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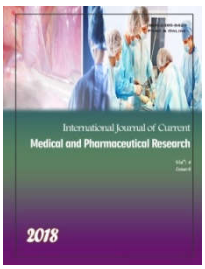

DEVELOPMENT AND VALIDATION OF A COUNTRY-SPECIFIC PREDICTION TOOL TO SCREEN POSTMENOPAUSAL WOMEN FOR OSTEOPOROSIS OR HIGH FRACTURE RISK

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ABSTRACT

Introduction: The current global prevalence of osteoporosis is over 200 millionpeople, but it can fluctuate in different populations not only country to country but also within different areas of the same country. Osteoporosis affects both developed and developing countries and has become a common chronic medical condition in Asian populations. The ageing of populations and the modern changes in lifestyle are further influencing the osteoporosis rate increase.
Aim: The aim of this review is to understand the prevalence of modifiable and non-modifiable risk factors for osteoporosis and increased fracture risk.
Finding: Current sedentary, machinery driven life styles and body image issues are affecting population bone health at the time of life where the bone mass accumulates preventing it from reaching its peak by adulthood and maintaining its quality thereafter. Earlier identification of those at risk may prevent complications later. More research is required to find affordable screening tools.

INTRODUCTION

Osteoporosis is defined as "porous bones".[1] It is a metabolic disease of the bones, clinically characterised by areduction in bone mineral density (BMD).[2] Healthcare professionals describe osteoporosis as a silent disease, as it progresses without symptoms until the patient experiences a clinical fracture.[3][4] Fractures can occur in any bone, however the most serious are those in the vertebral and hip bones.[2][5] The incidence of osteoporotic fracture is reported to be one in three for women and one in twelve men.[3][6] Bones grow in size and density during childhood and adolescence and gradually achieves 90% of peak bone mass by the age of 18 years in females and 20 years in males. The peak bone mass is reached around the age of 30 years in both males and females.[7] Usually, female bone density decreases significantly after the menopause compared to a male from the same age (50 years and over). Osteoporosis occurs mainly due to two reasons; a defect in achieving peak bone mass and/or accelerated bone loss.

Aim

The aim of this review is to inform the prevalence of modifiable and non-modifiable risk factors of osteoporosis and increased fracture risk globally and in Sri Lankato support further study aiming to develop and validate a country-specific prediction tool to screen women >40 years for osteoporosis and increased fracture risk in Sri Lanka.

Pathogenesis of osteoporosis

There are threemain bone cell types; osteoblasts, osteoclasts and osteocytes which are predominantly responsible for maintaining bone structure. The balance between bone formation and bone resorption is essential to maintain healthy bones. When resorption rate becomes faster than formation, osteoporosisoccurs. It is characterisedby perforations of the trabecular plates in the bones due to disruption of the micro-architecture of the osteoids. Further, the amount and variety of non-collagenous proteins in bone is altered. These changes reduce bone strength and enhance fragility, increasing the risk of fractures.[8][6]Osteoporosis can be either primary (idiopathic) or secondary (a consequence of other comorbidity) in nature.[6]

Epidemiology of osteoporosis

The current global prevalence of osteoporosis is over 200 million(Alquaiz *et al*., 2014; Cooper, Campion and Lj, 1992; Health Foundation., 2015).[9][10][11] This may fluctuate in different populations not only country to country but also within different areas of the same country.[12][13][14]It affects both developed and developing countries and has become a common condition in Asian populations. Wang *et al*. reviewed osteoporosis studies of Chinese people aged >50 yearsand

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found the prevalence to be 22.5% among men, and 40.1% among women.[15] It is estimated that up to a quarter of women of all ages in Japan have osteoporosis, with prevalence rising sharply after the age of 50 years.[4] The ageing of the population and changes in lifestyle further influencing the osteoporosis rate increase.[15][16][17]

