Preliminary study on the effects of high magnitude, low frequency of whole body vibration in physical activity of osteoporotic women

Studio preliminare dell’effetto delle vibrazioni ad alta intensità e bassa frequenza applicate sull’intero corpo in donne affette da osteoporosi e fisicamente attive

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SUMMARY

Aim. Osteoporosis is nowadays affecting a large population. Recent studies, performed on animals and human beings, have shown that high magnitude, low frequency mechanical stimuli produce anabolic effects on bone tissue, increasing both bone density and strength. Aim of this study is to verify the effects of whole body vibration on bone tissue of trained osteoporotic women underwent to high magnitude and low-frequency vibration exercise on a vibrating platform.

Methods. Twenty-six osteoporotic women, trained with low impact exercise regimen, voluntarily participated in the study and were randomly divided in two groups: experimental (E) and control (C). All subjects weren’t submitted to any pharmacological therapy. The T-score, Ultrasound Bone Profile Index (UPBI) was calculated using the Amplitude-Dependent Speed of Sound (AD-SoS) measured with QUS.

Results. Thirteen osteoporotic women following four months of ten-minute treatments, three per week, of high magnitude (3.0 g) and low frequency (30Hz) mechanical vibration improved the Amplitude-Dependent Speed of Sound (AD-SoS) QUS parameter from 1878.67±79.45 to 1971.17±78.69 m/s (P<0.002). The T-score in the experimental group shows an inversion trend passing from -3.50±1.13 to -2.18±1.12 (P<0.002) and the Ultrasound Bone Profile Index (UPBI) improves from 0.34±0.11 to 0.47±0.21 (P<0.01). In the control group (low impact exercise) any of these parameters considered shows significantly changes over the same period of time.

Conclusion. Given that these accelerations were well tolerated by the experimental cohort, that vibrations similar to these stimulated an increase in bone density and strength in humans, and that skeletal loading is an inevitable product of functional load bearing, we believe that vibration energy can represent not only a preventive approach but also a therapy for osteoporosis. For that, larger population scale studies must be performed in order to verify the effectiveness of vibration treatments and its combination with exercise regimen on the spine and the lower limbs to prevent bone loss falls and related bone fractures in elderly people.

KEY WORDS: Osteoporosis - Diabetes mellitus, type 2, genetics - Exercise - Maximum aerobic power.
Osteoporosis is currently affecting a large population. Over 40% of women in the United States over the age of 65 are currently affected, determining a cost, which exceeds $15B per year to the health care services. According to the E.S.O.P.O. study (Epidemiological Study On the Prevalence of Osteoporosis), in Italy 23% of women older than 40 years and 14% of men older than 60 years are affected by osteoporosis.

Many different prevention and treatment regimens have been developed to resolve the increasing problem of the osteoporosis and related fractures. Reversal of bone loss is then a critical goal for science for improving the long-term well being of the aged population. Several investigations have been conducted trying to identify an effective countermeasure to osteoporosis. However, while several pharmacological interventions have been implemented for the management of this disease, it seems that sometimes the risks connected to the side-effects exceed the apparent benefits. Several authors showed that the mechanical stimulus, mediated by physical activity or exercises, is the only mean which can positively influence not only the bone mass and strength but increasing muscle strength too. In addition, regular physical activity enhances health and physical fitness improving overall the quality of life in elderly population by providing a sense of well being of the aged population. Several investigations have been conducted trying to identify a valid system to evaluate the osteoporosis. Attualmente, nonostante siano stati istituiti variati interventi farmacologici per il trattamento di questa patologia, sembra che frequentemente il rischio derivante dagli effetti collaterali superi i benefici ottenuti. Per questo motivo alcuni autori hanno voluto dimostrare che uno stimolo meccanico (e quindi non farmacologico) medio dell'esercizio fisico, sia un ottimo mezzo per influenzare positivamente non solo la massa e la resistenza ossea, ma anche la forza muscolare. In aggiunta è stato detto come un'attività fisica regolare migliori la salute e la forma fisica determinando globalmente un incremento della qualità di
reducing the risk of deterioration of functional capacity. Moreover, the osteogenic adaptation of skeleton is site-specific and related to training regimens. Scientific evidence shows that low impact type movement, like endurance training, has not significant results in bone gain. Therefore, the impact type movement, that generates a versatile stimulus on whole muscle-skeletal system can generate osteogenic adaptation on skeletal sites. The loading-induced deformation in bone tissue (strain) are responsible of the adaptations in bone architecture and mass.

