

Review

Review of Body Shape and Size Index and obesity insights from recent studies in Pakistan

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Abstract: Obesity has emerged as a significant public health crisis globally, with its prevalence rising at an alarming rate across various demographics. Characterized by excessive fat accumulation, obesity is associated with numerous health complications, including cardiovascular diseases, type 2 diabetes, and certain cancers, along with mental health issues such as anxiety and depression. In Pakistan, the situation is particularly critical; studies indicate that adult obesity rates have increased from 21% in 2016 to 29% in 2024, while childhood obesity has surged from 9% to 19% over the same period. These trends highlight the pressing need for effective obesity assessment strategies and targeted public health interventions to mitigate the impact of obesity on health outcomes in the country. The traditional measure of obesity, the Body Mass Index (BMI), has been widely used due to its simplicity in calculating weight relative to height. While BMI provides a quick classification of individuals as underweight, normal weight, overweight, or obese, it has inherent limitations. BMI fails to consider variations in body composition, fat distribution, and demographic factors such as age, gender, and ethnicity. Reliance solely on BMI may lead to misclassification of individuals' health risks, undermining the effectiveness of obesity management strategies. There is a growing recognition for alternative measures, including the Body Shape and Size Index (BSSI), which accounts for multiple anthropometric variables to provide a more comprehensive assessment of obesity and its associated health risks. This review focuses on methodological advancements in the field of obesity assessment, specifically the evolution of BSSI, and synthesizes findings from recent studies conducted in Pakistan. Drawing on data from diverse populations, these studies highlight the potential of BSSI to improve obesity risk stratification by integrating measurements such as body surface area (BSA), weight, and height. The use of quantile regression (QR) techniques to create growth charts for BSSI enhances understanding of body composition across different age groups and genders, offering valuable insights for public health policy formulation. The implications of these findings underscore the importance of integrating BSSI into national health monitoring systems and public health initiatives, which could lead to more effective obesity prevention and management strategies tailored to the unique characteristics of Pakistani populations. Implementing innovative assessment tools like BSSI is crucial for addressing the pressing public health crisis of obesity and improving health outcomes in diverse communities.

Keywords: obesity; Body Shape and Size Index (BSSI); body mass index (BMI); public health; anthropometric measurements; quantile regression (QR); health outcomes; obesity assessment tools

1. Introduction

1.1. Definition of obesity and its health implications

Obesity is a complex and multi-factorial chronic disease characterized by excessive fat accumulation that poses health risks [1]. Based on body mass index (BMI), a popular index, it is normally defined by special criteria of weight, namely normal weight, overweight, and obesity [2]. Obesity can lead to many associated ailments such as type 2 diabetes mellitus cardiovascular diseases, specific types of cancer, and musculoskeletal diseases [3,4]. Besides, being overweight is another cause of worsening mental health, leading to depression and even anxiety [5–7]. These health implications stress a need for efficient evaluation and intervention approaches as more people develop obesity in recent years [8] (**Figure 1**).

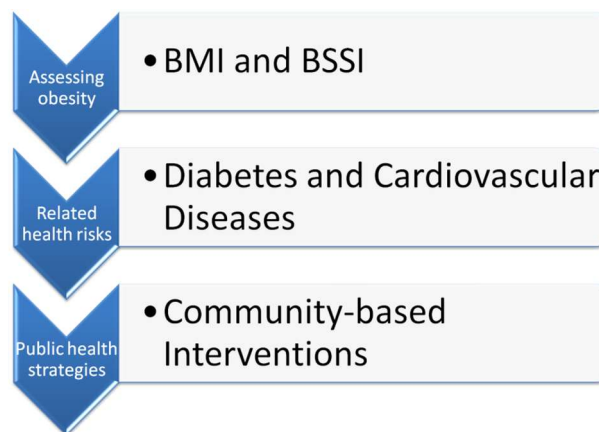


Figure 1. Framework for analyzing obesity.

1.2. Current prevalence of obesity in Pakistan

Pakistan faces a growing public health crisis related to obesity. Based on recent approximations, it became known that the proportion of obesity in the adult population in Pakistan has also increased significantly, from 21% in 2016 and 26% in 2021 to 29% in 2024 [9–13]. The adults are not left out on this upward prevalence trend; childhood obesity stands at 9%, 15% in the past five years, and 19% in 2024 for both the urban and rural dwellers [14–16]. It becomes essential to come up with prevention measures for obesity, especially for those groups that have very little access to health care and nutritional information. The disease of obesity is a global phenomenon that is driven by changes in lifestyles, urbanization, and the availability of processed and energy-dense food [17,18] (**Table 1**).

