Background. Globally, obesity is becoming a public health problem in the general population. Various determinants were reported by different scholars even though there are inconsistencies. Different biomarkers of obesity were identified for the prediction of obesity. Even though researchers speculate the factors, biomarkers, consequences, and prevention mechanisms, there is a lack of aggregate and purified data in the area of obesity.

Summary. In this review, the epidemiology, predisposing factors, biomarkers, consequences, and prevention approaches of obesity were reviewed.

Key Messages. The epidemiology of obesity increased in low-, middle-, and high-income countries. Even if the factors vary across regions and socioeconomic levels, sociodemographic, behavioral, and genetic factors were prominent for the development of obesity. There are a lot of biomarkers for obesity, of which microRNA, adipocytes, oxidative stress, blood cell profile, nutrients, and microbiota were promising biomarkers for determination of occurrence of obesity. Since the consequences of obesity are vast and interrelated, multidimensional prevention strategy is mandatory in all nations.

1. Introduction

The 2017 global nutrition report showed that 2 billion adults are overweight/obese and 41 million children are overweight worldwide [1]. In the last three decades, obesity increased globally; unexpectedly, it is also rising in low- and middle-income countries due to uncontrolled urbanization and nutrition transition (shifting dietary habit from traditional to westernized diet) [2, 3]. The global prevalence of overweight in children aged less than five years was increased modestly. The trend of overweight was heterogeneous in low- and middle-income countries. Meanwhile, the prevalence of obesity in children aged 2–4 years has increased moderately. In 1975, children with obesity aged 5–19 years were relatively rare, but it becomes highly prevalent in 2016 [4].

In the majority of European countries, the prevalence was increased from 10% to 40% in the last 10 years, and specifically in England, it increased more than threefolds [5].

The prevalence of obesity among reproductive-age women was 5.1% in India [6], 15.7% in Palestinian schoolchildren, and 34.8% among adult populations of Saudi Arabia [7]. The prevalence of overweight and obesity was 40.9% in Kuwait among children aged 6–8 years. Amazingly, their mothers’ perceive that they had healthy weight; in contrary, those children who have normal weight were also criticized by their mothers to be unhealthy [8].

A systematic review conducted in Africa among primary school educators revealed that the continental figure of obesity increased. In this review, the magnitude of obesity was measured based on three international standards, i.e., World Health Organization (WHO), Center for Disease Control (CDC), and International Obesity Taskforce (IOTF) cutoff points. Based on the criteria mentioned above, the prevalence of obesity was 6.1% (WHO criteria), 4.0% (IOTF criteria), and 6.9% (CDC criteria) [9]. Generally, the prevalence of obesity in Africa among schoolchildren lies between 4.4% and 21.2 percent [9–11].

Another critical issue is currently the emerging sarcopenic obesity. Sarcopenic obesity is defined as loss of skeletal muscle and excess body fat accumulation. Clinically, it can
be diagnosed through muscle biopsy, computed tomography
or magnetic resonance spectroscopy, bioelectrical impedi-
ance analysis (BIA), and dual energy X-ray. Primarily, the
consequence of sacopenic obesity end is liver cell damage
either carcinogen or any abnormality [12]. It is highly
prevalent in elder population even though it did not get
emphasis in the majority of countries.

2. Predisposing Factors of Obesity

Different scholars mention a lot of predisposing factors
which vary depending on geography, social conditions,
political and economic factors, and human genetics. In
aggregate, the commonest factors were sociodemographic,
behavioral, genetic, and living in obesogenic environment.

2.1. Sociodemographic Factors. Based on United Nations
Children’s Fund (UNICEF) causes of malnutrition analysis,
three causes were identified. According to the framework,
the basic causes including poverty, social condition, and
political, economic, ecological, and other factors were the
root reason for any form of malnutrition [13]. Different
literature studies explicitly identified sociodemographic
factors that were highly correlated with obesity, for example,
older age [2, 6], married (marital status) [14], low wealth
index [6, 10, 15–17], urban residency [6, 10, 16, 18], being
female [2, 9], learning in private schools [2, 9, 19, 20], easy
accessibility of junk and fired or energy-dense foods and
packed animal source foods due to free trade policy [2], rural
to urban migration, replacement of local agribusiness with
food retail [21], higher education level [6, 7, 22], and being
pregnant [6, 18]. In contrary to the previous findings, a study
conducted among French women shows that having a higher
income, a higher occupational class, and a higher educa-
tional level and having hot water at home reduce the oc-
currence of obesity [23] although the pathophysiology of hot
water at home and obesity occurrence was not yet studied.

