

Shake off Illness  
&  
Move into Fitness

# Vibration Therapy

Dr Dan Jan , MD



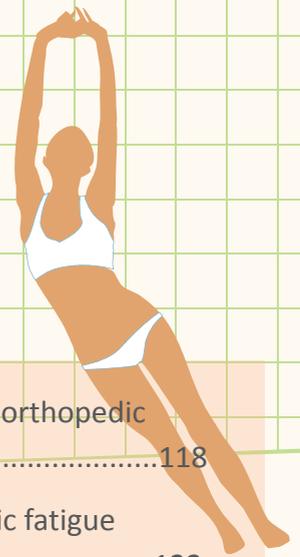
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# Quotations from leading experts of the world in vibration therapy

**“A whole-body vibration therapy for osteoporosis is the state of the science”**

-Professor Robert L.Kane from Minnesota state university, USA

**“WBV training is effective for reducing the risk for osteoporosis by increasing lumbar BMD and leg strength”**

-Professor von Stenfel S from University of Erlangen-Nueremberg, Germany

**“The whole body vibration does not affect the bone resorption but may lead to an increase in bone formation”**

- Dr Corrie H from Loughborough University , UK

**“Interestingly, well controlled vibration may be the cure rather than the cause of lower back pain”**

- Dr. Rittweger J from the Freie Universität Berlin, Germany

**“Controlled whole body vibration can improve elements of fall risk and health-related quality of life in elderly patients.”**

-Dr. Olivier Bruyere from WHO Collaborating Center for Public Health Aspects of Osteoarticular Disorders

**“WBVV training is as efficient as a fitness program to increase isometric and explosive knee extension strength and muscle mass of the upper leg in community-dwelling older men.”**

- Dr. Bogaerts AC from Catholic University of Louvain, Belgium

# Quotations from leading experts of the world in vibration therapy

**“These results suggest that WBVV acutely decreases arterial stiffness.”**

-Professor Otsuki T from St. Catherine University, Minnesota, USA

**“Translated to the human, this may represent the basis for the non-pharmacologic prevention of obesity and its sequelae, achieved through developmental, rather than metabolic, pathways.”**

-Professor Rubin CT from Stony Brook University, New York, USA

**“An 8-week WBVV training is effective in inducing positive body composition changes as well as increased muscle strength in women; it could be recommended as an alternative/complementary tool in physical activity or fitness programs.”**

-Dr Milanese C from Verona University, Italy.

**“Low-magnitude, high-frequency mechanical stimulation improves bone strength in the proximal femur and may be a possible nonpharmacologic treatment option for postmenopausal osteoporosis.”**

-Dr Tezval M from Georg-August-University of Goettingen, Germany

**“WBV training may have the potential to reduce VAT more than aerobic exercise in obese adults, possibly making it a meaningful addition to future weight loss programs.”**

-Professor Dirk Vissers, Antwerp University Hospital, Antwerp, Belgium

**“Vibration exercise may be an effective and low time consuming tool to enhance glycemic control in type 2 diabetes patients.”**

-Dr. Klaus Baum from the German Sport University Cologne, Germany

**“WBVV induces hyperventilation that might activate the pre-frontal cortical region, thus influencing cerebral responses through neuronal activation.”**

- Maikala RV from Liberty Mutual Research Institute for Safety, MA, USA.

**“These results suggest that tiny acceleratory motions--independent of direct loading of the matrix--can influence bone formation and bone morphology. “**

- Dr. Garman R from New York University, New York, USA

**“In individuals with total knee arthroplasty, both whole-body vibration and traditional progressive resistance exercise showed improved strength and function.“**

-Dr. Johnson AW from Brigham Young University, Utah, USA

**“A 6-week traditional exercise program with supplementary WBVV safely reduces pain and fatigue, whereas exercise alone fails to induce improvements.“**

-Dr. Alentorn-Geli University of Barcelona, Spain

**“Mechanical stimuli can be regarded as an additional device in PD therapy. “**

-Professor Haas CT from Goethe-Universität, Frankfurt, Germany

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**“Results of this initial investigation provide support for vibration therapy as a non-pharmacological treatment alternative.”**

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**“Whole-body vibration is a suitable training method to improve knee extension maximal strength, counter-movement jump, and flexibility in a young female athlete. “**

- Dr Fagnani F from University of Rome, Italy

**“Whole-body vibration is a suitable training method to improve some physical variables and the skill performance level on the horse jumping (front handspring) for female gymnastics students if it is properly designed.”**

–Coach Hameeda AA from Zagazig University, Egypt

**“Whole-body periodic acceleration with a horizontal motion platform improved vascular endothelial function in sedentary adults. This device might offer an alternative to active exercise for patients whose medical condition limits physical activity. “**

-Professor Matsumoto T from Shiga University of Medical Science

**“The whole body periodic acceleration (WBPA )improves coronary flow reserve (CFR) in healthy subjects and patients with coronary artery disease.”**

-Professor Shota Fukuda from Department of Medicine, Osaka Ekisaikai Hospital, Osaka, Japan

**“Treatment with WBPA for angina patients ameliorates exercise capacity, myocardial ischemia and LV remodeling through central and peripheral effects. The development of such a therapeutic modality will open a new field of the treatment of angina patients with old MI. “**

- Dr. Miyamoto S from Kyoto University, Japan

**“Periodic acceleration may provide a novel, affordable, non-invasive therapeutic option for the treatment of stroke.”**

-Dr. Martínez-Murillo R from Instituto Cajal, Consejo Superior de Investigaciones Científicas (CSIC), Madrid, Spain

**“WBPA is a novel method to induce eNOS and nNOS production in the endomyocardium. Therefore, WBPA may serve as a powerful non-invasive intervention to activate the beneficial cardiac effects of endothelial and neuronal NOS”**

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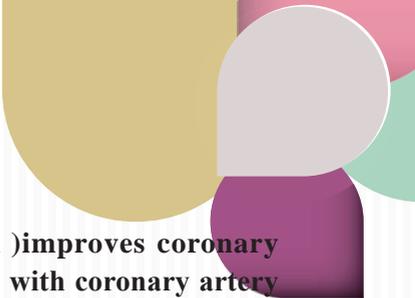
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## Preface

No one likes bitter drug or bloody surgery. All patients wish their doctors prescribe them panacea. So they can stay healthy but no need to take drugs, injections and operations. Therefore, there is no pain or side effects. However, this is a dream. There is no such reap-without-sowing thing. If it does exist, it actually all comes from us. For example, healthy diet, regular exercise, sufficient sleep, proper weight, adequate pressure, good emotional management, no smoking or binge alcohol, and having health check regularly. But for human nature, the easy thing is always hard to do.

Actually, I had same dream as my patients did. I looked for panacea from my clinical practice, new published journals or scientific magazines. Luckily, after a decade of diligent search, I found a closed “magic recipe”. The panacea is called “whole body vibration”. It is very easy and simple to do. Actually, you need not to do anything. What you need to do is standing on a vibration platform (or just lie on it) for 10-20 minutes a day. It can improve your health or improve your diseases. It is not an intervention procedure nor is it a drug. It is a passive exercise. I call it a panacea because it is so useful for health. Its effects are beyond one organ or one disease. I will introduce detail in the book. Roughly say, it can help prevent osteoporosis, improve cardiovascular diseases, prevent obesity and diabetes. It can also help increase muscle power, physical performance, balance and coordination, and improve many chronic disable diseases. It can help all kind of people including the elders, postmenopausal women, young men, children, athletes, and the disabled such as those who had stroke, cerebral palsy, Parkinson’s disease, chronic obstructive pulmonary disease, chronic constipation etc.

I know this may sound exaggerating to our smart readers. You won’t believe unless there are solid evidences. Therefore, in order to prove it, all statements in the book I will quote scientific studies and the published papers will be attached as references.

Moreover, the goal of publishing this book is not only to share good things with friends, but also to promote the whole body vibration exercise. This unique passive exercise is invented to help those who need or want exercise but are unable or difficult to do that. The most exciting thing is that this is a non-intervention, non-pharmacologic and affordable exercise with rarely- seen adverse effects.

The modern city lives have taken away the opportunity of exercise for most of people. As the book will discuss, “urbanization, obesity, and aging”, three phenomena led to many chronic diseases and caused huge damage to individual person and the whole society.

The whole body vibration exercise can help to repair the problems based on thorough scientific studies in the past 30 years. It does not only play a role for individual, family, and community to prevent diseases, but also work as a wise alternative to treat diseases or promote health.

My first contact with whole body vibration can trace back to 20 years ago. During 1990, while I was studying in School of Public Health of Harvard University in Boston, I had a chance to do homework regarding to vibration therapy. Later on, while I was working as medical director in the Novartis Pharmaceutical Company of Switzerland (2002-2007), I was responsible for clinical trial for a new osteoporosis drug- “Aclasta or Zometa”. After studying a great number of papers regarding to osteoporosis treatment, whole body vertical vibration popped out and caught my attention.

In 2008, I worked in a weight nutrition clinic in Taipei with other physicians. We used whole body vibration device to help people lose weight on daily practice. The patients loved it and the results were outstanding. Therefore, I collected related data and tried to write a book for people interested in this special exercise.

While writing this book, I try to write a book easy to read but also hope it can be used as a tool by my colleagues, physicians, teachers, scholars, and athlete trainers. It became a catch 22 to meet both needs. At the end, as you know, this book is a little academic to read. Today, whole body vibration is becoming a promising modern medical technology. It is now applied in new medical fields like “mesenchymal stem cell mechanobiology”, “tissue bioengineering” or “regenerative engineering”.



(Figure 1) A German scholar Dr. Wim visited the author in 1997. We discussed about the vertical vibration therapy and shared the experiences.

## Book Introduction

Some people may ask why Isaac Newton is great. Newton only discovered an apple falls to the ground and not soars to the sky. This is a joke. The gravity is really the ultimate power of the universe. Human being as well as other creatures on the Earth was born to adapt the gravity through hundred millions years of evolution. Their bodies, organs and functions are actually the result of chronic adaption to the earth gravity. However, as we are not aware of the oxygen in breathing, it is hard to discover its giant influence in our daily life. It was not until the gravity change, people realized their tremendous influence. For example, astronauts can't live in the low gravity airspace too long, otherwise, their muscle and bone will degenerate. Similarly, fighter pilots may face several gravity pressures during flight. This drastic gravity change may cause the pilots to coma, even crash their planes. This means that gravity change will lead to substantial impact to health of animals or human beings.

**To put it simple, the basic principle of whole body vertical vibration is based on the gravity change. The change can first affect the musculoskeletal nervous system, and then the endocrine and other physiological systems. In the end, it benefits our health.** Whole body vertical vibration machine uses mechanical force to push the body upward, and then let it fall down naturally by gravity. Just like rope jumping, playing basketball or race hurdles, there was strong impact on feet when the body leaves and touches the ground repeatedly. Whole body vertical vibration machine imitates this kind of exercise but much faster and can do it passively. The frequency of the vibration is always as high as 5-30 beats per second.

Our readers may be surprised how many body systems are involved in the whole body vertical vibration. These include skeletal system, muscular system, balance system, cardiovascular system, endocrine system, neurological system, metabolic and energy system, as well as respiratory system. After reading this book, you will see it does only take you 20-30 minutes a time, 3-5 times a week on this device. You will not feel exhausted or sweating but it will generate marvelous and extensive effects on your health. Honestly, it is beyond our imagination if it weren't because of the mighty gravity power.

The content of this book is separated into two parts: whole body vertical vibration and whole body horizontal vibration. Each consists of different theories, and

conducted by different equipments. Their medical functions are quite different as well. But they both belong to vibration therapy. Therefore, I put both of them into this book for readers.

In the vertical vibration part, this book will first introduce its theory and history. Then, it will discuss how it can benefit out health. Because vertical vibration machine was first invented to train astronauts to prevent their bone loss, there are most research papers on this topic. The studies were comprehensive. It included in vitro studies, stem cell studies, rat experiments, large mammal's experiments and clinical trials on postmenopausal women, adults and adolescents. Our readers can read many interesting studies with positive outcomes.

Secondly, we will discuss how whole body vibration helps strengthen muscles and improve coordination. Not only teenagers but also the elders, this exercise will lead to progressive improvement on their health. It will also reduce their back or joint pain. Certainly, their quality of life will be imprvoed.

Cardiovascular disease is recognized as the top killer of the middle-aged and elder people. It maintained top 1 of mortality ranking in US for decades. In chapter 9, we are going to talk about how whole body vibration can improve and prevent many kinds of cardiovascular diseases.

Obesity is abnormal accumulation of fat in subcutaneous or visceral tissues. Many studies of whole body vibration have been proven that it can inhibit fat storage. Traditional ways to control weight is either exercise to boost the metabolism or get on diet to reduce calorie intake. Surprisingly, whole body vertical vibration is an unprecedented new way to reduce the body fat. This pathway is through the change of stem cell differentiation and can be called "the revolution way". It can be applied alone, or combined with traditional diet, exercise or medications. (Chapter 10)

Obesity and diabetes are always identified as twins. "Diabesity" was dubbed because both obesity and diabetes often come together. Both dieases have similar risk factors. After discussing obesity, I will then move on to improve diabetes as well as to ameliorate the diabetes neuropathy. Some clinical trials have proved the effect of whole body vertical vibration can lower blood sugar and to be a method of treating diabetes. (Chapter 11)

In chapter 12, I will discuss an issue which many parents and children care – body height. Many advertisements boasted their products able to help youth taller but without any medical evidences. WBVV could stimulate the pituitary gland to increase growth hormone after vibration. It will stimulate the mechano-sensors in epiphyseal plate, which is composed of soft bone and is the center of growing tall. Vertical vibration will act on osteoblasts to generate new bone. WBV can inhibit bone absorption by osteoclasts as well. All of these are why WBVV help stimulate the growth of children and prevent short stature or bone insufficiency.

In chapter 13 to chapter 20, I will talk about how whole body vibration helps various chronic diseases., including cerebral palsy, arthritis and post-spine or joint surgery, fibromyalgia, Parkinson's disease, multiple sclerosis, chronic fatigue syndrome, chronic obstructive pulmonary diseases, chronic constipation etc. Many of them are not curable in modern medicine including Parkinson's disease, injury of spinal cord, cerebral palsy, multiple sclerosis. WBVV has been proved to be effective to help these patients.

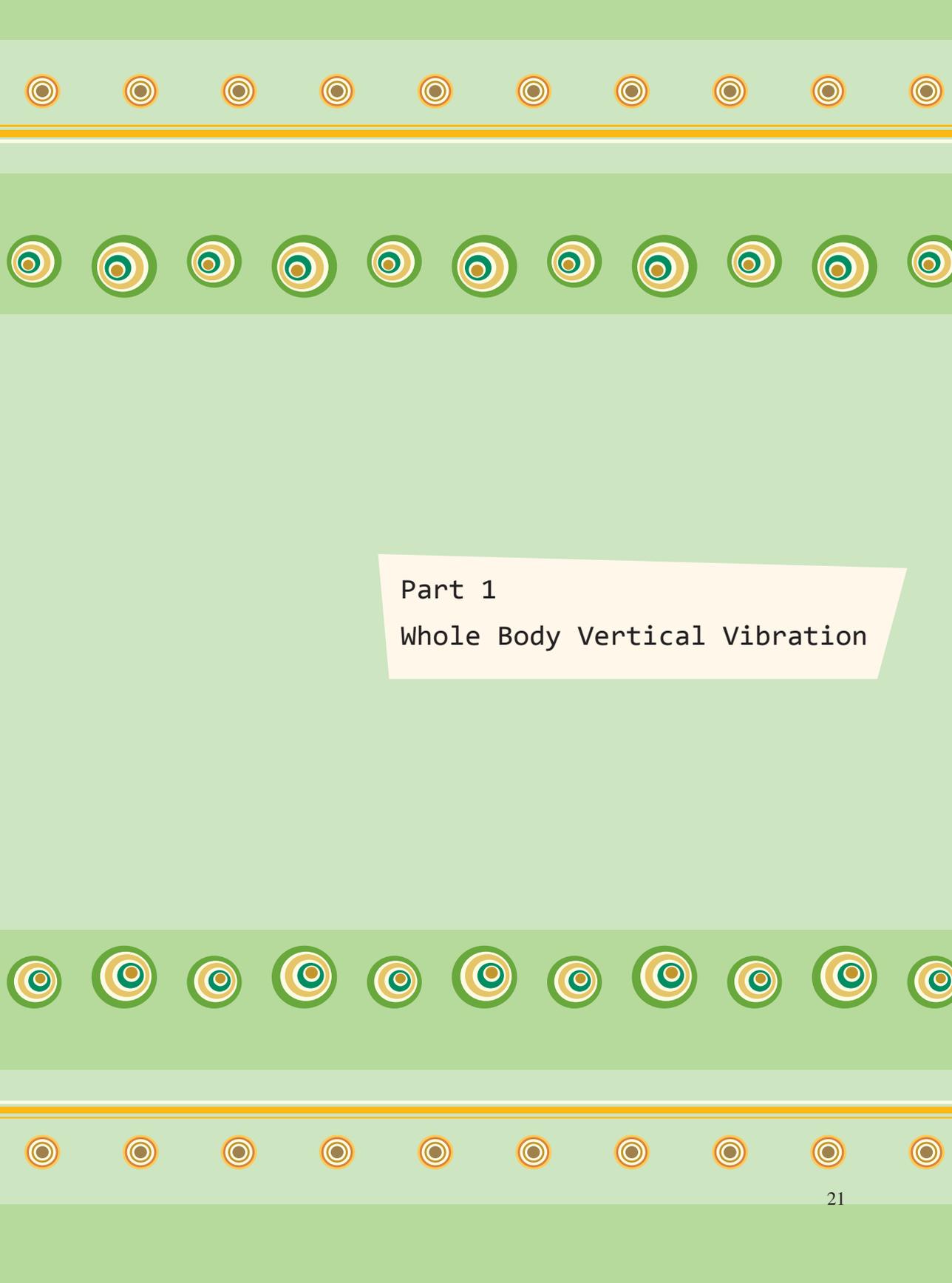
Also, I will talk about the benefits vibration brings to the the youth. Not only does it improve their exercising functions but also the cardio-pulmonary fitness. For athletes, it can improve their explosive strength, flexibility, muscle power, balancing, vertical jump and endurance. Interestingly enough, not only does it work on human athletes but also their animal counterparts like racing horses or racing dogs.

How come WBVV has such strong and extensive effects? In Chapter 24 its theory and mechanism will be explored. WBVV can boost muscle strength, vertical jump, joint stability and balancing based on “tonic vibration flex”. This reflex is a muscle contraction reaction in order to maintain our body balanced under vibration. Besides, hormone secretion and change of myoblast (original muscle cell) after vibration are also involved. Why vibrations can increase bone density? This is because vibration stimulates mesenchymal stem cells. These stem cells will change their differentiation route to increase bone cell and inhibit fat cells.

In chapter 25, I'll discuss how different hormones work and their functions after whole body vibration. Whole body vibration does not only stimulate the body physically, but also changes hormone in our body. After vibration, hormones change has been observed by scientists. These hormones include (1) adiponectin, (2) osteocalcin, (3) transforming growth factor-beta1, (4) nitric oxide, (5) osteopontin, (6) Growth hormones, GH, (7) Testosterone, (8) tPA and PAI-1. In chapter 26, safety precautions will be mentioned.

Chapter 27 will be the second part of this book. The whole body horizontal vibration will be fully elaborated. This type of horizontal vibration is also called “whole body periodic acceleration (WBPA)”. WBPA is a special designed vibration bed which people lay on it. Rhythmic horizontal vibration was applied to them in the direction of head to toe. Their functions are based on shear force produced by vibration. Shear force can stimulate endothelial cells to secrete nitric oxide (NO), which will dilate blood vessels, increase oxygen perfusion and protect cardiovascular organs.

Also, WBPA can prevent and improve ischemic heart disease, reduce myocardial infarction, treat pulmonary hypertension and peripheral vascular disease. WBPA is often used in emergency room as a assistant device to save lives. WBPA used whether before, after or in the middle of cardiopulmonary resuscitation, it does not only increase survival rate but also decrease the complications. WBPA is an effective and noninvasive powerful tool for doctors and patients to prevent and treat cardiovascular diseases and cerebral strokes.



Part 1  
Whole Body Vertical Vibration

## Chapter 1 Predicament of modern living

### Introduction

*Due to the radical changes of the technology and society, three phenomena have occurred today. They are known as urbanization, obesity, and aging. Because the city is always overcrowded and busy, people feel tension and pressure all the time. There's no enough space or time for them to exercise. Even the life span is extended, people are actually not healthier. Obesity and aging impacted our ability to exercise, which also lead to many chronic diseases. Lots of people have no time engaging in regular exercise, which has influenced their health seriously. This group of people needs an effective whole body passive exercise to recover their health.*

### (At a corner in the city)

#### Scene 1

A doctor advised a fat lady, “You need to exercise more, lose some weight, or your diabetes will be out of control.” The lady asked, “What kind of exercise shall I do?” The doctor replied, “Jogging or walking.” The lady said, “My knees hurt when jogging.” The doctor said, “How about swimming, swimming will be good too.” “Swimming? I don't dare to wear a swimsuit now, and there's no pool near my house... Can I swim in my bathtub?”

#### Scene 2

After going through the patient's report, the doctor said to patient, “Your waistline, blood pressure and blood cholesterol are too high, did you do exercises as I have told you before?” The middle-aged man replied with a bitter smile, “I'm too busy recently; I don't even have time to sleep.” “What about on weekends?” The man replied, “That's the time I get to sleep more.” The doctor shook his head and went on, “Would it be possible for you to get a treadmill at home. You can walk while watching TV.” “My living room is too small for that, does the massage chair have the same effect?”



### Scene 3

After the lumbar spine surgery, the old man asked the doctor how to take care of his body. The doctor replied, “Be careful when you walk, you are weak right now, it can be really dangerous if you fall.” The old man said, “What should I do then?” “Exercise regularly; it will definitely increase your muscle power.” said the doctor. The old man went on, “My legs are too weak to walk.” Then the doctor suggested him visiting hospital for rehabilitation. The old man questioned, “For only one time?” The doctor replied, “No, five times a week for 6 months to 1 year.” “Can I do it at home?” The old man questioned. “Probably not. You don’t have the equipments.” The old suddenly burst into tears, “Then what should I do? No one can take me to the hospital.”

## 1.1 People suffered from these 3 phenomena

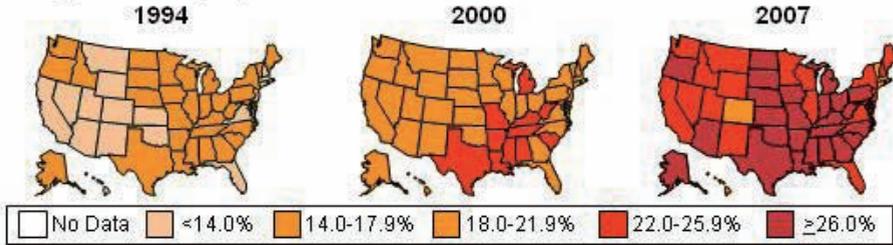
I believe most people are quite familiar with the situations above. According to the data of Taiwan in 2011 (population 23 millions that year), the elderly population is 2.5 million (11%); the population of the overweight and obesity is 4.5 million (19.5%), and that with the diabetes is 1.2 million (5%). The numbers have grown a lot since 1990. These phenomena do not only occur in Taiwan but also in other countries. (Figure2) People getting fatter and fatter have become a trend worldwide. People tend to get chronic and geriatric diseases as they are old. Obesity and aging, to be strict, are the results of the progress of modern science and medicine. In the past century, technology and medicine have advanced in leaps and bounds. It helps to improve the quality of our life. At the same time, it changes the environment as well as the pattern of diseases.

Take obesity as an example, 200 years ago, many people died of hunger. Thomas Robert Malthus (1776-1834), a famous demography scholar, once pessimistically predicted that the world would have one third of people starved for food deficiency. Ironically, thanks to the progress of science, people died of obesity today but not hunger. Today, in the United States, only one in three people has normal weight, the other two are either overweight or obese.

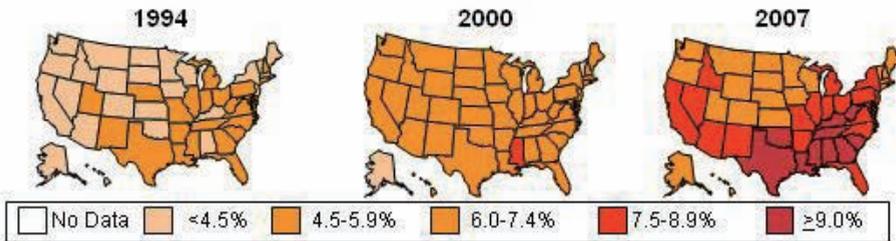
Talking about longevity, in the past thousands of years, people die of infectious diseases and malnutrition. Even in the late 19th century, average lifespan of Americans was only 40 years of age. The average lifespan of Americans today is 80 years old. People in some countries like Japan even live longer. To put it simply, the impact that the

technology and medicine had brought has led to the three phenomena - “urbanization, obesity, and aging”.

**Obesity (BMI  $\geq 30$  kg/m<sup>2</sup>)**



**Diabetes**



(Figure 2) Obesity and diabetes are often connected together. The upper one indicates the percentage of people who are obese in US; the lower indicates the percentage of people who have diabetes.

**1.1.1 Urbanization**

200 years ago, nine tenths of world population engaged in agriculture. 100 years ago, the figure was two thirds of world population. But until 2000; only 5% of the world population are still working in this ancient industry. Thanks to the rise of service industry as well as commerce, more and more people from the countryside swarm to urban city.

Big cities like Shanghai, Tokyo, New York, have over 10 million population . Countless cities accommodate millions of citizens. In the crowded city, every piece of land is valuable. There are not many green areas; even the living places are limited as well. It makes it difficult and expensive for the citizens to exercise. What’s more,



the mass transportations are so convenient in the city that most people take buses and elevators instead walking. Due to the long working hours, and the pressure from work, even for those who want to engage in sports and exercising, the limited time and space has restrained them from doing so. Therefore, urbanization has led to many chronics.



(Figures 3) Urbanization results in overcrowded cities. People in city are often too crowd and too busy to do exercise

### 1.1.2 Obesity

Compared to agricultural industry, the service industry as well as commercial industry required less labor power. Instead, they let the machines take over the jobs. Human beings no longer need to work hard physically. Plus, the development in commerce, food is easy and cheap to obtain. That's why people are getting fatter. Here comes the second impact of modern technology - obesity.

Obesity is the cause or major risk factor of many chronic diseases like hypertension, diabetes, heart disease, several kinds of cancers, and degenerative joints diseases. Take one thing for example; the diabetes mellitus was classified into two types, type I is juvenile type and occurred in the young children, type 2 is adult type which usually



strikes people in their middle age. However, type 2 DM now happens to the younger generation whose ages are under 30, who are most overweight or obese. What's even worse, once people put on more weight, it becomes more difficult for them to exercise. The reason is that our lower limbs need to support 2-3 times of our weight when we walk; 5-6 times of our weight when we run. Therefore, obesity will eventually cause early degenerative knees and pelvic arthritis. It is only getting worse once you cannot exercise.



(Figure 4) Modern people are getting fatter, which eventually leads to all kinds of chronics.

### 1.1.3 Aging

The third impact that technology has caused was the fact that humans' life span has been extended. Though it is wonderful to live longer and longer, human's organs still degenerate days by days. A lot of diseases start popping up once they reach the



old age, such as osteoporosis, joint degeneration, muscular dystrophy, coronary heart disease, cancer, stroke, Parkinson's disease, and Alzheimer's disease, etc. They deeply affect the elders' health and their quality of life. Furthermore, due to the low birth rate, taking care for the elders becomes a huge burden for the younger generations.

Unfortunately, these three phenomena cannot be cured by medicine. In fact, they are the by-product of the progress of medicine and technology. People exercise less because of these three reasons. The lack of exercising leads to the degeneration of our bones, muscles and cardiopulmonary function. These problems will deteriorate as time goes on and result in serious chronics and even disability.

To solve these problems, there are several solutions. For example, run on a treadmill at home or work out in the gym. Take the stairs sometime rather than taking the elevator. However, to practice those equipments like treadmill still requires a certain degree of muscle power and body coordination. These kinds of active exercises might be hard for the disabled or multi-disease patients to apply. Thus, a safe and effective passive exercise was invented to meet this new century's need.



(Figure 5) There are more and more elders in Taiwan just like other developed or developing countries. Aging is a major cause of chronic diseases and disability

## Chapter 2 Development of whole body vibration

### Introduction

*Passive exercise is to work out via machines instead of the person himself. It can be divided into two kinds, one only works on part of your body; the other one works on your whole body. Dr. Kellogg invented the very first vibration machine in 1900. On the other hand, the modern vertical vibration machine was invented by the Soviet Union in 1960s.*

*The astronauts' muscles will atrophy if they live under the weightlessness for too long. As well as their spines, hipbones will run off at the rate of 1-1.6% per month. That's why they can't stay in the weightless environment for a long period of time.*

*In order to solve this problem, scientists in Soviet Union invented the whole body vertical vibration machine to help train those astronauts. American astronauts could only stay in the space for about 300 days. However, through the training, the Soviet's astronauts can stay there up to 437 days. Whole body vertical vibration machine later served as the training method for athletes. Now this invention has been extendedly applied to many other medical fields.*

“Active movement” indicates that the bodies were moved by humans’ own will, such as walking, dancing, swimming, ball games or gymnastics, etc. On the opposite, “passive movement,” can be identified through its literal meaning, bodies are moved passively by machines or other people. Basically, passive movement can be divided into two kinds. One is called local passive movement and the other whole-body passive movement.

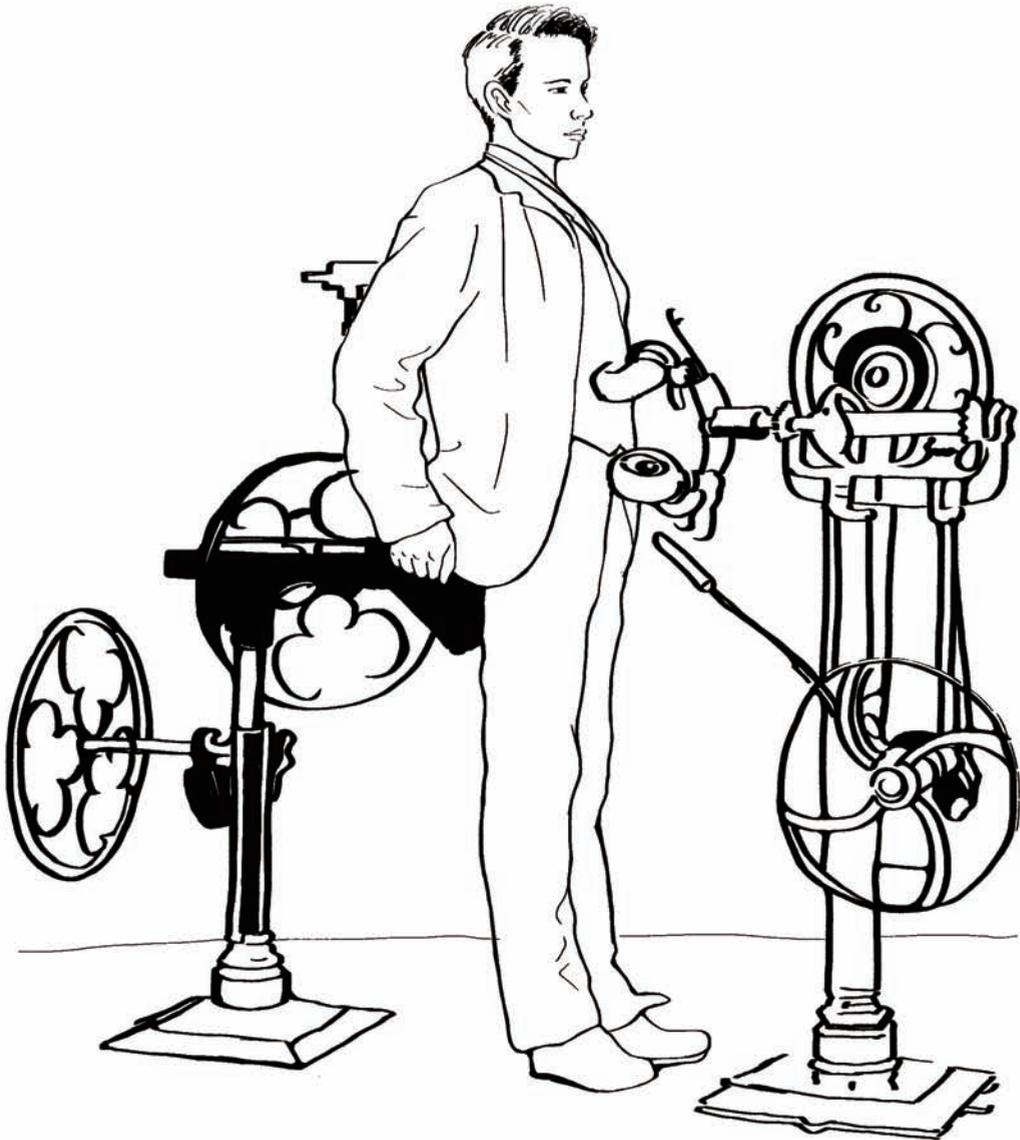


## 2.1 Local passive exercise

The most common local passive exercises are massage and rehabilitation. Both exercises need others' assistance. Nevertheless, there are many massage equipments can be seen in the market right now. Generally, this belongs to focal vibration and only stimulates the skin and a small group of muscles. It increases the blood circulation in some area as well. However, it only affects some parts of the body but not whole body. Currently, "transcutaneous electronic nerve stimulation," known as TENS was approved by FDA indicated for reducing pain in clinical use. And the other one is to help the patients of chronic obstructive pulmonary disease to spill out the sticky sputum. This is known as the "high-frequency chest wall vibration oscillation" which was often used in the chest wards.



(Figure 6) TENS is a kind of passive exercise but work only in some parts of body



(Figure 7) Dr. Gustav Zander, a doctor from Sweden, invented this focal vibration machine in 1880.

