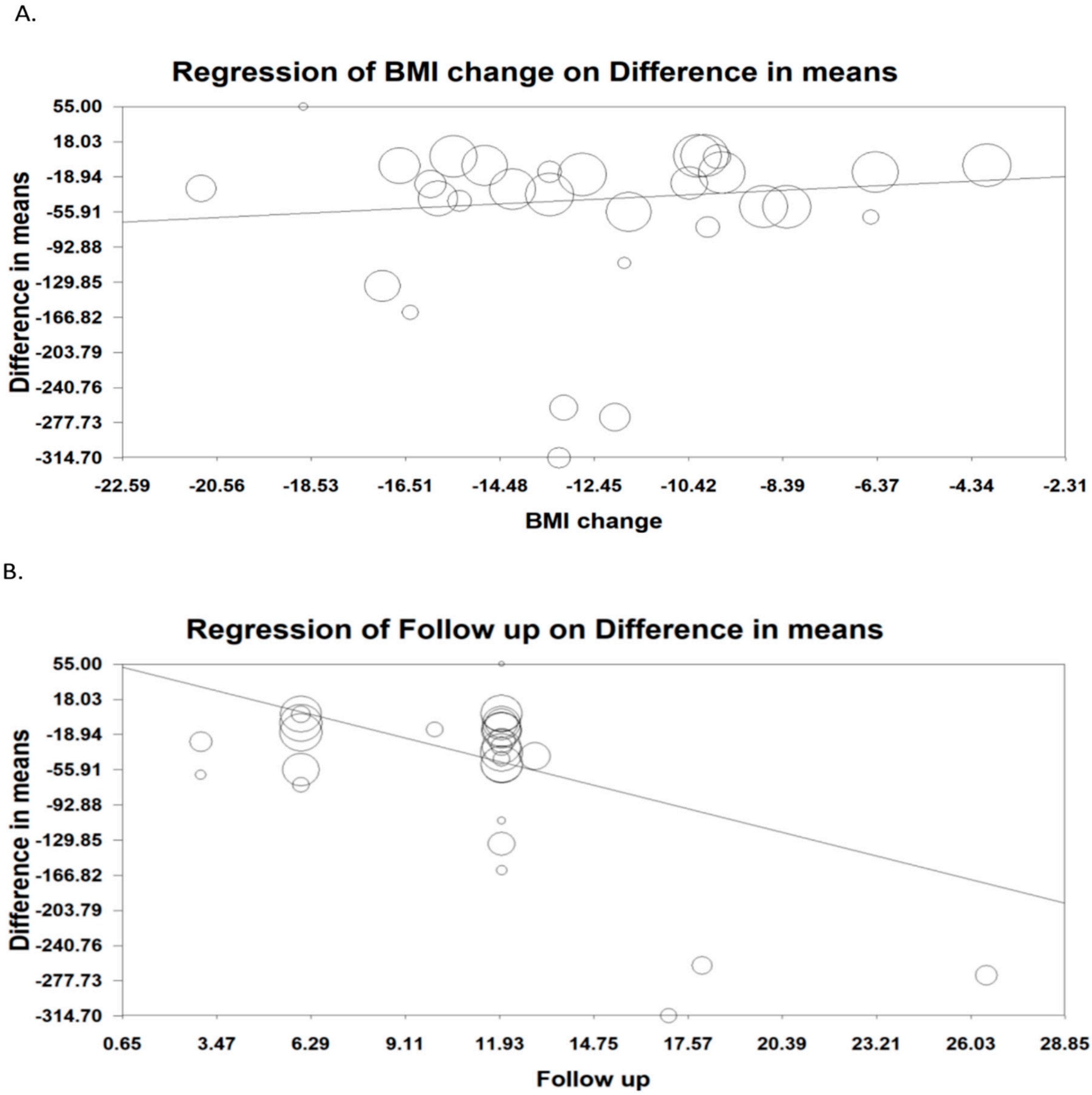


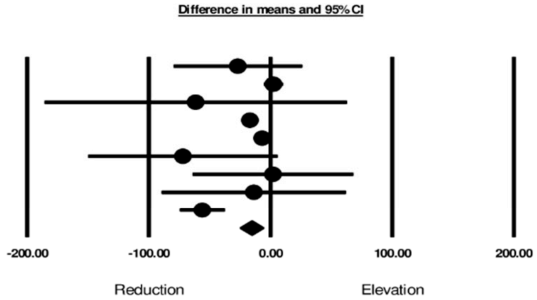
Figure 3. Random effect meta-regression for evaluating the effect of: (**A**) BMI change; (**B**) Follow-up duration.

3.4. Subgroup Analyses

In the sub-analyses, a significant difference in changes of circulating MCP-1 based on the length of follow-up (≥12 months and <12 months) (WMD: −15.387, 95% CI: −24.299, 9.620, $p < 0.001$; I^2: 96.87 for <12 months and WMD: −26.350, 95% CI: −33.822, −18.878, $p < 0.001$; I^2: 89.43 for ≥12 months) was shown (Figure 4). Furthermore, according to the type of bariatric surgery, there was a significant reduction in circulating MCP-1 concerning the type of bariatric surgery (WMD: −27.500, 95% CI: −68.457, 13.457, $p < 0.001$; I^2: 97.91 for LSG and WMD: −44.172, 95% CI: −57.124, −31.220, $p < 0.001$; I^2: 96.74 for RYGB) (Figure 5).

