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Obstructive sleep apnea risk and associated factors among patients with type 2 diabetes mellitus in Africa: systematic review and meta-analysis

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Abstract

Background Although obstructive sleep apnea affects people all across the world, there is limited information about the conditions in developing countries, notably in Africa. This study was conducted to address the aforementioned gaps by assessing the prevalence and determinants of obstructive sleep apnea risk among patients with type 2 diabetes mellitus in Africa.

Methods To strengthen the credibility and transparency of the study the Preferred Reporting Items for Systematic Reviews and Meta-Analysis Protocol (PRISMA—P 2015) guideline were utilized for the review. Two independent reviewers searched electronic databases such as PubMed, Science Direct, and African Journal Online. The researchers used Microsoft Excel for initial data import and STATA software for statistical analysis. Cochran's Q test was used to assess the presence of significant statistical heterogeneity I^2 statistic also used to quantify the degree of heterogeneity.

Results Electronic searches produced a total of 1072 papers. The study estimates that the pooled prevalence of OSA risk among patients with type 2 diabetes mellitus in Africa is 41.13% (95% CI: 17.95–54.30, $I^2 = 89.4\%$). There was significant heterogeneity among the selected studies (Q test $P < 0.001$) and I^2 ($I^2 = 89.4\%$). Hypertension (AOR = 4.07, 95%CI: 2.84, 5.81), being male (AOR = 3.06, 95%CI: 0.97, 9.62), body mass index of ≥ 30 kg/m^2 (AOR = 3.05, 95%CI: 0.86, 10.83) and neck circumference of 40 cm (AOR = 8.55, 95%CI: 4.83, 15.12) were factors associated with obstructive sleep apnea risk among patients with type 2 diabetes mellitus.

Conclusions The study found a high prevalence of high-risk obstructive sleep apnea risk among patients with type 2 diabetes mellitus. Male gender, body mass index of ≥ 30 kg/m^2 (obesity), neck circumference of > 40 cm and comorbid hypertension were significantly associated with obstructive sleep apnea risk among the study participants. The study emphasizes the importance of integrating obstructive sleep apnea screening and evaluation procedures into routine follow-up care for patients with type 2 diabetes mellitus.

Keywords Obstructive sleep apnea, Type 2 diabetes mellitus, Meta-analysis, Africa

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Background

Diabetes is a major cause of death and disability, with 1.5 million deaths directly attributed to the disease each year Gouda et al. 2019. According to the International Diabetes Federation (IDF), 24 million adults in Africa were estimated to be living with diabetes in 2021. A 129% rise in diabetes cases in Africa by 2045, bringing the number from 24 million to a projected 55 million, is a serious public health concern Cho et al. 2018. Type 2 diabetes as the major contributor to diabetes-related deaths and disability Ogurtsova et al. 2022. Chronically high blood sugar levels can harm nerves and blood vessels throughout the body, increasing the risk of major health complications such as heart disease, stroke, renal failure, blindness, and amputations Herman 2017.

Sleep disturbance can have a major impact on the upper airway muscles and the neurotransmitters that govern them, contributing to sleep apnea and other breathing disorders Zielinski et al. 2016; Eban-Rothschild et al. 2018. Sleep-disordered breathing (SDB) events are categorized based on the cause and presence of airflow during apneas (pauses in breathing). Obstructive sleep apnea (OSA) is indeed the most common type of sleep-disordered breathing (SDB). It is characterized by upper airway collapse, occasional hypoxia, and sleep fragmentation Sateia 2014. Obstructive sleep apnea (OSA) is a major public health concern on a global scale, impacting a vast number of people. Obstructive sleep apnea (OSA) can have a wide range of negative health consequences due to the repeated cycles of oxygen deprivation and sleep disruption it causes Benjafield et al. 2019; Young et al. 2009. People with type 2 diabetes (T2DM) are at a significantly increased risk of developing obstructive sleep apnea (OSA) Aronsohn et al. 2010.

Intermittent hypoxemia, a hallmark feature of OSA, plays a significant role in the development of insulin resistance in people with T2DM. Punjabi et al. 2002. Untreated Obstructive Sleep Apnea [OSA) can have a wide range of negative health consequences Marshall et al. 2008. The likelihood of death or cardiovascular disease in persons with OSA is exactly 2.5% and 4.5%, respectively Lee et al. 2013. During OSA episodes, the body experiences oxygen deprivation and disrupted sleep. This activates the body's stress response, causing inflammation and elevated blood pressure Siwasaranond and Nimitphong 2018.

According to previous studies conducted around the world, OSA is associated with advanced age Kalakattawi et al. 2017, male gender Viswanathan et al. 2017, large neck circumference Edmonds and Gunasekaran 2019; Saad et al. 2019, high body mass index Amin et al. 2017; Foster et al. 2009, increased waist circumference Foster et al. 2009, high waist-to-hip circumference ratio Lim et al. 2014, dyslipidemia Silva and Brito 2021, hypertension Schober et al. 2011, physical inactivity Mônico-Neto et al. 2018, smoking Saad et al. 2019, and alcohol consumption Simou et al. 2018.

Although OSA affects people all across the world, there is limited information about the conditions in developing countries, notably in Africa. This study was conducted to address the aforementioned gaps by assessing the prevalence and determinants of OSA risk among patients with type 2 diabetes mellitus in Africa.

Materials and methods

Protocol design and registration

To strengthen the credibility and transparency of the study the Preferred Reporting Items for Systematic Reviews and Meta-Analysis Protocol (PRISMA—P 2015) guideline were utilized for the review Shamseer et al. 2015 (Supplementary file). This systematic review and meta-analysis is registered in PROSPERO with the reference number CRD42024568823.

Eligibility criteria

The review includes all peer-reviewed papers that employed a cross-sectional study design to identify obstructive sleep apnea risk and associated factors in patients with type 2 diabetes, and studies published in English. The review excluded articles that were case series, had a questionable definition of risk of obstructive sleep apnea, or did not give quantitative information on obstructive sleep apnea outcomes.

Data sources and searching strategy

Two independent reviewers (WCT and SSW) searched electronic databases such as PubMed, Science Direct, and African Journal Online for works published between January 1 2010 and December 31 2024. In addition Google Scholar was used to search additional relevant articles for the review. For studies with unavailable full texts, contacted and asked the primary authors by email. The reference lists of previously uncovered studies were searched for further articles. The search results were managed using EndNote X7 software. Similarly, the entire text of the chosen articles was thoroughly examined in light of the inclusion criteria.