(Figure 8) Popular waist vibration during 1950s





(Figure 9) An American doctor John Harvey Kellogg invented the waist belt vibration machines in 1897, which later on became quite a fashion (Courtesy of Lifestyle Laboratory)



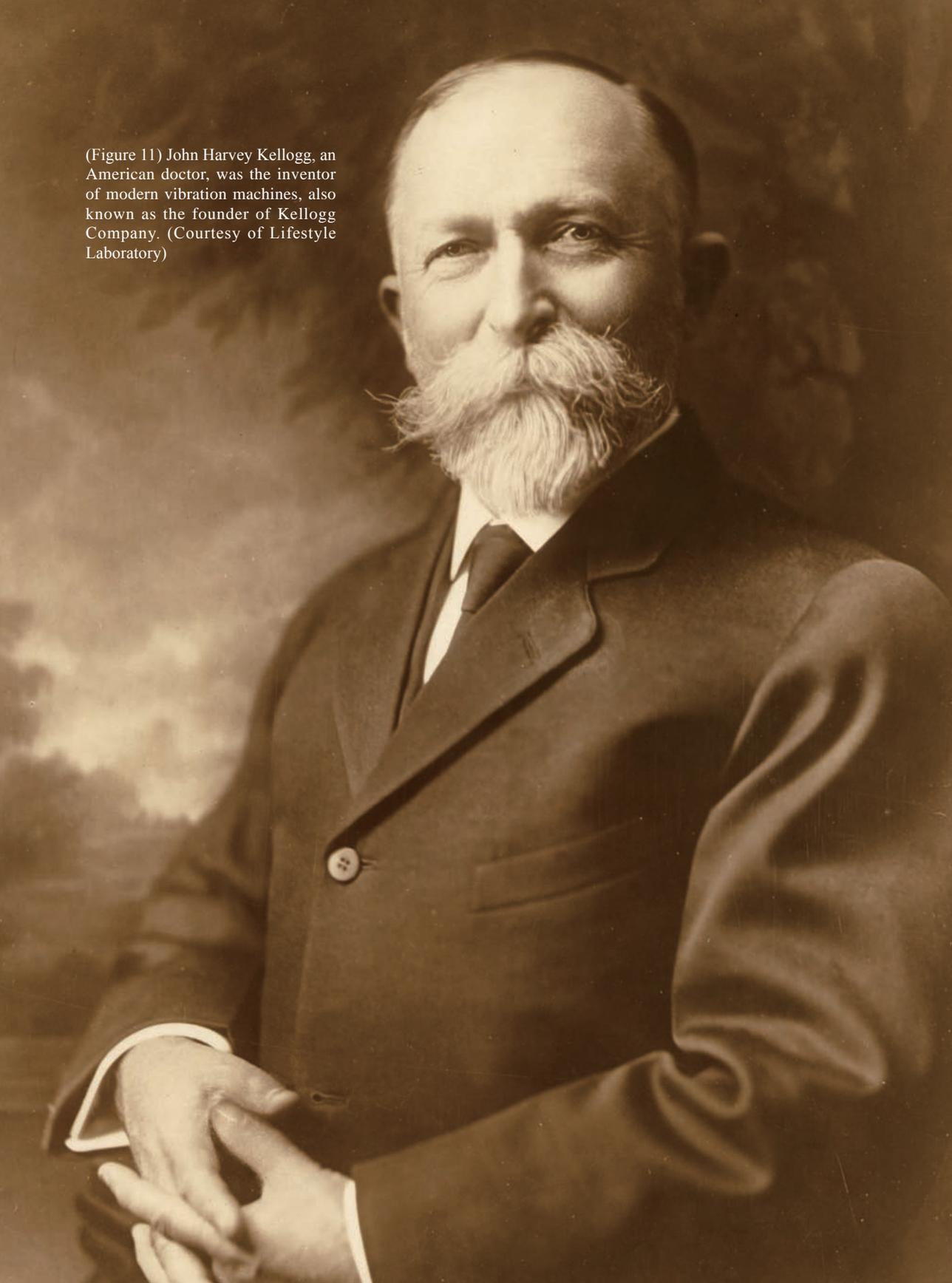
(Figure 10) High-frequency chest wall oscillation machine helps chronic obstructive pulmonary disease patients to remove sputum

## 2.2 Whole-body passive exercise in early stage

Dr. John Harvey Kellogg was the first one invented modern vibration machines. He is also known as the founder of the famous Kellogg breakfast cereal. He has invented more innovative rehabilitative equipments in the well-known Battle Creek Sanitarium in Michigan, U.S.A last century.

In 1895, in the Battle Creek, he designed a mechanical vibration chair. It could vibrate while the patients were sitting on it. He also designed a foot massage machine, which can be used by 2 or 4 people at once. The popular horseback riding fitness equipment was his invention as well. He eventually got the reputation of the father of passive exercise. The vibration chairs have the same principles as the modern vertical vibration machines. It can be viewed as the prototype of modern whole body vibration machines.

(Figure 11) John Harvey Kellogg, an American doctor, was the inventor of modern vibration machines, also known as the founder of Kellogg Company. (Courtesy of Lifestyle Laboratory)





(Figure 12) Whole body vibration chair machine(Courtesy of Lifestyle Laboratory)



## Part 1: Whole Body Vertical Vibration

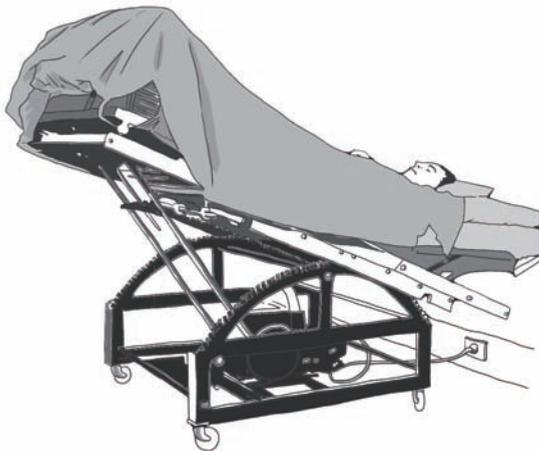
(Figure 13) Horse-riding vibration machine, invented by Dr John H Kellogg in 1900(Courtesy of Lifestyle Laboratory)





### 2.3 Whole body vertical vibration therapeutic approach

In 1950, poliomyelitis spread wildly around the whole world. Many children and teenagers were sick and their low limbs were paralyzed. They are so ill and have to lie on bed. Physiologist Whendon GD noted that those patients lost a great deal of nitrogen and calcium. Eventually, their muscles and bones became disuse atrophy. During the acute stage of poliomyelitis, patients were unable to get off from bed. What's even worse, it could impact their ability to breathe normally. Far back in 1949, he invented a similar whole body vibration bed. He called it rapid-rocking bed. The study showed that this equipment could increase the muscle strength as well as the breathing capability. His study was published in the famous New England Journal of Medicine and immediately his rapid-rocking bed became overnight sensation.<sup>(89)</sup>



(Figure 14) Physiologist Whendon GD invented the rapid-rocking bed in 1936. People who had heart problems seemed to benefit from this invention. Through electrical mechanical process, rapid-rocking bed would move up and down automatically to help the blood circulation.

## 2.4 Modern whole body vertical vibration

The modern whole body vertical vibration machine is the product of space competition between the United States and the Soviet Union. For astronauts stayed in zero gravity aerospace, studies showed that their muscle became atrophy rapidly and bone density lost 1-1.6% per month.<sup>(134)</sup> (Figure 15). If this problem could not be solved, astronauts won't e able to stay in outer space for too long. To solve this problem, scientists from Soviet Union invented a machine to train their astronauts. American astronauts could only stay in the space for about 300 days. However, through the training, the Soviet's astronauts can stay there more than 400 days. The Soviet's astronaut Valeri Polyakov even made the record of staying in the space 437 days in a single time, which was the longest record of history.



(Figure 15) Astronauts will lose 1-1.6% of their bone per month in airspace



## Chapter 3 Principles of Whole-body Vibration

### Introduction

*Through mechanical force, the whole body vertical vibrations generate a force against the gravity. Once the power is gone, humans are drawn back to the ground. Applying this kind of mechanism over and over again, it yields a force of impact of going up and down rapidly. This will stimulate the whole musculoskeletal nervous system. If the vibration is too strong or irregular, it could do harms to the body. Such as people who work on air drill will usually got neuromuscular vascular lesions.*

*Therefore, there are three variables that need to be concerned. They are direction, duration and intensity. The strength of the vibrations is determined by its frequency and amplitude. The unit is gravity (abbrev. g). Vertical vibrations like jumping rope. But jumping rope is an active exercise, with the amplitude of 15-25cm and the speed of 1 jump per minute. On the other hand, for vertical vibration machines, it vibrates at the speed of 1-20 Hz. (It can go up to 35 Hz for athlete training.) The speed of 1 Hz is 1 beat per second, 60 beats per minute.*

*The vertical vibration will normally keep it between 1-10mm. The intensity is usually controlled at 1g. (But it can go up to 3-4g for athlete training.) As you can see, whole-body vertical vibration is a rapid and small amplitude vibration. Even the intensity and direction need to be controlled strictly. Only through this strict control can benefit our health the most.*

These whole body vertical vibrators are based on the mechanical force. They generate a force against the gravity to push it upward. It yields a force of going up and down rapidly and stimulates the whole musculoskeletal nervous system. In fact, it is like playing the jumping rope. Vertical vibrations like jumping rope. But jumping rope is an active exercise, with the amplitude of 15-25cm and the speed of 1 jump per minute. On the other hand, for vertical vibration machines, it vibrates at the speed of 1-20 Hz. (It can go up to 35 Hz for athlete training.)

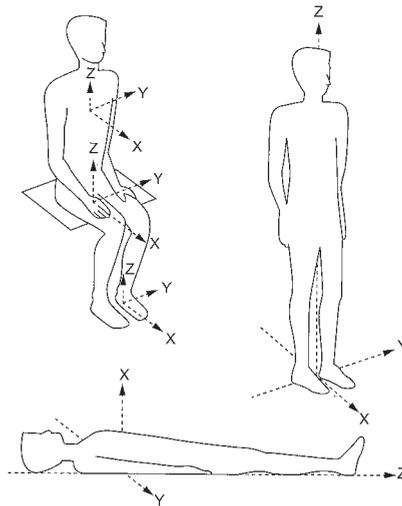
The speed of 1 Hz is 1 beat per second. If it's 10Hz, that means 600 beats in one minute. Except the training for athletes and astronauts, normally the amplitude is only 0.1~1.0cm. This kind of rapid vibration that goes up and down, we call it whole body vertical vibration. (Abbr. WBVV)

### 3.1 The harm of random high-frequency vibration

Vibration is a kind of energy originated from wave propagation in physics. If the amplitude, direction or intensity is not stable, the musculoskeletal and nervous system will hurt. This is what we call the "random vibration". This will definitely do harms to human body. Random vibration is like the turbulence we encounter on the airplane. This will not only make people sick but also cause physical harms.

The random vibration generates not only vertical direction vibration (feet to head, Z-axis) but also the horizontal direction and cross-sectional vibration (butt to belly, X-axis and right shoulder to left shoulder Y-axis). (Figure 16) The vibration that's not under control will produce three directional irregular forces and harm the body.

The uncontrolled and high-frequency vibration can lead enormous damage to human body. Workers in some occupations such as drillers, weeders, sawyers, crane driver, etc, are subject to the vibration injuries. These workers need to hold



(Figure 16) There are three directional vibrations, including X, Y and Z-axis.

on steering wheels or sit on the vibration site, which may produce strong, random high-frequency vibration. These vibrations will cause occupational injuries in a long term, such as peripheral circulatory dysfunction, Raynaud's syndrome, white finger disease, central and peripheral nerve dysfunction, and musculoskeletal disorders. In addition, the neuritis, muscle inflammation, lumbago, headache, vision and cochlear damage, can also happen. (Figure 17)

The frequency of such occupational contact is very high, which can reach as high as 100~500Hz. That is 6,000~30,000 beats per minute. Because of the high amplitude as well, their acceleration (intensity) can reach as high as 10g. However, the therapeutic whole body vibration is usually controlled between 10 to 20 Hz, and the intensity is under 1-1.2g. That is why we call it "low-frequency, low-intensity vibration."



(Figure 17) Random vibration can cause hurts to human body.

### 3.2 Principles of whole body vertical vibration

Three basic conditions are required in order to operate the WBVV effectively and safely. First of all, you need to control its direction. Vertical vibration can only have vertical force; horizontal vibration can only have horizontal force. Other directions of force should be avoided as much as possible.

Secondly, the intensity needs to be under control. The forces are determined by two elements. One is its amplitude and the other is its frequency. Amplitude is the distance between the highest point and the lowest point of vibration wave. Normally, the WBVV vibrates from 1mm to 1cm. As for the frequency, normally we use Hz to calculate it. It varies from 1 to 20 Hz. 1 Hz means one beat per second, aka 60 beats in one minute. Using these two elements, you'll get the real force through calculation, that we call it "gravity." (g) Except for athletes, military soldiers or astronauts' training, the force is usually controlled less than 1-2g.



## Part 1: Whole Body Vertical Vibration

Lastly, the time needs to be controlled as well. The longer it vibrates; our bodies will receive more pressure. Usually, the time is set at 10-20 minutes each time; but for the more appropriate time is determined by the intensity and your goal while operating the WBVV. Manuals are provided on the machines, you are recommended to read it beforehand.

The proper noun for the force of vertical vibration is called “Gravitational Acceleration.” It can be calculated as the following formula.

$$a = 2A \times (\pi f)^2 / 9800$$

“a” represents acceleration, the unit is “g.” “A” represents the amplitude; the unit is mm. “f” represents frequency, with the unit of Hz. “ $\pi$ ” is the constant 3.14.



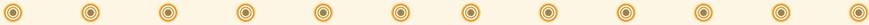
## Chapter 4 Benefits of whole body vibration

### Introduction

*There are multiple benefits of vertical Vibration. There are thousands of researches and documents about whole body vertical vibration, as it has existed for decades. Not only has it proved the fact that it can prevent osteoporosis, increase the muscle strength and coordination, but also found that it can help multiple diseases such as spinal cord injury, stroke, cerebral palsy, and Parkinson's disease, etc.*

*In addition, problems like obesity, growth retardation, or functional disorders like chronic constipation, fibromyalgia and chronic fatigue syndrome have received positive results through WBVV.*

*Recently, vertical vibration has expanded beyond the field of sports and became a non-pharmaceutical and non-invasive treatment in medical science. It is now called the "Vibration Therapy" or "Dynamic Motion Therapy."*



### 4.1 Non-pharmacological Vibration Therapy

The WBVV was invented by scientists of Soviet Union in order to help astronauts to stay in aerospace. Because there's no gravity in the space, their muscles and bones of these astronauts become weak and fragile gradually. WBVV can prevent that with anti-gravity training. Similar pathological changes developed in the disable elders and those patients who are ill and bound on bed. The lacking movement will eventually lead to musculoskeletal system regression.

These changes started with the muscle and joints disuse atrophy, which then destroys the ability of coordination and balance. Then, bones become really fragile and easy to break when fall. That kind of fracture was called "**fragile fracture**".

(Figure 18) Fragile fracture is much more serious than other fracture. It always lead to unusual comminuted fracture, multiple fracture or complex fracture, which is often difficult to treat or heal in practice.

This often happens in weight-bearing joints such as spine and hips. Once the fracture occurs, the patients usually need to stay in bed for a long period of time. The musculoskeletal and nerve system deteriorates once they cannot move by themselves. It goes into a vicious circle and may lead to pressure sores, infection or even death.<sup>(83)</sup>

For example, the cerebral stroke patients who are paralyzed will increase the chance of fall accident and accelerate the bone loss. First year after acute stroke, the incidence of fracture for such patients is 7 times higher than normal people. The eighth year after acute stroke, the patient still had 23% higher hip fracture chance than normal peers.<sup>(81)</sup> For those Parkinson's patients, the chance to get hip fracture is three times more than others (27% vs. 9%).<sup>(82)</sup> Some patients need to take steroids for a long term like patients of chronic obstructive pulmonary disease or rheumatoid arthritis, it always lead to drug-induced osteoporosis, and often cause fragile fracture as well.

These patients desperately need exercises to improve their strengths, bone density and balance in order to prevent fall and fractures. Passive exercise like WBVV has been proved to help them reduce chance of fragile fracture and improve their life quality.<sup>(84)</sup> In the following contents, I am going to introduce you the benefits of whole body vertical vibration in preventing and ameliorating many diseases. You can go to retrieve the information from the National Library of Medicine, Medline, to check out all the references enclosed in the end of the book.



(Figure 18) Complex fracture caused by fragile bone and osteoporosis.



During the past 30 years, there are over thousands research papers about whole body vertical vibration. It was first used to train astronauts, soldiers and athletes. Through this type of practice, athletes had great improvement in their explosive force, muscle strength, flexibility, endurance and coordination. Furthermore, their bone density increased as well. These positive results lit up the hope. Many doctors were trying to explore whether WBVV could apply to the elders or postmenopausal women to prevent them from fall and fracture. And more, whole body vertical vibration was tried to increase the muscle strength and the ability to coordination. The results turned out to be very positive which made them really excited.

Now it is more convincing that patients with disables disease like spinal cord injury, stroke, cerebral palsy or Parkinson's disease can be improved by WBVV. Other than that, its studies have expanded to many new fields. No matter problems like obesity, growth retardation or chronic constipation, fibromyalgia, or chronic fatigue syndrome can now be improved by the vertical vibration exercise.

Now, vertical vibration has expanded beyond the field of sports and became a non-pharmaceutical and non-invasive method in medical science. It is now called the “Vibration Therapy” or “Dynamic Motion Therapy.”

## 4.2 Benefits of whole body vertical vibration

There are thousands of researches and documents about whole body vertical vibration, as it has existed for decades. Below are the healing efficacies that have been proven. Today, the golden rule of the modern medicine is evidence-based practice. It means whatever you talk, show the research evidences. This is the top rule what the author sticks while writing this book. However, the results include a wide variety of fields. Plus, new information comes out every day. If there are things that are not correct or out of time, the comments of the readers are welcomed. The benefits of whole body vertical vibration are listed below; I will introduce them one by one in the following chapters.

1. Increase bone density and prevent osteoporosis
2. Enhanced joint and muscle movement
3. Increase muscle balance and coordination
4. Ease the pain of lower back



## Part 1: Whole Body Vertical Vibration

5. Prevent from falling
6. Improve the life quality for the elder
7. Improve cardiovascular function
8. Decrease the body fat
9. Lower the blood sugar or prevent diabetes
10. Help the growth of teenagers
11. Rehabilitation for stroke patients
12. Help recover from arthritis and bone operations
13. Improve fibromyalgia
14. Improve chronic fatigue
15. Improvement of Parkinson's disease
16. Rehabilitation for patients with spinal cord injury
17. Rehabilitation for cerebral palsy
18. Rehabilitation for patients with multiple sclerosis
19. Improvement of chronic obstructive pulmonary disease
20. Rehabilitation for bedridden patients
21. Improvement of chronic constipation
22. Improvement of teenagers' exercise ability
23. Training athletes
24. Improvement of hormones
25. Training animals



## Chapter 5 Vibration increases bone density and prevents osteoporosis

### Introduction

*Osteoporosis is prevailing chronic disease today. Due to the fact that the bone structure became weak, the body cannot take on its own weight or bear the pressure from external impact. It's easy to cause pain and end up in fracture. Osteoporosis becomes a serious health problem in today's society and threat to the elders as well. The fracture caused by osteoporosis may end up in bed for good or cause critical complications, such as arterial embolism, pressure sores, cardiovascular diseases, or even death. Therefore, the prevention and treatment of osteoporosis became a crucial topic of government, family, as well as each individual.*

*The medicines that are used to treat the osteoporosis today includes (1) Hormone Replacement Therapy. (2) Bisphosphonate. (3) Parathyroid preparations. These medicines may postpone the loss of bones. However, they caused some serious side effects and are rather expensive. Whole body vertical vibration has proved it as an effective, cheap and non-invasive way to prevent osteoporosis.*

### 5.1 Osteoporosis and its therapy

Osteoporosis expresses itself as low bone density and obvious destruction of trabecular structure. As if the concrete become soft after decades, it can no longer support the weight of a house. Eventually, osteoporosis will lead to fractures. Though, house has no pain feeling but osteoporosis can cause persistent and progressive pain to people. One day, fragile bony structure can not bear bodyweight and lead people disable or bed-ridden.

There are several risk factors to cause osteoporosis. The common ones are lack of sex hormones (estrogen or testosterone), insufficient exercise, inadequate vitamin D, not enough calcium, and the low parathyroid hormone. Sometimes, it's the side effect of other medical treatments, such as taking steroids for a period of time.

Osteoporosis often occurs in the elders, menopausal women, and some disables like spinal cord injury, morbid obesity or stroke, etc. It doesn't usually happen to young people. However, if they don't exercise regularly or get enough sunshine, it may happen to them.

Osteoporosis is a chronic disease which may proceed more than 10- 20 years. Take middle-aged women for example, their bone loss rate is about 1-2% every year. However, people will not pay attention to this problem until they noted pain or fracture. Actually, 50% of vertebrae compression fracture was not aware by people and only discovered by X-ray film. Osteoporosis and its complications have become a serious threat to the modern society.

In 2005, according to the National Osteoporosis Foundation, there are 10 million patients suffered from osteoporosis in the US, In addition, 34 million people belongs to high risk group. Osteoporosis induced fractures are estimated more than 2 million times, which cost \$19 billion medical expenses. The condition will become worse because the elder population skyrockets in recent years. It is estimated that there will be 3 million fractures and cost over \$25.3 billion medical expense by 2025.

The similar situation occurs in Taiwan and other developing countries. The vertebral bone fracture was 19% for female and 12% for male over 65 year old population in Taiwan. The fracture that induced by osteoporosis is difficult to recover. The patients may end up staying in bed for a long time or became disabled, or even lead to death. It has become a critical health issue for governments, families and individuals.

For osteoporosis patients, besides proper medical therapy, they need to change the diet and do exercise regularly. The approved therapies today include (1) Hormone Replacement Therapy (HRT), (2) Bisphosphonate, and (3) Parathyroid preparations. The effectiveness of supplementing calcium is not quite clear. Though these medicines are proven to postpone bone loss, it may trigger some unexpected side effects. Such as HRT, the estrogen replacement can prevent osteoporosis and ease the menopausal syndrome. But according to the Women's Health Initiative research in 2002, although HRT reduces the fracture 24%, it increases the incidences of heart disease, stroke, breast cancer, and cardiovascular disease after taking more than 5 years. So HRT today is not an option for osteoporosis treatment except some threaten situation. In such special condition, it is suggested to take small dose and short period.



Today physicians often prescribe bisphosphonate or parathyroid preparations to treat osteoporosis. For bisphosphonate, there are both oral and injection preparations. Oral alendronate (Fosamax Plus) is taken once a week. Bisphosphonate like Ibandronate (Boniva) is used as muscle injection once in three months. Zoledronic Acid (Aclasta) is also muscle injection but only once a year. The disadvantages of oral bisphosphonate are that the patients may have side effects of nausea, vomiting and abdominal discomfort. As preparation of muscle injection, the common side effects are fever, fatigue, diarrhea, or subcutaneous infection. These symptoms are related to cytokine release after bisphosphonate activates macrophages. Furthermore, bisphosphonate may cause serious complications like acute renal failure, esophageal cancer, or jaw necrosis (dead jaw syndrome).

Parathyroid preparation is another choice to treat osteoporosis. Parathyroid hormone plays a vital role in bone metabolism. This hormone can increase the resorption of calcium and phosphorus in kidney and small intestine. Besides preventing bone loss, it can also stimulate new bone formation. Parathyroid preparation like Teriparatide (Forteo), need to be injected daily. Side effects include muscle soreness, headache, high blood pressure, cough, and nausea.

Besides the discomfort and side effects, both drugs are also quite expensive. It is around \$20 per pill for alendronate and around \$500 per vial for Aclasta. And Forteo costs \$600 a vial. It will take at least \$500-600 a year to take one of these drugs.

## 5.2 Vibration increases bone density of mammals

### Introduction

*Like professor Robert L. Kane from University of Minnesota has said, "whole body vibration therapy is a state of the science for osteoporosis." Besides the experiments on the small- size animals like mice, they also conducted experiments in large-size mammals like sheep, menopausal women, the elders, adults, children, and even stem cells. Through all these experiments, it has shown that WVBB can increase the bone density and improve osteoporosis.*

*This chapter is going to introduce the studies of mouse and sheep experiments. Low intensity vibration does not only suppress bone loss, but also help stimulate new bone formation. The bone will turn from rod shape to stronger plate shape. This pattern of bone can bear more weight. To put it simply, WBVV can improve mammals' bone quantity as well as quality.*

Robert L. Kane, professor of department of public health, University of Minnesota, has led his team to review the published studies on the topic of whole body vibration and osteoporosis. In 2011, he published a review article in Journal of the American Medical Association (abbrev. JAMA), the title is "Whole-body vibration therapy for osteoporosis: state of the science."<sup>(1)</sup>

Comparing with current therapies of osteoporosis like hormone replacement therapy (HRT), bisphosphonate, or parathyroid preparations, whole body vertical vibration is unique. It is much cheaper, no drug side effects with many added values. Those osteoporosis medications can only improve the bone loss. But whole body vibration can also improve muscle strength, coordination, balance, physical performance and other functions beyond bone density. In addition, WBVV is the only therapy which use alone or combine with other osteoporosis medications. I am going to introduce many published clinical trials and animal studies to show how whole body vibration improves bone density. There are three parts in this section.



1. Animal experiment shows whole body vibration increases bone density.
2. Whole body vibration increases bone density of menopausal women and mice.
3. Whole body vibration increases bone density of children and teenagers.

### 5.2.1 Vibration and bone density of mice

Although whole body vertical vibration is a non-invasive device without toxicity like new drug, scientists decided cautiously to study first in animals (mice in this case) for its safety and effectiveness. Doctor Xie L, from Stony Brook University of New York, started his experiment in mice. The mice received WBVV 15 minutes every day for 3 weeks. He noted osteoclastic activity (bone destruction) in the trabecular metaphysis and epiphysis of the tibia was 33% and 31% lower ( $p < 0.05$ ) compared to age-matched controls. Bone formation rate of the cortical surface of the metaphysis was 30% higher ( $p < 0.05$ ) in WBVV group than in controlled group.<sup>(1)</sup>

Let's look at another study. Mice were divided into two groups, age-matched controls, and whole body vibration group at 45 Hz (0.3 g) for 15 min a day. After 6 weeks of WBVV, bone mineralizing surfaces of trabeculae in the proximal metaphysis of the tibia were 75% greater ( $p < 0.05$ ) than peers, while osteoclast activity was not significantly different. The tibial metaphysis of WBV mice had 14% greater trabecular bone volume ( $p < 0.05$ ) than control group, while periosteal bone area, bone marrow area, cortical bone area, and the moments of inertia of this region were all significantly greater (up to 29%,  $p < 0.05$ ). The soleus muscle also became stronger by WBVV with total cross-sectional area as well as type I and type II fiber area increase 29% more ( $p < 0.05$ ). **The results indicated that WBVV did not only increase bone density of mice but also their muscle mass and strength.**<sup>(2)</sup>

High-frequency whole body vibration can be osteogenic (means formation of new bone), but their function appears limited to weight bearing sites. Another study, a loading apparatus was designed to vibrate the left legs of eight mice, and right leg kept as control group. Small (0.3 g or 0.6 g) 45 Hz sinusoidal accelerations for 10 min a day were applied. After 3 weeks, trabecular metaphyseal bone formation rate and the percentage of mineralizing surface (MS/BS) were 88% and 64% greater ( $p < 0.05$ ) in left leg tibiae than that of right legs in 0.3 g group. At 0.6 g mice group,

bone formation rate and mineral apposition rate were 66% and 22% greater ( $p < 0.05$ ) in vibration tibiae.<sup>(3)</sup> **This exhibits the intensity of whole body vibration is not a condition of “the stronger, the better”. The optimal intensity falls in some range.** There are a dozen of similar WBVV studies in mice which had positive outcomes of bone density.

### 5.2.2 Vibration and bone density of sheep

The positive result of WBVV in mice is promising for scientist to further exploring. We can not ignore the giant difference between human beings and mice. So scientists then tried to study in large-size mammals (horses, sheep, and cows). Clinton Rubin, professor of Department of Biomedical Engineering of Stony Brook University in UNY, conducted experiments in sheep. It is not easy to do the study in sheep. They will not stand in the vibration platform still for 30 minutes. You have to bring them to the platform first and then fixed them between the rails. In the study, Rubin vibrated hind legs of sheep with 0.3g of WBVV, 20 minutes a day and let fore-legs without vibration as control group. After a year, he killed the sheep and checked the bone with microcomputer tomography.(Figure 19)



(Figure 19) It's proven that whole body vertical vibration increases bone density of sheep.



Rubin found out post-vibration hind-legs have significant difference from non-vibration fore-legs. Bone mineral content (BMC) was 10.6% greater ( $p < 0.05$ ), and the trabecular number (Tb.N) was 8.3% higher in the WBVV group ( $p < 0.01$ ). And trabecular space decreased 11.3% ( $p < 0.01$ ), indicating that new bone formation increased. A specific index called “trabecular bone pattern factor (TBPf)” decreased by 24.2% ( $p < 0.03$ ). (Because the bony tissue is three dimension structure, the pattern of the bone is as import as bone density. The trabecular bone pattern factor is an index to measure the 3 dimension architecture of bone tissue with 3D microscope). It was also noted there was significant increase in stiffness and strength n the longitudinal direction (12.1% and 26.7%, respectively; both  $p < 0.05$ ).<sup>(4)</sup>

The results of Rubin’s research showed that

- (1) Low level mechanical stimuli improve both quantity and quality of trabecular bone.
- (2) Trabecular bone pattern factor (TBPf) decreased, indicating trabecular morphology adapting from rod shape to plate shape.
- (3) Significant increase in stiffness and strength in the longitudinal direction indicated that the adaptation occurred primarily in the plane of weight-bearing.

From these experiments, we can conclude that low intensity WBVV could enhance quantity and quality of trabecular bone in the femur of large-size mammals like sheep.

### 5.3 Vibration increased bone density on menopausal omen

#### Introduction

*All animals including human beings have two kinds of bone cells which act against each other. One that produces bone called osteoblast, the other that breaks down bone called osteoclast. Once in menopause, ovary’s function gradually disappears, diminished estrogen hormone loses the ability to inhibit osteoclast function. Women will suffer from flush, palpitation as well as progressive osteoporosis. For the ovariectomized female rats, bone density drastically improved after whole body vibration. Study showed stiffness increased by 33%, connectivity increased by 35%, bone trabeculae area increased by 24%, spongy bone width increased by 9% and mineral increased by 8%.*

*Human clinical trial results also showed that bone density in hips increased by 0.93% and BM at femoral neck increased by 4.3%. The bone density increase of spine is not consistent but the exercise endurance and body balance improved. Dr. Stenge's ELVIS study showed that WBVV training is effective for reducing the risk for osteoporosis by increasing lumbar BMD, leg muscle strength and reduce the chances of fall.*

Menopause leads to osteoporosis because estrogen could not inhibit bone-resorption function of osteoclasts anymore. In the bone tissue, there are two kinds of bone cells, one that builds bone called osteoblast, the other breaks down bone called osteoclast.

Dr. Lawrence Riggs from Mayo Clinic in US has conducted a longitudinal cohort study of bone mineral density (BMD) in 139 normal women (ages 20-88 yr). He checked their bone density of these women periodically over an interval of several years. For peripheral bone like forearm, BMD did not change before menopause but decreased 1.01% a year after menopause. ( $p < 0.001$ ) For weight bearing bone like lumbar spine, bone loss occurred before menopause. It is about per year 1.3% loss ( $p < 0.001$ ) before menopause and 1.0% loss after menopause ( $p = 0.006$ ).<sup>(15)</sup> His data showed that actually before menopause, female is losing her bone in the weight-bearing skeletal bone like lumbar spine.

Bilateral ovariectomy works just as the natural menopause. Estrogen from ovary dropped and can not inhibit the function of osteoclasts. Such women will soon suffer from flush, palpitation as well as accelerated osteoporosis.

### **5.3.1 Vibration on ovariectomized rats**

The treatment and prevention of osteoporosis is a great challenge today. Since menopausal women are the most vulnerable group of osteoporosis, scientists tried to find ways to improve their bone density in order to diminish the threat of bone fracture. WBVV is an good alternative for its low-cost and non-invasive approach to help these women from osteoporosis.

Let also start with menopausal female rats. Tezveal M from Georg-August-University of Goettingen, Germany, examined the effect of whole-body vertical vibration (WBVV) on femoral intertrochanteric bone quality of rats. Tezveal used sixty female rats and used ovariectomized surgery to imitate the menopausal condition



of humans. 30 female rats received ovariectomized (OVX) operation (means remove bilateral ovaries) and another 30 received only sham-surgery. In each group, 15 rats received WBVV 15 minutes, twice a day with 3.9 g for 35 days and another 15 rats remained intact. After 3 months, all rats were killed, biomechanical strength and trabecular bone architecture of their femurs were analyzed. The results are obviously favoring WBVV subgroups in both ovariectomized or sham-surgery groups.<sup>(5)</sup>

Comparing with the controlled group without vibration, the outcomes as below :

1. Bone strength: examined by breaking test with a special loading breaking device showed ovariectomized rats with WBVV increased 33% and sham-operated rats with WBVV increased 9% ( $p < 0.05$ )
2. Bone connectivity: ovariectomized rats with WBVV increased 35% and sham-operated rats with WBVV increased 7% ( $p < 0.05$ )
3. Trabecular area (%): ovariectomized rats with WBVV increased 24% and sham-operated rats with WBVV increased 14% ( $p < 0.05$ )
4. Trabecular width : ovariectomized rats with WBVV increased 9% and sham-operated rats with WBVV increased 8% ( $p < 0.05$ )
5. Mineral content (after ashing) in left femurs (%): ovariectomized rats with WBVV increased 8% and sham-operated rats with WBVV increased 1% ( $p < 0.05$ )

WBVV significantly improved all parameters of bone strength in rats after WBVV. The result is more obvious in the ovariectomized rats. From the above experiments we know that vibration improves the bone density, strength and connectivity in rats. Even more benefits for female rats that had been ovariectomized with low estrogen. It works on other mammals. But how about in humans? Human beings are different from those animals after all. To solve this question, we need to study in human. (study in human is called clinical trial)

### 5.3.2 Vibration studies on postmenopausal women

The increase of bone density has been proved more than 30 % in the WBVV studies with rats or sheep. But the progress is not as much as in humans. Professor Verschueren from Katholieke University of Belgium studied seventy volunteers (age, 58-74 years). They were randomly assigned to whole body vibration training group, resistance training group, or control group. The WBVV group and resistance training group trained three times weekly for 24 weeks. Results showed there was no vibration-related side effects. Vibration training group improved isometric and dynamic muscle strength (+15% and + 16%, respectively;  $p < 0.01$ ) and also significantly increased bone density of the hip (+0.93%,  $p < 0.05$ ). No change in hip bone density was observed in resistance training group or control group (-0.60% and -0.62%, respectively; not significant). Serum markers of bone turnover did not change in any of the groups.<sup>(6)</sup>

Dr Gusi N from Extremadura University in Spain also did a research. 28 post-menopausal women were assigned to WBV group or walking group. Both experimental programs consisted of 3 sessions per week for 8 months. Each vibration session included 6 bouts of 1 min (12.6 Hz in frequency and 3 cm in amplitude with 60° of knee flexion) with 1 min rest between bouts. Each walking session was 55 minutes of walking and 5 minutes of stretching. The results showed that after 8 months, **bone density at the femoral neck in the WBV group increased by 4.3%** ( $p = 0.011$ ) compared to that of walking group. In contrast, bone density at the lumbar spine was unaltered in both groups. Balance was improved in the WBV group (29%) but not in the walking group.<sup>(7)</sup>



(Figure 20) WBV can improve the bone density of post-menopausal women



It always happens in clinical trials that some studies show positive outcomes and some do not. Experts solve these conflicting results by using statistics method called “meta-analysis”. Slatkovska L from Spain reviewed many random controlled studies and conducted a meta-analysis to understand the relationship of WBVV and bone density.<sup>(8)</sup> (Figure 20)

Slatkovska concluded that WBV significantly increased bone density of hip (+15mg/cm<sup>3</sup>) versus controls in postmenopausal women, but not significant for bone density of spine or tibia. For children and adolescents, WBV significantly increased bone density of spine (+6.2 mg/cm<sup>3</sup>) and tibia (+14.2 mg/cm<sup>3</sup>). Overall, Slatkovska confirmed WBV significantly improved bone density of the hip in postmenopausal women. He also confirmed WBV increased bone density of tibia and spine in children and adolescents.<sup>(8)</sup>

### **5.3.3 Erlangen longitudinal vibration studies and bone density**

The largest scale of study in the relationship of whole body vibration and osteoporosis in postmenopausal women was designed and conducted by Dr. von Stenge S from German Erlanger district. His study is called Erlangen Longitudinal Vibration Studies, (ELVIS). Here’s how his study went. A total of 151 postmenopausal women (age 68.5 average) were randomly allocated to (1) traditional training group; (2) vertical vibration plus traditional training group; (3) control group. Traditional training group did 20 minutes gymnastics sessions, 5 minutes balance training, 20 minutes functional training and 15 minutes dynamic squat training twice a week.

After 18 months, bone density gain in the lumbar spine was observed in both training groups. Bone density in traditional training group increased 1.5% and vibration plus traditional training group increased 2.1%. Comparing to the control group, there was less falls (0.7 falls per person) in vibration plus traditional training group and no significant difference in the other two groups. Thus, vibration plus traditional training works well in increasing lumbar spine bone density. Adding vibration training could decrease fall accidents.<sup>(9)</sup>

Then von Stengel conducted another study called the ELVIS-2 also in Erlangen district women. This time he tried to compare two different vibration devices: vertical vibration and rotational vibration to see how they affect the bone density of postmenopausal women. A total of 108 postmenopausal women (65.8 average) were randomly allocated to (1) rotational vibration training (RVT), i.e., three sessions per



## Part 1: Whole Body Vertical Vibration

week, for 15 min, including dynamic squat exercises; (2) vertical vibration training (VVT), i.e., as above; and (3) a control group.

