https://nephropathol.com DOI: 10.34172/jnp.2025.27622 J Nephropathol. 2025;14(3):e27622

Journal of Nephropathology

Association between oxidative balance score and metabolic syndrome: a systematic review and meta-analysis

Aliasghar Tabatabaei Mohammadi[1], Mohammad Reza Farnia[2], Afsaneh Mirshekari[3], Sara Rashki Ghalehno[4], Elham Ahmadipour[5], Zahra Bazargani[6], Elham Kebriyaei[6], Sina Salati[7], Mehrangiz Ghafari[8*]

[1]School of Medicine, Urmia University of Medical Sciences, Urmia, Iran
[2]Department of Emergency Medicine, Taleghani and Imam Reza Hospitals, School of Medicine, Kermanshah University of Medical Sciences, Kermanshah, Iran
[3]Department of Gastroenterology and Hepatology, School of Medicine, Amir al Momenin Hospital, Zabol University of Medical Sciences, Zabol, Iran
[4]Department of Cardiology, School of Medicine, Amir al Momenin Hospital, Zabol University of Medical Sciences, Zabol, Iran
[5]Independent Researcher, Private Clinic, Pezeshkan Street, Alvand Building, Shiraz, Iran
[6]Clinical Research Development Unit, Department of Pediatric, Valiasr Hospital, Fasa University of Medical Sciences, Fasa, Iran
[7]Department of Emergency Medicine, Nursing and Midwifery School, Torbat Heydariyeh University of Medical Sciences, Torbat Heydariyeh, Iran
[8]Department of Pathology, School of Medicine, Zabol University of Medical Sciences, Zabol, Iran

ARTICLE INFO

Article type:
Meta-analysis

Article history:
Received: 24 Jan. 2025
Revised: 8 Apr. 2025
Accepted: 11 Apr. 2025
Published online: 27 Apr. 2025

Keywords:
Metabolic syndrome
Dysmetabolic syndrome X
Cardiometabolic syndrome
Reaven syndrome X
Oxidative balance score

ABSTRACT

Introduction: Most patients with metabolic syndrome (MetS) are at enhanced risk of oxidative stress. This systematic review and meta-analysis assesses the association between oxidative balance score (OBS) and MetS (MetS).

Method: Cochrane, Web of Science, PubMed, ProQuest, Embase, and Google Scholar databases were searched until January 15, 2025. Data were analyzed using IBM SPSS Statistics 19.0 and STATA 14. The results with $P<0.05$ were considered to be statistically significant.

Results: Elevated OBSs were associated with declined risks of MetS in males (OR:0.88, 95% CI: 0.83, 0.93) and females (OR: 0.81, 95% CI: 0.76, 0.86). Likewise, elevated OBSs declined the risk of MetS in South Korea (OR: 0.75, 95% CI: 0.67, 0.84) and the USA (OR: 0.63, 95% CI: 0.53, 0.74), in the cohort (OR: 0.73, 95% CI: 0.63, 0.85) and cross-sectional (OR: 0.67, 95% CI: 0.58, 0.76) studies, in 40 to 49 years old patients (OR: 0.63, 95% CI: 0.53, 0.74) and patients aged 50 to 59 (OR:0.84, 95% CI: 0.77, 0.91), in the second (OR: 0.75, 95% CI: 0.66, 0.84) and third (OR: 0.50, 95% CI: 0.34, 0.74) tertiles, in the second (OR: 0.84, 95% CI: 0.78, 0.92), third (OR: 0.68, 95% CI: 0.59, 0.79), and fourth (OR: 0.50, 95% CI: 0.41, 0.61) quartiles, and in the fifth quintile (OR: 0.78, 95% CI: 0.63, 0.97). As such, the risk of MetS declined at elevated dietary oxidative balance score (DOBS) (OR: 0.79, 95% CI: 0.62, 1) and lifestyle-based oxidative balance score (LOBS) (OR: 0.39, 95% CI: 0.21, 0.71).

Conclusion: Elevated OBS, DOBS, and LOBS scores mitigate the risk of MetS. MetS risk is lower in the United States females and those in their fourth decade. Collectively, MetS is less probable to occur at elevated OBS levels.

Registration: This study has been compiled based on the PRISMA checklist, and its protocol was registered on the PROSPERO (ID: CRD42025643042 and Research Registry (UIN: reviewregistry1951) websites.

Meta-analysis

Introduction

Metabolic syndrome (MetS) is a cluster of interconnected factors that enhance the risk of dyslipidemia, hypertension, and abnormal serum glucose concentration (1). The incidence of MetS contrasts among ethnic groups and its worldwide prevalence in adults is estimated to be 10%–50% (2). MetS is predominantly associated with the occurrence of obesity and type 2 diabetes mellitus

*Corresponding author: Mehrangiz Ghafari,
Email: ghafari.mehr@yahoo.com

Implication for health policy/practice/research/medical education:
In a meta-analysis study we found that, elevated oxidative balance scores (OBSs), encompassing dietary and lifestyle-based components, are associated with a reduced risk of metabolic syndrome (MetS). Particularly, higher OBS levels are linked to a lower likelihood of developing MetS, a trend observed mainly in the United States females and individuals in their fourth decade, who exhibit lower MetS risk. Collectively, these findings suggest that maintaining elevated OBS levels can effectively mitigate the occurrence of MetS, highlighting the importance of antioxidant-rich diets and healthy lifestyle choices in preventing this condition.
Please cite this paper as: Tabatabaei Mohammadi A, Farnia MR, Mirshekari A, Rashki Ghalehno S, Ahmadipour E, Bazargani Z, Kebriyaei E, Salati S, Ghafari M. Association between oxidative balance score and metabolic syndrome: a systematic review and meta-analysis. J Nephropathol. 2025;14(3):e27622. DOI: 10.34172/jnp.2025.27622.

