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A comprehensive evaluation of predictors of obesity in women during the perimenopausal period: A systematic review and narrative synthesis

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ABSTRACT

Introduction: Obesity during perimenopausal transition can be attributed to various factors. Identifying these factors is crucial in preventing obesity and developing effective strategies to manage weight during this phase. This review aimed to systematically understand predictors of obesity during menopausal transition.

Methods: The review followed the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines and searched databases like PubMed, Wiley Online Library, and Cochrane Reviews. Cohort and cross-sectional studies in English language assessing obesity among menopausal women were included. The methodological quality was assessed using Joanna Briggs Checklist for critical appraisal. Risk of Bias (RoB) was generated using Review Manager 5.4.1 (RevMan). Identified predictors were assessed for overall quality of evidence using adopted Grading of Recommendations Assessment, Development and Evaluation (GRADE) approach.

Results: This review encompassed 42 studies, (21 cross-sectional and 21 cohort) with sample ranging from 164 to 107,243 across studies. Higher parity($\geq$ 3 children) emerged as a strong predictor of obesity across seven studies, with good-quality evidence. Lower physical activity was another predictor, supported by eight studies with good-quality evidence. Sociodemographic factors like lower education(<8 years or < than college degree), socioeconomic background, menopausal transition, and older age at menarche showed associations with weight gain, with moderate-quality evidence. Lifestyle factors (high-fat consumption, sedentariness, active smoking status, and psychological difficulties) also showed moderate-quality evidence.

Conclusion: This review underscores the multifaceted factors associated with obesity during the perimenopausal transition. Identifying these factors will be helpful in prevention and management of obesity among these women.

1. Introduction

Weight gain during the midlife years is considered an inevitable outcome of the menopausal transition. Women during midlife years are predisposed to weight gain due to various physiological, biological, endocrinological, and psychological changes [1,2]. The transitional changes greatly impact the behavioural habits of menopausal women resulting in unhealthy eating patterns, decreased physical activity, irregular sleep patterns, and worsened psychological health, all of which further predispose them to excessive weight gain during the transition [3–5].

Weight loss and management is known to be an effective intervention to improve overall quality of life during this phase however, it gets difficult to lose weight during the transitional phase [6,7]. Therefore,

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the prevention of weight gain during these years is effective and sustainable approach to tackle the increasing prevalence of obesity and associated metabolic conditions such as Type 2 Diabetes (T2D) [6], hypertension, and cardiovascular diseases [8]. Identifying predictors of weight gain and their integrated contribution can be considered an critical step for its prevention and management.

Obesity is considered as a multifactorial condition and is substantially linked to several factors including genetics, sociodemographic characteristics, lifestyle-related, and environmental factors [9]. The relative importance of predictors associated with obesity in this transition has been explored in various cross-sectional studies and randomized trials [10,11]. However, there is a lack of literature on the consolidated effect of etiological factors on weight gain among menopausal women. It is imperative to explore their relationship and contribution to the genesis of obesity during this transition. Identifying the contributions of these factors will play an important role in the development of targeted interventions to manage weight and improve overall health and quality of life during this crucial life stage. Furthermore, the identified predictors will be helpful for public health, healthcare policies, and gender-specific health strategies. Therefore, this review aims to systematically understand the predictors of obesity during perimenopausal transition.

2. Materials and methods

The aim and methods of the present review have been registered with the 'PROSPERO' (International Prospective Register of Systematic Reviews) with registartion number CRD42023420379. The review was carried forward in accordance with "Preferred Reporting Items for Systematic Reviews and Meta-Analyses" (PRISMA guidelines) [12].

2.1. Search strategy

Three electronic search engines (PubMed, Wiley Online Library, and Cochrane Reviews) and a longitudinal collection, Midlife in United States (MIDUS) were searched using relevant keywords for articles published in english language over the past 23 years (between January 2000 and October 2023). The combination of keywords were pilot tested and then used as search string for retrieving relevant articles from the literature: "(Obese* OR "Weight gain" OR Overweight) AND (Menopause* OR Postmenopausal OR Perimenopausal OR "Middle age") AND ("Risk Factor" OR Determinants OR Predictors OR "Behavioral Factors" OR "Psychological Factors)".

2.2. Inclusion and exclusion criteria

The systematic review included studies that (i) investigated factors associated with weight, Body Mass Index (BMI), abdominal obesity and/or body composition; (ii) included perimenopausal or postmenopausal women or women between 40 and 60 years of age-old; while randomized control trials and review articles were not included.

2.3. Study selection

Articles obtained from the search were then screened by two authors (AV and AM) for appropriate titles according to the predecided inclusion and exclusion criteria (Table S1). After title screening, the articles were screened for abstracts to assess their appropriateness and relevance. Articles that were duplicated or irrelevant were excluded at this stage. In the case of disagreements over the inclusion of articles, consensus or adjudication by third parties was sought. (PR and SC). Full-text articles were retrieved and finalized by the authors. Reference lists of the obtained articles were also checked to identify other potential articles. Afterward, the author thoroughly read the articles to extract important information.

2.4. Data extraction

The process of data extraction was done by one author independently (AV) and extracted data was reviewed by second author (AM). Study details such as study characteristics (design, location, duration of followup in cohort studies); population characteristics (number of participants, age group, BMI or the body weight of the participants; outcome measures, method for statistical analysis and potential factors associated with obesity among menopausal women were extracted from each article. The predictors were then grouped into the following categories to define the factors more effectively: sociodemographic, menopausal, lifestyle, and health related factors. Factors were listed down along with measures of effect like p-value, beta value, and odds ratio (OR).

2.5. Methodological quality

Before the quality assessment, studies were classified into cohort, cross-sectional and case-control studies. Methodological quality was evaluated with a standardized quality assessment tool by Joanna Briggs Institute Critical Appraisal tools: "JBI Critical Appraisal checklist for Cohort Studies (11-item)" and "JBI Critical Appraisal checklist for Cross-sectional Studies (8-item)" [13]. Study quality was defined as good, fair, and poor using the guidelines of the tools. Study quality was assessed by both authors independently (AV and AM). Any disagreements were resolved after consulation with co-authors (PR). "Cochrane Collaboration Tool Review Manager Version 5.3" was used to generate risk of bias graphs [14].

2.6. Grading of strength of evidence of predictors

The adopted Grading of Recommendations Assessment, Development, and Evaluation (GRADE) framework was used to assess the overall strength of evidence for predictors identified in the systematic search. Various parameters of GRADE approach (including 'risk of bias', 'impression', 'indirectness', 'heterogeneity', 'publication bias' and 'inconsistency') were modified and adopted to subjective grading considering the heterogeneity across studies. Identified factors were evaluated for the various parameters of GRADE approach as Yes, No or Unclear. Then, factors were classified into four categories i.e. high, moderate, low and very low [15]. Supplementary Table 2 presents the overall strength of identified predictors.

3. Results

3.1. Study selection

The primary electronic search yielded 7293 articles from PubMed, Wiley online library, Cochrane Reviews and MIDUS. The abstract screening process led to the selection of sixty eight articles based on their appropriateness. Out of sixty eight articles, sixteen were not available in full-text form, and thirteen did not fulfil the inclusion and exclusion criteria. Afterwards, three articles were extracted from the references list of finalized articles. Finally, forty two articles were retrieved for the data extraction Fig. 1 provides the follow chart of included studies.

3.1.1. Study characteristics

Tables 1A and 1B provides comprehensive characteristics of the cohort and cross-sectional studies respectively.

3.1.1.1. Study design. Out of the forty-two studies reviewed, twenty-one were cross-sectional, and the remaining twenty-one were cohort studies.