Results showed that BMD (bone mineral density) gain in the lumbar spine was observed in both vibration groups (RVT +0.7%, VVT +0.5%), which was significant compared with the control group (BMD -0.4%) but there was no difference between two vibration group. Regarding to hip neck BMD, it increases in both vibration groups (RVT +0.3%, VVT +1.1%) and remained no change in control group. Regarding to maximum leg strength, vibration group was significant 6% improved compared with control group. Both vibration groups improved as well but no difference with each other (RVT +27%, VVT +24%).

As the result, Dr. von Stengel concluded that WBV training is effective for reducing the risk for osteoporosis by increasing lumbar BMD and leg strength.<sup>(14)</sup>



## 5.4 Vibration can increase children and young men's bone density

### Introduction

*Not only can vibration increase bone mineral density (BMD) in menopausal women but also in that of children and youths. Research showed that the increased 2.7% bone density of the femoral neck, 17.7% of tibia and +6.72 mg/ml of spine. WBVV also works for young men with low bone density. The results showed that cancellous bone in the lumbar vertebrae and cortical bone increased by 2.1% and the femoral mid-shaft increased by 3.4%-6.2%. As a conclusion, even short period of continuous WBVV could increase bone formation and serves as an effective way to prevent future osteoporosis for children and young men.*

Besides those post-menopausal women, whole body vertical vibration can also elevate the bone density of male elders, young men and children. Dr Ezenwa B from University of Wisconsin had a study in the aged men and found that vibration helps increase bone density in lumbar spine, hips, femoral necks and humerus bone.<sup>(177)</sup>

Dr Corrie H from Loughborough University in UK, collected 61 senior participants: average age of 80, 24 males and 37 females. WBVV were applied for 12 weeks and bone formation markers (P1NP) and resorption markers (CTX) were measured at baseline and post-intervention. He found that P1NP increased by 17.5% ( $p=0.057$ ) and no significant difference in CTX. And there was no gender difference. **This study indicates that WBVV increases bone mineral density by stimulating more osteogenesis (new bone formation) without affecting bone resorption (old bone loss).** It also proved that WBVV could help male elders just like post-menopausal women to reduce osteoporosis.<sup>(178)</sup>

Dr Humphries B from CQ University of Australia, recruited 51 young women with the average age of 21 to conduct another experiment. He found after 16 weeks, the density of their femoral neck increased by 2.7% in the vibration group and 1.9% in the vibration plus resistance training group. In addition, the spine density also increased by 0.98% in vibration group.<sup>(10)</sup>

Ward K from Manchester, UK studied in children. He recruited 20 pre-or postpubertal children (4-19 years old). They received WBV 10 minutes a day, 5 days a week for 6 months. After 6 months, the tibia bone density in vibration group increased



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6.3% and the control group decreased 11.9%. It means that the net benefit of vibration to bone density may be a gain of 17.7% ( $p=0.003$ ).

For bone density of the spine, compared with placebo, the net gain after vibration is +6.72 mg/ml ( $p=0.14$ ). **The results of this random control study disclosed for the first time that whole body vertical vibration is anabolic to trabecular bone in children. WBV could enhance bone density of children.**<sup>(124)</sup> (Figure 21)



(Figure 21) WBV is proven to increase bone density in children.



Gilsanz VA from Children Hospital of Los Angeles, University of Southern California, was interested in how vibration helps musculoskeletal development of young women with low BMD. So here's what he did. A 12-month trial was conducted in 48 young women (15-20 years) with low BMD and a history of at least one bone fracture. Vibration group women underwent short-period (10 minutes requested) daily, low-level whole body vibration (30 Hz, 0.3g) and the remaining women served as controls. He found that cancellous bone of the lumbar vertebrae and cortical bone of the femoral mid-shaft in experimental group increased 2.1% ( $p=0.025$ ) and 3.4% ( $p<0.001$ ) compared to control group.

Interesting enough, when per protocol analysis was done, gains in both muscle and bone were strongly correlated to "compliance". The benefit of WBV can be found only if the subjects followed the instruction and continued use the device for at least 2 minute per day. For the subjects of compliance, the result was a 3.9% increase in cancellous bone of the spine ( $p=0.007$ ), 2.9% increase in cortical bone of the femur ( $p=0.009$ ), and 7.2% increase in musculature of the spine ( $p=0.001$ ) compared with controls and subjects of low compliance.

The study showed that **even a short period of continuous WBVV could increase new bone formation and serves as an effective way to prevent osteoporosis.**<sup>(125)</sup> In addition, this is the first study to explore the relationship of compliance of subject and the outcome of whole body vibration. All users shall follow the instruction and continue use a period of time in order to get benefits from WBV.

Pitukcheewanont P from Children's Hospital Los Angeles, USA, recruited children (average 10 years old) with low bone density to proceed a research. These children received a 30Hz, 0.3g vibration for 30 minutes, 3 times a week for 8 weeks. He found bone density of trabeculae increased 6.2% and cortical bone increased 2.1%. In addition, muscle mass also increased 6.1%. The biochemical marker "bone-specific alkaline phosphatase", which is an indicator of new bone formation, had significantly 16.6% elevation. Thus it proved that **WBVV can increase bone density and muscle mass in children with low bone density.**

## 5.5 Why vibration in human is not as effective as in mice or sheep

### Introduction

*In the research of mice and sheep, vibration is proven to increase bone density by 30% or more. How comes the bone density only increase 1-5% for menopausal women or teenagers? There are two possible reasons.*

- 1. Normally, women will lose their bone 1.5-5% annually. After vertical vibration, it will increase 1-5%. It literally means of 2.5 - 10% gain after WBV.*
- 2. Human beings and animals have different life span. The outcome is not so obvious perhaps because the duration of experiment in humans is not long enough.*

Some cautious readers may notice and ask why WBV can increase bone density of rat or sheep much more than that in human beings? In the research of rat and sheep, vibration is proven to increase bone density by 30% or more. But it only increases around 1-5% for menopausal women and teenagers? Why? There are two possible reasons to explain this phenomenon.

First, before the age of 30, women will lose their bone about 0.7% annually. After menopause, their bone will lose even more quickly. Trabecular bone, for example, will lose 5% annually. And for the total mass for bone, it will lose 1.5% every year. Therefore we can say that, without any intervention, women will lose their bone around 1.5-5% per year. But while receiving whole body vibration, these women increase their bone density 1-5%. It indicates that whole body vibration may actually raise bone density of the menopausal women by 2.5-10%.

The other reason is the different life-span between animals and human beings. The life span of rat is about 2 to 3 years, while sheep's approximately 10-11 years. Human's life span is much longer, around 70 or 80 years. So if scientists obtain outcomes of rat study in 35 days, and sheep in 1 year, it shall take at least 6 to 7 years to reach the similar outcome in human beings according to the life-span proportion. However, among all the clinical trials of WBVV in humans, no study exceeded 1.5 years. It is highly possible that without longer intervention, the result may not be as



obvious as in animals. We have evidence to prove that. ELVIS study by von Stengel showed that WBVV for 12 months did only increase spinal BMD 0.5%-0.7%. The bone density gain increased to 1.5%-2.1% when the study prolonged to 18 months.<sup>(9)</sup>

Reviewing all the studies regarding to the relationship of WBVV and bone density, we can conclude that **whole-body vertical vibration increases bone density, and decreases the chance of osteoporosis and subsequent falls and bone fracture.** This effect has been shown in post-menopause women, the elders, the children as well as the young. Why whole body vertical vibration can generate such bone strengthening effect? The secret exists in some specific cells of our body called “mesenchymal stem cells”. There are more details in the later chapter. (See Chapter 24 Why it works? the mechanism of whole body vertical vibration)

## Chapter 6 Vibration enhances balance and coordination

### Introduction

*The original purpose of whole body vibration was designed to help those people who are difficult to do exercises. In the former chapter, we have discussed the whole body vertical vibration enhances bone density. Nevertheless, even bone density is fine; it doesn't mean people can move freely. Free movement also requires the balance of systems, the coordination of different muscles groups, as well as sufficient muscle strength. To be able to keep the balance, it needs the integration of several systems including brain, vision, hearing and proprioception etc. Furthermore, joints and nerves need to be well functioned. To put it simply, free movement requires all the nerve, muscle, bone, and joint to be under a well and coordinated condition.*

*This is a complicated integration system. It may not work out if any link or part was out of order. In this chapter, we are going to introduce how whole body vertical vibration can increase muscle strength, including static and dynamic muscles, the knee joint extension strength, instant power, jumping ability, and flexibility. Moreover, vibration can go along with other exercises and stack up the positive effect.*

### 6.1 Movement and coordination

Imagine a young man sprained his calf muscle, it will be painful for him to walk. He perhaps needs a crutch to help his walking. Question for you, is the difficulty of his walking caused by osteoporosis or muscle? This question is easy to answer. The reason why I asked is because many people thought the movement obstacle of the elders is mostly because of the osteoporosis.

Young people take it for granted to move freely. Indeed, free movement is complicated. It requires a comprehensive integration of many organs and systems. In



order for human body to move freely, it needs the coordination of our brain, nerves, muscles, bones, and joints. (Figure 22) In this chapter, I am going to discuss how WBVV helps this integration system. Next chapter I will discuss the WBVV and nerve system.

Human muscles can be divided into two groups, (1) “skeletal striated muscle”, distributed in our trunk and limbs, and can be controlled by our will. (2) “smooth muscle”, distributed in our interior organs, like heart, stomach or intestine, and are not controlled by our will. There are 642 skeletal striated muscles in our body. Normally, these muscles come in pairs and act against each other. For example, biceps and triceps are a pair of muscles of arms. While biceps contracts, triceps relaxes and vice versa.



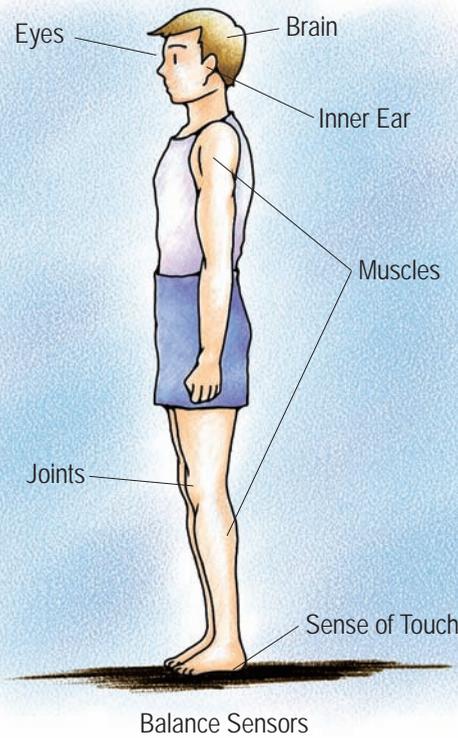
(Figure 22) In order to move freely, our body requires well coordination of nerves, muscles, bones, and joints.

More complicated movements like walking, jumping or dancing involve many pairs of muscles to work together. Each group of muscles needs to coordinate with others to perform smooth movement. Besides the coordination, muscles also need to be strong to act against the gravity. Or otherwise, the movement will be difficult.

Biophysics studies have shown that our knee joints bear our body weight when we are standing still. This bearing weight will become 2-3 times of our body weight when we are walking. And it will increase to 6-8 times of our body weight when we run or climb up the stairs or hills. Which means, take a 60 kg person for example, it requires 120-180 kg of strength to support his body when walking. The knees will bear as high as 360-480 kg when walk upstairs or climb hills. This is the main reason why the initial handicapped sign of the aged people is getting trouble to climb upstairs. So you

can figure out the knees and hips of the obese people bear enormous pressure when movement. (if you had extra 50kg in body, then it will increase 300-400kg load to your knees and legs when climbing or jogging) This explains why their hips and knees tend to early degeneration and are unable to do active exercises soon.

Even their muscles are strong and well-coordinated, people are not able to perform smooth movement without healthy balance system. For healthy balance system, it does not only involve musculoskeletal system, but also the central nervous system. This nervous system includes vision of the eyes, balance of the cochlear system in inner ear, proprioception of the brain, and motion integration system of the cerebellum. (Figure 23)



(Figure 23) Balance requires the integration of eyes, ears, brains, proprioception, tactile sensation, and all the muscles, bones, and joints.



Therefore, in order to promote the elders' ability of exercise, not only do we have to pay attention to their bone density or muscle strength but also the ability of balance and coordination. If their balance is not precise enough, they are vulnerable to fall injury. Fall often leads to serious fracture and bed-ridden status in the elders because of osteoporosis. All in all, to enhance the ability of coordination and balance of the elders has become one of major targets of physicians.

It is no doubt that the best way is to keep the elders engaged in active exercise like walking, running or swimming regularly. However, when they are restrained from those active activities, the best solution will be to undertake the whole body passive exercise. WBVV can help achieve this goal. I'm going to introduce how whole body vertical vibration can help increase muscle strength and coordination ability in the following sections.

## **6.2 Vibration increases muscle mass, strength and explosive power**

The elders do not only encounter osteoporosis but also muscle degeneration. A serious type of muscle wasting is called "sarcopenia." Many old people over 80 had sarcopenia. Besides bone and muscle regression, there is always accompanied with degeneration of the peripheral nerves. This is why the old people have poor hearing, poor taste, poor vision and poor touch sensation. These together affect the elders to move freely or actively. Through whole body vibration, these situations can be improved without taking medication or sport injury. WBVV becomes an alternative for these disabled elders to do exercise under physically restriction.

Dr Sven Rees, from University of Technology, Sydney in Australia, conducted a study with 43 healthy elders (age from 66 to 85). These old men are requested to do vertical vibration training 3 times a week, 5-8 minutes each time. He noted (1) decrease 12.4% time in sit-stand test; (2) increase 3.0% in 5 meter fast walk time; (3) increased 8.1% in knee strength. These figures in the traditional exercise group were 10.2%, 3.7% and 7.2% respectively. The result showed there was no difference between the active traditional exercise and passive whole body vibration training.<sup>(16)</sup>

An Bogaerts, from Catholic University of Louvain in Belgium, conducted another experiment in 97 elders with average age of 68. He divided them into three groups,

vibration group, exercise group and control non-exercise group. The study lasted for 1 year. After 1 year, comparing to non-exercise group, the vibration group showed (1) isometric muscle strength increased 9.8%; (2) muscle explosive power increased 10.9%; and (3) muscle mass increased 3.8%. On the other hand, the exercise group also improved in these items 13.1%, 9.8%, and 3.8%. From that you can tell, vibration group performed as well as exercise group. So, the passive exercise like whole body vertical vibration can be used as a substitute of active exercise.<sup>(18)</sup>

### 6.3 Vibration increases the static and dynamic muscle power and knee strength.

Verschuere SM, from Catholic University of Louvain in Belgium, has done a study in 70 menopausal women aging from 58 to 74. He divided them into three groups, vibration-training group, resistance-training group and the control group. The vibration-training group received 2.28-5.08g of vibration training three times a week for 6 months. Comparing to control group, the vibration group showed that their static and dynamic muscle power increased 15% and 16% respectively. However, the resistance-training group had no difference to control group. It proved that whole body vertical vibration did help increase muscle power in the senile women.<sup>(6)</sup>

Roelants M, a Verschuere's colleague, found that the elders increased the isometric and dynamic knee extensor strength by 15% after 24 weeks of whole body vertical vibration training. This result was pretty close to the resistance-training group (+18.4%). After 24 weeks of training, counter-movement jump height had significant 19.4% progress in the WBVV group ( $p < 0.001$ ), which was better than 12.9% progress of the resistance-training group. That progress in knee-extension strength, speed of movement or counter-movement jump performance did not appear until the 12th weeks of training.<sup>(20)</sup>

Thanks to Roelants, we now understand **that whole body vibration training needs to last a certain period of time in order to reach its effect. Such as knee-extension strength and counter-movement jump will not show the results until 12-weeks of training.** This is why there were some studies failed to show positive outcome. **Duration is a critical factor for whole body passive exercise and 12 weeks of vibration training seems to be a minimal requirement.**



## 6.4 Vibration increases maximal muscle power and bending force

Klarner A, from Friedrich-Alexande University in Germany, also did an trial in 108 postmenopausal women with average age of 66. He divided them into three groups, vertical vibration group, rotation vibration group and control group. Both vibration groups perform 15-minute training everyday, three times a week, and lasted for one year. The results showed (1) The maximum muscle power increased 24.4% in vertical vibration group, 26.6% in rotation vibration group but only 6.2% in the control group ( $p<0.001$ ). (2) The body maximum bending force, increased 12.2% in vertical vibration group, 11.5% in rotation vibration group, but decreased 5.5% in the control group ( $p=0.01$ ). (3) The pain of joints decreased in both vibration groups. ( $p<0.05$ ). This showed that both vibration groups had similar positive results. Therefore Klarner concluded that vibration can substitute traditional exercise and helps increase muscle strength, bending force, and also reduce joints pain.<sup>(19)</sup>

Chang Gung Memorial Hospital is one of the best medical centers in Taiwan. They recruited a group of elders with average age of 86, and trained them with vertical vibration 10-15 minutes, three times a week for 6 weeks. Then examine 1. Walk distance in 6-minute; 2. Time of sit-down stand-up and walk 6 meters; 3. The times to get up and sit down from chair in 30 second. The results showed that compared to the control group, after WBV, three parameters had significant progress.

## 6.5 Vibration can synergize with other exercises

Raimundo AM, from the Evora University in Portugal, compared vertical vibration exercise with walking exercise. The vibration group received 6 vertical vibrations with 1 minute break in-between, 12.6Hz, 3mm, 3 times a week. And walking group took 1 hour walk, 3 times a week. After 8 months, the result showed that walking group performed better in 4-meter walk test by shorten 20% of time ( $p=0.006$ ) and 12% faster in the stand-up-from-the-chair test ( $p=0.002$ ). As for counter-movement jump test, vibration group performed 7% better than walking group ( $p=0.025$ ). This study showed that passive exercise like whole body vertical vibration can combine with active exercise like walking to benefit the elders.<sup>(32)</sup>



## Part 1: Whole Body Vertical Vibration

Rehn B from Umea University in Sweden conducted a system review in this subject. He found that 9 out of 14 published papers proved that whole body vertical vibration could increase the static, dynamic and jumping power. This review also found that whole body vertical vibration can improve muscular performance by 5-16% for menopausal women.<sup>(22)</sup>

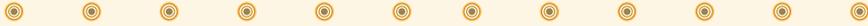


## Chapter 7 Vibration reduces back pain and joints pain

### Introduction

*Pain is the most common reason to restrain peoples from moving. It could cause by acute inflammation or chronic degeneration. The lesion could happen in any place like muscle, bone, fascia, tendon, synovial membrane, soft bone, bursa, joint, nerve root and subcutaneous tissue.*

*Because the transmission of vibration and pain share the same afferent nerve, the low-frequency vibration will occupy these nerves and inhibit the transmission of pain. The sense of pain then was diminished. Studies showed that whole body vertical vibration could ease back pain and joints pain. Therefore, it can improve the quality of life and the ability to exercise as well.*



### 7.1 Vibration relieves pain

Pain is the most common reason to restrain people from moving. It could cause by acute inflammation or chronic degeneration. Other causes like cancer, nerve compression, foreign body, adhesion or, laceration, etc are also not uncommon. The lesion could happen in any place like muscle, bone, fascia, tendon, synovial membrane, soft bone, bursa, joint, nerve root and subcutaneous tissue.

Although the muscles, bones and ligaments of the elders are degenerating, it may not affect their movement yet. Most of the time, it is the pain, which buzzed like annoying car-alarm, restrains the elders from normal movement.

Therefore, relieving pain is always the top goal of treatment. Rehabilitation physicians have already applied subcutaneous vibration to reduce acute and chronic pain. This device dubbed “TENS” (transcutaneous electronic nerve stimulation) is a kind of local body vibration machine. Dr Lundeberg TC published a study in 1983.



The study had 135 subjects with acute pain and 596 with chronic pain. The result showed 70% of patients felt pain remission with TENS therapy.<sup>(55)</sup>

This is because the transmission of vibration and pain share the same afferent nerve. When the low-frequency vibration occupies these nerves, it will inhibit the transmission of pain. So the sense of pain will be ignored by our brain. The pain seemed relieved after vibration.

Iwamoto J, from Tokyo University in Japan, recruited 50 menopausal women with osteoporosis and currently treated with bisphosphonates. These women were divided in two groups, one received whole body vibration while the other didn't. After one year, he examined their bone density and other biochemical index. There was no difference between two groups. **The only difference was that back pain in WBV group significantly reduced.** The possible reason was vibration relax their back muscles, and then reduced the intensity of pain.<sup>(53)</sup>

Rittweger J, from Free University of Berlin, on the other hand, compared the lumbar stretching exercises and whole body vertical vibration. He recruited 60 patients with age average 51, who are suffering from back pain. These cases were then separated into two groups randomly. After one year, back pain of these two groups obviously improved. This showed that **low-frequency low intensity whole body vertical vibration under well control won't cause muscle injury or back pain like occupational random vibration. On the opposite, it relieves back pain.**<sup>(54)</sup>

## 7.2 Vibration reduces pain of large joints

Klarner A, from Alexander University in Germany, proceeded a vibration experiment with 108 menopausal women with average age 66. The vibration women were trained in the platform 15 minutes each time, three times a week for 1 year. After one year, compared with control group, he noted that the vibration group had significantly lower level of pain intensity in large joints ( $p < 0.05$ ). The above experiments showed whole body vertical vibration did not only reduce back pain but also relieve the pain of large joints.<sup>(19)</sup>



## Chapter 8 Vibration reduces falls and improves quality of life

### Introduction

*Young people have a relative low incidence of fall in daily activities. Even they fall, serious damage is rarely seen. On the other hand, since muscles and joints of the elder are rather weak and uncoordinated, they are vulnerable to fall and get harms. Therefore, to reduce fall of the elders is one of the major medical goals. To avoid fall and tumble, first we have to improve their postural stability, and then to enhance their muscle strength and the ability of balance. Last but not least, it is to strengthen their proprioception.*

*Many researches have shown that whole body vertical vibration can help the elders to improve their postural stability, walking pace, walking distance, balance and proprioception. In the long run, it prevents them from fall and injury, and promotes them a higher quality of life.*

### 8.1 Vibration improves postural stability.

Muscles and joints of the elders are usually weak and poor-coordinated, which will easily lead to unstable posture and get fall. Sven Rees, from Australian Technology University, did a study to understand how whole body vertical vibration influences the postural stability of the elders. The patients were divided into three groups, vibration group, exercise group and control group. He used “one-legged postural steadiness test” to evaluate the static postural stability. After 8 weeks of experiment, the vibration group performed much better than the other two groups ( $p < 0.05$ ). Comparing to pre-test, vibration group had progress much more than the other groups. Thus we can see vibration training can help improve the postural stability and prevent fall in the elders.

(52)

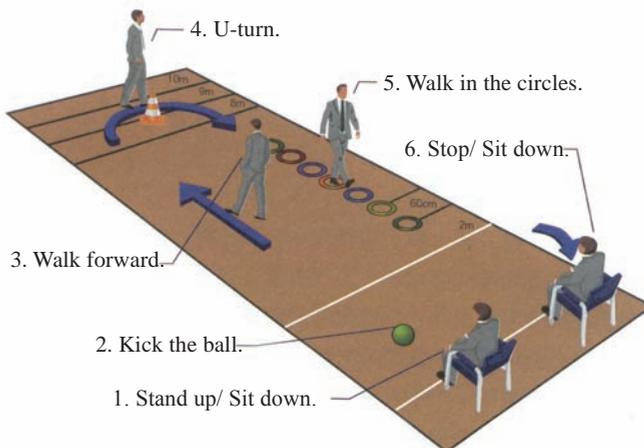
Dr Kazuhiro Kawanabe, from Tokyo University in Japan, divided 67 elders (average age of 72) into two groups. One group received regular exercise and the other group added vibration training to regular exercise. Comparing both group after two months of study, the vibration plus exercise group showed significant improvement in such

index like walking speed, length of pace and one leg standing time. In contrast, the pure exercise group did not show improvement. This research indicated that vibration can add with regular exercise to help the movement of the elders.<sup>(24)</sup>

Professor Wing-Hoi Cheung from Chinese University of Hong Kong came to a similar conclusion by his study. He applied whole body vertical vibration to their patients three minutes a day, three times a week, and last for three months. As a result, no matter walk speed ( $p < 0.01$ ), walk distance ( $p < 0.05$ ), or direction control ( $p < 0.01$ ), all exhibited much progress.<sup>(27)</sup> The results once again proved short duration of vertical vibration can improve the balance of the elders and prevent them from fall.

## 8.2 Vibration improves balance and coordination

For those institutionalized elders, they are tending to lose their functions of motion and coordination comparing to the counterparts at home. Ivan Bautmans, doctor of Free University of Belgium, has conducted an experiment in 24 residents with the average age of 77 in a nursing home. After six months of vertical vibration training, he noted that these elders improved in the following tests: (1) time of stand-up, 3-meter walk and sit-down; (2) The Tinetti Test.<sup>(17)</sup> (Figure 24)



(Figure 24) 1. Stand up/ Sit down. 2. Kick ball. 3. Walk forward. 4. U-turn. 5. Walk in the circles. 6. Stop/ Sit down.



### 8.2.1 Tinetti test

Tinetti Test is a common clinical test for assessing a person's static and dynamic balance abilities. It was developed by Professor Mary Tinetti from Yale University. It can test the strength, footstep, balance and coordination. The test can predict whether the surveying subjects will fall or not. The test consists of two-stage evaluation. The first stage is to ask the subjects to stand up from the chair, make a spin around and sit down with their eyes closed or open. The second stage is to ask them to walk forward in usual pace, and then ask them to come back with a fast and safe pace, and then sit down again. They are evaluated and graded by the observers standing beside. There will be two scores, balance score and total score.

Bautmans' study showed that these institutionalized elders got obvious progress in both of balance score and total score of Tinetti Test after receiving vibration training. These institutionalized elders performed better movement no matter standing, sitting, walking, balance or coordination. This proves WBV training can reduce and prevent fall of the elderly.

Dr Furness TP from Australian Catholic University had similar studies in the elders of the nursing home. After the vibration training, their time of stand-and-sit test reduced 3 seconds ( $p=0.05$ ), and the time of 3 -meter walk and sit down test reduced 0.9 second ( $p=0.01$ ).<sup>(28)</sup> Vibration training showed its benefits for the elders resided in the nursing home. WBV can be used as one of rehabilitation equipments.

### 8.3 Vibration improves quality of life and reduces fall

According to the statistics, 30% of the aged people over 65 had fall accident yearly. The chance rises to 40% when they are older than 75. For these elders, fall is the major cause of hospitalization, surgery, bed-ridden, even death. It is also a key factor to downgrade their quality of life. Since the previous studies have shown whole body vertical vibration can increase bone density, muscle strength and reaction time, Dr Olivier Bruyere from the World Health Organization (WHO) wondered whether vibration can also decrease the chances of fall accidents and promote their quality of life.

He recruited 44 seniors from nursing home. After 6 weeks of whole body vibration training, he found (1) 2.4 points improvement in footstep test. ( $p < 0.001$ ), 3.5 points improvement in balance score; (2) 11 seconds progress in stand-and-walk test. ( $p < 0.001$ ); (3) 8 out of 9 items of the SF-36 questionnaire improvement. This once again showed that vertical vibration training can actually keep the elders from fall and improve their quality of life.<sup>(47)</sup>

## 8.4 Vibration enhances proprioception

Besides six senses that people possess, there are another two special senses of human beings. These are known as sense of equilibrium and proprioception. Sense of equilibrium enables us to take balance action while our body goes slant. This sense is controlled by our cerebellum and inner ear. Proprioception is another sense to detect our own position. So even we are under a pitch-black environment, we can know where our body and limbs are. Proprioception is controlled by a group of specific cells called “proprioceptors” distributed in skeletal striated muscles and joints, which is very important in senile fall.

Dr. Trans T from Frederiksberg Hospital in Denmark was eager to know whether whole body vertical vibration can improve the proprioception of the elders. After experiment for 8 weeks, vibration group performed just as other studies, muscle strength and knee stretching force both increased compared to the control group. Additionally, Dr. Trans did a special examination called “threshold for detection of passive movement, TDPM”. This is a device to detect the proprioception. The blinded elders were asked to tell whether they feel the slight movement of their legs in the device. They tend to be more aware of slight movement after vibration training. It means that their knee proprioception has improved after vibration.<sup>(50)</sup>

Van Nes IJ from Sint Maartens Klinkiek in Holland had a study in stroke patients to see if vibration can help them to control posture. After vibration training with 0.6g, 3mm, there were improvements in all four items- standing, shifting with eyes open or closed weight-shifting speed ( $p < 0.05$ ). Thus, he got a conclusion that whole-body vibration may be a promising candidate to improve proprioceptive control of posture in stroke patients.<sup>(61)</sup>



## Chapter 9 Vibration prevents and ameliorates cardiovascular diseases

### Introduction

Although whole body vertical vibration is passive exercise, it can reach the equal effect as the aerobic exercise. Not only can it improve muscle strength, instant force, elasticity, and flexibility, it can improve human cardiopulmonary function as well. Cardiopulmonary function includes the exchange of oxygen, the ability of pumping blood, concentration of the oxygen in vein, and velocity of blood circulation. Moreover, researches have shown that vertical vibration can ameliorate the following cardiovascular functions. 1. Lower blood pressure and heartbeat. 2. Lower arterial stiffness. 3. Increase cerebral blood flow and oxygen perfusion. 4. Promote blood circulation. 5. Lower the chances of vascular occlusion.

The secret of whole body vertical vibration exists in a small gas –nitric oxide. Vibration can stimulate to release nitric oxide from inner wall of the blood vessels. Nitric oxide can dilate the central and peripheral vessels and then lowers blood pressure and heartbeat. Other than that, vertical vibration can increase the capacity of dissolving the fibrinogen and lower the incidence of blood clots and embolisms. In summary, vibration can reduce the chances of cerebral stroke or myocardial infarction.

Therefore, whole body vibration can improve the cardiovascular system function, and also prevent cardiovascular diseases. WBV can be applied with other treatments or medication as a supplementary therapeutic strategy.

In the previous chapters, we have fully discussed how whole body vertical vibration improves bone density, muscle strength, flexibility, balance and coordination etc. It's all about how vertical vibration affects our musculoskeletal system. However, there are much more than that. Whole body vibration can also benefit our cardiovascular system.

## 9.1 Vibration promotes cardiovascular function of the elders

For some people, walking is not a problem, but why some of them experience shortness of breath when running or jogging? It is because running depends not only on the coordination of muscles or joints, but also on fitness of cardiopulmonary function. Cardiopulmonary function includes oxygen exchange of lung, pumping volume of the heart, oxygen concentration of blood, and the speed of circulation. The easiest way to evaluate it is to measure your heartbeat during exercise. Take the figure of 220 minuses your age and multiplies it by 0.6. This is the minimal heartbeat that you shall tolerate for your age. You shall not feel discomfort, dyspnea or chest tightness when you exercise to that heartbeat. If you fail before you reach that figure, your cardiopulmonary function is probably not qualified for your age. As people age, cardiopulmonary function and musculoskeletal system will degenerate gradually. That's why the elders are often restrained from doing intense exercises.

The better choice to improve your cardiopulmonary function is to do aerobic exercise, like swimming, dancing, running, etc. However, it is always difficult for the elders to do such exhaustive exercises. The alternate solution is to use the passive exercise like whole body vertical vibration. By far, there are numerous evidences to prove that WBVV improves the elders' cardiopulmonary function.

Bogaerts AC worked in Katholieke Universiteit Leuven, Belgium. He was interested in whether whole body vertical vibration can improve cardiopulmonary function of the elders or not. So he conducted a large-scale experiment. 220 aged people, average age 67.1 were recruited and divided into three groups: vibration group, exercise group and the control group. After one year study, comparing to the control group, he found the vibration group (1) heart rate increased; (2) cardiopulmonary function index like "peak oxygen uptake" and "time-to-peak exercise" both improved; (3) muscle strength increased in both vibration and exercise groups.<sup>(49)</sup> He came to the conclusion that, **"whole body vertical vibration can effectively improve the cardiopulmonary function and muscle strength of the elders."**



## 9.2 Vibration lowers blood pressure and heartbeat

Ryan Gil, a master student of Florida State University, USA, wrote his thesis on the topic of WBVV and vascular system. He recruited obese young women and studied the effect of the whole body vertical vibration on autonomic nerve system. After six weeks of vertical vibration, compared the vibration group to the control group, he found out:

- (1) Blood pressure at rest dropped ( $p < 0.05$ ) which systolic pressure lowered 8mmHg and diastolic pressure lowered 4mmHg;
- (2) Heart rate during exercise reduced 7 beats per minute ( $p < 0.05$ );
- (3) Systolic pressure during exercise reduced 5mmHg;
- (4) Mean arterial pressure reduced 7mmHg ( $p < 0.05$ )

We can see that vertical vibration can help lower the heart beat as well as blood pressure.<sup>(57)</sup> He then concluded, “Whole body vibration can serve as a supplementary method to treat the cardiovascular disease of the obese women.”

Chang Gung Memorial University Hospital in Taiwan has also done a similar experiment to understand how vibration affects the elders' cardiovascular system and their quality of life. After six weeks of vibration training, the elders showed improvement in the following items, (1) systolic pressure lowered 16mmHg; (2) diastolic pressure lowered 6.4mmHg; (3) pulse pressure lowered 12.2mmHg; (4) The concentration of nitric oxide increased 5.1mm; (5) six-minute walk test increased 43 meters. These better vascular indexes told us that whole body vertical vibration can ameliorate the senile hypertension or arteriosclerosis and reduce subsequent cardiovascular complications.

## 9.3 Vibration reduces artery stiffness

Professor Otsuki T from St. Catherine University in Minnesota, US had another vibration trial in healthy young men. These subjects received vibration 60 seconds each time, a 60-second break-in between, total 10 times. After 20, 40, and 60 minutes, he tested their “brachial-ankle pulse wave velocity test”. This is a special device with pressure cuffs in arm and leg. The device can measure the pulse wave velocity of the



vessels. By this, the technician can detect the level of the rigidity of their arteries. In his experiment, the two groups didn't perform much difference in their blood pressure and heart beat. However, the brachial-ankle pulse wave velocity significantly decreased after 20 minute vibration (1137 vs. 1107) and after 40 minute (1137 vs. 1108) then it came to normal after 60 minutes (1137 vs. 1128).<sup>(58)</sup> Then the author concluded, "Whole-body vertical vibration can quickly reduce the hardness of arterial wall."

#### 9.4 Vibration enhances peripheral circulation

Because traveling long distance, the blood pressure became low when reaches to the end of the artery. If blood vessels are narrow here, then there will appear peripheral circulation problems. This poor circulation to the extremities often causes hypoxia in the involved tissues. Most common signs are weakness, numbness, pain, pale, cold, hyperpigmentation, loss hair, and claudication. Sometimes it could be very serious like poor wound healing and subsequent chronic ulcer, necrosis. The so called peripheral vascular disease (PVD) was commonly seen in diabetes patients with neuropathy and vasculopathy. But it is also common in those patients with heart diseases or blood coagulation problems. Therefore, increasing peripheral blood circulation can help these patients, relieve pain and diminish severe complications. Can WBVV increase the peripheral blood circulation? (Figure 25)



(Figure 25) WBVV increases peripheral blood circulation



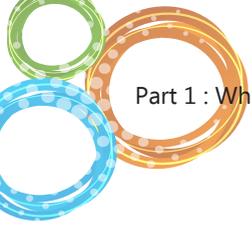
In the past, industrial random high-frequency vibration (like drilling) has been found deteriorating to reduce peripheral blood flow and cause ischemia of the limbs and fingers (so called white finger). K. Kersch-Schindl from University of Vienna, Austria, conducted a trial to evaluate alterations in muscle blood volume after whole body vibration. Twenty healthy adults performed a 9-min standing test. Alterations in muscle blood volume of the leg muscles and arterial blood flow of the popliteal artery were assessed with color power doppler sonography. The findings disclosed: (1) increased numbers in visible blood vessels; (2) Increased visible blood vessels that are wider more than 2mm. ( $p < 0.005$ ). The results indicate that low-frequency vibration performed is different from occupational random high-frequency vibration. Conversely, low-frequency vibration in the study proved to increase the peripheral blood circulation and blood volume.<sup>(87)</sup>

Lohman EB 3rd from Loma Linda University, California, also did a similar test. Healthy subjects were randomly divided into three groups: exercise group, vibration group and vibration plus exercise group. Skin blood flow was measured using a dynamic laser doppler sonography. He found that skin blood flow had no difference between the three groups prior to intervention. Immediately following the intervention a difference among groups was found. Post hoc test revealed that mean skin blood flow of vibration plus exercise group significantly increased after 10 minutes of intervention. Thus, we can see that short duration vibration plus exercise significantly increases peripheral blood circulation.<sup>(118)</sup>

How long does vibration take to work? Maloney-Hinds C from Loma Linda University found that peripheral blood circulation increased significantly after 4 minutes, peaking at the 5th minute and continued all the way to 10 minutes after vibration stops.<sup>(119)</sup>

## 9.5 Vibration reduces blood clots and infarction

The critical part of the cardiovascular disease is the blockage of the blood circulation. It will certainly lead to ischemia and cell death. Actually this can occur everywhere of our body, notoriously like cerebral stroke in brain, myocardial infarction in heart, pulmonary thrombosis in lung. Other places are also not uncommon seen, such as ischemic bowels, deep vein thrombosis of low leg, retinal occlusion of retina artery. The preventive way is to reduce the risk factors of the vascular thrombosis and infarction.