Study selection

All citations discovered by the search strategy were exported to EndNote software version X7 (Thomson Reuters, New York, NY), where duplicates were removed. Two independent reviewers (WCT and SSW) assessed the remaining citations' titles and deleted ineligible papers. Prior to data extraction, the whole texts of selected publications were obtained and rigorously reviewed to guarantee their eligibility. The analysis relied on data from articles that met the inclusion criteria.

Data extraction and quality assessment

Two independent reviewers (WCT and SSW) carried out the abstract and full-text reviews, as well as data extraction, using a standardized data abstraction form established on an MS-Excel sheet based on the order of information required from primary studies. Articles having methodological errors or insufficient reporting of results in the full text were excluded from the analysis. The data extraction format included the primary author's name, publication year, country, outcome measuring method, response rate, sample size, and prevalence of OSA risk. The differences between the two reviewers were resolved through discussion. Two authors (AMZ, and YAF) assessed the quality of the included studies using the Johanna Briggs Institute (JBI) quality evaluation checklist Institute 2017. The components of the JBI quality assessment checklist consists of the following nine items:

1. Pattern Body: Was the study design appropriate for the research question and target population (African T2DM patients in this case)?
2. Sample: Were participants selected in a way that represents the target population and minimizes bias?
3. Sample Size: Was the number of participants in the study large enough to draw reliable conclusions?
4. Concepts: Were the key concepts of interest (e.g., OSA, T2DM) clearly defined by the study?
5. Record Evaluation: Were the methods used to collect data from participants reliable and consistent?
6. Identification of the condition: Were valid methods used to diagnose OSA in the study?
7. Measurement: Were the same methods used to measure relevant variables (e.g., sleep apnea severity) for all participants?
8. Statistical Analysis: Were appropriate statistical methods used to analyze the data and draw conclusions?
9. Response Rate: Was the proportion of participants who completed the study high enough to ensure reliable findings? Each question is scored as 0 (not reported or unacceptable) or 1 (yes). The total score ranges from 0 to 9. Studies are categorized as low quality (0–4), medium quality (5 –6), or high quality Sateia 2014; Benjafield et al. 2019; Young et al. 2009 based on their total score.

Outcome measurement

The primary focus of the review is to determine the pooled prevalence (overall percentage) of OSA risk among patients with type 2 diabetes mellitus in Africa. Risk of obstructive sleep apnea was defined as Yes to 5–8 questions, or Yes to 2 or more of 4 STOP questions combined with male sex, or Yes to 2 or more of 4 STOP questions combined with BMI > 35 kg/m², or Yes to 2 or more of 4 STOP questions combined with neck circumference ≥ 40 cm based on STOP-Bang questionnaire or obstructive sleep apnea defined as a syndrome diagnosed with a positive berlin score in at least two of the three categories based on berlin questionnaire. The STOP-bang questionnaire, used to evaluate the risk of OSA It includes STOP (S: Snores loudly, T: Tired or drowsy during the daytime, O: Observed apnea, P: Pressure – elevated blood pressure, and the **BANG** (B refers BMI, A for Age, N for Neck circumference, and G for Gender). For every question, answering "Yes" ratings 1, and a "No" reaction ratings 0. The general rating of the document stages from 0 to 8, and sufferers had been classified for OSA threat in line with their corresponding scores Chung et al. 2016; Saleh et al. 2011.

Statistical analysis

Testing for heterogeneity

The researchers used Microsoft Excel for initial data import and STATA version 11 software for statistical analysis. Cochran's Q test was used to assess the presence of significant statistical heterogeneity. I^2 statistic also used to quantify the degree of heterogeneity. A p-value less than 0.05 indicates that the observed variability is unlikely to be due to chance alone Higgins et al. 2003. Heterogeneity had taken low heterogeneity ($I^2 < 25\%$), moderate heterogeneity ($25\% \leq I^2 \leq 75\%$) and high heterogeneity ($I^2 > 75\%$) Cumpston et al. 2019; Huedo-Medina et al. 2006. Given the anticipated heterogeneity, a random-effects model was used. This model acknowledges that the included studies are a sample of a larger population and accounts for the variability between them. The model is more suitable for estimating the overall prevalence when significant heterogeneity is present Borenstein et al. 2010. Subgroup analysis was done based on sampling procedure to compare the prevalence estimates within each group Sensitivity analysis was also undertaken to assess whether there is influential individual studies that are significantly impacts the combined results. Meta-regression analysis was also done to statistically examining whether study characteristics influence the reported prevalence.

Publication bias assessment

A graphical funnel plot tool was used to visually assess publication bias. In addition a statistical test that helps to quantify the likelihood of publication bias was utilized. A statistically significant p-value (less than 0.05) with Egger's test indicates potential bias.

Result

Study selection

Figure 1 shows the flow chart and selection technique for calculating the pooled prevalence of OSA risk among type 2 diabetic patients. Electronic searches produced a total of 1072 papers. These include 60 from PubMed, 30 from Science Direct, 941 from Google Scholar, and 41 from the African Journal Online. Approximately 852 duplicate articles were removed, and an additional 140 publications were rejected because they did not address the research topic. The full-text of the remaining 80 papers was reviewed for eligibility and quality. Furthermore, an item was rejected because the outcome variable was incorrectly supplied. Finally, only ten studies on the prevalence of OSA risk were reviewed (Fig. 1).

Overview of included studies

The current study included 10 original articles published until May 5, 2024, and a total of 2075 study participants. Three articles were obtained from Ethiopia Alemayehu et al. 2022; Abdissa 2020; Worku et al. 2023, Two from Nigeria Umoh et al. 2020; Obaseki et al. 2014, Three from Egypt Embarak et al. 2019; Agha et al. 2019; Sweed et al. 2023, and the remainder from Benin and Kenya Ade et al. 2021; Sokwalla et al. 2017. All the investigations were published in peer-reviewed journals. The first study was published in 2014 Obaseki et al. 2014, while the most recent study was released in 2024 Umoh et al. 2020. The included studies had sample sizes ranging from 42 to 383 people. All of the examined studies employed an institutional-based cross-sectional study design. The higher prevalence of OSA risk (60%) was observed in Egypt research Embarak et al. 2019, whereas the lowest prevalence from Benin Ade et al. 2021 (Table 1).

