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Research Article

Urban-Rural Disparities and Gender Dynamics in Obesity: Pioneering Strategies for Tailored Prevention and Treatment

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ABSTRACT

Background: Obesity is a complex, multifactorial health crisis with significant disparities influenced by gender and environment, particularly across urban and rural settings worldwide. Understanding these disparities is vital for developing targeted prevention and intervention strategies.

Objectives: This review aims to explore the biological, behavioral, environmental and socio-cultural factors contributing to urban-rural and gender disparities in obesity. It emphasizes the importance of personalized and culturally sensitive approaches for effective management.

Methods: A comprehensive synthesis of current epidemiological data, biological mechanisms, environmental influences and policy strategies was conducted, integrating quantitative figures, models and recent advances in genomics, metabolomics and digital health.

Results: Findings reveal that women generally exhibit higher obesity prevalence in high-income countries, largely due to hormonal influences and sociocultural norms, whereas disparities in low- and middle-income countries are influenced by urbanization and dietary transitions. Biological differences in fat distribution and hormonal regulation, coupled with environmental and behavioral factors, underpin these patterns. Urbanization exacerbates risk through sedentary lifestyles and processed food availability, with significant gender-specific implications. Emerging technologies and policy measures offer promising avenues for personalized and equitable obesity management.

Conclusion: Addressing obesity disparities requires an integrated approach that considers biological, environmental and psychosocial factors. Advances in precision medicine, digital health and multisectoral policies are critical for developing effective, culturally appropriate interventions aimed at reducing global obesity burden and health inequalities.

Keywords: Obesity, Gender disparities, Urban-rural differences, Adipose tissue distribution, Hormonal regulation, Environmental factors

1. Introduction

1.1. Background

Obesity has emerged as a formidable global health crisis, transcending geographical, socio-economic and cultural boundaries. Characterized by an abnormal or excessive accumulation of adipose tissue, obesity poses significant risks to individual and public health, contributing to the etiology and progression of numerous chronic conditions. According to the World Health Organization (WHO), in 2020, more than 650 million adults worldwide were classified as obese, a figure that has approximately tripled since 1975 when global obesity prevalence was considerably lower[1]. This alarming trend underscores the urgent need for comprehensive understanding and targeted intervention strategies[2].

Obesity is a complex, multifactorial disease influenced by an interplay of genetic, hormonal, behavioral, environmental and socio-economic factors. The pathophysiology involves dysregulation of energy homeostasis, adipocyte hypertrophy and hyperplasia and alterations in metabolic signaling pathways. The consequences extend beyond mere excess weight, leading to metabolic syndrome, type 2 diabetes mellitus (T2DM), cardiovascular diseases (CVD), certain cancers and psychosocial impairments. The global burden of obesity is substantial; the WHO estimates that obesity-related conditions account for 4 million deaths annually and contribute to increased healthcare costs, diminished quality of life and reduced life expectancy[3].

Despite the universal nature of obesity, its prevalence and manifestation exhibit significant disparities based on demographic, geographic and socio-economic factors. Among these, the influence of gender and residential environment has garnered increasing attention due to their profound impact on epidemiological patterns, biological mechanisms, behavioral determinants and therapeutic outcomes[4].

1.2. Definitions and basic concepts

Obesity is typically quantified using the Body Mass Index (BMI), a simple anthropometric measure calculated as weight in kilograms divided by height in meters squared (kg/m²). The WHO classifies adult obesity as a BMI ≥30 kg/m², with overweight defined as BMI between 25 and 29.9 kg/m². BMI alone does not adequately capture adipose tissue distribution or metabolic health; hence, additional metrics such as waist circumference, waist-to-hip ratio and body composition analyses are employed to assess central versus peripheral fat accumulation[5].

1.2.1. Adipose tissue distribution: Adipose tissue is distributed heterogeneously throughout the body, with distinct implications for health. Central (android) fat deposition, predominantly in the abdominal region, is strongly associated with insulin resistance, dyslipidemia, hypertension and cardiovascular risk. Conversely, peripheral (gynoid) fat, stored mainly in hips and thighs, appears to exert protective metabolic effects. The distribution pattern is influenced by sex hormones, with estrogen promoting peripheral fat storage and testosterone favoring central adiposity[6].

1.2.2. Gender differences: Biological sex and hormonal milieu significantly determine adipose tissue distribution and function. Women generally exhibit higher total body fat percentages (25-30%) compared to men (20-25%) at similar BMI levels, with a propensity for gluteofemoral fat accumulation. Men tend to develop central obesity, which correlates with higher cardiometabolic risk. Postmenopausal women experience hormonal shifts leading to increased visceral fat and metabolic disturbances[7].

1.2.3. Environmental factors: Urbanization and rurality influence lifestyle behaviors, dietary patterns, physical activity levels and exposure to environmental pollutants all of which modulate obesity risk. Urban environments often favor sedentary lifestyles and greater availability of calorie-dense foods, whereas rural settings may involve more physical labor but are increasingly affected by dietary westernization. This introduction underscores the complexity of obesity as a multifaceted disease influenced by an interplay of individual biological characteristics and environmental exposures. Recognizing the disparities rooted in gender and residential environment is essential for advancing personalized medicine, improving health outcomes and designing effective public health interventions[8].

The necessity of understanding the complex interactions between gender and environment in the context of obesity cannot be overstated. Such insights are vital for the development of targeted prevention strategies, personalized treatment modalities and equitable health policies aimed at curbing the global obesity epidemic[9].

1.3. Gender and residential area-specific advances in obesity

The existing body of research predominantly focuses on developing, validating and comparing anthropometric growth standards and indices tailored to the Pakistani population, employing advanced statistical methodologies such as Quantile Regression (QR), Gaussian (Z-score) Percentiles and semi-parametric Lambda Mu Sigma (LMS) approaches[10-19]. These efforts are aligned with the broader understanding that regional and population-specific growth references are vital for accurate assessment of body shape and size, particularly in diverse populations such as Pakistan, where socio-cultural and environmental factors significantly influence anthropometric traits[10]. Such tailored models facilitate precise evaluation of pediatric and adult growth patterns, which is crucial for early detection of obesity and metabolic disorders, as emphasized in recent epidemiological reviews highlighting the importance of biologically and environmentally sensitive assessment tools[11-13,17-19].

Extensive investigations have also explored associations between anthropometric measures such as Body Mass Index (BMI), Body Surface Area (BSA) and Body Shape Index (BSSI) and cardio-metabolic risk factors, including obesity and Type 2 Diabetes Mellitus (T2DM). These indices demonstrate promising utility as predictive markers for metabolic syndrome and related comorbidities, thereby serving as valuable tools for early diagnosis and targeted intervention in the context of personalized medicine[20,11-13,17-19]. Given the biological and environmental disparities discussed in recent literature such as gender-specific fat distribution, hormonal influences and environmental pollutants these anthropometric indices can enhance risk stratification tailored to regional and gender-specific profiles[19].