3.1.2. Sample characteristics

Tables 1A and 1B presents the key characteristics of the included

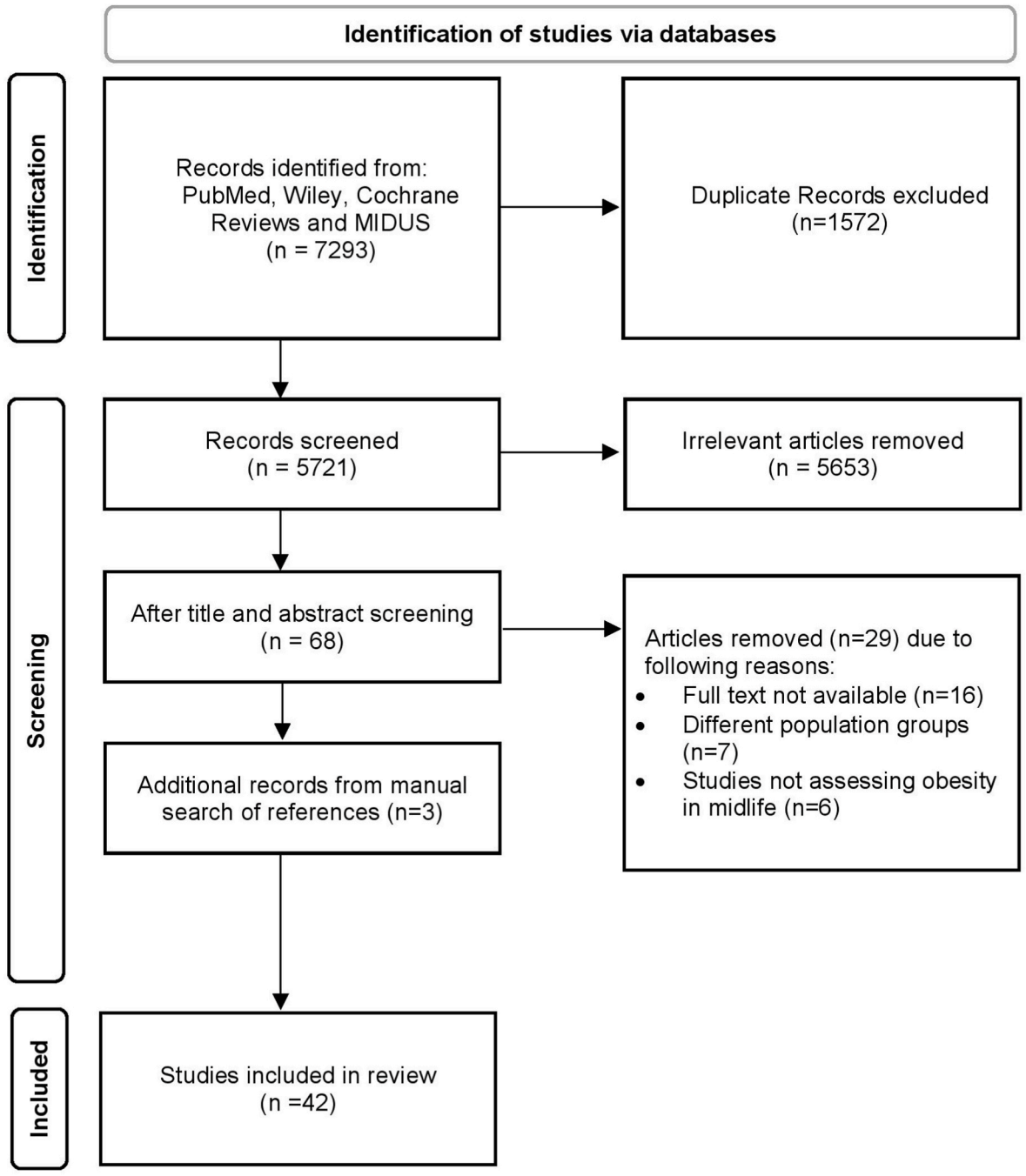

Fig. 1. PRISMA flowchart

studies in this review. Across studies, the sample size ranged from 164 [52] to 1,07,243 [21] participants with varying ratios of premenopausal, perimenopausal, and postmenopausal women. The mean age ranged from 40.1 ± 3.0years [48] to 67.25 ± 0.53years [43] and the mean BMI varied from 22.20 ± 0.05 kg/m^2 [43] and 33.2 ± 5.3 kg/m^2 [36]. Out of 42 studies includes, 16 were from the United States [15,21,52,17,22,24,25,31–33,35,36,54–56], 5 from Iran [16,18,47,49,53], 4 from Sweden [20,26,27,57] and, 3 each from South Korea [43,46,44], and China [38,58,59] and two from Brazil [50,45], and others from India [42], Australia [30], Mauritius [51], Portugal [23], Denmark [28], Scotland [29], Poland [39], Italy [34] and Ghana [37]. The follow-up in the studies ranged from 3 years [21,31,22,16]; 4 years [32], 5 years [30]; 6 years [28], 7 years [25], 8 years [24,35,26], 9 years [27] 12 years [33,20], while one cohort study had a follow-up of 40–50 years [29].

3.1.3. *Characteristics of outcome measures*

Studies included different measures of obesity such as body weight, and BMI; different measures of abdominal obesity such as waist circumference, hip circumference, and waist-to-hip ratio; and body composition. There are a few studies that had also measured weight gain or weight loss over the study's follow-up period.

3.1.4. *Quality of studies by critical appraisal*

The risk of bias graph summarizes the methodological quality of the cohort (Figs. S1A and S2A) and cross-sectional studies (Figs. S1B and

Table 1A
Predictors of obesity in women during the perimenopausal period across cohort studies.

S. N.	Study (Author, Year, Place, Type of study)	Sample characteristics	Outcome measured and Statistical Analysis	Predictors			
				Sociodemographic	Menopausal	Lifestyle-related	Health-related
1	Farahmand et., 2022 [16] Iran Cohort (3 yr)	N = 3876 Age: 33.5+_8.9	Mann–Whitney *U* test, GEE Outcome Measured: BMI, WC, WHtR, WHR, AI		Post-menopause: 5 % lower odds of general obesity (OR: 0.95, 95 % CI: 0.90–0.99) (P = 0.02) 6 % higher odds of central obesity (OR: 1.06, 95 % CI: 1.01–1.12) (P = 0.03)		
2	Pacyga et al., 2020 [17] USA Prospective cohort (9 yr)	N = 768 (Pre M: 64.6 % Peri M: 35.4 %) Age: 45–54 BMI>24.9: 60.7 %	Covariate adjusted model for regression Outcome Measured: BMI	Parity (≥2 vs 1) (OR = 0.38 [0.17, 0.83] ≥2 vs 1 live births ~ lower midlife BMI (β = −0.07; [−0.12, −0.03]; P = 0.002)			
3	Montazeri et al., 2019 [18] Iran Cohort (15 yr)	N = 929 Age: 43 ± 5 BMI: 29.5 ± 5		Age(β = 0.16 [0.11, 0.21]) Menopause (β = 1.11 [0.64, 1.59]) Interaction of Menopause X Time (β = −0.4, [0.6, 0.3]) (P < 0.001) *Negative Predictors* ANM (β = −0.03, [CI: 0.07,-0.001], P < 0.05)			
4	Schreiber & Dautovich, 2017 [19] US Secondary/archival analysis of MIDUS II longitudinal study Wisconsin	N = 5373 (Pre M: 2807 Peri M:675 Post M: 1891) Age: 44.7 ± 12.9 BMI: 23.7 ± 3.5	Pearson's correlation; T-test Outcome measured: Body weight BMI		Post-menopause (P < 0.05)	Stress-eating condition (β = 0.2, CI: 0.06, 0.3) (r = 0.4, P < 0.01)	Self-rated physical health (F = 25.4, P < 0.001, R^2 = 0.2) Depressive symptoms (β = −0.4, [-0.4, 0.1]) r = 0.1,P < 0.05). Depressive symptoms and stress eating *Post-M* (β = 0.3, [CI: 0.1, 0.5]
5	Reda et al., 2017 [20] Sweden Follow up survey of Cohort (12yr)	N = 33,422 (Pre-M: 29,559 Post-M: 3009) Age: 29-50 Weight (baseline) = 64.5	Multivariable logistic regression models Outcome measured: Weight	Multiparous one child: (β = −0.42 kg, P < 0.05) 2 or more children: (β = −0.39 kg, P < 0.001) *Negative Predictors* Age (45–50 years): (0.79, [0.73–0.85], P < 0.01)	*Negative Predictors* Post-menopause stage(P < 0.001) Older age at menarche (12 years) (β = −0.29, P < 0.05)	High energy intake (β = −0.32, P = 0.03) Cigarettes smoking 10–19 (OR:1.30, [1.21–1.39] P < 0.001) ≥20 (OR:1.17, [1.04–1.32] P = 0.01) Smoking Cessation (OR: 1.88, [1.68–2.11] P=<0.001) Decreased PA (OR:1.58 [1.48–1.68] P < 0.001) *Negative Predictors* High PA (−0.37 kg, CI: 0.63to −0.10) P < 0.01) High alcohol consumption (OR:0.90, P = 0.01)	Baseline weight >64.5 kg (OR: 1.2, CI: 1.14–1.26)
6	Greenberg et al., 2015 [21] US Prospective cohort (3 yr)	N = 1,07,243 (Post-M) Age: 60.7 (50–79)	Linear mixed model Paired t-tests Outcome measured: Weight			Chocolate consumption 1 serving of chocolate candy/m to 1/wk [0.76 kg	