Quality appraisal

The JBI quality rating criteria designed for analytical cross-sectional research were used (Supplementary file).

Meta-analysis

Pooled estimates of obstructive sleep apnea

The study estimates that the pooled prevalence of OSA risk among patients with type 2 diabetes mellitus in Africa is 41.13% (95% CI: 17.95–54.30, I^2 = 89.4%). The I^2 statistic (I^2 = 89.4%) suggests significant heterogeneity among the studies included in the analysis. Due to

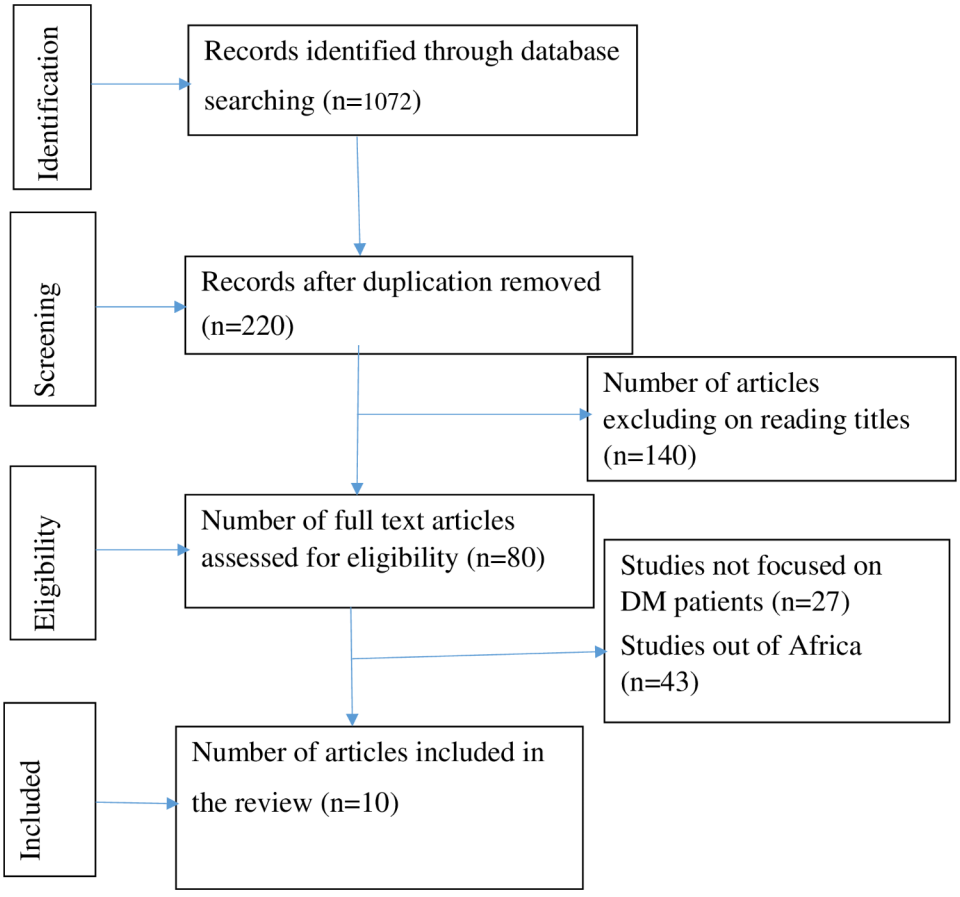

Fig. 1 PRISMA flow diagram for a systematic review and meta-analysis of prevalence and associated factors of obstructive sleep apnea risk among patients with DM in Africa (*N* = 10).

Table 1 Overview of included studies in the systematic review and meta-analysis of the prevalence of obstructive sleep apnea risk among patients with type 2 diabetes mellitus in Africa ($N=10$)

Author name	Pub year	Country	Sampling technique	Sample size	Prevalence	Questionnaire used
Wondie et al. 2022	2022	Ethiopia	purposive	204	42.2	Berlin
D. Abdissa 2020	2020	Ethiopia	consecutive	253	45.5	STOP BANG
Sokwalla et al. 2017	2017	Kenya	consecutive	245	44	Berlin
Worku et al. 2023	2023	Ethiopia	systematic random	335	31.97	STOP BANG
Obaseki, et al. 2014	2014	Nigeria	consecutive	117	27	Berlin
Serge Ade et al. 2021	2021	Benin	systematic random	383	14.1	STOP BANG
Mohammed A. et al. 2019	2019	Egypt	consecutive	42	10.61	STOP BANG
Embarak et al. 2019	2018	Egypt	consecutive	110	60	STOP BANG
Umoh et al. 2020	2020	Nigeria	consecutive	327	49.5	Berlin
Sweed et al. 2023	2023	Egypt	consecutive	59	78	STOP BANG