Age-related changes in BMD can vary with the gender.[18] Vulnerability to osteoporosis increases around age 50 years and over.[19] Globally, females are known to be more susceptible to osteoporosis than males.[20] Approximately 7.7% of men aged between 50 and 69 years are affected by osteoporosis, and as high as 12.5% in those aged 80 years or over.[21] The prevalence in Denmark, in those age >50 years was 40.8% in women and 17.7% in men.[22] Similarly, the Korean National Health and Nutrition Examination Survey 2008-2010 showed that 31.8% of men and 63.2% of women >70 years are affected by osteoporosis (Lee *et al*., 2014). Further, Korean women 50-59 years of age showed a steeper decline in BMD than in men, possibly related to the rapid decrease of oestrogen production at the menopause.[23]The BMD in the older Korean women (70 years and over), was comparatively lower than young adult females(aged 20-29 years) and men. This was expressed as 25.4% osteoporosis in the hip vs. 17.6% in men, 32.3% in the femoral neck vs. 27.2% in men, and 25.2% in the total lumbar spine vs. 9% in men.[24]

According to the International Osteoporosis Foundation (IOF) statistics, approximately 30% of postmenopausal women have osteoporosis in the United States and Europe.[11] The situation is similar in South and Southeast Asian countries. For example the Korean women>50 years have 32.9% overall risk of osteoporosis, mainly affecting the total hip, femoral neck, and lumbar spine.[24] Almost 50 million people in India are either osteoporotic or have reduced bone mass.[25] This prevalence varies from 8% to 62% depending on age and other factors, such as diet and body weight.[26] The Pakistani female population showed a high prevalence, indicating 5.6% to 17.8% in pre-menopausal females and 20% to 49.3% of postmenopausal females at high risk. Further, the risk increased from 55% in women in 45–54 years age group to 97% in women in the 75–84 years age group.[27]A study conducted by Begum *et. al.* (2015) in Bangladeshi women showed a high prevalence in the lumberspine and hip in rural women (39.2% and 76.4%) compared to Urban living (22.7% and 40.9%) women.[28]

A community osteoporosis survey conducted in 2004-2005 in Sri Lanka evaluated the prevalence of osteoporosis in both men and women of seven administrative districts and they have found nearly 45% of postmenopausal women and 5.8% of men >50 years are affected.[29][30][31] Conversely, in 2010, the prevalence in Sri Lankans below 50 years of age stood at 9% in women and 3% in men.[19]

Osteoporosis associated fracture risk

Osteoporosis raises the fracture risk in the elderly population in even a low trauma fall.[32][33] The International Osteoporosis Foundation says the risk of an osteoporotic fracture, is 1 in 3 women and 1 in 5 men around the world.[11] Further, patients with a history of fracture have an increased risk of experiencing a second fracture irrespective of BMD.[11][33] The most common osteoporosis-associated fracture sites are the hip, the spine and the wrists. There is a 40% life-time fracture risk in all menopausal women.[1][5] The probability of experiencing a fracture increases exponentially, with increasing age and low BMD in both women and men[12][21][1], and they may lead to disability or death. According toTuck and Francis (2002) there are 50,000 for earm fractures, 40,000 symptomatic vertebral fractures and 60,000 hip fractures in the UK each year.[6] The possibility of a hip fracture is two times greater in women than men in the USA and Europe.[12] The prevalence of osteoporotic fractures was 18.2% in Spanish men between the ages of 50 and 59 years and it increased to 29.4% with advancing age >70 years.[21] As stated by Melton, white men aged 50 or more in USA have 6% chance of hip fracture, whilst it is nearly three times higher (17%) in white women.[13] Frequent incidence of osteoporosis fractures of the hip, spine, and forearm were also reported in Denmark.[22]

The prevalence of osteoporosis fracture in hip, femoral neck and lumbar spine were respectively 5.4%, 7.7% and 5.7% in Korean men. Postmenopausal women in Korea had greatly increased fracture probability values, noted as 19.2% in femoral neck, 24.4% lumbar spine and 16.8% in total hip.[24] Irrespective of the type of fracture, adults who sustain a fracture are 50–100% more likely to have another one of a different type.[12]The Delhi Vertebral Osteoporosis Study showed a 17.1% prevalence of vertebral fractures in females>50years.[26]