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Table 1A (*continued*)

S. N.	Study (Author, Year, Place, Type of study)	Sample characteristics	Outcome measured and Statistical Analysis	Predictors			
				Sociodemographic	Menopausal	Lifestyle-related	Health-related
						(0.66, 0.85)] 1 to < 3serving/wk [0.95 kg (0.84, 1.06)] 3 servings/wk [1.40 (1.27, 1.53] (1 serving = 1 oz/ 28 g)	
7	Jung et al., 2015 [22] US Ancillary study of WHI-OS the Women's Health Initiative-Observational Study (3 years)	N = 612 (Post-M) Age: 50–79 White:84.2 %	Logistic regression Outcome measured: Weight gain	Race (African American: currently smoking) ≥3 % weight gain	Early menopausal transition (P = 0.03) Age at menopause (OR:0.97, P = 0.02)	Lower calories (P = 0.02) Less alcohol (P = 0.04) Less dietary fiber (African American) (OR: 0.92 [0.85–1.0], P = 0.05) Currently smoking (African American) (OR: 31.11 [2.91–8.67.6], P < 0.01) Weight loss attempts (P = 0.02)	BMI at baseline (OR:0.92, P = 0.001)
8	Pimenta et al., 2014 [23] Portugal Follow-up	N = 497 (Peri-M: 166 Post-M: 331) Age:42-60 BMI≤24.9 (Peri-M: 54.2 % Post-M: 50.6 %)	Chi-square; CFI; GFI; RMSEA. Outcome Measured: Body weight	Lower education (β = −0.146, P = 0.017),	Menopausal transition (*Peri-M to Post-M*) (β = 0.147, P = 0.013)	*Negative Predictors* PA (β = −0.111, P = .021)	Recent psychological distress (β = 0.191, P < 0.001) Body shape concerns (β = .313, P < 0.001
9	Wang et al., 2011 [24] US Prospective cohort (8 years)	N = 19,220 Age≥39 BMI ≥30 : 732	Cox models RR, HR Outcomes measured: Weight			Alcohol: Lower RR of overweight/ obese with increased alcohol 0g/d- RR: 1.0 ≥30g/d- RR: 0.73 (p < 0.0001)	
10	Blanck et al., 2007 [25] US Cohort Study (7 years)	N = 18,583 Age: 60.1 (40–69)	Linear regression Model, Multiple Regression Model Outcomes measured: Weight			Sedentariness (6 h/ d) (β = 1.11 [1.05,1.09] *Negative Predictors:* Recreational PA (18 MET h/wk) (β = 0.95 [0.92, 0.99] Non-recreational PA (117 MET hr/ week) (β = 0.95 [0.92, 0.99]	
11	Field, Willett, Lissner & Colditz, 2007 [26] Sweden Prospective cohort (8 years)	N = 41,518, Age: 53.7 ± 7.1 (41–68) BMI: 25.0 ± 4.5	Linear regression models Outcomes measured: BMI,	Parental body shape (p < 0.001). Obese parents (OR:1.98; [1.89–2.07])		Total fat intake (β = 0.11) Dietary fat composition PUFA (P < 0.0001) MUFA (P < 0.0001) Saturated fat (P < 0.005) Increase in total fat (P < 0.02), Vegetable fat (P < 0.003), Trans fat (P < 0.0001) 1 % increase in calories from *trans*-fat ~2.3 lb (1.80 o 2.86)	
12	Rosell, Håkansson & Wolk, 2006 [27]	N = 19,352 Age: 46.3 ±	Multivariate regression analyses			Dairy product intake	

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Table 1A (*continued*)

S. N.	Study (Author, Year, Place, Type of study)	Sample characteristics	Outcome measured and Statistical Analysis	Predictors			
				Sociodemographic	Menopausal	Lifestyle-related	Health-related
	Sweden Mammography Cohort (9year)	4.5 (40–55) BMI: 23.7 ± 3.5	Outcomes measured: Weight, weight change in 10yrs			≥1 serving/d Milk: 0.42 kg (P = 0.004) Cheese: 0.57 kg (P = 0.001) Decreased intake from≥1 to <1 serving/d Milk: 0.34 kg (P = 0.014) Increased intake from <1 to ≤ 1 serving/d Milk: 0.40 kg (P = 0.004)	
13	Overgaard et al., 2006 [28] Denmark Cohort (6 years)	N = 6404 Age: 45-65	ANOVA and 2 tailed tests Outcomes measured: Weight	Obese parents (P < 0.001) Women with 2 obese parents vs 1 obese parent (4.8 vs 2.4 kg, P = 0.03) Occupation (High work load ~ weight gain) (P = 0.04)			
14	Pierce and Leon 2005[[29]] Scotland Cohort (40–50 years)	N = 3743 Age: 45–52 Overweight: 30.7 % Obese:18.2 %	Chi-square test Multiple linear regression Outcomes measured: BMI	Parity (P = 0.003) *Negative predictors* SES at birth (P < 0.001) at adulthood (P < 0.001)	*Negative predictors* Age at menarche (r = 0.132, P < 0.001)	*Negative predictors* Smoking (P = 0.004)	Childhood BMI (48–149 m) (r = 0.193, P = 0.008)
15	Brown et al., 2005 [30] Australia Longitudinal (5years)	N = 8071 Age: 45-55 BMI:26.6 ± 5.20	Multivariate analyses Outcomes measured: Weight, BMI	Marital Status (P = 0.0008)	Menopause transition (M [CI], (P < 0.0001) Pre-M (1.71 [1.34, 2.08]) Peri-M (2.57 [2.33, 2.81]) Post-M(1.77 [1.23, 2.31]) Prior hysterectomy (2.7 [2.45, 3.00])	PA (Habitual) (P = 0.0022) Sedentariness (>8 h/d) (P < 0.0001) Smoking (P = 0.0001) *Quit smoking*~ 5.06 (4.39, 5.74), *Smoker* ~1.48 (1.13, 1.83)	
16	Howard et al., 2004 [31] US Cohort (3 years)	N = 3389 Age: 62 (50–79), BMI = 27.4 Race White: 60 %, Black: 20 %, Hispanic: 12 %, Asian/Pacific Islander: 8 %	Chi-square tests. Regression models Outcome measured: Weight, BMI, WC, Blood investigations	*Negative predictor* Age (β = −0.10, p < 0.0001) Whites β = −0.09, (P < 0.0001); Black β = −0.09, (P = 0.011); Hispanic β = −0.14, (P = 0.0001); Asian-Pacific β = −0.07, (P = 0.091) Race (Whites associated with Insulin resistance) (P = 0.002)			Insulin resistance (6.29, P = 0.027) Insulin sensitivity (6.45, P = 0.039) Among Whites: Insulin resistance (11.48, P = 0.002) Insulin sensitivity (P = 0.004)
17	Sammel et al., 2003 [32] US Prospective cohort (4 years)	N = 336 Age: 41.0 ± 3.5 (35–47) BMI = 29.3 ± 8.2 *African American* (49 %) *Caucasian American* (51 %)	Multivariate logistic regression Outcome measured: Weight gain	*Negative Predictors* Age: Peri-M (45–49): least likely to gain 10 lb (P = 0.039)		Higher sweets consumption [0.74 (0.60–0.91), P = 0.004]	Depression [1.9, 1.09–3.31; P = 0.024] Baseline BMI (P = 0.008)
18	Quatromoni et al., 2002 [33] US Longitudinal (12years)	N = 737 Age: 45 (30–89); BMI<24 at baseline	Multivariate Analysis Outcome measured:			Wine & Moderate eating [0.9, (0.4, 2.1)] Light eating [RR: 1.1(0.8, 1.6)] High fat diet [1.0 (0.7, 1.5] Empty calorie diet [1.4, 0.9, 2.2]	

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Table 1A (*continued*)

