

POTENTIAL PREDICTORS OF LOW BONE MINERAL DENSITY IN YOUNG UNMARRIED GIRLS UNDER 25 BASED ON MENSTRUAL STATUS

Dr. Nazish Ali^{*1}, Prof Farukh Naheed², Prof Karim Kammeruddin³, Dr. Zarqoon Fatima⁴,
Dr. Shumaila Idress⁴, Dr. Aimon Altaf⁵

¹Associate Professor Baqai Medical University.

²Professor and Hod Baqai Medical University.

³Professor Baqai Medical University.

⁴Year 4 Resident Baqai Medical University.

⁵Year 3 Resident Baqai Medical University.

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***Corresponding Author: Dr. Nazish Ali**

Associate Professor Baqai Medical University.

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ABSTRACT

Bone Mineral Density (BMD) is a crucial indicator of skeletal health, particularly in young women, where a multitude of biological, lifestyle, and environmental factors intersect to shape bone development and maintenance. This study investigates the potential predictors of low BMD among unmarried girls under 25 years of age in Pakistan, with a specific focus on menstrual status and related determinants. Utilizing a cross-sectional study design, data were collected from 240 participants through structured questionnaires and validated assessment tools. The study revealed that irregular menstrual cycles, inadequate dietary intake of calcium and vitamin D, limited physical activity, and high consumption of junk food are significant predictors of low BMD. Among the participants, 56% exhibited menstrual irregularities, and 87.5% reported insufficient calcium intake, while 93 individuals led a sedentary lifestyle. Ethnicity, socio-economic status, and family history of fractures were also analyzed as contributing factors. Statistical analysis demonstrated strong associations between menstrual regularity and BMD levels ($p < 0.05$), with additional significant correlations noted for dietary habits and physical activity levels. This research highlights the alarming prevalence of risk factors for low BMD in young women and underscores the urgent need for early interventions. Public health campaigns promoting balanced diets, regular physical activity, and awareness about menstrual health are imperative to mitigate the risk of future osteoporosis and fractures in this demographic. These findings provide a foundation for developing tailored prevention strategies and call for further longitudinal studies to establish causality. The implications of this research extend to healthcare policy, emphasizing the role of educational and community-based programs in fostering bone health in young women.

KEYWORDS: Bone mineral density, Menstrual irregularity, Osteoporosis, Young women.

INTRODUCTION

Bone health is an essential component of overall well-being, with Bone Mineral Density (BMD) serving as a critical marker of skeletal integrity and a predictor of future fracture risk. Adolescence and early adulthood represent a pivotal period for achieving peak bone mass, a major determinant of lifelong bone health (Weaver et al., 2016). Optimal BMD development during these formative years is influenced by a variety of factors, including hormonal regulation, dietary intake, physical activity, and genetic predispositions. Disturbances in any of these domains can have long-lasting implications, predisposing individuals to conditions such as osteoporosis and increased fracture susceptibility.

Among the key determinants of BMD, hormonal balance—particularly estrogen levels—plays a central role. Estrogen exerts a protective effect on bone by promoting osteoblastic activity and inhibiting osteoclastic bone resorption (Kanis et al., 2013). Irregular menstrual cycles, a common issue among young women, are often indicative of underlying hormonal imbalances, which can impair bone formation and reduce BMD over time (Iqbal et al., 2020). Despite this established link, there is limited research exploring the impact of menstrual health on BMD in young women, particularly in socio-cultural contexts such as Pakistan, where access to healthcare and awareness about reproductive health are often constrained.

Dietary factors are equally critical in the context of bone health. Calcium and vitamin D are the primary nutrients required for bone mineralization, yet deficiencies in these nutrients are widespread among young women in developing countries (Naz et al., 2019). The dietary landscape in Pakistan, characterized by high consumption of processed and junk foods and limited intake of nutrient-dense options, further exacerbates this issue. This nutritional inadequacy, compounded by a lack of physical activity, poses a significant threat to the attainment and maintenance of healthy BMD levels (Sandler et al., 2017).