(3). Likewise, MetS patients are mostly diagnosed with elevated oxidative stress and impaired antioxidant defense (4). Concerning these, research is progressively devoted to devising techniques to control oxidative stress and chronic inflammation, thereby mitigating the severity of chronic comorbidities and averting MetS (5).

Oxidative stress is a multifactorial condition emanating from an imbalance between antioxidant defenses and reactive oxygen species (ROS) generated by prooxidants (6). Diet, lifestyle, and medication critically contribute to the body's oxidative balance (7). Oxidative balance score (OBS) is a composite measure assessing exposure to prooxidant and antioxidant factors. As such, elevated OBS, imply a decline of oxidative stress (8-10). Oxidative balance score, in turn, outweighs other single markers by affording a holistic assessment of oxidative stress and antioxidant capacity (11). Research has previously reported an inverse association between OBS and chronic kidney disease and colorectal and prostate malignancies (12-14). Research in South Korea reveals that OBS in its second quartile (compared to its first quartile) is insignificantly correlated with MetS (15). In the USA, research reports a declined risk of MetS at elevated OBS (16). Concerning the inconsistency of studies in the literature, this systematic review and meta-analysis assesses the association between OBS and MetS.

Materials and Methods

This research was conducted based on the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) statement (17) and its protocol was registered in the international Prospective Registry of Systematic Reviews (PROSPERO) and Research Registry websites.

Search strategy

Cochrane, Web of Science, PubMed, ProQuest, Embase, and Google Scholar databases were searched by the authors with no time and ethnic restrictions until January 15, 2025. The keywords were electronic- and hand-searched using Medical Subject Headings (MeSH) and operators "AND" and "OR". Search strategy in Web of Science: Metabolic Syndrome OR Dysmetabolic Syndrome X OR Cardiometabolic Syndrome OR Reaven Syndrome X (All Fields) AND Oxidative balance score (All Fields).

PECO (Population, Exposure, Comparison, Outcomes)

The research population consisted of research evaluating the association between OBS and the risk of MetS. The exposure was elevated OBS, as compared to patients with lower OBS levels. The main outcome was the association between OBS and MetS.

Inclusion criteria

Observational studies evaluating the correlation between OBS and the risk of MetS were included in this meta-analysis.

Exclusion criteria

Duplicated and non-observational research, low-quality studies, incomplete research and studies lacking sufficient data, and articles published in conferences were all excluded from this study.

Quality assessment

Two authors assessed the quality of the search articles using the Newcastle Ottawa Scale (NOS) tool. In the NOS, each item can be awarded a maximum of one star, except for the comparability parameter in which a maximum of two stars can be given to each item. As such, each item is scored from 0 to 10, with 0 indicating the lowest quality and 10 implying the highest quality. The NOS's cut point was 6, where research with a score of 6 or more was included in this meta-analysis (18).

Data extraction

The authors separately extracted required data, including the name of the article's author(s), the mean age of participants, the study date and location, study type, the number of participants, the correlation between OBS levels and MetS (at a CI of 95%) with upper and lower limits in both males and females (based on the odds ratio [OR] and hazard ratio [HR]), and the correlation between elevated dietary oxidative balance score (DOBS) and lifestyle-based oxidative balance score (LOBS) levels and the risk of MetS.

Statistical analysis

Data were analyzed using the logarithm of OR and HR, by merging all the articles. The extent of heterogeneity was measured by the I^2 index. The random effects (RE) model was used for panel data analysis. Data were analyzed in STATA v14.0. The results with $P<0.05$ were regarded to be statistically significant.

Results

Our search delivered 131 articles, of which 55 were omitted as they were duplicates. After checking abstracts, 11 out of the remaining 76 articles were omitted as they had not full text accessible. Of the remaining 65 articles, 13 were further omitted as they had no adequate data required for analyses. Likewise, 46 out of the remaining 52 articles were excluded due to exclusion criteria, and 6 were ultimately included in this systematic review and meta-analysis (Figure 1).

All the six articles reviewed (2 cohort and 4 cross-sectional) covered 90276 participants (Table 1).

Elevated levels of OBS declined the risk of MetS (OR: 0.65, 95% CI: 0.58, 0.73) (HR: 0.87, 95% CI: 0.79, 0.95) (Figure 2).

According to the sub-group analysis, elevated OBS declined the risk of MetS in South Korea (OR: 0.75, 95% CI: 0.67, 0.84) and the USA (OR: 0.63, 95% CI: 0.53, 0.74), in the cohort (OR: 0.73, 95% CI: 0.63, 0.85) and cross-sectional (OR: 0.67, 95% CI: 0.58, 0.76) studies, and in 40 to 49 years old patients (OR: 0.63, 95% CI: 0.53, 0.74) and patients aged 50 to 59 (OR:0.84, 95%CI: 0.77, 0.91; Figures 3 to 5).