S. N.	Study (Author, Year, Place, Type of study)	Sample characteristics	Outcome measured and Statistical Analysis	Predictors			
				Sociodemographic	Menopausal	Lifestyle-related	Health-related
19	Cota et al., 2001 [34] Italy Cohort	N = 426; Age: 43–58; WHR≥0.8: 33.1 %	ANOVA; ANCOVA; Multiple regression analyses Outcome measured: Weight, BMI, WC, HC, Body composition (Body fat)	SES (P = 0.029); Dwelling (Countryside/suburbs) associated WHR (P = 0.005) *Negative Predictors ~ WHR* Education (P < 0.001) Self-employment (P < 0.001) Partner's work (P = 0.029)			Psychological symptoms (associated with WHR) Denial (P = 0.02); Laxity (P = 0.04) Symptoms of conversion (psychological disorder) (associated with WC) (t = 2.185; P = 0.029) Perception of disease (t = −2.025; P = 0.043)
20	Mitchell et al., 2001 [35] US Longitudinal (8 years)	N = 541 (Pre-M) Age: 42-50	Multiple linear regression Outcome Measured: Body weight, BMI, Body composition, Blood Profile				HRT users Higher BMI associated with CRP levels (R^2 = 0.27, P < 0.001) Visceral adipose tissue associated with CRP (P < 0.001) HRT vs Non HRT Lower SAT (319.9 [259.8–386.5] vs (346.1[291.9–464.5]) (p = 0.01) Baseline BMI & eighth year postmenopause CRP levels (r = 0.28, p = 0.005) vs (r = 0.57, p < 0.001)
21	McCrone et al., 2000 [36] US Longitudinal	N = 135 Age:60 ± 6 6 BMI: 33.2 ± 5.3	t-tests; Chi-square analysis Outcome measured: Weight, WHR			Early onset of obesity: Binge eating (P < 0.05)	Early onset of obesity: Depression (P = 0.09) Anxiousness (P = 0.06)

AI: Adiposity Indices; ANOVA: Analysis of Variance; ANCOVA: Analysis of Covariance; ANM: Age at Natural Menopause; AUDIT: Alcohol Use Disorders Identification Test; BF: Body fat; BMI: Body Mass Index; CFI: Comparative Fit Index; CRP: C-reactive Protein; FSH: Follicle-Stimulating Hormone; GEE: Generalized Estimating Equation; GFI: Goodness-of-Fit Index; HC: Hip Circumference; HR: Hazard Ratio; HRT: Hormone Replacement Therapy; m: month OR: Odd's Ratio; PA: Physical activity; Peri-M: Perimenopausal women; Post-M: Postmenopausal women; Pre-M: Premenopausal women; PR: Prevalence ratio; RMSEA: Root Mean Square Error of Approximation; RR: Risk Ratio; Qol: Quality of life; SAT: Subcutaneous Adipose Tissue; SES: Socio-economic Status; US: United States; WC: Waist circumference; WHR: Waist to Hip Ratio; Wt ch.: Weight change, MANW: Metabolically Abnormal Normal Weight; MAO: Metabolically Abnormal Obese; MHNW: Metabolically Healthy Normal Weight; MHO: Metabolically Healthy Obese; WHtR: Waist to Height Ratio; MET: Metabolic Equivalent, hr: hours, wk: week; d: day; lb: Pounds.
*Age in years. BMI in kg/m^2, Weight in kg.

S2B) in this systematic review. The summary of the JBI checklist for critical appraisal has been depicted in Tables S2 and S3.

Out of 21 cross-sectional studies, 17 were found to have a low risk of bias (total score more than 6 (more than 70 %) while 4 studies were in the medium range (50–70 %). Most of the cross-sectional studies lacked the identification of confounding factors and strategies to address their effect on the analysis. Among 21 cohort studies, 5 had low risk of bias and 11 had a medium risk of bias and 5 had a high risk of bias. Few studies with high-risk bias lacked details on follow-up, while most studies included detailed methodology.

3.2. *Predictors of weight gain among menopausal women*

Across 42 studies, weight gain among perimenopausal women can be attributed to a range of factors unique to perimenopausal transition. These factors can be classified as sociodemographic , menopausal, lifestyle-related, and health related factors (Table 2). In the following section, these factors have been discussed in detail.

3.2.1. *Sociodemographic factors*

Various sociodemographic factors identified as the predictors associated with weight gain included: age, education, occupation, socioeconomic status, race, parity, and marital status.

3.2.1.1. Age. Evidence for the association of age with obesity provided mixed results across the literature. Out of 42 studies, seven studied the association of age with obesity among perimenopausal women [48,31,32,47,18,20,50]. Three studies positively associated weight gain with age [47,18,50] while four studies found a negative association between age and obesity in the perimenopausal phase [48,31,32,20]. In a few studies, age at different reproductive milestones such as menarche [20,57,45,29], first childbirth [46], and menopause were significantly associated with obesity.

3.2.1.2. Parity. Parity was positively correlated with the extent of obesity across 9 studies. Higher parity (>3 children) was attributed as a potential predictor of obesity among perimenopausal women [43,56,47,53,46,50,29].

3.2.1.3. Education, occupation, and socioeconomic status. Several studies analysed the impact of education and occupation status on weight status during this phase. Of 42 studies, 8 negatively associated education status with different measures of obesity [50]. It was also reported that education of less than 8 years was significantly associated with obesity. According to five studies, occupation was a significant predictor of obesity among these women [47,57,50,28,34]. A higher prevalence of obesity was seen among unemployed and homemakers than working

Table 1B
Predictors of obesity in women during the perimenopausal period across cross-sectional studies.

S. No.	Study (Author, Year, Place, Type of study)	Sample characteristics	Outcome measured and Statistical Analysis	Predictors			
				Sociodemographic	Menopausal	Lifestyle-related	Health-related
22	Bonsu et al., 2023 [37] Ghana Cross-sectional	N = 378, A: 60.09 ± 6.24 37.8 % Obese 35.4 % Overweight	BMI, WC, WHR, WHtR Multivariate regression	Education (High school vs primary edu~8.6 times higher odds of obesity) Ethnicity (4.6times higher odds in Ga vs Northern tribe)			
23	Su et al., 2022 China Cross-sectional [38]	N = 387 A: 47.7 ± 6.6 Central obesity in 52.8 %	BMI, WC, Binary Logistic Regression and Multiple Interation Models		Peri- and post-menopause statuse ($p < 0.05$)	Not taking five servings of F/V per day >4 h of sedentary time Peri-M (OR:2.466, [CI]: 0.984–6.182; $p < 0.05$) Post-M (OR: 2.274, CI: 1.046–4.943; $p < 0.05$)	
24	Cieśla et al., 2021 Poland [39,40] Cross-sectional	N = 7500 Age: 55.5 ± 5.3 BMI<25 = 815 BMI≥25 = 1233	BMI, WHtR, % BF Multivariate logistic regression	–	–	Breasting feeding >12 m had lower obesity risk [OR 0.68; 95 % CI 0.47–0.98; P = 0.039)]	–
25	Chen et al., 2021 [41] China Cross-sectional	N = 646 (Pre-M: 302 Post-M: 344) Age:50.7 ± 3.1 BMI: 23.85 ± 3.09	Chi-square tests Multivariate logistic regression Outcome Measured: BMI, WC		Postmenopause (P < 0.008)	<6 h of sleep/day ~ abdominal obesity (OR = 2.08, P= .004) Didn't breastfeed [B = 1.51 (OR: 4.54, CI: 1.37, 15.0; P = 0.01)] *Negative predictors* 5 servings of fruits and vegetables ~ abdominal obesity [B = −0.57 (OR: 0.57, CI: 0.32, 0.99; P = 0.04)] Regular PA [B = −1.18 (CI: (P = 0.01)	Moderate/High Stress [B = −0.69, OR: 0.50,(CI: 0.26–0.97), P = 0.04]
26	Singhania et al., 2020 [42] India Cross-sectional	N = 400 (Peri-M: 56 Post-M: 344) Age: 53.65 ± 5.11 BMI:23.9 ± 4.84	T-test Chi-square Fisher's Exact test Regression Outcome Measured: BMI	Education (P = 0.008) SES (P = 0.020)	History of dysmenorrhea (P = 0.04) Age of menopause (P = 0.033) Menopausal symptoms [Joint and muscular discomfort (P < 0.001) Somato-vegetative domain (P = 0.029) Uro-genital domain (P = 0.028)]		
27	Chen et al., 2020 [40] China Cross- Sectional	N = 5373 Pre M: 2807 Peri M:675 Post M: 1891 Age: 44.7 ± 12.9 BMI: 23.7 ± 3.5	One-way ANOVA Chi-square tests Linear regression Outcome Measured: BMI, WC, WHR, Abdominal ultrasonography		Obesity & Postmenopause [OR:1.01: 0.77–1.34] Abdominal obesity with Menopause transition, [OR: 0.99: 0.82–1.19] Postmenopause [OR: 1.52: 1.26–1.84]		
28	Kimet al., 2016 [43] Republic of Korea Cross-sectional	N = 3347 (Post-M) MHNW (n:1602) Age:61.20 ± 0.30 BMI: 22.20 ± 0.05 MANW (n: 515) Age: 67.25 ± 0.53 BMI: 23.05 ± 0.07	ANOVA, Chi square test, Multivariate logistic regression Outcome measured: Weight BMI, WC Body size phenotype	Higher Parity: (3–4: OR = 1.396, P < 0.05) (5 or more: (OR = 1.978, P < 0.05) Low Education level (P = 0.05)			