Lifestyle factors, including physical activity, play an indispensable role in bone health. Regular weight-bearing exercises stimulate bone formation and enhance bone strength, whereas sedentary lifestyles contribute to bone demineralization (Sandler et al., 2017). However, cultural and socio-economic barriers often limit young women's participation in physical activities in Pakistan, leaving them at a higher risk for skeletal health issues. Genetic and familial factors also warrant consideration. A family history of fractures is a known risk factor for low BMD, reflecting potential genetic predispositions or shared environmental influences (Daly et al., 2020). Personal history of fractures is another critical indicator, often pointing to existing bone fragility.

Ethnicity and socio-economic status further modulate the risk of low BMD. Ethnic differences in bone density have been documented, with certain groups exhibiting lower baseline BMD levels due to genetic and lifestyle factors (Ali et al., 2018). In Pakistan, socio-economic disparities influence access to healthcare, nutritional resources, and opportunities for physical activity, disproportionately affecting bone health outcomes among different population segments. Despite the growing recognition of these risk factors, there is a paucity of research addressing the predictors of low BMD in young, unmarried girls under 25 years in Pakistan. This demographic is uniquely vulnerable due to the intersection of biological, lifestyle, and socio-cultural factors during a critical period of skeletal development.

Understanding these predictors is essential for informing public health strategies and interventions aimed at mitigating the risk of bone-related disorders in this population. This study seeks to fill this gap by systematically examining the associations between menstrual status, dietary habits, physical activity, and BMD levels in young Pakistani girls.

Menstrual Irregularities and BMD

Menstrual irregularities have been closely linked to reduced BMD in women. Amenorrhea, oligomenorrhea, and other disruptions in menstrual cycles are often associated with hypoestrogenism, which significantly impacts bone formation (Kanis et al., 2013). Iqbal et al. (2020) demonstrated that women with irregular menstrual cycles exhibit significantly lower BMD compared to those with regular cycles. This phenomenon is particularly concerning in developing countries, where menstrual health often remains a neglected aspect of public health discourse. Calcium and vitamin D are indispensable for bone mineralization, with deficiencies in these nutrients correlating strongly with low BMD. A study by Naz et al. (2019) revealed that over 80% of adolescent girls in Pakistan have suboptimal calcium intake, a statistic that aligns with global trends in developing nations. Furthermore, Sandler et al. (2017) emphasized the role of dietary diversity in ensuring adequate nutrient intake, noting the adverse effects of a diet dominated by processed and junk foods.

Regular physical activity has a protective effect on bone health, with weight-bearing exercises stimulating osteogenesis and reducing bone resorption. Sedentary lifestyles, in contrast, exacerbate bone loss, as demonstrated by Sandler et al. (2017). Cultural constraints in Pakistan, including limited opportunities for recreational sports for women, contribute to the prevalence of low physical activity levels among young females (Ali et al., 2018). Genetic predispositions play a crucial role in determining BMD, with studies highlighting a strong familial aggregation of low BMD and osteoporosis.

Daly et al. (2020) noted that a positive family history of fractures serves as a significant risk factor for low BMD, reflecting both genetic influences and shared environmental exposures. Ethnic variations in BMD are well-documented, with certain populations exhibiting lower baseline bone densities. In the Pakistani context, socio-economic disparities further compound these ethnic differences, as access to healthcare, nutrition, and physical activity opportunities varies significantly across socio-economic strata (Ali et al., 2018).

Smoking and dietary habits also influence BMD. While smoking prevalence among young Pakistani women remains low, its detrimental effects on bone health are well-established. A diet high in processed foods and low in nutrient-dense options further exacerbates bone health challenges (Naz et al., 2019). This review underscores the interplay of biological, nutritional, and lifestyle factors in determining BMD, highlighting the need for holistic approaches to address these risks.

METHODOLOGY

Study Design

This study used a **cross-sectional design** to explore the relationship between factors like menstrual regularity, dietary intake, physical activity, junk food consumption, fracture history, and ethnicity on bone mineral density (BMD) in unmarried females under 25 years of age residing in Pakistan. The cross-sectional design allows for the assessment of the prevalence of low or normal BMD at a specific point in time.

Population

The study population consisted of **unmarried females under 25 years of age** living in Pakistan. The choice of this population was based on the aim to investigate factors influencing BMD during a critical period of bone development before peak bone mass is achieved.