A.

Study name	Difference in means	Standard error	Variance	Lower limit	Upper limit	Z-Value	p-Value
Nasser M Rizk 2021	-26.800	26.837	720.202	-79.399	25.799	-0.999	0.318
Bratti 2021	2.390	3.913	15.314	-5.280	10.060	0.611	0.541
Alsharidah 2018	-61.500	63.207	3995.078	-185.383	62.383	-0.973	0.331
Valerie G. Sams 2016 a	-16.830	0.988	0.977	-18.767	-14.893	-17.031	0.000
Valerie G. Sams 2016 b	-6.740	0.982	0.964	-8.664	-4.816	-6.865	0.000
Heidi Immonen 2014 a	-72.000	39.536	1563.111	-149.490	5.490	-1.821	0.069
Heidi Immonen 2014 b	2.000	33.564	1126.571	-63.785	67.785	0.060	0.952
Bachmayer 2013	-13.700	38.527	1484.333	-89.212	61.812	-0.356	0.722
Scott V. Monte 2012	-56.000	9.306	86.600	-74.239	-37.761	-6.018	0.000
	-15.387	4.547	20.675	-24.299	-6.475	-3.384	0.001



B.

Study name	Difference in means	Standard error	Variance	Lower limit	Upper limit	Z-Value	p-Value
Ahmed Salman 2021	2.960	3.510	12.321	-3.920	9.840	0.843	0.399
Enrique Morales 2021	-32.000	6.842	46.811	-45.410	-18.590	-4.677	0.000
Yan 2021 a	-50.700	2.546	6.481	-55.689	-45.711	-19.916	0.000
Yan 2021 b	-50.400	2.730	7.455	-55.751	-45.049	-18.459	0.000
Mohamed Abdalla Salman 2020	3.040	3.452	11.918	-3.726	9.806	0.881	0.379
G. Lambert 2018	-109.580	81.911	6709.436	-270.123	50.963	-1.338	0.181
Rahul Yadav 2017	-134.000	21.000	441.000	-175.159	-92.841	-6.381	0.000
Nikkie van der Wielen 2017	-14.020	7.541	56.866	-28.800	0.760	-1.859	0.063
Aaron S. Kelly 2016 a	-7.320	14.187	201.281	-35.127	20.487	-0.516	0.606
Aaron S. Kelly 2016 b	-31.400	28.678	822.428	-87.608	24.808	-1.095	0.274
Ver?nica Gumbau 2014	-44.500	39.645	1571.765	-122.204	33.204	-1.122	0.262
Stine Brinklov Thomsen 2013 a	-14.670	5.151	26.529	-24.765	-4.575	-2.848	0.004
Stine Brinklov Thomsen 2013 b	-25.500	19.794	391.793	-64.295	13.295	-1.288	0.198
Marcelo Lima 2013	-161.600	63.595	4044.313	-286.244	-36.956	-2.541	0.011
Elise Dalmas 2011	-37.900	1.282	1.643	-40.412	-35.388	-29.568	0.000
Georg Schaller 2009	-262.000	31.233	975.516	-323.216	-200.784	-8.388	0.000
Moritz Hempen 2009	-314.700	40.677	1654.608	-394.425	-234.975	-7.737	0.000
Swarbrick 2008	-7.000	8.000	63.996	-22.679	8.679	-0.875	0.382
Victoria Catal?n 2007	-41.740	16.289	265.340	-73.666	-9.814	-2.562	0.010
Luigi Fontana 2007	55.000	119.576	14298.500	-179.365	289.365	0.460	0.646
Gerit-Holger Schernthaner 2006	-272.000	27.235	741.730	-325.379	-218.621	-9.987	0.000
	-52.292	6.994	48.922	-66.001	-38.584	-7.476	0.000