Another cause of obesity mostly in developing countries
is that early-life undernutrition leads to later-life obesity and
metabolic disorders. The correlation between childhood
under nutrition and the development of obesity in later life is
idiopathic; but there is a different hypothesis stated by the
scholars. Of those, the first is when there is an improvement
in the socioeconomic level, and living standards and ex-
posure to obesogenic environments outside the uterus leads
to obesity. This might be imbalance between intrauterine
and later life nutrient requirements. Secondly, the positive
response of under nutrition in the womb to protect vital
organs and the exposure to obesogenic environment may
lead to obesity. Additionally, the positive response of un-
dernutrition in the womb to protect vital organs and the
exposure to obesogenic environment may lead to obesity [2].

2.2. Behavioral Factors (Feeding Habit and Life Style).
Nutritionists always use the following proverb to explain the
effect of diet in our health “what you eat today; they
determine your life tomorrow.” Dietary habit is a major de-
terminant factor for our health, not merely to obesity.

Scientists, consuming energy-dense food, like con-
fectionaries, sugars, soft drinks, fats, and alcohol, were
highly correlated with obesity and chronic diseases
[11, 24, 25]. Different scholars mentioned that feeding habit
culture [26], consuming pastry foods [26], consuming
ultraprocessed food (refined carbohydrate) [21], excess al-
cohol consumption [10, 14], and monotonous diet or poor
diet quality [11, 24, 27, 28] increase the occurrence of
obesity. Eating breakfast and fruit reduces the occurrence of
obesity [27], and in other words, evening snack induces
obesity [29]. Furthermore, food store environment and
school food environment [15] for school age children expose
to obesity.

Many literature studies extensively identified that either
irregular physical exercise or physical inactiveness
[7, 10, 14, 15, 26, 30], watching television or prolonged
screen time [27, 30], short sleep duration or shift work
[15, 24, 30], stress, obesogenic environment (urbanization
and industrialization) [31], smoking [10], and frequent use
of a taxi for transportation [10, 32] were determinant factors
for overweight/obesity.

Watching electronic screens for more than 2 hours in-
creases the development of obesity because during simple
observation, the brain does not utilize glucose and as a result,
the metabolism of carbohydrate to glycogen and fat in-
creased consistently [27, 30]. The correlation between stress
and the development of obesity has different scientific
perspectives. Most scholars conclude that hormonal varia-
tion may be a cause. During stress, the cortisol levels rise
which is a cause for excess production of abdominal fat by
increasing appetite (daily intake) [33–35].

2.2.1. Genetic Factors. Evidence revealed that a family history
of obesity and different genetically arranged genes were a risk for
obesity [15, 26]. Genome-wide association studies (GWAS)
identified that more than 250 genes/loci were associated with
obesity. Of these genes, the fat mass- and obesity-associated
gene (FTO) showed an important role for development of theobesity
[23]. Evidence of these genes, the fat mass and obesity-associated
gene (FTO) showed an important role for development of the
obesity and type 2 diabetes. A study conducted among adults explicitly
recognizes the correlation between these genes and a higher
body mass index (BMI), fat mass index (FMI), and leptin
concentrations [32, 36–38]. Almost all studies included in this
review use cross-sectional study design, and majority of those
studies assess obesity with the WHO standard (Table 1).

3. Assessment Methods of Obesity

In nutritional science, there are four basic nutritional as-
seessment methods, i.e., anthropometric, biochemical, clin-
ical, and dietary methods [42]. Similarly, we can also assess
obesity through these methods. In this review, we discuss
two nutritional assessment methods (anthropometric and
biochemical) in detail.

3.1. Anthropometric Assessment. Obesity can be assessed
through BMI, waist circumference (WC), body fat per-
centage (BFP), and skin fold thickness (SFT). As evidenced
in the literature, the anthropometric method shows a
The correlation between the factors [18, 20, 43]. Recently, the classification of obesity was reevaluated and validated again with the consideration of morbidity and mortality at population level. Obesity is further classified into four categories: (1) normal weight obese (NWO), (2) metabolically obese normal weight (MONW), (3) metabolically healthy obese (MHO), and (4) metabolically unhealthy obese (MUO) [44]. The current approach is more reliable than the previous approach to predict obesity and its correlated disorders since using only BMI gives gross data which are difficult to interpret (Table 2).