## Part 1 : Whole Body Vertical Vibration

Two blood coagulation factors are critical in forming blood clots and thrombosis.

(1) tPA (tissue-type plasminogen activator): tPA is a kind of protein enzyme secreted by endothelial cell of the vessels. It catalyzes the conversion of plasminogen to plasmin, the major enzyme responsible for clot breakdown. In short, more tPA helps breakdown the blood clots.

(2) PAI-1 (plasminogen activator inhibitor 1): PAI-1 is the inhibitor of tPA mentioned above, mainly produced by the endothelium cells lining blood vessels, or part secreted by fat cells. It leads to blood clot. To sum up, more PAI-1 cause more blood clot or thrombosis.

Boyle LJ from Ball State University, Illinois, US, had a study to examine the fibrinolytic reaction by WBVV and exercise in men. He invited 20 healthy men (average age 23.8, BMI 25.6). These people are divided into 3 groups, exercise group, vibration group and the exercise plus vibration group. This was a cross study design, means these subjects will change to other group after a period of time. The results showed that the exercise plus vibration group had much higher tPA (clot breakdown protein, 0.87 to 3.21) and much less PAI-1(inhibitor of tPA, 6.54 to 4.89) than exercise group (0.71 to 2.4 tPA and 9.76 to 6.48 PAI-1) or vibration alone (0.83 to 1.00 tPA and 5.68 to 5.84 PAI-1).

In conclusion, vibration alone seems not to help anticoagulation function. But vibration plus exercise can reduce the risk of thrombosis (blood clot) comparing to exercise alone or vibration alone.<sup>(117)</sup>



## Chapter 10 Vibration decreases body fat and loses weight

### Introduction

*Obesity is one of the three major issues in today's society. To lose weight, you have to burn out the calories through exercise. This could be a hard task for a health person, not to mention the elders, the obese, or the disables. Can whole body vertical vibration help lose weight? Evidences showed that WBV can reduce the body fat storage.*

*The visceral fat can be metabolized more effectively by vibration than aerobic exercise. Besides, body fat loss or weight loss result are able to maintain for a period of time.*

*For modern medical science, it requires four steps to prove a therapy valid. These are cell experiment, animal experiment, human experiment, and the elucidation of molecular biological mechanisms. The whole body vertical vibration has gone through these steps and is proven to lower the body fat successfully.*

*Through whole body vertical vibration, we now realized a new way of controlling obesity. It is probably the only way without going through medication, dieting or stimulating metabolism. WBVV can be applied alone or combined with diet, exercise or medication.*

### 10.1 Vibration diminishes body fat

Obesity, as we have mentioned in the first chapter, it is one of the three major problems in our society nowadays, and it has frustrated many people. Reducing calories of your intake is the basic principle to lose weight. However, it is very hard to do. Another way is to exercise more, it is also very difficult for many people. Therefore, we need some passive exercise to solve the problem of obesity and fat accumulation. But, is whole body vertical vibration useful for losing weight?

Before we discuss this problem, we have to clarify one concept. What is overweight or obesity? Overweight or obesity does not mean carrying too much weight. Many athletes like basketball player, Michael Jordan, he weighs 105kg. Can we say he is overweight? Of course not! The definition of obesity or overweight is the accumulation of excess body fat in body. It is neither the muscles nor the bones, it is the storage of extra fat in body. To be more precise, you have to measure the fat weight of your body instead of your body weight. The fat percentage shall not be over 30% for female and not over 25% for male. It is even lower for teenagers. Michael Jordan has only 10-11% of body fat, which means he has only 10.5kg of body fat in his body. Therefore, he is not overweight.



(Figure 26) obesity is the accumulation of excess body fat.

Why we mention this? Because we have shown that whole body vertical vibration will increase bone density and muscle mass in the previous chapters. To put it simple, after you receiving vertical vibration training, the weight of your muscles and bones will definitely increase. Therefore, if you study whether vertical vibration helps losing weight, you shall not use body weight (BW) or body mass index (BMI) as the parameter. Because WBVV increases the weight of bone and muscle, the BW and BMI will increase as well.(figure 26)

Then what should we check? I will recommend the percentage of body fat, the weight of body fat, or your waist circumference. Recently, new body weight scale can measure the percentage of body fat as well. However, because the mechanism of the fat scale is bioelectrical impedance analysis (BIA), the results can easily be influenced by many factors like sweating, edema or moisture etc. Therefore, it needs to be measured several times, make a record or draw the trend line. As for the waistline, in order to measure it more accurately, you have to measure at the exact same spot every time. Measuring the waist circumference normally has no such disturbing factors. The only shortcoming is it does not change a lot within a short period of time and you have to measure in a fixed position (like navel) every time.



In chapter 24, we are going to discuss the reason why vertical vibration can help osteoporosis. The reason behind that is it stimulates new bone formation. New bone formation happens because a very specific phenomenon that a group cells called “mesenchymal stem cell” were stimulated.

Mesenchymal stem cells are parent cells of both bone cell (osteoblast) and fat cell (adipocyte). Mesenchymal stem cells differentiate either toward bone cells or fat cells. Whole body vertical vibration will influence the direction of mesenchymal stem cells differentiation. These mesenchymal stem cells will develop to bone cells instead of fat cells. This is fantastic double-win for people who suffered from obesity and osteoporosis today.

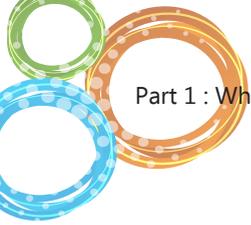
However, to prove something effective in modern medicine needs to go through 4 stages. Cells experiment (in vitro test) is the first stage. Animal experiments (in vivo test) is the 2nd stage. And the third stage is experiments on human beings (clinical trial). The fourth stage is DNA or protein experiments to elucidate what the intra-nuclear mechanism is. Research on vibration has done all four stage experiments and we’ll elaborate in the following chapters.

## 10.2 Vibration helps losing weight- animal experiments

Let’s take a look at animal studies. Luu YK from Stony Brook, New York University did a vibration experiment on male mice. (0.2g, 15 minutes a day, 5 days a week) He found that mesenchymal stem cells in their bone marrow increased by 46% in 6 weeks.<sup>(13)</sup> The result of more osteoblast and less fat cell was in accordance with the cell experiments results. (How do we know that? They analyzed the proteins within the cells and found that Runx2, which is a cellular protein to stimulate the osteoblasts, increased by 72%. While PPAR gamma, which is another cellular protein, inhibit the formation of fat cells, increased by 27%.)

The effect of new bone formation and fat suppression by stem cell became obvious after the 14th week. Visceral fat of the mice was suppressed and decreased by 28%. In the same time, bone trabeculae of tibia increased 11%. The results showed WBV had same fat reduction effect in humans as in animals.<sup>(13)</sup>

Maddalozzo GF from University of Oregon experimented with rats. After 12 weeks he found that vibration group had 10% ( $p < 0.03$ ) lower body weight and 22% ( $p < 0.05$ )

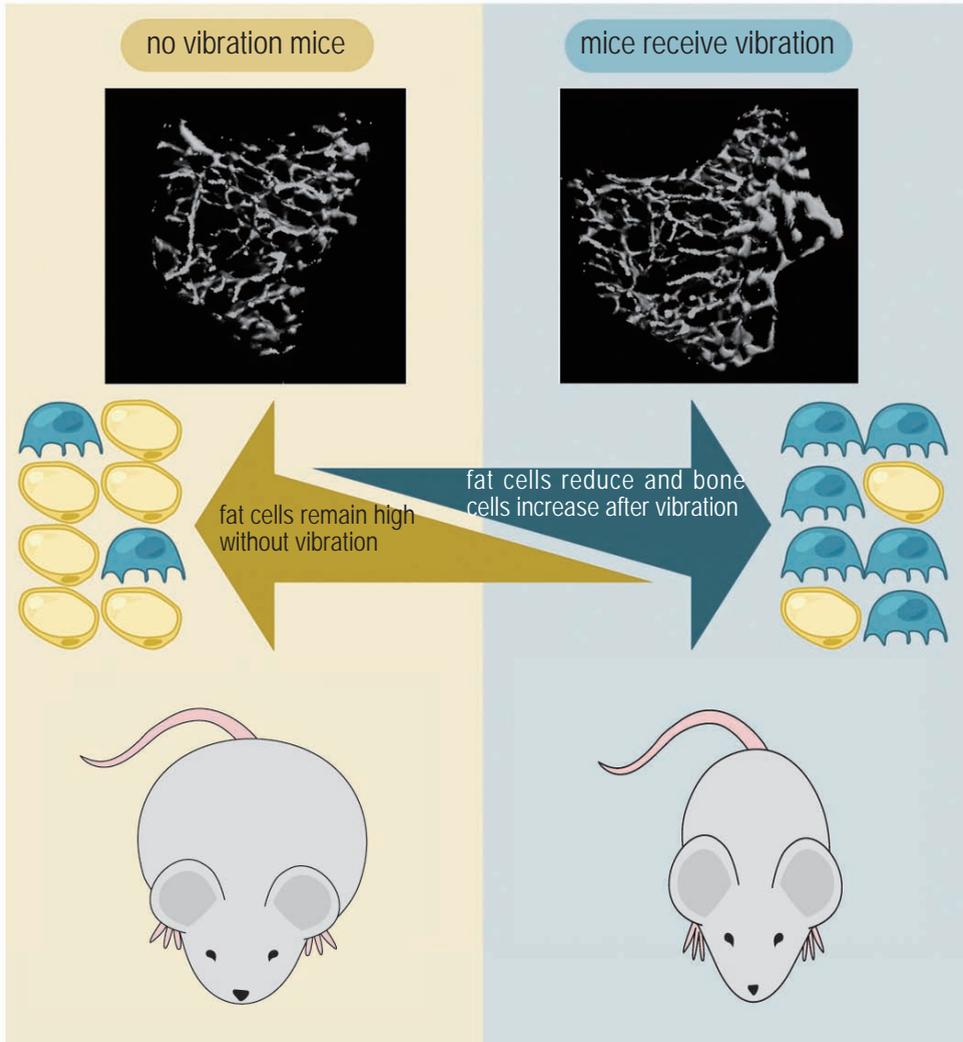


lower body fat. Leptin is a hormone with a key role in regulating energy intake and expenditure. Leptin controls our appetite, hunger, energy metabolism, and intake behavior. It is the most important adipose-derived hormones. In this study, leptin lowered by 53% ( $p < 0.01$ ). Dual-energy X-ray absorptiometry of lumbar spine revealed WBVV group significantly increased bone mineral content (+27%) and bone mineral density (+10.5%) than control group. Thus, these findings show that WBVV reduced body fat accumulation and increased bone density.<sup>(91)</sup>

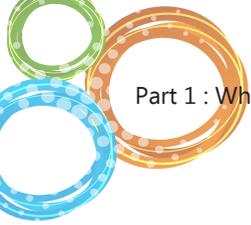
### 10.2.1 A new way to lose fat

Dr Rubin CT, chairman of the department of biomedical engineering, Stony Brook of New York University, conducted a experiment in mice to understand the effect of WBVV on weight or fat storage. After 15 weeks of WBVV, he noted that adipogenesis (new fat formation) in mice was inhibited by 27%. In addition, the non-esterified free fatty acid and triglyceride content in the liver also diminished by 43% and 39%, respectively. Both are risk factors of type II diabetes. Accordingly, **WBVV can inhibit the incidence of obesity and diabetes.**

In an effort to understand the relationship between whole body vibration and the differentiation of mesenchymal stem cells, Rubin CT adopted irradiated mice receiving bone marrow transplants to experiment. It revealed that 6 weeks of low-magnitude mechanical signals reduced mesenchymal stem cell differentiation into adipocytes by 19%. This indicated formation of adipose tissue in these models was deterred by a marked reduction in stem cell adipogenesis. So Rubin concluded, **“translated to the human, this may represent the basis for the non-pharmacologic prevention of obesity and its sequelae, achieved through developmental, rather than metabolic, pathways.”**<sup>(92)</sup> (figure 27)



(Figure 27) The vertical vibration is a kind of physical stimulation and will change the differentiation direction of stem cells. After the vibration, the stem cells will develop to bone cells instead of fat cells, therefore, the fat storage will reduce and the bone density will increase.



### 10.3 Vibration helps lose weight in people - clinical trials

In the following sections, we are going to see whether the clinical trials of WBVV had similar results of weight reduction like the studies in animals.

Luu YK from Stony Brook State University in New York had a 1 year clinical trial in 48 young women (15-20 year old) with osteopenia. It showed that low magnitude mechanical signals increased trabecular bone in the spine and kept visceral fat at baseline levels, whereas control subjects showed no change in BMD and increase in visceral fat. Luu concluded that low-magnitude WBV stimulates mesenchymal stem cells and can be a non-pharmacologic strategy to simultaneously prevent obesity and osteoporosis.<sup>(13)</sup>

Professor Milanese C from Verona University, Italy, conducted two clinical trials. Healthy, non-obese youth were randomly assigned to an 8-week trial of WBV. The results showed that body lean mass increased ( $p=0.009$ ) and body fat mass decreased ( $p=0.036$ ) in the whole vibration study population. Although waist circumference was unchanged or slightly reduced but skin fold thickness was significantly reduced.<sup>(93)</sup>

He did the second experiment in a group of obese middle aged women. They were assigned to ten-week WBV training. The result evaluated with dual-energy X-ray absorptiometry (DEXA) showed that vibration group had significantly lower BMI, total body fat and visceral fat. In opposition, the strength of their lower limbs increased.<sup>(94)</sup>

Both studies revealed that **WBV training will change the body composition, which includes reducing body fat, increasing lean mass and strengthening muscle power.** But body weight and BMI will not change for normal weight or young people after WBV. It is possible because fat loss is offset by increase of bone and muscle mass. **For obese women, body weight, BMI and body fat all go down. It suggests that for the purpose of weight loss, WBV works better in overweight or obese group.**<sup>(94)</sup>

#### 10.3.1 Vibration changes body composition

Fjeldstad C from University of Oklahoma invited 55 women to proceed a 8-month research. These women were assigned to resistance exercise group, vibration plus resistance exercise group or control groups. The vibration group showed significant



body fat reduction ( $p < 0.05$ ), whereas, the control group had an increase of their body fat ( $p < 0.05$ ). Both training groups exhibited significant increases in bone free lean mass of total body, arms and trunk regions ( $p < 0.05$ ) but not in the control group. It disclosed resistance exercise or vibration plus resistance exercise can change body composition. But only the combination of resistance training and whole-body vibration was effective to reduce body fat. It means that WBVV is an effective training tool to inhibit fat accumulation.<sup>(95)</sup>

González-Agüero A from Zaragoza University in Spain studied the adolescents with Down syndrome. He also found that their body fat declined and lean body mass increased after vibration training.<sup>(116)</sup>

Dr. Wilms B from Kantonsspital St. Gallen in Switzerland, hopes to know what WBV can do for obese women. 14 obese women (BMI 37.4) were randomized allotted to 2 different groups - traditional endurance training group and traditional training plus WBV group. After 6 weeks, he found that although body weight did not change, their waist circumference decreased in both groups (WBV -3.4 cm, no-WBV -1.7 cm) Thus, if WBV is added to endurance training, the effectiveness to reduce body fat could be doubled. Wilms analyzed and claimed that vibration is an independent factor beyond the exercise. Through bioelectrical impedance analysis, he found that the major difference existed in (1) phase angle, no-WBV increased  $0.20^\circ$  vs. WBV reduced  $0.19^\circ$ ;  $p = 0.04$ ; (2) estimated cell mass, no-WBV increased 0.8 kg vs. WBV decreased 0.3 kg;  $p = 0.02$ ). For actual fat mass, no-WBV decreased 0.45% and WBV decreased 0.8% which was had no significant difference. ( $p = 0.59$ ). (Phase angle is an indicator of health and low phase angle means better health as in WBV group.)

The unique contribution of the Wilms' study is he analyzed basal metabolic rate of two groups. His results disclosed that basal metabolic rate in no-WBV group increased 68 kcal in 24 hours compared to control group ( $p = 0.01$ ). For the WBV group, the metabolic rate increased 77 kcal in 24 hours ( $p = 0.01$ ). Compared to no-WBV group, WBV group was only 9 kcal more. There was no statistic difference in basal metabolic rate for these two groups.<sup>(96)</sup> It means that the effect of whole body vibration to reduce body fat was not because of raising basal metabolic rate.

As a conclusion, WBV can reduce body fat in obese women and improved their health shown in the declination of the phase angle. **Dr. Wilms also indicated that vibration is an independent pathway to reduce body fat, which is different from the way to raise basal metabolic rate like exercise. They are both independent**



**but additive. Through both vibration and exercise, the speed to lose body fat can be doubled.**

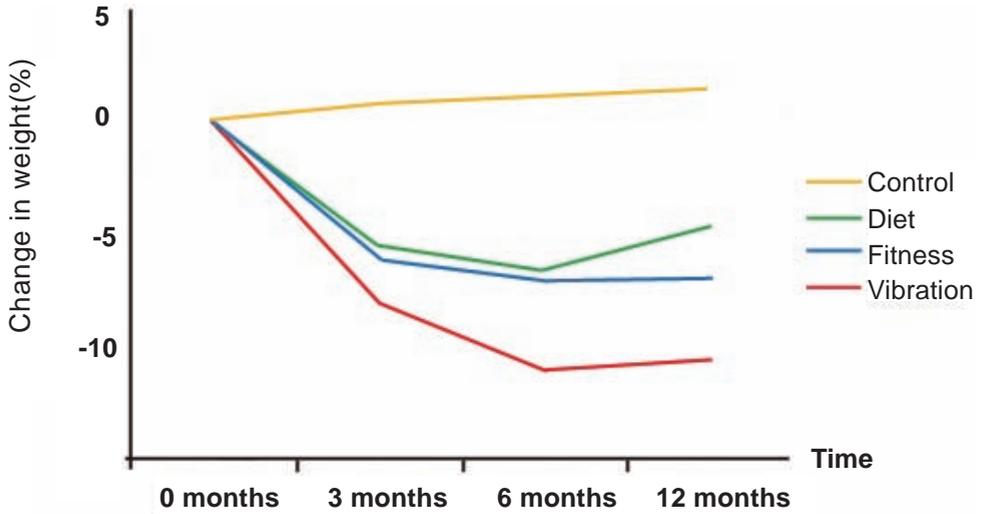
The study revealed that whole body vibration is unique to lose body fat. We are educated there are 2 ways to lose weight conventionally. One is dieting, which means you have to tolerate hunger and reduce your food desire. Another way is to raise your metabolism like exercise or take some medication like ephedrine or sibutramine. The downsides of exercise or taking pills are exhaustion, fatigue and difficult for those ill, injured or disabled. **Through these studies of whole body vibration, scientists realized that there is a third pathway to lose weight – path of stem cell differentiation.**

### **10.3.2 Vibration plus diet works better for weight loss**

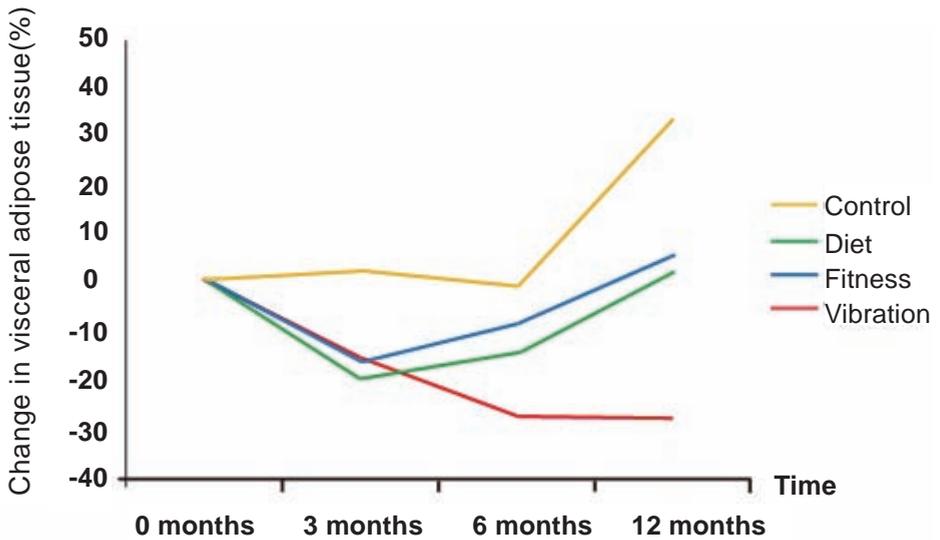
What if we combine all 3 methods for weight control? Would it work even better? A good question that Vissers D from University of Antwerp on Belgium tried to answer with study. In addition, he wanted to know the long-term effect of whole body vibration combined with caloric restriction or exercise. He designed a randomized, controlled study with a 6-month intervention period and a 6-month no-intervention follow-up. 79 participants were divided into 4 groups: the control group (CONTROL), the diet only group (DIET), the diet plus fitness group (FITNESS) and the diet plus WBV group (VIBRATION).

He found that body weight decreased significantly in all three intervention groups, but only FITNESS and VIBRATION managed to maintain a weight loss of 5% or more in the long term. To be precise, diet plus WBV group got 11% and 10.5% decrease in body fat while diet plus fitness group got 7% and 7% loss at 6 months and 12 months. (Figure 28)

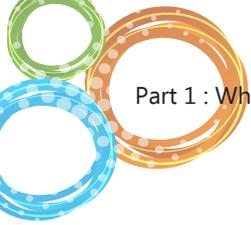
Visceral adipose tissue (VAT) changed most in VIBRATION group. The fat loss was 47.8g and 47.7g at 6th and 12th month respectively. In the same time, DIET group decreased 24.3g and 7.5g; FITNESS group decreased 17.6g and 1.6g; and CONTROL group decreased 3.6g and increased 26.3g ( $p < 0.001$ ) at 6th and 12th month.<sup>(97)</sup> (Figure 29)



(Figure 28) Weight change in all 4 groups, the bottom curve represents the vibration group<sup>(97)</sup>



(Figure 29) Visceral adipose tissue in all 4 groups. The bottom curve represents the vibration group; the other 3 groups rebounded after vibration stopped, only the vibration succeeded in maintaining the visceral adipose tissue level.



### 10.3.3 Vibration is effective in reducing visceral fat

We can see whole body vibration can diminish visceral fat more effectively than aerobics do. Vissers' study showed that the effect of WBV plus dieting was double comparing to dieting or exercise alone. **The amazing part regarding to this study is its long-term success of weight loss with WBV plus dieting. After six months of experiment, and subsequent six months of ad lib food or exercise, only the diet plus vibration group remained their slimming outcome. This indicated that whole body vibration which acts through the stem cell differentiation can help reduce fat storage more than the conventional ways do.**

This is certainly a great contribution since comparing with subcutaneous fat, visceral fat is much correlated to metabolic diseases like diabetes, hypertension, hyperlipidemia and heart disease. So, reducing the visceral fat does not only help people slimming but also prevent them from chronic diseases.

This is the longest study that I have ever read. I would like to introduce the design of vertical vibration in this study for your WBV daily practice. Vissers adopted the strategy to increase the intensity, speed, frequency, and duration of vibration progressively. It started with 30 seconds a time, total 10 times, and gradually added up to 60 seconds a time and total 22 times. The practice time in vibration platform took 11.9 minutes in the 3rd month and 14.2 minutes in the 6th month.

Vissers concluded that **“combining aerobic exercise or WBV training with caloric restriction can help achieve a sustained long-term weight loss of 5-10%. These preliminary data show that WBV may have the potential to reduce visceral fat more than aerobic exercise in obese adults, possibly making it a meaningful addition to future weight loss programs.”**

Dr. Wang SC from National Chung Cheng University in Taiwan also led his students on quite a few vibration projects. They found that the major factor to determine the amount of energy expenditure in WBV was intensity of the whole body vibration. And the energy expenditure in whole body vibration stimulus increased as the level of amplitude frequency increased.<sup>(98)</sup>



### 10.3.4 Molecular biology mechanism of vibration

From all the evidences above, we can see that WBVV is effective to reduce fat accumulation. The question is how it happens? The differentiation of mesenchymal stem cells is only at the cell level. What is the change inside of the cell or DNA? This is the mechanism at the molecular level that modern scientist need to elucidate. Thanks to Buer Sen from University of North Carolina and Clinton Rubin's team from Stony Brook of NY University, we now understand much more details of the underlying mechanism.

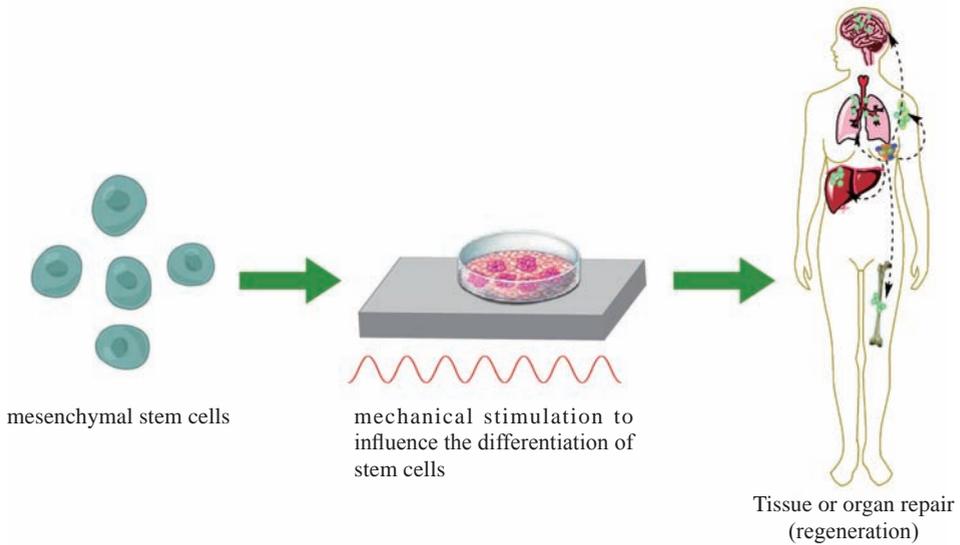
They did many experiments and proved that Akt plays a critical role. Akt also known as Protein Kinase B (PKB), is an intracellular protein kinase that mediate in multiple cellular processes such as glucose metabolism, apoptosis, cell proliferation, transcription and cell migration. It inhibits the formation of another enzyme-GSK-3 $\beta$  (Glycogen Synthase Kinase -3 $\beta$ ) At the same time, beta-catenin would be inhibited too because of nuclear translocation.

Both GSK-3 $\beta$  and beta-catenin are involved in energy metabolism, fat cell development, and body fat formation. If they are inhibited, fat cells could produce more two kinds of mRNA proteins, "peroxisome proliferator-activated receptor gamma (PPAR $\gamma$ )" and "adiponectin" by up to 35 and 50%, respectively. They are both receptors in the cells and play roles to suppress adipogenesis. Increase of PPAR $\gamma$  and adiponectin would inhibit new fat formation and accumulation in both animals and humans.<sup>(99)</sup>

Interestingly, Buer Sen also found that the new fat inhibition by mesenchymal stem cells are more dependent on vibration schedule than vibration intensity (magnitude or duration). As such, incorporating several brief mechanical vibrations within a 24h period may improve salutary endpoints in vivo than persistent stimulation.<sup>(100)</sup>

In recent years, more and more studies have been published. Currently it has become a very specific medical field called "Mesenchymal Stem Cells Mechanobiology." Many scientists applied mesenchymal stem cells mechanobiology into tissue bioengineering or regeneration bioengineering. It seems that the new field will produce many innovative therapies for tomorrow.<sup>(102)</sup>(Figure30)

In conclusion, all these medical studies in vitro, in vivo, clinical trials and molecular biology have shown that WBVV is a safe, cheap and effective way to weight loss and fat storage. WBVV can synergize with diet, exercise and life style change to achieve long-term weight loss. In addition, it can prevent osteoporosis simultaneously.



(Figure 30) Mesenchymal stem cell mechanobiology.



## Chapter 11 Vibration prevents and improves diabetes

### Introduction

*Physicians often considered diabetes and obesity are twins, because two thirds of obese people have diabetes, and 80% of diabetes cases are obese. Regular exercise can lower blood sugar for diabetes patient. However, can vertical vibration lower their blood sugar if they don't do exercise or can't do exercise? The answer is positive. Some studies have shown that vibration can increase glucose tolerance and lower glycated hemoglobin.*

*But how it happens? It is because there are insulin receptors on the surface of bone cells. While insulin enters into osteoblast, it can stimulate osteoblast to secrete a special hormone called "osteocalcin." Osteocalcin does not only involve in the metabolism of bone or accelerate new bone formation, but be responsible also for balancing blood sugar. While it is released, it will circulate to the pancreas and stimulate insulin secretion, and reinforce the utilization of blood sugar. Also, it raises insulin sensitivity and reduced visceral fat storage. This is a great breakthrough in recent bone studies.*

*Other than that, whole-body vibration can promote a kind of fat hormone called adiponectin. It can help suppress the formation of fat and balance the blood sugar.*

*Chronic diabetics' patients often suffer from peripheral neuropathy. Symptoms include pain, burning sensation, and sensory nerve abnormalities such as numbing, itching, tickling etc. Vertical vibration can reduce this kind of discomforts.*

Diabetes is one of the most disturbing and prevailing chronic diseases in the world. Approximately 5% of total population suffer from this disease. And for population age over 65, the figure soars to 12%. It leads to many severe complications. Major complications are: (1) "Retinopathy" affects vision; (2) "Nephropathy" affects renal functions; (3) "Peripheral neuropathy" affects peripheral nerve sensation. Also, obesity, hypertension, heart disease may happen simultaneously with diabetes or make worse by diabetes.

Studies have shown that regular exercises can reduce blood sugar for the diabetes. Boulé NG from Ottawa Health Research Institute in Canada, reviewed the research papers about the relation between exercise and blood sugar. There are 15 of aerobics and 2 of resistance exercises. He noted glycated hemoglobin (HbA1C), a serum marker represented long-term blood sugar control, was lower than the control group by 0.66% ( $P < 0.001$ ).<sup>(127)</sup> But can whole body vertical vibration lower blood sugar as exercise does?

### 11.1 Relationship between vibration and blood sugar

Klaus Baum from the German Sport University, Cologne, Germany, studied how whole body vertical vibration affected blood sugar of diabetes patients. He invited 40 diabetes patients, and divided them into three groups; 1. vibration group; 2. strength training group; and 3. control group. The vibration group was assigned to take up training 3 times a week for 12 weeks. The result showed that their fasting blood sugar did not change. Though, after oral glucose tolerance test, (OGTT, check blood sugar after taking 50 gram of sugar) he found that the area under curve (AUC) and peak glucose concentration of OGTT both reduced in the vibration and strength training group. HbA1c value tended to decrease below baseline in the vibration training group while it increased in two other intervention groups. These findings suggest that whole body vibration may be an effective and time-saving tool to enhance glycemic control in type 2 diabetes patients.<sup>(128)</sup>

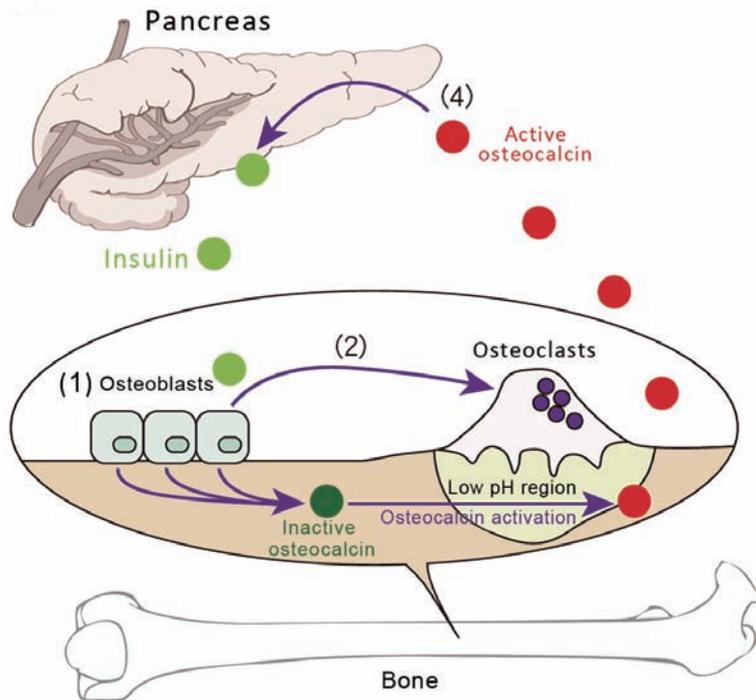
Di Loreto C from Perugia University, Italy, also found that after 25 minutes of 30Hz vibration training, the plasma sugar of healthy young men decreased compared to control group without vibration ( $p < 0.05$ ). He attributed this result to increasing glucose utilization by contracting muscles.<sup>(133)</sup>

Azarbayjani from Mohammad-Ali University, Iran, conducted a similar experiment as well. The subjects were also divided into three groups, the vibration group, exercise group, and control group. Then he noticed the vibration and exercise groups had relatively lower blood sugar than the control group ( $p = 0.02$ ). His team also checked the relationship between vibration and two relevant hormones - insulin and adiponectin. The results revealed that insulin decreased and adiponectin increased significantly after 4 weeks whole body vibration.<sup>(130)</sup>



## 11.2 Osteocalcin is a new hormone to reduce blood sugar

How can whole body vertical vibration lower blood sugar? What is the mechanism? Dr. Fukumoto S from Tokyo Medical University Hospital, Japan, had a special finding. He noted that the osteoblasts of mice secrete a special hormone called osteocalcin. The mechanism goes as follow. There is insulin receptor on the surface of bone cells. While insulin enters osteoblasts, it stimulates osteoblasts to secrete a special hormone called “osteocalcin.” Osteocalcin does not only involve in the metabolism of bone or accelerate the new bone formation, but it is responsible also for balancing blood sugar. While it is released, it will circulate to the pancreas and stimulate insulin secretion, and reinforce the glucose utilization. Also, it raises the insulin sensitivity and lowers visceral fat storage. This is a breakthrough finding in recent orthopedic researches. (Figure 31)



(Figure 31) Osteoblasts secrete osteocalcin. Osteocalcin can stimulate pancreas to secrete insulin, which helps to balance blood sugar.



So Fukumoto S commented that traditional concept that skeletal system is only weight supporting system is not right. Bone is in fact, also an endocrine organ.<sup>(131)</sup>

Further research has shown that osteocalcin must first be activated. The way to activate is the alteration of cell acid alkaline level (PH value). Mathieu Ferron from Columbia University, New York, has also proved it with experiment. When osteoclast proceeds bone resorption, it will change PH value of cell. The osteocalcin that secreted by osteoblast will turn into active osteocalcin. Active osteocalcin will then influences the glucose homeostasis.<sup>(132)</sup>

To put it simply, whole-body vertical vibration first stimulates osteoblast to secrete osteocalcin. Osteocalcin can circulate to pancreas and stimulate it to secrete insulin, which then lowers blood sugar and improve diabetes.

