

The Impact of Aging on Height and Its Influence on BMI: A Comparative Study

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SUMMARY

Title : The Impact of Aging on Height and Its Influence on BMI: A Comparative Study

Abstract

Background: Age-related height loss is a frequent physiological phenomenon in the elderly that can be due to osteoporosis and/or help in screening/early evaluation for osteoporosis and clearly affects the computation of Body Mass Index (BMI). This study assessed how height loss affected older persons' BMI classification and how it is related to osteoporosis.

Method: Quantitative cross-sectional study of 103 people aged 60 years and above. Information regarding body weight, osteoporosis status, current height and recalled height was obtained through structured evaluation techniques. Both current and recalled heights were used to calculate BMI. The data were analyzed using correlation analysis and descriptive statistics

Result: The outcome was that females accounted for 60.2% of the studied population and most of the participants (57.3%) were in the age group of 60–69 years. 76.7% of the participants were found to be shorter than 160 cm at present as compared to 66% when they were young adults. BMI calculated using present height revealed a higher prevalence of obesity (48.5%) as compared to 34% using recalled height. Mean BMI recall (27.54 kg/m^2) was lower than the mean BMI current (28.89 kg/m^2), indicating that BMI might be overestimated due to the loss in height. On average, women lost more height (4.34 cm) as compared to men (2.83 cm). Osteoporosis was found in 42% of the women and on average they lost 7 cm of height as compared to 2.42 cm in women without Osteoporosis.

Conclusion: A significant effect on BMI classification for age-related height loss may lead to an overestimation of obesity in the elderly. In addition, it was found that height loss was associated with osteoporosis, suggesting that height loss can be a good clinical diagnostic tool for bone health.

Keywords: Osteoporosis; Body Mass Index; Obesity; Sarcopenia; Bone Health.

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CHAPTER 1

INTRODUCTION

1. Background of study

The world is experiencing a significant demographic shift to an ageing population with a rapidly increasing proportion of the aged population. This change has resulted in an increase in age-related health issues, especially those impacting the musculoskeletal system [1]. The aging process is also associated with progressive physiological changes, including loss of bone density, muscle strength, and degradation of joint and spinal structures. Not only do these changes impair mobility and functional autonomy but also increase the risk of chronic diseases and disability in the elderly [2]. One of the most apparent but often overlooked aging effects is age-related height reduction caused by the structural changes of the spinal column. Progressive loss of height is caused by a combination of factors such as postural alterations, compression fractures of the spine, and degeneration of the intervertebral discs. In older people with osteoporosis, when low bone mineral density results in brittle bones and an increased risk of vertebral collapse, this phenomenon is especially important [3].

One of the most common and easy ways to define nutritional status and classify individuals into weight categories is the Body Mass Index (BMI). It is essential for recognising health hazards such as obesity, underweight and other nutritional disorders [4]. BMI is, however, very sensitive to accurate measurements of height, which might be impaired in the elderly due to height loss. Due to this fact, BMI may be inflated, thus leading to false categorisation of people and misevaluation of their health condition [5].

Osteoporosis is a severe societal health problem impacting millions of elderly citizens worldwide. Its characteristics are, reduced bone density and a predisposition to fracture, primarily the hip, wrist, and spine [6]. Vertebral fractures that are caused by osteoporosis are often asymptomatic but significant in causing abnormalities of the spine and shortening. The correlation between height loss, BMI misclassification, and osteoporosis remains a critical research issue because it impacts the diagnosis of elderly patients at an early stage, risk assessment, and treatment [7].

1.1.Ageing and physiological changes

The functional capacity and the structural integrity of the body slowly decline as the individual grows older, and this is a normal, progressive and irreversible process. The effect of disease on all organ systems and decreasing physiological reserve make elderly people more susceptible to illness leading to a lower quality of life. These changes affect overall health and the functional autonomy on a cell, tissue, and organ level [8].

1.1.1. Structural and functional changes with ageing

There are several changes in the body, both anatomical and functional, that happen as humans grow older. Besides alterations in tissue composition, such as augmented fibrosis and diminished elasticity, it also deteriorates the number and regenerative ability of cells. The activity of an organ can also diminish with time, as a result of atrophy. These structural changes are functionally manifested by a reduced metabolic rate, a compromised immune system, and a reduced ability to adapt to both environmental and physical stress [9].

The respiratory system is exposed to reduced lung capacity and efficiency, and the cardiovascular system is presented with reduced cardiac output and vascular flexibility. Similarly, the neurological system undergoes changes such as cognitive impairment and decreased nerve conduction. A combination of such functional impairments makes the elderly less physically fit and more vulnerable to chronic diseases [10].

1.1.2. Musculoskeletal changes in the elderly population

One of the systems most adversely affected by aging is the musculoskeletal system. Loss of bone mass occurs as a result of unequal bone formation and bone destruction, which increases the likelihood of osteoporosis and fractures. The vertebral column is particularly susceptible, leading to issues such as vertebral compression and spinal deformity, which is also a cause of reduction in height [11]. Sarcopenia refers to the loss of muscle mass and muscle strength as the person gets older, leading to a loss of mobility, balance issues, and increased falls. Joints also go through degenerative changes, such as cartilage loss and decreasing synovial fluid, which causes stiffness, discomfort, and a limited range of motion. Ligaments lose their elasticity, affecting stability and posture [12].

Such musculoskeletal alterations greatly affect body composition and anthropometric measurements, as well as physical functioning leading to issues of age-related loss of height, miscalculated BMI, and predisposition to osteoporosis among the older age groups [13].

1.2.Age-related height loss: Mechanism and Determinants

Height loss is a common physiological change observed in elderly individuals and is considered an important indicator of skeletal and spine health. It refers to the gradual loss of height as a result of ageing, which normally begins at mid-adulthood and becomes more pronounced later in life. On average, people tend to lose between 1 and 2 cm each decade after 40 years, with an even larger decline in the older age groups, with a greater effect on women [14].

Structural changes in the spinal column are the main cause of height reduction. The intervertebral discs provide cushions between the vertebrae and wear out over time, losing disc height and elasticity. Also, compression of vertebral bodies can be experienced due to loss of bone strength, especially in individuals with low bone mineral density. All these changes result in a shortening of the spinal column [15].

1.2.1. Body mass index (BMI)

Body Mass Index (BMI) is a simple, commonly used anthropometric measurement to assess the nutritional health of an individual, and categorise body weight in relation to height. It serves as an indirect measure of body fat and is commonly used in clinical practice, population health studies, and epidemiology to understand the risk of various health problems, including obesity, cardiovascular diseases, and metabolic diseases. BMI remains one of the most viable screening tools to conduct a population-level assessment because it is easy to calculate, and it is non-invasive [16].

1.2.2. Definition and calculation of BMI

BMI is defined as a person's body weight in kilograms divided by the square of their height in meters [17].

$$\text{BMI} = \frac{\text{weight (kg)}}{\text{height (m)}^2}$$

1.2.3. Intervertebral Disc degeneration

Intervertebral discs are shock absorbers between the vertebrae and serve to keep the spinal height and flexibility. The degenerative transformations that these discs undergo with age include droughtiness, loss of proteoglycan, and loss of flexibility. The nucleus pulposus loses moisture, and the annulus fibrosus becomes weak, leading to a loss in height of the disc [18]. As the size of disc gaps reduces, the total length of the vertebral column becomes shorter, and this adds a significant contribution to vertical loss. The degeneration of the discs also reduces the flexibility of the spine and may lead to such issues as disc bulging or herniation. The degeneration of the

intervertebral disc is a gradual, cumulative process, and one of the earliest causes of stature loss with age [19].

1.2.4. Vertebral compression fractures

Primary pathological causes of height loss include vertebral compression fractures, which are common in the elderly who suffer from osteoporosis. These fractures occur due to the failure of compromised vertebrae to withstand normal physiological forces. Often, they are asymptomatic or manifest with mild back pain, leading to underdiagnoses [20]. Every compression fracture produces measurable losses of height, and many fractures can produce significant shortening of the spine. In addition, these fractures cause dislocation of the spine, and can cause abnormalities like kyphosis. Osteoporosis severity is also greatly associated with the high occurrence of vertebral fractures and serves as a clinical marker of the condition [21].

1.2.5. Rate and pattern of height loss

The rates of height loss are different among people and tend to increase in old age. The average rate at which adults lose 1-2 cm per decade is after the age of 40, although it increases more rapidly near age 70. Women typically lose more height than men, due to postmenopausal bone loss and increased prevalence of osteoporosis. The loss of height may be progressive through degeneration of the disc or sudden in case of fractures in the vertebral bones [22]. The trend could be linear or episodic, based on these factors. Cumulative height reduction occurs in many elderly people and is an outcome of degenerative and pathological alterations that take place over time. In clinical terms, a loss of over 3-4 cm of an individual's peak adult height is a significant loss and can also signify spinal fractures or osteopenia. Having height change monitoring over a period of time can therefore be a simple and effective screening method for early detection of skeletal problems [23].

1.2.6. Anthropometric Assessment of the elderly population

Anthropometric evaluation is the systematic measurement of physical body parameters such as height, weight, BMI, circumferences, and skinfold thickness. In the aged, these parameters are critical for assessing nutritional status, body composition, and overall health. However, ageing causes various physiological and structural changes that might impair the quality and interpretation of anthropometric data, making assessment in geriatric patients more difficult than in younger populations [24].

1.2.7. Importance of body measurement in geriatrics

Accurate body measurements play an important part in the full health assessment of senior people. These are widely used to

- Determine nutrition status: Anthropometric measures like BMI, mid-upper arm circumference, and skinfold thickness are used to identify undernutrition, overweight, and obesity in elderly individuals [25].
- Evaluate health risk: Abnormal body composition is linked to an increased risk of chronic diseases such as cardiovascular disease, diabetes, and osteoporosis.
- Follow-up disease development: The variation of body measures over time may indicate worsening, muscle atrophy, or treatment recovery [26].
- Guide to clinical decision making: Nutritional therapies, pharmaceutical administration, and rehabilitation programs are often based on accurate anthropometric measurements.
- Evaluate functional status: Frailty is linked to limited muscle mass and body weight, impaired mobility, and a higher risk of falling [27].

1.2.8. Challenges in accurate height measurement

Measuring height effectively in senior people poses various obstacles due to age-related physiological changes and physical limitations:

❖ Age-related height loss:

Advancing loss in height through degeneration of intervertebral discs, spinal compression fractures and changes in posture may lead to underestimation of actual height. This affects measurement, such as BMI, and could cause misclassification [28].

❖ Postural deformities:

The elderly may have a hard time straightening up due to kyphosis (forward curvature of the spine), scoliosis, and stiffness in joints. Consequently, the normal standing height would not be a good indicator of body proportions [29].

❖ Spinal and joint degeneration:

Arthritis and compression of the spine and lower limbs (degenerative changes) can interfere with body alignment and reduce the accuracy of measurements [30].

1.2.9. Measurement errors and variability

Inconsistent placement, incorrect technique, or a lack of cooperation on the part of the individual may result in errors. Small mistakes in height measurement can have a substantial impact on BMI calculations because height is squared in the algorithm [31].

1.2.10. Alternative measurement methods:

Due to these challenges, alternative methods are often used, such as

- Arm span measurement
- Knee height estimation
- Demi span method [32].

1.3. Limitations of BMI in the geriatric population

The Body Mass Index (BMI) has been widely adopted as an easy and economical method of tracking nutritional health, but its applicability among the older population is limited. Aging is accompanied by major changes in body structure, composition, and height, which can jeopardise the accuracy and therapeutic utility of BMI. Consequently, the use of BMI alone in elderly individuals can give false implications regarding the health conditions and disease-proneness [33]

1.3.1. Influence of height loss on BMI calculation

The calculation of BMI is done based on height and weight, and since the height is squared in the formula, a slight loss in height can have a significant impact on the BMI scores. The degeneration of interspinal discs, compression fractures of the spine, and changes in posture cause height loss in the elderly, leading to the underestimation of actual height. Subsequently, body weight can be kept constant, yet BMI can be artificially increased. Consequently, individuals with higher BMIs are overdiagnosed as overweight or obese. This misclassification may conceal other underlying issues, such as starvation or loss of muscle, resulting in ineffective treatment choices [34].

1.3.2. Inability to assess body composition

One of the most significant disadvantages of BMI is that it does not distinguish between fat mass and lean body mass. Even when body weight remains constant, aging is related to sarcopenia (loss of muscle mass) and a proportionate rise in fat mass in senior populations.

Two individuals with the same BMI may have very different body compositions:

- One may have high muscle mass and lower fat.
- Another may have reduced muscle mass and increased fat [35].