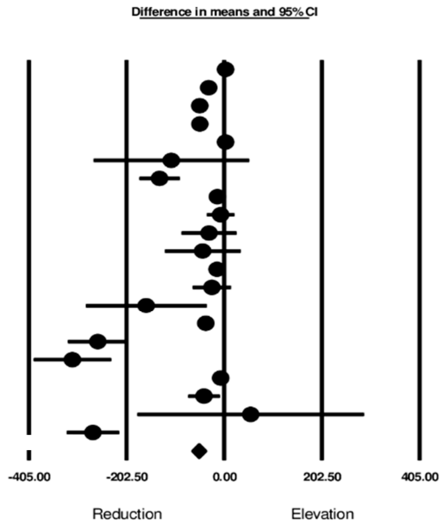
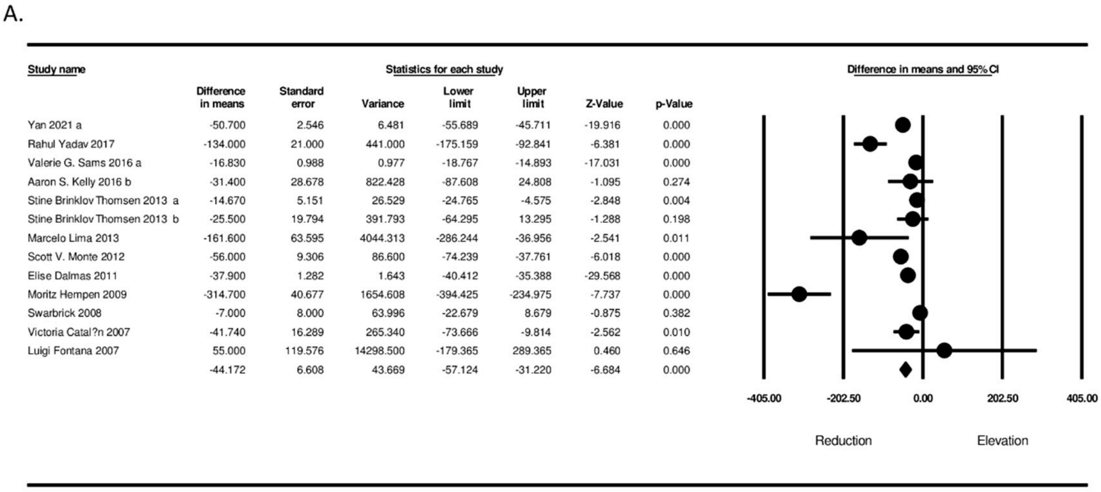
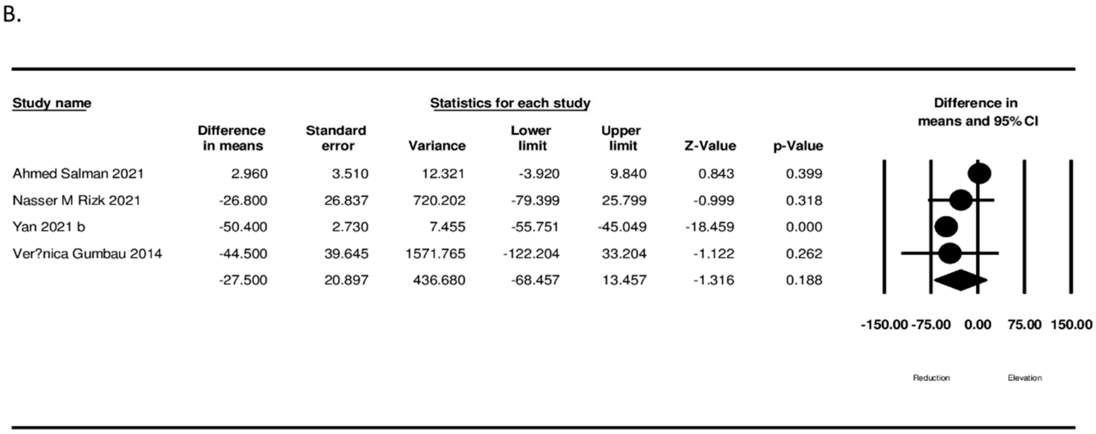


Figure 4. Subgroup analysis based on follow-up duration ((**A**), less than 12 months), ((**B**), equal or more than 12 months).



Study name	Difference in means	Standard error	Variance	Lower limit	Upper limit	Z-Value	p-Value
Yan 2021 a	-50.700	2.546	6.481	-55.689	-45.711	-19.916	0.000
Rahul Yadav 2017	-134.000	21.000	441.000	-175.159	-92.841	-6.381	0.000
Valerie G. Sams 2016 a	-16.830	0.988	0.977	-18.767	-14.893	-17.031	0.000
Aaron S. Kelly 2016 b	-31.400	28.678	822.428	-87.608	24.808	-1.095	0.274
Stine Brinklov Thomsen 2013 a	-14.670	5.151	26.529	-24.765	-4.575	-2.848	0.004
Stine Brinklov Thomsen 2013 b	-25.500	19.794	391.793	-64.295	13.295	-1.288	0.198
Marcelo Lima 2013	-161.600	63.595	4044.313	-286.244	-36.956	-2.541	0.011
Scott V. Monte 2012	-56.000	9.306	86.600	-74.239	-37.761	-6.018	0.000
Elise Dalmas 2011	-37.900	1.282	1.643	-40.412	-35.388	-29.568	0.000
Moritz Hempen 2009	-314.700	40.677	1654.608	-394.425	-234.975	-7.737	0.000
Swarbrick 2008	-7.000	8.000	63.996	-22.679	8.679	-0.875	0.382
Victoria Catal?n 2007	-41.740	16.289	265.340	-73.666	-9.814	-2.562	0.010
Luigi Fontana 2007	55.000	119.576	14298.500	-179.365	289.365	0.460	0.646
	-44.172	6.608	43.669	-57.124	-31.220	-6.684	0.000



Study name	Difference in means	Standard error	Variance	Lower limit	Upper limit	Z-Value	p-Value
Ahmed Salman 2021	2.960	3.510	12.321	-3.920	9.840	0.843	0.399
Nasser M Rizk 2021	-26.800	26.837	720.202	-79.399	25.799	-0.999	0.318
Yan 2021 b	-50.400	2.730	7.455	-55.751	-45.049	-18.459	0.000
Ver?nica Gumbau 2014	-44.500	39.645	1571.765	-122.204	33.204	-1.122	0.262
	-27.500	20.897	436.680	-68.457	13.457	-1.316	0.188

Figure 5. Subgroup analysis based on type of surgery ((**A**) RYGB) ((**B**) LSG).

3.5. Publication Bias

As shown in Figure 6, funnel plot asymmetry test assessed the publication bias of the studies.