Several studies have critically assessed the performance and applicability of various percentile estimation techniques and anthropometric indices across different age groups and sexes, underscoring the importance of developing gender- and age-specific reference standards[11-13,21,16,19]. Recent research advocates for the incorporation of BSSI as a superior prognostic marker for mortality risk and metabolic disturbances, aligning with the trend toward precision medicine and personalized health assessment[19]. These investigations contribute significantly to advancing anthropometric science within the South Asian context, providing a robust foundation for implementing population-specific growth assessment protocols. Such tailored approaches are essential for early detection of growth abnormalities, metabolic risks and obesity-related complications, ultimately improving health outcomes through more accurate, culturally relevant clinical evaluations.

1.4. Significance of study

Understanding the heterogeneity in obesity patterns is critical for developing effective, culturally sensitive and equitable prevention and treatment strategies. Evidence indicates that obesity prevalence is not uniform across populations but varies markedly based on sex, age, socio-economic status and geographic location. In high-income countries such as the United States and many European nations, women often demonstrate higher obesity prevalence compared to men, with estimates reaching approximately 40-45% among women versus 35-40% among men[22,23]. Conversely, in low- and middle-income countries, the gender gap may be narrower or even reversed, reflecting divergent socio-cultural norms, occupational shifts and lifestyle transitions.

The urban-rural divide significantly influences obesity epidemiology. Urban populations tend to exhibit higher obesity prevalence, attributed to sedentary lifestyles, increased access to processed foods and environmental factors conducive to weight gain. For example, data from Pakistan suggest that urban residents have an obesity prevalence of approximately 25-30%, compared to 15-20% among rural residents. Rural areas are not immune to rising obesity rates, especially amidst dietary westernization and mechanization of labor. Elucidating the intricate relationship between gender and residential environment is essential because these factors do not operate independently; rather, their intersectionality can compound disparities, thereby necessitating nuanced, targeted interventions.

1.5. Objectives of the study

The epidemiology of obesity reveals notable disparities influenced by gender and residential environment, with prevalence rates varying significantly across regions and settings. Globally, women tend to have higher obesity rates than men in high-income countries, driven by factors such as hormonal differences, cultural norms and lifestyle behaviors, whereas in low- and middle-income nations, the patterns are more heterogeneous. Urban populations generally exhibit elevated obesity prevalence due to sedentary lifestyles, increased access to processed foods and environmental factors conducive to weight gain, while rural areas are experiencing a rising trend linked to dietary westernization and mechanization of labor. These disparities underscore the importance of understanding intersectional influences to develop targeted, effective public health interventions aimed at reducing obesity-related health burdens worldwide.

2. Global Trends and Gender Disparities in Obesity Prevalence

Obesity has ascended to the status of a global health crisis, characterized by an alarming increase in prevalence across diverse populations worldwide. Recognized as a complex and multifactorial disease, obesity results from intricate interactions amongst genetic, hormonal, behavioral, environmental and socio-cultural factors. Its epidemiology exhibits pronounced disparities across different regions, income levels and demographic groups, with gender playing a significant role in shaping these patterns. Understanding the global trends and gender-specific differences in obesity prevalence is essential for informing targeted prevention strategies, optimizing clinical management and guiding public health policies aimed at reducing the burden of obesity and its associated comorbidities such as type 2 diabetes mellitus (T2DM), cardiovascular disease (CVD) and certain cancers[7,24].

This comprehensive analysis aims to delineate the global epidemiological patterns of obesity with an emphasis on gender disparities. It integrates current data, epidemiological trends, biological underpinnings and sociocultural influences, supported by quantitative figures and mathematical models where appropriate, to provide a nuanced understanding of these disparities. It also discusses how these factors intersect with environmental and lifestyle determinants across different regions, highlighting the importance of context-specific, culturally sensitive interventions.

2.1. Epidemiological Overview of Global Obesity Trends

2.1.1. Prevalence patterns across income levels and regions: Globally, obesity prevalence has more than doubled over the past four decades. According to the World Health Organization, in 2016, more than 650 million adults (13% of the world population aged ≥18 years) were classified as obese (body mass index [BMI] ≥30 kg/m²). The distribution of obesity is markedly heterogeneous, with high-income countries demonstrating the highest prevalence rates, yet low- and middle-income countries (LMICs) experiencing the most rapid increases[25]. In high-income nations such as the United States, Australia and many European countries, obesity prevalence among adults exceeds 35-40%. For instance, data from the CDC (2021) indicate that 42.4% of U.S. adults are obese, with a higher prevalence among women (44%) compared to men (37%). Similarly, European countries like the United Kingdom report adult obesity rates of approximately 27-35%, with women slightly surpassing men in prevalence[26].

In LMICs, obesity has historically been less prevalent but is now rising rapidly, especially in urban areas. In South Asia, for example, urban Indian women exhibit obesity prevalence of approximately 20-25%, with rural populations traditionally showing lower rates (10%), though these are increasing due to dietary transitions and urban migration. Sub-Saharan Africa and parts of Southeast Asia show emerging obesity trends, often with a higher prevalence among women[27].

2.2. Gender disparities in obesity prevalence: Biological and sociocultural perspectives

2.2.1. Biological underpinnings of gender differences: Biological sex significantly influences body composition, fat distribution and metabolic pathways, thereby shaping obesity risk profiles. Women generally possess higher total body fat percentages (25-30%) compared to men (20-25%) at equivalent BMI levels[1]. This disparity results from hormonal differences, primarily the actions of estrogen and testosterone, which regulate adipocyte differentiation and fat storage[28]. Fat distribution patterns differ markedly between genders. Women tend to accumulate peripheral (gynoid) fat, predominantly in the hips and thighs, which has been associated with a protective metabolic profile. Men typically exhibit central (android) fat deposition, especially visceral adipose tissue (VAT), which is metabolically active and strongly correlated with insulin resistance, dyslipidemia and increased cardiovascular risk[29].

Quantitatively, the waist-to-hip ratio (WHR) serves as a marker of fat distribution. Women usually present with WHR below 0.85, indicating peripheral fat accumulation, whereas men often have WHR exceeding 0.90, reflecting central adiposity. These distinctions have substantial implications for disease risk stratification[30]. Hormonal influences are pivotal. Estrogen promotes subcutaneous fat deposition and exerts vasoprotective effects, while testosterone favors visceral fat accumulation. Postmenopausal women experience a decline in estrogen levels, leading to increased visceral adiposity and heightened metabolic risk. Conversely, men with higher testosterone levels tend to develop more visceral fat, amplifying the risk of metabolic syndrome[31].