Epidemiological data on probability of osteoporotic fractureis very limited in Sri Lanka. The available data indicates a the 10-year major osteoporotic fracture probability in people >65 years is 11% in men and 14% in women.[33]The social burden of osteoporotic fractures also dramatically increases with aging of the world population. More of these injuries, increases the health care costs[12] with the direct care expenditures for osteoporotic fractures ranging from $12 to $18 billion per year in 2002 in the US, while indirect costs (e.g., loss of productivity) is likely to be billions of dollars.[30] Vertebral and hip fractures cause long-term immobilisation which enhance the risk of developing other medical complications such as pneumonia and thromboembolism. This increases the mortality rate by 20%.[5]

Risk factors of osteoporosis

The loss of bone mass and quality can occur due to three possible mechanisms; (a) failure to reach an optimal peak bone mass as a young adult, (b) excessive resorption of bone after peak mass has been achieved, (c) an impaired bone formation response during remodeling.[8]

Primary risk factors of osteoporosis

Age and Gender

Age is a major determinant of osteoporosis.[18][15] The bone mass accumulates throughout childhood and adolescence and reaches its peak by adult age. The bone turnover stays constant through midlife, and begins to decline in later years.[34][35]Bone loss usually starts in middle age, around the age of 50 years, in both genders and continues until the end of life. Due to the menopause the bone density declines drastically in females compared to men.[20][19][30][21] The reduction in oestrogen hormone level increases the bone resorption in both men and women.[36] Gonadal hormone changes take place slowly in men compared to women and significant changes are observed usually after 70 years of age.[13][19]As shown by Lekamwasam *et al*., (2009) after 50 years of age women lose 11.9% of their BMD for each ten year period, while men lose only

3.4%.Moreover, the starting point for bone mass, in most men, is comparatively higher than that in most women and therefore the net bone loss consequences are less significant for men than for women.[37][19][21]

Genetic factors

Osteoporosis and the fracture risk is related to the genetic composition of a person.[38] Therefore, the prevalence of osteoporosis and fragility fractures varies according to ethnicity and race.[19][31] In addition, family history of fracture is significantly associated with osteoporosis risk.[34][39]
Secondary risk factors

Effect of calcium and vitamin D on bones

Bone health is connected with calcium and vitamin D levels of the body.[34]A calcified bone contains nearly 70% of hydroxyapatite which is a mineral of Ca^{2+} and PO_4^{3-} and is the major inorganic component of bone matrix.[8] Further, it is important to build the micro-architecture of the bone, which is responsible for the bone rigidity and the hardness. Therefore, calcium deficiency in the body directly affects the strength of the bones.[40] Usually, individuals meet their calcium requirement via the dietary intake of food rich in calcium such as, milk and other dairy products (yogurt, butter, cheese) fish, meat, vegetables and fruits. Fermented milk, cultured with *Lactobacillus bulgaricus* and *Streptococcus thermophiles* promote better bone health in women.[9] Calcium deficiency can both affect the bone formation and cause excessive bone resorption to maintain the body calcium homeostasis. Hence, there is a significant correlation between the amount of dairy calcium intake, low bone mass and fracture risk.[21][41]