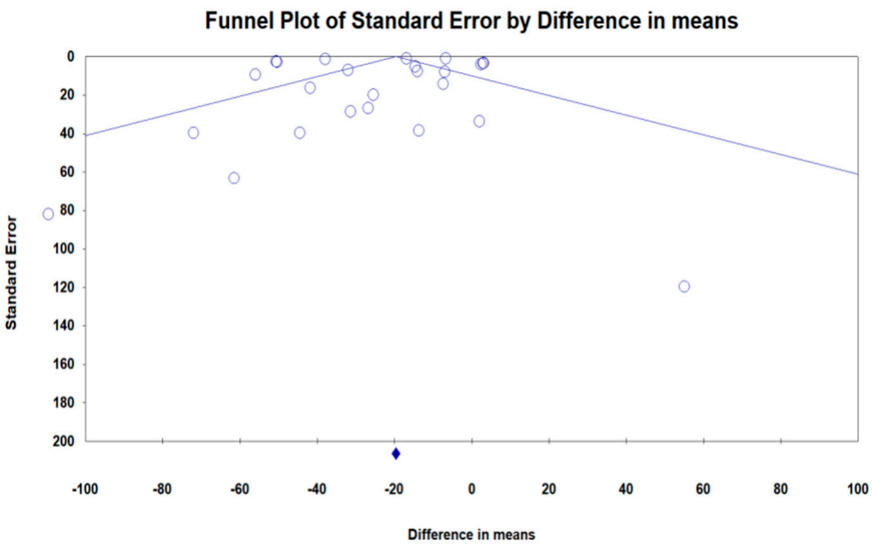


Figure 6. Funnel plot detailing publication bias in the publications describing the effect of BS on MCP-1.

Publication bias did not exist based on Egger's (intercept = −2.02, standard error = 1.295; 95% CI = −4.682, 0.623, t = 1.567, df = 28, two-tailed p = 0.128) and Begg's tests (Kendall's Tau with continuity correction = −0.193, z = 1.498, two-tailed p-value = 0.133) in detecting the impact of bariatric surgery on circulating MCP-1. Trim and fill test showed one "missing" study in order to adjust publication bias. Furthermore, "fail-safe N" analysis showed that 6014 papers could change the conclusions of this study (Figure 5).

4. Discussion

The results of this meta-analysis showed a significant decrease of MCP-1 concentration after bariatric surgery. It is important to stress that there was no association between the changes in BMI and absolute difference in MCP-1 levels, but a linear relationship between the changes in MCP-1 and the length of follow-up was shown.

MCP-1 is important in the atherogenesis and destabilization of atherosclerotic plaques, particularly in the early stages of atherogenesis. As a non-traditional diagnostic marker for atherosclerosis, high levels of MCP-1 may contribute to low-grade inflammation in obesity [47,48].

In an earlier study, one year following bariatric surgery, there was a considerable decrease in cytokines such as MCP-1. Weight loss improved adiposity serum biomarkers and obesity-related comorbidities [49]. Christiansen et al. [50] investigated a reduction in MCP-1 concentration after weight loss in severe obesity, and their results are consistent with the findings of this meta-analysis. However, the processes by which bariatric surgery improves endothelium damage biomarkers are mostly unknown. It is likely that the key mechanism responsible for the decrease of these indicators is the reduction of adipose tissue [51].

It is difficult to explain why there was no association between the changes in BMI and absolute difference in MCP-1 levels. The reason might be that although it is the most widely used indicator of obesity status in clinical settings and population health research, BMI is not the optimal measure for obesity. Since BMI is an indirect measure of obesity, it does not account for the location of adipose tissue (subcutaneous vs. visceral fat) differentiate between fat mass or lean mass (muscle mass, bone density etc.), or account for variation in body composition [52]. This might be the answer as to why no association between the changes in BMI and absolute difference in MCP-1 levels could be found. However, various mechanisms other than decreased fat tissue mass, such as decreased inflammation, decreased nutrient absorption, lower energy intake, or decreased need for the liver to detoxify ingested drugs, might have an impact on circulating MCP-1 levels as well [53].

In line with previous study, we showed that both LSG and RYGB improve the obesity and inflammatory conditions of patients, However, a gastric bypass was found to be more beneficial as compared to gastrectomy [54].

Most pro-inflammatory cytokines began to decrease early after surgery and continued to decline in the medium- and long-term. The current study found that MCP-1 decreased with weight loss and that this drop was consistent in long-term follow-up. In this sense, metabolic improvement seems to be an early change after bariatric surgery that may favor obesity-induced inflammation resolution [55].

The decrease of MCP-1 after bariatric surgery as an indication of anti-inflammatory effect might offer subsequent protection from obesity-related comorbidities such as insulin resistance, ACVD, and maybe some types of cancer, which are all associated with obesity.

This meta-analysis has certain limitations: some studies did not have a control group, had small patient groups, and were not randomized; however, the results were still strong following the leave-one-out sensitivity analysis. Second, we were unable to account for the impact of different bariatric surgery approaches, which could result in a significantly higher or reduced response.

5. Conclusions

Bariatric surgery significantly decreases MCP-1 concentration, but there was no association between the changes in BMI and absolute difference in MCP-1 levels before and after the surgery. However, a linear relationship between the changes in MCP-1 and the length of follow-up has been shown. A reduction in circulating levels of MCP-1 could be regarded as a potential factor in explaining the positive impact of bariatric intervention on cardiometabolic outcomes beyond weight loss.

This systematic review and meta-analysis was not registered.