### 3.1.1. Biochemical Methods

Among the nutrition assessment methods, the biochemical method is objective and more reliable. There are two types of biochemical methods, functional and static methods. The functional method is used when there is a deficiency or an excess of nutrient which leads to functional impairment [42]. Unexpectedly, obese children have significantly lower ability to identify taste types and qualities correctly due to lesser number of fungiform papillae in the tongue [50].

### 4. Biomarkers

Biomarkers are biological indicators for certain disorders in our body. Different categories of biomarkers were reported globally. Among those, the commonly and widely implemented ones are microRNAs, inflammatory biomarkers, adipocytokines, oxidative stress, gut microbiotas, level of nutrients, and blood cell profiles.
4.1. Micro-RNAs. A study conducted among children identified four miRNAs overexpressed in patients with obesity (miR-222, miR-142–3, miR-140-5p, and miR-143) and two miRNAs (miR-122 and miR-34a) overexpressed in children with obesity and nonalcoholic fatty liver disease (NAFLD) and/or insulin resistance. Circulating miRNAs are promising diagnostic biomarkers of obesity and other disorders such as cardiovascular diseases [51]. Another study also reports eight miRNAs which are found in obese population, that is, PTEN gene (hsa-miR-130b-3p, hsa-miR-142-5p, hsa-miR-148a-3p, hsa-miR-21-5p, hsa-miR23a-3p, hsa-miR-320a, and hsa-miR-486-5p) [46, 47, 52]. Early detection of changes in circulating miRNA levels represents a promising strategy for characterizing obesity and to adjust diet. Moreover, the presence of biomarkers at the early stage is usually associated with metabolic disease or syndrome. As a result, identification of these miRNA is a good strategy for the diagnostic approach as well as to prevent the occurrences [36].

4.2. Inflammatory Biomarkers. Researchers depict that inflammatory biomarkers (C-reactive protein, interleukin-6, and tumor necrosis factor) were identified in obese population [46, 47].

4.3. Adipocytokines. Adipocytokines can play a role in the observed link between obesity and its associated morbidities. It has high predictive potential for identification of adverse cardiovascular conditions. Similarly, Plasminogen Activator Inhibitor-1 (PAI-1) was found as an independent risk factor for obesity-related metabolic disorders, even though it needs further investigation on mechanisms of action [53]. Other reviews also suggest that adiponectin, omentin, apelin, leptin, resistin, and fatty-acid-binding protein-4 were promising biomarkers for obesity [46, 47].

4.4. Oxidative Stress. High oxidative stress in the body is usually associated with high anthropometric measurement results, specifically BMI and waist-hip ratio [47, 53]. Among various antioxidants, F2 isoprostanes are widely used to assess lipid oxidation and have demonstrated their ability to predict biological changes and cardiovascular diseases resulting from obesity even though the specificity and sensitivity are not determined. Also, glutathione peroxidase has strong antioxidant and antiatherosclerotic properties. Additionally, complement factor 3 and Monocyte Chemoattractant Protein-1 (MCP-1) promote fat deposition and are also associated with atherosclerosis, excess fat accumulation, and adverse cardiovascular risk [53].

4.5. Gut Microbiota. Helicobacter pylori is an indicator for development of obesity; even though the exact pathophysiology is unknown, most studies correlate with gastrointestinal hormones such as leptin and ghrelin. In normal physiology, ghrelin facilitates food intake and leptin is involved in reduction of food consumption. It is evidenced that there is low serum leptin and ghrelin levels in H. pylori-positive patients. As a result of the level of leptin, food intake will be reduced. So its reduction may be involved in excessive dietary intake and obesity. In contrary, reduction of plasma ghrelin concentration ends with a physiological adaptation to the positive energy balance associated with obesity [47, 54].

4.6. Blood Cell Profile. The morbid obesity group had significantly higher platelet counts, plateletcrit (PCT) values, and platelet-to-lymphocyte ratio (PLR) values. The values of white blood cell count and red cell distribution width (RDW) were higher and statistically significant in the obese population [55].