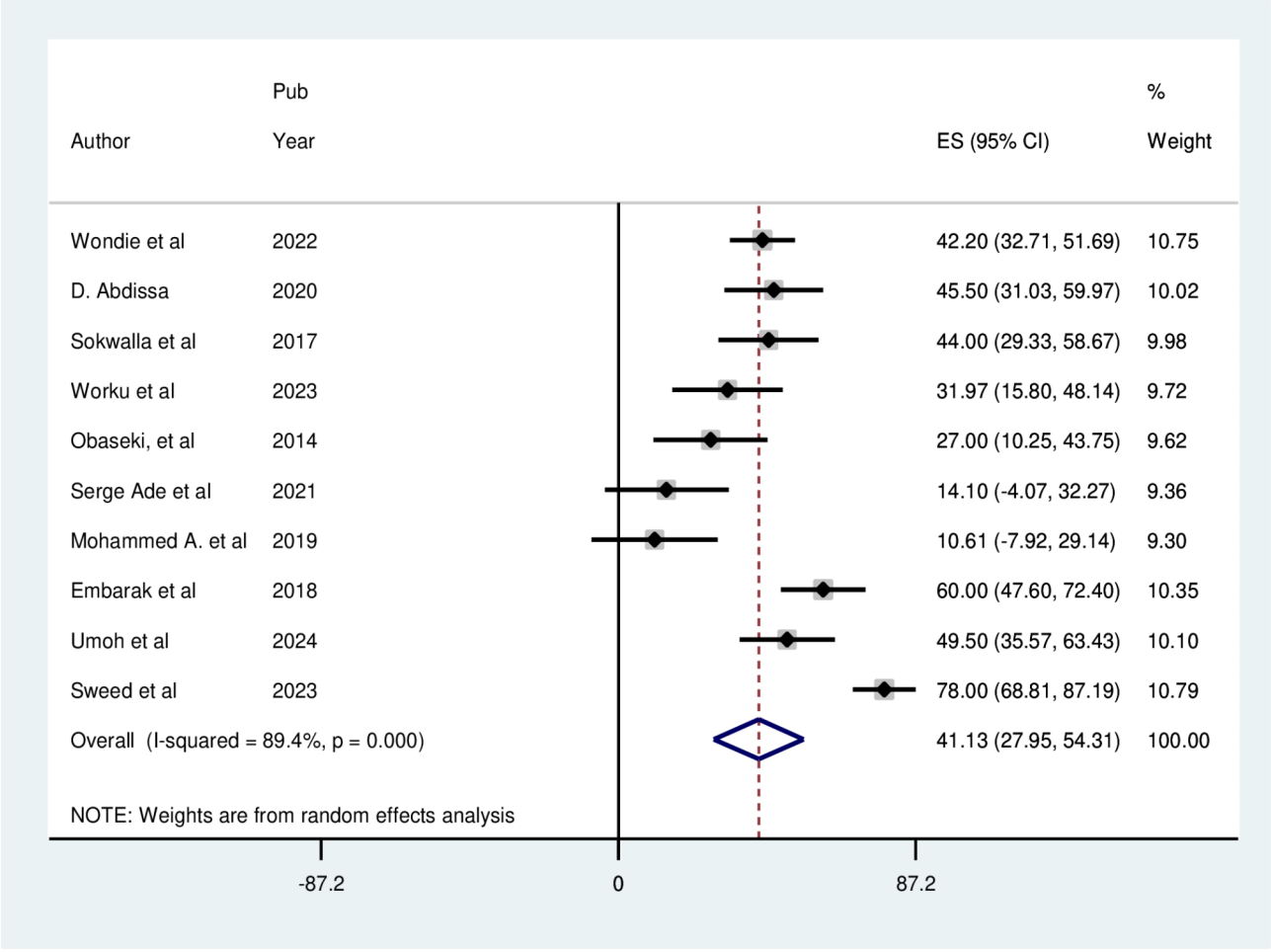

Fig. 2 Forest plot for the prevalence of OSA risk among patients with type 2 diabetes mellitus Subgroup analysis.

the high heterogeneity, the researchers used a random-effects model to estimate the pooled prevalence (Fig. 2).

The subgroup analysis suggests the highest pooled prevalence of OSA risk (45.42%) was found in studies that used non-probability sampling methods (Fig. 3).

Publication bias

The funnel plot visually showed an uneven distribution of studies, suggesting potential bias. Egger's test statistically confirmed this bias with a p-value of 0.007, which is significant at the 5% level (Fig. 4).

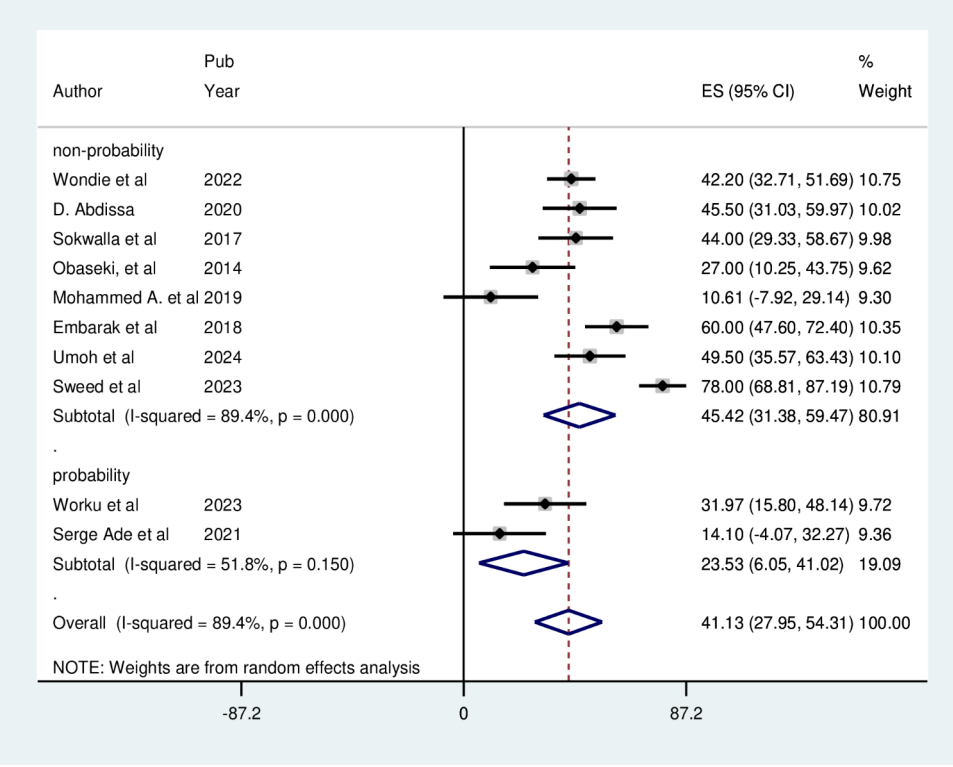

Fig. 3 A subgroup analysis of the forest plot showing the pooled prevalence of obstructive sleep apnea risk among patients with type 2 diabetes mellitus in Africa based on sampling procedure.