Author Contributions: Conceptualization, T.J., M.A., Ž.R. and A.S.; Methodology, A.S.; Validation, M.A. and P.K.; Formal analysis, T.J., P.K. and A.S.; Resources, Ž.R.; Data curation, T.J., M.A. and P.K.; Writing—original draft, T.J., Ž.R. and A.S.; Writing—review & editing, Ž.R., P.K. and A.S.; Visualization, A.S. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: Not applicable.

Acknowledgments: Tannaz Jamialahmadi was supported by the Wael-Almahmeed & IAS research training grant.

Conflicts of Interest: The authors declare no conflict of interest.

References

1. Catalán, V.; Gómez-Ambrosi, J.; Ramirez, B.; Rotellar, F.; Pastor, C.; Silva, C.; Rodríguez, A.; Gil, M.J.; Cienfuegos, J.A.; Frühbeck, G. Proinflammatory Cytokines in Obesity: Impact of Type 2 Diabetes Mellitus and Gastric Bypass. *Obes. Surg.* **2007**, *17*, 1464–1474. [CrossRef]
2. Engin, A.B. Adipocyte-Macrophage Cross-Talk in Obesity. *Obes. Lipotoxic.* **2017**, *960*, 327–343. [CrossRef]
3. Inoue, S.; Egashira, K.; Ni, W.; Kitamoto, S.; Usui, M.; Otani, K.; Ishibashi, M.; Hiasa, K.-I.; Nishida, K.-I.; Takeshita, A. Anti-Monocyte Chemoattractant Protein-1 Gene Therapy Limits Progression and Destabilization of Established Atherosclerosis in Apolipoprotein E–Knockout Mice. *Circulation* **2002**, *106*, 2700–2706. [CrossRef] [PubMed]
4. Bianconi, V.; Sahebkar, A.; Atkin, S.L.; Pirro, M. The regulation and importance of monocyte chemoattractant protein-1. *Curr. Opin. Hematol.* **2018**, *25*, 44–51. [CrossRef] [PubMed]
5. Bachmayer, C.; Lammert, A.; Hasenberg, T.; Hammes, H.-P. Healthy Obese and Post Bariatric Patients—Metabolic and Vascular Patterns. *Exp. Clin. Endocrinol. Diabetes* **2013**, *121*, 483–487. [CrossRef] [PubMed]
6. Sutanto, A.; Wungu, C.D.K.; Susilo, H.; Sutanto, H. Reduction of Major Adverse Cardiovascular Events (MACE) after Bariatric Surgery in Patients with Obesity and Cardiovascular Diseases: A Systematic Review and Meta-Analysis. *Nutrients* **2021**, *13*, 3568. [CrossRef] [PubMed]
7. Tsilingiris, D.; Koliaki, C.; Kokkinos, A. Remission of type 2 diabetes mellitus after bariatric surgery: Fact or fiction? *Int. J. Environ. Res. Public Health* **2019**, *16*, 3171. [CrossRef]
8. Jamialahmadi, T.; Alidadi, M.; Atkin, S.L.; Kroh, M.; Almahmeed, W.; Moallem, S.A.; Al-Rasadi, K.; Rodriguez, J.H.; Santos, R.D.; Ruscica, M.; et al. Effect of Bariatric Surgery on Flow-Mediated Vasodilation as a Measure of Endothelial Function: A Systematic Review and Meta-Analysis. *J. Clin. Med.* **2022**, *11*, 4054. [CrossRef] [PubMed]
9. Jamialahmadi, T.; Reiner, Ž.; Alidadi, M.; Kroh, M.; Almahmeed, W.; Ruscica, M.; Sirtori, C.; Rizzo, M.; Santos, R.D.; Sahebkar, A. The Effect of Bariatric Surgery on Circulating Levels of Lipoprotein (a): A Meta-analysis. *BioMed Res. Int.* **2022**, *2022*, 8435133. [CrossRef]
10. Jamialahmadi, T.; Reiner, Ž.; Alidadi, M.; Kroh, M.; Cardenia, V.; Xu, S.; Al-Rasadi, K.; Santos, R.D.; Sahebkar, A. The Effect of Bariatric Surgery on Circulating Levels of Oxidized Low-Density Lipoproteins Is Apparently Independent of Changes in Body Mass Index: A Systematic Review and Meta-Analysis. *Oxidative Med. Cell. Longev.* **2021**, *2021*, 4136071. [CrossRef]
11. Jamialahmadi, T.; Reiner, Ž.; Alidadi, M.; Kroh, M.; Simental-Mendia, L.E.; Pirro, M.; Sahebkar, A. Impact of Bariatric Surgery on Pulse Wave Velocity as a Measure of Arterial Stiffness: A Systematic Review and Meta-analysis. *Obes. Surg.* **2021**, *31*, 4461–4469. [CrossRef]
12. Nabavi, N.; Ghodsi, A.; Rostami, R.; Torshizian, A.; Jamialahmadi, T.; Jangjoo, A.; Nematy, M.; Bahari, A.; Ebrahimzadeh, F.; Mahmoudabadi, E.; et al. Impact of Bariatric Surgery on Carotid Intima-Media Thickness in Patients with Morbid Obesity: A Prospective Study and Review of the Literature. *Obes. Surg.* **2022**, *32*, 1563–1569. [CrossRef] [PubMed]