---

**Table 2: Phenotype of obesity and its biomarkers.**

<table>
<thead>
<tr>
<th>Type of obesity</th>
<th>Benchmarks</th>
<th>Biomarkers</th>
<th>References</th>
</tr>
</thead>
<tbody>
<tr>
<td>Normal weight obese (NWO)</td>
<td>(A) BMI = 18.5–25 (normal weight)</td>
<td>Proinflammatory cytokines</td>
<td>[44–47]</td>
</tr>
<tr>
<td></td>
<td>(B) Higher fasting glucose level</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(C) Did not have metabolic syndrome</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(D) High body fat percentage</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>✓ Men—23.5%</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>✓ Women—29.2%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Metabolically obese normal</td>
<td>(A) BMI = 18.5–25 (normal weight)</td>
<td>Presence of steatosis, concentrations of</td>
<td>[44–46, 48]</td>
</tr>
<tr>
<td>weight (MONW)</td>
<td>(B) High body fat percentage &gt; 30</td>
<td>high-density cholesterol, triglycerides, and</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(C) Low insulin sensitivity/</td>
<td>inflammation biomarkers</td>
<td></td>
</tr>
<tr>
<td></td>
<td>hyperinsulinemia</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(D) Metabolic syndrome happen</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Metabolically healthy obese</td>
<td>(A) BMI &gt; 30 (obese)</td>
<td>Elevated high sensitivity C-reactive protein</td>
<td>[44, 45, 48, 49]</td>
</tr>
<tr>
<td>(MHO)</td>
<td>(B) High body fat percentage &gt; 30</td>
<td>(hs-CRP) and TG</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(C) Proper sensitivity of insulin</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Metabolically unhealthy obese</td>
<td>(A) BMI &gt; 30 (obese)</td>
<td>Higher TG, FGB, TG/HDL-C levels, and lower</td>
<td>[44, 45, 49]</td>
</tr>
<tr>
<td>(MUO)</td>
<td>(B) High body fat percentage &gt; 30</td>
<td>levels of HDL</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(C) Insulin resistant, diabetes mellitus</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
| FBG: fasting glucose; TG: triglyceride; HDL: high-density lipoprotein.
4.7. Nutrients. High availability of branched-chain amino acids (BCAA), nonesterified fatty acids, organic acids, acylcarnitines, deficient 25(OH) vitamin D serum concentrations, and phospholipids was identified as potential biomarkers for obesity [56, 57].

5. Health Impact of Obesity

High BMI and accumulation of body fat mass are an important predictor for metabolic disorders [43]. Obesity during pregnancy leads to adverse neonatal outcomes (skeletal muscle injury, respiratory distress syndrome, injury to peripheral nervous system, bacterial sepsis, convulsion, hypoglycemia). Additionally, it increases the rate of cesarean section [58–60] and morbidity for the women [61].

Obesity is also associated with a range of comorbidities, including diabetes mellitus [7], dyslipidemia [7], hypertension [7], cardiovascular disease, obstructive sleep apnea, chronic obstructive pulmonary diseases [62], cancer [63, 64], chronic disease morbidity and mortality, premature death [24, 62], and atrial fibrillation [65]. Hypertension was also strongly associated WC, BMI, and waist hip ratio (WHR) [66].

A review conducted in the USA population shows that the magnitude of obesity among coronary heart disease patients was increased [31]. The effect of obesity varies in different age groups; a systematic review identified that students with obesity in tertiary education have low academic performance and poor achievements either due to weight gain bias stigma or metabolic disorder [67]. A 25-year longitudinal study from 1986 to 2011 conducted in America showed that baseline obesity better predicts long-term risk of cerebrovascular death in black individuals as compared to white people. More research should explore factors that explain why racial differences exist in the effects of obesity on cerebrovascular outcome. Findings also have implications for personalized medicine [4].

As indicated from another systematic review, obesity may influence the course of renal cell carcinoma (RCC) patients, although the interplay between obesity and RCC warrants a large prospective confirmation [68].

Central obesity is highly correlated with kidney injury [62, 69]. It also has significant correlation with urinary incontinency. Specifically, central obesity correlates with intra-abdominal pressure, which exerts forces in the pelvic floor. Polycystic ovary syndrome (POS) was highly correlated with obesity which is highlighted in different clinical and epidemiological studies [70].

Obesity also leads to anatomical deformity; a study conducted in Egypt among schoolchildren explicitly shows that the occurrence of flat foot was high among obese children. The presence of flat foot leads to foot pain which is significantly manifested with increased level of adipocyte cytokines, as well as adiponectin, leptin, resistin, IL-6, and TNF-α, compared to subjects with normal BMI [71]. Physical inactiveness like slow waking/decreased velocities [72, 73] and mental comorbidities [72] were also other consequences of obesity.