In addition, vitamin D plays a significant role in bone health.[42]It regulates intestinal absorption of calcium through the brush border membrane of the enterocytes. In the body, vitamin D(calciferol) is available in to forms: D_2(ergocalciferol) and D_3 (cholecalciferol). D_3 is the circulating form while D_2 is the active metabolite responsible for the major biological actions. Vitamin D is synthesised in human skin under the influence of ultraviolet B radiation, which photolyses provitamin D_3 to previtamin D_3. Additional amounts are obtained from vitamin D enriched foods.Exposure to sunlight is immensely important to fulfill the vitamin D requirement of the body.[9] Vitamin D deficiency (VDD) has become a global health problem as it appears prevalent in all age groups and ethnicities.[43][44] Other than restricted exposure to sunlight, dark skin tone, due to melanin pigmentation, limits the endogenous vitamin D synthesis.[45]Hypovitaminosis D reduces calcium absorption from intestine and increases bone resorption, resulting in low bone mass. Additionally, some medications interfere with calcium absorption; such as corticosteroids, anticonvulsants, immunosuppressive medications, NSAIDs and some antibiotics.[34]

Lifestyle choices and behaviors

Alongside the clinical, nutritional and genetic factors, life-style behaviors are associated with development of osteoporosis.[46] Smoking, excessive alcohol consumption and caffeine intake are major concerns because they prevent the body from achieving the optimal peak bone mass at teenage and increasing the bone loss in adults.[46][34][21][19]

Bodyweight and physical exercise are important determinants of BMD. Bodyweight, which is used to calculate Body Mass Index (BMI) is a reflection of bone mineral content. Also BMI, while lacking sensitivity and specificity, due to variance like height and ethnicity, is a simple indicative of total fat mass.[37] Further, lean mass, fat mass, bone mineral content and BMD of various skeletal sites are significantly and positively correlated, leaving lean mass as the strongest predictor of total body bone mineral content and BMD in premenopausal women.[29]In addition, physical activity is significantly associated with improvement of BMD and lean mass.[47] Therefore, a lack of physical exercise and low body weight lead to reduced BMD.[46][33][19][34] Naves *et al*. (2005) highlighted that there was a rapid bone loss in their study sample of Spanish men, who have significantly low BMI. The bone loss was observed in the lumbar spine, hip and trochanter regions. Furthermore, in the modern industrialised world, modifications of life style including changes in dietary intake, occupation, increased sedentary behaviors and inequality increase the risk of osteoporosis.[15]Further, the posture of sitting, walking and standing; lying down in spun or back positions and in stressors such as meeting day to-day functioning could affect the development and shaping of bone.
Osteoporosis is more common in people with lower education levels[19][48]; this may be due to inability to reach information on healthy life style habits or employment.[9] Some people appear not to realise that they are at risk of developing osteoporosis.[4] On the other hand some people think that they have no self-responsibility of preventing osteoporosis.[46] According to statistics, 57% of female students of between 16 and 18 years of age in UK schools did not know that menstruation and menopause are risk factors of osteoporosis whereas 12% females had not heard or read anything about osteoporosis.[46]

Further, family income indirectly increases the risk of osteoporosis by limiting both nutritional foods and education opportunities.[19] Moreover, there are people who do not necessarily take actions to prevent osteoporosis due to financial constraints, although they understand the risk.[4]

Long-term use of glucocorticoids

Among these medications glucocorticoids induced osteoporosis is most common. Glucocorticoid therapy places patients at high risk of bone fragility fractures.[49] Glucocorticoids are commonly used to treat inflammation and suppress immune-mediated diseases such as rheumatoid arthritis, pulmonary diseases, inflammatory bowel disease, psoriasis and organ transplants.[50] Regardless of the positive effects, glucocorticoids have toxic effects on bone. For example a prednisolone daily dose higher than 7.5mg for more than 3 months could impair bone health.[51] Glucocorticoids have a direct inhibitory effect on osteoblast function and reduce bone formation. Further, glucocorticoids increase osteoblast and osteocyte apoptosis. In addition, corticosteroids inhibit intestinal calcium absorption and cause renal leak of calcium. This tends to reduce serum calcium, leading to increased osteoclastic bone resorption due to secondary hyperparathyroidism.[50][52][51]