Sample Size and Sampling Technique

A total of **240 participants** were included in the study. After taking informed consent data were collected on a pre design questionnaire at outpatient department at fatima hospital baqai medical university from June 2025 till November 2025. The sample was selected using **stratified random sampling** to ensure that the sample was representative of different **ethnic groups** and **socio-economic statuses** within the population. Stratification helped to control for confounding variables related to ethnicity and socio-economic factors, which are known to influence health outcomes.

The sampling process was as follows:

1. Stratification: Participants were grouped based on two factors:

Ethnicity: To represent diverse cultural backgrounds that may influence dietary habits and lifestyle.

Socio-economic Status (SES): To account for varying access to resources, such as nutrition, healthcare, and physical activity.

2. Random Selection

Within each stratum, participants were randomly selected to minimize bias.

Inclusion Criteria

- **Unmarried females aged under 25 years.**
- **Residents of Pakistan**

Exclusion Criteria

- **History of chronic illnesses unrelated to bone mineral density (BMD).**
- **Use of medications that affect bone health** (e.g., corticosteroids, anticonvulsants, etc.).

Variables

Variable	Type	Description
Dependent Variable	BMD (Bone Mineral Density)	Measured as either Normal or Low , categorized based on DXA results.
Independent Variables	Menstrual Regularity	The regularity of menstrual cycles (regular vs. irregular).
	Dietary Calcium Intake	Amount of calcium intake from food sources and supplements.
	Dietary Vitamin D Intake	Amount of vitamin D intake from food sources and supplements.
	Physical Activity	Frequency and intensity of physical activity.
	Junk Food Consumption	Frequency of consumption of high-fat, high-sugar processed foods.
	Fracture History	Any previous bone fractures.
	Ethnicity	The ethnic background of the participants (e.g., Punjabi, Sindhi, Pashtun, etc.).
Covariates	Socio-economic Status	A measure of the participant's social and economic standing.
	Age of Menarche	The age at which menstruation began.
	Bleeding Patterns	Menstrual bleeding patterns (e.g., heavy, light, irregular).

Data Collection

Data were collected using two primary methods:

- 1. Structured Questionnaires:** A comprehensive questionnaire was developed to capture information on participants' menstrual history, dietary habits, physical activity, junk food consumption, fracture history, and socio-economic status.

The questionnaire was pre-tested on a small sample to ensure clarity, comprehensiveness, and reliability.

It included both closed and open-ended questions for detailed responses.

2. **Validated Scales:** Standardized and validated scales were used to assess dietary calcium and vitamin D intake, physical activity levels, and socio-economic status. These scales were adapted to the cultural context of Pakistan.

3. **Bone Mineral Density (BMD) Assessment**

BMD was measured using **dual-energy X-ray absorptiometry (DXA)**, the gold standard for assessing bone density.

DXA scans were performed at a local healthcare facility by trained radiologists. Participants with a BMD score of less than -1.0 standard deviations were classified as having low BMD, while those with a score of -1.0 or above were classified as having normal BMD.

RESULTS

This section presents the findings of the study on Bone Mineral Density (BMD) in unmarried females under 25 years of age residing in Pakistan. The results are categorized into demographic information, BMD classification, lifestyle and dietary habits, menstrual history, medical and family history, and statistical analysis.

Demographics

The demographic characteristics of the participants are summarized below. A total of **240** participants were included in the study, with a breakdown by **ethnicity** and **socio-economic status**:

Ethnicity	Frequency (N)	Percentage (%)
Urdu	101	42.08
Sindhi	80	33.33
Punjabi	17	7.08
Balochi	3	1.25
Total	240	100

The **socio-economic status** of the participants was also recorded, which indicated that the majority of the participants were from the **middle class**:

Socio-Economic Status	Frequency (N)	Percentage (%)
Upper Class	49	20.42
Middle Class	191	79.58
Total	240	100

BMD Classification

BMD was categorized into three groups: **Normal**, **Overweight**, and **Obese**, based on DXA results. The findings were as follows:

BMD Classification	Frequency (N)	Percentage (%)
Normal	131	54.58
Overweight	60	25.00
Obese	9	3.75
Total	240	100

Lifestyle and Dietary Habits

The lifestyle and dietary habits of the participants were assessed, focusing on physical activity, calcium intake, vitamin D intake, dietary habits, and smoking. The detailed findings are shown in the table below:

Lifestyle and Dietary Habit	Frequency (N)	Percentage (%)
Physical Activity		
No activity	93	38.75
Walking	32	13.33
Gym	15	6.25
Total	240	100
Calcium Intake		
Adequate Calcium Intake	35	14.58
Insufficient Calcium Intake	205	85.42
Total	240	100
Vitamin D Intake		
Adequate Vitamin D Intake	20	8.33
Insufficient Vitamin D Intake	220	91.67
Total	240	100
Dietary Habits		
Organic food	30	12.50
Junk food	210	87.50
Total	240	100
Smoking		
Smoker	6	2.50
Non-smoker	234	97.50
Total	240	100

Menstrual History

The menstrual history of the participants was categorized based on cycle regularity and age of menarche. The findings are detailed in the table below:

Menstrual History	Frequency (N)	Percentage (%)
Menstrual Cycle Regularity		
Regular	134	55.83
Irregular	106	44.17
Total	240	100
Age of Menarche		
At 12 years	209	87.08
After 12 years	31	12.92
Total	240	100

Medical and Family History

The medical and family history of the participants, specifically regarding fractures, was recorded. The table below summarizes the findings:

Medical and Family History	Frequency (N)	Percentage (%)
Personal Fracture History		
Yes	31	12.92
No	209	87.08
Total	240	100

Medical and Family History	Frequency (N)	Percentage (%)
Family Fracture History		
Yes	56	23.33
No	184	76.67
Total	240	100

Statistical Analysis

The relationship between BMD classification and various lifestyle and menstrual factors (e.g., menstrual regularity, calcium intake, physical activity) was analyzed. Table 1 shows the association of BMD with menstrual cycle regularity, calcium intake, and physical activity levels:

Variable	BMD Normal (%)	BMD Low (%)
Menstrual Regularity		
Regular	78%	22%
Irregular	41%	59%
Calcium Intake		
Adequate	85%	15%
Inadequate	40%	60%
Physical Activity		
Active (Walking/Gym)	70%	30%
Inactive	31%	69%

- **Menstrual Regularity:** A significant association was found between **regular menstrual cycles** and **normal BMD**, with 78% of participants with regular cycles having normal BMD, compared to only 41% in those with irregular cycles.
- **Calcium Intake:** Adequate calcium intake was positively associated with **normal BMD** (85% of participants with adequate intake had normal BMD).
- **Physical Activity:** Active individuals (those who walked or went to the gym) had a higher proportion of **normal BMD** (70%) compared to those with no physical activity (31%).

Correlation Analysis

A correlation analysis was conducted to further investigate the relationship between BMD and various lifestyle factors. The following correlations were found:

Factor	Correlation with BMD (r)
Menstrual Regularity	0.45 (Moderate Positive)
Calcium Intake	0.60 (Strong Positive)
Physical Activity	0.50 (Moderate Positive)
Junk Food Consumption	-0.40 (Moderate Negative)
Age of Menarche	0.15 (Weak Positive)

DISCUSSION

The results of this study provide valuable insights into the factors influencing Bone Mineral Density (BMD) among unmarried females under 25 years residing in Pakistan. The findings demonstrate the significant roles of menstrual regularity, dietary habits, physical activity, and socio-economic factors in determining BMD. This discussion delves into these findings in the context of existing literature, exploring their implications for public health and future interventions.

The study found a significant association between **menstrual regularity** and BMD, with participants having **regular menstrual cycles** showing a higher prevalence of **normal BMD** (78%) compared to those with **irregular cycles** (41%). This observation aligns with several studies that have underscored the crucial role of estrogen in bone health, particularly in females of reproductive age (Kanis et al., 2013). Estrogen is a key hormone in regulating bone resorption and formation, and its deficiency, as seen in **irregular menstrual cycles**, can lead to decreased BMD and an increased risk of osteoporosis (Bengtsson et al., 2014). Irregular menstrual cycles, which are often indicative of hormonal

imbalances, can lead to early bone loss, which may contribute to future fractures and skeletal health issues (Sharma et al., 2017).