Table 1. Prevalence of obesity in Pakistan (2016, 2021, 2024).

Year	Adult obesity rate (%)	Childhood obesity rate (%)
2016	21%	9%
2021	26%	15%
2024	29%	19%

1.3. Overview of traditional methods to assess obesity: BMI

BMI is the most widely used tool for assessing obesity in clinical settings and epidemiological studies. It is calculated using an individual's weight in kilograms divided by the square of their height in meters (kg/m^2) [6,19]. BMI offers a simple and quick method for categorization, allowing healthcare professionals to classify patients into different weight categories (normal weight, overweight, and various degrees of obesity) without requiring sophisticated equipment or extensive training. According to the WHO classifications, a BMI of 18.5–24.9 kg/m^2 is considered normal, while a BMI of 25.0–29.9 kg/m^2 indicates overweight, and a BMI of 30.0 kg/m^2 and above is classified as obese [20,21].

There are problems with measurements such as BMI; they cannot very accurately characterize some degree of body fatness and may misrepresent certain health risks of obesity in various populations [22,23]. BMI does not reflect differences in fat topography, body build, age, sex, or ethnic background [24,25]. Neighbors might have completely different body make-up even if their BMI is the same, and, therefore, BMI is not the optimal tool that might help understand the risks associated with obesity [26–28]. This has led to a replacement for an increasing concern that reliance on the BMI measurement can cause misinterpretation of people as either healthy or at risk for obesity-related complications [29].

Limitations of BMI as an accurate measure of body fat

The problem with BMI is the fact that it has several drawbacks that defeat the purpose of using it as a good measure of body fat. One of the biggest issues is that BMI does not differentiate between lean body mass (muscle) and fat mass [30,31]. Sportspeople or individuals with large muscles will have bigger BMIs thanks to mass from muscles, yet they have low body fat [32,33]. People with normal weight may possess a high amount of VF, which is determined by health risk levels for metabolic diseases; thus, a normal-weight person is at a higher risk of disease than what the scale depicts [29,34,35].

BMI is known to be sensitive to the differences in population and demographics in that constant fluctuation renders it a poor barometer of obesity-related health risks [35,36]. Some ethnic group individuals have different body fat topographical distributions that are not captured by BMI. People from Asian countries develop metabolic disorders at significantly lower BMIs compared to people of European descent [37]. The employment of one approach to categorize obesity may adversely affect the outcomes of the obesity intervention process.

1.4. Introduction and rationale for the development of Body Shape and Size Index (BSSI)

In response to the limitations of BMI, researchers have sought alternative measures for assessing obesity that more accurately reflect body fat distribution and body composition. One such innovation is the BSSI, which incorporates multiple anthropometric measurements to provide a more holistic assessment of an individual's health status [38]. The BSSI is designed to quantify body shape and size using components such as body surface area (BSA), weight, and height, thereby offering a more comprehensive perspective on an individual's risk of obesity-related

health complications. The development of the BSSI aims to address the shortcomings of traditional methods by offering a more accurate representation of body composition and fat distribution. It considers factors such as age, gender, and population differences that influence body shape and size [39]. By utilizing quantile regression techniques, researchers can create growth charts that provide valuable insights into BSSI at different age groups, thereby identifying trends related to obesity risk [31].

The introduction of the BSSI is particularly relevant in the context of populations like Pakistan, where the prevalence of obesity is rising, yet traditional metrics may not adequately capture the true burden of obesity [31]. By developing and validating the BSSI, researchers aim to create a tool that public health officials and practitioners can use to assess obesity risk more accurately and devise effective intervention strategies tailored to the unique characteristics of the population. Through the BSSI, public health programs can focus on addressing the specific factors contributing to obesity while considering the demographic diversity of individuals. The BSSI has the potential to enhance the understanding of body shape and size variations in different populations, ultimately leading to improved health outcomes and the reduction of obesity-related health disparities (**Table 2**).

Table 2. Differences between BMI and BSSI.