Pregnancy and breast feeding

Both pregnancy and breast-feeding interfere with maternal calcium homeostasis, leading to lower bone mineral density in mothers. During pregnancy, calcium is transferred to the fetus mainly in the second and third trimesters when fetal bone development peaks.[8] Maternal bone is the main source of calcium for the fetus and therefore mother loses 3-7% of bone

mineral content in lactation.[53] Researchers have proved that pregnancy and breast feeding increase the risk of osteoporosis at older age of women.[37] A significant amount of maternal bone loss is restored after 6-12 months of the weaning period if the diet is rich in calcium.[54][53]

Disease of the thyroid and parathyroid glands

Dysfunction of the thyroid or parathyroid glands, have a direct effect on bone health. The calcemic hormones, insulin, growth hormone and androgens promote skeletal growth and maturation, while glucocorticoids are all deleterious to normal skeletal functions.[8] Use of calcium supplements and hormone replacement therapy (HRT) protect against developing osteoporosis, however they are only supportive treatment.[19]

Parathyroid hormone (PTH) and calcitonin (CT) hormone maintain the normal calcium homeostasis in the human body. PTH increases the osteoclasts involved in the bone resorption process and increases calcium serum levels to resolve serum calcium deficiencies. In contrast CT inhibits bone resorption and reduces serum calcium. Hyperparathyroidism and reduced levels of CT are responsible for low BMDin the affected individuals.[8][55] Primary hyperparathyroidism occurs due to hyperplasia in parathyroid gland. Sustained hyperparathyroidism destroys the balance between bone formation and resorption while increasing bone turnover.[51] This reduce bone mineral content and increase the risk of osteoporosis.

Secondary hyperparathyroidismis a major reason for osteoporosis. Long-term low serum calcium levels induce parathyroid activity and leads to excessive secretion of parathyroid hormone in this situation. This enhances bone resorption leading to reduced BMD and as a consequences osteoporosis.[56][57][58]Low calcium intake, impaired intestinal calcium absorption, increase in calcium excretion due to renal diseases and deficiency in vitamin D are all predominant underlying causes of secondary hyperparathyroidism.[59][56]

Hypogonadism

Hypogonadism is a major cause of secondary osteoporosis. Oestrogen deficiency has a critical role in bone loss in both genders.[60] Oestrogenacts on all three bone cell types and influences bone metabolism. The significant decrease of oestrogen in women due to menopause, damages the trabecular network of bones resulting a reduction in both BMD and bone quality.[9][18] This explains the greater prevalence of osteoporosis and fragility fractures in women than in men. Testosterone is responsible for male bone health. Age related decline in testosterone hormone levels reduces the bone health in men.[61] However, literature shows that low oestrogen levels are associated with the greater fracture risk in elderly men even they have normal testosterone levels.[60]

Investigations for osteoporosis and fragility bone fractures
BMD assessment by DEXA scanning

BMD is the most reliable predictor of osteoporosis level of risk.[34][24][25]In current clinical practice, the diagnosis of osteoporosis is based on the estimation of BMD.[21]The world health organisation (WHO) established diagnostic criteria for osteoporosis based on BMD 'T-scores.' T-score is the number of standard deviations (SDs) by which the patient's BMD differs from the mean peak BMD of young healthy people of same gender.[34]T- score is calculated as below.[62][63]

$$Tscore = \frac{Patient's\ BMD - Population\ peak\ BMD}{Standard\ deviation\ (SD) of\ population\ peak\ BMD}$$

WHO osteoporosis diagnosis criteria[48][64][65][66][67] are:

- "Normal- A value of BMD that is higher than or equal to 1 SD below the young adult female reference mean (T-score ≥ −1 SD).
- Low bone mass (osteopenia)- A value for BMD lower than 1SD below the young female adult mean, but higher than 2.5 SD of this value (−1 >T-score > −2.5 SD).
- Osteoporosis- A value for BMD lower than or equal to 2.5 SD below the young female adult mean (T-score ≤−2.5 SD).
- Severe osteoporosis (established osteoporosis)- A value for BMD lower than or equal to 2.5 SD below the young female adult mean and the presence of 1 or more fragility fractures.