BMI fails to account for this discrepancy, making it an unreliable predictor of genuine nutritional and metabolic state in people. This limitation is especially relevant for recognising disorders like

sarcopenic obesity, in which people have a normal or high BMI but have low muscle mass and functional capacity [36].

1.3.3. Ethnic and age-related variation

The interpretation of Body Mass Index (BMI) is largely affected by ethnic and age variations that restrict its universal use, particularly in the elderly. Body composition, fat distribution, and metabolic risk vary among various ethnic groups at the same levels of BMI [37]. To illustrate, Asian populations are already more likely to have a higher percentage of body fat and are prone to metabolic diseases like diabetes and cardiovascular disease at lower BMI than Western populations. Besides ethnic variations, aging influences body composition because it leads to fat deposition, especially central adiposity, and reduced lean muscle mass and bone density. Such age variations make the relationship between BMI and the real health risk less significant [38].

1.3.4. Impact of height loss on BMI classification

The elderly population is a highly affected group when it comes to the accuracy of BMI classification due to the effect of age on height. Since BMI is calculated based on height and weight, weight loss without corresponding height loss can bias the BMI scores. This complicates effectively estimating nutritional adequacy and health risks in older people, making it critical to grasp both the mathematical and clinical implications of height reduction [39].

1.3.5. Mathematical and clinical implications

Height is negatively associated with BMI; therefore, any slight decrease in height could cause an uneven rise in BMI. The degradation of intervertebral discs, compression of the spine, and changes in posture of the elderly lead to height loss and, consequently, artificially high BMI scores. Mathematically, this creates a systematic error in the determination of BMI [40].

This distortion could lead to the wrong assessment of the health condition of an individual. Healthcare providers can assume more body fat or obesity when, in reality, the change in BMI can be explained by less height rather than more weight. This may have an impact on diagnosis, risk assessment, and treatment planning, especially for disorders like cardiovascular disease, diabetes, and osteoporosis [41].

1.3.6. Risk of Misclassification Bias

The loss of height causes a form of measuring bias that may cause people to be put in the wrong BMI categories. Elderly individuals, who were once considered to be of normal weight, can be re-categorized as overweight simply because they have less height. Even people whose muscles have

shrunk and accumulated fat can have a normal BMI, which hides their health problems. Such misclassification bias is particularly problematic in epidemiology and clinical evaluation, as it may lead to erroneous prevalence rates of obesity and associated conditions. It also has an impact on the validity of BMI as a screening tool among the elderly [42].

1.3.7. Overestimation of overweight and obesity

One of the most significant implications of height loss is an overestimation of overweight and obesity rates among the elderly. As BMI values rise artificially due to decreased height, a larger proportion of the population may be classed as overweight or obese without an actual increase in adiposity [43].

- Unnecessary clinical intervention, such as weight reduction programmes
- Misguided public health strategies based on inflated obesity prevalence.
- Failure to detect undernutrition or sarcopenia, which are common in elderly populations [44].

1.4.Osteoporosis: pathophysiology and clinical significance

Osteoporosis is a systemic skeletal disorder, which is marked by a lack of bone strength and increased vulnerability to fractures. It is fairly common among the elderly population and is a significant source of morbidity and disability, as well as reduced quality of life. The clinical significance of osteoporosis lies not just in the loss of bone but also in its sinister nature and perilous effects, such as a fragility fracture, which may be caused by the slightest trauma [45].

1.4.1. Bone remodelling imbalance

Bone is a dynamic tissue and is continually remodelling through a carefully regulated process of bone formation by osteoblasts and bone resorption by osteoclasts. These systems collaborate with people in good health to maintain bone strength and mineral balance. Nonetheless, as we get older, this balance is disrupted, leading to an increase in bone resorption and a reduction in bone production. Bone loss is also a result of hormonal changes, especially the reduction of estrogen in postmenopausal women. Less calcium uptake, lack of vitamin D and physical exercise are all causes of poor bone development. This imbalance leads to a net loss of bone mass with time, which makes bones more vulnerable and susceptible to trauma [46].

1.4.2. Micro architectural deterioration

Besides bone mass loss, osteoporosis results in significant changes in bone tissue microarchitecture. The internal structure of bone, particularly trabecular (spongy) bone, thins, become less linked, and more porous. Cortical bone becomes weaker and thinner. Although bone

mineral density seems to be slightly reduced, this degradation diminishes the mechanical strength of bone. This reduces the capacity of bones to be able to absorb stress; thus, bone is more prone to fracture due to normal stresses experienced in the body. These are irreversible structural changes that are significant in the onset and progression of osteoporosis [47].

1.4.3. Fracture risk complications

The most grave effect of osteoporosis is that it predisposes individuals to fragility fractures that may be caused by low-impact events such as simple falls or even daily activities. The most commonly affected are the hip, vertebrae (spine) and the wrist. Vertebral fractures may manifest themselves without any symptoms, but may lead to persistent back pain, spinal deformities (e.g. kyphosis), and significant height loss. Hip fractures are especially serious and related to hospitalisation, long-term impairment, loss of independence, and high mortality in the elderly population [48].

Complications of osteoporotic fracture include.

- Chronic pain and reduced mobility
- Increased risk of subsequent fractures
- Functional decline and frailty
- Psychological effects such as depression and reduced quality of life
- Economic burden due to long-term healthcare needs [49].

1.4.4. Interrelationship between height loss and osteoporosis

Two closely related diseases that have common underlying mechanisms and often co-occur in older age groups are height loss and osteoporosis. Reduced height does not necessarily happen due to normal ageing, and may, in many cases, be a sign of an underlying skeletal injury, in this case, diminished bone mineral density due to osteoporosis. The association is therapeutically meaningful since alterations in stature may serve as a simple and timely indicator of unhealthy bone [50].

One of the relationships between height loss and osteoporosis is the vertebral compression fractures. Osteoporosis leads to weakening and porosity of bones; vertebrae are particularly vulnerable to loss even under normal body pressure. These fractures can be silent and asymptomatic, but lead to a reduction in vertebral height, causing an objective loss in overall height. Repeated or numerous vertebral fractures can cause severe height loss and spinal abnormalities. Besides fractures, osteoporosis leads to structural alterations of the spine, including

the weakening of vertebral strength and the altered position of the spine. This often causes thoracic kyphosis, or forward curvature of the spine, which enhances height loss. The presence of curvature and compression of the spine causes a change in posture of the person, making him/her look stooped and short [51].

1.4.5. Association between height loss severity and fracture risk

The extent of height loss associated with age is strongly associated with a high risk of osteoporotic fractures, particularly among older individuals. Height loss is not only a natural consequence of aging, but it can also be a sign of some spinal injury and bone fragility. With an increase in the amount of height loss, this typically suggests progressive structural degeneration of the spine, commonly due to repeated fractures of the vertebrae [52]. As per research, individuals who have lost greater height are more susceptible to vertebral fractures, most of which are clinically silent. A single vertebral fracture adds up to spinal shortening, and multiple fractures significantly speed up height loss. Consequently, height loss is a helpful and noninvasive clinical indicator of high-risk people when it comes to the risk of fractures [53].

1.4.6. Impact on functional status and quality of life

The functional level and the overall quality of life of elderly people are greatly affected by age-related height loss, particularly in combination with osteoporosis. Physical performance also declines significantly since the structural changes in the spine continue, and since the spine is compressed and postural deformities such as kyphosis form. These changes limit the capacity to do fundamental everyday activities like walking, standing, bending, and lifting, limiting independence and increasing dependency on caregivers [54].

The ability to move and balance difficulties can be considered one of the most drastic consequences of height loss. Disturbed spinal positioning results in a change of the centre of gravity in the body and leads to instability and risk of falling. This is of particular concern to the elderly, whereby a fall can result in fracture, hospitalisation, and permanent impairment. In addition, the back pain that occurs due to vertebral fractures also extends and reduces physical activity, which causes atrophy and impairment of the muscles. Height loss and related spinal deformities can lead to respiratory impairment (severe kyphosis). Compression of the thoracic cage can cause a decrease in the capacity of the lungs, resulting in low exercise capacity and fatigue. These physical restrictions also prevent normal everyday life and involvement in social and recreational activities [55].

1.4.7. Socioeconomic factors affecting elderly health.

The health of the senior population is significantly influenced by socioeconomic factors. The crucial factors are income, education level, and access to healthcare and living conditions. Reduced poverty eliminates access to healthy foodstuffs, medication, and diagnostic tests, including the bone mineral density examination, which puts one at risk of osteoporosis. Educational level also affects the knowledge of health, nutrition and preventive behaviour, with low literacy levels linked to poor health-seeking behaviour. The identification and treatment of age-related illnesses are further slowed by limited access to healthcare services, especially in rural or disadvantaged locations. Loss of physical and psychological health among the older generation may be caused by poor living conditions and lack of social support networks [56].

1.4.8. Impact of socioeconomic factors on health outcomes

While high BMI is considered a risk factor, some literature suggests that a BMI in the overweight range in the elderly might be related to better mortality and it is called “Survival Paradox”. A moderately high BMI can act as a nutritional reserve in times of chronic illnesses and reduce the severity of wasting. However this is complicated by age related height loss and false increase in BMI which can lead to misclassification and can mask underlying conditions like sarcopenia and malnutrition.

The influence of socioeconomic differences on the health outcomes of senior individuals has a direct effect on nutrition, lifestyle, and managing diseases. Financial limitations lead to inadequate nutrition, which results in deficiencies of calcium, vitamin D, and protein, putting people at risk of bone loss and fracture. Physical inactivity, smoking and poor eating habits are lifestyle choices often related to socioeconomic status and cause musculoskeletal degeneration. Social support and isolation can cause poor treatment adherence, risk of depression and deterioration of overall quality of life. Consequently, these contribute to the worsening of age-related diseases, such as height loss, BMI misclassification, and osteoporosis, which is why specific therapies and more convenient access to healthcare are necessary [57].

1.5. Future direction in Anthropometric research

Anthropometric assessment remains an important method of determining health risk and nutrition status, although its inability to accurately perform the same in elderly populations highlights the

necessity of future development. Future research in this field must focus on developing more accurate, age-specific, and therapeutically relevant methods of assessment that consider physiological alterations that occur with aging, including skeletal loss, altered body composition, and decreasing height. One of the key opportunities is the development of age-adjusted anthropometric indices that better reflect the actual body composition of older individuals. Traditional measures, like BMI, misclassify people since they do not differentiate lean and fat masses. New indices that consider such factors as bone density, muscle mass and fat distribution are needed to enhance diagnostic accuracy.

New technologies in body composition analysis such as the dual-energy X-ray absorptiometry (DEXA), bioelectrical impedance analysis (BIA), and imaging offer better measures of lean mass and fat. Further research ought to be directed towards the enhancement of the usability, affordability, and accessibility of these technologies in the community, especially in the low-resource community.

1.6. Scientific background to research

Aging is connected with increasing physiological and anatomical changes, which primarily affect the musculoskeletal system. Ageing is associated with a progressive loss of bone mineral density (BMD), muscle mass and degeneration of the spine, including dehydration of the intervertebral discs and spinal compression. This results in age-related loss of height, a prevalent but important clinical problem among the elderly. Meanwhile, Body Mass Index (BMI) is widely used to assess nutritional status; however, this is greatly influenced by height measurements. In the elderly population, reduced height without weight loss can lead to overestimation of BMI and misclassification. Also, osteoporosis, a common age-related disease characterised by reduced bone quality and fracture risk, is a major cause of height loss due to spinal fractures. Therefore, the relationship between height decrease, BMI measurement and osteoporosis provides a scientific basis for this research and highlights the need for improved methodology assessment in the elderly.

- Aging leads to musculoskeletal degeneration, including bone loss and muscle reduction.
- Intervertebral disc degeneration and vertebral compression contribute to height loss.
- BMI depends on height, making it sensitive to age-related stature reduction.
- Height loss can cause an artificial increase in BMI values.
- Increased risk of BMI misclassification (overweight / obesity) in elderly individuals
- Osteoporosis is a major cause of vertebral fractures and height reduction.

- BMI does not reflect body composition changes such as sarcopenia.
- Combined effects of height loss and osteoporosis complicate health assessment in geriatrics

AIM:

The purpose of this study is to use a quantitative approach to assess the impact of age-related height loss on Body Mass Index (BMI) classification and its relationship with osteoporosis in senior people.