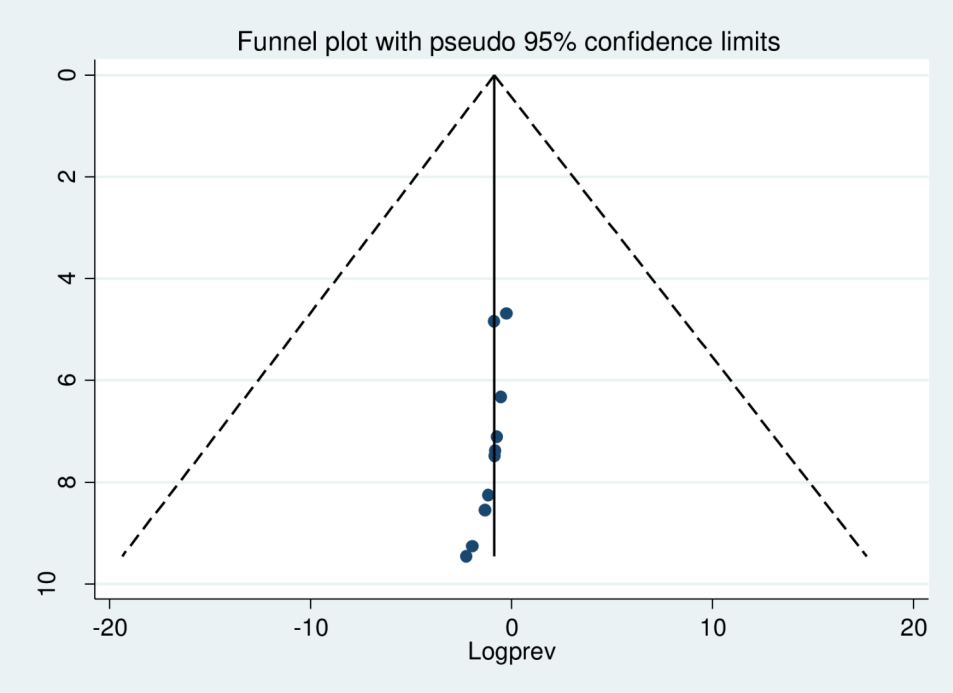

Fig. 4 Funnel plot showing publication bias.

Meta-regression and sensitivity analysis

The subgroup analysis found a substantial degree of variability between studies. We conducted a meta-regression and sensitivity analysis to determine the source of heterogeneity. In the meta-regression analysis, we employed the following study covariance: publication year, sample size, and participants. However, the study found that none of these factors were statistically significant contributors of heterogeneity. We also performed a sensitivity analysis to examine the impact of each study on the overall effect sizes. No single primary study affected the total pooled prevalence of obstructive sleep apnea risk among patients with type 2 diabetes mellitus in Africa.

Associated factors of obstructive sleep apnea risk

Patients with hypertension had a 4.07-fold (AOR=4.07, 95%CI: 2.84, 5.81) greater risk of having OSA than their counterparts. Male study participants exhibited a 3.06-fold higher risk of OSA than female individuals (AOR=3.06, 95%CI: 0.97, 9.62). Patients with a BMI≥30 kg/m² were 3.05 times (AOR=3.05, 95%CI: 0.86, 10.83) more likely to have OSA than their counterparts. Patients with a neck circumference of 40 cm or more were discovered to have an 8.55 times (AOR=8.55, 95%CI: 4.83, 15.12) increased likelihood of being at high risk of OSA than their counterparts (Fig. 5).

Discussion

This study determines the prevalence and associated risk factors of high risk OSA risk among type 2 diabetes patients. The study estimated a pooled prevalence of high-risk OSA at 41.13% among African T2DM patients. Therefore, the research outcomes suggest that T2DM patients need to be screened for OSA by health care providers in health facilities in the early course of their follow-up and treatment to reduce the burden of high-risk OSA and related complications. To date, (insulin resistance) IR has been proven as a pathogenic mechanism connecting OSA to OSA-related diseases, and therefore, many attempts were targeted at finding an appropriate way to measure IR. Notably, among the methods used the TyG index has been proven to be one of the easier-to-dose and cost-effective surrogates of IR with a diagnostic and prognostic value comparable to other IR markers, such as the HOMA-IR or the hyperinsulinemic/euglycemic clamp (HEC). This result was in line with findings from Saudi Arabia 44.3% Algeffari et al. 2020, and in India 47.3% Bamanikar et al. 2020. However, the results of this study were higher than those conducted in Brazil, and Saudi Arabia, which reported that the prevalence of high risk of OSA was 17%, and 15.2%, respectively Kalakattawi et al. 2017; Fonseca and Moreira 2021. The possible reason for this might be underlying demographic or

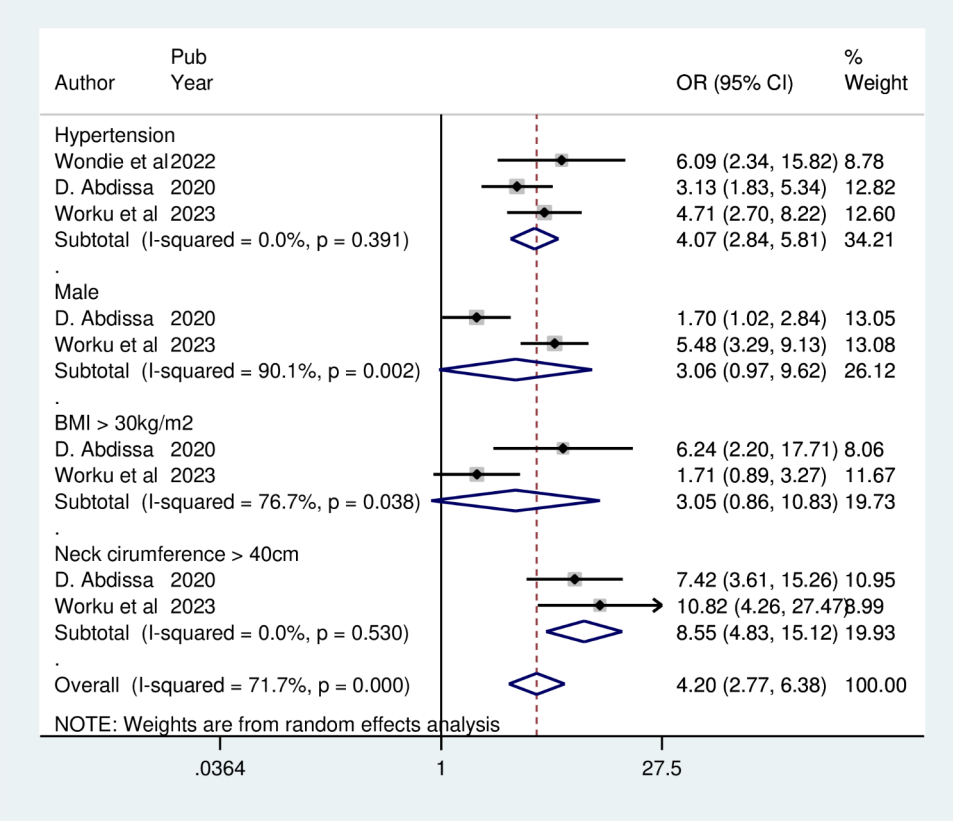

Fig. 5 Factors associated with OSA risk among patients with type 2 diabetes mellitus in Africa.

genetic differences between the populations studied that influence OSA risk and different questionnaires or diagnostic techniques to assess OSA risk.