Metric	BMI	BSSI
Definition	Weight (kg)/height (m ²)	Combines weight, height, and BSA
Considerations	No consideration for fat distribution	Considers fat distribution, body composition
Population variability	Lacks precision across demographics	More accurately reflects ethnic differences
Health risk assessment	May misclassify health risks	Provides a nuanced assessment of health risks

1.5. Objectives

The objective of this review article is to address the pressing public health crisis of obesity, particularly in the context of Pakistan, by critically assessing traditional obesity assessment methods like BMI and proposing BSSI as a more comprehensive alternative. The review aims to explore recent advancements in the application of BSSI, including the use of quantile regression techniques for developing growth charts, to enhance the accuracy of obesity risk assessments. It strives to inform public health policies and intervention strategies that consider the socio-economic and demographic factors influencing obesity, ultimately advocating for a multidimensional approach to obesity prevention that integrates innovative measures alongside traditional metrics.

2. Literature review

2.1. The concept of BSSI

The BSSI is an innovative metric designed to assess obesity by taking into account multiple anthropometric measurements, aiming to provide a comprehensive understanding of body composition and fat distribution. Traditional methods of measuring obesity, primarily BMI, rely solely on weight-for-height calculations,

often leading to incomplete assessments of an individual's health status [40]. In contrast, the BSSI synthesizes several components: weight, height, and BSA, which collectively facilitate a more holistic evaluation of body shape and size.

The BSSI is particularly valuable because it considers not only absolute weight but also the surface area in conjunction with height, promoting a better understanding of how body fat is distributed across various populations [40]. This multidimensional approach allows practitioners to evaluate obesity risk more accurately by considering ethnic differences, variations in body composition related to lifestyle factors, and the physiological implications of specific body shapes [41–44]. Given the increasing prevalence of obesity, particularly in countries like Pakistan, the BSSI could serve as a significant tool for public health professionals when implementing targeted health interventions that consider demographic variability.

Research indicates that the BSSI can highlight individuals at risk for obesity-related health complications, as it provides a finer resolution of assessment compared to BMI [30]. For instance, individuals might present with similar BMIs but possess varying levels of fat mass and distribution. BSSI has thus emerged as a more nuanced indicator in recognizing health risks, especially among diverse populations where body composition patterns differ [12,45].

2.2. Methodological approaches

2.2.1. Quantile regression (QR) as a statistical tool

QR is a statistical technique that extends traditional linear regression methods by estimating the conditional quantiles of the response variable [40]. Unlike ordinary least squares regression, which focuses on the mean of the dependent variable, QR provides insights into the distributional impact of independent variables across various quantiles. This approach is particularly beneficial in health studies that investigate the relationships between body shape indices and health outcomes, as it allows for a more comprehensive understanding of how body composition impacts health at different levels of obesity.

Within the context of BSSI, QR has been utilized to construct growth charts that reflect the distribution of BSSI across different age groups and genders [28]. By employing quantile regression, researchers can portray how changes in body shape and size are associated with varying obesity levels, thus offering valuable insights into health trends across diverse demographic segments [29,30]. This methodology is poised to yield tailored health recommendations by indicating not only whether an individual falls below, at, or above recommended thresholds but also how their body shape and size should influence clinical assessments and health interventions.

In comparative studies, QR has been shown to outperform traditional statistical methods, particularly in scenarios where the relationship between variables is non-linear or affected by outliers [28]. Given that obesity manifests distinctly across various population segments, the applicability of QR in analyzing BSSI metrics enhances the precision of obesity assessments, thereby supporting academic discourse on health equity and targeted interventions.

2.2.2. Comparative studies

Recent research has focused on comparing QR with more traditional metrics like Gaussian percentiles and raw percentiles when analyzing BSSI. This comparative examination has significant implications for the understanding and interpretation of growth patterns among various populations. Hussain et al. [31] conducted a comparative evaluation that illustrated QR's superiority in capturing more nuanced variations in body shape and size across the obesity spectrum.

In these studies, methodologies typically employ a combination of statistical techniques to assess how different percentile methods correlate with health outcomes associated with obesity. For example, Gaussian percentiles assume a normal distribution of the data, which can mask variations present in skewed distributions typically observed in anthropometric data [23]. Raw percentiles merely rank the data without context, potentially leading to misinterpretations in understanding growth trends related to obesity.