### **11.3 Vibration decreases the inflammatory response of the immune system**

Yu JC from Georgia Regents University, Augusta, USA, used a special species of mice born without leptin for experiments. These mice are short of leptin hormone to suppress their appetite. They will keep on eating and eventually lead to obesity and diabetes. He trained these mice 20 minutes vibration a day for 8 weeks. The result disclosed that their glycated hemoglobin, which is a marker of long-term blood sugar control, greatly decreased. It was even better than those were controlled by hypoglycemic drugs. After 4 days of whole body vibration training, normal mice even taking great amount of glucose, their blood sugar still remain at the ideal level. More importantly, whole body vibration does not only stimulate osteocalcin secretion, it also produces some anti-inflammatory substances from immune system.

In the past decade, more evidences revealed that diabetes is closely connected to chronic inflammation. Some experts even consider chronic inflammation of pancreas is the etiology of diabetes. Persistent chronic inflammation can lead to the prostration of pancreatic islets. Yu found a immune protein  $\gamma$ -H2AX which attacks DNA within the cells will reduce 5 times after vibration. It implied that WBV may help diabetes through the suppression of chronic inflammation.<sup>(135)</sup>





In summary, the relation between whole-body vertical vibration and diabetes is as follows. WBVV can reduce blood sugar, ameliorate diabetes and decrease the chance of developing diabetes through three mechanisms.

- (1) Osteocalcin, secreted by osteoblast, can stimulate the secretion of insulin to lower the blood sugar.
- (2) Suppress chronic inflammation of immune system, then inhibits the development of diabetes.
- (3) Adiponectin, secreted by adipocytes, can accelerate the glucose metabolism, and promoting insulin sensitivity.

## 11.5 Vibration improves diabetic neuropathy

The diabetic neuropathy is drastic, chronic and often unbearable. Symptoms include pain, burning, numbing, itching, tickling etc. The current treatment is to take drugs, include 1. Analgesics like tramadol. 2. tricyclic antidepressants like tofranil. 3. Antiepileptic drugs such as carbamazepine, gabapentin, etc. These medications are not ideal or very effective. It is estimated that they can control only 30 to 50% of those nerve pains. However, they had couples of adverse effects such dizziness, drowsiness, dry mouth, low blood pressure, weight gain and movement disorders. They may even cause the cognition or balance disorder which can lead to more fall accidents.

It is obvious that the treatment for diabetic neuropathy today is not ideal. So scientists look for better alternative. And whole body vertical vibration is one of choices. Many researches have shown that pain and numbness can be improved after WBVV. Junggi Hong from Willamette University, Oregon, US, had a case report. A diabetes patient, who suffered from peripheral nerve pain for 5 years, got a positive progress after 8 weeks of vibration.<sup>(136)</sup>

Yoosefinejad, from University of Tehran in Iran, also reported that a 52-year-old diabetes female had obvious improvement after six weeks of vertical vibration. Her muscle strength, flexibility, and the ability of balance also improved.<sup>(137)</sup>



Guzman RJ from Oregon University conducted a vibration experiment with 21 diabetic's patients for 12 weeks. The vibration schedule was 3 minutes vibration, 4 times, 1-minute break in between, 3 times in week. After the training, he discovered that the Brief Pain Inventory Short Form (BPI-sf) score went down from 5.61 to 2.39. And the pain severity score also decreased. He noted pain score kept reducing by weeks. These implied that whole-body vertical vibration may help diabetes patients to ameliorate the discomforts of diabetic neuropathy.<sup>(138)</sup> (Figure 35)



(Figure 35) WBV can reduce pain of diabetic neuropathy



## Chapter 12 Vibration strengthens bone and height in adolescent

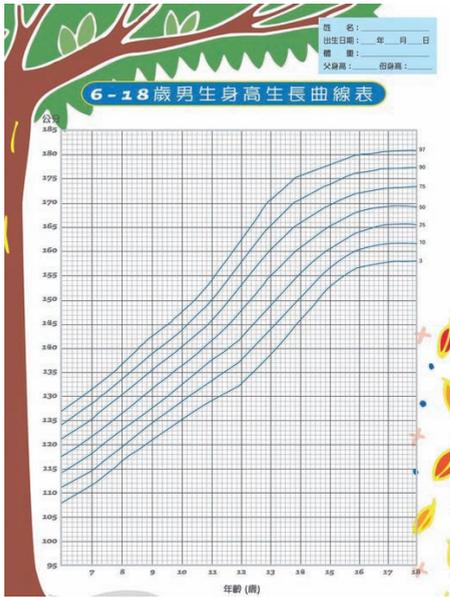
### Introduction

There are 3 influences that WBVV brings to help kids and adolescents grow: (1) Increase growth hormone, the critical hormone for them to grow up or tall. Many children didn't grow tall because they lacked the so called "growth hormone surge", which means their GH was relatively low; (2) It stimulates the mechano-sensor in epiphyseal growth plate, which can stimulate new bone formation and suppress the bone destruction by osteoclasts. Also, vibration stimulates growth in long bones, and the lengths of long bones determined the height; (3) Vibration stimulates majorly in long bones of lower body in kids and adolescents. Body height is mostly decided by the lengths of our lower bodies and vibration stimulates mostly in our lower body including, ankles, tibias, knees and hips.

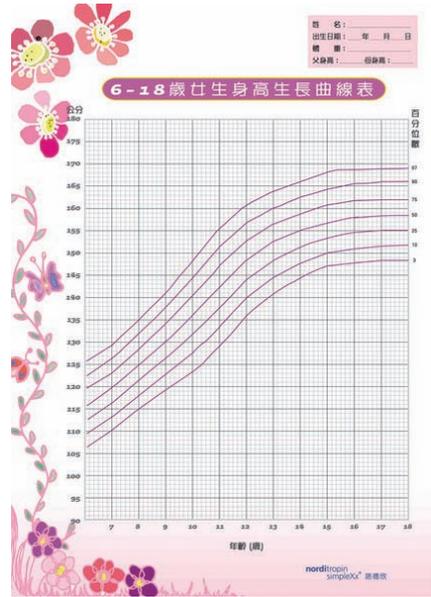
From these 3 reasons, theoretically, WBVV could help grow taller for adolescents. WBVV is a non-invasive approach to help stimulate children's growth and prevent bone weakness.

Today, children in Taiwan are 2-3 cm taller than that age of their parents. Since height is kind of normal distribution, half of them are shorter than average, some will be very short. Many products boast that they can help with growing taller, but almost none of them have proofs.

The only medicine to get taller approved by FDA is the growth hormone injection. It is very expensive, at a cost of more than \$35000-50000 USD a year. It costs even more for girls (Figure 34), because estrogen will accelerate the closing of epiphyseal growth plate. So if the period comes, these girls need to inject another drug to suppress estrogen - leuplin. National Health insurance bureau in Taiwan only pays for those kids with height percentile under 3 percentile of their age. There will be no payment after the bone age reaches 16 for boys and bone age 14 for girls. (Figure 35)



(Figure 34) Growth chart of boys in Taiwan age 6-18.

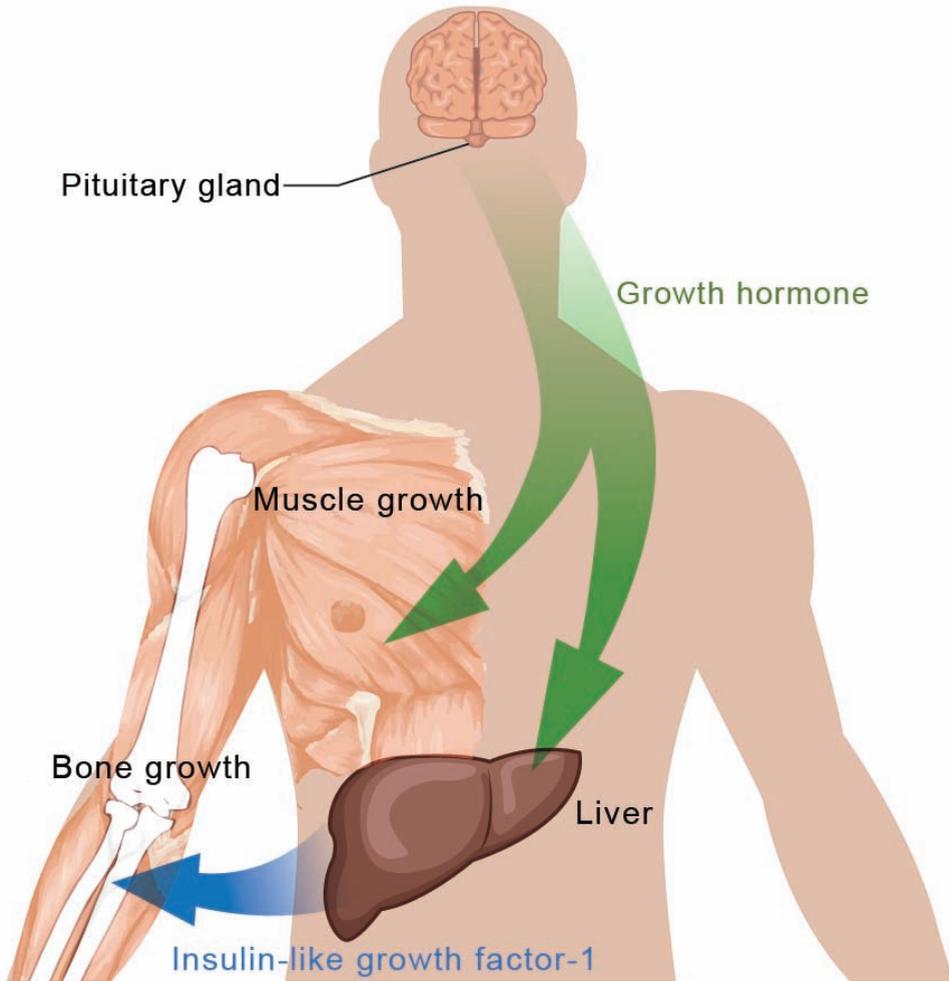


(Figure 35) Growth chart of girls in Taiwan age 6-18.

## 12.1 Vibration stimulates release of growth hormone

Growth hormone, GH, secreted by the pituitary gland in our brain, is one of the main hormones of human body. It is a peptide hormone that stimulates growth, cell reproduction and regeneration in humans. Lacking of GH while growing in adolescent will lead to growth retardation. They are usually not taller than 140-150cm. Lacking of GH in adulthood will lead to sexual dysfunction, muscle weakness, hair loss, osteoporosis, high cholesterol, body fat storage, poor memory, and fatigue etc. In short, shortness of GH will accelerate the aging process.

After GH secretion from pituitary gland, it circulates to the liver and stimulates the live to secrete another hormone called insulin-like growth factor 1 (IGF-1). Then IGF-1 will circulate to other organs and execute the same functions of GH. (Figure 36) Actually, IGF-1 is as another type of growth hormone. So, IGF-1 and GH are used replaceable in this book.



(Figure 36) After GH is secreted from pituitary gland, it goes into the liver instead of function on the body organs. It stimulates another hormone called Insulin-like growth factor 1 (IGF-1). Then IGF-1 would go to all organs to execute the functions of GH.



Whole body vibration can stimulate the release of growth hormone. Cardinale M from Olympics Research Ins in UK did experiments on elders average 70 years old. Nothing changed after single vibration (5 minutes per session, squats), but after a few times vibrations, he found that GH and cortisol substantially increased ( $p < 0.001$ ) without fatigue or other sickness.<sup>(103)</sup>

Bosco C from Italy experimented in young men average 25 years old with 60 seconds vibration with an interval of 60 seconds, 10 times, 6 minutes break after the 5th one, 4mm. After vibration, physical performance enhanced. As well as the concentration of serum GH increased from 6.2ng to 28.2ng ( $p = 0.01$ ).<sup>(36)</sup>

Giunta M from Italy experimented in obese young women (averaged age 22, BMI 39). He found that GH substantially increased after vibration with or without squat training.<sup>(104)</sup>

Sartorio, a colleague of Giunta M, sought to resolve the difference. He divided the subjects into 3 groups: (A) Vibration group, (B) Maximal isometric voluntary contractions group, and (C) Vibration with maximal isometric voluntary contractions group. He found GH improved in all 3 groups but GH in group B and C substantially increased comparing to group A. (+4.3, +18.8 and +20.8ng).

Kvorning T from South Denmark University had a similar research result as Sartorio. His 3 groups are squatting group, vibration group and squatting plus vibration. All growth hormone in 3 groups elevated, of whom the squatting plus vibration group increased most, serum GH concentration increased by 0.5ng, 0.2ng and 1.17ng respectively.

Some of my students asked me, “Since vibration increases growth hormone secretion, does it mean that it can stimulate youth’s growth and make them grow taller?”

This is an interesting question. I must say, “Until now, no exact experiments have been done by scientists, but theoretically, it is highly possible.” (Please also refer to Chapter 25 Enhancing body hormone by vibration for more information)



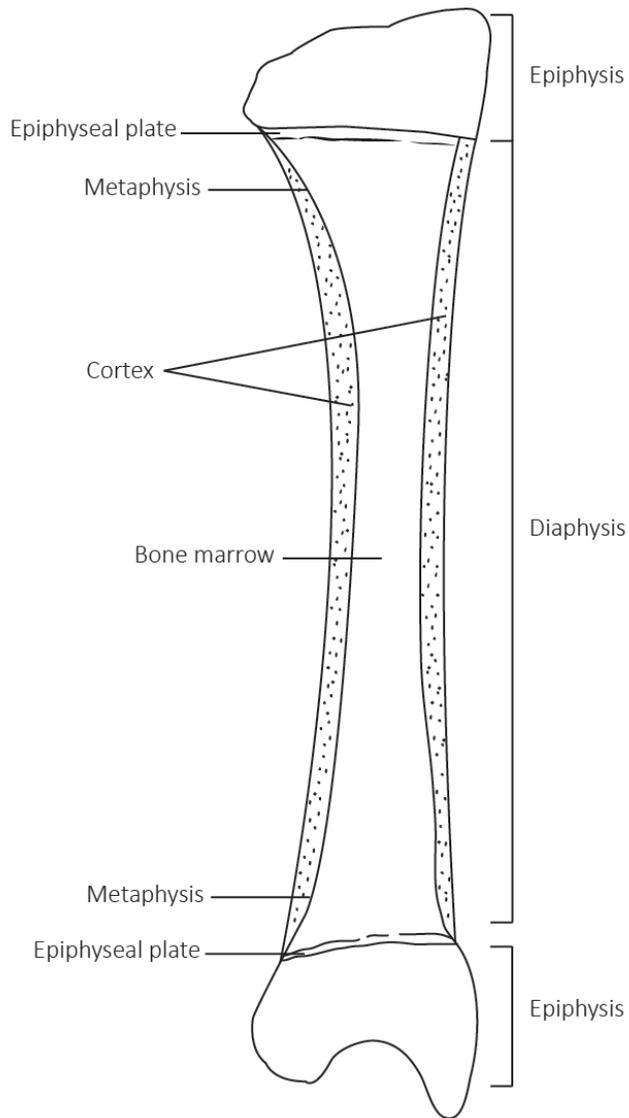
## 12.2 Factors influence height

Individual height is mainly determined by gene. That's why westerners in general are taller than Asians. The second factor of height is the nutrition and that's why kids grow taller nowadays than their parents or grandparents. Why the youths grow and adults don't? First of all, we have to explore the mechanism of growing tall.

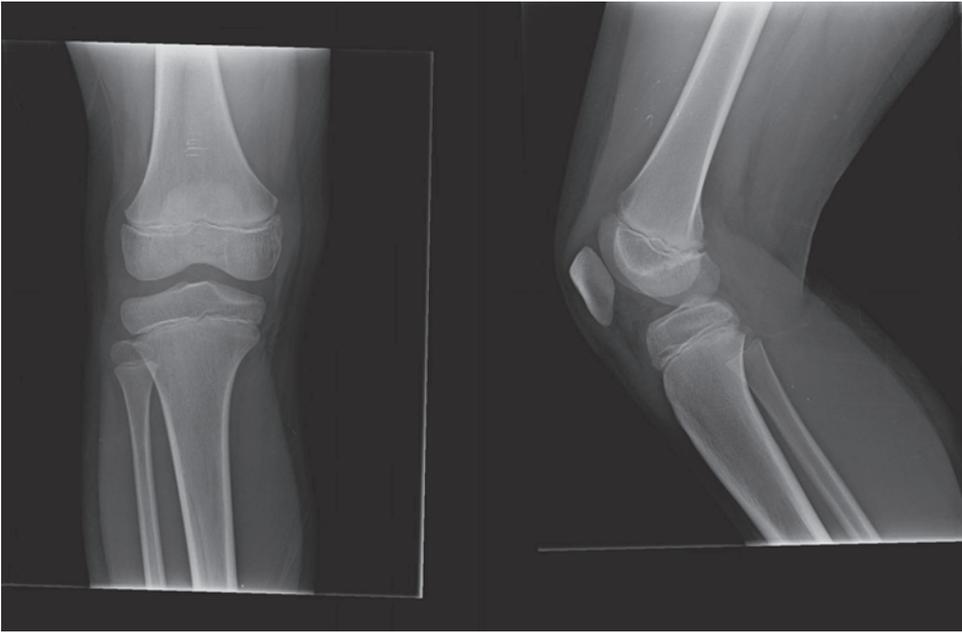
One's height is mainly determined by length of the spine and lower body. Because the length of spine dose not different a lot, most part of height is determined by long bones of lower body. A long bone has four parts. It is epiphysis, epiphyseal plate, metaphysis and diaphysis. (Figure37) The epiphyseal plate exists between the distal epiphysis and the middle diaphysis. The major difference in children and adults lies in epiphyseal plate. The plate is found in children and adolescents but disappeared in adults who have stopped growing.(Figure 39) This epiphyseal plate is consisted of the soft bone (cartilage) and often called the epiphyseal growth plate or growing plate. Under X ray, it shows as a black narrow band in children or adolescent. (Figure 38) These soft bone owns special capability to continue developing to new bone bi-directionally in the long bone and consequently increase the body length.

As a conclusion, **the critical factor to grow taller is the numbers and the sizes of cartilages inside the epiphyseal plate.** When compressed by external force, the cartilages would get hurt and its growth will be suppressed. On the other hand, when the bone was stretched, the length of bone will extend. Research showed that the height can be changed as much as 53% under these intervening forces.<sup>(108)</sup> For example, a hunchbacked kid wouldn't be as tall as a normal kid due to the compression to his epiphyseal growth plate.

Thus, we know, besides gene, nutrition and hormone, epiphyseal growth plate is the fourth factor to decide the human body height. Actually, epiphyseal growth plate is the ultimate determinant of growth. There are two factors that can affect epiphyseal growth plate. (1) **Peripheral vascular supply:** Injuries might lead to cartilage cells mal-developed or dead. The common causes in children are over-exercise or sports injuries. (2) **mechanical modulation.** It includes pressure, stretch, compression, torque and shear forces. Those forces lead to bone remodeling. Imagine what happen if children's epiphyseal growth plates were pinned up? Some scientists actually did those brutal experiments on animals. They found that cartilage cells inside of epiphyseal plate died and the animal stopped growing.<sup>(109)</sup> (Figure 40) Therefore, the mechanical force is crucial to growth of epiphyseal growth plate. If scientists adjust mechanical force to affect epiphyseal plate, they can influence body height.



(Figure 37) There are four parts in a long bone, from sides to the middle: epiphysis, epiphyseal plate, metaphysis and diaphysis.



(Figure 38) children's epiphyseal growth plates are composed of cartilages, which looks like a black band under x ray. When cartilages turn into hard bones, epiphyseal plates would disappear and the children would stop growing.



(Figure 39) Adult knee X film shows no growth plate.



### 12.3 Exercise stimulates height

Exercise is a very good mechanical modulation for growth. Children need adequate exercise to stimulate the growth of epiphyseal plates. However, overtraining might lead to mild fractures and injuries on epiphyseal growth plates. Lacking of exercise means shortage of mechanical stimulation in growth plate. This would affect the growth as well. Bradney M from University of Melbourne in Australia recruited a group of 10-year-old boys to do moderate exercise for 8 months. He found improvements in bone mass, size, volumetric density and bone strength. Femoral mid-shaft cortical thickness increased and endocortical diameter decreased. There was no periosteal expansion but volumetric bone density increased. Cortical thickness and volumetric bone density did not change in controls. The growing skeleton is sensitive to exercise. Moderate and readily accessible weight-bearing exercise undertaken before puberty may increase femoral volumetric bone density by increasing cortical thickness.<sup>(110)</sup>

**“It is well known that bone tissue adapts its structure to the mechanical load environment. Recent research has illuminated the biological response of bone to mechanical loading at the cellular level.”<sup>(111)</sup>** It is because there is mechanic receptor inside of bone cells. This mechanic receptor is called mechanosensor. E Tanck from Nijmegen University Hospital, Holland, proved that from the growth plate towards the diaphysis, the pores of the trabecular structure were gradually filled in with bone, which resulted in increased density and cortical bone. Merging of metaphyseal trabeculae into cortex is likely to be governed by mechanical stimuli.<sup>(112)</sup> So if it is proven that WBVV could improve the development of cortical bones of the adolescent, then we can assume that WBVV could help them grow taller.

### 12.4 Vibration stimulates new bone formation in mice

Dr Xie L from Stony Brook University, one of the most important vibration labs in US, experimented on adolescent mice. After 3 weeks of WBV, bone destruction (osteoclastic) activity in the trabecular metaphysis and epiphysis of the tibia was 33% and 31% lower than in age-matched controls. Bone formation rate on the endocortical surface of the metaphysis were 30% greater in WBV.<sup>(113)</sup> Therefore, vibration can stimulate new bone formation of metaphysis and epiphysis and suppress the bone destruction activity in adolescent rats.



Xie did another similar experiment. This time he did it with 0.3g, 15 minutes vibration every day. Following 6 weeks of WBV, bone mineralizing surface in the proximal metaphysis of the tibia was 75% greater than the control group. The tibial metaphysis of WBV mice had 14% greater trabecular bone volume. Periosteal bone area, bone marrow area, cortical bone area, and the moments of inertia of this region were all significantly greater (up to 29%). Hence, we can see that **mechanosensors of the bones are stimulated and functioned after whole body vibration. The mechanosensors are very sensitive and don't require strenuous, long-term activity to initiate a structurally relevant response in the adolescent musculoskeletal system. If maintained into adulthood, the beneficial structural changes in trabecular bone, cortical bone, and muscle may serve to decrease the incidence of osteoporotic fractures and sarcopenia later in life.**<sup>(114)</sup>

Tanck E from Nijmegen University Hospital, Holland, proved that there are two stages in bone development. The initial stage is the increase in trabecular density and the second stage is the adaptation of the trabecular architecture.<sup>(115)</sup>

## **12.5 Lower body workouts stimulate growth hormone, but upper body workouts don't**

West DW from McMaster University in Canada found that there was no increase in growth hormone or testosterone with only upper body workouts like arms or shoulders training. However, with lower body workouts like squats, GH or testosterone increased substantially.<sup>(120)</sup> So we need to know which part of the muscles that WBVV affects.

Slatkovka L did a research in 2010 and found that WBVV could increase lumbar spine density in children and adolescents (+6.2mg/cm<sup>3</sup>) and tibia bone density (+14.2mg/cm<sup>3</sup>). That is to say, vibration mainly affects lumbar spine and low limbs (tibia and around tissues).<sup>(8)</sup>

Bressel E from the Utah State University found that the sites affected by vibration of children are different from adults due to their mass. Vibration transmission in children was 42% and 62% greater than adults on the ankle and hip, respectively (p=0.03). Vibration transmission to the head is not different from adults.<sup>(121)</sup> It means that the lower body of children receives more vibration force than upper body does. From research mentioned above, we know that vibration acting on lower body will stimulate



secretion of growth hormone and testosterone. As a result, vibration can probably help stimulate the growth in children.

**Conclusion:** vibration stimulating may help adolescents grow taller

To sum up, there are 3 influences that WBVV may help kids and adolescents grow taller: (1) it increase IGF-1 and GH, the most important hormones for teenagers to grow; (2) It stimulates the mechanosensors in epiphysis, accelerates new bone formation and suppresses osteoclast activities; (3) Vibration stimulates the long bones of lower body and spine in kids and adolescents. From these 3 reasons, we are convinced that WBVV may help stimulate growth taller in adolescents. We look forward to seeing more related research in the future. (Figure 41)



(Figure 41) Based on theory and research, WBVV can help adolescents to grow taller

## Chapter 13 Vibration improves patients of cerebral stroke

### Introduction

*Cerebral stroke often lead to body paralysis like quadriplegia or hemiplegia. Stroke patients are difficult or unable to do exercise actively. These people urgently need rehabilitation or passive exercises to prevent the dysfunction of their limbs and trunk. (Figure 42). Whole body vibration could help those patients because they can do this type of exercise while sitting or lying on that platform. WBVV provide many benefits for the stroke patients, including: (1) boost blood/oxygen circulation in the brain, prevent the brain from hypoxia, lower blood pressure; prevent recurrent stroke or, blood clot formation; (2) improve their strength, posture control, balancing, flexibility and mobility of joints. Plus, it enhances walking speed and prolongs walking distance; (3) it prevents post-stroke immobile osteoporosis. Please also see chapter 27 regarding preventing cardiovascular stroke or temporary cerebral anoxia by horizontal vibration.*

A neurologist once said, "Stroke is a brutal killer, for they never kill people directly, but torture them slowly to death." Even a mild stroke could affect body movements. Massive stroke could lead to multiple disabilities. Cerebral stroke often lead to quadriplegia (all limbs can not move) or hemiplegia (left or right side limbs can not move). Stroke patients are difficult or unable to do exercise actively, and urgently need devices or rehabilitation to help them performing passive exercises. Limbs without exercise or physical therapy will result in muscle dystrophy, rigidity or even contracture (Figure 43). Whole body vibration could help those patients, especially the vertical type of vibration, because they can do this type of exercise while sitting or lying on that platform.



(Figure 42) Strokes often lead to quadriplegia or hemiplegia. Stroke patients need rehabilitation or passive exercises to prevent the dysfunction of their limbs and trunk

### 13.1 Vibration improves posture control of stroke patients

Van Nes IJ from Sint Maartens Klinkiek in Holland had a study in stroke patients to see if vibration can help them to control posture. After vibration training with 0.6g, 3mm, there were improvements in all four items- standing, shifting with eyes open or closed weight-shifting speed ( $p < 0.05$ ). Thus, he got a conclusion that whole-body vibration may be a promising candidate to improve proprioceptive control of posture in stroke patients.<sup>(61)</sup>

He did another 6-week experiment with 53 stroke patients who had just gotten acute stroke within 3 days. All of them received physical rehabilitation but one group added whole body vibration training (with 4 times, 45 seconds, 0.6g, 3mm, 5 days a week for 6 weeks). After 6 weeks and 12 weeks, he tracked their results and found no significant results between both groups, but no side effects either.<sup>(62)</sup>



(Figure 43) Without movement or activities, the trunk and limbs of post-stroke patient will become atrophy, stiffness and contracture

### 13.2 Vibration increases muscle strength of stroke patients

Tihanyi TK from Saint John's Hospital of Budapest in Hungary showed positive results. He recruited 16 acute stroke patients, averaging 27 days after stroke, receiving whole body vibration therapy (6 sessions, 1 minute per session, 5mm). He noted that in the WBV group

- (1) isometric and eccentric knee extension torque increased 36.6%
- (2) eccentric knee extension torque increased 22.2%
- (3) EMG amplitude increased 44.9% and median frequency in the vastus lateralis increased 13.1%



- (4) ability to generate mechanical work during eccentric contraction improved 17.5%.
- (5) biceps femoris contraction during isometric reduced 8.4% and eccentric 22.5% .

These results suggest that one bout of whole body vibration can transiently increase force and muscle activation of the quadriceps muscle affected by a stroke.<sup>(183)</sup>

He also proceeded another experiment to see whether vibration works better in paralytic leg or non- paralytic leg. After a WBVV training for 6 weeks (5mm, 3 times a week), he noticed that WBVV produced better outcome in the paralytic leg, but there was no influence to the healthy leg.<sup>(63)</sup> It implied that WBVV can offer rehabilitation benefits to the stroke patients during their acute stage.

### 13.3 Vibration improves cerebral circulation

Maikala RV is a fellow in Liberty Mutual Research Institute for Safety, Massachusetts. He studied to understand how vibration affected the blood circulation in the brain. 13 healthy males received a random order of 3, 4, 5 and 6 Hz (nearly 0.9g) whole body vibration. During WBV, subjects performed right-hand maximal voluntary intermittent rhythmic hand grip contractions for 1 minute. Subjects demonstrated highest oxygenation and blood volume values at 4.5 Hz. Compared to WBV alone, addition of hand grip exercise during WBV further increased oxygenation (0.07 vs. 0.004,  $p=0.003$ ) and blood volume (0.156 vs. 0.066,  $p=0.000$ ) in the right forehead. Peak oxygen uptake did not correlate to changes in oxygenation and blood volume ( $p>0.01$ ).

The findings of Maikala were that WBV induces hyperventilation which then activates the pre-frontal cortical region of brain. Through the neuronal activation, the blood flow and volume were then promoted.<sup>(59)</sup>

### 13.4 Vibration decrease blood clotting

The most worried thing for stroke patients is to get another stroke. The repeated stroke is called “recurrent stroke.” Studies showed that the possibility of suffering from another stroke is as high as 30% within 5 years of the first stroke. This is 15



times high comparing to healthy people. The most dangerous period is their first year after stroke. Statistics revealed 13% of them had recurrent stroke in the first year and 4% in the 2nd to the 4th year. Many of them became bed-ridden status or quadriplegia.<sup>(176)</sup>

Why does stroke recur in the same patient? The reason is probably because most stroke patients had poor-controlled hypertension, diabetes, obesity, hypercholesteremia, heart disease or peripheral vascular disease. These diseases actually led to constricted vessels, lesions of vascular inner wall or abnormal blood coagulation function. If these underlying pathologies did not improve, another stroke was inevitable. WBVV could help ameliorate cardiovascular diseases, diabetes and obesity through many mechanisms. You may review chapter 9, 10 and 11. As a result, WBVV can help prevent recurrent stroke and improve the disability such as muscle strength, flexibility, and balancing. Therefore, WBVV is an optimal tool for stroke patients either in acute or chronic stage.

General speaking, stroke can be classified into two categories. The first type is hemorrhagic stroke which means the brain has bleeding from ruptured vessel. This type is relatively rare, only 13% of all strokes. Another type is ischemic stroke, which means brain is short of blood supply because some vessels are blocked. This condition can be caused by local thrombosis or by drifting embolus from distant vessels. About 87% of strokes belong to this type. Whether thrombosis or embolism, it first causes ischemia (lack of oxygen) in brain and then lead to subsequent brain infarction and necrosis.

In order to reduce the thrombosis or embolism, the most useful strategy is to stop the process of blood clotting. Two important proteins, which antagonist to each other, play critical roles in forming blood clots.

(1) tPA (tissue-type plasminogen activator): tPA is a kind of enzyme protein which is secreted by endothelial cell within the blood vessel. It can catalyze the conversion of plasminogen to plasmin, which is the major enzyme responsible for clot breakdown. In short, more tPA will help breakdown of blood clots.

(2) PAI-1 (plasminogen activator inhibitor-1): PAI-1 is antagonist of tPA mentioned above. They are produced by the endothelium (cells lining blood vessels), or secreted by fat cells. Its function is inhibiting tPA and facilitating the formation of blood clot. To sum up, more PAI-1 causes more blood clot and thrombosis.



Evidences showed WBVV can reduce the thrombosis and embolism by promoting tPA and diminishing PAI-1. We can see from the study of Boyle LJ, a professor of Ball State University in Illinois. He had an experiment with 20 young healthy men (average 23.8 years, BMI 25.6) These young men were divided them into 3 groups, exercising group, vibration group and the exercise plus vibration group. This is a cross designed study and the subjects will change their group in series. The results showed that the exercise plus vibration group had higher tPA (blood clot breakdown protein) and less PAI-1 (inhibitor of tPA) than exercise or vibration alone. In conclusion, exercise alone is useful to inhibit the chance of blood clotting. But vibration plus exercise can reduce the risk of thrombosis (blood clot), and this is much more effective than exercise alone. (Table 13.4).<sup>(117)</sup>

	tPA(before)	tPA(after)	PAI-1(before)	PAI-1(after)
Exercise plus Vibration group	0.8	3.21	6.54	4.89
Exercise group	0.71	2.40	9.76	7.48
Vibration group	0.83	1.00	8.68	5.84

Table 13.4 tPA and PAI after vibration

In summary, WBVV helps to (1) boost blood/oxygen circulation in the brain, prevent the brain from hypoxia; (2) enhance fibrinolysis, which is a process that prevents blood clots from growing and formation; also prevents recurrent stroke; (3) for acute stroke patients, it could improve their muscle contraction power, mobility and proprioception; (4) for chronic stroke patients, it could improve their strength, posture control, balancing, flexibility and mobility of joints. Besides, it enhances walking speed and prolongs walking distance. Furthermore, it prevents them from fall accidents and raises their quality of life. (please also refer to chapter 6 and chapter 8)

## Chapter 14 Vibration improves osteoarthritis and post-orthopedic surgery

### Introduction

*Osteoarthritis (OA) also known as degenerative arthritis is a very common disease in the aged population. WBVV could help patients with OA to improve their muscle power, knee extension power and proprioception. Recently, more people received knee replacement or artificial implants thanks to progress of orthopedic surgery. For artificial implants, vibration improves ratio of bone-to-implant contact (BIC) and peri-implant bone fraction (BF). It means vibration accelerates the healing of implants in surgery place. For those who have received total knee arthroplasty, their knee extensor power, mobility and contraction power had obvious progress after whole body vibration. Thus we conclude that whole body vibration could replace the traditional resistance training and help post-joint surgery recovery.*

### 14.1 Vibration helps osteoarthritis patients

Osteoarthritis (OA) also known as degenerative arthritis is a very common disease in the aged population. And it's also the main reason to impede their walk and free movement. Dr. Trans T from Frederiksberg University, Denmark, wanted to know if vibration works to help patients with osteoarthritis. After progressive vibration training twice a week for 8 weeks, vibration group had obvious improvement on their (1) muscle strength and (2) knee extension power. Additionally, Trans did a special examination called "Threshold for Detection of Passive Movement, TDPM". This is a device to detect the proprioception. The blinded elders were asked to tell whether they feel the slight movement of their legs in the device. They tend to be more aware of the slight movement after the vibration training. It means that their knee proprioception has improved.<sup>(50)</sup> Thus, whole body vibration is a safe, cheap and effective way to help the elders with osteoarthritis.



## 14.2 Vibration accelerates the healing of artificial implant surgery

How WBVV works for patients after orthopedic surgery? The study of bone response to mechanical stimuli has become hot topic these years. It is now known that mechanical stimuli like WBVV have a marked influence on cells involved in new bone formation (osteogenesis) and undifferentiated mesenchymal stem cells. Toru Ogawa from Catholic University of Louvain, Belgium, interested in this topic and conducted a study. A custom-made titanium implant was inserted into 42 rats all with artificial induced tibia fracture. These rats were divided 2 groups: one group was control group with ad lib activity and another group received WBVV with 0.3g, 5 days a week.