At the same time, elevated OBS declined the risk of MetS in the second (OR: 0.75, 95% CI: 0.66, 0.84) and third (OR: 0.50, 95% CI: 0.34, 0.74) tertiles, in the second (OR: 0.84, 95% CI: 0.78, 0.92), third (OR: 0.68, 95% CI: 0.59, 0.79), and fourth (OR: 0.50, 95% CI: 0.41, 0.61) quartiles, and in the fifth quintile (OR: 0.78, 95% CI: 0.63, 0.97). Nonetheless, there was no significant correlation between OBS and the risk of MetS in the second (OR: 0.86, 95% CI: 0.73, 1.01), third (OR:

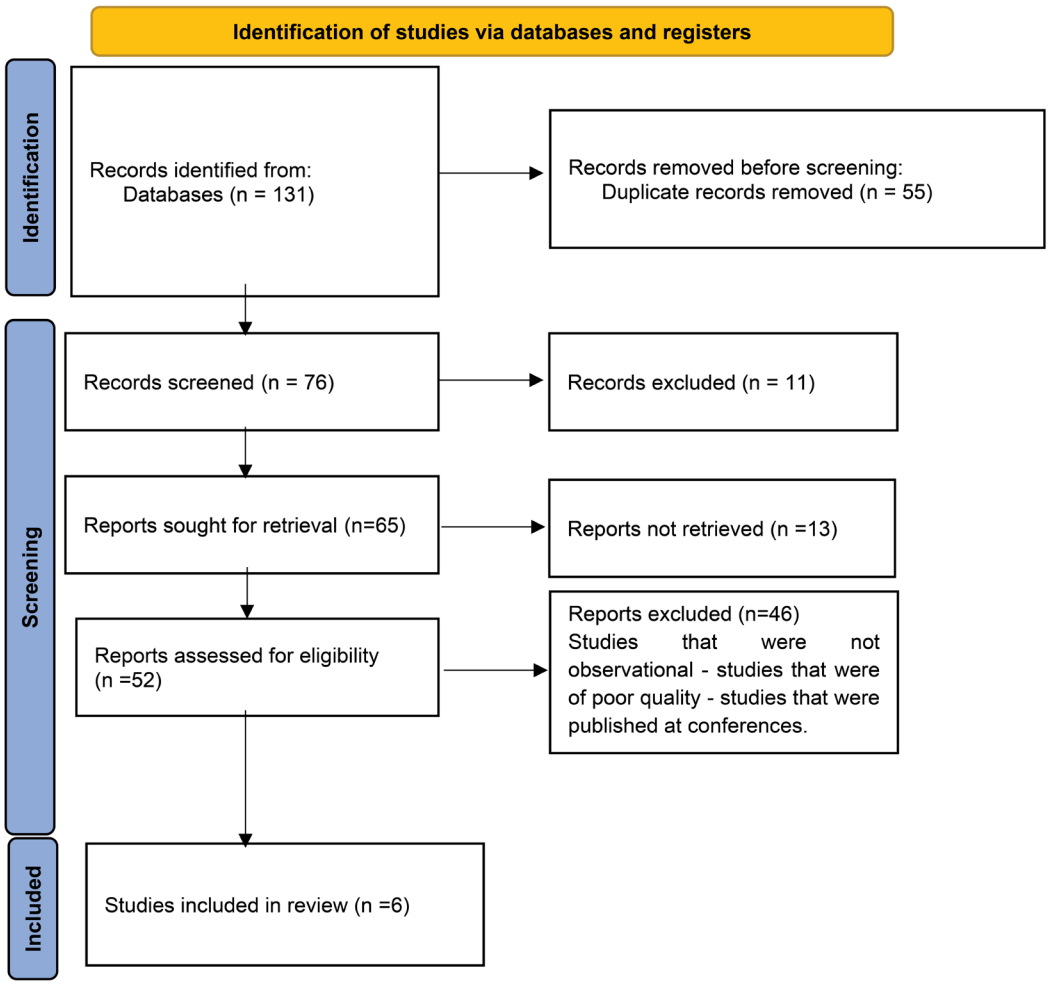

Figure 1. The PRISMA flowchart of study selection.

Table 1. Summarized information of the studies

Author, year	Country	Design	Sample size	Mean age	Duration of study	Stage
Lu Y, 2024 (19)	USA	Cross-sectional	NR	NR	2011-2018	Total
			2644	48		Quartile 2
			2417	47		Quartile 3
			2262	46		Quartile 4
Kim M, 2024 (20)	Korea	Cohort	5216	53.1	2004-2013	Quintile 2
			5809	53.1		Quintile 3
			5164	53.1		Quintile 4
			5327	53.1		Quintile 5
Xu Z, 2024 (16)	USA	Cross-sectional	11171	41	2007-2018	Total
			2883	41		Quartile 2
			2971	42		Quartile 3
			2536	42		Quartile 4
Li J, 2024 (21)	USA	Cross-sectional	16850	45.19	from 1999 to 2010	Total
			4548	45.73		Quintile 2
			3697	45.22		Quintile 3
			3965	44.65		Quintile 4
Park HM, 2023 (KNHANES) (22)	Korea	Cohort	2735	>19	2021	Total
			NR	NR		Tertile 2
			NR	NR		Tertile 3
Park HM, 2023 (KoGES) (22)	Korea	Cohort	5807	40-69	2021	Total
			NR	NR		Tertile 2
			NR	NR		Tertile 3
Lee HS, 2017 (15)	Korea	Cross-sectional	1169	56.62	2007 to 2008	Quartile 2
			2195	55.24		Quartile 3
			910	54.3		Quartile 4

NR: Not reported.