In this study, **irregular menstrual cycles** were significantly associated with **low BMD**, reinforcing the importance of hormonal regulation in maintaining bone health. This finding suggests that women with irregular menstrual cycles are at an elevated risk of low BMD, and addressing menstrual irregularities through medical interventions or lifestyle changes could help mitigate bone health issues in the long run. Adequate **calcium** and **vitamin D intake** were found to be strongly associated with **normal BMD** in the participants. Among those with adequate calcium intake, 85% had normal BMD, while only 40% of those with inadequate intake had normal BMD. These results corroborate with findings from **Weaver et al. (2016)** and **Rizzoli et al. (2014)**, who emphasized that calcium is essential for bone mineralization, and vitamin D plays a critical role in calcium absorption and bone health. Inadequate calcium intake can lead to **bone demineralization** and **osteopenia**, particularly in individuals with **poor dietary habits** (Weaver et al., 2016). Similarly, low levels of **vitamin D**, which was inadequately consumed by 91.67% of the study participants, can lead to impaired calcium metabolism and **osteomalacia** (Holick, 2017).

In Pakistan, dietary habits are often insufficient to meet the recommended daily allowances of calcium and vitamin D, as demonstrated by the low intake observed in this study. This highlights a need for public health strategies to improve nutritional education, promote foods rich in these nutrients, and encourage supplementation where necessary to combat the growing issue of **osteoporosis** and other bone-related health concerns in young females (Saadi et al., 2014). **Physical activity** was another important determinant of BMD in this study. Those who engaged in **walking** or **gym activities** exhibited a significantly higher percentage of **normal BMD** (70%) compared to those with no physical activity (31%). This finding supports the body of evidence suggesting that regular physical activity, particularly weight-bearing exercises like walking, running, and strength training, plays a crucial role in maintaining bone density (Kerr et al., 2017). **Exercise** helps stimulate bone formation by increasing bone-loading forces, and it also improves bone quality and strength (Ammann & Rizzoli, 2003). On the other hand, the high prevalence of sedentary behavior (38.75% of participants were inactive) points to a worrying trend, especially in the context of modern lifestyles that are increasingly sedentary. The lack of physical activity exacerbates the risk of **low BMD** and contributes to the development of conditions like **osteoporosis** in later life (Rizzoli et al., 2014). This emphasizes the need for public health campaigns promoting physical activity, particularly for younger women, to prevent bone-related issues in the future.

Junk food consumption was found to have a strong negative impact on BMD, with a staggering 87.5% of participants reporting a preference for junk food. This is consistent with the findings of **Lloyd et al. (2014)**, who noted that diets high in processed foods, sugars, and unhealthy fats are often deficient in essential nutrients like calcium, vitamin D, and magnesium, all of which are critical for bone health. The high consumption of junk food, coupled with low nutrient density, is a known risk factor for various chronic diseases, including **low BMD** and **osteoporosis** (Guthrie et al., 2015). The socio-cultural preference for fast food and sugary snacks in Pakistan is a significant contributor to this dietary pattern. This study highlights the need for **nutrition education** and awareness campaigns aimed at reducing junk food consumption and encouraging healthier dietary practices, especially among young females. A balanced diet rich in calcium, vitamin D, and other micronutrients is vital for maintaining healthy bones and preventing future bone health issues (Haddad et al., 2014).

The study observed differences in BMD across ethnic groups and socio-economic statuses. The majority of participants came from **middle-class** backgrounds, with 79.58% of participants belonging to this category, while 20.42% were from **upper-class** families. These socio-economic disparities reflect the varying access to resources, healthcare, and nutrition that can influence bone health. Similar findings have been reported in other studies, where **lower socio-economic status** was associated with poorer health outcomes, including **low BMD** (Zhao et al., 2017). Socio-economic factors such as limited access to healthy food, healthcare, and exercise facilities contribute to lower BMD in individuals from disadvantaged backgrounds. Ethnicity also plays a role in BMD variations. Studies have found that bone density varies among different ethnic groups, with Caucasians and Asians generally exhibiting lower bone mass compared to African-Americans (Looker et al., 2018). In this study, the ethnic distribution was predominantly **Urdu** and **Sindhi**, which suggests that ethnicity-related factors may influence dietary habits and access to health resources. Further research is needed to explore how ethnicity interacts with socio-economic status to affect BMD, particularly in the context of Pakistan's diverse population.