Objective

- To determine the extent and prevalence of height loss among the elderly population
- To evaluate the association between height loss and osteoporosis
- To analyze the correlation between BMI values at present and as a young adult

CHAPTER 2 : SCIENTIFIC BACKGROUND TO THE RESEARCH

This research aims to study height loss in elderly individuals (aged 60 years and above) and its influence on BMI as well as understand how it relates to aging and osteoporosis. Height loss is a common but often overlooked indicator of underlying osteoporosis and bone fragility. By comparing current measured height with recalled young-adult height and collecting basic health information, this study will identify patterns of height reduction and its association with osteoporosis and gender.

The study is cross-sectional, observational, and involves non-invasive measurements only. Each participant's height was measured once using a stadiometer, and a short questionnaire was completed. The findings will help in estimating height loss in individuals as they age.

All researchers consistently agree that height decreases with increasing age.

- The decline is faster in women, especially after menopause.
 - Loss of height negatively affects BMI accuracy, often increasing BMI even without weight gain.
 - Height loss is also an indicator of poor musculoskeletal health, frailty, and higher mortality risk.
 - More population-specific studies are needed to understand variations and to adjust BMI interpretation in older adults.
-
- Holt, Altayar and Alpers (2023) [61] conducted a long-term study using the FraminghamHeart Study data and found that average height loss from 40 to 80 years is about 3.6 cm in men and 4.8 cm in women.
 - Sorkin et al. (1999) [63] studied adult height changes over several decades and observed that height decline can begin as early as 30 years of age. By 70 years, men had lost approximately 3 cm and women about 5 cm.
 - Fernihough and Mills (2014) [64] reported that height decreases consistently as people age. Men lose around 0.08–0.10% of their height per year and women lose 0.12–0.14%.
 - Ji et al. (2023) [65] found that even short-term follow-up in elderly groups showed noticeable height loss.
 - Iwasaki et al. (2023) [66] studied a very large population and discovered that a height loss of just 0.5 cm over 2 years increased the risk of death from all causes in both males and females.

- Srikrajang and Komolsuradej (2024) [67] proposed a “height-changing score” to measure height loss due to aging.
- Ensrud, K. E., et al. (1997) [68], Height loss as a marker of osteoporosis and vertebral fractures.

CHAPTER 3

MATERIAL AND METHODOLOGY

2.1 Study Design

We have used a quantitative, observational, cross-sectional method to examine the effect of age-related height loss on Body Mass Index (BMI) classification and its association with osteoporosis in the elderly population. A cross-sectional method was used because it facilitates the measurement of variables such as height loss and/or osteoporosis at a given point in time, enabling comparisons and statistical associations.

2.2. Study Setting

The data has been collected from elderly people in clinical and community settings, with anthropometric and clinical indicators recorded.

2.3. Study Population

Participants are geriatric adults aged 60 and up, representing both genders. This age group was chosen because of the increased prevalence of musculoskeletal deterioration, height loss, and osteoporosis with advancing age.

2.4. Sample Size

The study has 103 participants. The sample size was calculated depending on the availability of complete and accurate data.

2.5. Sampling technique

Participants are selected using a convenience sampling method, considering accessibility and willingness to participate.

➤ Inclusion criteria

- Individuals aged ≥ 60 years.
- Both male and female participants
- Individuals providing informed consent.
- Participants with complete anthropometric and clinical data

➤ Exclusion criteria

- Individuals with severe spinal deformities unrelated to aging.
- Individual not able to stand up for height measurement
- Critically ill or bedridden patients

2.6. Material used

- Stadiometer for height measurement
- Calibrated weighing scale for body weight measurement
- Bone mineral density (BMD) reports

2.7. Methodology

2.7.1. Data collection procedure

Data was gathered using a pre-designed structured data collection form to ensure uniformity and consistency. To ensure confidentiality and facilitate analysis, each participant was granted a unique identification number.

➤ Variable recorded

a) Demographic variable

- Age (years)
- Gender (male/female)

b) Anthropometric variables

- Recalled (maximum adult) height (cm)
- Current measured height (cm)
- Body weight (kg)

c) Clinical variable

- Osteoporosis status (yes/no)
- History of fractures

2.8. Measurement procedures

➤ Height measurement

Participants' current height was measured with a stadiometer while standing erect, barefoot, and properly aligned.

➤ Recalled height

Recalled height is the greatest adult height ascertained from participant recall or available medical data.

➤ Weight measurement

Body weight was measured using a standard calibrated weighing scale, with subjects wearing light clothing and no shoes.

➤ Calculation of height loss

Height loss was calculated as:

Height loss (cm) = Recalled height – present height

This parameter reflects the extent of age – related reduction in stature.

➤ BMI calculation

Body mass index (BMI) was calculated using the standard formula:

$$BMI = \frac{Weight (kg)}{height (m)^2}$$

BMI values were used to classify individuals into standard categories and to assess the impact of reduced height or BMI classification.

2.9. Data analysis

- Descriptive statistics (mean, standard deviation, percentage) were calculated.
- Results are presented in the form of a table and a graphical representation.

Ethical Approval

This study was conducted in accordance with the principles of the Declaration of Helsinki. The protocol (Ref No: MOH/IEC/2025/AP-074) was reviewed and approved by the Institutional Ethics Committee (IEC) of Maruti Hospital, Talod, Gujarat. Formal written informed consent was obtained from all senior participants or their legally authorized representatives prior to their

inclusion in the study. To protect participant privacy in accordance with local health data regulations, all data were anonymized and stored securely.

CHAPTER 4

RESULTS

3.1. Demographic characteristics of the study population

The below table gives a baseline demographic of the participants in the study. Demographic factors such as age and gender are important in determining physiological changes, height loss, Body Mass Index (BMI) and osteoporosis. This paper involved 103 individuals aged 60 and above.

Table 1: Age distribution of the participants (n = 103)

Age Group (years)	Frequency (n=103)	Percentage (%)
60–69	59	57.3%
70–79	30	29.1%
≥80	14	13.6%
Total	103	100%

Almost 60% (n = 59) of the participants in the study were between the age 60 and 69. 29.1% (n = 30) of the participants were between the ages of 70 and 79, while 13.6% (n = 14) were 80 and above.

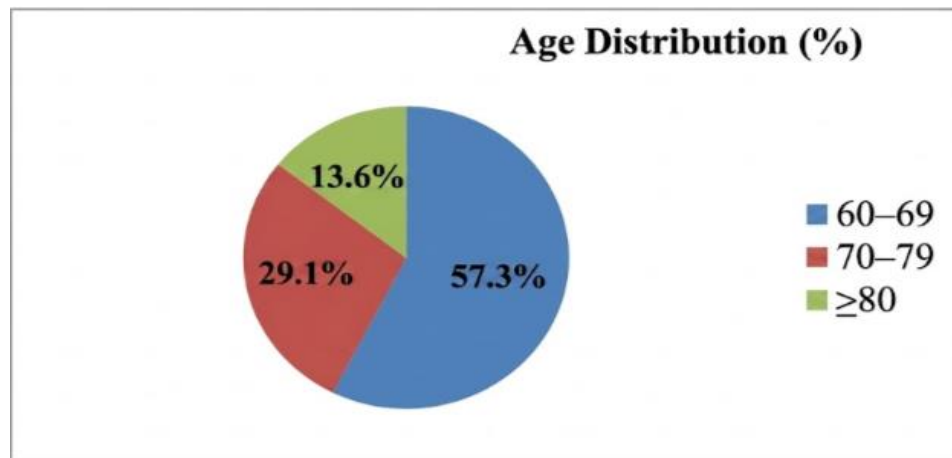


Figure 1: Pie chart of age distribution of study participants

Table 2: Gender distribution of participants (n = 103)

Gender	Frequency	Percentage (%)
Male	41	39.8%
Female	62	60.2%
Total	103	100%

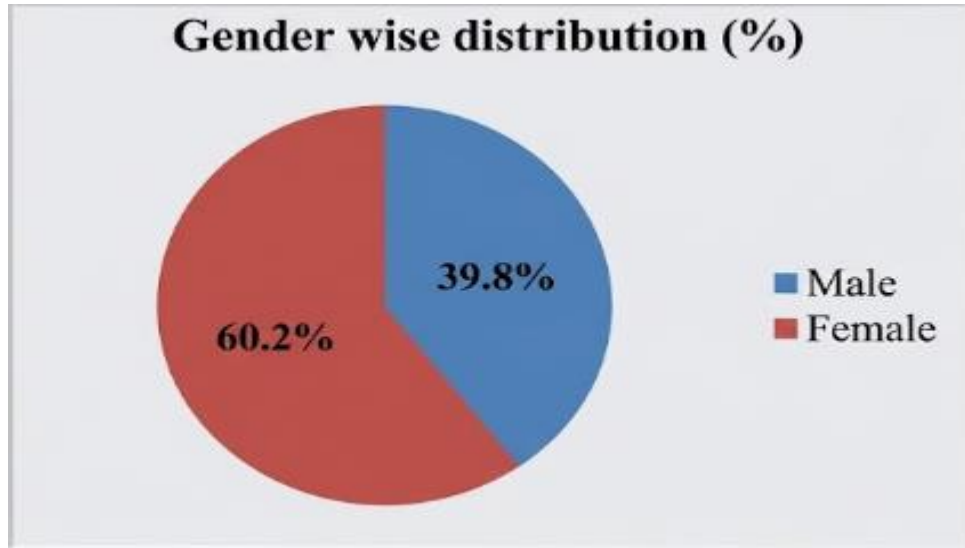


Figure 2: Pie chart of gender distribution of participants

3.2. Anthropometric characteristic

This study provides the anthropometric measurements of the study population, which are recalled height (maximum adult height), current height and body weight. Such data are necessary to identify age-related height loss and Body Mass Index (BMI), which is a crucial factor in this study.

Table 3: Recalled Adult Height of participants (n =103)

Recalled Height (cm)	Frequency	Percentage (%)
< 160 cm	68	66.0%
160–170 cm	30	29.1%
> 170 cm	5	4.9%
Total	103	100%

According to the table, 66.0% (n = 68) of the study population had a recalled height of less than 160 cm. Just 4.9% (n = 5) of the participants had a recalled height greater than 170 cm, whereas 29.1% (n = 30) had a recalled height between 160 and 170 cm. According to these results, the majority of participants were relatively shorter adults.

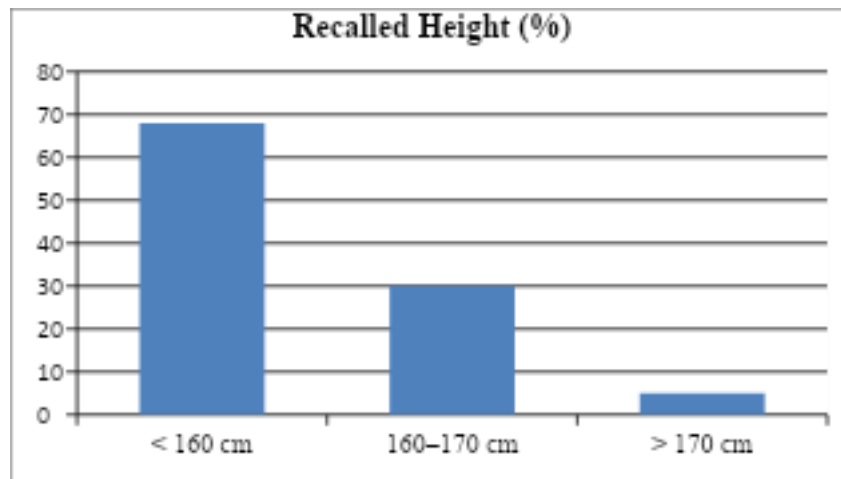


Figure 3: Distribution of Recalled height (%)

Table 4: Current Height of Participants (n= 103)

Current Height (cm)	Frequency	Percentage (%)
< 160cm	79	76.7%
160–169 cm	23	22.3%
> 170 cm	1	1.0%
Total	103	100%

According to the table, 76.7% (n = 79) of the participants had a current height of less than 160 cm. Just 1.0% (n = 1) of the participants were taller than 170 cm, whereas 22.3% (n = 23) were between

160 and 169 cm. The results indicated that participants have lower current heights as compared to recalled ones and that may be suggestive of age-related height loss.