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Table 1B (*continued*)

S. No.	Study (Author, Year, Place, Type of study)	Sample characteristics	Outcome measured and Statistical Analysis	Predictors			
				Sociodemographic	Menopausal	Lifestyle-related	Health-related
		MHO (n = 480) Age: 60.23 ± 0.48 BMI: 26.91 ± 0.10 MAO (n = 570) Age: 64.20 ± 0.43 BMI: 27.88 ± 0.11 *MHNW vs MANW vs MHO vs MAO*					
29	Bang et al., 2016 [44] Republic of Korea Cross- sectional	N = 7301 (Pre-M: 4374 Post-M: 2927) Age: 19 to 92	*t*-test, Chi-square test Outcome measured: BMI WC, and WHtR			*Pre-M* Alcohol consumption BMI: (OR: 1.58 [1.08–2.31], P = 0.01) WC: (OR:1.94 [1.11–3.00], P = 0.04) WHtR: (OR:1.80 [1.24–2.61], P = 0.03) AUDIT score (p = 0.001) BMI: OR: 2.02 [1.18–3.46] WC: OR: 2.75 [1.70–4.87] WHtR: OR: 2.86 [1.78–4.59]	
30	Gonçalves et al., 2016 [45] Brazil Cross-sectional	N = 253 (Pre-M: 123 Post-M: 130) Age: 50.2 ± 5.8 (40–60) BMI: 28.1 ± 5.6	Prevalence Ratios (PR); Deviance test; Multiple regression Outcome measured: BMI	No Home-ownership (PR = 1.26)[1.06; 1.50], P = 0.011).	Age at menarche (P = 0.012) Menopause related QoL (P = 0.002) Menopausal symptom severity (PR[CI]) Mild (2.02 [1.05,3.89] P = 0.035), Moderate (2.03; [1.07; 3.85] P = 0.030) Severe (2.53[1.36; 4.70] P = 0.003)	Use of medicines (PR = 1.26 [1.01; 1.26], P = 0.041) Opted for weight loss diet/Dieting (PR = 1.49 [1.26; 1.79] P < 0.01)	
31	We et al., 2016 [46] South Korea Secondary analysis of KNHANES data (Cross-sectional)	N = 4382 (Post-M) Age: 63.7 ± 0.3 BMI >25: 37.1 %	t-tests, Ch-square tests, Multivariate regression analysis Outcome measured: BMI, WC	Higher parity (P = 0.001) Age at first childbirth (β = −0.062, SE = 0.020, P = 0.0025)			
32	Hajiahmadi, Shafi, Delavar 2015 [47] Iran Cross-sectional	N = 216 (Pre-M: 106 Post-M: 110) Age: 51.4 ± 5.2 (45–63) BMI: 29.1 ± 5.1.	Chi square test Multiple logistic regressions Outcome measured: BMI	Older age (P = 0.0001) Occupation (Housewife) (OR: 1.70 [1.17–2.47], P = 0.001) Parity (≥3) (OR: 1.77[1.26–2.47], P = 0.001)	Premenopausal stage (P = 0.002)		
33	Tucker et al., 2015 [48] US Cross-sectional	N = 281 (Pre-M: 225 Peri-M: 36 Post-M: 20) Age: 40.1 ± 3.0	General linear model (GLM) Outcomes measured: BMI and % BF	*Negative Predictors (Associated with Prudent pattern)* Older age (F = 8.9, P = 0 .0031) Higher education level (χ^2 = 6.2, P= .0125)		Meat pattern BF%: F = 4.5 (P = 0.03) BMI: F = 4.2 (P = 0.04) *Negative Predictors* Prudent diet pattern ~BF%: F = 8.5, (P = 0.0038) BMI: F = 4.4 (P = 0.0363). Low fat milk pattern BF%: F = 5.4 (P = 0.02)	

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Table 1B (*continued*)

S. No.	Study (Author, Year, Place, Type of study)	Sample characteristics	Outcome measured and Statistical Analysis	Predictors			
				Sociodemographic	Menopausal	Lifestyle-related	Health-related
						BMI: F = 9.5(P = 0.002)	
34	Ghorbani et al., 2015 [49] Iran Cross-sectional	N = 749 Age: 40–60 (50.7 ± 4.5) BMI: 28.6 ± 4.3	Chi Square test; Logistic regression Outcomes measured: BMI	Education (<12 year) (OR = 1.52, CI: 1.09–2.10, P = 0.01)	Pre-menopause (OR = 1.58, CI: 1.06–2.36, P = 0.026)		
35	Gravena et al., 2013 [50] Brazil Cross-sectional	N = 456 (Post-M) Age: 58.7 ± 5.7 (45–69) BMI: 28.6 ± 5.5 White: 85.1 %	Multivariate logistic regression Outcomes measured: BMI, WC	Education (<8 of schooling) [OR: 1.76 (1.14–2.37), P < 0.01] Occupation (unpaid) [OR: 1.69 (1.09–2.63) P = 0.01] Age (65–69) [OR: 2.25 (1.17–4.36) 5P < 0.01] Parity (3 or more) [OR: 1.78 (1.06–3.00 P = 0.02)]	No use of HRT [OR: 1.69 (1.09–2.63) P = 0.01]		
36	Bhurosy and Jeewon 2013 [51] Mauritius Cross-sectional	N = 400 (Pre-M: 215 Post-M: 185) Age (Pre-M: 34 Post-M: 53) BMI (Pre-M: 23.4 ± 4.29 Post-M:24.9 ± 3.24)	t- test, Chi-squared test Measures of obesity: BMI, WC, HC, WHR	SES (P = 0.042)	Post-menopausal stage (P = 0.001)		
37	Boynton et al., 2008 [52] US Cross-sectional Seattle,	N = 164 (Post-M) Age: 60.7 ± 6.7 BMI: 30.53.9	One-way analysis of variance, Chi-square Test, Pearson correlations Outcome measured: BMI, BF%			Diet quality (Healthy Eating Index) (P = 0.04)	
38	Azadbakht & Esmaillzadeh 2007 [53] Iran Cross-sectional	N = 926 (Post-M: 51 % Pre-M: 49 %) Age: 48 ± 5 (40–60) BMI: 29.46 ± 4.6	Factor Analysis; Pearson correlation; ANCOVA; Logistic regression; Multiple linear regression analysis; Outcome measured: Weight, WC, WHR	Parity (>3) (OR:1.31, P < 0.05)	Post-menopause (OR:1.22, [OR: 1.02–1.61]; P < 0.05)	Low vitamin C intake (OR: 2.31; [1.25–4.25], P < 0.05) Low calcium intake (OR: 1.30; [1.07–3.78], P < 0.05), Fat intake >0.61 g (OR: 1.41; [1.11–3.06], P < 0.05) Dairy consumption (cheese, milk, yoghurt and kashk) (r = −0.2, P < 0.05) PA: OR:2.11; [1.40–2.53], (P < 0.05)	Depression (1.36; [1.02–1.93])
39	Sternfeld et al., 2005 [54] US Cross-sectional	N = 459 (250 Chinese, 209 white) Age: 42–52 Chinese (n, Weight) Pre-M: (78, 56.7) Post-M: (79, 53.8) White (n, Weight) Pre-M: (45, 71.6) Post-M: (46, 68.2)	*t*-test, Wilcoxon rank sum tests, Multivariate Linear regression Outcome measured: Body composition (lean mass, % BF), WC	*Negative predictors* Race (Chinese) Lean mass (P < 0.0001) Fat mass (P < 0.0001) WC (P < 0.0001) % BF (P < 0.0001) *Negative predictors (for* % BF) Education (<college degree) (β = −4.449, SE = 2.024)	Menopause Status associated with Fat mass & % BF (P = 0.005) *Negative predictors (for* lean mass) Late Peri-M/Post-M (Chinese: P = 0.09; Whites: P = 0.004)	PA associated with WC (P = 0.05) PA associated with Lean Mass (Chinese) (P = 0.02) *Negative predictors (for % BF)* Moderate PA (P = 0.003) Vigorous PA (P = 0.002) (White)	Overall health (β = 6.411, SE = 2.076)
40	Gavaler & Rosenblum 2003 [55] US Cross- Sectional	N = 649 (Post-M) *Whites (*n = 270) Age: 58 ± 0.6y BMI:26.4 ± 0.3 *American Indian* (n = 226), Age: 58 ± 0.9 BMI:29.5 ± 0.4	One-way analysis of variance; Multiple linear regression; Outcome measured: BMI, WHR	Race (P < 0.001) [Black (β = +0.133) Asian (β = −0.133)] SES (β = −0.064) (P < 0.001)	Menopausal weight gain (β = +0.094) (P = 0.001) Serum hormone levels (P < 0.001) FSH (β = −0.264) E2 (β = −0113) Testosterone (β = +0.093)	% calories from fat (β = +0.104) (P < 0.001) *Negative Predictors* (P < 0.001) Smoking (β = −0.154) Fitness (β = −2.38) Alcohol consumption (β = −0.074)	