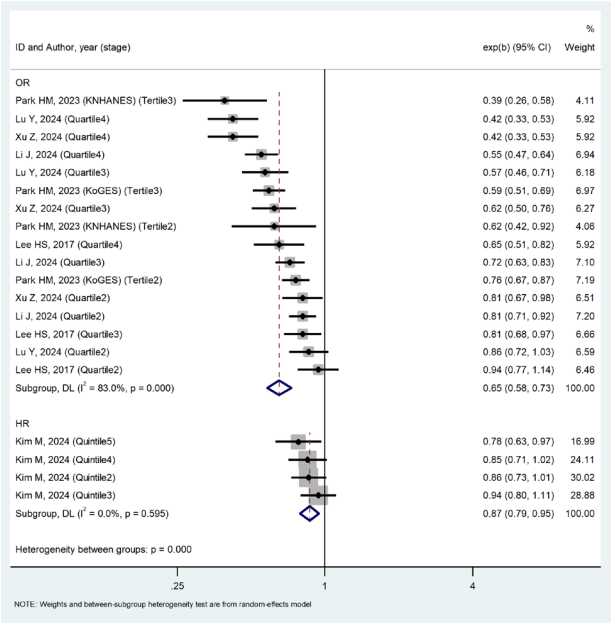

Figure 2. Forest plot showing the association between OBS and metabolic syndrome.

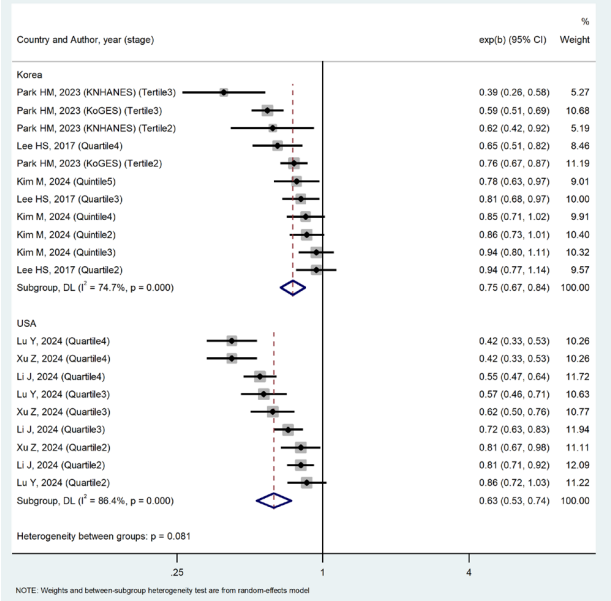

Figure 3. Forest plot showing the association between oxidative balance score and metabolic syndrome by place.

0.94, 95% CI: 0.80, 1.11), and fourth (OR: 0.85, 95% CI: 0.71, 1.02) quintiles. However, there was only one research reporting data based on quintiles (Figure 6).

Elevated OBS were associated with declined risks of MetS in males (OR:0.88, 95% CI: 0.83, 0.93) and females (OR: 0.81, 95% CI: 0.76, 0.86) (Figures 7 and 8).

As such, the risk of MetS declined at elevated DOBS (OR: 0.79, 95% CI: 0.62, 1) and LOBS (OR: 0.39, 95% CI: 0.21, 0.71) scores (Figures 9 and 10).

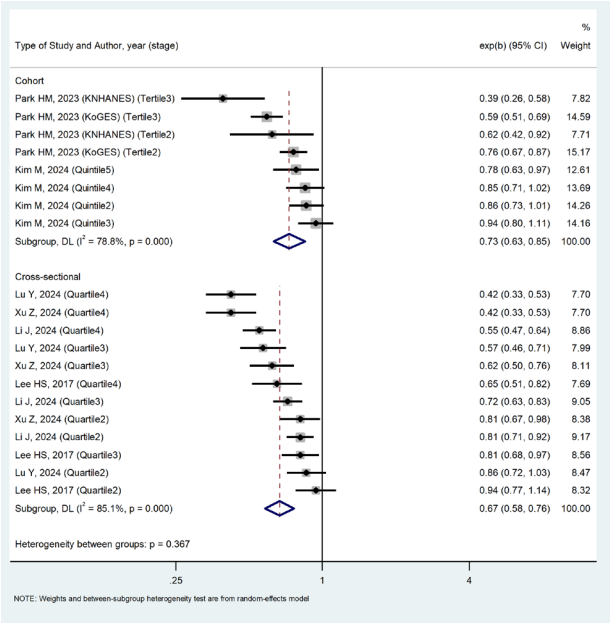

Figure 4. Forest plot showing the association between oxidative balance score and metabolic syndrome by design.

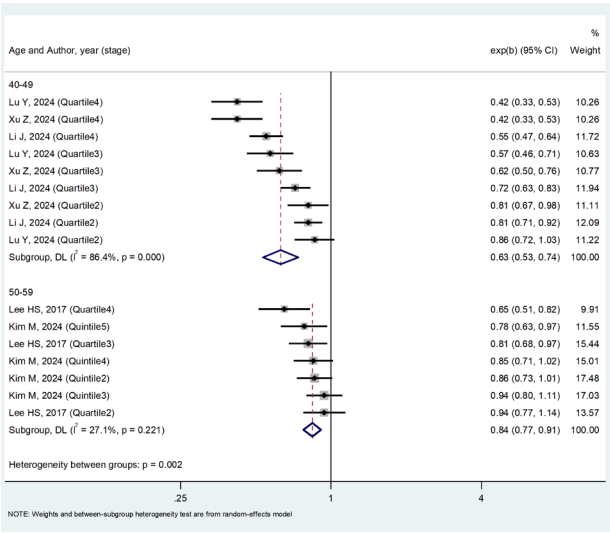

Figure 5. Forest plot showing the association between oxidative balance score and metabolic syndrome by mean age.

As with the funnel plot depicted in Figure 11, the publication bias is insignificant and references are searched completely ($P = 0.068$).