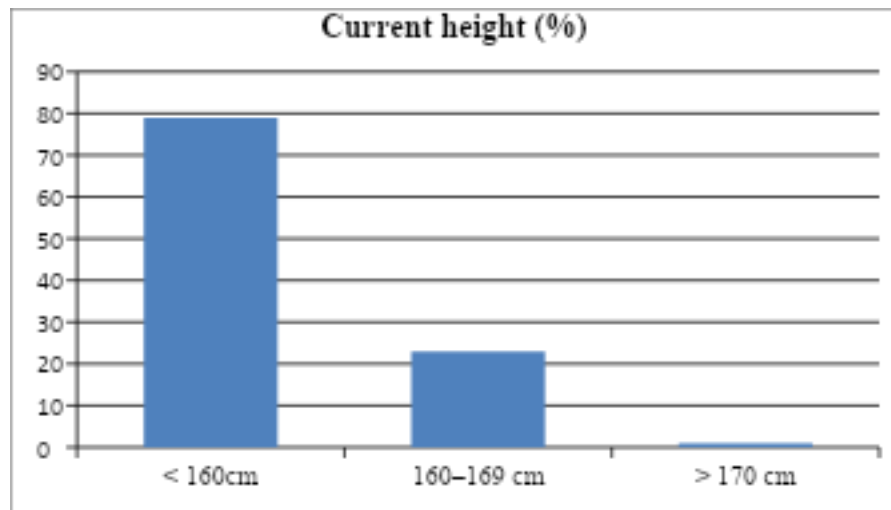


Figure 4: Distribution of Current Height (%)

3.3. Assessment of height loss

Height loss was calculated using the formula.

Height loss = Recalled height – Current height

Table 5: Comparison of height of participants (n= 103)

Height Category	Recalled Height n (%)	Current Height n (%)
< 160 cm	68 (66.0%)	79 (76.7%)
160–169 cm	30 (29.1%)	23 (22.3%)
> 170 cm	5 (4.9%)	1 (1.0%)
Total	103 (100%)	103 (100%)

The above table shows that there was an increase in the percentage of people shorter than 160 cm from 66.0% (based on recalled height) to 76.7% (based on current height). Similarly, the number of people taller than 170 cm decreased from 4.9% to 1.0%, and the percentage of people of 160–

169 cm decreased from 29.1% to 22.3%. The results indicate that there is height loss in the participants, which indicates age-related height loss in the study group.

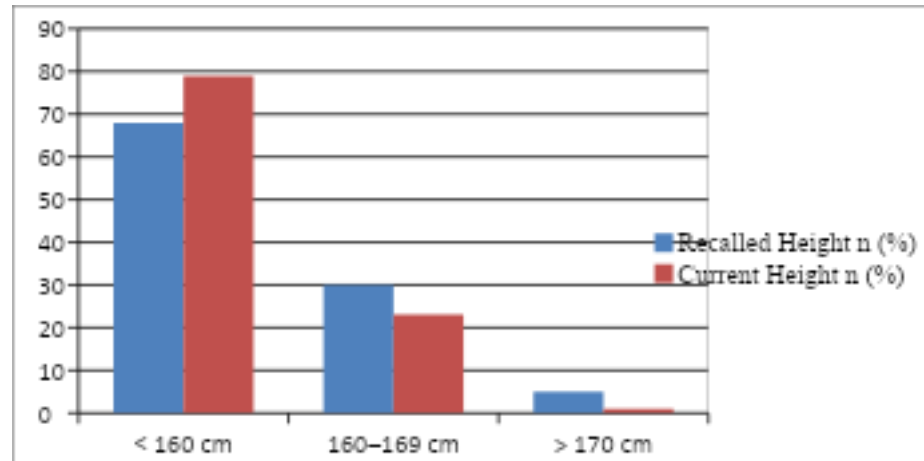


Figure 5:

Comparison of Recalled height and Current height among participant

Table 6: Loss of height among participants

Height loss(cm)	Frequency	Percentage
< 2	15	14.6%
2-4	60	58.3%
5-6	9	8.7%
7-8	14	13.5%
> 8	5	4.9%

Total	103	100
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From the table it can be interpreted that more than half of the participants loss a height of 2-4, only 4.9% lost more than 8 cm, 14.6% lost less than 2 cm, 8.7% lost 5-6 cm and 13.5 % lost 7-8 cm. We can say that majority of the participants did not lose too much height.

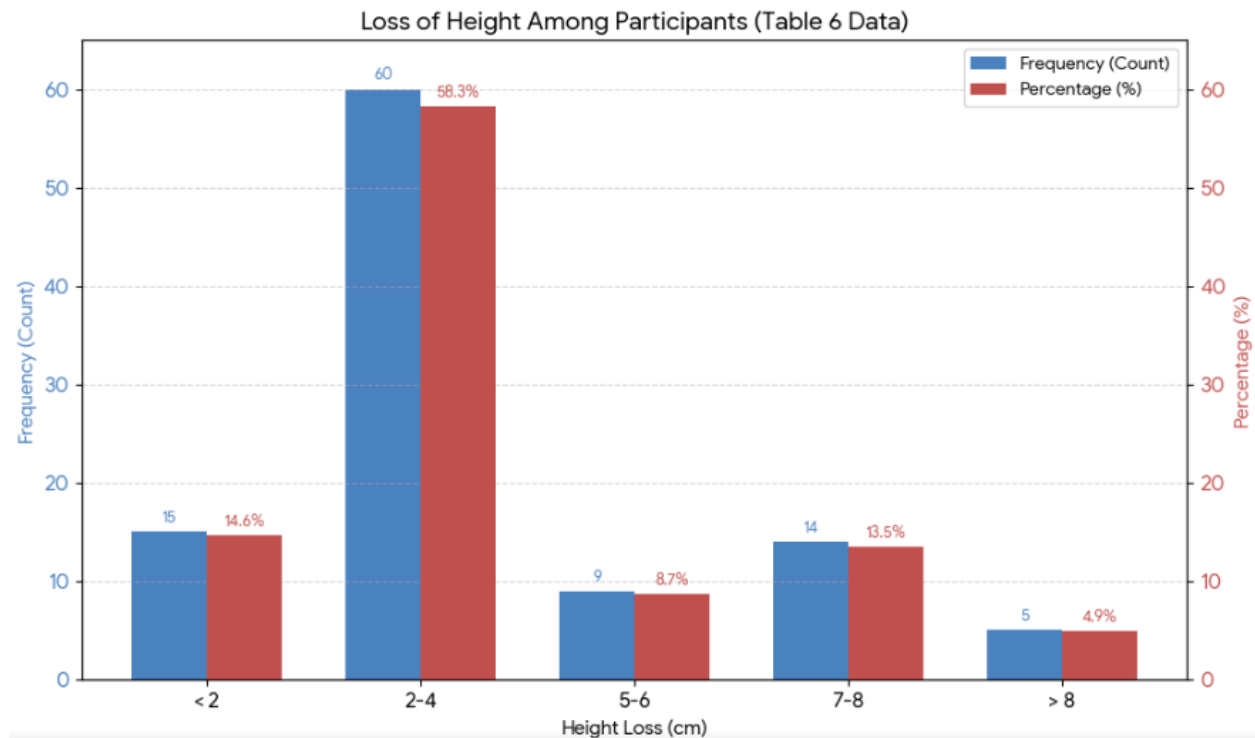


Figure 6 : Loss of height among participants

Table 7: Distribution of height loss among men

Height loss (cm)	Frequency	Percentage
< 2	6	14.63%
2-4	29	70.73%
5-6	5	12.20%
7-8	1	2.44%
> 8	0	0%

Total	41	100%
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The above table shows that majority of males lost height of less than 4 cm and just a few of them lost more than 4 cm.

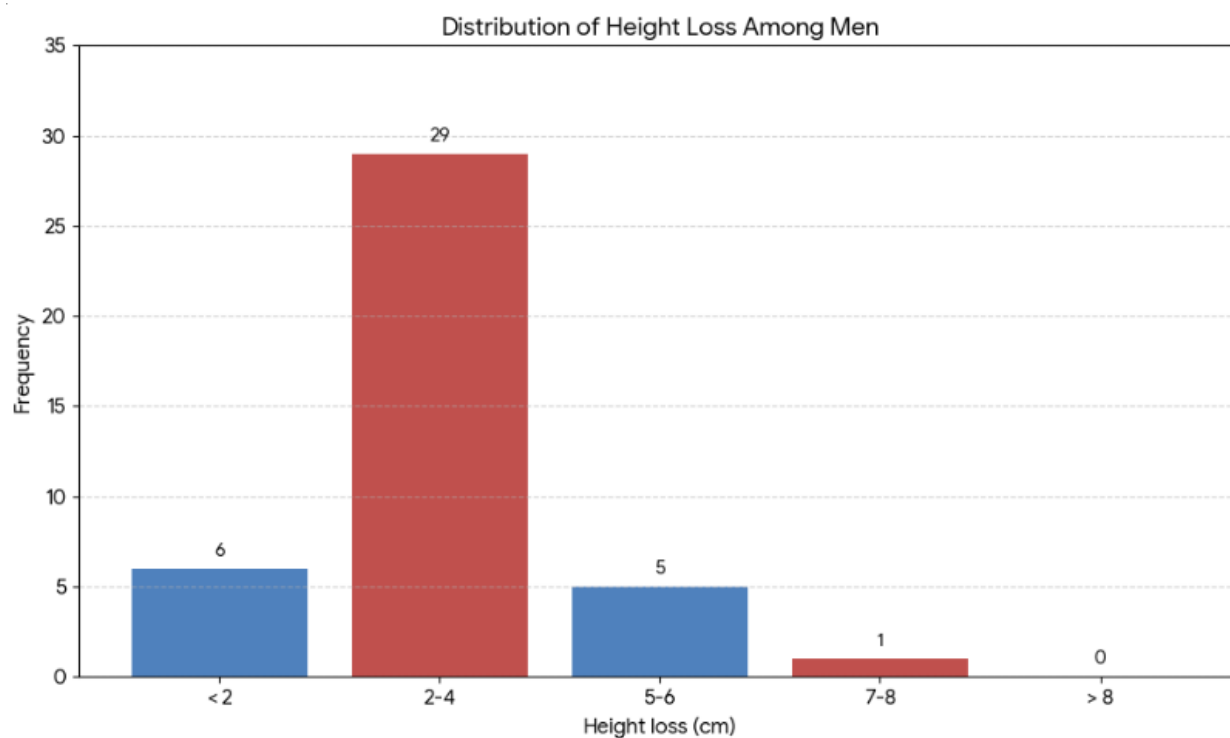


Figure 7 : Distribution of height loss among men

Table 8: Distribution of height loss among women

Height loss (cm)	Frequency	Percentage
< 2	9	14.52%
2-4	31	50%
5-6	4	6.45%
7-8	13	20.97%

> 8	5	8.06%
Total	62	100%

The above table suggests that half of the female participants lost height between 2-4 cm and there are quite a few participants who lost height more than 4 cm. Around 21% lost 7-8 cm and 5 participants lost more than 8 cm.

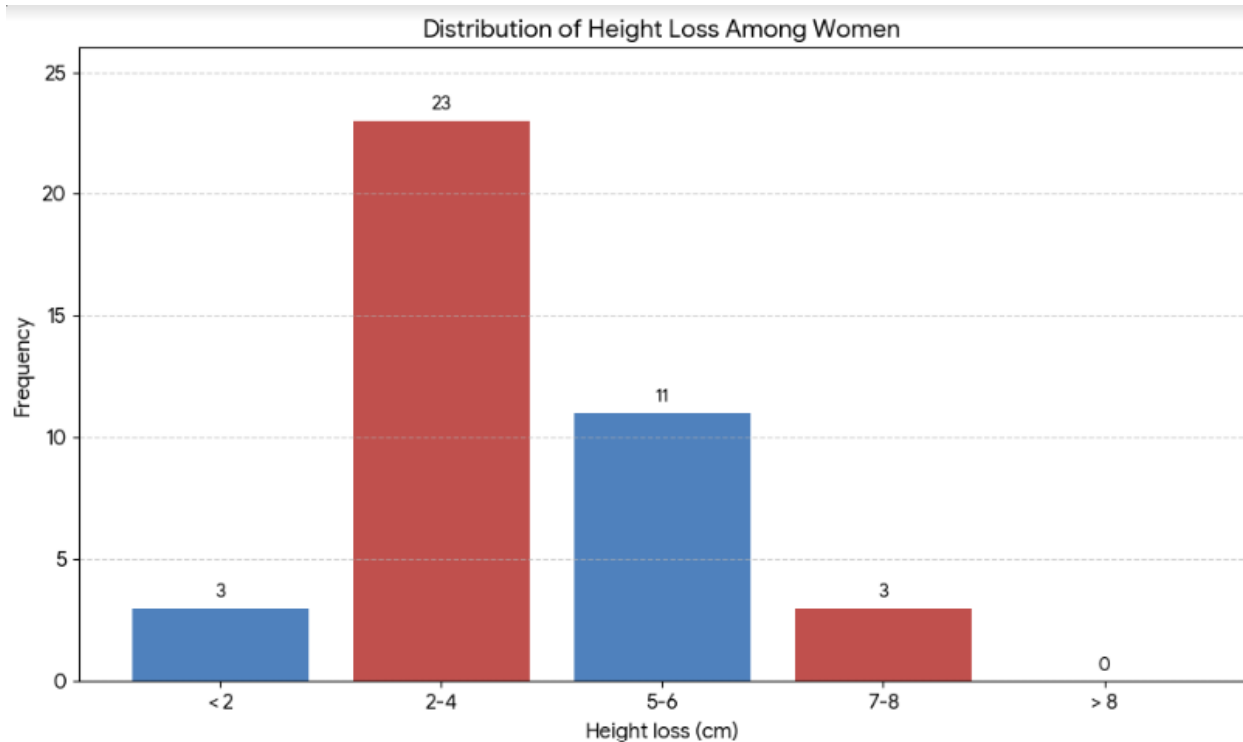


Figure 8 : Distribution of height loss among women

Table 9: Comparison of height loss among Men and Women

Height loss	Percentage Men	Percentage Women
< 2	14.63%	14.52%
2-4	70.73%	50%
4-6	12.20%	6.45%
6-8	2.44%	20.97%
>8	0%	8.06%
Total	100%	100%

The above table suggests that women lose more height on average as compared to men.

