Identification of Osteoporosis by using stress wave method

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Abstract -*Osteoporosis is a medical condition in which the bone becomes brittle & fragile from loss of tissue, typically as a result of hormonal changes or deficiency of calcium or vitamin D. Currently diagnostic methods - MRI, X-Ray, CT or DEXA which are expensive and not affordable, other portable devices are not accurate. The stress waves are generated in the long bone (tibia) by the impact of impulse force using rubber pad hammer which is been collected by 3 axis accelerometer. It measures static acceleration of gravity in tilt-sensing as well dynamic acceleration resulting from motion or shock and interfaced to LabVIEW via myDAQ that gives voltage & acceleration as output by creating new VI, this acceleration & voltage is further been converted to frequency.Eighteen subjects were evaluated with age group of 20 Years to 60 years, results varied between 113Hz to 86 Hz. These techniques gives a better understanding of dynamic behavior of bone under impact force and natural frequency of stress wave signal is clear indication of mechanical stiffness of bone under investigation.Hence the impulse response method can be used for detection of osteoporosis. The technology developed can be converted into Hand held device for osteoporosis estimation.*

***Key Words*:**Osteoporosis, LabVIEW, Impulse method, stress wave, myDAQ, Osteopenia.

1. INTRODUCTION

Disease characterized with low bone mass and having deterioration in the microarchitecture of bone tissues is called Osteoporosis. It is estimated that worldwide an osteoporotic fracture occurs every three seconds. . It's a silent disease as there are often no symptom. At 50 years of age, one in three women and one in five men will suffer a fracture in their remaining lifetime. For women, the risk of hip fracture is higher than the risk of breast, ovarian and uterine cancer combined. For men, the risk is higher than the risk for prostate cancer. At 50 years of age, one in three women and one in five men will suffer a fracture in their remaining lifetime. For women, the risk of hip fracture is higher than the risk of breast, ovarian and uterine cancer combined. For men, the risk is higher than the risk for prostate cancer. [5].approximately, 50% of the people with one osteoporotic fracture will have the risk of new fractures, and the risk rises exponentially with each fracture. The number of patients suffering from Osteoporosis are 8.7 % among men of 50-60 years, & 20.7 % among women of 40-60 years out of 13.1 x 10^8 total population of India.Osteoporosis is a medical condition that causes the bones to become brittle and more prone to fractures due to loss of bone density. [6] It is quickly becoming a more common ailment among an aging population. Osteoporosis leads to increase in risk of fractures with advancing age. Osteoporotic fractures are common among females reaching Menopause that is around 45 years and male popu lation above 50 yrs.As per recent data available approximately 163 million Indians are above the age of 50 (2001), this number is expected to increase to 230 million by 2015 [5]. Even conservative estimates suggest that out of these, 20 per cent of women and about 10 - 15 per cent of men would be osteoporotic. Nearly 25 million are estimated to be suffering from Osteoporosis, 20%, ie, ~46 million, are women with osteoporosis. Further, increase in life expectancy has resulted in an increasing number of senior citizens globally; life expectancy at present is ~67 years in India and is expected to increase to 71 years by 2020 and to 77 years by 2050 [23]. Further, ~10% of the Indian population is older than 50 years at present; however, these figures are likely to go up to 34% by 2050 [7]. Thus, increasing longevity and a greater proportion of the Indian population over the age of 50 years are likely to result in an increased number of people affected by osteoporosis.

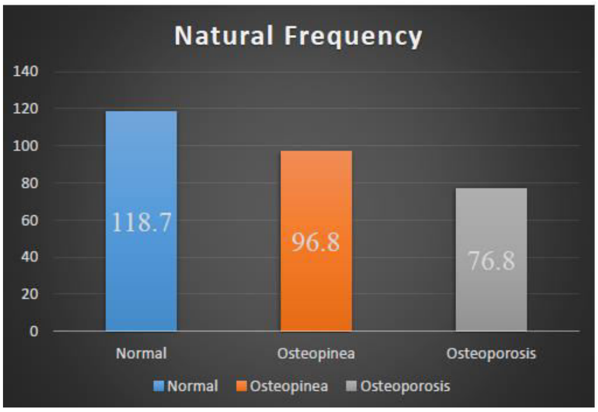
According to the World Health Organization [6], diagnosis is based on T-score, is as follows > -1.0 Normal; Osteopenia, -1 to -2.5; and Osteoporosis, < -2.5. Z-scores are used in evaluations of premenopausal women, men younger than 50 years, and children and teenagers (younger than 20 years).