Discussion

In this research, elevated OBS declined the risk of MetS in males, females, South Korea, the USA, cohort research, cross-sectional studies, patients aged 40 to 49 and 50 to 59 years, in the second and third tertiles, in the second, third, and fourth quartiles, and the fifth quintile, respectively by 12%, 19%, 25%, 37%, 27%, 33%, 37%,

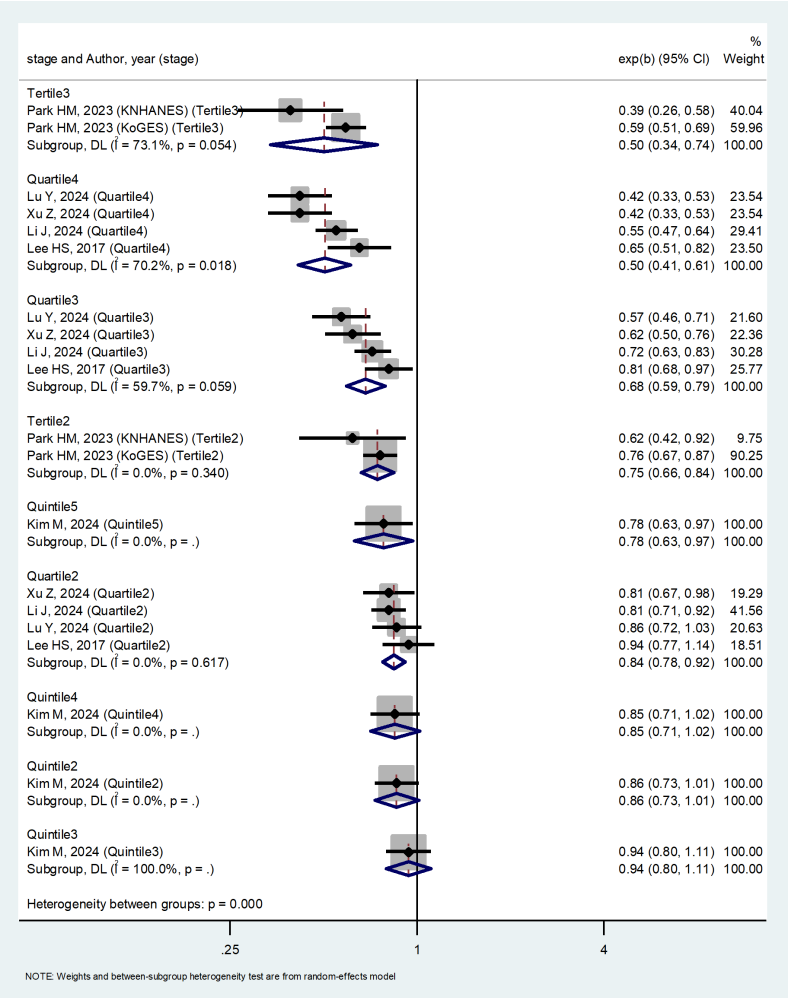

Figure 6. Forest plot showing the association between OBS and metabolic syndrome by stage.

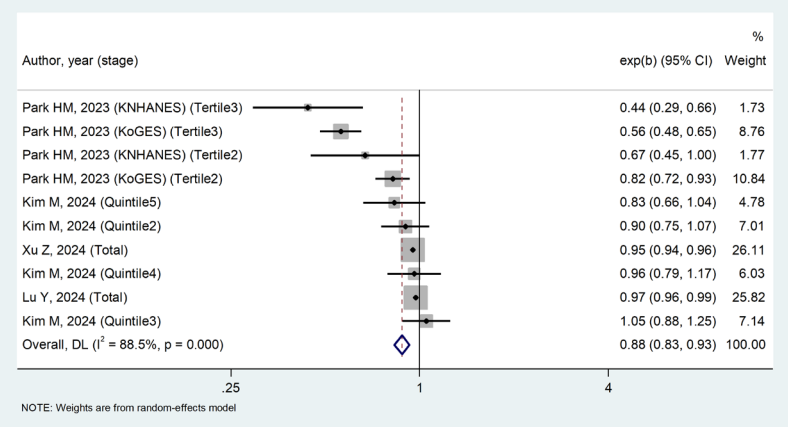

Figure 7. Forest plot showing the association between oxidative balance score and metabolic syndrome in males.

16%, 25%, 50%, 16%, 32%, 50%, and 22%. Likewise, elevated DOBSs and LOBSs declined the risk of MetS, respectively by 21% and 61%.

The cross-sectional research by Li et al (21) in the USA assessing the association between OBS and MetS revealed a lower risk of MetS at the highest quartile of OBS (OR: 0.55, 95% CI: 0.47, 0.64). Lu et al (19) reported a declined risk of MetS at elevated OBS (OR: 0.95, 95% CI: 0.94, 0.96). They further revealed a significant difference in the association between the risk of MetS and DOBS (OR: 0.97, 95% CI: 0.96, 0.98) and LOBS (OR: 0.61, 95% CI: 0.58, 0.64). In a similar research, Xu et al (16)

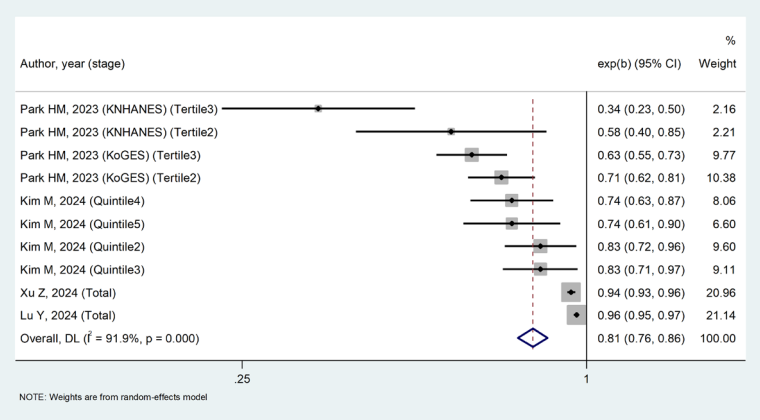

Figure 8. Forest plot showing the association between oxidative balance score and metabolic syndrome in females.