The recommended reference range for BMD was determined in the Third National Health and Nutrition Examination Survey (NHANES III) database for femoral neck measurements in white women aged 20 to 29 yearsand endorsed by the International Osteoporosis Foundation (IOF),the National Osteoporosis Foundation (NOF), and the International Society of Clinical Densitometry (ISCD).[65][66][67] According to WHO, the approved standard criterion of diagnosis of osteoporosis is the BMD of femoral neck with total hip or lumber spine also assessed adhering to above principle.[68][65][66][67] Further, the ISCD recommends obtaining BMD measurements of the posteroanterior spine and hip to avoid overestimations.[69]

The gold standard method of assessing BMD is Dual Energy X-ray Absorptiometry (DEXA).[9][65][21] In this method, the body site under investigation is placed in the path of two x-ray beams with different energies and the beam attenuation is measured. BMD is calculated as the ratio of bone content to the scanned area.[70][71] This method has a high predictive validity which comprises a significant sensitivity and specificity.[9][65] DEXA scanning is used in two ways; either centrally or peripherally, depending on the skeletal site measured. Central DEXA is used to measure BMD of the lumber spine and hip bones while peripheral DEXA measures the peripheral bones such as the distal forearm, phalanx and tibia. Central DEXA systems are the current choice in diagnosis of osteoporosis. Peripheral DEXA systems are portable, less expensive and frequently used in screening and early risk assessment tools.[69]

Ultrasound bone scanning

There is an increased trend of using ultrasound bone scanners to detect bone strength and fracture risk.[71][72] This technology evaluates both quantitative and qualitative characteristics of bone.[73] The frequency of Quantitative Ultrasound (QUS) waves lies between 200 kHz and 1.5 MHz.[74] QUS bone scanning is well established amongst researchers, since it is cheaper, portable, free of ionizing radiation and accepted as a reliable method of predicting osteoporosis fractures.[75][76] These devices utilize three main types of technology; broadband ultrasound attenuation (BUA), speed of sound (SOS) and quantitative ultrasound stiffness index.[71]BUA measures the frequency dependence of attenuation of the ultrasound signal that occurs as energy is removed from the

wave, primarily by absorption and scattering in the bone and soft tissue.[71][77] It is calculated from the slope between attenuation of sound signals and its frequency. The BUA measurement unit is dB/MHz.[74] SOS measures the distance that ultrasound signal travels per unit of time and is measured in meters per second (s/m).[78][71][74] Quantitative ultrasound stiffness index is mathematically and automatically calculated from the BUA and SOS.[[78][77][71][74]

QUS is significantly correlated with BMD(Prins *et al*., 1998).[79] In site specific bone assessments QUS has shown r-values between 0.6-0.9 and clearly reflected BMD. Researcher demonstrates that QUS is a strong predictor of BMD and this technology can be used to estimate osteoporosis and fragility fractures in both prospective and cross-sectional studies.[79][74] According to the meta-analysis results of Marín *et al*., QUS measurements are significantly associated with fracture risk, mainly of elderly women and considered a simpler and valid alternative to DEXA to assess future fracture risk at non-spinal sites.[75]In addition, QUS is a significant predictor of osteoporotic fractures and hip fractures, similar to other axial or peripheral measures of bone strength, but is a weaker predictor than femoral neck BMD for hip fractures.[76] Moreover, QUS fracture probability in conjunction with high clinical risk factors can be used to initiate osteoporosis patient management when DEXA is not accessible.[80]