The mechanical strain, for determining the effects on bone remodelling, is related to other specific factors like magnitude, frequency and application time. Changes of gravitational conditions can be produced also by varying magnitude and frequency of mechanical stimul, like mechanical vibrations applied to the whole body. Recent clinical studies have suggested that the whole body vibration represents a mechanical stimulus enough to improve both the muscular performance. \(^{21-24}\) The interaction between muscle and bone responds to patterns of use or disuse with relative alterations in structure and strength. \(^{25, 26}\) The whole body vibration has been shown to effectively counteract bone loss not only in animal model, \(^{27-30}\) but in human beings also.

The first clinical studies on human being show a positive effects in adolescents with cerebral palsy \(^{31}\) and in osteoporotic female. \(^{32}\) Recently other authors show the increase as in muscle strength than in bone mass after exposition to vibration stimulus in post-menopausal women. Rubin showed an improvement bone mass density (BMD) of 1.5% in the spine and 2.17% in the femur, whereas the control group lost 1.6% in the spine and 2.13% in the femur, in postmenopausal women submitted at Whole Body Vibration (WBV) treatment at 30 Hz of frequency for 20 min (2 bouts of 10 min) per day, every day for 12 months. Improvements on BMD and muscular strength was found also after six months of WBV treatment at frequency of 35-40 Hz and magnitude of 5 g. \(^{34}\) These results seem to suggest that this intervention may have an anabolic effect on bone tissue. In contrast, the modest physical activity at low impact doesn’t have any effect on BMD of postmenopausal woman. \(^{11}\)

Aim of this study is to verify the effects of whole body vibration associated to exercise training at low impact, on bone tissue of osteoporotic woman in the population anziana riducendo il rischio di un deterioramento funzionale. Inoltre è noto che l’adattamento osteogenico dello scheletro avviene in modo sito-specifico ed è correlato al regime di allenamento. \(^{12, 13}\) Esiste un’evidenza scientifica che dimostra come un movimento a basso impatto, ad esempio esercizi di resistenza, non determini una variazione significativa sul l’aumento della massa ossea. Al contrario movimenti con impatto, che generano uno stimolo variabile sull’intero sistema muscolo-scheletrico, possono determinare una variazione osteogenica a livello scheletrico. \(^{14, 16}\) Allo stesso modo le deformazioni del tessuto osseo determinate dal carico sono responsabili di cambiamenti nell’architettura e nella massa ossea.

Lo stimolo meccanico necessario per determinare un effetto rimodellante sull’osso deve però essere correlato ad altri fattori quali l’ampiezza, la frequenza ed il tempo di applicazione. Delle perturbazioni del carico possono essere prodotte anche cambiando l’ampiezza e la frequenza dello stimolo meccanico come durante l’applicazione di vibrazioni meccaniche all’intero corpo (Whole Body Vibration - WBV). \(^{21}\) Recentemente altri autori hanno dimostrato che le WBV rappresentino uno stimolo meccanico sufficiente a determinare un incremento della performance muscolare. \(^{21-24}\)

L’interazione fra muscolo e osso è correlata all’uso e al non uso mediante variazioni nella struttura e nella forza. Le WBV si sono inoltre dimostrate efficaci nel contrastare la perdita di massa ossea non solo nel modello animale, \(^{27-30}\) ma anche nell’uomo.