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Table 1B (*continued*)

S. No.	Study (Author, Year, Place, Type of study)	Sample characteristics	Outcome measured and Statistical Analysis	Predictors			
				Sociodemographic	Menopausal	Lifestyle-related	Health-related
		Black (n = 78) Age:53 ± 1.1 BMI:31.3 ± 0.8 *Hispanics* (n = 54) Age:54 ± 1.3 BMI:30.1 ± 1.0 *Asian* (n = 21), Age:58 ± 1.5 BMI:24.2 ± 0.6			No HRT (β = +0.083), (P < 0.001)		
41	Matthews et al. 2001 [56] USA Cross-sectional	N = 16,065 (Pre-M: 33 % Peri-M: 31 % Post-M: 36 %) Caucasians: 50 % African-American: 28 % Others: 22 % Age: 40 - 55 Median Weight = 70.50 ± 20.68	Multivariate linear regression, F- test Outcome measured: BMI	Age (OR: 0.002 [0.001,0.003] F = 24.05, P = 0.001) Parity (OR:0.006 [0.003, 0.008], F = 23.01, P = 0.001]	Type of Menopause ~ Surgical menopause (OR:0.032, [0.022,0.042],F = 13.11, P = 0.002) *Negative predictors* Hormone Use (OR: 0.029 [-0.038,-0.020], F = 42.25, P = 0.002]	*Negative Predictors* PA (OR: 0.057 [-0.06,-0.054], F = 1377.1, P = 0.07) Current Smoking (OR: 0.046, [-0.054,-0.037], F = 91.6, P = 0.01)	
42	Lahmann et al. 2000 [57] Sweden Cross-Sectional	N = 5464 (Pre-M: 48 % Post-M: 51 %) Age: 56.6 ± 9.7 (45–73) BMI: 25.3Healthy Obese	Multivariate regression Outcome measured: Weight, BMI, WC, WHR,	Education *Wt ch.* [β = −0.522, P < 0.0001] *%BF*[β = −0.350, P < 0.0001] *WC* [β = −0.397 P < 0.0001] Parity *Wt ch.* [β = 0.418, P = 0.001) *WC*: [β = 0.585, P < 0.0001] *WHR [*β = 0.004P < 0.0001] Occupation {Own *Wt ch. [*β = −0.244, P = 0.017] *% BF* [β = −0.122, P = 0.01] *WC* [β = −0.279, P = 0.005] *WHR:* [β = −0.002, P = 0.004] Parental occupation *Wt ch.* [β = −0.388, P < 0.0001 % BF [β = −0.122, P = 0.033] WC [β = −0.329, P < 0.0001}	Age at menarche *Wt ch* [β = −0.58 P < 0.0001] *%BF* [β = −0.199 < 0.0001 *WC* [β = −0.442, P < 0.0001 Time since menopause (r = −0.05, P = 0.017) HRT *Weigth change* β = −0.85; P = 0.019 *WC* [β = −0.85, P = 0.016]	Smoking Ex-smoker β = 2.553 ± 0.353; P < 0.0001 Never-smoker β = 2.403 ± 0.334; P < 0.0001) PA β = −0.744 ± 0.119; P < 0.0001 Alcohol user β = −0.686 ± 0.351, P = 0.051 No change in diet β = −1.052 ± 0.326 P = 0.001)	Self-rated health (β = −0.631 ± 0.110, P < 0.0001)

AI: Adiposity Indices; ANOVA: Analysis of Variance; ANCOVA: Analysis of Covariance; AUDIT: Alcohol Use Disorders Identification Test; BF: Body fat; BMI: Body Mass Index; CRP: C-reactive Protein; E2: Estrogen; FSH: Follicle-Stimulating Hormone; GLM: General Linear Model; HC: Hip Circumference; HR: Hazard Ratio; HRT: Hormone Replacement Therapy; m: month OR: Odd's Ratio; PA: Physical activity; Peri-M: Perimenopausal women; Post-M: Postmenopausal women; Pre-M: Pre-menopausal women; PR: Prevalence ratio; RR: Risk Ratio; Qol: Quality of life; SES: Socio-economic Status; US: United States; WC: Waist circumference; WHR: Waist to Hip Ratio; Wt ch.: Weight change, MANW: Metabolically Abnormal Normal Weight; MAO: Metabolically Abnormal Obese; MHNW: Metabolically Healthy Normal Weight; MHO: Metabolically Healthy Obese; WHtR: Waist to Height Ratio; MET: Metabolic Equivalent, hr: hours, wk: week; d: day; lb: Pounds.
**Age in years. BMI in kg/m^2, Weight in kg.*

women [47]. Furthermore, employment status, parents' occupation, poor working conditions, extra working hours, and psychological workload were identified as significant factors contributing to weight gain [57,50,28]. Numerous studies have found inconsistent associations between obesity and socioeconomic status (SES). SES in adulthood as well as during childhood are found to be associated with obesity among perimenopausal women. Ownership of the house was also associated with obesity in a cross-sectional study [45].

3.2.1.4. Race. A total of seven studies investigated the relationship between different races and obesity prevalence. Asian Americans [56], Asians [55], Chinese, Americans, and African-Americans [22] were found to have a negative association with weight gain during menopausal years. While whites and African Americans were found to be more predisposed to obesity than their counterparts across studies.

3.2.2. *Menopausal factors*

Various menopausal factors like the menopausal stage, type of menopause, transition phase, menopausal symptoms, and their severity were found to be associated with obesity. The literature provides mixed

Table 2
Factors associated with obesity among perimenopausal women.