QR allows for the examination of not only central tendencies but also variations across the entire distribution. It has been particularly useful in uncovering how socioeconomic factors and gender disparities impact obesity prevalence and health outcomes [20,34]. Moreover, studies have illustrated that QR can provide insights into the influence of income on BSSI, helping public health officials tailor interventions based on socioeconomic contexts.

The comparative studies have shown that while both Gaussian and raw percentiles provide essential data about population growth, QR yields deeper insights concerning subgroup variations. This is particularly relevant in the Pakistani context, where socio-economic status and cultural factors play a critical role in shaping health behaviors and outcomes [17,28–30]. By acknowledging these factors, QR-based analyses can facilitate the design of targeted public health programs that consider local contexts and conditions.

The use of BSSI as an alternative assessment tool, combined with the advantages of quantile regression, represents a crucial advancement in obesity research. Continued comparative studies are necessary to further validate BSSI through diverse methodologies, laying the groundwork for more effective public health strategies to combat the rising tide of obesity-related health issues, particularly in developing countries such as Pakistan.

3. Summary of findings from recent studies

3.1. Inclusion criteria for reviewed studies

To ensure the relevance and reliability of the findings discussed, the reviewed studies adhered to the following inclusion criteria.

3.1.1. Population characteristics

- Participants included children, adolescents, and adults from diverse age groups.
- Studies encompassed both genders and various ethnic and regional groups within Pakistan.
- Socioeconomic diversity was considered, including participants from different income levels and urban/rural settings.

3.1.2. Sample size

- Studies employed sufficiently large sample sizes (generally over 700 participants) to ensure statistical validity and representativeness.

3.1.3. Anthropometric measures

- Included studies utilized measurements such as weight, height, BSA, and other relevant anthropometric parameters necessary for calculating BSSI.
- Studies employed standardized measurement techniques to ensure data comparability.

3.1.4. Study design

- Cross-sectional studies for establishing growth charts and assessing prevalence.
- Longitudinal studies for examining changes over time and assessing health outcomes.
- Comparative studies evaluating different statistical methods (e.g., quantile regression vs. traditional percentiles).

3.1.5. Data quality and representativeness

- Participants were selected based on clear inclusion/exclusion criteria, ensuring data quality.
- Studies aimed for representative samples reflective of the general Pakistani population or specific subgroups (e.g., low-income, urban/rural).

3.1.6. Analytical methods

- Use of validated statistical techniques such as quantile regression, Gaussian percentiles, or Z-scores.
- Clear documentation of methods used for data analysis and interpretation.

3.2. Establishing growth charts for BSSI

In recent efforts to establish growth charts for the BSSI, Hussain et al. [31] utilized a comprehensive methodology that involved extensive data collection from diverse demographic groups across Pakistan. The study comprised a sizable sample of over 7224 participants, which included children, adolescents, and adults, thus providing a robust dataset that reflects various ages, genders, and socioeconomic backgrounds. The participants were meticulously selected to ensure representative demographics, paying particular attention to variations in ethnic backgrounds, urban versus rural residency, and gender distribution [31].

The main findings of this study revealed a significant positive correlation between BSSI and traditional obesity indicators, such as BMI. The research demonstrated that higher BSSI values were associated with increased obesity levels and a higher prevalence of obesity-related co-morbidities, including hypertension and diabetes. The study highlighted critical thresholds for BSSI that could effectively stratify risk levels among Pakistani populations, paving the way for tailored obesity prevention campaigns [31].

The implications of these findings for public health policies in Pakistan are profound. The establishment of BSSI growth charts provides healthcare professionals and policymakers with a valuable tool to identify at-risk individuals more accurately. It supports the development of targeted intervention strategies

aimed at addressing the growing obesity epidemic in the country. As obesity rates continue to rise, public health campaigns can leverage this information to promote healthier lifestyle choices, preventive measures, and community-based health initiatives that emphasize the importance of monitoring body composition along with traditional metrics like BMI [44].

3.3. Examining the relationship between obesity and income distribution

Another significant exploration into the determinants of obesity was conducted by Hussain et al. [31], focusing on the relationship between obesity and income distribution in Pakistan. This study utilized a statistical framework that considered various socioeconomic factors, analyzing data from approximately 2223 participants stratified by income levels. The study incorporated detailed demographic data, including age, gender, and regional characteristics, to provide a nuanced understanding of how income influences body composition metrics like BMI and BSSI.