Il primo studio clinico eseguito sull’uomo ha dimostrato effetti positivi in adolescenti con paralisi cerebrale \(^{31}\) e in donne affette da osteoporosi. \(^{32}\) Recentemente altri autori hanno dimostrato un incremento sia della forza muscolare che della massa ossea dopo l’esposizione ad uno stimolo vibratorio nelle donne in età post-menopausale. \(^{33}\)

Rubin ha dimostrato un aumento della densità della massa ossea (BMD) dell’1,5% nella colonna e del 2,17% nel femore in pazienti osteoporotici sottoposti a WBV ed una perdita dell’1,6% nel rachide e del 2,13% nel femore nel gruppo di controllo. Le donne in età post-menopausale erano state sottoposte a WBV mediante un trattamento a 30 Hz di frequenza per 20 minuti (2 cicli da 10 minuti) al giorno, ogni giorno per 12 mesi. L’aumento della BMD e della forza muscolare è stato dimostrato anche dopo 6 mesi di WBV alla frequenza di 35-40Hz e intensità di 5 g. \(^{34}\) Questi risultati sembrano suggerire che questo trattamento possa avere un effetto anabolico sul tessuto osseo. Al contrario un’attività fisica ridotta ed a basso
ic women underwent to 4 months of low-frequency vibration exercise on a vibrating platform. For ethical reasons connected not only to the experimental nature of this study but also to the short time of treatment, it was used the Quantitative Ultrasound that represents a feasible, sensitive and non-invasive method for assessing bone tissue, over others methods that use radioactive sources or ionizing radiations.

### Materials and methods

#### Subjects

To evaluate the effects of whole body vibration on bone loss condition, twenty-six osteoporotic women (T-score = 3.67 ± 1.10, Age 63 ± 8.6 years, Weight 66.12 ± 10.7 kg, Height 161.7 ± 5.9 cm) (Table I), recruited from the Outpatient Service of Rehabilitation Medicine in Tor Vergata University General Hospital, voluntarily participated in the study and were randomly divided in two groups: experimental (E) and control (C). The inclusion criteria regarded the normal nutritional status, determined by questionnaire submitted during the first clinical examination, stable body weight maintenance, estimated calcium intake over 500 mg/die and suitable feeling with vibration stimulus for the subjects participating to experimental group. Moreover for this group in respect to homogeneity of vibration stimulus produced from vertical oscillating device, the range of body mass of included subjects was comprise from 55 kg to 85 kg. Table I presents physical characteristics of the subjects of both groups. The exclusion criteria consisted of none pharmacological therapy for osteoporosis in previous two months to this experiment, recent history of bone fractures (at least two years), presence impatto non produce effetti sulla BMD delle donne in età post-menopausale.

L’obiettivo di questo studio era verificare gli effetti delle WBV associate ad un programma di esercizi a basso impatto sul tessuto osseo di donne affette da osteoporosi, sottoposte a 4 mesi di esercizi con vibrazioni a bassa frequenza su una piattaforma vibrante. Per ragioni etiche correlate non solo alla natura sperimentale di questo studio ma anche al breve tempo di trattamento, per la valutazione della massa ossea è stato utilizzato un ecografo quantitativo che rappresenta uno strumento semplice, sensibile e non invasivo per valutare il tessuto osseo, al contrario di altri metodi che utilizzano fonti radioattive o radiazioni ionizzanti.

### Materiali e metodi

#### Soggetti

Per valutare gli effetti delle WBV sulla perdita di massa ossea, sono state reclutate 26 donne affette da osteoporosi (T-score = 3.67 ± 1.10, età 63 ± 8.6 anni, peso 66.12 ± 10.7 kg, altezza 161.7 ± 5.9 cm) (Tabella I) presso il Reparto Universitario di Medicina Riabilitativa dell’Ospedale di Tor Vergata. Ogni partecipante ha aderito volontariamente allo studio ed i soggetti sono stati suddivisi in modo casuale in due gruppi: sperimentale (E) e controllo (C). I criteri di inclusione sono stati: un normale stato nutrizionale indagato mediante un questionario consegnato durante la prima visita, un peso corporeo stabile nel tempo, un apporto giornaliero di Calcio stimato di circa 500 mg/die e la tolleranza allo stimolo vibratorio (per i soggetti appartenenti al gruppo E). In aggiunta, per il gruppo E, per ottenere un’omogeneità dello stimolo vibratorio (prodotto da un dispositivo oscillante in senso verticale), la variabilità della massa corporea dei soggetti inclusi nello studio è stata ristretta tra i 55 e gli 85 kg. La Tabella I riassume le caratteristiche dei soggetti di entrambi i gruppi.