FRAX tool

Screening for osteoporosis fractures at younger age is important to prevent osteoporosis fractures, because fractures contribute to loss of independence in older individuals. It is hypothesised that the use of bone scanners to detect the low BMD and the use of clinical risk factors may predict the risk of fractures in young people to enable correction and prevention of future fractures. The University of Sheffield, UK launched the FRAX tool in 2008. The data collected by the WHO Collaborating Centre for Metabolic Bone Diseases hosted inthe University (1991-2010)were used to develop Fracture Risk Assessment tool (FRAX).[81] This tool can be used to determine the fracture probability in both men and women based on exposure to clinical risk factors. The FRAX algorithms give the 10-year probability of a fracture for 40-90 years old people. The outputs of this tool are 10-year probability of hip fracture and the 10-year probability of a major osteoporotic fracture of the spine, forearm, hip or humerus.[82] The FRAX tool integrates data from nine epidemiological studies conducted in several geographic regions including North America, Europe, Asia and Australia.[83] Further, it uses risk factors that have been validated in 11 independent cohorts with similar geographic distributions.[82]

Risk factors included in FRAX are age, sex, height, weight, BMI, previous fracture, parent history of hip fracture, current smoking, alcohol use, rheumatoid arthritis, glucocorticoid use and secondary osteoporosis. The FRAX tool is designed to work even without BMD values and it provides a solution to the limitations in access to central DEXA facilities. Apart from the clinical risk factors, FRAX uses epidemiological data on mortality, life expectancy and incidence of fractures to calculate the fracture probability. Since these epidemiological data vary in different communities, a uniform FRAX model which matches for all communities is implausible. As a result ethnic-specific FRAX models were developed in many countries and populations.[84]

The Sri Lankan FRAX model was officially launched on 15th March, 2012.[1] It is considered as a surrogate model since it used hip fracture data of a surrogate population i.e. Singaporean- Indians(Lekamwasam, 2013).[29] Further, age specific non-hip fracture incidence data of a Swedish community and Sri Lankan age specific mortality data were incorporated to build Sri Lankan FRAX model.[29]

Other osteoporosis screening tools

There are many other tools developed as prescreening tests for osteoporosis fractures based on clinical risk factors. These tools help to identify patients at risk of osteoporosis and who would benefit from directing to a DEXA scan. Then, the DEXA facility will not be unnecessarily used. The most commonly used tools are SCORE (Simple Calculated Osteoporosis Risk Estimation), ORAI (Osteoporosis risk assessment instrument), OST (Osteoporosis self-assessment tool) and SOFSURF (Study of Osteoporotic Fractures Simple Useful Risk Factors).[85] The formula of OST was built using age and body weight.[86] Current oestrogen use is considered in ORAI whilst nonblack race, rheumatoid arthritis, non-traumatic fractures in wrist, rib or hip after 45 years age, and prior use of oestrogen therapy is evaluated in SCORE tool.[87][88] According to Gourlay *et al*. (2005) OST, ORAI and SCORE tools are equally reliable in identifying risk of osteoporosis in postmenopausal women aged 45-64 years. Similar performances for these three tools were found in USA and Netherlands postmenopausal women.[89] Further, these three tools demonstrated the ability to detect women with osteoporosis risk in older USA women particularly aged 67 years or older.[90] The Korean Osteoporosis Risk-Assessment Model (KORAM) is one such pre-screening tool specifically developed and validated for Korean postmenopausal women based on age, weight and hormone replacement therapy.[91][92] The seven-variable osteoporosis prescreening model developed and validated by Matin *et al*. (2015) for Iranian postmenopausal women was successful in referring patients for bone mineral densitometry. The SAPORI index (São Paulo Osteoporosis Risk Index) was developed by analyzing an osteoporosis and fracture-risk assessing questionnaire in 4332 pre-, peri- and postmenopausal women from the community in Brazil.[44]

Summary

The current sedentary, machinery driven life styles and body image issues affecting the population bone health at the time of life where the bone mass accumulates throughout life span preventing it from reaching its peak by adulthood and maintaining its quality thereafter. Identifying those at risk earlier in life may prevent complications after the age of 50 years. More research is required to develop affordable screening tools, but ultrasound devices that are cheap and portable, used in conjunction with predictive models appear to offer a practical way to extend screening to a wider population at acceptable cost.

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