13. Jamialahmadi, T.; Jangjoo, A.; Rezvani, R.; Goshayeshi, L.; Tasbandi, A.; Nooghabi, M.J.; Rajabzadeh, F.; Ghaffarzadegan, K.; Mishamandani, Z.J.; Nematy, M. Hepatic Function and Fibrosis Assessment via 2D-Shear Wave Elastography and Related Biochemical Markers Pre- and Post-Gastric Bypass Surgery. *Obes. Surg.* **2020**, *30*, 2251–2258. [CrossRef] [PubMed]
14. Jamialahmadi, T.; Banach, M.; Almahmeed, W.; Kesharwani, P.; Sahebkar, A. Impact of bariatric surgery on circulating PCSK9 levels as marker of cardiovascular disease risk: A meta-analysis. *Arch. Med. Sci.* **2022**, *18*, 1372–1377. [CrossRef] [PubMed]
15. Jamialahmadi, T.; Reiner, Ž.; Alidadi, M.; Almahmeed, W.; Kesharwani, P.; Al-Rasadi, K.; Eid, A.H.; Rizzo, M.; Sahebkar, A. Effect of Bariatric Surgery on Intima Media Thickness: A Systematic Review and Meta-Analysis. *J. Clin. Med.* **2022**, *11*, 6056. [CrossRef] [PubMed]
16. Coelho, C.; Crane, J.; Agius, R.; McGowan, B. The Bariatric-Metabolic Physician's Role in Managing Clinically Severe Obesity. *Curr. Obes. Rep.* **2021**, *10*, 263–273. [CrossRef] [PubMed]
17. Carmona-Maurici, J.; Cuello, E.; Ricart-Jané, D.; Miñarro, A.; Baena-Fustegueras, J.A.; Peinado-Onsurbe, J.; Pardina, E. Effect of bariatric surgery on inflammation and endothelial dysfunction as processes underlying subclinical atherosclerosis in morbid obesity. *Surg. Obes. Relat. Dis.* **2020**, *16*, 1961–1970. [CrossRef]
18. Sutton, A.J.; Abrams, K.R.; Jones, D.R.; Jones, D.R.; Sheldon, T.A.; Song, F. *Methods for Meta-Analysis in Medical Research*; Wiley: Chichester, UK, 2000.
19. Higgins, J.P.T.; Green, S. (Eds.) Cochrane Handbook for Systematic Reviews of Interventions Version 5.1.0 [Updated March 2011]. The Cochrane Collaboration, 2011. Available online: www.handbook.cochrane.org (accessed on 26 November 2022).
20. Wells, G.A.; Shea, B.; O'Connell Da Peterson, J.; Welch, V.; Losos, M.; Tugwell, P. The Newcastle-Ottawa Scale (NOS) for Assessing the Quality of Nonrandomised Studies in Meta-Analyses. Oxford. 2000. Available online: https://www.ohri.ca/programs/clinical_epidemiology/oxford.asp (accessed on 26 November 2022).
21. Borenstein, M.; Hedges, L.; Higgins, J.; Rothstein, H. *Comprehensive Meta-Analysis, Version 2*; Biostat: Englewood, NJ, USA, 2005; Available online: https://www.meta-analysis.com/ (accessed on 26 November 2022).
22. Banach, M.; Serban, C.; Ursoniu, S.; Rysz, J.; Muntner, P.; Toth, P.P.; Jones, S.R.; Rizzo, M.; Glasser, S.P.; Watts, G.F.; et al. Statin therapy and plasma coenzyme Q10 concentrations—A systematic review and meta-analysis of placebo-controlled trials. *Pharmacol. Res.* **2015**, *99*, 329–336. [CrossRef]
23. Duval, S.; Tweedie, R. Trim and Fill: A Simple Funnel-Plot-Based Method of Testing and Adjusting for Publication Bias in Meta-Analysis. *Biometrics* **2000**, *56*, 455–463. [CrossRef]
24. Salman, A.; Salman, M.; Sarhan, M.D.; Maurice, K.; El-Din, M.T.; Youssef, A.; Ahmed, R.; Abouelregal, T.; Shaaban, H.E.-D.; GabAllah, G.M.; et al. Changes of Urinary Cytokines in Non-Diabetic Obese Patients after Laparoscopic Sleeve Gastrectomy. *Int. J. Gen. Med.* **2021**, *14*, 825–831. [CrossRef]