#### I criteri di esclusione sono stati: assenza di una terapia farmacologica per l’osteoporosi nei 2 mesi precedenti allo studio, anamnesi positiva per una frattura recente (entro 2 anni), presenza di mezzi di sintesi metallici, pazienti affetti da osteogennesi imperfetta, presenza di osteoartrosi (valutazione mediante Rx), patologie cardiopolmonari, gastrointestinali, renali o epatiche, anamnesi positiva per patologia tumorale maligna, patologie neuromuscolari o psichiatriche. Il protocollo di studio è stato approvato dal Comitato Etico della Società Italiana di Scienze Motorie.
of metallic synthesis implants of osteoreduction, osteogenesis imperfecta and presence of osteoarthritis (evaluated by X-ray), cardiopulmonary disease, gastrointestinal, renal and hepatic disease, history of malignancy, mental and neuromuscular disturbance. The protocol and study design was approved by approved by the Ethical Committee of the Italian Society of Sport Science.

Training protocol

The subjects of both groups participated, all together, at the same exercise training program (one hour three times per week for four months) in the same centre. One training session of one hour length, consisted in warm-up period of 15 min (walking and jogging), followed by flexibility and joint mobility exercises for 15 min, free body exercises for 15 min and low impact step exercise for 10 min. The end part of training session was dedicated to cool down exercises (5 min).

In addition, the subjects of experimental group performed the vibration treatment in the same day before the exercise training program.

Whole body vibration training protocol

The subjects of experimental group were instructed on the outcomes and the potential benefits associated with their participation in the study. Each subject was familiarised with the experimental protocol and signed an informed participation consent. Subjects under specific traditional treatment for osteoporosis with previous history of fractures or bone injuries were excluded from the study. They underwent to the experimental treatment consisting of whole body vertical sinusoidal vibration delivered through a specially designed vibrating plate (Nemes LB, Boscosystem, Rieti, Italy). The magnitude of vibration was 3 g (1g = 9.81 m · s$^{-2}$) and the frequency was 30Hz. The subjects exercised three times per week for a total period of four months. The treatment protocol has been previously described. The total vibration exposure was ten minutes per session. The subjects were standing with both legs in semi-squat position (knees bent at 100°) and were allowed to hold a standing stationary metal bar to maintain equilibrium during the exposure to vibration (Figure 1). To obtain a complete whole body vibration the mechanical

Figure 1.—Position assumed by subjects of the Experimental Group on vibrating plate (Nemes).

Figure 1. — Posizione assunta dai soggetti del Gruppo Sperimentale sulla pedana vibrante (Nemes).
waves, generated by vibrating plate, were also transmitted to the hands through the metal bar connected to it. During the time-course of the experiment, none of the subjects in the experimental group reported any discomfort from the treatment and only one subject of this group, after the first week of vibration treatment, dropout from this experiment without appreciable reason. The compliance of each subject participant to this study, calculated as the number of days attended divided by the 48 days in four months trial (3 days per week for 16 weeks) was about 88%, without statistical difference between both groups.