In 2013, estimates suggested that ~ 50 million people in India had *T*-scores of < - 1, i.e osteoporotic [8].As Osteoporosis is a skeletal condition of growing interest and concern, called "the silent disease," "brittle bone disease," or "thinning of the bones," it often lacks symptoms until a fracture occurs. It is a disease in which the microarchitecture of bone becomes structurally faulty and weakened, also becomes susceptible to minor forces that can cause fracture. Its precursor, osteopenia, exhibits the same micro architectural faults, but to a lesser degree. Both of these forms of bone loss, however, pose significant challenges to the health care community.

Currently, the most common methods of diagnosis are; Magnetic Resonance Imaging (MRI), X-Ray Computed Tomography (CT), or Dual-Energy X-Ray Absorptiometry (DXA). The major disadvantage with these techniques is that radiography is relatively insensitive to the disease in its early stages [7]. This is because the bone mineral density of the patient has just started to decrease. MRI, CT, and DXA scans can start to reliably detect osteoporosis only after some substantial amount of bone loss, usually greater than 30%.

Therefore this method is to demonstrate a technology which is non-invasive, reliable, easy to operate, inexpensive tool. The technology has diagnostic potential in the early detection and assessment of osteoporosis and osteopenia. Based on Frequency analysis of stress wave signal [3], it is found that the Natural Frequency is significantly decreased in osteopenia to 96.8 Hz and Osteoporosis subjects to 76.8 Hz, indicating low bone mineral mass, mechanical strength and stuffiness as given in the Chart Showing Standard Natural Frequency.

Chart showing Standard natural frequency



Literature Survey

The Current methods and recent advances in the diagnosis of osteoporosis discusses about different methods to diagnose osteoporosis. Devices Used to Detect Osteoporosis are divided into 2, Central and Peripheral Devices, ie, Conventional radiography, Single-photon and x-ray absorptiometry [9], Dual-photon and x-ray absorptiometry, Quantitative computed tomography, Quantitative ultrasound. Quantitative magnetic resonance. Rosa Lorente et al. [2], states that, Dual Energy X-ray Absorptiometry (DEXA) is the gold standard method for diagnosing osteoporosis and estimating fracture risk. DEXA is non-invasive, has low radiation exposure, and provides an accurate and precise measurement of BMD at the femoral neck, spinal vertebrae, wrist, and total body. Special software that compute and display BMD measurements on a computer monitor. DEXA measures bone mineral content (g) which represents total mass of an area [4]. Nick muller et al., [24] describes 3 methods that can measure osteoporosis ie Electrical Impedance Tomography, Infrared Scattering Sensors, and Microwave Antenna Sensors, but the results are not much accurate Eugenia quirosroldana et al. has done Comparison between the gold standard DXA with calcaneal quantitative ultrasound based-strategy (QUS) to detect osteoporosis in an HIV infected cohort [4].On comparing the results between Calcaneal QUS & DXA, although osteoporosis screening by DXA is the gold standard method, there is an increased interest in the use of other screening methods including calcaneal QUS. The advantages of QUS being radiation-free, fast, portable, less time-consuming, and can be performed at a considerably lower unit cost. Thus, it is practical for use in the community for mass screening, In case individuals are found to suffering from osteoporosis they can be further evaluated with DEXA. G.p.Gokullaxmi et al., [3], states that stress wave which is generated by the impact of a hammer on a tibial bone can be picked up by 3 - axis accelerometer, which displays the output in terms of frequency. The frequency obtained is compared with standard wave frequency and the bone is determined whether it is Osteoporosis, osteopenia or normal bone.

As per literature review the most common methods of diagnosis are: Magnetic Resonance Imaging (MRI), X-Ray, Computed Tomography (CT), or Dual-Energy X-Ray Absorptiometry (DXA). These devices are expensive the least which is peripheral device (portable bone densitometer) costs around 5 Lakhs. These are not affordable and not portable. DEXA is around 20 Lakhs. With huge cost and non-portability these devices are confined for specialized centers. They cannot be used for mass screening purposes and do not find a place in the General Physicians armoury. The patients cannot afford the cost of test for Osteoporosis. Hence the Stress wave method to identify Osteoporosis needs to be verified and the possibility of it to be converted into a portable device to detect Osteoporosis needs to be explored.

2. Methodology

The experimental setup comprises an impulse force hammer and a ceramic shear type accelerometer (ADXL 345) within built charge, amplifiers. The coupler provides constant current

International Journal of Scientific Research in Engineering and Management (IJSREM)
Volume: 04 Issue: 05 | May -2020 ISSN: 2582-3930

excitation required by accelerometers and decouples the DC bias voltage from the output signal. The experimental setup for in vivo assessment of detecting changes in frequency in superficial long bones by impulse wave propagation method,isshown in Figure 1: Block Diagram of Setup for Detection.