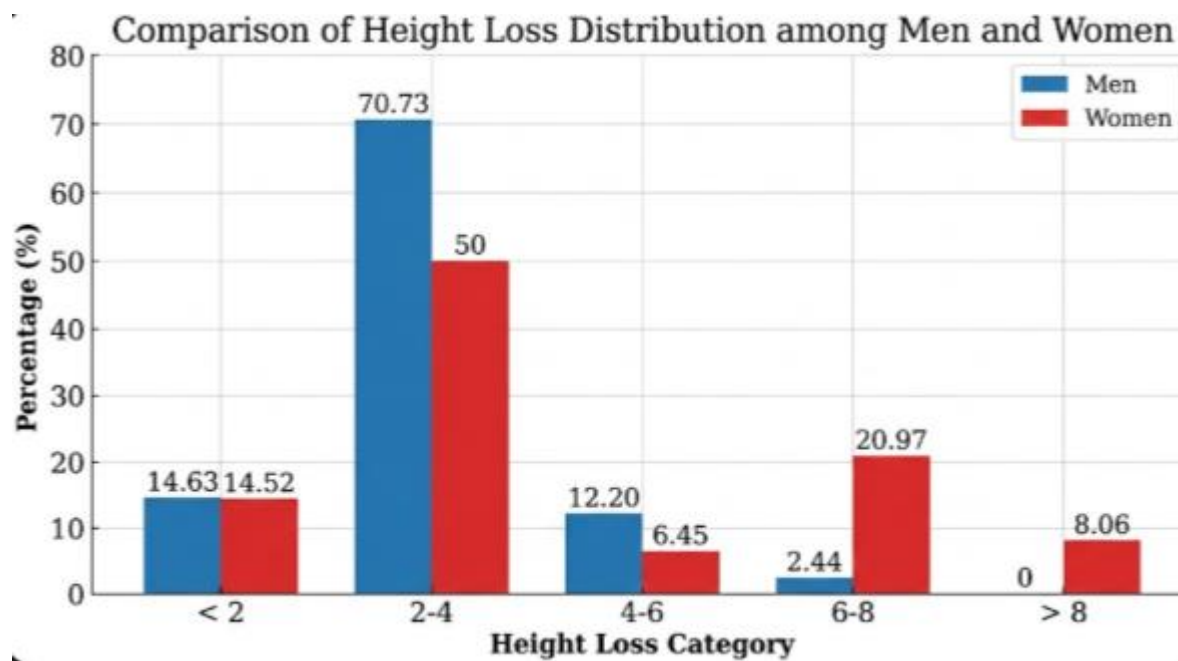


Figure 9 : Comparison of height loss among Men and Women

Table 10: Mean height loss across genders

Mean height loss	3.73 cm
Mean height loss in Men	2.83 cm
Mean height loss in Women	4.34 cm

From the above table we can observe that mean loss of height among all participants is 3.73 cm and women on average lost more height (4.34 cm) as compared to men (2.83 cm) which can imply that it could be because of osteoporosis which is more common among women.

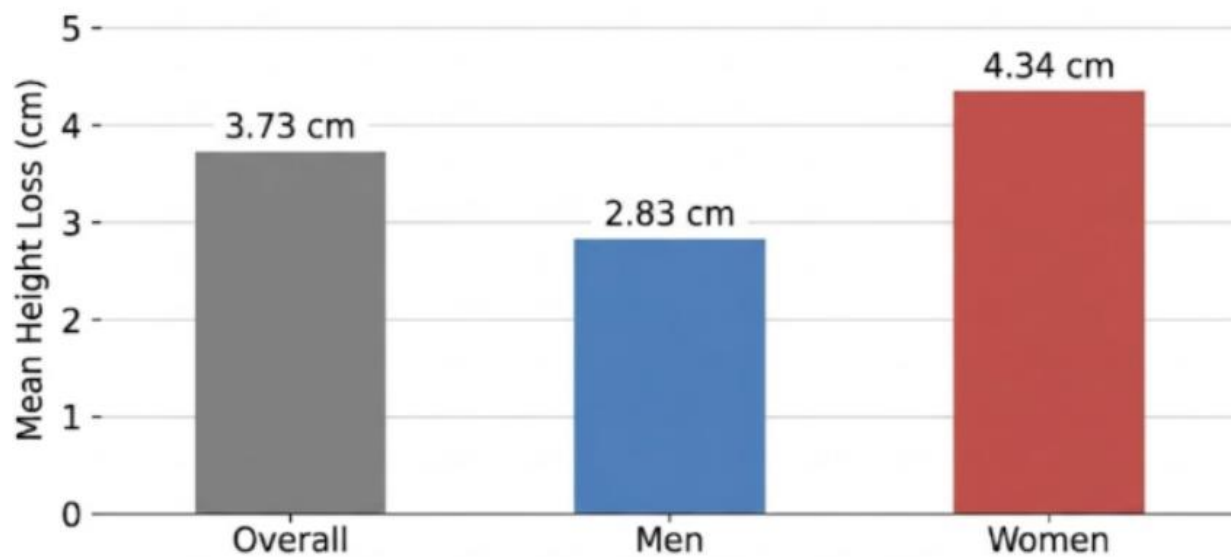


Figure 10 : Mean height loss across genders

Table 11: Body weight Distribution (n = 103)

Weight (kg)	Frequency	Percentage (%)
< 50	15	14.6%
50–59	23	22.3%
60-69	14	13.6%
70-79	24	23.3%
80-89	12	11.7%
>90	15	14.6%
Total	103	100

As shown in the table, the most predominant group (23.3%, n = 24) was those who weighed between 70 and 79 kg while 22.3% (n = 23) were in the range 50 and 59 kg respectively. The participants who weighed less than 50 kg and more than 90 kg respectively formed 14.6% (n = 15) of the study population. Furthermore, 11.7% (n = 12) weighed between 80 and 89 kg, and 13.6% (n = 14) weighed between 60 and 69 kg. From the table we can interpret that participants are well distributed across all categories.

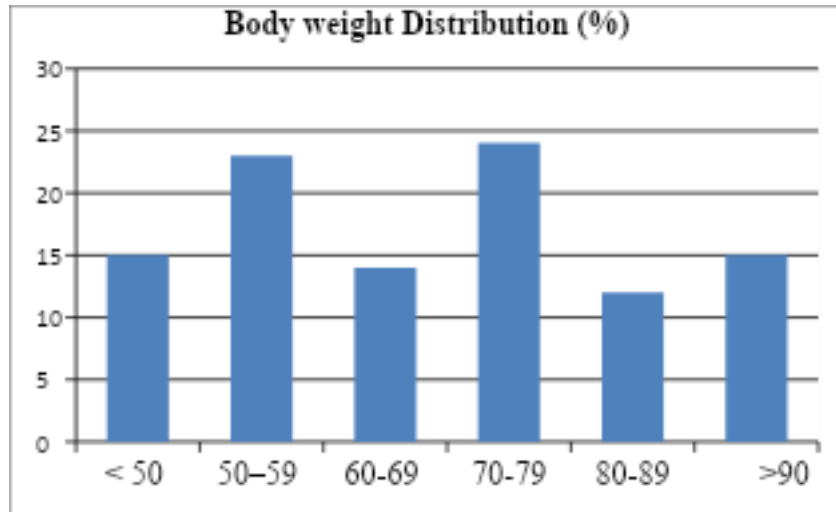


Figure 11 : Distribution of body weight among Participant (%)

3.4. Body mass index (BMI) analysis

In this Body Mass Index (BMI) of the participants BMI was calculated based on the present measured height and the recalled (maximum adult) height to determine the impact of height loss with age on the classification of BMI. The comparison helps to identify possible nutritional misclassification among elderly citizens.

BMI was calculated using the standard formula.

$$\text{BMI} = \frac{\text{Weight (kg)}}{\text{height (m)}^2}$$

Table 12: BMI Classification Using Current Height (n = 103)

BMI Classification	BMI Range (kg/m ²)	Frequency (n)	Percentage (%)
Underweight	< 18.5	0	0.0%
Normal weight	18.5 – 24.9	27	26.2%
Overweight	25.0 – 29.9	26	25.2%
Obese	≥ 30.0	50	48.5%
Total		103	100%

The table shows that nearly half of the people (48.5%, $n = 50$) were considered to be obese, based on BMI calculated using their present height. In the individuals, 25.2% ($n = 26$) were overweight and 26.2% ($n = 27$) had normal body weight. The findings indicate that obesity is a major problem in the older population in this study and only one fourth of the subjects had normal BMI.

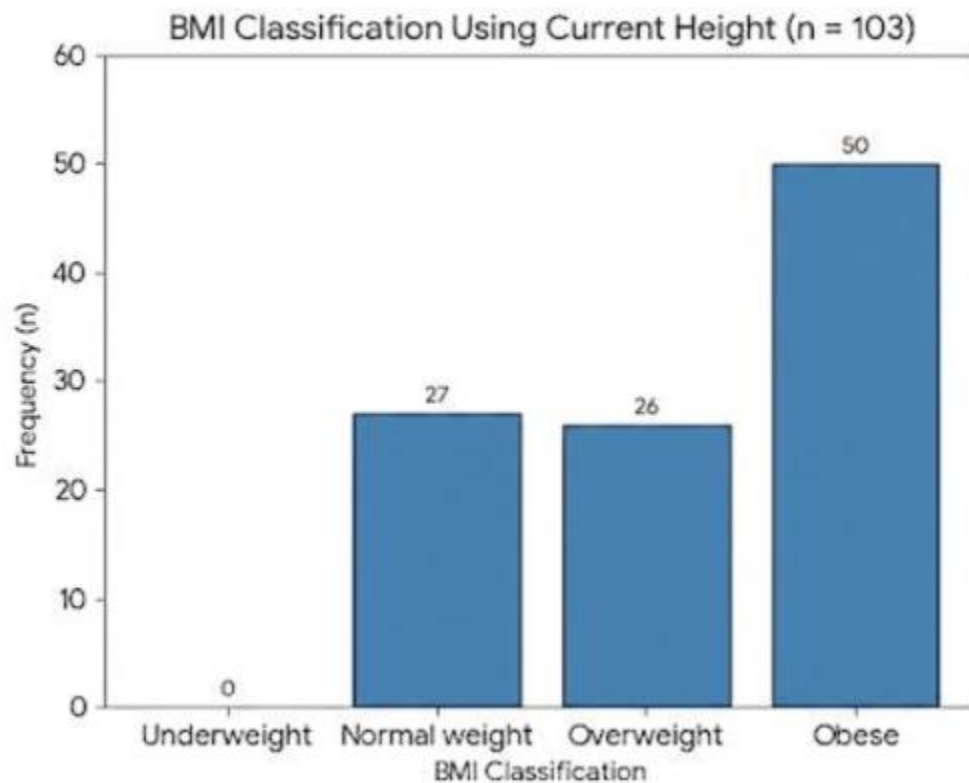


Figure 12 : BMI classification using current height among participants (%)

Table 13: BMI Classification Using Recalled Height (n = 103)

BMI Classification	BMI Range (kg/m²)	Frequency (n)	Percentage (%)
Underweight	< 18.5	5	4.9%
Normal weight	18.5 – 24.9	30	29.1%
Overweight	25.0 – 29.9	33	32%
Obese	≥ 30.0	35	34%
Total		103	100%

Based on BMI determined using recalled height, 34% (n = 35) of the subjects were categorised as obese, 32.0% (n = 33) were overweight, 29.1% (n = 30) were of normal body weight and 4.9% (n = 5) of the individuals were underweight.