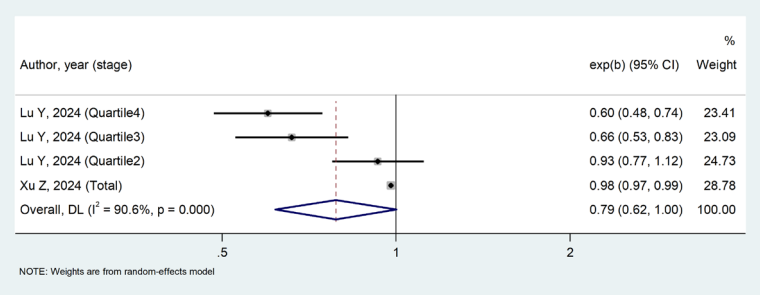

Figure 9. Forest plot showing the association between dietary oxidative balance score and metabolic syndrome.

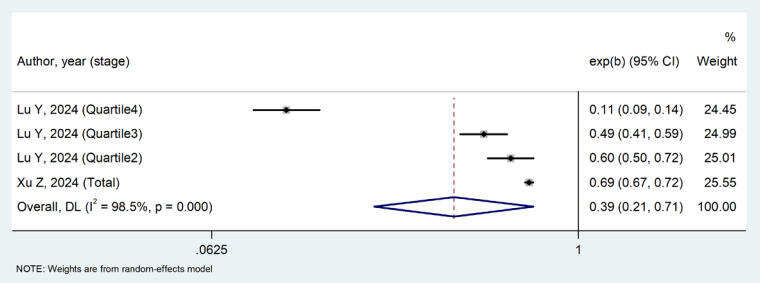

Figure 10. Forest plot showing the association between lifestyle oxidative balance score and metabolic syndrome.

reported that patients with higher OBS are at lower risk of MetS (OR: 0.95, 95% CI: 0.94, 0.96). These reports agree with the present meta-analysis, suggesting declined MetS risk at elevated OBS due to mitigated oxidative stress. As with these studies, LOBS outweighs DOBS in mitigating the risk of MetS.

Li et al (23) studied the elderly and reported that LOBS inversely correlates with systolic blood pressure and triglycerides, but is directly associated with HDL. Recently, Liu and Chen (24) reported an inverse correlation between OBS and the occurrence of non-alcoholic fatty liver disease (OR: 0.94, 95% CI: 0.93, 0.96). Wang et al (25) reported that elevated OBS (OR: 0.92, 95% CI: 0.90, 0.94 and OR: 0.96, 95% CI: 0.95, 0.97), DOBS (0.96 (0.94, 0.98) and 0.98 (0.96, 1), and LOBS (0.63 (0.59, 0.67) and 0.76 (0.72, 0.80) are correlated with a declined risk of abdominal obesity and visceral fat accumulation.

Zhu et al (26) reported that participants in the highest quartile of OBS (Q4) (compared to those in the lowest quartile of OBS (Q1) have a lower risk of obesity (OR: 0.43, 95% CI: 0.36, 0.50). Jin et al (27) studied 11,936 participants and reported that OBS (OR: 0.94, 95% CI: 0.93, 0.98), DOBS (OR: 0.96, 95% CI: 0.92, 0.96), and LOBS (OR: 0.74, 95% CI: 0.69, 0.79) are inversely correlated with the 10-year risk of atherosclerotic cardiovascular disease. Previously, Yang et al (28) reported that participants with lower OBS (compared to those with higher OBS) are at higher risk of cardiovascular diseases

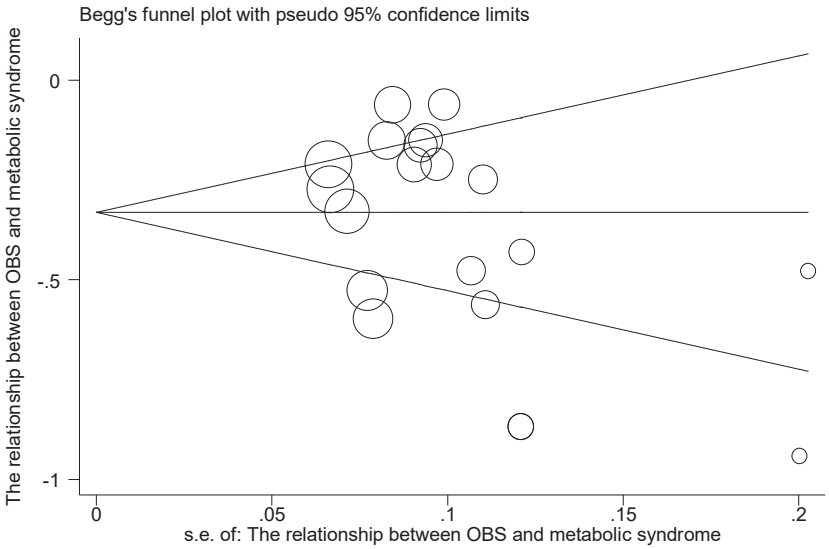

Figure 11. Diagram of publication bias.

(OR: 1.53, 95% CI: 1.17, 2.01).