2.2.2. Sociocultural and behavioral factors: Sociocultural norms and behavioral patterns profoundly influence gender disparities in obesity. Women in high-income countries often face societal pressures related to body image, which can influence dieting behaviors, physical activity and healthcare engagement[32]. Physical activity levels are generally lower among women, especially in urban settings, due to safety concerns, cultural restrictions or caregiving responsibilities. For example, global data from the World Health Organization[1] indicate that women are approximately 20-30% less likely to meet physical activity guidelines compared to men.

Dietary behaviors are also gender-specific. Women may be more prone to emotional eating or dieting, leading to cycles of weight fluctuation. In LMICs, women often have limited access to nutritious foods due to socio-economic constraints, leading to both undernutrition and obesity a paradoxical coexistence[33]. Psychosocial stress and mental health factors contribute variably. Urban women report higher levels of stress, which can trigger cortisol-mediated visceral fat accumulation. Emotional eating, driven by stress or depression, further exacerbates adiposity among women[34].

2.3. Regional disparities in gender-specific obesity trends

2.3.1. High-income countries: In high-income settings, women consistently demonstrate higher obesity prevalence than men. For instance, in the United States, 44% of women are obese versus 37% of men[22]. This disparity may be attributed to hormonal influences, cultural norms emphasizing slenderness in men and differences in physical activity levels[35]. Women tend to develop central obesity during reproductive years and postmenopause, increasing their risk for metabolic syndrome (MetS). In fact, the prevalence of metabolic syndrome among women exceeds that of men in many high-income countries, with estimates around 35-40% versus 25-30%, respectively[36].

2.3.2. Low- and middle-income countries: In LMICs, the gender gap in obesity prevalence is often narrower, with some regions reporting higher rates among men. In urban South Asia, male obesity rates reach approximately 15-20%, with women at similar or slightly higher levels. Cultural factors such as gendered food allocation, physical activity patterns and reproductive health influence these trends[37]. In sub-Saharan Africa, rural men engaged in mechanized agriculture exhibit obesity rates of 8-12%, whereas women, often involved in household activities, display lower rates (~10%), although urbanization and dietary westernization are increasing these figures rapidly[38].

Mathematical modeling of these patterns indicates that the odds ratio (OR) for obesity associated with female gender in high-income countries exceeds 1.5, while in LMICs ors vary between 1.0 and 1.3, depending on urbanization level[39].

2.4. The impact of urbanization on gender disparities

Urban environments significantly influence obesity trends, with profound gender-specific implications. Urbanization involves lifestyle changes such as decreased physical activity due to mechanized transport and sedentary occupations, increased access to processed foods and altered social norms[31]. Urban women often experience higher rates of central obesity, partly due to reduced physical activity and increased caloric intake. Data from developing countries reveal that urban women's prevalence of abdominal obesity (waist circumference ≥88 cm) can reach 45-50%, compared to 20-25% in rural women[40].

Urban men also experience increased obesity rates, often driven by dietary westernization and reduced occupational physical activity. The urban-rural obesity prevalence ratio (PR) in men is typically around 1.2-1.4, whereas for women, it can be as high as 2.0, signifying a more pronounced urban effect on women[24].

2.5. Biological and physiological variations influencing obesity

2.5.1. Fat cell differentiation and storage: The biological mechanisms underlying gender differences involve adipocyte biology. Estrogens stimulate the proliferation and differentiation of preadipocytes into subcutaneous adipocytes, predominantly in gluteal-femoral regions. Visceral adipose tissue (VAT), which accumulates centrally, is influenced more by androgens and cortisol[41]. Visceral fat is more lipolytically active, releasing free fatty acids (FFAs) directly into portal circulation, thus impairing hepatic insulin sensitivity. Quantitatively, VAT volume correlates with increased risk of insulin resistance; each standard deviation increases in VAT area (measured via imaging techniques like MRI or CT) associates with a 1.5-fold increase in the odds of metabolic syndrome[42].

2.5.2. Hormonal regulation: Menopause in women results in decreased estrogen, leading to increased visceral fat and a shift toward a male-pattern fat distribution, thereby elevating cardiometabolic risk. Conversely, testosterone deficiency in men is linked to increased adiposity[43]. Emerging evidence suggests that environmental endocrine-disrupting chemicals (EDCs), prevalent in urban pollution, interfere with hormonal pathways, further influencing adipogenesis and fat distribution in a gender-specific manner. For example, phthalates and bisphenol A (BPA) can mimic estrogen or interfere with androgen signaling, affecting fat accumulation patterns[44].

2.6. Sociocultural and lifestyle determinants

2.6.1. Dietary patterns and food environment: Dietary behaviors are deeply rooted in cultural norms and economic conditions. In high-income countries, women's diets often include higher carbohydrate and sugar intake, influenced by marketing and social norms. Fast food and processed snacks are prevalent, contributing to positive energy balance[45]. In LMICs, rapid urbanization and globalization have introduced Western dietary patterns characterized by energy-dense, nutrient-poor foods. Women's increased participation in the workforce and urban migration have led to higher caloric intake, often exceeding energy expenditure[46].

2.6.2. Physical activity and sedentary behavior: Physical activity levels are inversely related to urbanization. Data from the WHO indicate that only 25-30% of women in urban settings meet recommended physical activity levels, compared to 45-50% of men. Cultural restrictions, safety concerns and caregiving responsibilities limit women's mobility and recreational activity[47]. In rural areas, physical activity is primarily occupational, with agricultural work providing substantial energy expenditure. However, mechanization and urban migration are reducing these physical activity levels, especially among women[48,49].

2.6.3. Psychosocial factors and mental health: Urban stressors, including social isolation, noise pollution and economic pressures, influence eating behaviors and metabolic health. Women in urban environments report higher levels of stress-related eating, which involves increased intake of high-calorie, palatable foods. Cortisol production during chronic stress enhances visceral fat deposition, further exacerbating cardio metabolic risk[50].

2.7. Quantitative data and mathematical modeling of disparities

2.7.1. Prevalence and odds ratios

Table 1: Regional Disparities in Obesity Prevalence and Gender Odds Ratios.

Region	Female Obesity Prevalence (%)	Male Obesity Prevalence (%)	Gender Odds Ratio (OR)	References
North America (USA)	42.4	36.2	1.54	CDC, 2021
Europe (EU countries)	40	35	1.33	Eurostat, 2022
South Asia (urban India, Pakistan)	20-25	15-20	1.25-1.30	Haque et al., 2021
Sub-Saharan Africa	15-Oct	12-Aug	1.2-1.25	WHO Regional Reports
Middle East	45-50	40-45	1.2-1.3	WHO Eastern Mediterranean Data

The odds ratios (ORs) indicate that women are significantly more likely to be obese than men in high-income countries, whereas in LMICs, the ORs are lower but still indicate a gender disparity favoring higher female prevalence **(Table 1, Figure 1&2)**[1,22,23,51,52].