The findings revealed that individuals from lower-income brackets exhibited higher prevalence rates of obesity compared to their higher-income counterparts. Furthermore, the study uncovered notable gender disparities; women, particularly from lower socioeconomic backgrounds, showed significantly higher obesity rates than men. This trend was attributed to various factors, including limited access to nutritious foods, lack of awareness regarding healthy lifestyle choices, and cultural factors that influence food consumption patterns [30,42].

This research highlights the critical need for public health interventions that address socioeconomic inequalities in the context of obesity. Policymakers are encouraged to consider targeted outreach programs that provide education on nutrition and physical activity, especially in low-income communities. By addressing the unique challenges faced by different income groups, public health strategies can be designed to effectively combat obesity while also promoting health equity [30,43].

3.4. Comparative evaluation of percentile methods for BSSI

The comparative analysis of percentile methods for BSSI was conducted by Shehzad et al. [43], which investigated the efficacy of various statistical approaches for establishing growth charts. This study explored three distinct percentile methodologies: quantile regression, Gaussian percentiles, and raw percentiles, analyzing data from a diverse cohort of 9906 individuals from both urban and rural settings in Pakistan. The comparative nature of this research aimed to discern the impact of different methodologies on the interpretation of obesity and growth trends within the population.

Findings from the study indicated that quantile regression provided a more accurate portrayal of the distribution of BSSI within the cohort, particularly revealing skewness and variations that traditional methods failed to capture. While Gaussian percentiles offered a standard normalization, their underlying assumptions regarding data distribution often led to misclassification of obesity risk among specific subgroups particularly in populations with higher variability in body

composition. Raw percentiles, although simpler, did not offer insights into the underlying distribution characteristics, which are crucial for understanding growth trends [1].

The implications of method choice on understanding growth trends in the population are substantial. By adopting quantile regression for establishing BSSI growth charts, researchers and public health officials can acquire a more nuanced understanding of obesity within different demographic segments, allowing for the development of tailored interventions that address specific population needs. This study reinforces the importance of methodological rigor in obesity research and suggests that adopting advanced statistical techniques can significantly enhance the quality of insights derived from anthropometric data [30].

3.5. Comparison of quantile regression and Gaussian Z-scores to BSA

A pivotal study by Hussain et al. [40] focused on comparing quantile regression with Gaussian Z-scores in assessing BSA as an integral component of BSSI measurement. The methodology encompassed a longitudinal framework involving a sample of 3473 participants, with detailed anthropometric measurements taken to accurately calculate both BSA and BSSI values over time. By employing a robust statistical design that included repeated measures, the study aimed to elucidate the significance of BSA as a public health measure in conjunction with BSSI [28–30].

The results indicated that while Gaussian Z-scores offered a standardized measure, quantile regression provided deeper insights into the variability of BSA among different demographic segments. The study concluded that using quantile regression allowed for a more flexible interpretation of the relationships between BSA, body composition, and health outcomes across varied percentiles, thereby enhancing the understanding of obesity and its associated risks [29].

This study's contributions extend beyond methodological advancements, as they emphasize the need for integrated approaches that combine various anthropometric measures when assessing health outcomes. By linking BSA closely with BSSI evaluations, public health officials can better understand the multifaceted nature of obesity and its implications. This could potentially lead to enhanced health monitoring systems that account for various risk factors associated with body composition, thereby fostering a more comprehensive public health strategy to combat obesity-related health issues effectively [28,29] (**Table 3**).

Table 3. Comparative summary of key studies on BSSI.

Study	Sample Size	Methodology	Key Findings	Implications
Hussain et al. [40]	7224	Quantile regression for growth charts	Established correlation between BSSI and obesity-related co-morbidities.	Provides a tool for targeted public health interventions and risk assessment tailored to Pakistani populations.
Hussain et al. [42]	2223	Statistical analysis of income	Found that lower income correlates with higher obesity rates, particularly among women.	Underlines the need for socioeconomic-targeted health programs and policies addressing inequalities.
Shehzad et al. [43]	9906	Comparative analysis of percentiles	Illustrated the efficacy of quantile regression over traditional methods.	Supports adopting QR for more accurate growth charts and risk assessment in diverse populations.
Hussain et al. [31]	3473	Longitudinal study of BSA	Highlighted the variability of BSA and its implications for health outcomes.	Promotes integrated anthropometric assessments for better health monitoring and intervention planning.