Sociodemographic factors	
Age	Results were contradictory however, older women were more obese [47], Women of 45–50 yr inversely associated with weight gain [32,20] while 65–69 yr old women were more predisposed to obesity [50] Older age was positively associated with adherence to prudent diet, inversely associated with weight gain [48,31].
Race	Inconclusive results: Whites, African Americans [56,22], Black [55]were positively associated with obesity while Asian-Americans, Asians (Chinese) [56,55,54]were negatively associated with obesity.
Parity	Higher parity ($\geq$ 3 children) positively associated with obesity [43,25,47,53,46,50,29]
Education	Lower level of education positively associated with obesity [43,57,34] Education **< college degree** [34], **<8 years** [54], <12years [50] positively associated with weight gain While two studies positively associated education with obesity [42,37] Higher education is associated with better compliance for prudent diet [52].
Socioeconomic factors	Inconclusive: socioeconomic status was inversely associated in two studies [55,29] while positively associated with obesity across other studies [45,42,51] Occupation of partner and parents, ownership of house were inversely associated with menopausal weight gain Housewives were more predisposed to weight gain than employed women
Menopausal factors	
Menopausal stage	Perimenopause and postmenopausal phase were positively associated with higher BMI while premenopausal phase was negatively associated [56, 22,54,53,16,38,23,30,51,19,40] Few studies associated premenopause with obesity [47]
Age at menopause	Inconclusive results due to limited studies [22,42].
Type of menopause	Surgical menopause positively associated with obesity [56,30]
Menopausal symptoms	Limited studies however, the severity of menopausal symptoms was positively associated with menopausal weight gain [45,42]
Age at menarche	Negatively associated with obesity [20,57,45,29]
Age at first pregnancy	Limited studies however, negatively associated with obesity [46]
Use of Hormone Replacement Therapy	Negatively associated with menopausal weight gain [56,55,33,35,57,50]
Lifestyle-related factors	
Dietary habits	Consumption of high-fat diet, meat diet, stress eating, binge eating and overeating were positively associated with weight gain. While, yogurt consumption, high fibre intake, fruits and vegetables, and prudent diet were inversely associated [52,48,55,22,33,53,20,26,27,38,40]. Binge eating, emotional eating were associated weight gain and indirectly associated with weight gain [36,19].
Physical activity	Sedentariness (More than 4 h) [38] was positively associated with weight gain while increased physical activity was inversely associated with obesity [56,54,25,53,20,57,30,23,40].
Sleep	Delayed sleep timing associated with weight regain [40].
Smoking	Smoking in past were positively associated with weight gain [20,57,30,29]; "Never smoker" negatively associated with weight gain[35,36], smoking negatively associated [56,55].
Alcohol consumption	Alcohol consumption came out as a negative predictor of weight gain [55,22,24,20,57] However, positive association was seen with higher alcohol consumption in a study by Bang et al. (2016) [44].
Health-related factors	
Psychological health	Mood swings, stress, depression, anxiety and body image issues emerged as positive predictor of weight gain [23,32,34,41,53]
History of obesity	History of excess weight, childhood obesity, and parental obesity were positively associated with menopausal obesity [29]
Overall health & comorbidities	Inversely associated with obesity; presence of chronic diseases positively associated with obesity [57,34].

results about the relationship between menopausal status and obesity. Postmenopausal status was positively associated with obesity in six studies [53,16,58,51,19,41], [18] while two studies found a negative association [54,20]. However, few studies have linked obesity with the pre-menopause phase [47,49]. Besides menopausal status, five studies associated the menopausal transition with weight gain. Obesity rates were higher among women in early menopausal transition [21]. A cross-sectional survey associated surgical menopause and an early menopausal transition with higher BMI [56]. Menopausal symptoms such as joint and muscular pain and somato-vegetative symptoms were also significantly associated with obesity [45,42]. Usage of ***hormone replacement therapy*** was found to be negatively associated with obesity across all the studies included in this review ($P < 0.01$) [56,55,57,50].

3.2.3. *Lifestyle related factors*

Lifestyle behavioural practices including eating habits, physical activity pattern, sleep quality, and intake of tobacco and alcohol were extensively studied across the studies.

3.2.3.1. Dietary behaviour. Dietary behaviour is considered as a crucial element in the management of obesity across all life stage. Studies from this review investigated the dietary intake, food group consumption, and nutrient intake of the participants. Across studies, energy intake [20], and quantity and quality of fat [55,53,26] were positively associated with weight gain, while nutrients such as calcium, vitamin C [53] and dietary fiber [22] were negatively associated with obesity among perimenopausal women.

Different diet patterns were explored to assess their effect on weight among perimenopausal women. Consumption of five servings of fruits and vegetables was inversely correlated with abdominal obesity [41] and general obesity [38]. A prudent and low-fat diet tended to negatively influence weight gain, while meat diets had a significantly negative effect on weight gain and BMI among menopausal women [48]. Factors such as higher age and education were linked to better compliance to a prudent diet and indirectly negatively associated with body weight and BMI [48]. Eating habits such as stress eating conditions and binge eating were significantly associated with higher body weight [36,19]. The usage of food as a coping mechanism among women was associated with the early onset of obesity [36].

3.2.3.2. 24 hour movement behaviour. 24 hour behaviour comprising of time spent in physical activity, sedentary behaviour and sleep came out as pertinent behavioural factor related to obesity among perimenopausal women.

3.2.3.2.1. Physical activity. Physical activity (PA) is the most varied component of lifestyle that may lead to fluctuations in energy balance. Low physical activity level was found to be associated with higher weight gain across many studies [56,54,25,57,23]. A prospective study reported that women with low or no PA were more likely to gain >5 kg weight [30]. On the contrary, regular physical activity decreased the risk of general obesity as well as central obesity ($p = .04$) [41]. Women who exhibited high levels of PA showed a negative weight change as compared to women who had decreased physical activity [20]. The intensity of PA was found to be associated with obesity parameters;

women with light PA had higher WHR compared to women with heavy PA ($P < 0.05$) [53]. Furthermore, some sociodemographic characteristics like education ($P = 0.04$) and marital status ($P = 0.02$) were associated with changes in physical activity (PA level) and in turn weight status [25].

3.2.3.2.2. Sedentariness. Sedentariness is common among perimenopausal women due to chronological aging and the occurrence of menopausal symptoms [54]. The long sitting hours, increased sedentariness, lower steps per day, and decreased PA were positively associated with obesity [25,26,30,23]. Two studies included in this review positively associated sedentariness with obesity [25,30]. A cross-sectional survey by Su et al., correlated >4 h of sedentary time/-day with obesity among perimenopausal and postmenopausal women [38].

3.2.3.2.3. Sleep. Sleep was identified as a predictor in one of the studies which found association of sleep (fewer than 6 h) with higher odds of central obesity (OR = 2.08, 95 % CI = 1.26–3.42) [41].

3.2.3.3. Alcohol consumption. A total of six studies studied the role of alcohol consumption in genesis of obesity among perimenopausal women. Out of six, five reported a negative relationship between alcohol consumption and obesity [55,22,24,20,57] while a study by Bang et al., (2016) associated high alcohol consumption with increased obesity indices [44].

3.2.3.4. Tobacco consumption. Literature reported that women usually gain weight after quitting smoking [57]. Findings from several cross-sectional surveys indicated a position association between weight gain and ex-smokering status. While few studies suggested that smokers tend to have lower body fat compared to others [57]. Some other studies negatively associated smoking with obesity [56,55].

3.2.4. Health related factors

3.2.4.1. Parental history of obesity. Significant correlation was seen between family history of obesity and obesity among perimenopausal women [26,28]. Participants with obese parents gained more weight compared to those without obese parents [28]. Another study revealed that if one or both parents were overweight, the risk of obesity was doubled compared to if neither parent was overweight at 50 [26].

3.2.4.2. Childhood BMI. One study among the included studies, reported a positive correlation between childhood obesity and a higher risk of perimenopausal weight gain [29].

3.2.4.3. Use of medications. Consumption of many medicines such as antidepressants, steroids, insulin and beta-blockers has been strongly associated with obesity [45]. Findings from the "Women's Health Initiative" have reported a strong association between the consumption of some medicines with weight gain in postmenopausal women [60].

3.2.4.4. Psychological health. Women during their menopausal transition come across a spectrum of psychosocial changes such as mood swings, stress, anxiety, and depression, which affect overall health and quality of life [61]. Across studies, the perimenopausal women were found to have low self-esteem and body image concerns, hampering their overall health and predisposing them to weight gain [23]. Depression has been positively associated with weight gain among these women [36,32,23]. Hampered psychological health has been linked to unhealthy lifestyle behaviours, including unhealthy eating habits like binge eating, cravings and midnight snacking which may be adopted to combat stress [36,19,62]. Therefore, psychological health must be considered important to address among these women.

4. Important predictors associated with obesity among menopausal women

An assessment of the strength of evidence of identified predictors associated with obesity was conducted using the GRADE approach. The predictors were classified as "high quality", "moderate quality", "low quality" and "very low quality" according to various parameters of GRADE approach [15]. Parity and physical activity were among the factors with high quality evidence, while education, social economic status, menopausal transition, age at menarche, high fat consumption, sedentary lifestyle, active smoking status and psychological difficulties were the factors with moderate quality evidence. On the other hand, many factors were found to be with low (age, occupation, ownership of the house, race, age at first pregnancy, age at menopause, use of HRT, hysterectomy, alcohol intake, binge eating, parental history of obesity) and very quality evidence (dwelling, time since menopause, menopausal symptoms, menopausal weight gain, diet quality, energy intake, prudent and meat diet, fitness, overall health and perception of diseases).