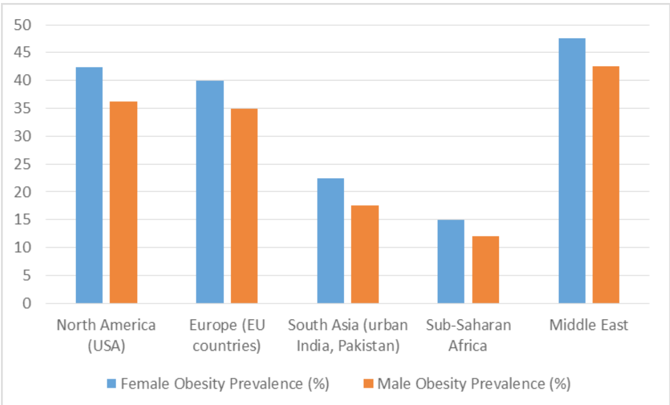

Figure 1: Male versus Female Obesity Prevalence.

2.7.2. Temporal trends: Longitudinal data reveal that obesity prevalence has increased by approximately 2-3% annually over the past two decades in most regions, especially among women in urban settings. For example, in India, female obesity increased from 10% in 1990 to 22% in 2015, representing a doubling within 25 years[53]. The global landscape of obesity is characterized by distinctive gender-specific patterns shaped by biological, behavioral and sociocultural factors. Women in high-income countries exhibit higher prevalence rates driven by hormonal influences, sociocultural expectations and lifestyle factors, whereas in LMICs, rising obesity among both genders reflects rapid urbanization, dietary westernization and mechanization of labor[54].

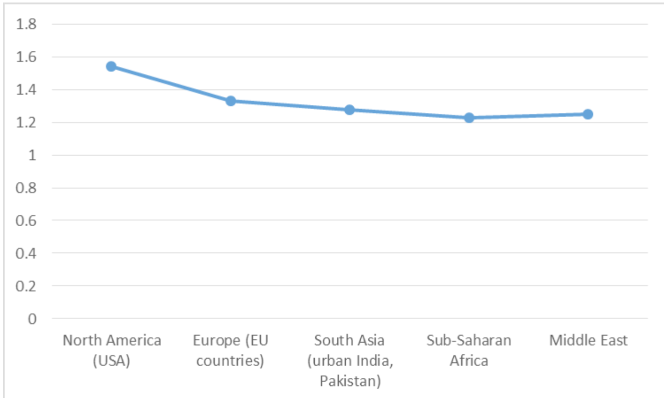

Figure 2: Gender Odds Ratio (OR) across different Regions.

Mathematical modeling and epidemiological data underscore the dynamic and evolving nature of these disparities, necessitating culturally sensitive, gender-responsive and region-specific interventions. Recognizing the complex interplay of these factors is crucial for effective public health strategies aimed at curbing the obesity epidemic and its associated health burdens globally[55].

3. Biological and Physiological Differences in Obesity

The pathophysiology of obesity is intricately linked to biological and physiological differences that vary significantly between genders. These differences influence fat distribution, adipocyte function, hormonal regulation and metabolic pathways, ultimately affecting the risk profiles for obesity-related diseases. Recognizing these gender-specific biological factors is essential for understanding disparities in obesity prevalence, phenotypic expression and associated metabolic complications. This section provides a comprehensive exploration of the biological and physiological distinctions, emphasizing adipose tissue distribution, hormonal regulation and environmental influences on these mechanisms **(Table 2)**[56].

Table 2: Summary of Key Biological and Physiological Differences in Obesity by Gender.

Aspect	Women	Men	Notes/Implications
Body Fat Percentage	25-30% at similar BMI	20-25% at similar BMI	Women have higher total fat percentages
Fat Distribution	Gynoid (peripheral: hips, thighs)	Android (central: visceral fat)	Different risk profiles
Waist-to-Hip Ratio (WHR)	<0.85	>0.90	Marker of fat distribution and risk
Hormonal Influence	Estrogen promotes subcutaneous fat	Testosterone promotes visceral fat	Postmenopause increases visceral fat in women
Response to Environmental Endocrine Disruptors	Sensitive to BPA, phthalates	Less sensitive but affected by hormonal changes	Impact on fat accumulation and distribution

3.1. Adipose tissue distribution: Gender-specific patterns

3.1.1. The role of sex in fat depot localization: Adipose tissue is not uniformly distributed throughout the body; instead, its localization varies based on biological sex, genetic predisposition and environmental factors. Women tend to predominantly store fat in peripheral regions, notably the hips, thighs and gluteal areas-a pattern referred to as gynoid or gluteofemoral adiposity. This distribution is considered metabolically protective due to its association with favorable lipid profiles, increased insulin sensitivity and reduced cardiovascular risk[57].

Men predominantly accrue central or android adiposity, characterized by visceral fat accumulation within the abdominal cavity. Visceral adipose tissue (VAT) is metabolically active, secreting pro-inflammatory cytokines such as interleukin-6 (IL-6) and tumor necrosis factor-alpha (TNF-α), which promote insulin resistance, dyslipidemia and atherosclerosis. Quantitatively, imaging studies utilizing magnetic resonance imaging (MRI) or computed tomography (CT) have demonstrated that men possess approximately 30-50% more visceral fat area than women at comparable BMI levels, translating into a higher cardiometabolic risk profile. Studies report that men often exhibit ratios exceeding 0.5, indicating dominant visceral fat, whereas women typically maintain ratios below 0.3[58].

3.1.2. Hormonal regulation of fat depot specificity: The differential fat distribution pattern is primarily governed by sex hormones, notably estrogen and testosterone, which modulate adipocyte differentiation, lipolysis and storage capacity in specific tissues. Estrogen enhances the proliferation and activity of preadipocytes in subcutaneous fat depots, favoring peripheral fat storage[59]. Estrogen's influence involves activating estrogen receptors (ERα and ERβ) in adipocytes, leading to increased expression of genes conducive to lipid storage in subcutaneous tissues. This effect is particularly evident during reproductive years, where estrogen levels are high, correlating with gynoid fat predominance. Postmenopause, with declining estrogen, women often experience a shift toward central adiposity, increasing their risk for metabolic syndrome[60].

Testosterone in men promotes visceral fat accumulation by stimulating adipocyte differentiation within the visceral region. Testosterone inhibits subcutaneous fat proliferation, favoring a visceral distribution. It also influences lipolytic activity, with higher testosterone levels correlating with lower overall fat mass but increased visceral adiposity[61]. Quantitative data suggest that estrogen decreases lipolysis in peripheral fat, with a reduction of approximately 10-15% in lipolytic activity compared to premenopausal levels, contributing to fat accrual in the lower body. Conversely androgen excess in women (e.g., polycystic ovary syndrome) is associated with increased visceral fat and metabolic disturbances[62].