On the other hand, the current finding was lower than a study done in USA 86% Foster et al. 2009, UK 57% West et al. 2006, Thailand (75.6%) Siwasaranond and Nimitphong 2018, and China (60%) Zhang et al. 2016. The decreased prevalence observed in this study could be attributed from different reasons. Studies from the USA and India included people who were mostly overweight or obese, which are known risk factors for OSA. People in the African study might have lower socioeconomic status compared to those in other regions, potentially leading to under-diagnosis Manin et al. 2015. Studies in Thailand and China employed polysomnography, considered a gold standard but resource-intensive. The African study might have used questionnaires or less-comprehensive techniques, potentially leading to underestimation of OSA risk prevalence.

The study found that patients with hypertension have a higher risk of developing high-risk OSA compared to those with normal blood pressure. This aligns with previous studies conducted in India, Thailand, and UK Siwasaranond and Nimitphong 2018; Viswanathan et al. 2017; Subramanian and Adderley 2019. The likely explanation is the body responds to hypoxia by activating the sympathetic nervous system, which is responsible for the "fight-or-flight" response. This increased sympathetic activity can lead to elevated heart rate and blood pressure Baguet et al. 2012. The study found that males were 3.06 times more likely to have high-risk OSA compared to females. This finding aligns with previous research conducted in Norway Fredheim et al. 2011, and South Korea Shim et al. 2011. The cause of these disparities is unknown, however men have higher testosterone levels, which might contribute to upper airway narrowing and increase OSA risk. Conversely, estrogen in females might have a protective effect. In addition men might have anatomical differences in their upper airways, making them more prone to collapse during sleep compared to women Kapsimalis and Kryger 2002.

The study found that patients with a BMI of 30 kg/m² or higher were more likely to have high-risk OSA compared to those with a lower BMI. This aligns with prior studies conducted in China, European and India Viswanathan et al. 2017; Amin et al. 2017; Zhang et al. 2015. Excess weight, particularly around the neck, narrows the upper airway, making it more prone to collapse during sleep. Obesity can reduce functional residual capacity, further limiting airflow during sleep Fogel et al. 2004. The study found that patients with a neck circumference of 40 cm or more were 8.55 times more likely to have high-risk OSA compared to those with a smaller neck size. This finding is consistent with a previous study conducted in Jordan Saad et al. 2019. The larger neck circumference is likely linked to increased fat deposits around the upper airway and throat. This tissue crowding can narrow the airway, making it more prone to collapse during sleep and potentially leading to OS.

Strength and limitations of the study

The study's main strength is that it provides data on the overall epidemiology of OSA risk in the African population. Furthermore, one of the process's strengths is its comprehensiveness, which included a search of four different databases. The pooled OSA risk prevalence presented here should be a useful starting point for understanding the disease burden in Africa and guiding future lines of research, prevention design, and resource allocation and planning. The study has certain limitation. First, the studies included in the review might have used different criteria to diagnose OSA risk. This can lead to inconsistency in the reported prevalence, making it difficult to compare results accurately. In addition the questionnaire are useful to diagnose OSA they declare only risk prevalence of OSA. Second, the study does not have data from all African countries. This limits the generalizability of the findings to the entire continent. Third, the studies included were cross-sectional studies. They cannot definitively prove cause-and-effect relationships.

Conclusions and recommendation

The study found a high prevalence of high-risk obstructive sleep apnea among patients with type 2 diabetes mellitus. Male gender, body mass index of ≥30 kg/m² (obesity), neck circumference of >40 cm and comorbid hypertension were significantly positively associated with obstructive sleep apnea among the study participants. The study emphasizes the importance of integrating obstructive sleep apnea screening and evaluation procedures into routine follow-up care for T2DM patients. Physicians are advised to be especially vigilant about monitoring for obstructive sleep apnea in T2DM patients with BMI≥30 kg/m², neck circumference>40 cm and hypertension. The finding of the study is important for physicians to provide special attention to T2DM patients who are male in gender, having body mass index of ≥30 kg/m² (obesity), neck circumference of >40 cm and comorbid hypertension for early notice of high-risk OSA to take preventive care and to minimize further complications.

Abbreviations

DM	Diabetes mellitus
OSA	Obstructive Sleep Apnea
WHO	World Health Organization

Supplementary Information

The online version contains supplementary material available at https://doi.org/10.1186/s41606-024-00112-9.

Supplementary Material 1

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Author contributions
WCT: hypothesized and designed the review, writing the proposal, data extraction, performed data analysis, and drafted the manuscript, quality appraisal, and interpretation of the findings. SSW helped in data extraction. AMZ, YAF: helped quality appraisal. Finally, the authors reviewed and approved the final manuscript.

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Data availability
No datasets were generated or analysed during the current study.

Declarations

Ethics approval and consent to participate
Not applicable since the studies used were systematic reviews and meta-analyses.

Consent for publication
Not applicable.

Competing interests
The authors declare no competing interests.

Supporting information
PRISMA checklist and quality assessment of included articles using the Joanna Briggs Institute (JBI) critical appraisal checklist (Supplementary file).