25. Rizk, N.M.; Fadel, A.; AlShammari, W.; Younes, N.; Bashah, M. The Immunophenotyping Changes of Peripheral CD4+ T Lymphocytes and Inflammatory Markers of Class III Obesity Subjects after Laparoscopic Gastric Sleeve Surgery—A Follow-Up Study. *J. Inflamm. Res.* **2021**, *14*, 1743–1757. [CrossRef] [PubMed]
26. Morales, E.; Porrini, E.; Martin-Taboada, M.; Luis-Lima, S.; Vila-Bedmar, R.; de Pablos, I.G.; Gómez, P.; Rodríguez, E.; Torres, L.; Lanzón, B.; et al. Renoprotective role of bariatric surgery in patients with established chronic kidney disease. *Clin. Kidney J.* **2021**, *14*, 2037–2046. [CrossRef] [PubMed]
27. Yan, Y.; Wang, F.; Chen, H.; Zhao, X.; Yin, D.; Hui, Y.; Wang, G. Efficacy of laparoscopic gastric bypassvslaparoscopic sleeve gastrectomy in treating obesity combined with type-2 diabetes. *Br. J. Biomed. Sci.* **2021**, *78*, 35–40. [CrossRef] [PubMed]
28. Bratti, L.D.O.S.; Carmo, A.R.D.; Vilela, T.F.; Souza, L.C.; de Moraes, A.C.R.; Filippin-Monteiro, F.B. Bariatric surgery improves clinical outcomes and adiposity biomarkers but not inflammatory cytokines SAA and MCP-1 after a six-month follow-up. *Scand. J. Clin. Lab. Investig.* **2021**, *81*, 230–236. [CrossRef] [PubMed]
29. Salman, M.A.; Abdallah, A.; Mikhail, H.M.S.; Abdelsalam, A.; Ibrahim, A.H.; Sultan, A.A.E.A.; El-Ghobary, M.; Ismail, A.A.M.; Abouelregal, T.E.; Omar, M.G.; et al. Long-term Impact of Mini-Gastric Bypass on Inflammatory Cytokines in Cohort of Morbidly Obese Patients: A Prospective Study. *Obes. Surg.* **2020**, *30*, 2338–2344. [CrossRef] [PubMed]
30. Lambert, G.; Lima, M.M.D.O.; Felici, A.C.; Pareja, J.C.; Vasques, A.C.J.; Novaes, F.S.; Rodovalho, S.; Hirsch, F.F.P.; Matos-Souza, J.R.; Chaim, A.; et al. Early Regression of Carotid Intima-Media Thickness after Bariatric Surgery and Its Relation to Serum Leptin Reduction. *Obes. Surg.* **2018**, *28*, 226–233. [CrossRef] [PubMed]
31. Alsharidah, M.; Alghamdi, F.; Aldosri, H.; Alharbi, A.; Alwarthan, A.; Bamihrez, F.; Alkhaldi, H.; Alsaif, F.; Hassanain, M. Assessment of liver inflammation and fibrosis after weight loss secondary to bariatric surgery in patients with nonalcoholic fatty liver disease. *HPB* **2018**, *20*, S444. [CrossRef]
32. Yadav, R.; Hama, S.; Liu, Y.; Siahmansur, T.; Schofield, J.; Syed, A.A.; France, M.; Pemberton, P.; Adam, S.; Ho, J.H.; et al. Effect of Roux-en-Y Bariatric Surgery on Lipoproteins, Insulin Resistance, and Systemic and Vascular Inflammation in Obesity and Diabetes. *Front. Immunol.* **2017**, *8*, 1512. [CrossRef] [PubMed]
33. van der Wielen, N.; Paulus, G.; van Avesaat, M.; Masclee, A.; Meijerink, J.; Bouvy, N. Effect of Endoscopic Gastroplication on the Genome-Wide Transcriptome in the Upper Gastrointestinal Tract. *Obes. Surg.* **2017**, *27*, 740–748. [CrossRef] [PubMed]
34. Sams, V.G.; Blackledge, C.; Wijayatunga, N.; Barlow, P.; Mancini, M.; Mancini, G.; Moustaid-Moussa, N. Effect of bariatric surgery on systemic and adipose tissue inflammation. *Surg. Endosc.* **2016**, *30*, 3499–3504. [CrossRef] [PubMed]
35. Kelly, A.S.; Ryder, J.R.; Marlatt, K.L.; Rudser, K.D.; Jenkins, T.; Inge, T.H. Changes in inflammation, oxidative stress and adipokines following bariatric surgery among adolescents with severe obesity. *Int. J. Obes.* **2016**, *40*, 275–280. [CrossRef] [PubMed]