4. Implications of BSSI for public health

4.1. Relevance of BSSI as a potential tool for obesity assessment

The BSSI has gained relevance as a vital tool for assessing obesity, particularly as concerns mount over the limitations of the conventional BMI. While BMI remains a widely employed metric for categorizing individuals into weight classifications, it does not account for critical factors such as body fat distribution and muscle mass, which significantly influence health outcomes [28]. By integrating multiple anthropometric measurements, the BSSI offers a more nuanced perspective on body composition, thereby enhancing its utility in clinical settings and public health initiatives.

Research has demonstrated that the BSSI provides a more accurate reflection of obesity-related health risks compared to BMI. Studies indicate a strong correlation between elevated BSSI values and the prevalence of obesity-related co-morbidities, such as hypertension, type 2 diabetes, and cardiovascular diseases, particularly within diverse populations [27,30,44]. This ability to identify individuals at higher risk of developing these conditions underscores the significance of adopting BSSI as a standard assessment tool.

The BSSI has the potential to enhance early detection and intervention strategies for obesity management. As obesity rates climb globally, the ability to detect variations in body shape and size can inform more effective public health campaigns aimed at obesity prevention. The BSSI not only identifies individuals at risk but also aids clinicians in personalizing treatment approaches based on an individual's unique body composition profile [26,30]. This capability is particularly crucial in areas like Pakistan, where diverse body shapes and cultural practices significantly influence obesity trends and health outcomes.

4.2. Recommendations for integrating BSSI in public health strategies

For the effective integration of BSSI into public health strategies, several actionable recommendations can be proposed. Firstly, extensive training programs for healthcare professionals must be implemented to ensure that they understand the methodology and advantages of BSSI over traditional measures like BMI. Such education will help clinicians better assess and interpret BSSI data while using it to inform treatment decisions and community health initiatives [14,30]. These training programs should be embedded into existing healthcare education frameworks and continuing education opportunities to promote widespread understanding of BSSI.

Secondly, public health campaigns should raise awareness about BSSI among the general population. These campaigns must emphasize the shortcomings of BMI as a singular measure of obesity and promote the understanding that the BSSI offers a more comprehensive evaluation of health risks associated with body shape and size. By focusing on awareness of body composition rather than weight alone, public health messaging can encourage healthy lifestyle choices that prioritize overall health rather than conforming to arbitrary weight benchmarks [21,23,45,46].

Integrating BSSI into national health monitoring systems is crucial. Policymakers should consider the utility of BSSI in vital health surveys that collect

demographic data on body shape and size across various population segments. This type of data can illuminate patterns of obesity and inform targeted public health interventions tailored to specific demographic characteristics [30,31,47]. By aligning public health surveillance with BSSI measures, authorities can establish benchmarks for successful interventions and allocate resources more effectively to combat obesity.

A commitment to ongoing research is essential for the continuous refinement of BSSI applications in diverse populations. Public health entities should fund research initiatives aimed at validating BSSI across various demographic contexts and exploring its correlation with other health outcomes. Research efforts should also investigate how BSSI can be effectively employed in combination with existing obesity assessment tools. This multidimensional approach can lead to a more holistic understanding of obesity management and inform the adaptation of public health strategies to local needs and trends.

4.3. Potential future research areas focusing on BSSI and its applications in different demographics

The development of BSSI opens several avenues for future research, particularly in its application across different demographics. One of the key areas for exploration is the validation of BSSI in diverse ethnic populations within Pakistan and globally. Future studies should focus on assessing how variations in body composition across ethnic groups may influence the relationship between BSSI, health risks, and obesity-related diseases. Understanding these dynamics will not only enhance the applicability of BSSI but also contribute to personalized clinical practices that consider ethnic variations in body shape and composition [30,36,48–52].

Another promising area of research involves longitudinal studies that track how changes in BSSI correlate with health outcomes over time. By examining large populations across various demographics, researchers can gather insights into how shifts in body shape and size impact metabolic health, psychological well-being, and overall quality of life. Such studies are essential for establishing a stronger causal framework linking BSSI with health outcomes, thereby solidifying its role as a critical measure in obesity assessment [28].

Exploring the integration of BSSI with behavioral and environmental factors may shed light on effective intervention strategies. Future research can focus on how socioeconomic, cultural, and environmental contexts influence body shape and size, shaping obesity risk. This exploration can facilitate the design of community-specific interventions that target factors known to be associated with higher BSSI measurements, leading to tailored public health programming [7,28,53].