Amazingly, obesity has significant effect on the reproduction of human. Sexual dysfunction is highly prevalent in men with severe with erectile dysfunction in diabetic patients was likely a significant contributing factor for sexual dysfunction in obese population [74–76].

Obesity leads to development of different cancers; this is why, cancer epidemiology abruptly increased worldwide. Obesity also promotes breast cancer formation [77] and formation of Barrett’s esophagus (BE) [78]. BE has been defined as a pathological state in which the stratified squamous epithelium of the distal esophagus has been replaced by the metaplastic columnar epithelium with goblet cells. The formation of BE predisposes patients to esophageal adenocarcinoma (EAC) [78].

The impact of obesity varies based on the trait and biological differences like sex. Also, it has an etiological role in the death of most people globally [62]. In general, the public health significance of obesity is highly integrated with country’s economic, social, and political affairs.

6. Prevention and Treatment Mechanism

Obesity is a disorder which occurs due to individual behaviors and the living environment. As a result of this, to prevent obesity, both legal and voluntary counseling services are mandatory. Obesity can be prevented or treated based on the following approach.

6.1. Nutrition Education. Nutrition education is one of the common legal approaches practiced at schools to reduce obesity in the USA. Disseminating health education and developing dietary consumption standards at organization level also have significant impact [79]; weight loss programs [70] and diabetes prevention approaches were effective programs to reduce obesity which is reported elsewhere [80]. Interventional studies which are entitled as “Healthy Primary School of the Future” implemented in Dutch are primarily focused on lunch health education, healthy diet approach, and physical activity session, lowering children’s BMI z-scores [82]. Another program conducted in Brooklyn entitled as “Live Light Live Right program” is a life style intervention that uses medical assessment, nutritional education, access to physical fitness classes, and behavioral modification to reduce BMI Z-Scores [83]. Even moderate physical activity is effective to control overweight/obesity among pregnant women [83, 84].

6.2. Developing Nonsedentary Life Style Plan. Physical activity, reducing sedentary time, reducing fast food consumption, sleeping 7–9 hours per day, avoiding smoking, and moderate alcohol drinking habit were effective interventions to reduce obesity [85].

6.3. Healthy Food Subsidization and Taxation of Junk Food. The good news regarding obesity is that the government can reduce obesity by subsidization of healthy foods or...
increasing taxation of junk foods. This is strongly implemented in the UK; this scenario shows that an increment of price of high sugar snacks by 20% shows significant reduction in energy intake, BMI, and prevalence of obesity. As a result, increasing taxation or price for unhealthy foods is an effective approach to control obesity and their metabolic disorder [86].

6.4. Surgery. Metabolic and bariatric surgery in the pediatric population provides evidence-based effective treatment of severe obesity and related comorbid diseases in the USA [87].

7. Conclusion and Future Perspectives

Obesity is becoming a severe public health problem; its epidemiology is increasing rapidly. The exposure factors vary across different geopolitics. Primarily, living in obese-sogenic environments such as sedentary life style, urbanization, and rural to urban migration, consuming energy-dense foods, and physical inactivity were determinants. There are a lot of biomarkers, of which microRNAs, adipocyttes, oxidative stress, and microbiota were promising for determination of obesity. Since the consequences of obesity are vast and interrelated, a multilevel prevention strategy is mandatory. For future researchers, the sensitivity of the anthropometric measurement tool was not studied. So it is better to study sensitivity and its correlation with the best promising biomarkers since they reduce health cost and facilitate early identification of obesity.

Conflicts of Interest

The authors declare that there are no conflicts of interest.

References


S. Shaharyar, L. R. Lara, J. Omar et al., "Obesity and metabolic phenotypes (metabolically healthy and unhealthy variants) are significantly associated with prevalence of elevated C-reactive protein and hepatic steatosis in a large healthy Brazilian population," *Journal of Obesity*, vol. 2015, Article ID 178526, 6 pages, 2015.


F. Celmi, J. P. Wagner, W. C Giehl et al., "Obesity and 25(OH)D serum concentration are more important than vitamin D intake for changes in nutritional status indicators: a
population-based longitudinal study in a state capital city in southern Brazil,” *Nutrients*, vol. 11, no. 10, p. 2366, 2019.