The wound healing condition of these post-implant surgery rats were observed at day 3, 7, 14 or 25. At day 25, they received an injection of [ $^{18}\text{F}$ ] sodium fluoride, which can be absorbed into the tissue. Then he detected this radioactive element to trace two parameters: (1) bone-to-implant contact (BIC); and (2) peri-implant bone fraction (BF). His results showed that WBVV significantly increased bone-to-implant contact (BIC) and peri-implant bone fraction (BF). (Figure 44). Bone to implant contact (BIC) is the percentage of the implant surface in contact with bone on a microscopic level. And peri-implant bone fraction (BF) means the new bone formation existing around the tissue of the artificial implant. The results indicated that WBVV stimulated new bone formation around new implant and accelerated its healing.<sup>(78) (184) (185)</sup>



(Figure 44) Vibration accelerates bone-to-implant healing after surgery



Garman R from New York University tried to understand whether WBV enhances osteogenesis (new bone formation) or not. He designed a special vibration device to simulate left tibia of 8 mice and used their right tibia as control. After 3 weeks 0.3g vibration, in left tibia, metaphyseal bone formation rate was 88% greater and the percentage of mineralizing surface was 64% greater ( $p < 0.05$ ). At 0.6 g, bone formation rate and mineral apposition rate were 66% and 22% greater ( $p < 0.05$ ). Change in bone morphology only happened in the epiphysis, where left tibia displayed significantly greater cortical area (+8%) and thickness (+8%). The study proved that tiny vibration motion could accelerate new bone formation and change bone morphology.<sup>(79)</sup>

### **14.3 Vibration increases extension and contraction power after total knee replacement**

Now, scientist will explore the studies in human beings. Johnson AW from Brigham Young University in Utah, invited 16 patients who just had their total knee replacement surgery. One group received WBVV and another group received traditional progressive resistance (TPRE) training. There was a significant increase in knee extensor strength and improvement in mobility, as measured by maximal volitional isometric contraction and “time up and go test “(TUG), respectively, for both groups ( $p < 0.01$ ). The WBVV knee extensor strength improved 84.3% while TPRE increased 77.3%. TUG score improved 31% in the WBVV group and 32% for the TPRE group. There was no significant difference between groups for strength or muscle activation or for mobility. No adverse side effects were reported in either group. In individuals with total knee replacement surgery, both WBVV and TPRE showed improved strength and function. Thus, WBVV works as well as the traditional resistance training, and help patients recover after orthopedic surgery.<sup>(80)</sup>

In summary, whole body vertical vibration can replace the traditional exercise and helps those people receiving artificial-implant orthopedic surgeries. WBVV can help accelerate new bone formation, facilitate new implant healing, enhance the strength of the joints and improve the mobile functions after surgeries.(Figure 45)



(Figure 45) With WBVV, knee functions would be improved for patients with total knee arthroplasty



## Chapter 15 Vibration improves fibromyalgia and chronic fatigue syndrome

### Introduction

*Fibromyalgia (FM or FMS) is a common disease yet hard to diagnose or treat today. It is characterized by chronic widespread pain, with symptoms like fatigue, sleep disturbance, and joint stiffness. Patients often complain pain in many different areas of their body, including head, neck, shoulder, upper back, waist or hip.*

*Chronic fatigue syndrome (CFS) is a group of medical conditions characterized by persistent fatigue and other specific symptoms that lasts for a minimum of six months in adults. The fatigue is not due to exertion and not relieved by rest. Symptoms of CFS include malaise after exertion, un-refreshing sleep, widespread muscle and joint pain, severe headache, cognitive difficulty, chronic and severe mental and physical exhaustion, repeated sorethroat, pain in neck or armpits lymph nodes.*

*Many experts consider that these two annoying chronic diseases have same etiology. Although we don't fully understand their mechanisms yet, but they are probably both caused by neuromuscular dysfunction. Vibration plus exercise is a safe and effective approach to alleviate pain brought by fibromyalgia and chronic fatigue syndrome.*

### 15.1 Vibration helps patients of fibromyalgia

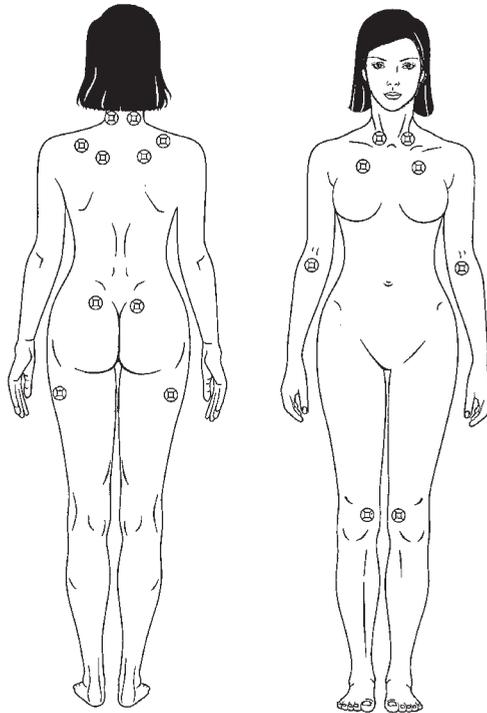
Fibromyalgia (FM or FMS) is a common disease yet hard to diagnose or treat. It is characterized by chronic widespread pain, with symptoms like chronic fatigue, sleep disturbance, and joint stiffness. Patients often complain pain in different areas of their body, including head, shoulder, upper back, waist or hip. (Figure 46)

Alentorn-Geli E from University of Barcelona in Spain conducted a study to see if WBVV can help fibromyalgia patients. He divided these patients into 3 groups: (1) vibration plus exercise; (2) exercise group; and (3) control group. He evaluated the level of pain, fatigue, stiffness and depression with “visual analogue scale” and



“fibromyalgia impact questionnaire”. After 6 weeks, he found that the vibration plus exercise group had lowest score in pain and fatigue items comparing to the other two groups. It seems that vibration plus exercise is a safe and effective way to mitigate the pain and fatigue of fibromyalgia patients.<sup>(51)</sup>

Gusi N from Extremadura University in Spain conducted another experiment with 41 fibromyalgia patients. After whole body vibration (3 times a week, 45-60 seconds, repeated six times, 12.5Hz) for 12 weeks, dynamic balance had 36% increase in vibration group but no change in control group. This study showed that vibration enhances dynamic balance in patients with fibromyalgia.<sup>(71)</sup>



(Figure 46) common-seen trigger points in fibromyalgia patients.  
It is also a diagnosis criteria

## 15.2 Vibration helps patients of chronic fatigue syndrome

Chronic fatigue syndrome (CFS) is a group of medical conditions characterized by persistent fatigue and other specific symptoms that lasts for a minimum of six months in adults. The fatigue is not caused by exertion and can not relieve by rest. Symptoms of CFS include malaise after exertion; un-refreshing sleep, widespread muscle and joint pain, severe headaches, cognitive difficulties, chronic and severe mental and physical exhaustion, repeated sore throat, pain in neck or armpits lymph nodes. (Figure 47)



(Figure 47) chronic fatigue syndrome

Many experts consider that these two annoying chronic diseases have same etiology. Although we don't fully understand their mechanisms yet, but they are probably both caused by neuromuscular dysfunction. Jo Nijs pointed out that their core problem is “central sensitization”.<sup>(72)</sup>

Since it's a neuromuscular problem, and WBVV proved helpful for fibromyalgia patients, it may help patients of chronic fatigue syndrome as well. Saggini R from G. D'Annunzio University in Italy tried to treat chronic fatigue syndrome with aerobic exercise plus WBV for 6 months. The results are amazing. All patients measured with “visual analogue scale (VAS)”, or “muscle performance analysis” showed significant improvement.<sup>(73)</sup>

Why it works? Remember the principle of whole body vibration is based on “tonic vibration reflex,” which is neuromuscular reflex induced by whole body vibration. (please refer to chapter 24 why it works? the mechanism of whole body vibration training) Scientists now understand that fibromyalgia and chronic fatigue syndrome are both diseases of “neuromuscular dysfunction” or “central sensitization”. WBV can mitigate neuromuscular dysfunction or central sensitization through preoccupying afferent nerve of pain transmission. This will block or relieve their symptoms. This is very like the mechanism of how vibration relieves back and joints pain. (see Chapter 7 Vibration reduces back pain and joint pain). But further and more studies are needed.



## Chapter 16 Vibration helps patients of Parkinson's disease

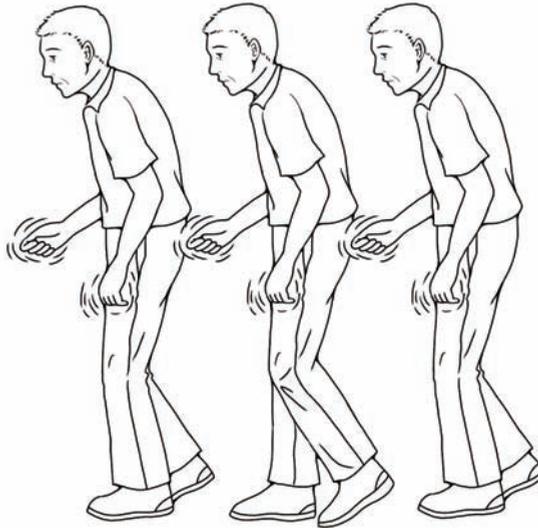
### Introduction

*Parkinson's disease is one of top 3 disable diseases of the elders, along with stroke and Alzheimer's. This is a degenerative disorder of the central nervous system. The cause of this disease is still unknown. The motor symptoms of Parkinson's disease result from the death of dopamine-generating cells in substantial nigra and basal ganglia. Lacking of dopamine results in symptoms of tremor, rigidity, slowness of movement and disturbing gait. Due to dyskinesia, patients with Parkinson's disease have difficulty to perform active exercise and need passive exercise. Research showed that WBVV is effective on posture control for Parkinson's disease.*

*King's research showed that WBVV helps improve symptoms of Parkinson's disease. Precisely speaking, rigidity lowered, tremor reduced, distance of step increased, and executing grooved pegboard test speeded. So, King concluded that "WBVV is a non-pharmacological substitute therapeutic approach for treating Parkinson's disease."*

*Haas CT's research team also stated: "WBVV can be regarded as an additional device in physical therapy in PD."*

Parkinson's disease is one of the top 3 diseases of the elders, along with stroke and Alzheimer's in the world. Parkinson's disease is a degenerative disorder of the central nervous system. The cause of this disease is still unknown. The motor symptoms of Parkinson's disease result from the death of dopamine-generating cells in the brain stem including the area of substantial nigra and basal ganglia. Dopamine is a major neurotransmitter in our brain. It controls and tunes the fine muscle movement and gait. Lacking of dopamine will result in symptoms like tremor, rigidity, slowness of movement and unstable gait. (Figure 48) Currently, the drugs used to treat motor symptoms are levodopa, dopa decarboxylase inhibitor, dopamine agonists and MAO-B inhibitors. Anti-cholinesterase drug can help tremor symptom.



(Figure 48) Tremor, rigidity and slowness of movement are top 3 features of Parkinson's disease

## 16.1 Vibration improves posture control, rigidity and tremor of Parkinson's patients

There are many researches on WBV and Parkinson's disease, Most of the study results seemed promising. Ebersbach, a neurologist from Parkinson Clinic in Germany, found that WBVV performed as well as the conventional physiotherapy to improve balance and gait of Parkinson's patients. For posture control, WBVV works even better than conventional physiotherapy. He used “quantitative dynamic postureography” to evaluate the posture control in Parkinson's patients. His result showed significant progress in vibration group but not in physiotherapy group.<sup>(64)</sup>

Professor King LK, from Wilfrid Laurier University in Canada, took “Unified Parkinson's Disease Rating Scale” (UPDRS) to evaluate the gait of Parkinson's patients. Then he used a special test called ”grooved pegboard test” to evaluate the control ability of upper limbs. All symptoms were alleviated and motor function improved after whole body vibration. Precisely speaking, rigidity lowered, tremor reduced, distance of step increased, and executing grooved pegboard test speeded. So, King concluded that “WBVV could be considered as a non-pharmacological alternative for treating Parkinson's disease.”<sup>(179)</sup> (Figure 49)



(Figure 49) Parkinson's disease patient inserts peg into grooves on board, the time is recorded.

## 16.2 Vibration improves motor symptoms of Parkinson's disease

Haas CT from the Goethe University in Frankfurt, Germany, had a similar experiment. The results showed that there was significant improvement in motor function for those Parkinson's patients (+17% in the UPDRS motor score). This was a crossed study so the subjects were then switched from control group to experiment group. He found a consistent results. Other than that, scores on tremor and rigidity improved 25% and 24%. Hass concluded that this outcome were unlikely only because WBVV changed the peripheral nerve sensation. He thought this was highly likely because WBVV activated the related synergized motor areas and then improved its neurotransmission.<sup>(180)</sup>

## 16.3 Is vibration a placebo in Parkinson's disease?

In opposition, Arias P from La Coruna University in Spain had different opinion. He thought these effects above were only placebo effect. His research showed that the experiment and control group had similar improvements in step length, UPDRS, motor UPDRS, balancing, reach and touch, grooved pegboard test ( $p < 0.001$ ).<sup>(181)</sup>



## Part 1: Whole Body Vertical Vibration

Are these positive effects only because of the self-deception of Parkinson's patients? Goetz CG from Rush Presbyterian St. Luke's Medical Center, in Chicago has studied this placebo effect. He can not accept this placebo theory and pointed out this conflicting data might result from the low sensitivity of both UPDRS and ADL tests, which may lead to wrong conclusion.<sup>(182)</sup>

To sum up, many scholars are confident about using WBVV as a powerful tool to help Parkinson's disease. As Hass' research team in Germany said," WBVV can be regarded as an additional device in physical therapy in PD."<sup>(181)</sup>



## Chapter 17 Vibration helps patients of spinal cord injury

### Introduction

*Patients with spinal cord injury are total or half paralyzed depending on the lesion site of spine cord. All of these patients can not move their lower part of trunk. Most of them are unable to control bladder or rectal function and need urine catheterization or colon enema. For now, medical treatment is limited and cannot recover their neurological functions. Because they are unable to exercise, their bone and muscle degenerated very fast. They need some kind of passive exercise to help them. WBVV is an effective way to do so. Studies have shown it could improve their walking speed, pace coordination, step length and flexibility. WBV also, enhances blood circulation of low limbs and increase their muscle mass. In addition, it reduces the quadriceps spasticity and prevents them from other infections.*

Spine (or called vertebrae) located in the middle of our back, connected head and legs. Spine cord exists within vertebrae and is consisted of a bundle of spine nerves. Spinal cord like brain or cranial nerves belongs to central nerve system. Central nerves are unable to regenerate when they die. It means the injury of the spinal cord will cause permanent damage. Spinal cord injury whether caused by accident or other trauma will lead to paralysis below the damaged site. Modern medicine yet has no effective way to repair this injury. And that's why many experts tried alternatives like whole body vertical vibration to help these victims.

Ness LL, from the University of Miami, treated 17 spinal cord injury patients for over a year with WBV (45sec, 4 times a day, 3 days a week, total 12 times) He found that there was significant improvement in their walking speed with 3.7 meter per minute faster ( $p < 0.001$ ). The reasons for such progress are because (1) increase in cadence; (2) step length increased in both legs; (3) better coordination between legs. These 3 parameters had statistically significant progress.<sup>(66)</sup>



Herrero AJ from the Research Center on Physical Disability, León, Spain, found the walking progress mentioned above is because vibration accelerates blood flow of low limbs and furthermore increased muscle mass of legs.<sup>(67)</sup>

Spinal cord injury can cause a variety of muscle disorders, from myoclonus to more serious muscle dystonia, spasticity and uncontrolled movements. Spasticity is one of the common muscle disorders in these patients. Ness analyzed those patients to see if the spasticity got improved after vibration. And the answer is YES that the spasticity of thigh quadriceps is actually relieved. This was not an instant improvement, but a delayed one. However, it could last for as long as 8 days.<sup>(68)</sup>

Wirth F from the University of Cologne, Germany, conducted a further experiment in mice. Both healthy mice and spinal cord injury mice were divided two groups. One group received whole body vibration and another group as control. He noted the time to use vibration is counted. If vibration initiated at the 7th day after injury, it didn't work. But it worked very well at the 14th day after injury. After vibration, their body weight support ability significantly improved. This ability was fully recovered between 6-12 weeks. Microscopy examination noticed the density of synaptic terminals in the lumbar spinal cord was restored at 12 weeks. The amazing thing is WBV even led to a significant improvement of bladder function at 6-12 weeks after injury. These findings provide the first evidence for functional benefits of WBV in an animal spinal cord injury model.<sup>(69)</sup>

The mechanism of WBVV is tonic vibration reflex, which is neuromuscular contraction reaction to keep the body balanced. (see Chapter 24 Why it works-the mechanism of whole body vibration training) But how does vibration influence people lack of muscle tonic reflex like patients of spinal cord injury?

Sayenko DG from Toronto Rehabilitation Institute, Toronto, Canada, had a research on how vibration improves recovery on soleus H-reflex in patients. (The H-reflex is a reflectory reaction of muscles after electrical stimulation of sensory fibers in their innervating nerves). He found that that acute modulation of spinal motoneuronal excitability during WBV can be achieved in the absence of voluntary leg muscle contractions. It means that WBV helps the spinal cord injury patients through another route. This is different from tonic vibration reflex in healthy people.<sup>(70)</sup>

National Taiwan University had similar study in spinal cord injury patients. They found that low frequency low amplitude vibration improves the flexibility of these patients and also prevents them from other infections.



## Chapter 18 Vibration helps patients of cerebral palsy and multiple sclerosis

### Introduction

*Cerebral palsy (CP) is an umbrella term denoting a group of non-progressive, non-contagious motor conditions that cause physical disability in human development, chiefly in the various areas of body movement.*

*Multiple sclerosis (MS) is a degenerative disease of neurons. The insulating outlayers (called myelin sheaths) of neurons in the brain or spinal cord are damaged. This damage called demyelination will disrupt the electric signals to transmit to other neurons. It will result in a wide range of neurological dysfunctions.*

*Both diseases will lead to motion disturbance, imbalance and physical disability. They will need rehabilitation and whole body vibration can provide them help. Research showed that WBV helps improve the walking ability and reduce the spasticity of cerebral palsy children. In addition, WBV enhances strength and improves movement. It also helps improve walking ability and posture control for multiple sclerosis patient.*

Cerebral palsy (CP) is an umbrella term denoting a group of non-progressive, non-contagious motor conditions that cause physical disability in human development, chiefly in the various areas of body movement. Kids with cerebral palsy often have motor dysfunctions including seizure, paraplegia, spasticity, epilepsy, dysarthria, athetosis and involuntary movement, along with other communication disorders, sensory impairments, intellectual disability, learning disabilities, urinary incontinence, fecal incontinence, and/or behavioral disorders.(Figure 50)

Because WBV can ameliorate some neuromuscular problems, scientist tried to use WBV in patients with cerebral palsy. Two experiments showed positive results. Dr. Ruck J from the Shriners Hospital in Canada trained cerebral palsy children with whole body vertical vibration. He found that the vibration training group increased their walking speed by 2.8 meter per minute. ( $p=0.03$ ) Thus, vibration can help these cerebral palsy children by improving their walking ability.<sup>(74)</sup>



## Part 1: Whole Body Vertical Vibration

Ahlborg L from Danderyd Hospital in Sweden had another study. He recruited 14 adults with cerebral palsy and divided them into resistance training group and vibrating training group. After 8 weeks, he noted vibration group had obviously reduction in their knee spasticity and whole motor function measured with “Ashworth Scale” significantly improved. When measured muscle power with “isokinetic dynamometry”, muscle strength increased in the resistance training group at the velocity 30 degrees/s and in both groups at 90 degrees/s. To conclude, whole body vibration helps cerebral palsy patients to improve their motor function.<sup>(75)</sup>



(Figure 50) There are many types of motor dysfunctions of cerebral palsy including seizures, paraplegia, spasticity, epilepsy, dysarthria, athetosis and involuntary movement.



## 18.1 Vibration and multiple sclerosis

Multiple sclerosis is also a kind of neurologic disease. Neurons are like wires, wrapped with insulating coat to protect them. This outer coat is called “myelin sheath”. Multiple sclerosis (MS) is an inflammatory disease in which their myelin sheath in the brain and spinal cord degenerated, disappeared or died. This damage called demyelination will disrupt the electric signals to transmit to other neurons. It will result in a wide range of neurological dysfunctions.

The cause of MS is unknown. It might occur as a result of some combination of environmental factors such as infection, genetics, autoimmune disease or organic phosphorus poison. The mechanism of demyelination is not clear but is obviously connected to autoimmune dysfunction and involvements with T-cells and macrophages. The most common symptoms of MS are incoordination, spasm and atonia. Lower body and distant muscles were mostly affected.

Schuhfried O from the Medical University of Vienna conducted a strict random double-blinded trial. The intervention group received WBV (2.0-4.4 Hz oscillations at 3-mm amplitude, 1+1min per session). The placebo group received transcutaneous electrical nerve stimulation (TENS). He compared the effect on posture control, mobility and functional reach test. The tests were performed before intervention, 15 minutes, 1 week, and 2 weeks after the intervention.

What were the results? (1) time of get up and go test scientifically improved ( $p=0.041$ ) with one second less (-1 vs. +0.7); (2) results on posturographic assessment (to test the posture control) were obviously better than the control group (+7.0 vs. +0.3); (3) no differences were noted for the Functional Reach Test. The results showed that WBVV helps postural control and mobility in multiple sclerosis patients.<sup>(76)</sup>

Jackson KJ, a professor from University of Dayton in Ohio, wanted to know what the optimal vibration frequency to help multiple sclerosis is. He recruited 15 patients with multiple sclerosis. 30 seconds of WBV at either 2 Hz or 26 Hz were applied to these subjects and compared their strength and torque. There was no significant difference between baseline torque values and those measured at one, 10, and 20 minutes after either vibration exposure. However, there was a consistent trend of higher torque values after 26-Hz WBV when compared with 2-Hz WBV for both quadriceps and hamstring muscles. This indicates 26 Hz WBV may help the motor function for these multiple sclerosis patients.<sup>(77)</sup>

## Chapter 19 Vibration helps patients of cystic fibrosis and chronic obstructive pulmonary disease

### Introduction

*Cystic fibrosis (CF) is an autosomal recessive genetic disorder that affects many organs but mainly the lungs. It is characterized by abnormal transport of chloride and sodium across epithelium of organs. This will lead to thick, viscous secretions because of the exocrine glands dysfunction. The involved exocrine will become cystic and fibrotic and lost its function. It is a rare disease in Taiwan but not rarely seen in western countries. CF eventually leads to difficult of breathing and severe pulmonary infections. There is no effective treatment today.*

*Chronic obstructive pulmonary disease (COPD) is a type of progressive pulmonary disease characterized by poor airflow and pulmonary function. The patients of COPD suffer from wheezing, shortness of breath and hypoxia. It is often seen in patients with emphysema, chronic bronchitis, pneumoconiosis and old tuberculosis.*

*Research showed that WBVV increases lung muscle function for cystic fibrosis patients and COPD patients. WBV can improve their walking distance, exercise ability and daily activities. WBV also improve their ability of cough and removal sputum.*

### 19.1 Vibration helps patients of cystic fibrosis

Cystic fibrosis (CF) is an autosomal recessive genetic disorder that had generalized genetic defect of exocrine glands which lead to the abnormal viscosity of mucus. This will cause an accumulation of mucus in many exocrine and exocrine-associated organs and eventually cause fibrosis and cystic change of these exocrine glands. It happens in many organs but most critically occurs in the lungs. The accumulation of thick, sticky sputum inevitably causes frequent pulmonary infections and symptoms of chronic cough or shortness of breath. No effective treatment has been proven yet but whole body vibration can provide some helps.



Rietschel E from the University of Cologne tried to use whole body vibration to treat 10 patients with cystic fibrosis. These patients received WBV of 2 sessions per day, 3-minute a session, 5 days a week for 3 months. The results showed improvement on chair-rising time ( $p < 0.03$ ), maximum force ( $p < 0.02$ ), maximum power ( $p < 0.01$ ), and speed ( $p < 0.02$ ). Also increase in maximum 2 legs jump ( $p = 0.02$ ) and velocity ( $p = 0.01$ ). The peak jump force ( $p = 0.02$ ) and velocity ( $p = 0.01$ ) of the two-leg jump significantly improved. Even though there were no significant improvement in pulmonary function test FEV1 (Forced Expiratory Volume in 1 Second) and FVC (Forced Vital Capacity), but these results demonstrate that WBV can improve muscle functions in CF patients.<sup>(85)</sup> Roth J from Children's Hospital of Eastern Ontario obtained similar results in his study for CF patients.<sup>(86)</sup>

## 19.2 Vibration helps patients of chronic obstructive pulmonary disease

Chronic obstructive pulmonary disease (COPD) is a type of progressive pulmonary disease characterized by poor airflow and pulmonary function. The patients of COPD suffer from wheezing, shortness of breath and lack of oxygen. It's often seen in patients who had emphysema, chronic bronchitis, pneumoconiosis and old tuberculosis before.

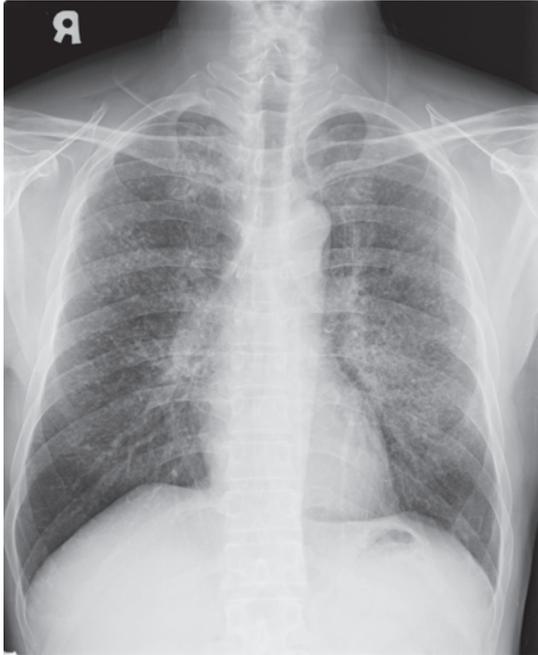
COPD is actually a very common disease. Globally, 10% of people older than 40 have moderate COPD and up to 25% may have mild COPD. This is because of tobacco smoking, secondhand smoke, air pollution and exposures to fumes and dusts in environment. COPD is the 4th leading cause of death worldwide. Its mortality is rising while cardiovascular disease is falling. COPD is expected to be the 3rd leading cause of death in the next 20 years.(Figure 51)

Dr. Gloeckl R from Schoen Klinik in Germany had a study in 82 COPD patients, mostly in their 3rd or 4th stage of COPD. (author note: there are 5 stages of COPD, stage 0- at risk, stage 1- mild, stage 2- moderate, stage 3- severe, stage 4- very severe) Study group received 3 minutes vibration, 3 times per day, with squat posture, for 3 weeks. Results showed that 1) 6 minutes walking distance improved 27 meters ( $p = 0.046$ ); 2) time of sit down/stand-up test decreased 1.9 seconds ( $p = 0.067$ ) Thus, WBV may improve COPD patients with their ability to perform daily activities.<sup>(129)</sup>



## Part 1: Whole Body Vertical Vibration

For cystic fibrosis, tuberculosis, emphysema, chronic bronchitis, pneumoconiosis or other COPDs which are caused by smoking, infections or air pollutions, WBVV can improve their muscle function and ability of expectoration since the mechanism of these diseases are quite similar.



(Figure 51)X ray film of a COPD patient, the lung parenchyma is chronically destroyed.



## Chapter 20 Vibration helps bedridden patients and improves chronic constipation

### Introduction

*All reasons that lead to bed-ridden status will cause osteoporosis and muscular dystrophy, joints degeneration and bedsore in a short period of time. These people need assistance by passive exercises. Research shows that whole body vertical vibration reduces muscular dystrophy, shorten the period of muscular dystrophy and increases the bone formation of disc area.*

*Constipation happens for many reasons; whole body vertical vibration might be helpful to ameliorate chronic constipation.*

### 20.1 Vibration reduces lumbar spine deconditioning in bed-rest

Belavy DL, from Muscle and Bone Research Center, Berlin wanted to know how whole body vibration affects lower back muscles and spinal erectors on bedridden patients. He conducted a study with 20 health young men. These subjects were requested to lie on bed for 8 weeks and then divided into two groups. One group received whole body vibration training and another group did not. Then MRI (magnetic resonance imaging) was used to examine and trace the physiological changes of these subjects for 6 months. He found that the dystrophy of multifidus muscle closed to spine was not fully stopped. Still, the vibration group exhibited less multifidus muscle atrophy ( $p=0.024$ ) and its atrophy did not persist as long as in the control group (which last for 3-months;  $p<0.006$ ). Spinal lengthening ( $p=0.03$ ) and increases in disc area ( $p=0.041$ ) were also reduced. Overall, vibration group had less muscle atrophy and shorten muscle atrophy period compared to that of the control group.<sup>(90)</sup>(Figure 52)



(Figure 52) Bed-ridden patient lead to osteoporosis and muscular dystrophy, joints degeneration & bed-sores

## 20.2 Vibration improves chronic constipation

Embarrassing and uncomfortable, constipation has been agony of the butt for many people. It's estimated more than 30 percent of women and elder people suffered from chronic constipation. Constipation is defined as "a condition, more than 25% of the time, in which bowel movements are infrequent or incomplete". The patterns of constipation include bowel straining, hard stool, incomplete evacuation, or less than two defecations in a week. The causes of constipation are numerous, varying from no time to toilets to intestine tumors. Simple classifications as the follows:

- (1) Neurological factors: stroke, Parkinson's disease, cerebral palsy, spinal cord injury, dementia, brain tumor, muscular dystrophy, multiple sclerosis or megacolon;
- (2) Side effect of drugs: anti-cholinergic drugs, diuretics, antacids that contains calcium or aluminum, prozac, anti-epileptic, ferric agents and morphine;
- (3) Metabolic or endocrine diseases: diabetes, hypothyroidism, hyperparathyroidism, hypokalemia and hypocalcaemia;
- (4) Tumors: colon cancer, polyposis or tumors of pelvis;
- (5) Autoimmune diseases such as scleroderma, myasthenia gravis;
- (6) Mental diseases such as depression or anxiety;
- (7) Unknown reasons such as IBS (Irritable Bowel



Therefore, there is no single solution for constipation. You have to explore and solve the underlying cause first. For chronic constipation accompanied with stroke, Parkinson's disease, cerebral palsy or spinal cord injury, whole body vibration can help improve their motor functions. So it also benefits their chronic constipation. As we discussed before, this is because WBV elicits tonic vibration reflex. Scientists indicated the mechanism of vibration in constipation might be mediated by neuron-muscular reflex and muscle tonic reflex. These reflexes stimulated bowel movement and increased intestine peristalsis (wave movement of gut wall). It is why WBV can help for these chronic constipation patients.

Dr. Wu TJ from the physical therapy department in Chungwa Christian Hospital in Taiwan undertook a study to understand the relationship of WBV and chronic functional constipation. This might be the first paper in the world regarding to this topic. He studied 28 patients with functional chronic constipation. Half of them received WBVV, 3 times a week, 15 minutes a session, 2mm, 12Hz for 2 weeks. The result exhibited that WBVV group significantly reduced the "total constipation severity instrument (CSI)" and "obstructive defecation subscale score" compared to the control group. But the level of pain or "health-related quality of life" did not show difference.<sup>(139)</sup> Therefore, he concluded that whole body vertical vibration could help the patients with functional chronic constipation. However, we are looking for more researches to explore this particular topic.

## Chapter 21 Vibration improves physical performance of the youth

### Introduction

*We'll discuss the effects of whole body vibration on the physical performance of the young people (but not athletes). Some researches noted that the vertical jump height as well as the leg extension power increased after young people received 16 weeks of whole body vibration training.*

*Other studies showed that WBVV can reduce postural sway and increased at selected angular velocities. These will enhance the static balance and knee strength. The vertical jump height was promoted because whole body vibration strengthened the neuromuscular adaptation of lower body.*

In the previous chapters, we mentioned many benefits of whole body vertical vibration to the elders, the disabled and people who are not able to exercise. Though, whole body vertical vibration was originally designed to train the young healthy astronauts. WBV is also helpful this young group. This chapter I'll discuss how whole body vibration improve the physical performance of the youth (ordinary people, not athletes). WBV is proved to enhance their muscle strength, explosive power, vertical jump height, flexibility and endurance. Regarding to training athletes with WBVV, I will discuss in the chapter 22.

### 21.1 Vibration promotes vertical jump force, knee strength and knee stability of the youth

Trovinen S from UKK Institute in Finland, had a research in 56 young men (non athlete) aged 18 to 38 for 16 weeks of whole body vibration training. It showed that their vertical jump height increased 8.5 % ( $p=0.001$ ). The extension strength of low limbs increased 3.7% at 12th week while no difference at 24th week. Other



3 parameters - shuttle run, griping power and balancing test showed no significant difference. Hence he concluded that the vertical jump height was promoted in these young men. The reason is WBV enhances their lower body power through neuromuscular adaptation.<sup>(21)</sup>

Spiliopoulou SI from University of Aristotle in Greek had another research in 38 women (average 33 years old) with 12 weeks WBVV. After WBVV training, he evaluated their static balance, postural sway, and knee extension strength. After vibration, he found (1) postural sway reduced; (2) Isokinetic strength significantly increased at selected angular velocities. He concluded that WBV is beneficial to young women on their static balance and isokinetic knee strength.<sup>(23)</sup>

Melnyk M from Freiburg University in Germany studied how vibration training worked on the knee stability of 23 young men. The young men were vibrated with 60 seconds WBV, 0.6g, 4mm, twice. Then he measured the SLR (short latency responses) and the MLR (medium latency responses) with EMG (electromyography). The results showed while there were no significant changes in latency, the size of the lateral and medial hamstring SLR (short latency responses) was significantly increased after WBV ( $p=0.039$  and  $p=0.043$ , respectively). No significant differences were found for the hamstring MLR (medium latency responses) size after WBV. Maximum tibial translation was significantly decreased after WBV ( $p=0.031$ ). His results showed that a single WBV exposure has a positive effect on knee joint stability as a short-term adaptation on neuromuscular level.<sup>(26)</sup>

Humphries B from Central Queensland University, Australia recruited 51 healthy young women (average age of 21) to conduct a study. They were divided into 3 groups: WBV group, WBV plus resistance training group and the control group. The duration was 16 weeks and the target was to examine if there was a significant difference in bone density. The final result showed that bone density of femoral neck in the vibration groups increased 2.7%. For vibration plus resistance training group, their bone density increased 1.9% of femoral neck and 0.98% in spine.<sup>(10)</sup>

## Chapter 22 Vibration improves the performance of athletes

### Introduction

*Whole body vertical vibration training has been extensively applied in the field of fitness and sports since it helps improve muscle strength, vertical jump height, explosive power and balancing. Researches showed that whole body vertical vibration training before the game can promote sports performances of athletes..*

*It increases vertical jump ability as well as leg extensor power and flexibility around the knees; thus, prevent injury of muscles and tendons. It also helps warm-up of the athletes. Plus, loading whole body vertical vibration training could further improve muscle dynamics and mobility.*

*Whole body vertical vibration training has been extensively applied to athletes in various sports arena, including dancers, basketball players, volleyball players, sprinters, skate racers, skaters, hockey players and gymnasts.*

We mentioned that Russia invented whole body vertical vibration in the previous chapters. They used it as a secret weapon to train their astronauts, which made a record of 120 days longer outer-space stay than their American counterparts. After the secret was disclosed, the coaches around the world can not wait to train their athletes with this magic machine. This sensation caught the attention of scientists. Since 1980s, many scientists and coaches started tried to know what and how whole body vertical vibration can do on the athletes. Many distinguished studies have been published since then. (Figure 53)(Courtesy of Bodygreen Co.)

### 22.1 Vibration increase peak force

McBride JM from Appalachian State, University, in Alabama, US researched on how whole body vertical vibration training affects force output and motor neuron excitability. The experimental group exercised on vibration platform while the



control group exercised without vibration. He tested it before exercise, right after exercise, 8 minutes after exercise and 16 minutes after exercise. The results showed that peak force was significantly increased in the vibration group right after exercise (+9.4%) and 8 minutes after exercise (+10.4%) ( $p < 0.05$ ). But there was no significant difference in motor neuron excitability. In conclusion, if the athletes received WBV 8-16 minutes before the sports match, it could enhance their sports performance through the increase of peak force.<sup>(25)</sup>

### 22.1.1 Vibration increases the strength of vertical jump, knee extension and flexibility

Turner AP from the University of Edinburgh in UK tried to find the appropriate intensity and frequency of WBV to help the athletes. His studied showed short vibration (30 seconds) with 40Hz, 8mm can promote countermovement jump height by 6%. Other frequency or intensity did not exhibit similar effect.<sup>(29)</sup>

Dabbs NC from California University, US, found similar results. The WBV he took was 30Hz, amplitude of 6.5mm, four 30 seconds sessions with 30 seconds interval. In spite of no increase in speed or power, he noted vertical jump height increased significantly by 2.5cm ( $p < 0.05$ ).<sup>(30)</sup>

(Figure 53) Tomas Gustafson from Sweden won three gold medals of speed skating in 5km (1984 Olympic), and 5km, and 10km (1988 Olympic)(Courtesy of Bodygreen Co.)