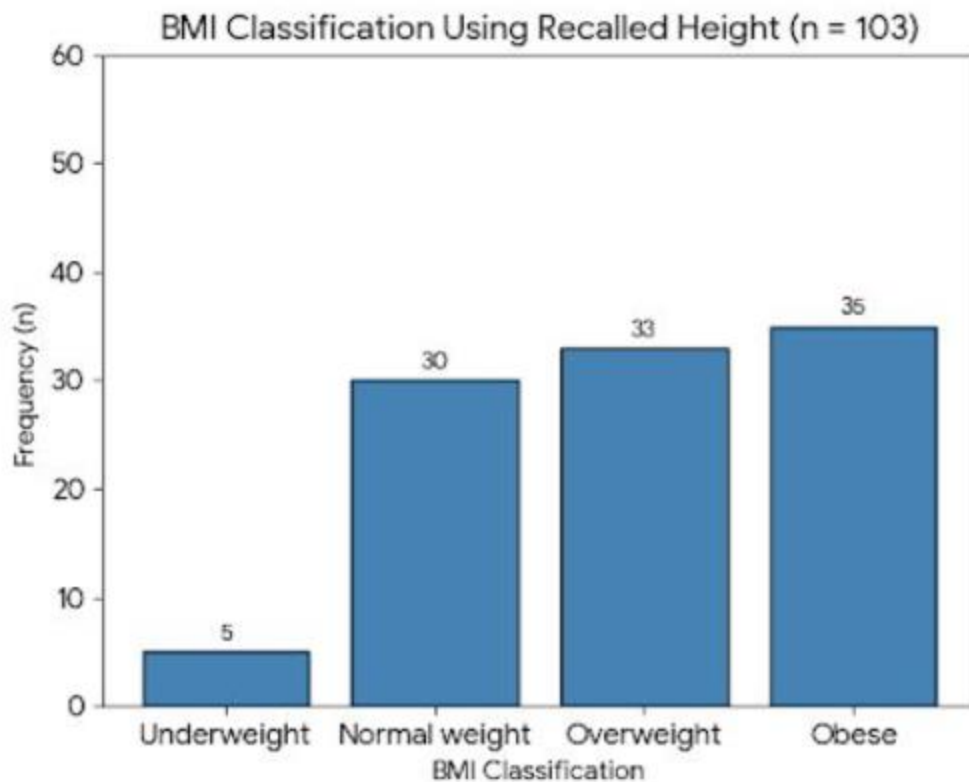


Figure 13 : BMI classification using recalled height among participant (%)

Table 14 - Comparison of BMI current height and recalled height

BMI Range (kg/m ²)	Frequency (current height)	Frequency (Recalled height)
< 18.5	0	5
18.5 – 24.9	27	30
25.0 – 29.9	26	33
≥ 30.0	50	35

50 participants fall into the obese category using current height as compared to 35 with recalled height. 5 subjects fall into the underweight category using recalled height as compared to 0 with current height. The table states that BMI is overestimated using current height as compared to recalled height.

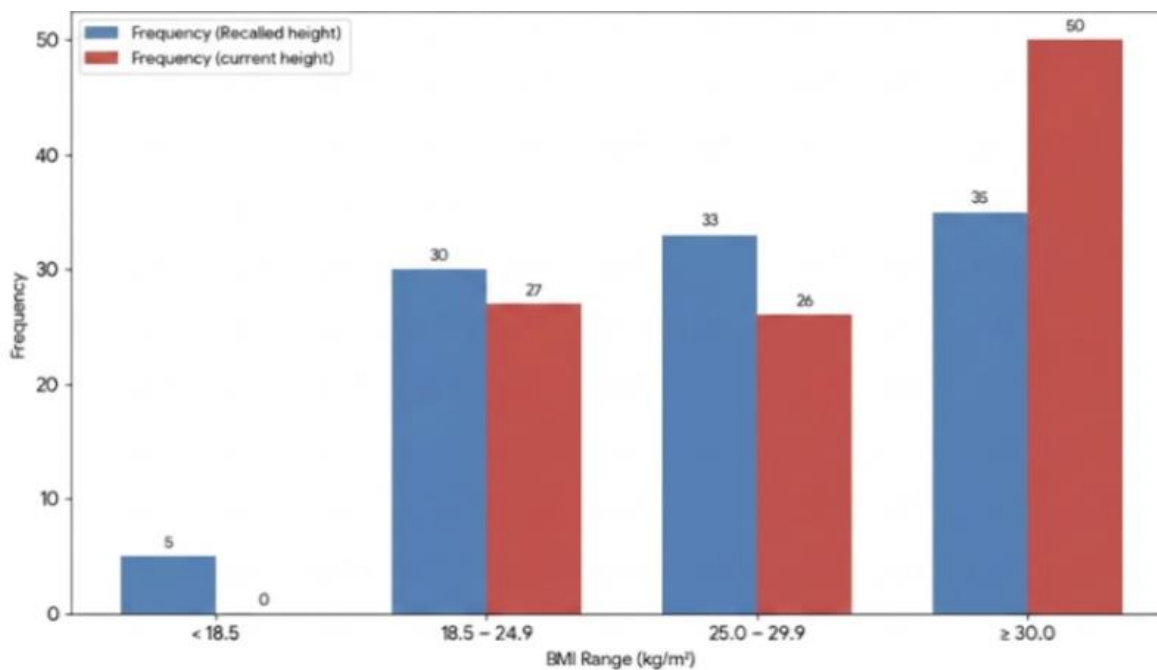


Figure 14 : Comparison of BMI current height and recalled height

Table 15 : Mean BMI Comparison

Height Parameter Used for BMI Calculation	Mean BMI (kg/m ²)
BMI using Recalled Height	27.54
BMI using Current Height	28.89

The mean BMI measured current height (28.89 kg/m²) was higher than the mean BMI measured by recalled height (27.54 kg/m²) as shown in the table. This discrepancy implies that senior people's BMI levels may be artificially raised by age-related height loss, which could result in an overestimation of their overweight and obesity status.

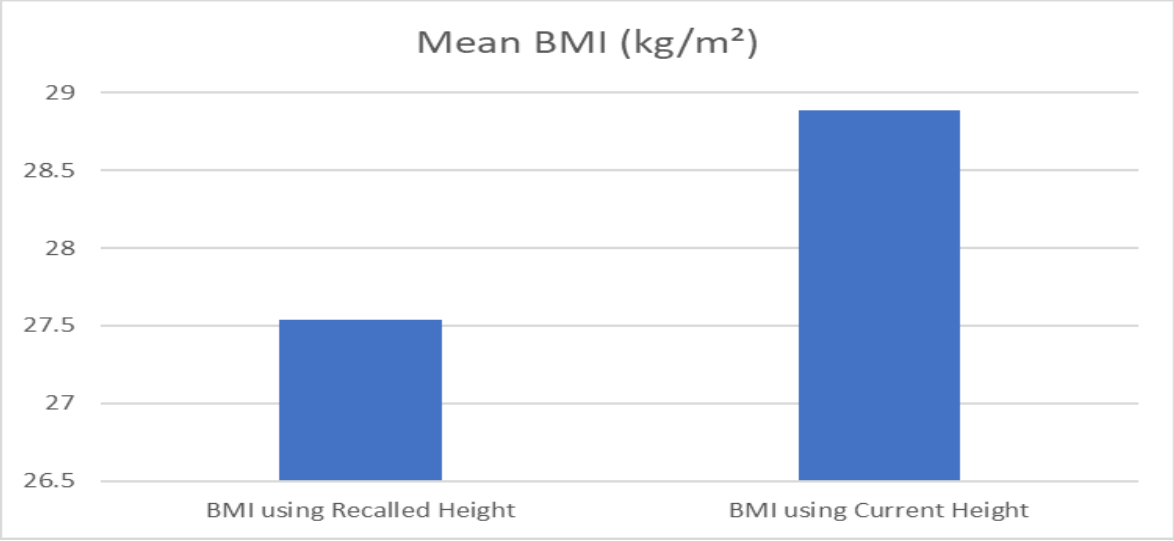


Figure 15 : Mean BMI Comparison

Table 16: Comparison of BMI Classification in Men

Mean BMI of Men using recalled height	29.59
Mean BMI of Men using current height	30.65

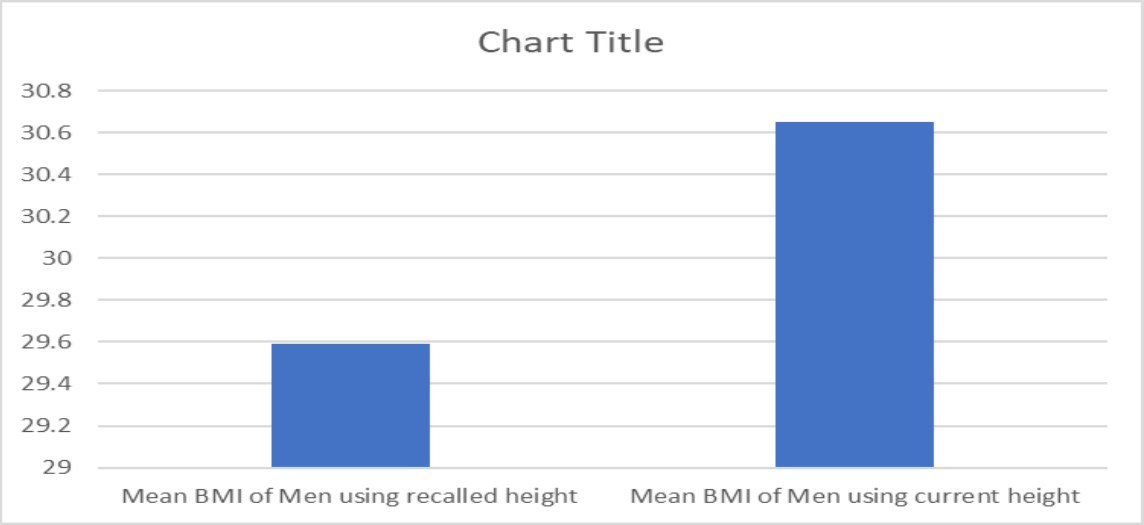


Figure 16 : Comparison of BMI Classification in Men

Table 17: Comparison of BMI Classification in Women

Mean BMI of women using recalled height	26.19
Mean BMI of women using current height	27.73

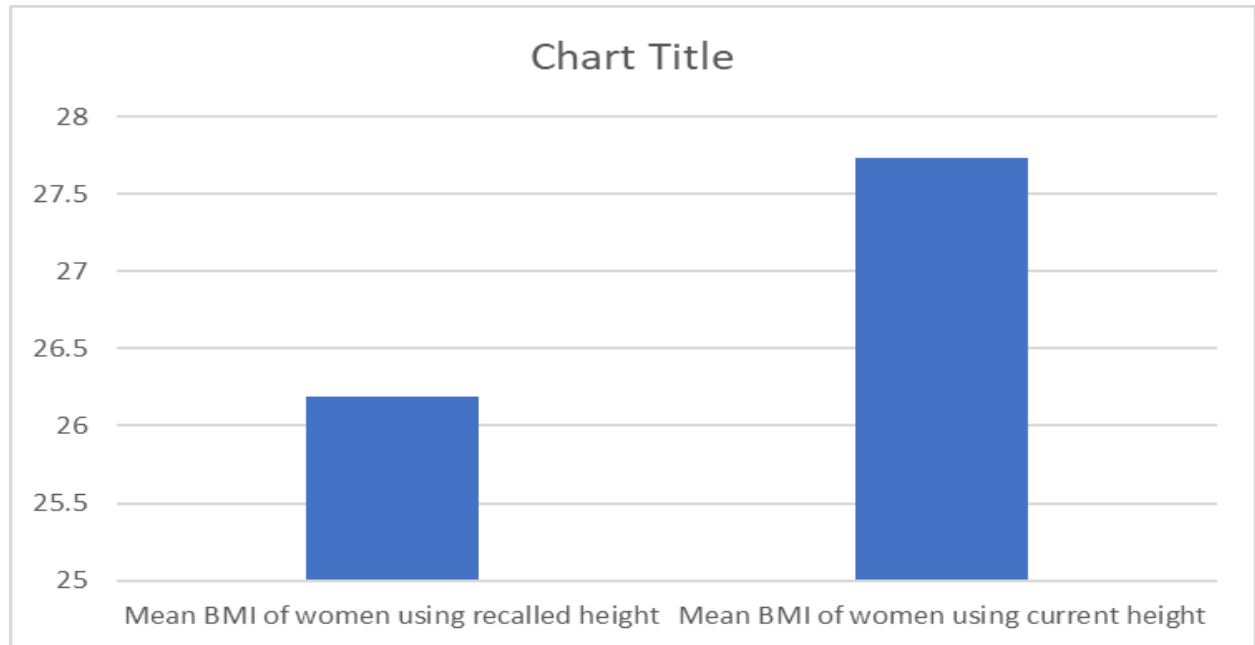


Figure 17 : Comparison of BMI Classification in Women

3.5. Osteoporosis status

This part illustrates the prevalence of osteoporosis among the participants of the study. The methodology described the assessment of the osteoporosis status based on available clinical data and bone mineral density (BMD) reports. The prevalence of osteoporosis in the sample population informs about the cost of bone health loss in the elderly population.