36. Immonen, H.; Hannukainen, J.C.; Iozzo, P.; Soinio, M.; Salminen, P.; Saunavaara, V.; Borra, R.; Parkkola, R.; Mari, A.; Lehtimäki, T.; et al. Effect of bariatric surgery on liver glucose metabolism in morbidly obese diabetic and non-diabetic patients. *J. Hepatol.* **2014**, *60*, 377–383. [CrossRef] [PubMed]
37. Gumbau, V.; Bruna, M.; Canelles, E.; Guaita, M.; Mulas, C.; Basés, C.; Celma, I.; Puche, J.; Marcaida, G.; Oviedo, M.; et al. A Prospective Study on Inflammatory Parameters in Obese Patients After Sleeve Gastrectomy. *Obes. Surg.* **2014**, *24*, 903–908. [CrossRef] [PubMed]
38. Thomsen, S.B.; Rathcke, C.N.; Jørgensen, N.B.; Madsbad, S.; Vestergaard, H. Effects of Roux-en-Y Gastric Bypass on Fasting and Postprandial Levels of the Inflammatory Markers YKL-40 and MCP-1 in Patients with Type 2 Diabetes and Glucose Tolerant Subjects. *J. Obes.* **2013**, *2013*, 361781. [CrossRef]
39. Lima, M.M.O.; Pareja, J.C.; Alegre, S.M.; Geloneze, S.R.; Kahn, S.E.; Astiarraga, B.; Chaim, A.; Baracat, J.; Geloneze, B. Visceral fat resection in humans: Effect on insulin sensitivity, beta-cell function, adipokines, and inflammatory markers. *Obesity* **2013**, *21*, E182–E189. [CrossRef]
40. Monte, S.V.; Caruana, J.A.; Ghanim, H.; Sia, C.L.; Korzeniewski, K.; Schentag, J.J.; Dandona, P. Reduction in endotoxemia, oxidative and inflammatory stress, and insulin resistance after Roux-en-Y gastric bypass surgery in patients with morbid obesity and type 2 diabetes mellitus. *Surgery* **2012**, *151*, 587–593. [CrossRef]
41. Dalmas, E.; Rouault, C.; Abdennour, M.; Rovere, C.; Rizkalla, S.; Bar-Hen, A.; Nahon, J.-L.; Bouillot, J.-L.; Guerre-Millo, M.; Clément, K.; et al. Variations in circulating inflammatory factors are related to changes in calorie and carbohydrate intakes early in the course of surgery-induced weight reduction. *Am. J. Clin. Nutr.* **2011**, *94*, 450–458. [CrossRef]
42. Schaller, G.; Aso, Y.; Schernthaner, G.; Kopp, H.-P.; Inukai, T.; Kriwanek, S.; Schernthaner, G. Increase of Osteopontin Plasma Concentrations After Bariatric Surgery Independent from Inflammation and Insulin Resistance. *Obes. Surg.* **2009**, *19*, 351–356. [CrossRef]
43. Hempen, M.; Kopp, H.-P.; Elhenicky, M.; Höbaus, C.; Brix, J.-M.; Koppensteiner, R.; Schernthaner, G.; Schernthaner, G.-H. YKL-40 is Elevated in Morbidly Obese Patients and Declines After Weight Loss. *Obes. Surg.* **2009**, *19*, 1557–1563. [CrossRef]
44. Swarbrick, M.M.; Stanhope, K.L.; Austrheim-Smith, I.T.; Van Loan, M.D.; Ali, M.R.; Wolfe, B.M.; Havel, P.J. Longitudinal changes in pancreatic and adipocyte hormones following Roux-en-Y gastric bypass surgery. *Diabetologia* **2008**, *51*, 1901–1911. [CrossRef]
45. Fontana, L.; Eagon, J.C.; Colonna, M.; Klein, S. Impaired Mononuclear Cell Immune Function in Extreme Obesity Is Corrected by Weight Loss. *Rejuvenation Res.* **2007**, *10*, 41–46. [CrossRef]
46. Schernthaner, G.; Kopp, H.-P.; Kriwanek, S.; Krzyzanowska, K.; Satler, M.; Koppensteiner, R.; Schernthaner, G. Effect of Massive Weight Loss induced by Bariatric Surgery on Serum Levels of Interleukin-18 and Monocyte-Chemoattractant-Protein-1 in Morbid Obesity. *Obes. Surg.* **2006**, *16*, 709–715. [CrossRef]
47. Sartipy, P.; Loskutoff, D.J. Monocyte chemoattractant protein 1 in obesity and insulin resistance. *Proc. Natl. Acad. Sci. USA* **2003**, *100*, 7265–7270. [CrossRef]
48. Yuasa, S.; Maruyama, T.; Yamamoto, Y.; Hirose, H.; Kawai, T.; Matsunaga-Irie, S.; Itoh, H. MCP-1 gene A-2518G polymorphism and carotid artery atherosclerosis in patients with type 2 diabetes. *Diabetes Res. Clin. Pract.* **2009**, *86*, 193–198. [CrossRef]
49. Makarewicz-Wujec, M.; Henzel, J.; Kępka, C.; Kruk, M.; Wardziak, Ł.; Trochimiuk, P.; Parzonko, A.; Dzielińska, Z.; Demkow, M.; Kozłowska-Wojciechowska, M. Usefulness of MCP-1 Chemokine in the Monitoring of Patients with Coronary Artery Disease Subjected to Intensive Dietary Intervention: A Pilot Study. *Nutrients* **2021**, *13*, 3047. [CrossRef] [PubMed]
50. Christiansen, T.; Richelsen, B.; Bruun, J.M. Monocyte chemoattractant protein-1 is produced in isolated adipocytes, associated with adiposity and reduced after weight loss in morbid obese subjects. *Int. J. Obes.* **2005**, *29*, 146–150. [CrossRef]
51. Komorowski, J.; Jankiewicz-Wika, J.; Kolomecki, K.; Cywinski, J.; Piestrzeniewicz, K.; Swiętoslawski, J.; Stepien, H. Systemic blood osteopontin, endostatin, and E-selectin concentrations after vertical banding surgery in severely obese adults. *Cytokine* **2011**, *55*, 56–61. [CrossRef] [PubMed]
52. Rothman, K.J. BMI-related errors in the measurement of obesity. *Int. J. Obes.* **2008**, *32*, S56–S59. [CrossRef]
53. Seyyedi, J.; Alizadeh, S. Effect of Surgically Induced Weight Loss on Biomarkers of Endothelial Dysfunction: A Systematic Review and Meta-Analysis. *Obes. Surg.* **2020**, *30*, 3549–3560. [CrossRef] [PubMed]
54. Sachan, A.; Singh, A.; Shukla, S.; Aggarwal, S.; Mir, I.; Yadav, R. An immediate post op and follow up assessment of circulating adipo-cytokines after bariatric surgery in morbid obesity. *Metab. Open* **2022**, *13*, 100147. [CrossRef]
55. Villarreal-Calderon, J.R.; Cuellar-Tamez, R.; Castillo, E.C.; Luna-Ceron, E.; García-Rivas, G.; Elizondo-Montemayor, L. Metabolic shift precedes the resolution of inflammation in a cohort of patients undergoing bariatric and metabolic surgery. *Sci. Rep.* **2021**, *11*, 12127. [CrossRef] [PubMed]