3.2. Environmental and lifestyle influences on fat distribution

3.2.1. Urbanization, diet and physical activity: Environmental factors, including diet and physical activity, can modulate the inherent biological patterns of fat distribution. Urban lifestyles characterized by sedentary behavior, psychological stress and high-calorie diets can exacerbate central fat accumulation, especially in women with hormonal susceptibilities[63]. In urban settings, increased consumption of processed foods rich in refined carbohydrates, trans fats and sugar-sweetened beverages promotes caloric excess and visceral fat deposition. Sedentary lifestyles, with reduced physical activity levels often below 150 minutes/week of moderate exercise further contribute to negative fat redistribution[64].

Research indicates that stress-induced cortisol elevation in urban environments promotes visceral adiposity. Cortisol, a glucocorticoid hormone, enhances lipogenesis in visceral fat depots via activation of the glucocorticoid receptor (GR), increasing VAT volume by approximately 20-30% in chronically stressed individuals[65]. In rural populations engaged in physically demanding activities, fat distribution tends to favor peripheral depots, with a lower V/S ratio and decreased risk of metabolic syndrome. However, mechanization and dietary westernization are leading to shifts toward central adiposity even in these populations[66].

3.3. Hormonal regulation and metabolic variability

3.3.1. Sex hormones and their influence on metabolic pathways: Estrogen exerts multiple protective effects on lipid metabolism, glucose homeostasis and cardiovascular health. It enhances high-density lipoprotein (HDL) levels by approximately 15-20% and suppresses low-density lipoprotein (LDL) cholesterol, reducing atherogenic risk. Estrogen also improves insulin sensitivity, decreasing fasting insulin levels by about 10-15% in premenopausal women[67]. The influence of estrogen on adipocyte function can be summarized by its action on PPARγ (peroxisome proliferator-activated receptor gamma), a key regulator of adipogenesis. Estrogen upregulates PPARγ expression in subcutaneous fat, promoting healthy lipid storage[68].

Postmenopause, with estrogen levels declining from an average of 200-300 pg/mL to below 50 pg/mL, women experience increased visceral fat accumulation up to 30-40% of total adiposity elevating their risk for metabolic syndrome and cardiovascular disease[69]. Testosterone, prevalent in males at approximately 300-1000 ng/dL, influences adiposity by enhancing visceral fat deposition. Testosterone deficiency in men (e.g., hypogonadism) correlates with increased visceral fat, with visceral fat mass increasing by approximately 15-20% per 10% decrease in circulating testosterone[70].

3.3.2. Endocrine disruptors and environmental chemicals: Environmental exposures, especially in urban pollution, include endocrine-disrupting chemicals (EDCs) such as bisphenol A (BPA), phthalates and polychlorinated biphenyls (PCBs). These agents can interfere with hormonal signaling, affecting adipogenesis, fat distribution and metabolic health[71]. BPA mimics estrogen, binding to estrogen receptors and altering gene expression related to adipocyte differentiation. Studies demonstrate that BPA exposure correlates with a 12-20% increase in visceral fat area among exposed populations, with stronger effects observed in women with hormonal sensitivities[72].

3.4. Environmental impact on biological mechanisms

3.4.1. Pollution, endocrine disruption and inflammation: Urban pollution introduces a milieu of pollutants capable of influencing adipocyte function and systemic metabolic health. Particulate matter (PM2.5) inhalation induces systemic inflammation, which can exacerbate insulin resistance and promote visceral fat accumulation[73]. Particulate matter exposure has been associated with an increase in inflammatory cytokines such as IL-6 and TNF-α, which impair insulin signaling pathways. The effect is particularly pronounced in women with hormonal susceptibilities, such as postmenopausal women or those with hormonal imbalances, due to their heightened sensitivity to environmental perturbations[9].

Chronic low-grade inflammation driven by environmental pollutants can increase the adipose tissue macrophage infiltration by 40-60%, further promoting insulin resistance and metabolic dysfunction, especially in visceral depots[74].

4. Behavioral and Socioeconomic Determinants of Obesity

Obesity is a multifaceted condition influenced not only by biological and environmental factors but also significantly shaped by behavioral and socioeconomic determinants. These factors modulate individual choices, access to resources and cultural norms, thereby affecting the prevalence and distribution of obesity across different populations. Understanding the intricate interplay of dietary behaviors, physical activity patterns and socioeconomic status (SES) is crucial for developing effective, targeted interventions. This section explores these determinants in detail, emphasizing their regional variations, underlying mechanisms and implications for public health **(Table 3)**[75].

Table 3: Behavioral and Socioeconomic Determinants.

Determinant	Urban	Rural	Impact/Notes
Food Environment	Processed, calorie-dense foods abundant	Traditional, whole foods	Urbanization increases obesogenic diet
Physical Activity	Reduced, sedentary lifestyles	High occupational activity	Mechanization reduces rural activity
Socioeconomic Status	Low SES linked to poor diet, less activity	Similar trends	Food deserts, limited resources
Healthcare Access	Better in urban; limited in rural	Scarce facilities	Affects diagnosis and management
Cultural Norms	Shift towards slimness in urban areas	Body size as prosperity in some cultures	Influences behaviors

4.1. Dietary patterns and food environment

4.1.1. Urban versus rural dietary landscapes: The nutritional environment varies markedly between urban and rural settings, influencing obesity risk through differences in food availability, dietary habits and cultural practices. Urban environments typically provide residents with extensive access to processed, energy-dense foods, which are often high in refined carbohydrates, saturated fats and added sugars. Supermarkets, convenience stores and fast-food outlets are widespread, creating an "obesogenic" food environment characterized by high-calorie options that are easily accessible and heavily marketed[76]. Empirical data suggest that urban dwellers consume, on average, 25-30% more processed foods compared to their rural counterparts. For instance, in metropolitan areas of India, the intake of sugar-sweetened beverages (SSBs) has increased by approximately 15-20% over the past decade, correlating with rising obesity rates among urban women and men. The prevalence of fast-food consumption among urban women aged 20-40 years has been reported to be as high as 35-40%, influenced by convenience, social norms and targeted advertising[77].

Fast-food marketing strategies often focus on women, especially those balancing work and family responsibilities, emphasizing convenience and affordability. These marketing campaigns leverage social media, celebrity endorsements and promotional discounts, shaping dietary choices that favor calorie-dense foods. The cumulative effect contributes to positive energy balance, with some studies estimating that urban residents consume an excess of 300-500 kcal/day compared to rural residents, significantly increasing obesity risk[78]. Rural populations traditionally rely on diets rich in whole grains, legumes, vegetables and lean meats components associated with lower caloric density and higher satiety. Globalization and market integration have led to the infiltration of processed foods into rural markets. Market surveys in Southeast Asia indicate that processed snack consumption in rural areas has increased by 20-25% over the last decade, contributing to shifts in dietary patterns. Rural food insecurity, paradoxically, can coexist with obesity a phenomenon termed the "hunger-obesity paradox" where reliance on inexpensive, calorie-rich, nutrient-poor foods leads to weight gain despite insufficient intake of micronutrients[79].