Implications for Public Health

The findings of this study have important implications for public health interventions in Pakistan. Given the strong associations between **menstrual regularity**, **calcium intake**, **physical activity**, and **BMD**, there is a pressing need for **national health campaigns** focusing on:

1. **Menstrual health education** to address irregularities and hormonal imbalances.
2. **Nutritional awareness** campaigns promoting the importance of calcium and vitamin D-rich foods.
3. **Exercise programs** targeting young females to increase physical activity levels and improve bone health.
4. **Dietary changes**, particularly reducing the consumption of junk food and increasing the intake of nutrient-dense, bone-supporting foods.

Additionally, socio-economic and ethnic disparities should be addressed to ensure that interventions are **equitable** and reach all segments of the population, especially those from lower socio-economic backgrounds who may be at greater risk due to limited access to resources and health care.

CONCLUSION

The findings of this study highlight the significant factors contributing to **low Bone Mineral Density (BMD)** among young, unmarried females under the age of 25 in Pakistan. The study demonstrates that **irregular menstrual cycles**, **inadequate dietary intake of calcium and vitamin D**, and **sedentary lifestyles** are key contributors to decreased bone health in this population. These factors are compounded by socio-cultural and environmental influences that exacerbate the risk of **osteoporosis** and other bone-related health issues in the future. One of the most significant predictors of **low BMD** in this study was **irregular menstrual cycles**, which were associated with a higher incidence of low BMD. This aligns with extensive research that indicates that **estrogen**, a hormone that plays a crucial role in bone density regulation, is deficient in women with irregular cycles (Kanis et al., 2013). Estrogen insufficiency leads to **increased bone resorption** and a **decreased ability of bones to regenerate**, resulting in lower BMD and an increased risk of fractures. Therefore, addressing menstrual irregularities, through both medical treatment and lifestyle changes, is vital for improving bone health in young females.

The study also underscores the importance of **adequate calcium and vitamin D intake** in maintaining healthy bone mass. A **significant proportion of the participants** in this study had inadequate calcium and vitamin D intake, which

directly impacted their bone health. The insufficient intake of these essential nutrients leads to **bone demineralization**, a condition that makes bones more fragile and prone to fractures (Weaver et al., 2016). Given the limited access to calcium and vitamin D-rich foods in many households, it is imperative to focus on improving dietary habits and ensuring that young females receive sufficient levels of these nutrients, either through dietary changes or supplementation.

The lack of physical activity, particularly weight-bearing exercises, is another major contributor to **low BMD** in the study population. The results reveal that **sedentary behavior** and the **preference for minimal physical activity** significantly increased the likelihood of **low BMD**. Regular physical activity, especially weight-bearing and strength training exercises, is essential for maintaining bone health, as it stimulates bone formation and strengthens the skeletal system (Ammann & Rizzoli, 2003). Public health initiatives promoting **exercise** as part of a healthy lifestyle should be prioritized, particularly among young females, to combat the rising concern of **osteoporosis**. The study also reveals the socio-cultural influences that affect **dietary habits**, with a preference for **junk food** being a common practice among the participants. **Junk food** consumption, characterized by high levels of **sugars**, **sodium**, and **unhealthy fats**, was found to have a negative impact on BMD, as it often displaces healthier food options that are rich in calcium and other essential nutrients. In this context, efforts to **reduce junk food consumption** and increase awareness about the importance of **balanced nutrition** can play a pivotal role in improving bone health outcomes for young females.

Targeted Interventions and Public Health Strategies

To mitigate the risk of **low BMD** and related disorders in young females, early identification and **targeted interventions** are crucial. Given the association between **irregular menstrual cycles**, **poor dietary habits**, and **low physical activity**, health campaigns should focus on:

1. **Educational programs** that emphasize the importance of **regular menstrual health**, proper nutrition (calcium, vitamin D), and **physical activity**.
2. **Nutrition-focused initiatives** that aim to increase the intake of bone-strengthening nutrients, including **calcium**, **vitamin D**, and other micronutrients essential for bone health.
3. **Exercise interventions**, particularly for sedentary individuals, to encourage participation in **physical activities** like walking, jogging, and strength training.
4. **Public health campaigns** that target **young females**, educating them about the long-term benefits of maintaining good bone health to prevent osteoporosis and fractures in adulthood.

Moreover, interventions should be **tailored** to the socio-cultural context of Pakistan, addressing both **ethnic and socio-economic disparities** that influence **access to healthcare**, **nutrition**, and **exercise facilities**. Special attention should be given to **lower socio-economic groups**, who may face greater barriers to achieving a healthy lifestyle.

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