Quantitative Ultrasonogrammetry (QUS) Measurement

Quantitative ultrasound (QUS) measurements were performed before and after the three months treatment period in the proximal phalange of digit II and IV of the dominant arm, using a DBM Sonic 1200 (Igea, Italy) ultrasound device. Two probes are applied to the lateral surface of the fingers, one acting as generator of signal (US frequency = 1.5MHz) and the other as receiver. The coupling of them with the skin is mediated by a water-based gel. The velocity at which the US traverses the phalanges, in a lateral-medial direction, was calculated by rate between the distance separating the probes, directly measured by the calliper, and the time elapsing from the emission of the US signal to its reception and expressed in m/s. The device measures the time when the electrical signal, generated an amplitude of 2mV at the receiving probe, thus the QUS parameter calculated is the Amplitude-Dependent Speed of Sound (AD-SoS) for each four fingers and its average value. The AD-SoS has been shown reflecting the mass and the elasticity of bone. The phalanges reflect the largest variations of BMD over lifetime in women. The decreasing of AD-SoS is correlated with decreasing of BMD and loss of trabecular structures, typical conditions of elderly women.

Among the other parameters analysed by the device, in the present study, in addition to the average values of AD-SoS and the Ultrasound Bone Profile Index (UBPI) also the T-score will be considered.

The UPBI is an optimum logistic multivariate model, derived from different parameters, for fracture discrimination. It expresses the probability
that the subject has a vertebral fracture at the
time of QUS evaluation.44

The T-score was calculated using the AD-SoS
measurements. The individual values of QUS
were then converted to a T-score according to the
following formula:

\[
\text{T-score} = \frac{\text{measured values} - \text{average values in young adult}}{\text{SD in young adult}}
\]

The device has been calibrated by manufac-
turer using a composite mother phantom and
weekly calibrations are performed to control the
ultrasound velocity in a Plexiglas phantom. All the
QUS measurements were performed by the same
operator. The intraoperator reproducibility was
already scientifically documented45 and the
Coefficient of Variation (SD*100/Mean of mea-
surements) of repeated examinations was 0.15%
for AD-SoS parameter, calculating on repeated
measurements effectuated in the same day on
the second finger of a subject 30 times. In vivo
short term reproducibility was also assessed by
measuring 5 times 7 subjects, randomly selected
from both groups, at an interval time not exceed-
ing 7 days; the CV% was 0.75. All the measure-
ments effectuated in this study were performed
blind, because the operator didn’t know the
belonging of patients at the experimental or con-
trol group.

Statistical analysis

The data were analysed using the statistical
software for the Social Science (SPSS Inc.). A
paired Student’s t-test was used when compar-
ing longitudinal data within the each group of
women. The p values resulting from this cal-
culations are two sided and the minimum lev-
el of p value to be considered as significant is
0.05. The data referred to the subject’s charac-
teristics are expressed as mean ± standard devi-
ation.

Results

As expected, the evaluation of the control
group (trained subjects only) showed mainly no
changes over the QUS parameters in four months
time (Table II). In detail, only five subjects
showed slight improvements. On the other hand,
the experimental group (vibrated and trained
subjects) showed remarkable improvements on
the AD-SoS QUS parameter (p=0.002), on the
l’indebolimento della struttura trabecolare ossea,
condizione tipica delle donne anziane.42, 43

Nello studio, oltre ai parametri analizzati dal
sistema di acquisizione ed in aggiunta alla media
dell’AD-SoS ed all’Ultrasound Bone Profile Index
(UBPI) è stato misurato anche il T-score.

L’UBPI è un modello logistico multivariato ottimale
che, mediante l’analisi di diversi parametri, discrimi-
na il rischio di frattura. Questo valore esprime in
sostanza la probabilità di avere una frattura
vertebrale nel momento dello studio QUS.44

Il T-score è stato calcolato utilizzando i valori di AD-
SoS misurati. I singoli valori di QUS sono stati convertiti
in T-score utilizzando la seguente formula:

\[
\text{T-score} = \frac{\text{valore misurato} - \text{valore medio in gio-
vani adulti}}{\text{SD in giovani adulti}}
\]

Lo strumento di misurazione è stato inizialmen-
te calibrato dal produttore utilizzando una matri-
ce composita; successivamente sono state effettuate
calibrazioni settimanali per saggiare la velocità degli
ultrasuoni utilizzando una matrice in Plexiglas.