Moreover, Kong et al (29) reported an inverse correlation between total OBS, DOBS, and LOBS with dyslipidemia. They further compared the second, third, and fourth quartiles of OBS with the first quartile of OBS (as a reference), with respective ORs of (OR: 0.86, 95% CI: 0.77, 0.97), (OR: 0.80, 95% CI: 0.72, 0.91), and (OR: 0.63, 95%CI: 0. 56, 0.70). meanwhile, Tan et al (30) found a lower chance of disposing to MetS-related steatosis in participants in the highest tertile of OBS, compared to those in their lowest tertile (OR: 0.72, 95% CI: 0.57, 0.92).

The above findings affirm that elevated OBS, decrease the risk of systolic blood pressure, triglycerides, obesity, nonalcoholic fatty liver disease, metabolic dysfunction-associated steatohepatitis, cardiovascular disease, dyslipidemia, abdominal obesity, and visceral fat accumulation. Accordingly, oxidative stress is a main contributor to numerous diseases.

Conclusion

This meta-analysis revealed that elevated OBS decline the risk of MetS. Except for a study reporting data by quintile, in other studies (and at elevated OBS), females, the US participants, and participants aged 40 to 49 were less likely to develop MetS, respectively compared to males, South Koreans, and participants aged 50 to 59. LOBS further outweighed DOBS in mitigating the risk of MetS.

Limitations of the study

In the reviewed studies, OBS has not been assessed as a unique category (i.e., by tertile, quartile, and quintile) and the number of studies covered in this meta-analysis was trivial. The OBS range was not reported in the categories. In some studies, evaluations were not based on the gender of participants. Ultimately, the studies have been conducted only in the USA and South Korea.

Acknowledgments

The authors would like to thank Diana Sarokhani for guidance and editing of manuscript registration on the PROSPERO and research registry websites.

Authors' contribution

Conceptualization: Aliasghar Tabatabaei Mohammadi and Zahra Bazargani.
Data curation: Mehrangiz Ghafari and Afsaneh Mirshekari.
Formal analysis: Mohammad Reza Farnia, Sina Salati, and Elham Kebriyaei.
Investigation: Aliasghar Tabatabaei Mohammadi and Sara Rashki Ghalehno.
Methodology: Mohammad Reza Farnia, Sina Salati, and Sara Rashki Ghalehno.
Project management: Mehrangiz Ghafari.
Supervision: Aliasghar Tabatabaei Mohammadi.
Validation: Afsaneh Mirshekari and Elham Ahmadipour.
Visualization: Elham Ahmadipour and Sina Salati.
Writing–original draft: All authors.
Writing–reviewing and editing: All authors.

Conflicts of interest

There are no competing interests.

Ethical issues

This investigation has been compiled based on the PRISMA checklist, and its protocol was registered on the PROSPERO (International Prospective Register

of Systematic Reviews) with (ID: CRD42025643042) and Research Registry website with (Unique Identifying Number (UIN) reviewregistry1951) websites. Besides, the authors have observed ethical issues (including plagiarism, data fabrication, and double publication).

Funding/Support

No funding.