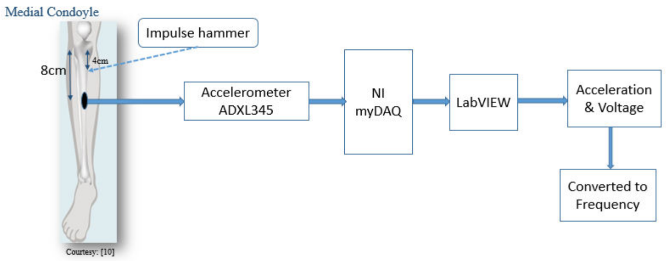


Fig -1: Block Diagram of setup for detection

Impulse response measurements were performed non-invasively on the tibia. The choice of the tibia as a measurement site is validated by the fact that it contains approximately 25-30% trabecular bone and 70- 75% cortical bone by volume, and is subjected to extreme loading conditions during daily activities as per S. Cheng et al., study [17]. The trabecular bone is highly active in remodeling process and shows changes within bone tissue earlier than cortical bone. Observable changes are also seen in cortical bone during bone metabolism [25]. Men have been estimated to loose, on average, about 25% of their cortical bone, and women lose 35% of their cortical bone over their lifetime. So the net bone mineral loss occurring in the skeleton can be observed in tibia. Moreover, the medial side, of tibia is approximately flat and soft tissue thickness is minimum, making it an ideal choice for accelerometer mounting in impulse response study.

The experimental arrangement was such that the subject was asked to sit on a chair with their leg well placed vertically on a vibration free wooden platform, as described by G.p. Gokullaxmi et al., [3]. The pre-selected points for the hammer strike and for the accelerometer mounting were determined on the skin surface and marked. The accelerometer is placed on the fascia's medial in tibia at a distance of 8 cm from medial condoyle using adhesive without imposing extra loading on bone. In this configuration of mounting, accelerometers are only sensitive to the axial acceleration, and no attempt was made to measure any other mode of acceleration.

The stress waves are generated by the impact of hammer on the medial side of the proximal tibia at a distance of 4 cm from medial condoyle. The impact force applied through impulse hammer is standardized between 2 - 2.5N for each impact, which is obtained by dropping the hammer from a vertical distance of 5 cm. The above force is chosen to optimize the pulse width, maximize the signal to noise ratio and to ensure absolutely no pain to the subject. The application of the impact force is parallel to the axis of both accelerometers and therefore approximately perpendicular to the facieses medial. The force and acceleration outputs were amplified by in-built amplifiers and observed simultaneously on oscilloscope.

In Figure 1, shows experimental setup for detection of osteoporosis by impulse response technique. Impulse hammer is used to generate impulse stress on the long bone such as tibia , placed at 8cm from knee then Accelerometer ADXL345 is used to collect the impulse of stress generated by bone, accelerometer converts the stress into the voltage which is been future processed by using NI myDAQ, which collects the voltage and gives to the NI LabVIEW in which the future processing is carried out as shown in the flow chart in figure 2 [1], and its description is as mentioned in the Flowchart Description below.

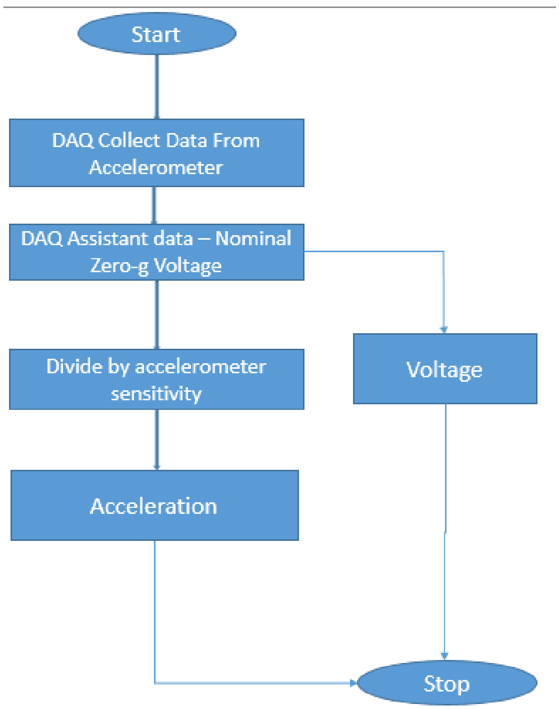


Fig -2: Flow Chart of Program

Then the output obtained in LabVIEW is in Acceleration and Voltage, but according to the standards described we need to have output in frequency, hence we are converting it to frequency by using Advanced Mechanical Engineering Solutions Sinusoidal (Sine) Motion Calculator (Vibration Calculator) [16].