Tutte le misurazioni QUS sono state eseguite dal-
lo stesso esaminatore. La riproducibilità intra-ope-
ratore era già stata documentata precedentemen-
te.45 Il coefficiente di variazione (SD*100/media
delle misure) di misure ripetute è stato dello 0,15%
pere il parametro AD-SoS, calcolato su 30 misurazioni
eseguite nella medesima giornata sul II dito di un
soggetto. La riproducibilità a breve termine in vivo
è stata anche valutata eseguendo le misurazioni 5
tolte in 7 soggetti, selezionati in modo casuale in
entrambi i gruppi, ad un intervallo non superiore ai
7 giorni. In questo caso il CV% è stato di 0,75. Tutte
le misurazioni dell’UBPI hanno eseguite in cieco,
dato che l’operatore non sapeva se il pazien-
te apparteneva al gruppo dei casi o dei controlli.

Analisi statistica

I dati sono stati analizzati mediante un pro-
gramma statistico dedicato alle Scienze Sociali (SPSS
Inc.). Per confrontare dati longitudinali all’interno
di ogni gruppo è stato utilizzato il test t di Student per
variabili dipendenti. Da questo calcolo è derivata
una curva di distribuzione due code per il valore p,
che è stato considerato statisticamente significativo
se inferiore a 0,05.

I dati relativi alle caratteristiche dei soggetti sono
stati espressi come: media ± deviazione standard.

Risultati

Come ci attendevamo, la valutazione del gruppo
di controllo (solo allenamento) non ha dimostrato
per cambiamenti significativi dei parametri valutati con
QUS durante i 4 mesi di trattamento (Tab. 2). Nello
The magnitude of musculo-skeletal interactions is of paramount importance for the maintenance of bone integrity. Physical activity performed early in life has been shown to contribute to high peak bone mass.\textsuperscript{46} The results of this study confirm the scientific evidence that some forms of exercise, in particular those producing high impact forces, seem to be able to reduce or reverse the age-related risk of bone loss,\textsuperscript{47} whereas low impact exercise regimen doesn't have effects on remodelling bone tissue.\textsuperscript{11} In effect a lack of weight bearing activity could favour a sort of mechanical fragility,\textsuperscript{48} reducing in this way signals critical to the maintenance of bone mass.\textsuperscript{46}

Vibration represents a strong stimulus for musculoskeletal structures due to the need to quickly modulate muscle stiffness to accommodate the vibratory waves.\textsuperscript{39} Our results suggest that vibrations transmitted to the body by means of vibrating plates may be an effective alternative countermeasure to bone loss. This hypothesis is strongly supported by the effects of such treatment on human skeletal muscles. Vibration has been in fact shown to produce remarkable enhancement in strength and power production following acute\textsuperscript{22, 23} and chronic treatments.\textsuperscript{49} The extent of the response observed in our experiment (increase in QUS T-score by 57%) is surprising. However, it is our opinion that high magnitude (3 g), low frequency (30 Hz) and time of exposure (10 min) of vibration treatment could be assimilated to an high impact mechanical stimulus like that experienced during contact time (\(\sim 200\) milliseconds) in ballistic movements (drop jump or specifico solo 5 pazienti hanno mostrato un lieve incremento dei valori analizzati. Al contrario, nel gruppo dei casi (vibrazioni ed allenamento) è stato evidenziato un notevole aumento del parametro AD-SoS (QUS (\(p=0,002\)), dell’ UPBI (\(p=0,01\)) e del T-score (\(p=0,002\)) (Tabella II), tranne che in un soggetto.

**Discussion**

The magnitude of musculo-skeletal interactions is of paramount importance for the maintenance of bone integrity. Physical activity performed early in life has been shown to contribute to high peak bone mass.\textsuperscript{46} The results of this study confirm the scientific evidence that some forms of exercise, in particular those producing high impact forces, seem to be able to reduce or reverse the age-related risk of bone loss,\textsuperscript{47} whereas low impact exercise regimen doesn't have effects on remodelling bone tissue.\textsuperscript{11} In effect a lack of weight bearing activity could favour a sort of mechanical fragility,\textsuperscript{48} reducing in this way signals critical to the maintenance of bone mass.\textsuperscript{46}

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**Table II**—Mean values ± SD of AD-SoS and UPBI before (Pre) and after (Post) three months in Experimental Group treated with Whole Body Vibration and in Control Group. Statistical differences in either groups were analysed using Student’s t-test for paired observation.