4.1.2. Dietary quality and nutritional transition: The quality of diet is a critical determinant of obesity development. Urban diets often involve higher consumption of refined grains, sugar-laden beverages and processed snacks, whereas traditional diets emphasize unprocessed, fiber-rich foods. The shift towards Westernized dietary patterns is associated with increased intake of saturated fats and added sugars, which are linked to increased visceral adiposity and insulin resistance. For example, an increase in added sugar intake (from 10% to 20% of total calories) has been associated with a 15-20% increased risk of developing obesity-related metabolic disorders[80].

4.2. Physical activity and sedentary lifestyle

4.2.1. Urban sedentary behaviors: Urbanization has transformed physical activity patterns, often leading to sedentary lifestyles that significantly contribute to energy imbalance. Modern urban environments favor transportation modes such as automobiles, buses and subways, reducing the necessity for active commuting. Occupational shifts from manual labor to desk-bound jobs further diminish physical activity levels. Leisure activities increasingly involve screen-based entertainment television, computers, smartphones leading to prolonged sedentary periods[81]. Data from the World Health Organization (WHO) indicate that only 25-30% of urban adults meet the recommended physical activity guidelines of at least 150 minutes of moderate-intensity activity per week. Among women, this percentage drops further to 15-20%, owing to safety concerns, cultural restrictions and caregiving responsibilities limiting outdoor activity participation[82].

4.2.2. Rural physical activity and its decline: In rural settings, physical activity has traditionally been high due to manual labor associated with agriculture, animal husbandry and household chores. This lifestyle contributes to higher energy expenditure, acting as a protective factor against obesity. Nonetheless, mechanization of farming tools, motorized transport and technological advances have resulted in a decline in physical activity levels among rural populations[83]. Recent surveys illustrate that rural adults' physical activity levels have decreased by approximately 10-15% over the past decade, leading to rising obesity prevalence. Rural men in Southeast Asia now report average daily physical activity levels that are 20-25% lower than in previous generations, correlating with increased BMI and waist circumference[79].

4.3. Socioeconomic factors and access to resources

4.3.1. The impact of socioeconomic status on dietary and physical activity patterns: Socioeconomic status (SES) profoundly influences health behaviors, including diet, physical activity and healthcare utilization. In urban low-SES populations, limited financial resources often restrict access to fresh, healthy foods, leading to reliance on inexpensive, calorie-dense processed foods. Food deserts areas with limited access to affordable, nutritious foods are prevalent in impoverished urban neighborhoods, further exacerbating poor dietary choices[84]. Statistical analyses reveal that urban low-SES groups have 30-40% higher prevalence of obesity compared to higher SES groups within the same urban area. This disparity is driven by factors such as limited access to recreational facilities, unsafe neighborhoods restricting outdoor activity and lack of health literacy. For example, in the United States, adults in the lowest income quartile exhibit obesity rates of 40-45%, compared to 25-30% in higher-income groups[85].

In rural areas, socioeconomic disadvantages hinder access to healthcare, health education and healthy foods. Limited infrastructure results in fewer opportunities for physical activity, such as gyms or parks and healthcare services for screening and managing obesity-related conditions. Cultural perceptions of body weight also influence health-seeking behaviors; in some rural communities, higher body weight may be associated with prosperity and health, reducing motivation for weight management[86].

4.3.2. Healthcare access and health literacy: Limited access to healthcare services hampers early detection, counseling and management of obesity. In rural settings, healthcare facilities are often sparse, with patient-to-provider ratios exceeding 1,000:1 in some regions. This gap delays diagnosis and intervention, allowing obesity and its complications to progress unchecked[87]. Health literacy a person's capacity to obtain, process and understand basic health information is often lower in socioeconomically disadvantaged populations. Limited health literacy diminishes the likelihood of adopting healthy behaviors, such as balanced diets and regular physical activity or seeking timely medical advice[88].

5. Cultural and Psychosocial Influences on Obesity

Cultural and psychosocial factors are fundamental determinants of obesity, shaping individual behaviors, perceptions and responses to environmental stimuli. These influences often operate through complex pathways involving societal norms, mental health and behavioral coping mechanisms. Understanding these facets is essential for designing culturally sensitive and psychologically informed interventions aimed at preventing and managing obesity across diverse populations **(Table 4)**[33].

Table 4: Cultural and Psychosocial Influences.

Aspect	Key Points
Body Image Norms	Higher BMI seen as prosperity in some cultures; slimness valued in others
Cultural Barriers	Restrictions on women's activity; traditional diets
Stress & Mental Health	Chronic urban stress promotes visceral fat via cortisol
Social Perceptions	Stigma or acceptance varies by culture

5.1. Cultural norms and body image perceptions

5.1.1. Societal ideals and body size ideals: Cultural perceptions of body image significantly influence health behaviors related to diet and physical activity. In many traditional societies, a higher body mass index (BMI) is often associated with wealth, prosperity and health. For example, in sub-Saharan Africa, parts of Southeast Asia and certain Middle Eastern cultures, larger body size is regarded as a symbol of social status and well-being. This cultural valorization reduces motivation for weight management and can hinder public health efforts aimed at reducing obesity prevalence[89]. Quantitatively, surveys indicate that in some rural African communities, over 60% of women with BMI >30 kg/m² report positive social perceptions associated with their body size, such as being seen as healthy or prosperous. Such perceptions can diminish the perceived need for lifestyle modifications and influence social pressures that discourage weight loss efforts.

Urbanization often shifts these norms toward valuing slimness, especially among women, driven by Western beauty standards propagated through media, fashion and celebrity culture. For instance, in urban China and India, over 70% of women aged 20-35 associate slenderness with attractiveness and success. These shifting norms influence gender-specific behaviors, with urban women engaging more actively in weight control practices, including dieting and exercise, driven by societal pressures and personal aspirations[90].

5.1.2. Cultural barriers and facilitators: Cultural beliefs may also influence attitudes toward physical activity, dietary choices and health-seeking behaviors. For example, some cultures regard physical activity as unnecessary or even inappropriate for women, especially in conservative societies. Such norms reduce participation in physical activity; in certain Middle Eastern communities, less than 20% of women report engaging in regular exercise, primarily due to cultural restrictions[91]. Some cultures incorporate traditional food practices that promote balanced nutrition, such as the Mediterranean diet, which is associated with lower obesity rates. Recognizing these cultural strengths provides opportunities to reinforce healthy behaviors within culturally relevant frameworks[92].

5.2. Psychosocial stress and mental health

5.2.1. Urban living and stress-induced obesity: Urban environments are characterized by high levels of psychosocial stress arising from factors such as job insecurity, social isolation, pollution and economic instability. Chronic stress activates the hypothalamic-pituitary-adrenal (HPA) axis, leading to elevated cortisol levels, which promote visceral adiposity and increase appetite, particularly for high-calorie comfort foods[93]. Research indicates that individuals experiencing persistent stress exhibit a 20-30% higher likelihood of developing obesity compared to unstressed counterparts. For instance, a longitudinal study in urban populations found that women under chronic stress were 1.5 times more prone to emotional overeating, with cortisol levels positively correlating ($r=0.65$, $p<0.01$) with increased waist circumference[94].