5. Discussion

Predictors of menopausal obesity identified in this systematic review are classified into four domains: sociodemographic, menopausal, lifestyle, and health-related predictors. The strength of evidence indicated parity and physical activity as strong predictors of obesity, while moderate strength predictors included education, socioeconomic status, menopausal transition, and age at menarche as well as high-fat consumption, sedentary lifestyle, active smoking status, and psychological difficulties.

The first domain of predictors identified in this review emphasized *sociodemographic factors*. Among these, an *education level lower than 8 years of schooling* emerged as an important predictor of obesity with moderate quality of evidence. A similar association was reported in a systematic review conducted to assess the relationship between obesity and education outcomes in adults [28]. Studies correlate lower education with low purchasing power, lack of access, and awareness of healthy eating habits while better education marked better awareness and compliance [14,29,63]. In addition, *socioeconomic status* was also negatively associated with weight gain. However, studies included had poor to moderate methodological quality and were predominantly conducted in Western countries, making it challenging to implicate these findings to the Indian women.

Besides demographic factors, higher *parity* came out as a strong predictor of obesity among perimenopausal women in this review. Studies explain the positive association of obesity with higher parity to the weight retained by the women with each pregnancy [39,34]. Studies suggest weight retention with each pregnancy adds up to the other physiological changes throughout adulthood, resulting in further weight gain during menopause. A systematic review assessing the relationship between parity and metabolic syndrome also established a positive relation between higher parity and higher chances of obesity [37]. Since higher parity came out as a strong predictor of weight gain, interventions must be developed for postpartum women to sensitize them about the long-term implications of weight retained with each pregnancy and to encourage them to adopt weight management practices.

The *menopausal factors* were identified as the second domain of predictors. The menopausal transition, characterized by a combination of biopsychosocial changes, including hormonal imbalances, vasomotor symptoms, psychological susceptibility, and bone and mineral loss, contributes to the accumulation of excessive fat in midlife. The co-occurrence of active menopausal stages and aging mediates unhealthy dietary habits, exercise, and sleep patterns that are generally seen as the primary cause of weight gain [6]. Early *menarche* was also correlated with higher BMIs and greater weight gain among perimenopausal women in this review. This also accords with the findings from existing literature, inversely associating age at menarche with weight gain in

menopausal years [19].

Lifestyle habits such as dietary habits and physical activity are well-recognized predictors of weight gain through all phases of life. In our review, dietary factors such as diet quality, energy intake, fiber intake, and proportion of different food groups are identified as significant contributors to weight gain. However, not many factors emerged as good quality evidence except for *fat consumption*. A prudent diet with high proportions of *fruits and vegetables* was negatively linked with weight gain, though the evidence was not qualitatively strong. The strength of overall evidence of other diet-related factors was found low as the number of studies focusing on dietary factors were less and had poor methodological quality. The low-quality evidence illustrates a research gap in the association of dietary factors with perimenopausal weight gain and calls for good-quality studies in this direction.

The 24 h movement behaviour encompassing physical activity, sedentariness and sleep, is an important modifiable factor strongly associated with obesity. Among the three factors, *"physical activity"* emerged as a crucial negative predictor of obesity, supported by good strength of evidence. Along the same lines, sedentariness was positively associated with obesity with moderate quality of evidence. The significant role of PA in the regulation of weight has been established across the literature. A systematic review to evaluate the role of PA in the prevention of obesity among adults, concluded 150 min/week of moderate-to-vigorous intensity PA ($\geq$3 METS) as an effective intervention for the prevention of weight gain [41]. Furthermore, *smoking status and its transition* was found to have a complex relationship with weight gain. *Current smoking status* was a strong negative predictor of weight gain, while smoking history (ex-smokers) was positively associated with weight gain. Increased risk of weight gain is associated with metabolic changes and declining estrogen [60]. Tobacco consumption also interferes with estrogen metabolism due to its antiestrogenic nature [61].

Psychological health emerged as a key *health-related predictor* with moderate strength of evidence. Perimenopausal women are predisposed to a range of psychological disorders ranging from depression, anxiety, distress, and deteriorated sleep. A meta-analysis reported almost 1.5 times increase in the risk of obesity among patients with anxiety and other related issues [22]. Findings were reiterated by this systematic review that psychological symptoms such as stress, depression, and body image issues were found to be positively correlated with obesity [52,26, 62]. These symptoms were also associated with unhealthy eating habits such as stress eating and emotional eating, triggering overeating and favoring weight gain [26]. Since, menopausal women are already vulnerable to psychological distress during the transition, it is crucial to address their psychological well-being.

Identified predictors in this review can also be classified into modifiable and non-modifiable predictors. Modifiable predictors are lifestyle habits like diet, physical activity, smoking status, and psychological health to some extent. Through this review, we can implicate that these women should be counselled to increase the consumption of fiber-rich prudent diet and limit their intake of fatty foods while engaging in regular exercise. Working on these modifiable factors will help to reduce the predisposition to obesity during this transition. Furthermore, women with a high risk of obesity due to the presence of non-modifiable predictors like women with low education and socio-economic status, high parity, and physiological changes due to menopausal transition should be identified in healthcare settings. These women should be sensitized regarding the predisposition to weight gain and counselled to take early intervention steps by working on modifiable factors. Prevention and protection against obesity also reduce the risk of obesity associated metabolic diseases such as Type 2 Diabetes (T2D), hypertension, non-alcoholic fatty liver disease and cardiovascular diseases.

6. Clinical relevance

This systematic review identified a spectrum of predictors of obesity among perimenopausal women, including sociodemographic characteristics, menopausal, lifestyle factors, and health-related. Identifying these predictors can help in developing targeted preventive strategies for women in this age group. By recognizing strong predictors, healthcare providers can identify high-risk groups and offer targeted interventions. Furthermore, policymakers can use the findings to inform and implement public health initiatives aimed at reducing obesity rates among perimenopausal women. Lastly, research gaps and limitations identified through this systematic review can also help provide directions for future research.

7. Limitations

The findings of this review should be interpreted in light of certain limitations including heterogeneity across included studies in terms of study design, study characteristics and outcome measures as well as publication bias which may introduce certain biases. Furthermore, our literature search was majorly constituted by databases such as PubMed, Wiley and Cochrane reviews which might have led to missing out on some other important articles in the field. Also, there was a lack of studies from developing countries. The strengths of this review includes its robust methodology which included assessment of risk of bias of studies as well as overall strength of the evidence that was evaluated using various parameters of GRADE approach. Furthermore, this systematic review gives insights about predictors of weight gain during menopausal transition.

8. Implications and future research

Predictors with strong evidence must be used to provide targeted counseling to women to raise awareness about obesity, its associated risks, and effective strategies for prevention and management. Healthcare providers play a pivotal role in delivering this information to empower women to make informed decisions about their health. They should also sensitize the policymakers and stakeholders about the significant role of identified predictors including factors like parity, physical activity levels, fat consumption, smoking history, and more. Identified predictors should be considered pertinent while formulating comprehensive strategies aimed at preventing and managing obesity among perimenopausal women at individual-level and population-wide initiatives. Furthermore, predictors with low or very low-quality evidence serve as valuable directions for future research projects. High-quality research with robust methodologies should be prioritized to study the role of these specific factors and establish insights into their associations with obesity in perimenopausal women. Furthermore, identifying crucial factors from robust methodology studies in future and implementing tailor-made interventions to prevent weight gain can greatly improve the efficacy and sustainability of weight loss interventions during perimenopausal stage.

9. Conclusion

Through this systematic review, parity and physical activity came out as strong predictors of weight gain during menopausal transition. While sociodemographic factors such as education, socio economic status, menopausal transition, age at menarche were associated with weight gain with moderate quality of evidence. Lifestyle factors such as high fat consumption, sedentary lifestyles, active smoking status and psychological difficulties also had moderate quality of evidence for weight gain. However, several dietary factors also correlated with weight gain, though the overall evidence was relatively low. Future studies with sound methodology should be carried on finding the association of dietary intake and eating behaviour with weight gain during menopausal transition.

Declaration of competing interest

The authors declare no conflict of interest.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.dsx.2023.102933.

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