<table>
<thead>
<tr>
<th>QUS Variables</th>
<th>Control Group</th>
<th>Experimental Group</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Pre</td>
<td>Post</td>
</tr>
<tr>
<td>T-Score</td>
<td>-3.69 (0.96)</td>
<td>-3.85 (1.15)</td>
</tr>
<tr>
<td>AD-SoS (m/s)</td>
<td>185 (67.13)</td>
<td>185 (80.50)</td>
</tr>
<tr>
<td>UPBI</td>
<td>0.29 (0.13)</td>
<td>0.28 (0.15)</td>
</tr>
</tbody>
</table>

**Discussion**

La forza delle interazioni muscolo-scheletriche è di grande importanza nel mantenimento della massa ossea. È stato dimostrato che l’attività fisica, eseguita sin dalla giovane età, contribuisce al mantenimento di un elevato valore di massa ossea.\textsuperscript{46} Il risultato di questo studio conferma l’evidenza scientifica che alcune forme di esercizio, in particolare quelle che producono alte forze di impatto, sono in grado di ridurre o invertire la perdita ossea.\textsuperscript{47} Al contrario esercizi a basso impatto non hanno effetto sul rimodellamento del tessuto osseo.\textsuperscript{11} In effetti la mancanza di attività che prevedano forze di impatto può favorire una sorta di indebolimento dei tessuti e, di conseguenza, determinare la riduzione di quei segnali fondamentali nel mantenimento della massa ossea.\textsuperscript{48} Le vibrazioni rappresentano un forte stimolo per le strutture muscoloscheletriche poiché il corpo necessita di variare velocemente la rigidità muscolare per contrastare la perdita di massa ossea. Questa ipotesi è fortemente sostenuta dagli effetti di questo tipo di trattamento a livello muscolare. Le vibrazioni, infatti, sono state giudicate un valido metodo per ottenere un considerevole incremento della resistenza e della forza muscolare a seguito di un trattamento di breve\textsuperscript{22, 23} o lunga durata.\textsuperscript{49} L’entità della risposta osservata nel nostro studio (aumento del 57% del T-score misurato con QUS) è sorprendente. Pensiamo che un trattamento con vibrazioni di questo genere (alla
high jump, high velocity run), enough to influence the bone tissue remodelling. Moreover, also some influence from hormones could have determined such a remarkable adaptation to vibration treatment considering that the total exposure time to vibration was relatively short. In fact vibration has been shown to acutely increase testosterone and growth hormone levels in healthy individuals following the same protocol used in the current experiment. Taking into consideration the results of these preliminary studies it would not seem farfetched then to suggest that the combination of high-frequency mechanical stimuli and hormonal responses provided by vibration could represent an anabolic signal to musculo-skeletal tissues. The higher improvement obtained in these study respect to the results present in scientific literature, could be due to different factors. One of these, associated to the overestimation of QUS measurement, following our opinion, could regards the effects of incommensurable vibration transmitted by metal bar to the hand directly, determining a local effect that could not completely representative of proper skeletal specific sites of the QUS measure. However, the present findings demonstrate, the effectiveness of high impact stimulus of vibration exercise on bone tissue and provide support for its use as a non-pharmacological intervention to prevent and/or reverse bone loss in humans.

These preliminary studies are promising, longer term, larger population scale studies must be performed in order to verify the effectiveness of vibration treatments and its combination with exercise regimen on the spine and the lower limbs to prevent bone loss falls and related bone fractures.

References/Bibliografia
13) Vuori I. Health benefit of physical activity with special reference to interaction...