References

1. Kassi E, Pervanidou P, Kaltsas G, Chrousos G. Metabolic syndrome: definitions and controversies. BMC Med. 2011;9:48. doi: 10.1186/1741-7015-9-48.
2. De la Iglesia R, Loria-Kohen V, Zulet M, Martinez J, Reglero G, Ramirez de Molina A. Dietary strategies implicated in the prevention and treatment of metabolic syndrome. Int J Mol Sci. 2016 Nov 17:1877. doi: 10.3390/ijms17111877.
3. Saklayen M. The global epidemic of the metabolic syndrome. Curr Hypertens Rep. 2018;20:12. doi: 10.1007/s11906-018-0812-z.
4. Raut S, Khullar M. Oxidative stress in metabolic diseases: Current scenario and therapeutic relevance. Mol Cell Biochem. 2023;478:185-96. doi: 10.1007/s11010-022-04496-z.
5. Monserrat-Mesquida M, Quetglas-Llabrés M, Capó X, Bouzas C, Mateos D, Pons A, et al. Metabolic syndrome is associated with oxidative stress and proinflammatory state. Antioxidants (Basel). 2020 Mar 9:236. doi: 10.3390/antiox9030236.
6. Poljsak B, Šuput D, Milisav I. Achieving the balance between ROS and antioxidants: when to use the synthetic antioxidants. Oxid Med Cell Longev. 2013;2013:956792. doi: 10.1155/2013/956792.
7. Moylan J, Reid M. Oxidative stress, chronic disease, and muscle wasting. Muscle Nerve. 2007;35:411-29. doi: 10.1002/mus.20743.
8. Chen X, Wang C, Dong Z, Luo H, Ye C, Li L, et al. Interplay of sleep patterns and oxidative balance score on total cardiovascular disease risk: Insights from the National Health and Nutrition Examination Survey 2005-2018. J Glob Health. 2023;13:04170. doi: 10.7189/jogh.13.04170.
9. Zhang W, Peng S, Chen L, Chen H, Cheng X, Tang Y. Association between the Oxidative Balance Score and Telomere Length from the National Health and Nutrition Examination Survey 1999-2002. Oxid Med Cell Longev. 2022;2022:1345071. doi: 10.1155/2022/1345071.
10. Hernández-Ruiz Á, García-Villanova B, Guerra-Hernández E, Amiano P, Ruiz-Canela M, Molina-Montes E. A review of a priori defined oxidative balance scores relative to their components and impact on health outcomes. Nutrients. 2019:774. doi: 10.3390/nu11040774.
11. Goodman M, Bostick R, Dash C, Flanders W, Mandel J. Hypothesis: oxidative stress score as a combined measure of pro-oxidant and antioxidant exposures. Ann Epidemiol. 2007:394-9. doi: 10.1016/j.annepidem.2007.01.034.
12. Lakkur S, Goodman M, Bostick R, Citronberg J, McClellan W, Flanders W, et al. Oxidative balance score and risk for incident prostate cancer in a prospective US cohort study. Ann Epidemiol. 2014;24:475-8. doi: 10.1016/j.annepidem.2014.02.015.
13. Ilori T, Sun Ro Y, Kong S, Gutierrez O, Ojo A, Judd S, et al. Oxidative balance score and chronic kidney disease. Am J Nephrol. 2015;42:320-7. doi: 10.1159/000441623.
14. Kong S, Bostick R, Flanders W, McClellan W, Thyagarajan B, Gross M, et al. Oxidative balance score, colorectal adenoma, and markers of oxidative stress and inflammation. Cancer Epidemiol Biomarkers Prev. 2014 Mar 23:545-54. doi: 10.1158/1055-9965.EPI-13-0619.
15. Lee H, Park T. Pathway-driven approaches of interaction between oxidative balance and genetic polymorphism on metabolic syndrome. Oxid Med Cell Longev. 2017;2017:6873197. doi: 10.1155/2017/6873197.
16. Xu Z, Lei X, Chu W, Weng L, Chen C, Ye R. Oxidative balance score was negatively associated with the risk of metabolic syndrome, metabolic syndrome severity, and all-cause mortality of patients with metabolic syndrome. Front Endocrinol (Lausanne). 2024;14:1233145. doi: 10.3389/fendo.2023.1233145.
17. Moher D, Shamseer L, Clarke M, Ghersi D, Liberati A, Petticrew M, et al. Preferred reporting items for systematic review and meta-analysis protocols (PRISMA-P) 2015 statement. Syst Rev J. 2015;4:1e9. doi: 10.1186/2046-4053-4-1.
18. Stang A. Critical evaluation of the Newcastle-Ottawa scale for the assessment of the quality of nonrandomized studies in meta-analyses. Eur J Epidemiol. 2010;25:603e5.
19. Lu Y, Wang M, Bao J, Chen D, Jiang H. Association between oxidative balance score and metabolic syndrome and its components in US adults: a cross-sectional study from NHANES 2011-2018. Front Nutr. 2024;11:1375060. doi: 10.3389/fnut.2024.1375060.
20. Kim M, Shin D. Effects of the Interaction Between Oxidative Balance Score and Polygenic Risk Scores on Incidence of Metabolic Syndrome in Middle-Aged Korean Adults. Antioxidants (Basel). 2024:1556. doi: 10.3390/antiox13121556.
21. Li J, Liu Y, Li J, Feng Z, Bai L, Feng Y, et al. Association between the oxidative balance score with metabolic syndrome traits in US adults. Diabetol Metab Syndr. 2024:263. doi: 10.1186/s13098-024-01500-y.
22. Park H, Han T, Kwon Y, Lee J. Oxidative balance score inversely associated with the prevalence and incidence of metabolic syndrome: analysis of two studies of the Korean population. Front Nutr. 2023;10:1226107. doi: 10.3389/fnut.2023.1226107.
23. Li Y, Yuan H, Li Q, Geng S, Chen X, Zhu Y, et al. Lifestyle-based oxidative balance score and its association with cardiometabolic health of the community-dwelling elderly: a cross-sectional secondary analysis. Front Cardiovasc Med. 2022;9:1000546. doi: 10.3389/fcvm.2022.1000546.
24. Liu Y, Chen M. Dietary and lifestyle oxidative balance scores are independently and jointly associated with nonalcoholic fatty liver disease: a 20 years nationally representative cross-

sectional study. Front Nutr. 2023;10:1276940. doi: 10.3389/fnut.2023.1276940.
25. Wang K, Deng M, Wu J, Luo L, Chen R, Liu F, et al. Associations of oxidative balance score with total abdominal fat mass and visceral adipose tissue mass percentages among young and middle-aged adults: findings from NHANES 2011–2018. Front Nutr. 2023:1306428. doi: 10.3389/fnut.2023.1306428.
26. Zhu Z, Bai H, Li Z, Fan M, Li G, Chen L. Association of the oxidative balance score with obesity and body composition among young and middle-aged adults. Front Nutr 2024;11:1373709. doi: 10.3389/fnut.2024.1373709.
27. Jin D, Lv T, Chen S, Chen Y, Zhang C, Wang X, et al. Association between oxidative balance score and 10-year atherosclerotic cardiovascular disease risk: results from the NHANES database. Front Nutr. 2024:1422946. doi: 10.3389/fnut.2024.1422946.
28. Yang X, Zhang Z, Ye F, Liu P, Peng B, Wang T. Association between oxidative balance score and cardiovascular diseases: mediating analysis of methylmalonic acid based on the NHANES database. Front Nutr. 2024:1476551. doi: 10.3389/fnut.2024.1476551.
29. Kong X, Gao X, Wang W. Oxidative balance score and associations with dyslipidemia and mortality among US adults: A mortality follow-up study of a cross-sectional cohort. JPEN J Parenter Enteral Nutr. 2024;48:735-45. doi: 10.1002/jpen.2661.
30. Tan Z, Wu Y, Meng Y, Liu C, Deng B, Zhen J, et al. Trends in Oxidative Balance Score and Prevalence of Metabolic Dysfunction-Associated Steatotic Liver Disease in the United States: National Health and Nutrition Examination Survey 2001 to 2018. Nutrients. 2023;15:4931. doi: 10.3390/nu15234931.