5.2.2. Gender differences in stress responses: Gender differences in stress response and coping strategies influence obesity trajectories. Women tend to respond to stress through emotional overeating, a behavior driven by hormonal mechanisms involving cortisol, serotonin and dopamine pathways. Neuroimaging studies reveal that women with high stress levels show increased activation of the limbic system, associated with emotional regulation and reward processing, which correlates with increased intake of palatable, energy-dense foods[95]. Men may respond to stress via different behavioral pathways, such as increased alcohol consumption or reduced physical activity. Quantitative data suggest that men under stress are 35% more likely to engage in sedentary behaviors, including screen time, which contributes to decreased energy expenditure[7].

5.2.3. Mental health and obesity: Psychosocial factors such as depression, anxiety and low self-esteem are both causes and consequences of obesity, creating a bidirectional relationship. Epidemiological data indicate that individuals with clinical depression have a 1.2-1.8 times higher risk of developing obesity. Conversely, obesity can exacerbate mental health issues through social stigmatization and reduced quality of life, forming a vicious cycle that complicates management[96].

5.3. Impact of residential area on obesity management and treatment

5.3.1. Healthcare infrastructure and utilization: The geographic location of residence exerts a profound influence on access to healthcare services, which in turn affects the management and treatment of obesity. Urban residents generally benefit from well-established healthcare infrastructure, including specialized clinics, multidisciplinary teams and advanced diagnostic facilities. These centers facilitate comprehensive obesity management programs encompassing behavioral counseling, pharmacotherapy and surgical options[97]. Rural populations face significant barriers such as geographic isolation, scarcity of trained healthcare providers and limited access to evidence-based interventions. For example, in low-resource settings, the ratio of healthcare providers to population can be as high as 1:5000 in rural areas compared to 1:1000 in urban centers. Consequently, rural residents are less likely to receive timely diagnosis, counseling or pharmacological therapy, leading to higher rates of untreated or poorly managed obesity[98].

5.3.2. Pharmacological and surgical interventions: Pharmacotherapy for obesity, including agents like liraglutide and naltrexone/bupropion, operates through mechanisms such as appetite suppression, delayed gastric emptying and modulation of reward pathways. These drugs' pharmacokinetics and pharmacodynamics may be influenced by adipose tissue distribution and metabolic state, which are affected by gender and environment[99]. Lipophilic drugs like liraglutide, which are extensively distributed into adipose tissue, may exhibit variable efficacy depending on body fat composition. For instance, individuals with higher visceral fat may experience different drug absorption and metabolism profiles. While current guidelines do not specify gender-specific dosing, emerging evidence suggests that personalized dosing strategies considering individual biological and environmental factors could optimize outcomes[100].

Bariatric surgery, such as Roux-en-Y gastric bypass and sleeve gastrectomy, requires thorough preoperative assessment that accounts for gender-specific anatomical and hormonal considerations. Postoperative care must be tailored to address differences in weight loss trajectories and nutritional needs, which vary by gender and residential context due to disparities in healthcare access[101].

5.4. Lifestyle interventions and community-based programs

5.4.1. Urban settings: Urban environments often provide structured settings for lifestyle interventions, including weight management clinics, fitness centers and community programs. These resources enable individuals to participate in supervised exercise, dietary counseling and behavioral modification programs. However, environmental barriers such as safety concerns, time constraints and work commitments can hinder adherence. Data suggest that only 30-40% of urban obese individuals participate regularly in such programs, with dropout rates exceeding 25% within six months[102].

5.4.2. Rural settings: In rural areas, formal programs may be scarce or nonexistent. Nonetheless, community-based, culturally tailored initiatives can effectively promote healthy behaviors. These programs leverage local social networks, traditional practices and community leaders to foster engagement. For example, in rural India, village health volunteers have organized group physical activities and nutritional education sessions, resulting in a 15-20% reduction in obesity prevalence over two years[103].

5.4.3. Tailoring interventions: Culturally and environmentally tailored interventions considering local dietary patterns, physical activity opportunities and social norms are more likely to succeed. Incorporating local food practices, respecting cultural perceptions of body image and addressing socioeconomic barriers can enhance adherence and sustainability[104]. Cultural and psychosocial influences are pivotal in shaping obesity risks and management strategies. Societal norms regarding body image, mental health and stress responses significantly modulate behaviors that contribute to or mitigate obesity. Recognizing the diversity of these influences across different residential settings and cultural contexts is essential for developing effective, culturally sensitive interventions. Tailoring approaches to address these psychosocial factors holds promise for improving obesity outcomes globally[105].

6. Modern Perspectives and Future Directions in Obesity Management

The landscape of obesity management is rapidly evolving, driven by advances in biomedical science, technology and public health policy. The integration of personalized medicine, digital health tools and multisectoral policy initiatives holds promise for addressing the complex interplay of genetic, behavioral, environmental and social determinants of obesity. This section provides an in-depth analysis of emerging strategies and future directions, emphasizing the importance of tailoring interventions to individual and population-level needs and promoting sustainable, equitable health outcomes[106].

6.1. Personalized and precision medicine in obesity

6.1.1. The role of genomics, metabolomics and phenotyping: Recent advances in genomics have revolutionized the understanding of obesity's heterogeneity. Genome-wide association studies (GWAS) have identified over 100 loci associated with BMI, fat distribution and metabolic risk factors. For instance, variants in the FTO gene are linked to increased appetite and adiposity, accounting for approximately 1.5-2.0% of BMI variance. Recognizing such genetic predispositions enables clinicians to stratify patients based on their risk profiles and tailor interventions accordingly[107]. Metabolomics the comprehensive analysis of metabolites provides insights into individual metabolic phenotypes. Certain metabolomics signatures, such as elevated branched-chain amino acids, are associated with insulin resistance and central obesity. Phenotyping based on metabolic profiles allows for targeted nutritional and pharmacological strategies, optimizing efficacy while minimizing adverse effects[108].

6.1.2. Gender-specific and environmentally informed interventions: Gender differences in hormonal profiles, adipose tissue distribution and gene expression impact both the pathophysiology of obesity and treatment response. For example, women tend to accumulate subcutaneous fat, which is metabolically less harmful than visceral fat predominant in men. Pharmacogenomics studies indicate that drug efficacy and side effect profiles may differ by gender; for instance, lipophilic drugs such as liraglutide may have different pharmacokinetics in individuals with varying fat distribution. Incorporating genetic and hormonal data into clinical decision-making fosters a move toward precision medicine, where interventions be they pharmacological, dietary or behavioral are customized[109]. Pharmacotherapy efficacy varies according to individual biological parameters. For instance, individuals with higher visceral adiposity may respond differently to GLP-1 receptor agonists like liraglutide, with some studies reporting up to 15-20% greater weight loss in this subgroup. Similarly, pharmacokinetic modeling suggests that dosing adjustments based on body composition could enhance outcomes. Bariatric surgery, such as sleeve gastrectomy or gastric bypass, requires preoperative risk stratification considering gender, age, BMI, comorbidities and psychological factors. Postoperative management must be personalized, including nutritional supplementation and behavioral support, to optimize weight loss and minimize complications[110].