Table 18: Distribution of Osteoporosis

Osteoporosis Status	Frequency (n)	Percentage (%)
Present	26	25.2%
Absent	77	74.8%
Total	103	100%

The table shows that 25.2 % (n = 26) of the study participants had osteoporosis and 74.8% (n = 77) did not have osteoporosis, underscoring the significant burden of declining bone health among the elderly.

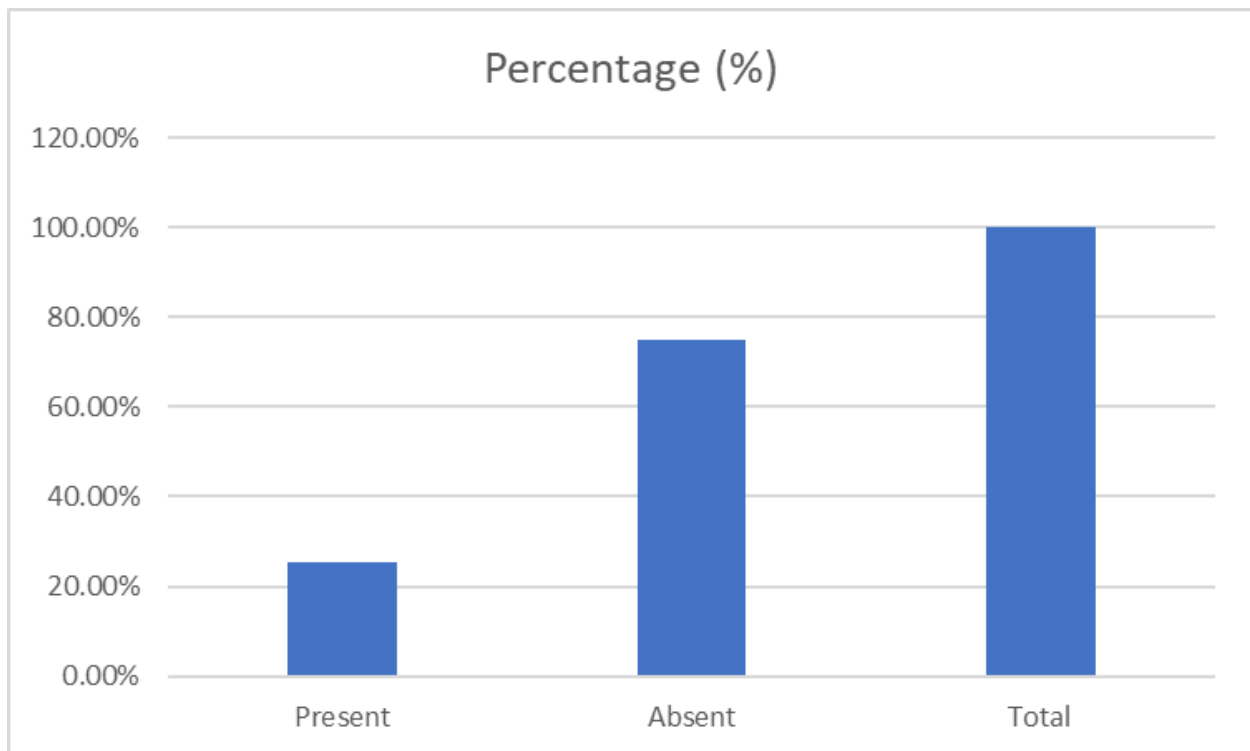


Figure 18 : Distribution of Osteoporosis among participant's (%)

Table 19: Men's Osteoporosis Status

Osteoporosis Status	Frequency	Percentage (%)
Present	0	0
Absent	41	100
Total	41	100%

The table shows that 100% (n = 41) of the individuals in this group were categorised as absent, the table shows that none of them had an osteoporosis diagnosis.

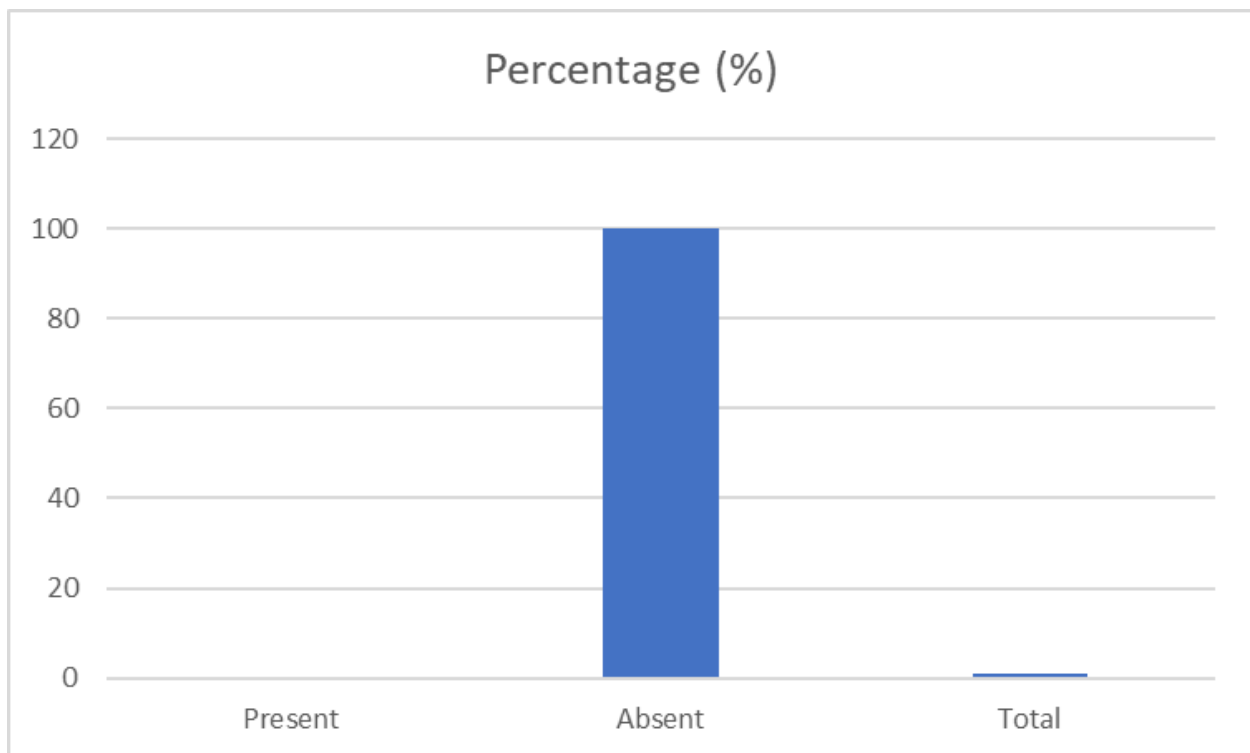


Figure 19: Men's Osteoporosis Status

Table 20: Women's Osteoporosis status

Osteoporosis Status	Frequency	Percentage (%)
Present	26	42%
Absent	36	58%
Total	62	100%

The table shows that 42% (n = 26) of the people were diagnosed with osteoporosis, and 58% (n = 36) were not. The results presented here demonstrate that there was a high prevalence of Osteoporosis among older women.

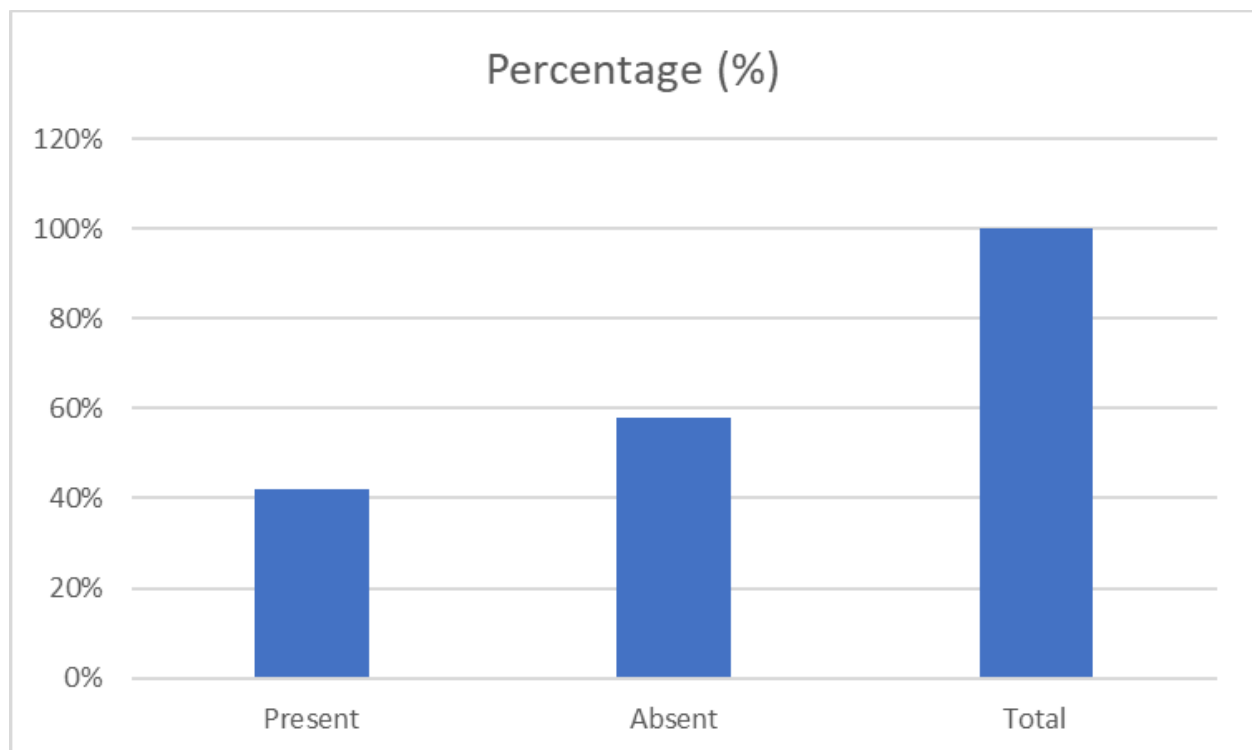


Figure 20 : Distribution of Osteoporosis among Female participants (%)

3.6.Association between Height Loss and Osteoporosis

This section investigates the link between the severity of height loss and the presence of osteoporosis among research participants. Height loss was classified into five groups (<2 cm, 2-4 cm, 4-6 cm, 7-8 cm, >8cm) and its correlation with osteoporosis status.

Table 21: Distribution of Osteoporosis across height loss in Women

Height loss (cm)	Osteoporosis present (%)	Osteoporosis absent (%)	Total
< 2	0 (0%)	9 (25%)	9
2-4	5 (19.2%)	26 (72.2%)	31
5-6	4 (15.4%)	0 (0)	4
7-8	12 (46.2%)	1 (2.8%)	13
>8	5 (19.2%)	0 (0%)	5
Total	26	36	62

From the table we can clearly see that women with Osteoporosis have lost more height than women without Osteoporosis. 46.2% of Women with Osteoporosis have lost height of 7-8 cm and 19.2% have lost more than 8 cm. On the other hand, 97.2% (25%+72.2%) of women without Osteoporosis have lost a height of 4 cm and less. Only one woman without osteoporosis lost a height of >8 cm.