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References

Abdissa D. Prevalence of obstructive sleep apnea risk and associated factors among patients with type 2 diabetes mellitus on follow up at Jimma Medical Center, Southwest Ethiopia. J Clin Translational Endocrinol. 2020;21:100234.
Ade S, Alassani AC, Wachinou PA, Youzeu AT, Imorou A, Fanou L, et al. Risk of obstructive sleep apnea and quality of sleep among adults with type 2 diabetes mellitus in a sub-saharan Africa city. Pan Afr Med J. 2021;40:264.
Agha MA, Shehab-Eldin W, Helwa MA. Obstructive sleep apnea in patients with type 2 diabetes mellitus. Egypt J Chest Dis Tuberculosis. 2019;68(4):560–6.
Alemayehu W, Mammo T, Betemariam G, Atsede G, Daniel T, Fetene T, et al. Obstructive sleep apnea risk and its associated factors among type 2 diabetes mellitus patients at wolkite university specialized hospital, Wolkite, Southern Ethiopia, 2021. A comparative cross-sectional study. Diabetol Metabolic Syndrome (Web). 2022;14(1):1–13.
Algeffari MAA, Almesned A, Alghammas N, Albulayhi S, AlGoblan A. Obstructive sleep apnea among people with type 2 diabetes in Saudi Arabia: a cross-sectional study. Majmaah J Health Sci. 2020;6(2):32.
Amin A, Ali A, Altaf QA, Piya MK, Barnett AH, Raymond NT, et al. Prevalence and associations of Obstructive Sleep Apnea in South asians and White europeans with type 2 diabetes: a cross-sectional study. J Clin Sleep Medicine: JCSM : Official Publication Am Acad Sleep Med. 2017;13(4):583–9.
Aronsohn RS, Whitmore H, Van Cauter E, Tasali E. Impact of untreated obstructive sleep apnea on glucose control in type 2 diabetes. Am J Respir Crit Care Med. 2010;181(5):507–13.
Baguet JP, Barone-Rochette G, Tamisier R, Levy P, Pépin JL. Mechanisms of cardiac dysfunction in obstructive sleep apnea. Nat Reviews Cardiol. 2012;9(12):679–88.
Bamanikar A, Duggal S, Sharma S, Rana S. Assessment of risk for obstructive sleep apnea by using STOP-BANG questionnaire in type 2 diabetes mellitus. Int J Diabetes Developing Ctries. 2020;40(2):173–7.
Benjafield AV, Ayas NT, Eastwood PR, Heinzer R, Ip MSM, Morrell MJ, et al. Estimation of the global prevalence and burden of obstructive sleep apnoea: a literature-based analysis. Lancet Respiratory Med. 2019;7(8):687–98.
Borenstein M, Hedges LV, Higgins JP, Rothstein HR. A basic introduction to fixed-effect and random-effects models for meta-analysis. Res Synthesis Methods. 2010;1(2):97–111.
Cho NH, Shaw JE, Karuranga S, Huang Y, da Rocha Fernandes JD, Ohlrogge AW, et al. IDF Diabetes Atlas: global estimates of diabetes prevalence for 2017 and projections for 2045. Diabetes Res Clin Pract. 2018;138:271–81.
Chung F, Abdullah HR, Liao P, STOP-Bang Questionnaire. A practical Approach to screen for obstructive sleep apnea. Chest. 2016;149(3):631–8.
Cumpston M, Li T, Page MJ, Chandler J, Welch VA, Higgins JP, et al. Updated guidance for trusted systematic reviews: a new edition of the Cochrane Handbook for Systematic Reviews of Interventions. Cochrane Database Syst Rev. 2019;10(10):Ed000142.
Eban-Rothschild A, Appelbaum L, de Lecea L. Neuronal Mechanisms for Sleep/Wake Regulation and Modulatory Drive. Neuropsychopharmacology: Official Publication Am Coll Neuropsychopharmacol. 2018;43(5):937–52.
Edmonds PJ, Gunasekaran K. Neck Grasp predicts obstructive sleep apnea in type 2. Diabetes Mellitus. 2019;2019:3184382.
Embarak S, Abbas A, Al-Nashar HY, Farag SE. The relationship between obstructive sleep apnea and diabetic retinopathy in type 2 diabetes patients, Zagazig University Hospitals, Egypt. Egypt J Chest Dis Tuberculosis. 2019;68(3):290–5.
Fogel RB, Malhotra A, White DP. Sleep. 2: pathophysiology of obstructive sleep apnoea/hypopnoea syndrome. Thorax. 2004;59(2):159–63.
Fonseca MAD, Moreira AKS. Relationship between obstructive sleep apnea syndrome and functional capacity in patients with diabetes mellitus type 2: an observational transversal study. 2021;67(6):878–81.
Foster GD, Sanders MH, Millman R, Zammit G, Borradaile KE, Newman AB, et al. Obstructive sleep apnea among obese patients with type 2 diabetes. Diabetes Care. 2009;32(6):1017–9.
Fredheim JM, Rollheim J, Omland T, Hofsø D, Røislien J, Vegsgaard K, et al. Type 2 diabetes and pre-diabetes are associated with obstructive sleep apnea in extremely obese subjects: a cross-sectional study. Cardiovasc Diabetol. 2011;10:84.
Gouda HN, Charlson F, Sorsdahl K, Ahmadzada S, Ferrari AJ, Erskine H, et al. Burden of non-communicable diseases in sub-saharan Africa, 1990–2017: results from the global burden of Disease Study 2017. Lancet Global Health. 2019;7(10):e1375–87.
Herman WH. The global burden of diabetes: an overview. In: Dagogo-Jack S, editor. Diabetes Mellitus in developing Countries and Underserved communities. Cham: Springer International Publishing; 2017. pp. 1–5.
Higgins JP, Thompson SG, Deeks JJ, Altman DG. Measuring inconsistency in meta-analyses. BMJ (Clinical Res ed). 2003;327(7414):557–60.
Huedo-Medina TB, Sánchez-Meca J, Marín-Martínez F, Botella J. Assessing heterogeneity in meta-analysis: Q statistic or I2 index? Psychol Methods. 2006;11(2):193–206.
Institute JB. The Joanna Briggs Institute critical appraisal tools for use in JBI systematic reviews. Critical Appraisal Checklist for Cohort Studies. 2017.
Kalakattawi RMN, Kalakattawi AMN, Alsuqati FA, Alzhrani SA, Alhamyani AH, Alhamyani AH, et al. Risk of Obstructive Sleep Apnea Assessment among patients with type 2 diabetes in Taif, Saudi Arabia. J Clin Med Res. 2017;9(12):1002–6.
Kapsimalis F, Kryger MH. Gender and obstructive sleep apnea syndrome, part 2: mechanisms. Sleep. 2002;25(5):499–506.
Lee JE, Lee CH, Lee SJ, Ryu Y, Lee WH, Yoon IY, et al. Mortality of patients with obstructive sleep apnea in Korea. J Clin Sleep Medicine: JCSM : Official Publication Am Acad Sleep Med. 2013;9(10):997–1002.
Lim YH, Choi J, Kim KR, Shin J, Hwang KG, Ryu S, et al. Sex-specific characteristics of anthropometry in patients with obstructive sleep apnea: neck circumference and waist-hip ratio. Ann Otol Rhinol Laryngol. 2014;123(7):517–23.
Manin G, Pons A, Baltzinger P, Moreau F, Iamandi C, Wilhelm JM, et al. Obstructive sleep apnoea in people with type 1 diabetes: prevalence and association