6.2. Digital health and telemedicine: Transforming obesity care

6.2.1. Bridging the urban-rural gap: Digital health technologies are transforming healthcare delivery, especially for populations in remote or underserved areas. Telemedicine enables clinicians to conduct virtual consultations, monitor patient progress via wearable devices and provide ongoing education. For example, mobile health (mHealth) applications can track dietary intake, physical activity and weight fluctuations, providing real-time feedback and motivation.

Data indicate that adherence to digital interventions can increase by 30-50%, with some programs demonstrating an average weight loss of 5-10% over six months. These tools are particularly valuable for women and rural residents who face barriers to traditional healthcare access, thereby promoting gender-sensitive and culturally appropriate care.

6.2.2. Personalized digital interventions: Artificial intelligence (AI) and machine learning algorithms can analyze large datasets to customize behavioral interventions. For example, AI-driven apps can identify patterns in individual data such as stress levels, sleep quality and activity and adapt recommendations accordingly. Mathematical models can predict the likelihood of adherence or relapse, enabling clinicians to intervene proactively.

Virtual coaching and tele-supervision can enhance motivation and accountability, addressing psychosocial barriers identified previously. The integration of digital health with electronic health records (EHRs) facilitates comprehensive, longitudinal management of obesity, encompassing biological, behavioral and social data.

6.3. Policy and public health interventions: Creating supportive environments

6.3.1. Multisectoral strategies to address disparities: Combating obesity at a population level necessitates policies that foster health-promoting environments. Urban planning can promote physical activity through the development of pedestrian-friendly infrastructure, cycling lanes and accessible green spaces. For instance, increasing walkability scores by 10-20% has been associated with a 5-10% reduction in obesity prevalence in urban communities.

Regulations on the marketing of unhealthy foods and beverages, especially targeting children and adolescents, are critical. Evidence suggests that restricting advertising of high-sugar snacks and SSBs can reduce consumption by 15-25% among youth.

In rural settings, policies should focus on improving access to nutritious foods, such as subsidizing fruits and vegetables and establishing community-based programs that leverage local resources. For example, school-based nutrition programs can reduce childhood obesity prevalence by 10-15%, especially when culturally tailored.

6.3.2. Gender-sensitive policy initiatives: Gender disparities in healthcare access and resource allocation demand targeted policies. Ensuring equitable access to weight management clinics, counseling services and educational programs is vital. For instance, implementing community outreach that addresses cultural norms and gender roles can increase participation among women, who often face social constraints.

The future of obesity management rests on integrating cutting-edge scientific insights with innovative technological solutions and comprehensive policy measures. Emphasizing personalized and precision approaches allows for interventions that consider individual genetic, hormonal, behavioral and environmental factors, thereby enhancing efficacy and sustainability. Digital health tools, including telemedicine and AI-driven applications, have the potential to bridge healthcare disparities, particularly in rural and underserved populations and facilitate gender-sensitive, culturally appropriate care. Simultaneously, multisectoral policies that promote healthy environments such as active transportation infrastructure, healthy food accessibility and regulatory measures are essential for creating systemic change.

Research must continue to explore the complex interactions among biological, environmental and psychosocial determinants, prioritizing longitudinal, multi-ethnic studies that can inform tailored interventions. Mathematical modeling and data analytics will play a pivotal role in predicting outcomes, optimizing resource allocation and personalizing care. Achieving equitable and sustainable reductions in obesity prevalence demands a collaborative effort among clinicians, policymakers, researchers and communities. By embracing innovative strategies grounded in scientific evidence and cultural sensitivity, the global health community can make significant strides toward reversing the obesity epidemic and improving health outcomes for diverse populations worldwide.

7. Conclusion

This comprehensive review underscores the multifaceted nature of obesity, highlighting the critical influence of gender disparities and environmental context on its epidemiology, pathophysiology and management. Biological differences, including adipose tissue distribution and hormonal regulation particularly the roles of estrogen and testosterone play pivotal roles in shaping distinct obesity phenotypes and associated cardio metabolic risks across sexes. Sociocultural norms, lifestyle behaviors and environmental exposures further modulate these biological predispositions, contributing to regional and urban-rural variations in prevalence. Recognizing the intersectionality of biological, behavioral and environmental determinants is essential for developing precision medicine approaches, enabling tailored interventions that optimize therapeutic efficacy and mitigate health disparities.

Looking forward, integrating advancements in genomics, metabolomics and digital health technologies offers promising avenues for personalized, gender-sensitive obesity management. Precision medicine, coupled with culturally competent behavioral and community-based strategies, can enhance adherence and outcomes. Multisectoral policy initiatives aimed at creating health-promoting environments such as active urban infrastructure, regulation of obesogenic marketing and equitable access to nutritious foods are crucial for sustainable population-level impact. Addressing the complex interplay of biological, psychosocial and socio-economic factors through innovative, evidence-based and culturally adapted interventions is imperative to stem the global obesity epidemic and reduce its associated morbidity and mortality.

8. Conflict of Interest Statement

Authors have no conflict of interest.

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12. Informed Consent / Patient Consent

The data has been collected with the consent of respondents.

13. Data availability statement

Data will be available upon request.

14. Authors Contribution

Waqas Ghulam Hussain and Fareed Shareef conceived, designed and did statistical analysis & editing of manuscript. Waqas Ghulam Hussain and Fizzah Fareed did data collection and manuscript writing. Waqas Ghulam Hussain, Fareed Shareef and Fizzah Fareed did review and final approval of manuscript.

15. Other Journal Specific Statements

None.

16. Abbreviations

BMI	:	Body Mass Index
WHO	:	World Health Organization
T2DM	:	Type 2 Diabetes Mellitus
CVD	:	Cardiovascular Diseases
VAT	:	Visceral Adipose Tissue
WHR	:	Waist-to-Hip Ratio
EDCs	:	Endocrine Disrupting Chemicals
MRI	:	Magnetic Resonance Imaging
CT	:	Computed Tomography
HDL	:	High-Density Lipoprotein
LDL	:	Low-Density Lipoprotein
GWAS	:	Genome-Wide Association Studies
mHealth	:	Mobile Health
AI	:	Artificial Intelligence
LMS	:	Lambda Mu Sigma
QR	:	Quantile Regression
BSSI	:	Body Shape and Size Index
BSA	:	Body Surface Area
PI	:	Ponderal Index
CDC	:	Centers for Disease Control

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