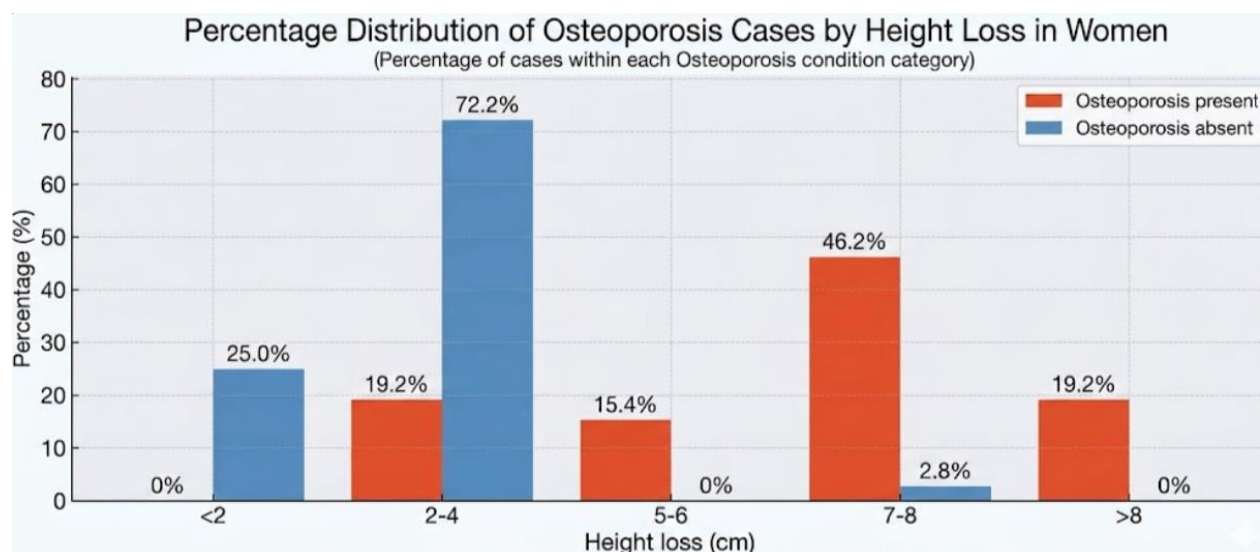


Figure 21 : Distribution of Osteoporosis across height loss in Women

Table 22 : Average loss of height in women with and without Osteoporosis

Mean loss in Osteoporosis	7 cm
Mean loss without Osteoporosis	2.42 cm

From the above table it is clear that women with osteoporosis lose much more height as compared to women without it.

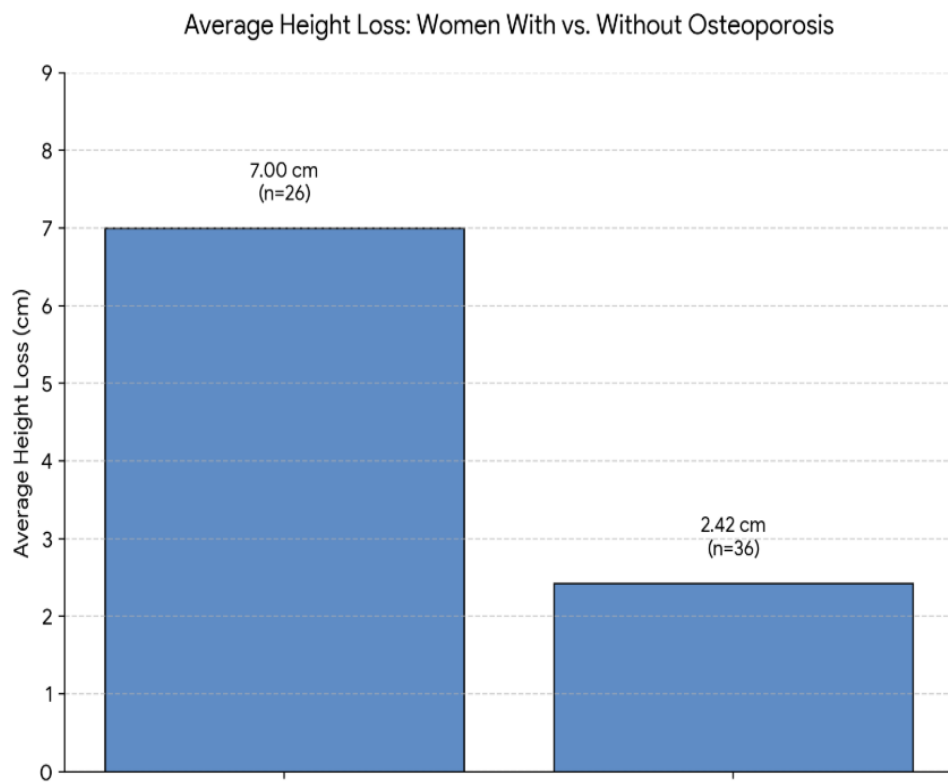


Figure 22 : Average loss of height in women with and without Osteoporosis

CHAPTER 5

DISCUSSION

The study confirms that the age group 60–69 years, which made up 57.3% of the study population, comprised the bulk of the elderly participants. Higher age categories had fewer participants, especially those 80 years of age and beyond (13.6%). This suggests that involvement declined with age and that younger elderly people made up the majority of the research population. Women had a substantially higher prevalence of osteoporosis (42%) than men (0%). The frequency increased with age, reaching significantly greater levels in later age groups, particularly among women.

The study found that 76.7% of the seniors were less than 160 cm in height, while only 1.0% were over 170 cm.

The study shows that obesity was relatively common among the senior population with almost half (48.5%) of the sample population being obese when BMI was calculated using the current height. The findings also indicate that many people were affected by both overweight and obesity, indicating that the effect of an excess body weight is greater in the elderly.

There is a strong association between osteoporosis and height decline in women. Women with Osteoporosis lost significantly more height (7 cm) as compared to women without it. Based on

this, height loss could be considered as an indicator for identifying risk of osteoporosis. Compston et al., (2013) [60] looked at 52,939 postmenopausal women and discovered that 6.9% of them had fractures in the span of three years. The incidence of ankle fracture was shown to rise with larger body weight (HR = 1.05 per 5 kg, $p < 0.001$), whereas the likelihood of upper arm/shoulder and clavicle fractures was found to decrease with greater height. In general, the correlation between body mass index (BMI), height, weight, and risk of fracture differs according to the location of the fracture [62].

The results in the current study, where a higher mean BMI was calculated using current height (28.89) compared to recalled height (27.54), show that height reduction with age leads to a rise in the value of BMI. This indicates that the decrease in height in elderly people can account for the increase in BMI and lead to a misclassification and misestimation of nutritional status. Holt et al., (2023) [61] define that in the Framingham Heart Study, height declines with age, beginning after age 40 and averaging 4.8 cm for women and 3.6 cm for men by age 80. Due to this decrease in height, around 12.5% of women and 10% of men were “incorrectly” classed as overweight, and approximately 10% and 8% were “incorrectly” classified as obese. By the age of 70, this percentage had increased even more. A more accurate risk assessment was provided by BMI computed using youthful (initial) height, which demonstrated stronger correlations with diseases, including diabetes and hypertension. The results show that when older people use corrected (young) height instead of current height, BMI accuracy increases [63].

According to the study, 26 female participants (42%) had osteoporosis; no male participants had the condition. About. According to these results, older women in the research population were far more likely than men to acquire osteoporosis. Somily et al., (2025) [62] reported that the majority of the 92 osteoporosis patients in the research, who ranged in age from 37 to 100, were women over 60. Age, feminine gender, steroid use, and rheumatoid arthritis were important risk variables. 88% had no serious problems, while about 50% suffered bone problems. Additionally, variations in calcium and vitamin D levels were noted [64].

The incorrect classification of BMI in elderly is more than just a calculation error, it provides a strong argument against the “Obesity paradox”. While many studies suggest that moderately high BMI may be protective, the findings in this study suggest that the benefits may not be real. If an older person’s BMI goes up because of loss of height due to factors like vertebral compression and

osteoporosis and not due to gain for muscle or fat, then the high BMI is a marker of fragility and not health. This suggests that the protective effect of obesity in old people as suggested by many studies in the past is a mismeasurement because the mathematical denominator has decreased, falsely shifting an individual into a higher BMI category. By looking at BMI calculated using current height clinicians may be ignoring patients with sarcopenia and osteoporosis. Therefore, this study argues on the use of current height in the elderly to calculate BMI which is done to monitor musculoskeletal degeneration.

CHAPTER 6

CONCLUSION

The present study revealed that the age-related decline in height significantly affected the osteoporosis and Body Mass Index (BMI) classification of the elderly. Results indicated that using current height instead of BMI would lead to overestimation of overweight and obesity due to the decrease in height with age. The higher the mean BMI calculated with current height compared to

the BMI calculated from recalled height suggests high risk for dietary misclassification in older age groups.

In addition, there was a strong positive correlation between osteoporosis and height loss in women meaning that, a greater height loss resulted in a higher risk of osteoporosis or vice versa. Prevalence of osteoporosis was higher among female participants, highlighting the effects of ageing and postmenstrual osteoporosis on bone health.

Study revealed that height loss has a stronger association with osteoporosis implying that it is a great measure of impairment in bone health among the elderly population.

Moreover, the results show that the body mass index (BMI) computed with the aid of current height is higher than BMI calculated using recalled height (28.89 as compared to 27.54). This difference was more in women (1.54) as compared to men (1.06). Results also indicate that women with Osteoporosis lost much more height than women without Osteoporosis (7 cm as compared to 2.42 cm). This shows that more elaborate evaluation methods are required, and how BMI may be inadequate when it comes to looking after the elderly. Height changes with age should be taken into account in epidemiological and clinical studies. The precision of the BMI classification and the detection of osteoporosis can be improved by the recall of height or other methods of determining height, with regular monitoring of height loss. These results highlight the need for preventive measures such as correct nutrition, exercise and early diagnosis in the reduction of the impact of osteoporosis and the improvement of health and well-being in the elderly. The limitations of using the BMI as an indicator of health in the elderly, particularly without taking into account the changes in height as a result of ageing. It suggests the need to include self-reported height or other anthropometric measures to improve their accuracy. These findings also highlight the importance of regular height measurement, early screening for osteoporosis, and prevention measures, such as appropriate nutrition, exercise and bone. These can reduce the risk of fracture in older people, enhance the quality of life and guide treatment.

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APPENDICES

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Appendix 1

CONSENT FORM

I, _____, voluntarily agree to take part in this study.

I understand that:

1. My height will be measured and I will answer a few questions.
2. The study involves minimal risk and no invasive procedures.
3. My participation is voluntary and I can withdraw at any time.

4. My information will be kept confidential.
5. No payment is provided.

Participant Name: _____

Signature/Thumbprint: _____

Date: _____

Investigator Name: _____

Signature: _____

Witness (if required): _____

Appendix 2

QUESTIONNAIRE FOR PARTICIPANTS

Participant Code: _____

A. Demographic Information

1. Age: _____
2. Gender: Male / Female
3. Weight: _____ kg
4. Height (measured): _____ cm
5. Recalled young-adult height: _____ cm

B. Medical History

6. Have you been diagnosed with osteoporosis? Yes/No
7. Are you on medication for osteoporosis?
8. Do you have any investigation reports of osteoporosis?
9. Do you have any weight loss / weight gain history?

C. Lifestyle Information

10. Daily physical activity level: Low / Moderate / High
11. Dietary calcium intake: Low / Moderate / High
12. Sunlight exposure: Low / Adequate

D. Additional Comments

Appendix 3

ETHICAL APPROVAL

MARUTI ORTHOPAEDIC HOSPITAL
Talod, Gujarat, India Institutional Ethics Committee (IEC)
Ref No. MROEC/2023/04-076
Date: 15 November 2023
CERTIFICATE OF ETHICAL APPROVAL

To:
Dr. Arjun Singh
Master's Student, Clinical Nutrition
University of Turku, Finland

Project Title: The Impact of Aging on Height and its Influence on BMD: A Cross-sectional Study
Principal Supervisor: Dr. Shing Mali, Director, Maruti Orthopaedic Hospital
Academic Supervisor: Dr. Atsuko, Professor, University of Turku

The Institutional Ethics Committee (IEC) of Maruti Orthopaedic Hospital, Talod, Gujarat, has reviewed the research proposal and associated documents submitted for the aforementioned study.

1. Documents Reviewed: The following documents were reviewed and found to be in accordance with the ethical standards required for clinical research involving human participants:

- Form of Ethical Application
- Participant Information Sheet and Informed Consent Form
- Patient Assessment Questionnaire
- Curriculum Vitae (CV) of the Investigator and Supervisors

2. Committee Decision: After a thorough evaluation, the committee finds that the study design adheres to the ethical principles outlined in the Declaration of Helsinki and the National Ethical Guidelines for Biomedical and Health Research (NME).

The study is deemed to have minimal risk to participants. The committee is satisfied with the measures taken to ensure participant anonymity, data confidentiality, and the voluntary nature of participation.

The Institutional Ethics Committee hereby grants full ethical approval for the conduct of this study at Maruti Orthopaedic Hospital.

Approved by:

Dr. Shing Mali
Director, Maruti Orthopaedic Hospital
Head of Institutional Ethics Committee
Talod, Gujarat, India