The advancement of digital health technologies presents an opportunity for innovative research into the application of BSSI. Researchers might explore how smart phones and wearable devices can be utilized for real-time tracking of body measurements linked to BSSI, fostering more dynamic health assessments. Such technology-driven approaches could enable preventive health strategies tailored to individual needs, promoting proactive rather than reactive health management

[15,28,54].

The emerging relevance of BSSI as a tool for obesity assessment underscores the necessity for its integration into public health strategies aimed at addressing the growing obesity crisis. By adopting the BSSI alongside traditional metrics, healthcare professionals can more accurately identify and treat individuals at risk, facilitating targeted interventions that respond to the unique needs of diverse populations. In light of the dynamic nature of obesity as a public health issue, continued research focusing on refining BSSI, understanding its implications across different demographics, and fostering awareness will provide valuable insights that support effective combating of obesity and its associated health risks. A multi-faceted approach to obesity assessment not only enhances health equity but ultimately leads to improved health outcomes and reduced health disparities across populations. The integration of BSSI within public health infrastructures positions it as an essential instrument in contemporary obesity research and strategy formulation. As the landscape of public health evolves, embracing innovative metrics like BSSI will be crucial in addressing the complexities of obesity in a holistic, informed manner.

4.4. Validation of BSSI beyond the Pakistani context

The current body of research on BSSI predominantly pertains to its development and validation within the Pakistani population. The extensive studies conducted by Hussain et al. [31,40,42] involve large, diverse cohorts from across Pakistan, encompassing various age groups, genders, and socio-economic backgrounds. These investigations have demonstrated significant correlations between BSSI and traditional obesity indicators, as well as its potential utility in risk stratification and growth chart development tailored to the Pakistani demographic. However, there is a conspicuous absence of evidence indicating that BSSI has been validated in populations outside Pakistan or in broader international contexts. While the conceptual framework of BSSI considers ethnic differences and demographic variability, empirical validation studies in other ethnicities or geographic regions are lacking. Although promising within the Pakistani setting, the generalizability and applicability of BSSI beyond this context remain to be established through further cross-cultural and multi-ethnic validation studies. Such research is essential to determine whether BSSI can serve as a reliable and universal tool for obesity assessment across diverse populations globally [55–65].

4.5. Challenges in practical implementation of BSSI

Implementing BSSI as a standard tool for obesity assessment in Pakistan faces numerous practical challenges. One of the primary obstacles is the resource and infrastructure limitation, particularly in rural and underserved areas. Accurate measurement of components such as BSA, height, and weight requires calibrated equipment and standardized protocols, which may be lacking in many healthcare settings. Without proper infrastructure, consistent and reliable data collection becomes difficult, hindering the widespread adoption of BSSI. Another significant challenge pertains to training and capacity building among healthcare professionals.

Transitioning from traditional BMI assessments to BSSI demands comprehensive training programs to ensure accurate measurement, calculation, and interpretation of results. Many healthcare workers, especially those in resource-constrained environments, may have limited access to ongoing educational opportunities, which could compromise the effectiveness of implementation. Ensuring that personnel are adequately skilled and confident in using BSSI is crucial for its successful integration.

Standardization and validation across diverse populations pose additional hurdles. Pakistan is a multicultural society with varied ethnicities, ages, and socio-economic backgrounds, all of which influence body composition. For BSSI to be effective as a universal tool, it must be validated across these different demographic groups, requiring large-scale, longitudinal studies. Developing region-specific thresholds and cutoffs that accurately reflect local population characteristics is resource-intensive and time-consuming, delaying its routine use. Cultural and societal acceptance also influence the feasibility of adopting BSSI. Public perceptions about body measurements and health assessments can vary widely, and there may be resistance or misconceptions about new indices. Cultural sensitivities related to body image and health-related privacy issues can further impede community engagement and compliance. Overcoming these societal barriers necessitates targeted awareness campaigns and community education to foster acceptance and understanding.