Fagnani F from University of Rome trained female athletes with whole body vertical vibration for 8 weeks. This training increased their knee extensor strength, counter-movements jump height and flexibility. The improvement of flexibility is important not only for performance in game but also for the prevention of the muscle-tendon injury.<sup>(38)</sup>

### **22.1.2 Vibrator type, age and gender affect training results**

Marin PJ, from the European University in Spain reviewed 30 WBV published papers and conducted a meta-analysis. He took effect size (ES) of individual study to analyze the factors of muscle power. He found the most important factor for slow adaption is the type of WBV. Vertical type vibration is better than rotational type vibration. (ES = 0.99 vs. 0.36) Age is the second factor. The younger the subject is, the better the vibration works.<sup>(34)</sup>

David M from Ball State University found WBV improved countermovement jump better in female athletes than male athletes. It seems gender is an important factor too.<sup>(37)</sup>

### **22.1.3 Loaded vibration further increases muscle power**

Hazell TJ from the University of Ontario in Canada found that while exercised with loaded whole body vibration (weightlifting or dumbbell on WBV platform), it could further boost muscular activity. The research showed that whole body vertical vibration training alone increased muscular activity by 2.5% ( $p < 0.05$ ) and it increased by 3.5% with loaded dynamic squats. The external load was 30% of their body weight.<sup>(31)</sup>

## **22.2 Vibration helps warm-up**

Cochrane DJ from Massey University in New Zealand found that the muscle temperature can increase 0.3 degree per minute after whole body vibration, which is relatively high comparing to biking 0.15 degree and hot bath 0.09 degree ( $p < 0.001$ ). Regarding to the metabolic rate, whole body vertical vibration training is identical to biking with a rate of 19 liter per kg per minute. But whole body vertical vibration is an efficient tool to help warm-up for athletes before sport or game.<sup>(33)</sup>

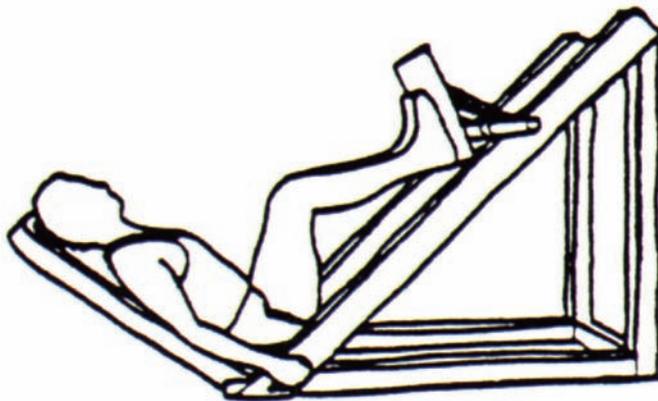


### 22.3 Vibration and dancers

Dancing could be one of the sports that require most leaping and jumping. And that's why in Mandarin, dance is called "leaping dance". Wyon M from University of Wolverhampton in UK trained the dancers with whole body vertical vibration (35Hz, twice a week, 5 minutes per session for 6 weeks). The result demonstrated that the vertical jump height of these dancers significantly increased. ( $p < 0.05$ )<sup>(40)</sup>

Marshall LC from Trinity Laban art school in London obtained similar results. Furthermore, he noted that active range of movement of joints in those female dancers also improved.<sup>(41)</sup>

Annino G from Tor Vergata in Rome, Italy, experimented with ballet dancers. The results exhibited that whole body vertical vibration with load training did not only increase jump height but also leg-press speed and force. (Figure 53) So he concluded, "The results show that WBV training is an effective short-term training method to improve knee-extensor explosiveness in elite ballerinas."<sup>(42)</sup> (Figure 54)



(Figure 54) Leg-Press training: after WBVV, leg-press speed & force improved.



## 22.4 Vibration and basketball players

Basketball is one of the most popular sports in the world. There are many professional teams in US, Europe, even Taiwan and many other developing countries. Whole body vertical vibration helps basketball players to achieve better sports performances. Colson SS from France trained basketball players with whole body vertical vibration for four weeks. His results showed that there was an obvious boost in isometric knee strength ( $p < 0.001$ ) as well as countermovement jump height ( $p < 0.05$ ). Thus, whole body vertical vibration training can help basketball players to increase power on their lower limbs and knee joints.<sup>(39)</sup>

### 22.4.1 Vibration enhances explosive power and posture stability

Fort A from University of Girona in Spain trained young female basketball players with whole body vertical vibration. He tried to understand how long a whole body vertical vibration training is optimal. So he had the training program for two parts, 8 weeks as first stage and 7 weeks as second stage. The result displayed that countermovement jump height increased 6.47% ( $p < 0.001$ ) in the first stage, and 3.38% ( $p < 0.001$ ) in the second stage. Total is 10.07% improvement ( $p = 0.005$ ).

“One-leg hop test” improved as well. On the right leg increased 10.12% in the first stage ( $p < 0.001$ ) and 4.05% in the second stage. Left leg did similar progress with 9.63% and 5.54% in two stages. It means about 14-15% improvement for “one-leg hop test”.<sup>(43)</sup>

The other indicator, “lateral deviation of the center of pressure in the closed eyes test”, decreased after whole body vertical vibration training. In first stage, there was 22.20% reduction in the right leg ( $p = 0.043$ ) and 34.77% in the left leg ( $p < 0.001$ ). In the second stage, it was 10.94% decrease in the right leg but 1.19% increase in the left leg. The total decrease of this score was 33.14% ( $p = 0.027$ ) in right leg and 33.58% in left leg ( $p = 0.043$ ).

In conclusion, the results show that a 15-week whole-body vibration training improves explosive strength and postural stability in adolescent female basketball players. Significant results were noted in the first 8 weeks. But their performance improved more to 15 weeks.<sup>(43)</sup>



## 22.5 WBV and athletes in different areas

### 22.5.1 Vibration and volleyball players

Elite volleyball players need own outstanding leaping ability and explosive power. Sarah Hilgers from the University of North Dakota recruited volleyball players to study. He found that their 1-minute and 5-minute vertical jump height increased 2.5 cm and 1.6 cm after 3 days of whole body vertical vibration training ( $p=0.034$ ).<sup>(44)</sup>

### 22.5.2 Vibration and sprinters

Greece is the origin of Olympics as well as the homeland of marathon. Giorgos Paradisis from University of Athens used whole body vertical vibration (6 weeks, 3 times a week, 2.5 mm and 2.28 g) to train the sprinters. After 6 weeks of WBV training, he noted that in the performance of 60-meter sprint race, (1) performance at 10th m, 20th m, 40th m, 50th m and 60th m significantly improved with an overall 2.7% improvement. (2) step length and running speed improved 5.1% and 3.6%, and the step rate decreased 3.4%. (3) the countermovement jump height increased 3.3%, and the explosive strength endurance improved 7.8%. The 6 week WBV training produced significant progress in sprint running kinematics and explosive strength performance in these sprinter athletes.<sup>(45)</sup>

### 22.5.3 Vibration and skeleton racers

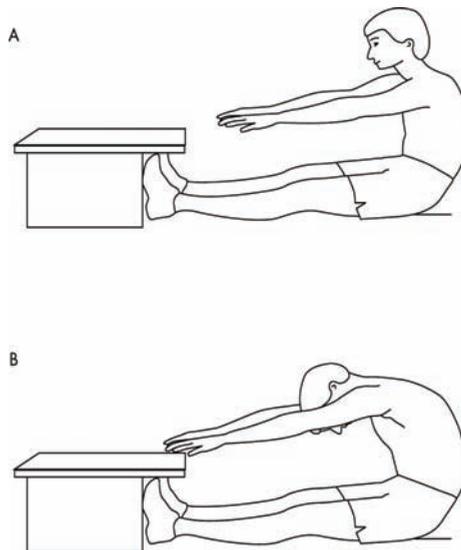
Skeleton is a fast winter sliding sport in which athlete rides a small sled down a frozen track while lying face down. It is an official competition sport at Winter Olympics. Nicola Bullock from the Australian Institute of Sport found that racers got tired after the first round of the game and they tended to slow down on the second round. However, with whole body vertical vibration training during the interval, they can do better on the second round.<sup>(46)</sup>

### 22.5.4 Vibration and gymnasts

Hameeda AA from University of Zagazig in Egypt researched whole body vertical vibration training effects on female gymnasts. Whole body vibration training induced significant improvement of their physical variables (muscle strength of the arms, muscle strength of the two men, muscle of the abdomen, muscle strength-to-back, muscular ability of legs, speed and flexibility) ( $p < 0.05$ ). In addition, the skill performance level on the horse jumping (front handspring) improved among female gymnastics students after 8 weeks of training ( $p < 0.05$ ). There was no significant change in the control group. So Hameeda concluded whole-body vibration is a suitable training method for female gymnasts.<sup>(48)</sup>

### 22.5.5 Vibration and hockey players

Hockey is one of speedy sports. Cochrane DJ from Massey University in New Zealand found that hockey players had significant improvement after WBVV training. Their countermovement jump height increased by 3cm while the biking group and the control group didn't. Also he used "sit and reach test" (Figure 55) to assess their flexibility. The flexibility of these hockey players increased significantly 8.2%, while the other two groups did not.<sup>(56)</sup>



(Figure 55) Sit and reach test.



## Chapter 23 Vibration improves physical performance of animals

### Introduction

*People invest a vast of money for human athletes in order for better performance in arena, so do they for their animal athletes. The health and fitness of racing horses or dogs are very important assets since they are cash cows of their owners.*

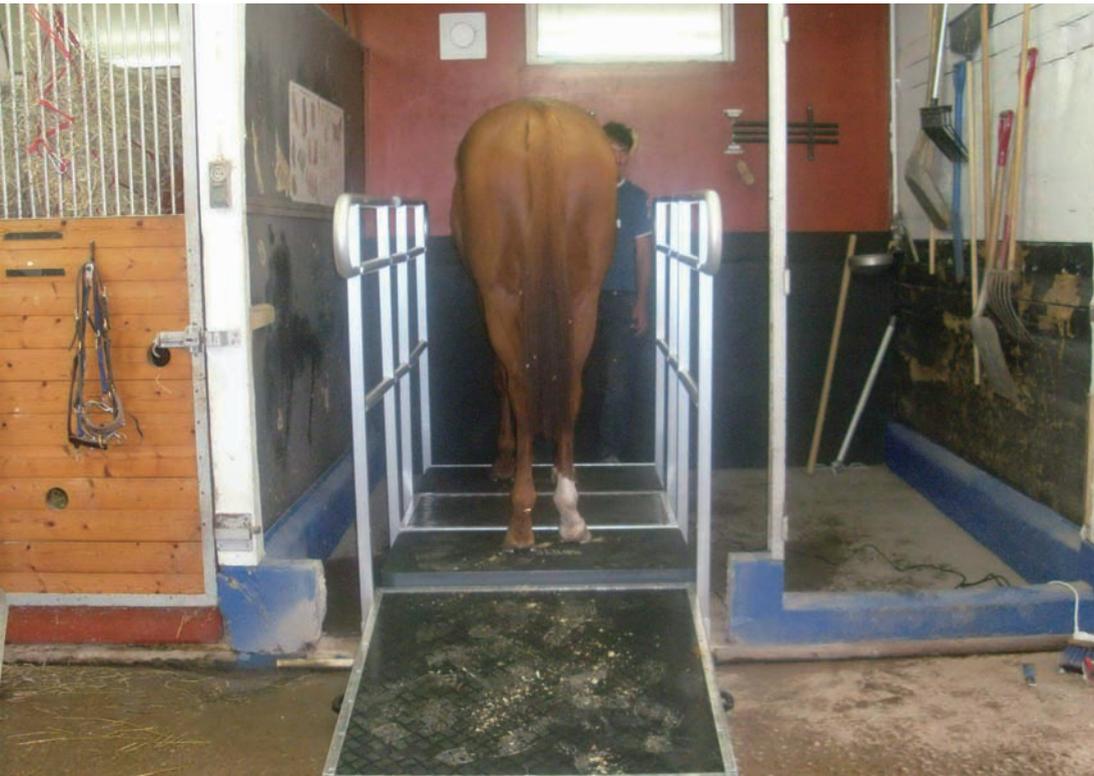
*Besides horses and dogs, whole body vibration training actually applied to all animals with economic values like sheep, cow, etc. WBVV is a useful training tool for animals like for humans.*

Imagine a racing horse competing in a race. The key to win depends on its explosive power, endurance, speed, flexibility, and coordination. The possible threats while racing are fall or broken their legs. Through whole body vibration training, both targets can be achieved.

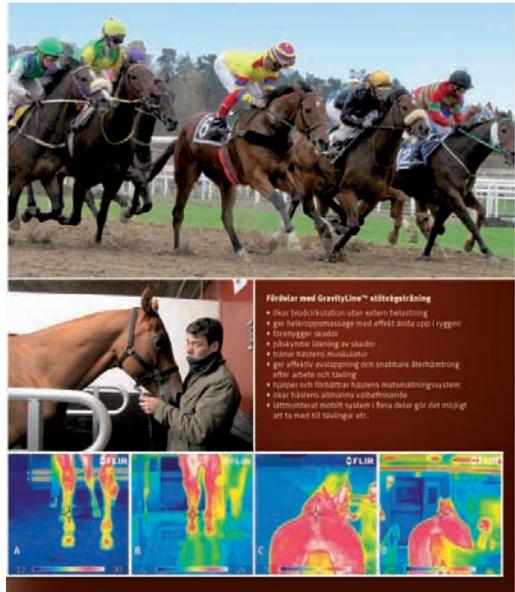
Scientists discovered whole body vibration training is more effective in animals than it in humans. The reason is obvious. Because whole body vibration is more effective to the lower body and legs than to the upper body, animals walk with 4 legs but people walk with 2 legs only.(Figure 56-58)

Take whole body vibration training for racing horses for example; it needs a large platform (Figure 56). The horse was carried to the platform and turn on the vibrator. Intensity of the whole body vibration depends on its training purpose.

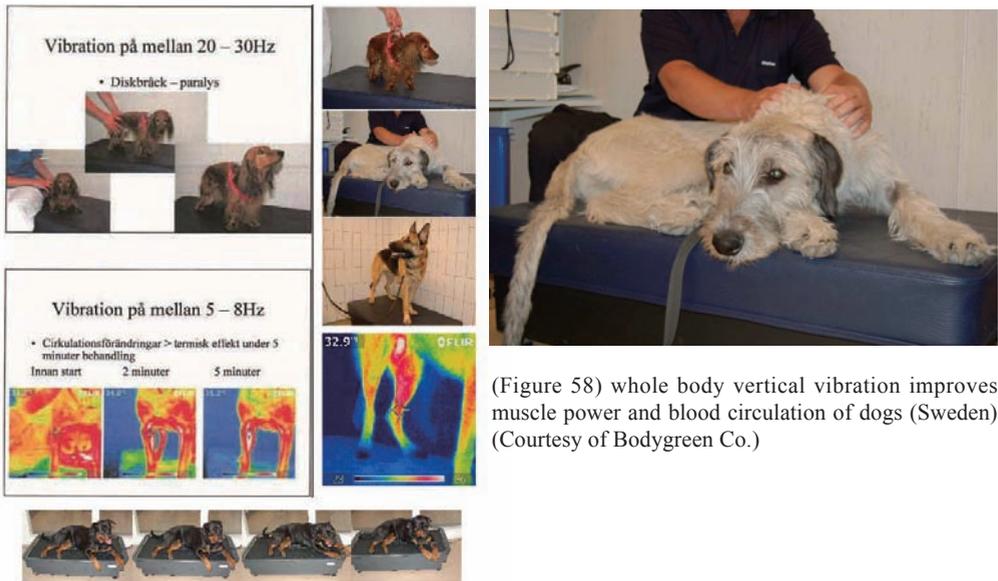
1. To help circulation: frequency 5-8 Hz, 3 times a week and 20 minutes per session.
2. To increase muscle and reduce fat: frequency 10-20 Hz, 3 times a week and 20 minutes per session.
3. Strength training: amplitude 1mm, frequency 20-30 Hz, 3 times a week and 20 minutes per session.



(Figure 56) The large platform of whole body vibration for training horses(Courtesy of Bodygreen Co.)



(Figure 57) Studies on how vertical vibration training improve muscle power and explosive power of racing horse (Sweden)(Courtesy of Bodygreen Co.)



(Figure 58) whole body vertical vibration improves muscle power and blood circulation of dogs (Sweden) (Courtesy of Bodygreen Co.)



## Chapter 24 Why vibration works? The mechanism of whole body vertical vibration

### Introduction

*People know that the sun rises in the east and sets in the west. But why doesn't it rise in the north and set in the south? Smart scientist like Nicolaus Copernicus discovered that it's because of the earth revolving around the sun. Some people may ask why earth revolves around the sun. Will it be easier if earth and the sun stay at where they are all the time? Sir Isaac Newton pointed out it does not happen because of gravities between the earth and the sun. Comprehensive science shall be able to explain the reason behind the events.*

*We mentioned that whole body vertical vibration could strengthen the muscle power, vertical jump height, joint stability and the balance. How does it work? The principle is "tonic vibration reflex", which is muscle contracture reaction to keep hormones and subsequent myoblast differentiation.*

*And why vibration improves bone density? This is another mechanism. It is because of the mesenchymal stem cells. After vibration, bone cells derived from stem cell will be produced more and fat cells also derived from stem cell will be inhibited. It means bone cells and fat cells are inversely proportional to each other. This also explains why lack of exercise makes people fat as well as low bone density. After vibration, mesenchymal stem cells received mechanical signals and then change their differentiation direction to more bone cells and less fat cells.*

### 24.1 Why vertical vibration improves physical performance

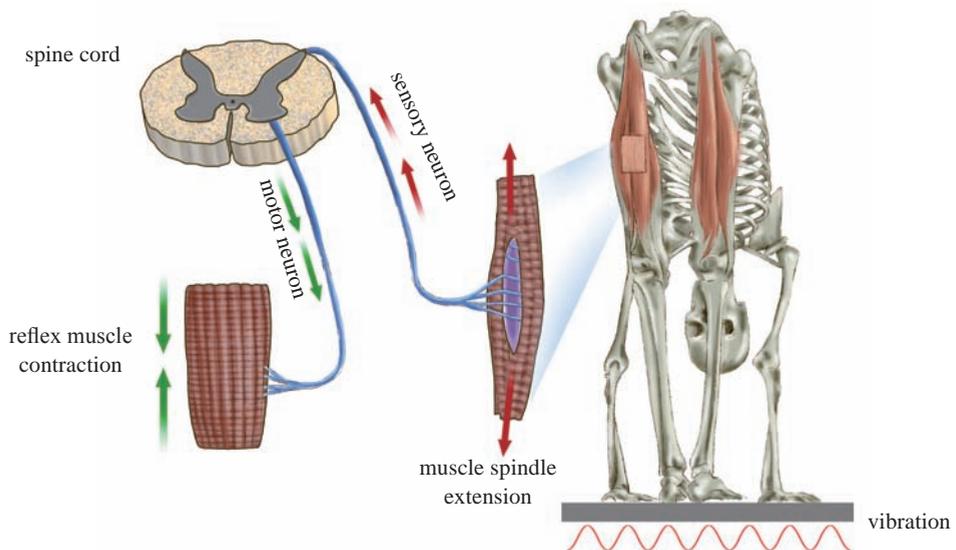
If you are curious about why whole body vertical vibration training works, here are some scientific theories to back it up.



### 24.1.1 Theory of “tonic vibration reflex”

Tenenbaum thought WBV was because vibration can increase blood circulation and muscle temperature. Liebermann & Issurin thought it was the change of perception by vibration. However, the most popular theory now is that vibration will produce a response called “tonic vibration reflex” which will then strengthen the subsequent neuromuscular activities.

Eklund and Hagbarth had the pilot study. They inserted the device upon the tendon and observed such tonic reflex (1966). Nordlund and Thorstensson, from the Swedish School of Sport and Health Sciences in Sweden, presented “**tonic vibration reflex theory**” in 2007. Tonic vibration reflex means that when muscle spindles receive the sinusoid wave of vertical vibration will produce a tendon muscle contraction reaction.<sup>(35)</sup> Muscle spindle is a spindle shape device within muscle fiber, which is a special sensory receptor primarily function to detect the change of the muscle fiber length. They convey the message of fiber length change to our spine cord.(Figure59)



(Figure 59) Tonic vibration reflex is the mechanism of whole body vertical vibration



Nishihira Y, from Tsukuba University in Japan, also did a study and showed that sense of vibration is transmitted by a thicker sensory neuron called Ia neuron. Then the signal was transmitted to motoneuron pool in spine cord which will generate a spontaneously reflex back to muscle and causes the contractions of the related muscles. This purpose of the tonic vibration reflex is to keep the body balance from fall during vertical vibration.<sup>(60)</sup>

### 24.1.2 “Vibration stimulates hormone” theory

Bosco from Italy advocated another theory called “**vibration stimulates hormones secretion**” in 2000. Bosco found that both growth hormone and testosterone increased significantly but stress hormone like cortisol decreased in those young men after whole body vertical vibration. The change of hormones will affect their physical performances. To sum up, whole body vertical vibration can improve physical performance because of the neuromuscular reflex reaction and subsequent hormone secretion.<sup>(36)</sup>

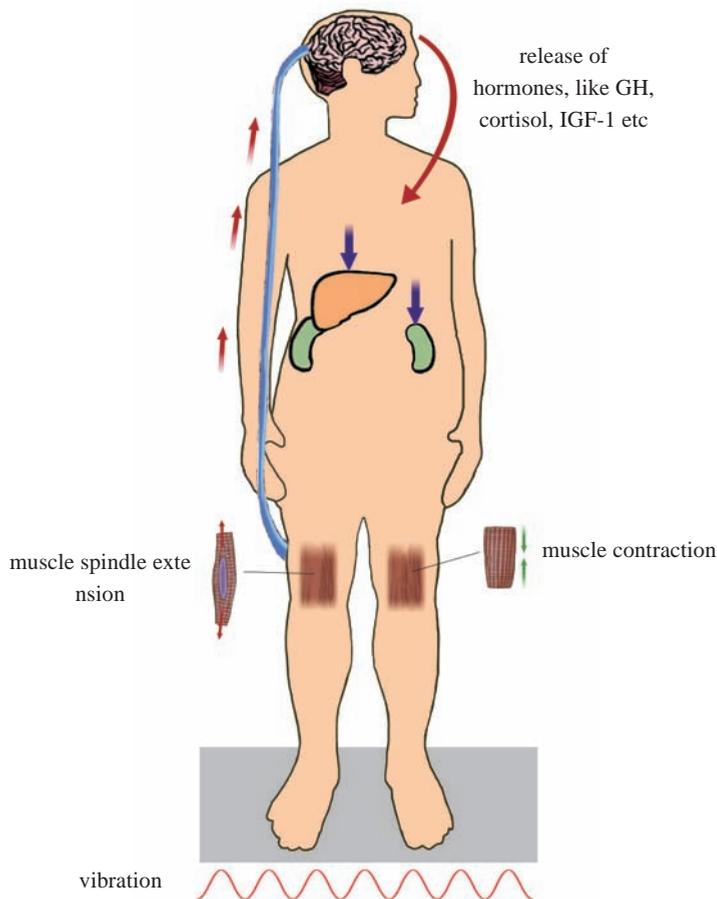
### 24.1.3 “Vibration stimulates myoblast” theory

Due to the advance of molecular biotechnology, theory like this is not persuasive enough. Dr. Wang CZ from Kaohsiung Medical University found that vibration stimulated reaction of myoblast and increased the growth of muscle fibers. Under 8Hz and 10 Hz stimulation, Type I collagen and decorin , which are two of ECM (extracellular matrix) proteins, had significant gene expression. And MRFs, MyoD and myogenin, which are modulating factors of the myocyte elevated with the length and dosage of vibration. Also, numbers and length of myotubes had obvious increase under 8Hz and 10Hz stimulation. So in the molecular level, whole body vibration stimulates DNA on the nucleus of myoblast, which then enhances the expression of extracellular matrix proteins and MRFs. The WBV stimulation enhances myotube formation and lengthens the myotube of myoblast. This will eventually strengthen the muscle mass and power of the subjects and enhance their physical performances.<sup>(65)</sup>

This means that tonic vibration reflex is at the beginning stage. The bimolecular level for vibration to work is that myotubes in muscle fibers increased their numbers and magnitude.



To wrap up, the theory and mechanism of how WBV affects muscles goes like this. First, WBV stimulates tonic vibration reflex through the signal to motorneuron pool in spine cord. Then the spine cord ordered the muscle to contract in order to maintain the balance of body. At the same time, vibration also stimulates pituitary or adrenal glands to secrete hormones. The change leads to acute and chronic neuromuscular adaption and effects of hormones on target organs. Lastly, these stimulate myoblast, changes protein reaction in nucleus, boost numbers and magnitude of myotubes and in turn enhance new muscle formation and muscle strength, and finally lead to better physical performance.”(Figure 60)



(Figure 60) The model of Bosco, besides vibration tonic reflex of muscles, hormones are released and involved after vibration



## 24.2 Secret of vibration increasing bone density

In Chapter 5, we have introduced how vibration increases bone density in cells, in animals and humans. But these results also made many scientists wonder why such short-period vibration can enhance bone density in animals and humans. What is the reason or the mechanism behind it? Thanks to the dedication of many scientists, we now understand it is because of stem cells, precisely, “mesenchymal stem cells”.

### 24.2.1 Vibration and mesenchymal stem cells

There are two kinds of stem cells, one is hematopoietic stem cells (HSCs, means blood-generating stem cells) and the other one is mesenchymal stem cells (MSCs). Mesenchyme means embryonic connective tissue that is derived from the mesoderm of fetus and can differentiate into a variety of connective tissue cells. Mesenchymal stem cells exist in bone marrows. It exists not only in the baby or umbilical cord but also in the bone marrow of adults. They grow and differentiate actively in vivo and also in vitro. They can differentiate into a variety types of cell, including osteoblasts (bone cells), chondrocytes (cartilage cells) and adipocytes (fat cells). This ability is called pleiotropic potential (means multi-differentiation) which is a unique power and only belongs to stem cells in our body.

Mesenchymal stem cells are also in charge of restoring, repairing and regenerating human tissues. The numbers of stem cells decrease as we grow older. For example, fractures healing in young people is faster and easier but not in the elders. The reason behind is that the elders have much less mesenchymal stem cells for self-healing. Also, the decline in quality and quantity of mesenchymal stem cells is a factor why elders tend to get osteoporosis since there are no enough stem cells to produce new bone.

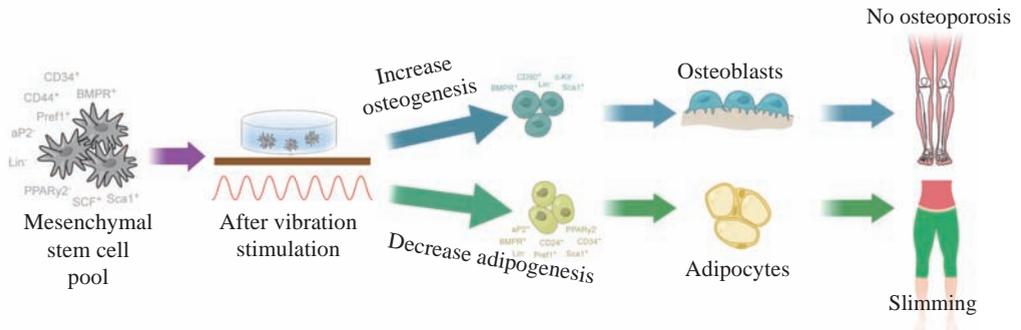
Mesenchymal stem cells are ideal tissue-regeneration material because they can differentiate into a variety of connective tissues. But how it happens is always attractive to many scientists. Until recently, scientists disclosed some of its mystery as how it is influenced by external factors like physical forces beyond inherited gene control.



### 24.2.2 Stem cell differentiation to bone cells or fat cells

Scientists knew that bone cell and fat cells come from a same origin. Actually both of them are developed from mesenchymal stem cells. It is mutual exclusive phenomenon that if mesenchymal stem cells differentiate into bone cell, they will not differentiate into fat cells and vice versa. And this means bone cells and fat cells are inversely proportional to each other. This also explains why lack of exercise makes people fat and low bone density.

After mechanical stimulation of vibration, the mechanical signals could stimulate mesenchymal stem cells to change its differentiation route. Mesenchymal stem cells will develop to osteoblast but not adipocytes. (Figure 61)



(Figure 61) Mesenchymal stem cells differentiate either toward bone cells or fat cells. Whole body vertical vibration induces mesenchymal stem cells toward bone cells instead of fat cells.



Recent studies showed that low intensity mechanical signals, such as whole body vertical vibration could inhibit subcutaneous and visceral fat cells without consuming extra calories. Mesenchymal stem cell is an ideal material for scientists to conduct tissue regeneration or organ repair. What scientists shall do is to manipulate the direction of its differentiation. Low intensity low frequency mechanical signal like WBV can play an ideal role to influence the direction of mesenchymal stem cells' differentiation. This is why whole body vertical vibration can help people to prevent osteoporosis and obesity at the same time.

In conclusion, we can kill two birds with one stone. WBV currently was extensively applied to be as a non-invasive technique to prevent osteoporosis and obesity.<sup>(62)</sup>

### **24.2.3 Experiments of mesenchymal stem cells**

Luu YK from Stony Brook State University in New York conducted a vibration experiment on mice (0.2g, 15 minutes a day, 5 days a week). He found that mesenchymal stem cells in bone marrow increased by 46% in 6 weeks. The result is similar to the cell studies, which results in more osteoblasts and less adipocytes. (How do we know that? They analyzed intracellular proteins and found that Runx2, which is up-regulating factor of osteoblasts, increased 72 %, while PPAR gamma, which is a down-regulating factor to suppress the fat formation, decreased by 27 %.)

The impact of WBV on mesenchymal stem cells lineage was evident at 14th week, where visceral fat formation was suppressed by 28%, whereas trabecular bone volume fraction in the tibia was promoted by 11%. This result is in line with the studies in humans.<sup>(13)</sup>

In summary, vibration stimulates mesenchymal stem cells to differentiate into osteoblasts, thus improve osteoporosis and increase bone density.



## Chapter 25 Vibration and hormones

### Introduction

*Whole body vibration does not only stimulate the body physically, but it also changes the hormone secretion inside of our body. Hormones today is defined as chemical substances that delivers biological message and affects cells in some organs or whole body. A variety of hormones change after whole body vertical vibration are noticed by scientists. These hormones include (1) Adiponectin; (2) Osteocalcin; (3) Transforming growth factor-beta1; (4) Nitric oxide; (5) Osteopontin; (6) Growth hormones, GH; (7) Testosterone; (8) tPA and PAI-1.*

*Whole body vibration stimulates various hormones secretion and affects our body extensively. As a result, whole body vertical vibration does not only prevent illness but also helps to boost the health.*

As mentioned above, the mechanism of vertical vibration is “tonic vibration reflex”. This reflex leads to muscle contraction and subsequently a serial of other reactions including hormone change. Both enhance physical performance and leads to many influences in our body. Tonic vibration reflex leads to acute or chronic adaptation of musculoskeletal system and hormones act on related target organs with various physiologic responses. In this chapter, I will elaborate more on the relationship between whole body vibration and hormones.

### 25.1 New classification of hormones

First of all, you need to know what the definition of hormone or endocrine is. In the past, scientists define hormone as chemical substance secreted by some organ, carrying biological messages, circulating in blood vessels and functioning on some tissues or systems afar, e.g., pituitary hormone, thyroid hormone and insulin. It is not really true because some hormones do not circulate in the blood or have extensive effects, instead, they act only on its nearby area with local influence. So today, hormone



is redefined as any kind of messenger in our body. Depending on how far they travel in our body, there are 3 kinds of them: (1) the long-distance traveler is called **endocrine** which could travel afar and work on the whole body; (2) the local traveler, is called **paracrine**, which only work on nearby cells, such as blood clotting factor or dopamine secreted by neuronal synapse; (3) hormones that acts on the same cell which releases them, is called **autocrine**, such as interleukin secreted by T- lymphocyte. In the following paragraph we will discuss about the hormones triggered by WBV, which includes all 3 kinds of the hormones mentioned here.

Let's take a look at the clinical trial by Dr Humphries B from Central Queensland University, Australia. He recruited 51 healthy young women (average 21 year) to proceed an experiment. The duration was 16 weeks and the aim was to examine if there was a significant differences in bone density and hormone. The final result showed that the bone density in femoral neck vibration group's increased. This is not a surprise. What surprised him is the dramatic hormone changes in these participants. His study results exhibited that vibration group and vibration plus resistance training group had 60% and 58% increase of adiponectin; 48% and 30% increase of transforming growth factor-beta1; 17% and 34% increase of nitric oxide; 50% and 36% reduction of osteopontin; 19% and 34% reduction of interleukin-1  $\beta$ ; 38% and 39% reduction of tumor necrosis factor-alpha.<sup>(10)</sup> These indicate that vibration has substantial influences to the hormone of the human body. How these hormones change our body is somewhat complicated. I will give a brief introduction of these hormones for our readers. (Table 25.1)

	Vibration group	Vibration plus resistance group
Adiponectin	+60%	+58%
Transforming growth factor-beta1	+48%	+30%
Nitric oxide	+17%	+34%
Osteopontin	-50%	-36%
Interleukin-1 $\beta$	-19%	-34%
Tumor necrosis factor-alpha.	-38%	-39%

(Table 25.1) hormones change after vibration



## 25.2 Vibration increases adiponectin and decreases diabetes and obesity

Adiponectin is a specific protein produced and secreted by fat cell which is related to metabolism and homeostasis of glucose and lipid. The increase of adiponectin correlates reversely with the body fat mass and BMI (Body Mass Index), that is to say, people who are overweight or obesity have relatively lower concentration of plasma adiponectin. In contrast, thinner people or people who lose weight have higher plasma adiponectin. Patients with hyperinsulinemia (too much insulin in blood) or type 2 diabetes also have lower adiponectin which is similar to overweight or obese people. There are medical evidences that decrease of adiponectin will correlate to insulin resistance. Insulin resistance is now recognized as the risk factor of diabetes and obesity. The increase of adiponectin will promote the utilization of blood sugar, inhibit the glucogenesis in liver as well as promote insulin sensitivity. This study showed that whole body vibration can raise adiponectin by 60%. Thus, whole body vibration is helpful to reduce fat accumulation or diabetes through elevation of adiponectin hormone.

## 25.3 Vibration increases osteocalcin and reduces blood sugar

Bone helps control diabetes? It sounds crazy and incredible. But Fukumoto S from Tokyo Medical University Hospital, Japan discovered a hormone called “osteocalcin” which produced by bone cells can improve diabetes. It is because that there are insulin receptors on the surface of osteoblast cell. Through these receptors, insulin could stimulate osteoblast to secrete osteocalcin. Osteocalcin does not only control the turnover of bones or stimulate new bone formation, but also involved in the balance of blood glucose. After whole body vibration, osteocalcin will be released from osteoblast. Osteocalcin circulates to pancreas and stimulates pancreas to secrete insulin. Insulin promotes the utilization of the peripheral blood glucose, increases insulin sensitivity and reduce visceral fat storage. This is actually a breakthrough finding in bone research these years. Bone was supposed to be only the skeletal supporting system in human being. No body has ever thought that bones can also secret hormone and influence blood sugar like other endocrine organ. No wonder professor Fukomoto said, “Bone is also an endocrine organ.”<sup>(131)</sup>

## **25.4** Vibration boosts immune function

Transforming growth factor-beta 1 or TGF- $\beta$ 1 is a kind of messenger produced by immune cells. They are specific proteins function as immune booster. Whole body vibration can increase TGF- $\beta$ 1 by 48%. As a result, vibration enhances the immune function of human body.