In this study 18 subjects were selected of different age groups in which both Male and Fe-Males were included. The subjects were evaluated for osteoporosis by using Stress wave analysis as mentioned above. The results were of different frequencies ranging from normal to osteoporosis. Where the standard Natural frequency of Normal Bone is 118.7 Hz - 96.8 Hz, Osteopenia is 96.8 Hz - 76.8 Hz, and Osteoporosis is less than 76.8 Hz [3] & [17].

When any force is applied on the bone, its natural frequency is varied based on material of bone and it can be easily related to the impact force. As amplitude of vibration is sustainable, if any load is applied on bone then there is increases in amplitude, which can be easily related to the frequency. And also the method is of software prototype the output obtained from LabVIEW code where in form of Acceleration and voltage. Hence it had to be converted to frequency, by using Advanced Mechanical Engineering Solutions Sinusoidal (Sine) Motion Calculator (Vibration Calculator) [16].

Then results obtained are segregated based on age group and gender of the subjects, we obtained different frequencies ranging from normal to osteoporosis. The values of natural frequency for normal, osteopenia and osteoporosis subjects were analyzed by this technique. Table 1 shows the frequency in Hz with number of subjects taken and variation of frequency with respect to that of the stress wave generated by using impulse hammer.

Table -1: Frequency Ranges Results Obtained for 18 subjects.

Subject No.	Age group range [years]	Gender	Obtained Frequency [Hz]	Normal Frequency Range [Hz]	Condition of Bone - NORMAL / Osteopenia / Osteoporosis
1	20-30	Female	99.71007	96.8-118.7	Normal
2	20-30	Female	97.70992	96.8-118.7	Normal
3	30-40	Female	88.71045	76.8-96.8	Osteopenia
4	30-40	Female	87.8411	76.8-96.8	Osteopenia
5	20-30	Male	109.8803	96.8-118.7	Normal
6	20-30	Male	99.70956	96.8-118.7	Normal
7	30-40	Male	89.7063	76.8-96.8	Osteopenia
8	30-40	Male	90.70973	76.8-96.8	Osteopenia
9	40-50	Male	80.70974	76.8-96.8	Osteopenia
10	40-50	Male	81.70992	76.8-96.8	Osteopenia
11	40-50	Male	84.70996	76.8-96.8	Osteopenia
12	40-50	Male	82.7099	76.8-96.8	Osteopenia
13	50-60	Male	80.70963	76.8-96.8	Osteopenia
14	20-30	Female	113.3061	96.8-118.7	Normal
15	50-60	Male	75.49651	< 76.8	Osteoporosis
16	40-50	Female	82.7099	76.8-96.8	Osteopenia
17	30-40	Female	88.70992	76.8-96.8	Osteopenia
18	20-30	Female	98.0581	96.8-118.7	Normal

Frequency analysis of stress wave signal was carried out for all the subjects. It is found that the natural frequency is significantly decreased in osteopenia and osteoporosis subjects indicating low bone mineral mass, mechanical strength and stuffiness. Hence we can conclude with age groups determined that younger has normal range but as the age increases there are subjects found with osteopenia and in elderly subjects we found one subject in osteoporosis range. we inferred the on results obtained in study age group of 20 – 30 years was found normal range between 96.8 - 118.7 Hz, 30 - 40 years & 40 - 50 years found to be osteopenia between 76.8 - 96.8 Hz and 50 - 60 years had osteoporosis < 76.8 Hz is been correlated with literature review.

3. CONCLUSIONS

This method can be converted into Hand Held Device for Detection of osteoporosis which is compatible, cost effective, and accurate, nearly to the clinically proven other methods of detecting osteoporosis and specially the Gold standard DEXA as discussed in literature survey.

The values obtained should be validated with the clinically proven DEXA machines at clinically aerated labs. The technology demonstrated can be converted into a pocket Hand held device for osteoporosis estimation.

The impulse response technique for monitoring the stress wave propagation in long bone (tibia) bone has been effectively used in the assessment of osteoporosis. Eighteen subjects were evaluated for osteoporosis with age group ranging from 20 Years to 60 years, the results varied between 113 Hz to 86 Hz. Hence we conclude that impulse response method can be used for detection of osteoporosis.

The technique gives a better understanding of the dynamic behavior of bone under impact force, and the natural frequency of stress wave Signal is a clear indication of mechanical stiffness of the bone under investigation. The study is non-invasive, reliable, easy to operate, inexpensive and has diagnostic potential in the early detection and assessment of osteoporosis and osteopenia.

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BIOGRAPHIES

Thasneem Fathima is working on Osteoporosis and its detection. Have published a Review paper on Osteoporosis estimation.