Integration into existing public health systems presents administrative and policy-related challenges. Updating national health monitoring protocols and surveillance systems to incorporate BSSI requires policy revisions, resource allocation, and coordination among multiple stakeholders. These bureaucratic processes can be slow and may face resistance from institutions accustomed to traditional metrics like BMI. Additionally, the initial costs associated with acquiring measurement tools, training personnel, and updating data systems could be substantial, raising concerns about sustainability and cost-effectiveness. Data management and privacy considerations add another layer of complexity. Collecting detailed anthropometric data linked with health records demands robust data security measures to protect individual privacy. Ensuring ethical handling of sensitive information becomes more challenging when scaling up to national levels, especially in the absence of clear data governance frameworks.

Public awareness and education about the benefits of BSSI are essential but challenging to achieve. Many individuals and communities may lack understanding of the limitations of BMI and the advantages of a more comprehensive assessment tool. Overcoming misinformation, cultural barriers, and low health literacy requires well-planned and culturally sensitive communication strategies. Technological barriers must be addressed. The potential of digital health tools and real-time monitoring of BSSI is promising but depends on reliable internet connectivity, digital literacy, and access to smartphones or wearable devices. In many parts of Pakistan, such technological infrastructure remains limited, restricting the feasibility of deploying high-tech solutions for large-scale BSSI assessment and monitoring.

While BSSI offers significant potential for improving obesity assessment and management, its practical implementation is challenged by infrastructural,

educational, cultural, policy, and technological barriers. Overcoming these obstacles requires coordinated efforts among policymakers, healthcare providers, researchers, and communities. Only through comprehensive planning and resource allocation can BSSI be effectively integrated into Pakistan's public health framework, ultimately contributing to more accurate and equitable obesity management strategies.

5. Conclusion

The BSSI represents a significant advancement in the field of obesity assessment and present a viable alternative to the traditional BMI. This comprehensive review highlights the growing concern of obesity as a multifaceted public health crisis, particularly within the context of Pakistan, where prevalence rates have escalated alarmingly in recent years. The limitations of BMI, which primarily relies on height and weight to classify individuals, have been well-documented and underscore the urgent need for a more nuanced approach to understanding body composition and its associated health risks. As demonstrated in various studies, the BSSI's integration of multiple anthropometric measurements allows for a more accurate reflection of body fat distribution, ultimately leading to improved identification of individuals at higher risk for obesity-related diseases. The evidence presented through recent research indicates that the BSSI serves as a valuable tool for not only diagnosing obesity but also for informing targeted intervention strategies. Researchers have established correlations between BSSI values and the prevalence of obesity-related co-morbidities, such as hypertension and diabetes, which are critical in shaping obesity management policies. The establishment of growth charts for BSSI, supported by quantile regression techniques, offers healthcare professionals a robust framework for assessing obesity risk across diverse population segments, considering factors such as age, gender, and ethnicity. This multidimensional approach is particularly pertinent in multicultural societies like Pakistan, where variances in body composition could have far-reaching implications for health outcomes.

For public health policymakers, the findings of this review emphasize the necessity of integrating BSSI into national health monitoring systems and intervention programs. By shifting the focus from BMI to a more multifaceted measure like BSSI, public health initiatives can be adapted to reflect the unique demographic and socio-economic circumstances confronting different populations. The evidence suggests that tailored educational campaigns and community-based health interventions, rooted in the insights gleaned from BSSI assessments, can enhance health equity and address the disparities associated with obesity management in low-resource settings. This review highlights several potential research avenues aimed at refining and validating BSSI across diverse ethnic and socio-economic groups both within Pakistan and internationally. Longitudinal studies assessing the relationship between changes in BSSI and health outcomes over time, as well as investigations into the socio-cultural factors influencing body composition, are essential for solidifying the role of BSSI as a critical metric in obesity research and management. Additionally, the integration of digital technologies for real-time BSSI monitoring presents an exciting frontier for

advancing personalized healthcare strategies aimed at obesity prevention.

The BSSI offers a promising avenue for refining obesity assessment, which is vital in combating the growing epidemic of obesity and its associated health complications. As the body of research supporting the BSSI continues to grow, it is imperative that healthcare practitioners, researchers, and policymakers work collaboratively to leverage its capabilities for a more nuanced understanding of obesity. Such collective efforts can lead to more informed health policies, effective intervention strategies, and ultimately, better health outcomes for diverse populations grappling with the challenges of obesity. The ongoing evolution of obesity measurement tools, such as the BSSI, signifies a vital shift towards a more comprehensive and equitable public health framework that addresses the complexities of obesity in a culturally sensitive and scientifically robust manner.

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