with micro- and macrovascular complications. Diabet Medicine: J Br Diabet Association. 2015;32(1):90–6.
Marshall NS, Wong KKH, Liu PY, Cullen SRJ, Knuiman MW, Grunstein RR. Sleep apnea as an independent risk factor for all-cause mortality: the Busselton Health Study. Sleep. 2008;31(8):1079–85.
Mônico-Neto M, Moreira Antunes HK, Dos Santos RVT, D'Almeida V, Alves Lino de Souza A, Azeredo Bittencourt LR et al. Physical activity as a moderator for obstructive sleep apnoea and cardiometabolic risk in the EPISONO study. Eur Respir J. 2018;52(4).
Obaseki DO, Kolawole BA, Gomerep SS, Obaseki JE, Abidoye IA, Ikem RT, et al. Prevalence and predictors of obstructive sleep apnea syndrome in a sample of patients with type 2 diabetes Mellitus in Nigeria. Nigerian Med Journal: J Nigeria Med Association. 2014;55(1):24–8.
Ogurtsova K, Guariguata L, Barengo NC, Ruiz PL-D, Sacre JW, Karuranga S, et al. IDF Diabetes Atlas: global estimates of undiagnosed diabetes in adults for 2021. Diabetes Res Clin Pract. 2022;183:109118.
Punjabi NM, Sorkin JD, Katzel LI, Goldberg AP, Schwartz AR, Smith PL. Sleep-disordered breathing and insulin resistance in middle-aged and overweight men. Am J Respir Crit Care Med. 2002;165(5):677–82.
Saad AMJ, Hiyasat D, Jaddou H, Obeidat N. The prevalence of high risk obstructive sleep apnoea among patients with type 2 diabetes in Jordan. Diabetes Res Clin Pract. 2019;152:16–22.
Saleh AB, Ahmad MA, Awadalla NJ. Development of arabic version of Berlin questionnaire to identify obstructive sleep apnea at risk patients. Annals Thorac Med. 2011;6(4):212–6.
Sateia MJ. International classification of sleep disorders-third edition: highlights and modifications. Chest. 2014;146(5):1387–94.
Schober AK, Neurath MF, Harsch IA. Prevalence of sleep apnoea in diabetic patients. Clin Respir J. 2011;5(3):165–72.
Shamseer L, Moher D, Clarke M, Ghersi D, Liberati A, Petticrew M, et al. Preferred reporting items for systematic review and meta-analysis protocols (PRISMA-P) 2015: elaboration and explanation. BMJ (Clinical Res ed). 2015;350:g7647.
Shim U, Lee H, Oh JY, Sung YA. Sleep disorder and cardiovascular risk factors among patients with type 2 diabetes mellitus. Korean J Intern Med. 2011;26(3):277–84.
Silva R, Brito TP. Major risk factors for obstructive sleep apnea monitored in the home. A cross-sectional study. 2021;139(6):643–7.
Simou E, Britton J, Leonardi-Bee J. Alcohol and the risk of sleep apnoea: a systematic review and meta-analysis. Sleep Med. 2018;42:38–46.
Siwasaranond N, Nimitphong H. The relationship between diabetes-related complications and obstructive sleep apnea in type 2. Diabetes. 2018;2018:9269170.
Sokwalla SM, Joshi MD, Amayo EO, Acharya K, Mecha JO, Mutai KK. Quality of sleep and risk for obstructive sleep apnoea in ambulant individuals with type 2 diabetes mellitus at a tertiary referral hospital in Kenya: a cross-sectional, comparative study. BMC Endocr Disorders. 2017;17(1):7.
Subramanian A, Adderley NJ. Risk of Incident Obstructive Sleep Apnea among patients with type 2 diabetes. 2019;42(5):954–63.
Sweed RA, Wahab NHAE, El Hooshy MS, Morsy EY, Shetta DM. Obstructive sleep apnea in patients with type 2 diabetes mellitus in Egyptian population. Egypt J Bronchol. 2023;17(1):55.
Umoh VA, Akpan EE, Ekrikpo UE, Idung AU, Ekpe EE. The risk of obstructive sleep apnea among patients with type 2 diabetes Mellitus. Nigerian Med J. 2020;61(1):32–6.
Viswanathan V, Ramalingam IP, Ramakrishnan N. High prevalence of obstructive sleep apnea among people with type 2 diabetes Mellitus in a Tertiary Care Center. J Assoc Phys India. 2017;65(11):38–42.
West SD, Nicoll DJ, Stradling JR. Prevalence of obstructive sleep apnoea in men with type 2 diabetes. Thorax. 2006;61(11):945–50.
Worku A, Ayele E, Alemu S, Legese GL, Yimam SM, Kassaw G, et al. Obstructive sleep apnea risk and determinant factors among type 2 diabetes mellitus patients at the chronic illness clinic of the University of Gondar Comprehensive Specialized Hospital, Northwest Ethiopia. Front Endocrinol. 2023;14:1151124.
Young T, Palta M, Dempsey J, Peppard PE, Nieto FJ, Hla KM. Burden of sleep apnea: rationale, design, and major findings of the Wisconsin Sleep Cohort study. WMJ: Official Publication State Med Soc Wis. 2009;108(5):246–9.
Zhang R, Guo X, Guo L, Lu J, Zhou X, Ji L. Prevalence and associated factors of obstructive sleep apnea in hospitalized patients with type 2 diabetes in Beijing, China 2. J Diabetes. 2015;7(1):16–23.
Zhang P, Zhang R, Zhao F, Heeley E, Chai-Coetzer CL, Liu J, et al. The prevalence and characteristics of obstructive sleep apnea in hospitalized patients with type 2 diabetes in China. J Sleep Res. 2016;25(1):39–46.
Zielinski MR, McKenna JT, McCarley RW. Functions and mechanisms of Sleep. AIMS Neurosci. 2016;3(1):67–104.

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