Tumor necrosis factor-alpha (TNF- $\alpha$ ) is also a messenger secreted by macrophage to fight against inflammation of our body. Whole body vibration could increase tumor necrosis factor-alpha by 38%. Accordingly, vibration could strengthen the immune function against the infection of virus or bacteria.

## **25.5** Vibration enhances nitric oxide secretion and improves cardiovascular function

Nitric Oxide (NO) is a gas hormone secreted by endothelial cells of vascular wall. It can relax vascular muscle, dilate blood vessel, increase blood volume and oxygen perfusion. Therefore, NO can help improve hypertension, ischemic heart disease or cerebrovascular dementia. Studies show that whole body vibration increases NO by 17% and thus reduces chance of cardiovascular diseases. It implies that if whole body vibration is used since young, it may prevent from hypertension, heart diseases and cerebral strokes in old. (Figure 62)

Osteopontin is a protein that participates in bone remodeling and helps increase osteoclast function of bone resorption. Osteopontin decreased by 50% in vibration group in the study. Hence, for young females, whole body vibration could increase bone density, decrease bone resorption and prevent osteoporosis in the future.<sup>(10)</sup>

## **25.6** Vibration increases growth hormone secretion

Growth hormone (GH), secreted by pituitary gland, is one of the main hormones in human body. It is a peptide hormone that stimulates growth, cell production and regeneration in humans. Lacking of GH before puberty could lead to dwarfism or low body height. While lacking of GH in adulthood could lead to sexual dysfunction, muscle weakness, hair loss, osteoporosis, hypercholesterolemia, cardiovascular disease, body fat storage, memory loss, and easy fatigue etc.



Whole body vertical vibration could stimulate body to release growth hormone. (Referring to Chapter 12 Vibration helps bone formation and growth in youth) Cardinale M from Olympic Medical Institute in UK found that those elderly people's GH and cortisol increased substantially ( $p < 0.001$ ) after whole body vibration.<sup>(103)</sup>

### 25.7 Vibration increases testosterone and decreases cortisol

Bosco C from Italy had an experiment on young men. After vibration, he noted their physical performance enhanced. In addition, the concentration of growth hormone increased from 6.2ng to 28.2ng ( $p = 0.01$ ) and that of testosterone decreased. (682 vs. 464,  $p = 0.03$ )<sup>(36)</sup>

Another study with obese young women (average 22 years old with BMI of 39) by Giunta M from Italy exhibited that GH substantially increased after vibration with or without squat training.<sup>(104)</sup> However, Cardinale had another experiment in young healthy men, but there was no difference in GH after vibration.<sup>(105)</sup>

Sartorio, a colleague of Giunta M, sought to resolve such inconsistency. He separated the subjects in 3 groups: (A) vibration group, (B) maximal isometric voluntary contractions group and (C) vibration with maximal isometric voluntary contractions group. He found GH improved in all 3 groups but GH had substantially increased in group B and C comparing to group A (+18.8ng, +20.8ng v.s +4.3ng,). Thus, vibration combined with isometric voluntary contraction such as squatting help to stimulate more GH than vibration alone.<sup>(106)</sup>

Kvorning T from South Denmark University obtained a similar result as Sartorio. His 3 groups are squatting group, vibration group and squatting plus vibration group. GH in blood increased in all 3 groups, but squatting plus vibration group elevated most. The rise of GH in three groups is 0.5ng, 0.2ng and 1.17ng, respectively. Testosterone raise most in the vibration group, but cortisol raise most in the squatting plus vibration group.<sup>(107)</sup>

In summary, scientific evidences showed that most effective way to elevate GH or testosterone concentration in blood to help our health is taking the isometric voluntary contraction such as squatting position on the whole vertical vibration platform.

## 25.8 Vibration inhibits blood clotting hormone

Cerebral stroke or myocardial Infarction (commonly known as heart attack) has a very close connection to blood coagulation. Blood coagulation form blood clot (thrombus or infarct) in our vessels. Thrombus or infarct can block out blood circulation and lead to hypoxia, ischemia or death of the involved tissues. It is possible to reduce the chance of thrombosis or infarction if we can suppress the process of blood clotting. In order to do that, we have to understand the mechanism of blood clot formation. Actually there are two proteins in our body antagonist to each other to achieve this balance.

Both proteins are: (1) tPA (tissue-type plasminogen activator) is a kind of protein enzyme secreted by endothelial cell (cells lining in blood vessels). It catalyzes the conversion of plasminogen to plasmin and is the major enzyme responsible for clot breakdown. In short, tPA helps breakdown of blood clots and inhibits the thrombus; (2) PAI-1 (plasminogen activator inhibitor-1) is the antagonist of tPA, produced by the endothelial cells or fat cells. Opposite to tPA, PAI-1 accelerates the formation of blood clot. It means more PAI-1 cause more thrombus and subsequent thrombosis.

Boyle LJ from Ball State University in US had an experiment with 20 young healthy men. He divided them into 3 groups: exercise group, vibration group and the exercise plus vibration group. The results showed that the exercise plus vibration had higher tPA (clot breakdown protein) and much less PAI-1 (clot formation protein) than exercise or vibration alone.

This result showed that vibration plus exercise could reduce the risk of thrombosis or infarction of brain, heart or other organs through change of PAI-1 and tPA.<sup>(117)</sup>



## Chapter 26 Safety precautions of whole body vibration

### Introduction

*Even whole body vertical vibration has more than 40 years history, severe side effects are rarely seen. But just like other exercises, the potential injuries or side effects may occur if we don't pay attention to our physical condition, follow manual instructions or over-training. Especially for those who use vertical vibrators at home, it could lead to adverse effects if they don't follow doctor's or coach's instruction, ignoring the frequency, duration or intensity.*

*According to the literatures, adverse effects could be local or systemic. The most common local side effects are skin redness, itching or rashes. The frequent systemic effects are dizziness, headache, inner ear imbalance, muscle soreness, nausea and mal-digestion. Under some circumstances e.g., pregnancy, post-surgery or severe diseases like acute myocardial infarction, the use of WBVV shall be restricted or stopped for the safety concern.*

The invention of whole body vibration was to help those disables who are unable or difficult do exercises. Adverse side effects were rarely seen for those handicaps such as spinal cord injury, bone fractures, cerebral stroke, Parkinson's disease or cerebral palsy etc received whole vertical vibration. With regard to the astronauts, athletes or young men who received high intensity vibration training for enhancing power, flexibility, muscle power, jumping or coordination, the adverse effects are either rarely occurred.

There are two kinds of whole body vibration machines in the market - home use and professional use. Home use machine is relatively safe since the machine is already set to low amplitude and low frequency. Commonly its intensity is under 1g. However, professional type machine is set much stronger with higher amplitude and higher frequency. People shall be cautious to use such machine because they are designed for athletes but not common people. You are advised to read the manual instruction before you start to use the machine. If you use a professional vibration device, ask a coach or a doctor to teach you as possible as you can.



According to literatures, adverse effects could be local or systemic.

1. Most common local side effects are skin redness, itching or rashes. It is because whole body vibration will increase peripheral circulation and focal skin hyperthermia. This happens more common if the frequency is over 30Hz. But the symptom is always transient and disappeared soon after vibration.
2. Most common systemic effects are dizziness, headache. Inner ear imbalance, muscle soreness, nausea and mal-digestion may sometimes happen. Only a few incidents have been reported by FDA in the last 30 years. One case was an osteoporotic patient who had a fall and subsequent fracture during vibration. A suspected vibration related deep vein thrombosis was reported. A case reported vibration led to his operation bone-screw loosen.<sup>(122)</sup> Another case complained cramping pain of renal stone after vibration.<sup>(123)</sup>

## 26.1 Relative contraindications of whole body vibration

Whole body vibration is unsuitable or has to use very carefully in some conditions. It is imperative for those people to consult their doctor or professional expert before using it.

1. Pregnancy
2. Epilepsy
3. Gallstones, Kidney stones, Bladder stones
4. Articular Rheumatism and Arthrosis
5. Heart failure
6. Cardiac dysrhythmias
7. Cardiac Disorders (Post MI)
8. Metal or synthetic implants (e.g. pacemaker, artificial cardiac valves, recent stents, or brain implants)
9. Chronic back pain (after fracture, disc disorders or spondylosis )
10. Severe Diabetes Mellitus with peripheral vascular disease or neuropathy
11. Tumors (excluding metastases in the musculoskeletal system)
12. Spondylolisthesis without gliding
13. Movement Disorder and Parkinson



14. Chondromalacia of the joints of the lower extremities, osteonecrosis and chondrosis
15. Arterial circulation disorders
16. Venous insufficiency with ulcer cruris
17. Morbus Sudeck Stadium II (CRPS)
18. Lymphatic edema
19. Postoperative wounds
20. Acute Rheumatoid Arthritis

## **26.2 Absolute contraindication of whole body vibration**

The following groups SHOULD NOT use whole body vibrator and need to re-evaluation of doctors even the conditions turn better.

1. Acute Inflammations, Infections and/ or Fever
2. Acute Arthropathy or Arthrosis
3. Acute Migraine
4. Fresh (surgical) Wounds
5. Implants of the spine
6. Acute or Chronic Deep Vein Thromboses or other thrombotic afflictions
7. Acute disc related problems, Spondylosis, gliding Spondylolisthesis or Fractures
8. Severe Osteoporosis with BMD < 70mg/ml • Spasticity ( after stroke or spinal cord lesion)
9. Morbus Sudeck Stadium I (CRPS I)
10. Tumors with metastases in the musculoskeletal system
11. Vertigo or Positional Dizziness
12. Acute Myocardial Infarction



### 26.3 Levels of vibration

There are four levels of vibrations according to its frequency, amplitude and duration.

1. Threshold of perception: The minimal level of vibration human can perceive.
2. Threshold of discomfort: The level of frequency which causes discomfort and unpleasantness to humans.
3. Threshold of fatigue: Vibrations that cause fatigue and decrease performance efficiency. But the physical or mental influence is temporary and can be recovered after vibration stops.
4. Threshold of danger: Vibration that exceed the tolerance limit of human. It does not only cause serious physical and mental reactions, but also lead to permanent damage.

Therefore, our recommendation is to use vibration at the level of threshold of perception. Do not practice too strong or too long. Vibration is similar to medication. Appropriate drugs can treat disease, but too many or too strong, may cause unexpected injuries or adverse effects. For the majority of you who are not professional athletes or astronauts, home type vibration machine will suit your need, and be recommended. Be sure to start with the low frequency and intensity. Adjust the intensity or change your posture until you feel comfortable.



Part 2

Whole Body Horizontal Vibration or  
Whole body Periodic Acceleration (WBPA)





## Chapter 27 WBPA saves lives, reduces complications and improves cardiovascular diseases

### Introduction

*The so called 'whole body periodic acceleration (WBPA)' is that people lie on a special designed mechanic platform, and horizontal vibration (Figure 63) were given to them in the direction of head to toe at the frequency of 2.33Hz or 140 times per minute.*

*This kind of motion along human vertebrae paralleling blood vessels will stimulate endothelial cells of the vascular wall. This impact of motion in physical term is called "shear force". Shear force can elicit a soluble gas- nitric oxide (NO) synthesized and secreted from endothelial cells of vascular wall, which could dilate blood vessels, increase oxygen perfusion to protect our hearts and brains.*

*Furthermore, for cardiovascular organs, NO could also 1) reduce the platelet aggregation; (2) reduce white blood cell adhering to vascular wall ; (3) inhibit proliferation of vascular smooth muscle; (4) inhibit proliferation of collagen.*

*These functions will suppress vascular inflammation, relax vessel and increase oxygen perfusion. Cardiovascular diseases could happen if NO concentration is low in blood. Studies showed that the damage of metabolic pathway of NO is frequently seen in .patients with diabetes, atherosclerosis or hypertension. Different from whole body vertical vibration which is based on tonic vibration reflex and the gravity, whole body periodic acceleration (WBPA) is based on the shear force and nitric oxide functions on cardiovascular systems.*

This is a unique exercise. Whole body vertical vibration resembles to rope-jumping and people can do it by himself. But whole body horizontal vibration is impossible to do by oneself. There is no any exercise compatible to this special movement. One, somewhat closed to horizontal vibration is the mother hugs her baby in her arm,



swinging back and forth. It is hearsay that WBPA is invented by the inspiration of this intimate action. However, it is impossible to have a vibration of 140 times per minute without mechanical help. Because whole body periodic acceleration or WBPA is not easy to understand, I will call it whole body horizontal vibration or just WBPA in this book.



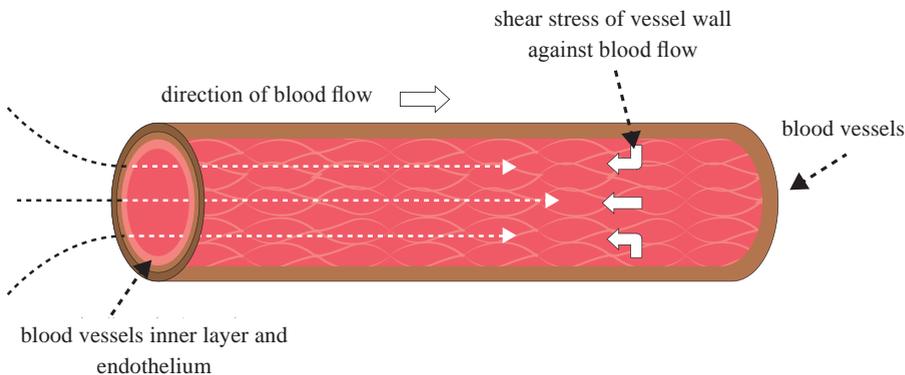
(Figure 63) WBPA is a horizontal vibration in the direction of head to toe to body(Courtesy of Bodygreen Co.)

After a decade of research and experiments, whole body horizontal vibration has been proved to have the following health benefits.

1. Prevent and ameliorate ischemic heart disease
2. Prevent and ameliorate cerebral thrombosis or infarction
3. Reduce complication of myocardial Infarction
4. Ameliorate pulmonary hypertension
5. Prevents and ameliorate peripheral vascular disease
6. Prevents and ameliorate diabetes
7. Increase the survival rate in cardiopulmonary resuscitation
8. Reduce cardiovascular complication in cardiopulmonary resuscitation

## 27.1 WBPA produces shearing force in blood vessel

The horizontal force from toe to head derived from WBPA is mechanic force called “shear force” or “shear stress”. Shear force is one of several common mechanic forces in physics terms. It is a kind of stress. Stress means an internal force of an object which counteracts with an external force. The stress like compression or tension is perpendicular to the object’s surface, but the shear stress is parallel to the surface. Because the pumping force of the heart, the blood flow will produce a shear force to the inner wall of vessels. This shear force is affected not only by blood flow velocity, but also blood viscosity and the size of blood vessels.<sup>(147)</sup> Currently scientists can use doppler ultrasound or MRI to measure the shearing force in blood vessels (Figure 64).



(Figure 64) blood flow will produce a force to blood vessel wall.  
That force is called “shear force” or “shear stress”

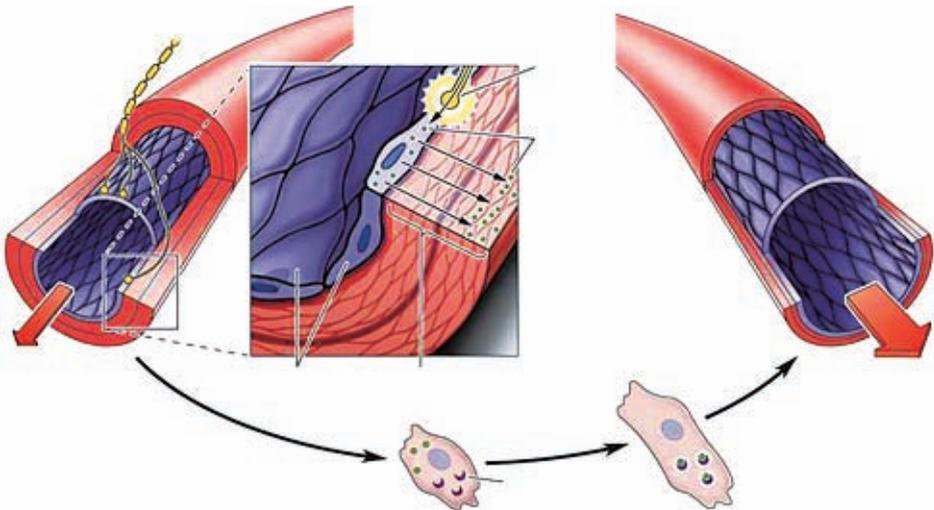
Shear force can elicit a soluble gas- nitric oxide (NO) synthesized and secreted from endothelial cells of vascular wall. NO is smaller than oxygen (O<sub>2</sub>), so it is easy for them to penetrate vessel wall to neighbor tissues or organs. NO can relax vascular muscle, dilate vessel and protect important organs like heart or brain. In mammals including humans, NO, though very tiny, has become an important biological messenger involved in many physiological processes. Although NO is a kind of gas, but interestingly enough, in the million years of evolution history, it has evolved into a messenger just like growth hormone, insulin or other hormones (Also see Chapter 25 vibration and hormones).



### 27.1.1 WBPA stimulates blood vessels to synthesize and secrete nitric oxygen

NO is a super small gas. By experiences, physicians have known that chemicals produce NO can dilate blood vessels in decades. For example, physician ordered “nitroglycerin” to treat angina and “sodium nitroprusside” to treat hypertension. It is because these drugs can stimulate releasing NO in our body. And NO can dilate blood vessel, lower blood pressure and raise blood volume to ameliorate diseases.

Though, this tiny gas is a biological messenger in human body is still incredible by the medical field until recently. After debating for decades, precise and strict studies confirmed that NO is undoubtedly a functional human biological messenger. They are synthesized and secreted by endothelial cells of vascular wall. Their major functions are dilating blood vessels, increasing blood flow and oxygen perfusion. (Figure 65) 3 scientists, Robert F. Furchogott, Louis J. Ignarro and Ferid Murad wined Nobel prize of 1988 for their contribution in identifying and elaborating NO mechanism. Scientists now realized that NO is not only the gas messenger of human beings but also all of vertebrates. NO is also called “endothelium-derived relaxing factor (EDRF)” due to its function. It’s an important autocrine and paracrine hormone. This means NO only actions on itself or cells nearby.



(Figure 65) NO is gas hormone. It is secreted by endothelial cell of vessels. It functions on its own or nearby cells. NO can relax blood vessel and protect cardiovascular organs

### 27.1.2 Functions of nitric oxide

Nitric oxide can dilate blood vessels, increase oxygen perfusion and even help improving erectile function of male. In fact, NO is how Viagra works. Viagra was originally a drug to treat hypertension through relaxing and dilating blood vessels. It was an accident finding that this drug can improve impotence of male. This is because Viagra stimulates to release NO and improves the function of cavernous body of penis. Recently, Pfizer pharmaceutical company conducted a large-scale experiment with Viagra and showed that it could also ameliorate pulmonary hypertension. The new drug called Revatio for this new indication. Plus, Viagra could also apply to treat the altitude sickness. Viagra used to treat these 3 diseases all because of the function of NO. (Figure 66)



(Figure 66) Viagra's function comes from NO

For cardiovascular organs, nitric oxide can provide these benefits: (1) reduce the platelet aggregation; (2) reduce white blood cell adhering to vascular wall ; (3) inhibit proliferation of vascular smooth muscle; (4) inhibit proliferation of collagen. These functions will suppress vascular inflammation, relax vessel and increase oxygen perfusion. Cardiovascular diseases could happen if NO concentration is low in blood. Studies showed that the damage of metabolic pathway of NO is frequently seen in patients with diabetes, atherosclerosis or hypertension.<sup>(140)</sup>

The synthesis of NO needs a specific protein called "nitric oxide synthases. There are 3 kinds of NO synthase - eNOS, nNOS and iNOS. Endothelial NOS (eNOS), is generated by endothelium cells of blood vessel wall and is involved with regulating vascular function. Neuronal NOS (nNOS) is produced by nerve cells in both central and peripheral nervous system, which helps to cells communication.

iNOS is like a ballistic missile, produced by macrophages to use as a weapon in our body. Macrophages will produce iNOS to attack bacteria when they intrude our body. Since NO is a free radical with free electrons, it could sabotage DNA of bacteria and kill them. Therefore, it plays a critical role in the human immune systems.<sup>(141)</sup>



Now let's review the papers on animal and human studies to see what the benefits of WBPA have. I'll discuss this topic in seven sections.

- (1) WBPA increases release of NO in human body.
- (2) WBPA prevents and ameliorates cardiovascular diseases.
- (3) WBPA saves life and prevents complications when pplied before, after or in t  
he middle of cardiopulmonary resuscitation.
- (4) WBPA prevents and ameliorates cerebrovascular disease.
- (5) WBPA prevents and ameliorates peripheral vascular diseases.
- (6) WBPA prevents and ameliorates pulmonary hypertension
- (7) WBPA prevents and ameliorates diabetes



## 27.2 WBPA increases release of NO in human body

### Introduction

Many researches showed that WBPA would stimulate endothelial cells to secrete NO synthases. There are 3 kinds of NO synthases: eNOS, nNOS and iNOS. Endothelial NOS (eNOS), is generated by endothelium cells of blood vessel wall and is involved with regulating vascular function. Neuronal NOS (nNOS) is produced by nerve cells in both central and peripheral nervous system, which helps to cells communication. iNOS is produced by macrophages and used its free radicals to attack bacteria or virus.

Besides NO, after WBPA, our body also release many chemicals to help health such as serum nitrite, prostacyclin, PGE-2, tPA and D-dimer. It means that WBPA does not only dilate blood vessels but also inhibits inflammation and reduces blood clotting. These could diminish the chance of cardiovascular thrombosis or infarction and show significant benefits to our health.

Shearing force by WBPA could stimulate endothelial cells to release NO from blood vessels. This is why WBPA benefits our cardiovascular system. This mechanism has been confirmed by many experiments.

In order to understand the relationship of WBPA and nitric oxide, Arkady Uryash from Mt. Sinai Medical Center, Florida, conducted a study with rats. The results disclosed that the stronger of the WBPA was, the stronger of the blood vessels were dilated. This reason was because eNOS was activated and subsequent nitric oxide released. The activation of eNOS is regulated by Akt/phosphatidylinositol 3-kinase (PI3K) pathway in the cell.<sup>(142)</sup>

Heng Wua had similar results. He discovered it is not only eNOS, but also nNOS are participated in the activities. **Most important finding he noted was that these NO activation effect can last more than 24 hours after WBPA.**<sup>(143)</sup>

WBPA did not only release NO in vivo but can also be repeated in vitro. Adams JA studies with isolated pig's artery in plate proved that NO release significantly increased after WBPA.<sup>(144)</sup> Li Y proved that pulsatile shear stress substantially induced



NO production in endothelial cells of ovine fetoplacental artery. This is through the mechanisms of both PI-3K-mediated eNOS activation and elevations in eNOS protein levels.<sup>(145)</sup>

But how much can WBPA release nitric oxide? Adams JA had a study on pigs to study this issue. After WBPA, he noted the concentration of eNOS, peNOS and nNOS increased 2.3, 6.6 and 3.6 times respectively. This showed WBPA can substantially stimulate NO release in pigs.<sup>(149)</sup>

Actually WBPA affects not only nitric oxide. Adams JA used pigs to do another experiment. He found that not only NO, but also vasoactive and fibrinolytic activity increased. With WBPA +/- 0.4g, 180 times per minute for 60 minutes, he noted serum nitrite, prostacyclin, PGE-2, tissue-type plasminogen activator (tPA) and D-dimer all increased comparing to the control group. There is no significant difference in epinephrine, norepinephrine, cortisol and coagulation factors.

Prostacyclin and PGE-2 could inhibit blood vessel inflammation. Tissue-type plasminogen activator, tPA, is a kind of protein enzyme secreted by endothelial cell within the blood cell. It catalyzes the conversion of plasminogen to plasmin, the major enzyme responsible for clot breakdown. In short, more tPA would help breakdown of blood clots. D-dimer is a fibrin degradation product (or FDP), a small protein fragment presents in the blood after a blood clot is degraded by fibrinolysis. Pulsatile and laminar shear stress to the endothelium induced by WBPA can promote these vasoactive and fibrinolytic activities.<sup>(157)</sup>

Sackner MA conducted a clinical trial in healthy people and patients with chronic inflammation. He noted that NO is released into circulation and dilates the vessels after WBPA no matter what group it is.<sup>(146)</sup>



## 27.3 Benefits of WBPA in heart

### Introduction

*WBPA increases blood flow in animal experiments. Assessed by colored Doppler sonography, blood flow increased in all organs after WBPA. The statistically significant increase included the epicardium (71%), endocardium (93%), cerebrum (183%), brain stem (177%), renal cortex (53%), ileal mucosa (69%), gastric antral mucosa (72%), and liver (86%). Spleen and skeletal muscle blood flow increased without statistical significance, 38% and 158% after WBPA. The blood flow returned to baseline 10 minutes after discontinuation of WBPA. But blood flow in myocardial muscle is an exception, where blood flow can remain significantly high. These effects may be desirable in clinical conditions like myocardial ischemia or cerebral hypoxia. It implies that WBPA can help improve ischemic cardiovascular diseases.*

*For patients with coronary artery heart disease, coronary flow reserve improved substantially after WBPA. It proves that WBPA may improve coronary artery function for patients with coronary heart disease.*

*WBPA also help lower the "left ventricle (LV) end-diastolic volume index" and elevated the "LV ejection fraction". Thus, WBPA helps improve exercising ability for patients with myocardial ischemia, lessens left ventricular dysfunction and ameliorates angina pectoris. Other studies showed that WBPA could reverse left ventricle remodeling after myocardial infarction.*

*In summary, WBPA can improve the exercising ability, reduce myocardial ischemia and reverse left ventricular remodeling. WBPA is a modern therapy to improve angina and myocardial infarction.*

Theoretically, NO can dilate blood vessels, but how it performs in human beings or animals. Professor Adams JA from Mt Sinai Medical Center in Miami tried to understand how and where NO dilates the vessels. So he conducted a study applied low intensity WBPA (4Hz, 0.4g) in little pigs. Regional blood flows, as assessed by colored microspheres, increased during WBPA relative to values obtained before WBPA. Assessed by colored Doppler sonography, blood flow increased in all organs



after WBPA. The statistically significant increase included the epicardium (71%), endocardium (93%), cerebrum (183%), brain stem (177%), renal cortex (53%), ileal mucosa (69%), gastric antral mucosa (72%), and liver (86%). Spleen and skeletal muscle blood flow increased without statistical significance, 38% and 158% after WBPA. The blood flow returned to baseline 10 minutes after discontinuation of WBPA. But blood flow in myocardial muscle is an exception, where blood flow can remain significantly high. These effects may be desirable in clinical conditions like myocardial ischemia or cerebral hypoxia. These effects may be desirable in clinical conditions of low tissue oxygen delivery and perfusion, like myocardial ischemia or cerebral hypoxia, meaning that WBPA could help improve their conditions.<sup>(155)</sup>

Matsumoto T, doctor from Shiga University of Medical Science Hospital in Japan, gave WBPA (2-3Hz, 2.2m/s<sup>2</sup>, 45 minutes a day for 4 weeks) to sedentary workers. He found that the dilatation of brachial artery increased by 11% (p<0.05), but the control group with oral nitroglycerin did not change. So he concluded that” **WBPA with a horizontal motion platform improved vascular endothelial function in sedentary adults. This device might offer an alternative to active exercise for patients whose medical condition limits physical activity.**”<sup>(151)</sup>

Dr. Shota Fukuda from Osaka Ekisaikai Hospital, Japan, conducted a study with 15 healthy people and 20 patients with coronary heart disease. He measured their coronary flow reserve after WBPA, which increased by 0.4 (p <0.001) in average. Even for patients with coronary heart disease, 8 out 20 displayed an increase of 0.3 (p < 0.01) after WBPA. Therefore Dr Shota concluded that **WBPA improve coronary artery function for both healthy people and patients with coronary heart disease.**<sup>(152)</sup>

Dr. Miyamoto S is professor of Kitano Hospital in Osaka, Japan, recruited 26 patients with angina pectoris who were not indicated for percutaneous coronary intervention and/or coronary artery bypass grafting. They were randomly assigned to remain sedentary (sedentary group) or undergo 20 sessions of WBPA for 4 weeks (WBPA group). The WBPA group was given 2-3Hz, ±2.2m/s<sup>2</sup>, 45 minutes per session, 5 days a week vibration. The outcome was examined with treadmill electrocardiography and adenosine sestamibi myocardial scintigraphy. By treadmill electrocardiography, he noted the time to appear ST depression wave ( a sign of heart strain or ischemia) in WBPA group delayed by 53% (p<0.01). Similarly, severity score of myocardial scintigraphy during adenosine infusion decreased from 20 to 14 (p<0.001) and severity score at rest also decreased from 13 to 8 (p<0.01). On



scintigraphic images at rest, LV end-diastolic volume index decreased 18% ( $p < 0.01$ ) with an augmentation of LV ejection fraction from 50% to 55% ( $p < 0.01$ ). In contrast, all parameters remained unchanged in the sedentary group. In conclusion, treatment with WBPA for patients with angina ameliorates myocardial ischemia and improves exercise capacity and LV function.<sup>(154)</sup>

During his studies in Kyoto medical school in Japan, Miyamoto S also did a study with 26 patients with myocardial infarction who have ever received percutaneous coronary intervention (PCI) or coronary artery bypass graft (CABG). The experimental group was also given a 2-3Hz,  $\pm 2.2\text{m/s}^2$ , 45 minutes, 5 times per week WBPA for 4 weeks. He used treadmill electrocardiography and evaluated with Bruce protocol (a diagnostic test used in the evaluation of cardiac function). He found that for the WBPA group, the time for appear ST depression wave delayed from 4.4 minutes to 6.4 minutes ( $p < 0.05$ ); double product (means the heartbeat times systolic pressure) improved from 15,400L to 17,400 mmHg.beats/min ( $p < 0.05$ ). LV end-diastolic volume index dropped from 73ml/m<sup>2</sup> to 60ml/m<sup>2</sup> ( $p < 0.05$ ) and LV ejection fraction increased substantially from 50% to 55% ( $p < 0.05$ ). The result showed that WBPA could reverse LV remodeling for angina patient after myocardial infarction.

Severity score of myocardial scintigraphy during adenosine infusion dropped from 20 to 14 ( $p < 0.05$ ) and resting severity score also lowered from 13 to 8 ( $p < 0.05$ ), showing that the areas of myocardial infarction and potential areas of myocardial ischemia both decreased.

As a result, Miyamoto S concluded, **"Treatment with WBPA for angina patients ameliorates exercise capacity, myocardial ischemia and left ventricular remodeling through central and peripheral effects. The development of such a therapeutic modality will open a new field of the treatment of angina patients with old MI."**<sup>(174)</sup> (The term "ventricular remodeling" implies a decline in function and "reverse remodeling" in cardiology implies an improvement in ventricular mechanics and function.)

Kohler M from Zurich University Hospital in Switzerland conducted another study in patients with congestive heart failure. Most of them were not in good condition with left ventral ejection fraction (LVEF)  $< 35\%$ , heart failure stage  $> 2$ nd stage and 6 of them had intermittent claudication (a special pattern of walking pain). They were given WBPA 40 minutes a day, 5 days a week for 5 weeks.



The results showed that their “6 minute walk distance” increased by 105 meters ( $p<0.05$ ) and improved postischemic skin hyperemia ( $p< 0.05$ ). In 4 of 6 patients with intermittent claudication, quality of life, treadmill walk distance and post-ischemic skin hyperemia improved after WBPA ( $p<0.05$ ). WBPA can improve the quality of life and exercise capacity for those patients with severe heart failure, intermittent claudication or not candidates for surgery. The clinical benefits appear to be mediated through improvement of endothelial function.<sup>(173)</sup>



## 27.4 WBPA used in cardiopulmonary resuscitation

*Cardiac arrest (no heart beat) and apnea (no breathing) are both signs of dying and need cardiopulmonary resuscitation (CPR) right away; otherwise people will die of no blood circulation and oxygen supply. Since WBPA could dilate blood vessels, increase blood flows and oxygen perfusion for vital organs like brain and heart, scientists try to apply it in emergency treatment. Does it really work?*

*There will be 3 parts in this section to see whether WBPA works. First section is WBPA applied prior to cardiopulmonary resuscitation. The second part is WBPA applied after cardiopulmonary resuscitation. The third part is WBPA applied during the process of cardiopulmonary resuscitation. The results showed that WBPA could reduce death rate and increase cardiopulmonary resuscitation success rate under all three conditions.*

*Comparing to the common automatic CPR device in ER-thumper CPR, WBPA is as effective, if not better. Some studies showed some advantages like higher LVEF (left ventricular ejection fraction), higher wall motion score index and more blood flows in brain, heart and kidneys. WBPA preconditioning reduced myocardial infarct size by 40%, improved contraction and the cardioprotective effects lasts more than 72 hours.*

*Based on animal model, we can conclude if WBPA were to be used with heart disease patients periodically, their conditions could improve. Even myocardial infarction happened, the prognosis will be better.*

*In summary, WBPA is a novel, effective and non-invasive approach to prevent and treat cardiovascular and peripheral vascular diseases. Whether WBPA is used before, after or during the process of cardiopulmonary resuscitation, it does not only raise the survival rate, but also decrease the vital organs injuries and other ischemic complications.*

Since scientists discovered WBPA help dilate blood vessels, increase oxygen perfusion and reduce apoptosis of cardiomyocyte (apoptosis means the cell death and cardiomyocyte is cardiac muscle cells), ER doctors couldn't wait to try this therapy to see if it works to raise the survival rate in emergency room. Any cause lead to death will go through the stage of "cardiac arrest." If we can elevate oxygen perfusion and reduce ischemic damage of the heart, it is for certain that we are able to elevate the success rate of cardiopulmonary resuscitation. (Figure 67)



Dr. Jose A Adam and his colleagues of Mount Sinai Medical Center in Miami are pioneers in this field and have published many articles on this topic.



(Figure 67) WBPA used before, after and during cardiopulmonary resuscitation can help raise survival rate and reduce complications



### 27.4.1 Therapeutic WBPA used before cardiopulmonary resuscitation (CPR)

Adams had 20 pigs in experiments and divided them to 2 groups, WBPA and control group. These pigs were electrified to shock and cardiac arrest. Then cardiopulmonary resuscitation (CPR) was given to save these pigs. Compared to the control group, he noted these pigs received WBPA before CRP (sometimes called preconditioning pigs) showed such benefits. (1) less cardiac dysrhythmia and less myocardial stunning; (2) more blood flow to brain, heart, kidney, and ileum; (3) two biochemical indicators of injured cardiac muscle – Treponin-I and CKMB were 35% lower than the control group; (4) four indicators on NO release - eNOS, p-eNOS, t-Akt and p-Akt all improved significantly. WBPA preconditioning confers early cardioprotection in a model of whole body ischemia reperfusion injury.<sup>(153)</sup>(Figure 68)



(Figure 68) After WBPA, the production of nitric oxide (NO) confers cardioprotection to pigs



Adams did another experiment on pigs. WBPA was applied on half of pigs before these pigs were electrified to ventricular fibrillation for 8 minutes. Another half of pigs without WBPA were used as control. Then he saved the shocked pigs with continuous manual chest compression and defibrillation for 10 minutes or until return of spontaneous circulation (ROSC).

Those pigs in WBPA pre-managed group displayed less arrhythmia after the recirculation of blood (7 vs. 35;  $p < 0.05$ ) and also less myocardial stunning. NO synthases (eNOS and p-eNOS) were substantial increase in WBPA pre-managed group pigs. This NO synthases increase was accompanied with the increase of phosphorylated Akt (p-Akt). It means that preconditioning WBPA will protect heart during cardiac arrest in part due to activating eNOS through p-Akt.<sup>(148)</sup> (Figure 69)

Uryash A found similar results. His studies use rats instead of pigs. Rats received WBPA beforehand, and then ischemia reperfusion injury was produced by ligation of left coronary artery (LCA). He found that survival rate increased in all WBPA preconditioned animals. 3 days and 7 days of WBPA preconditioning rats (1 hour per day) reduced myocardial infarct size by 41% and 38% respectively. And they exhibited better left ventricular function. Uryash found that the protection window for the heart lasted more than 72 hours.<sup>(150)</sup>

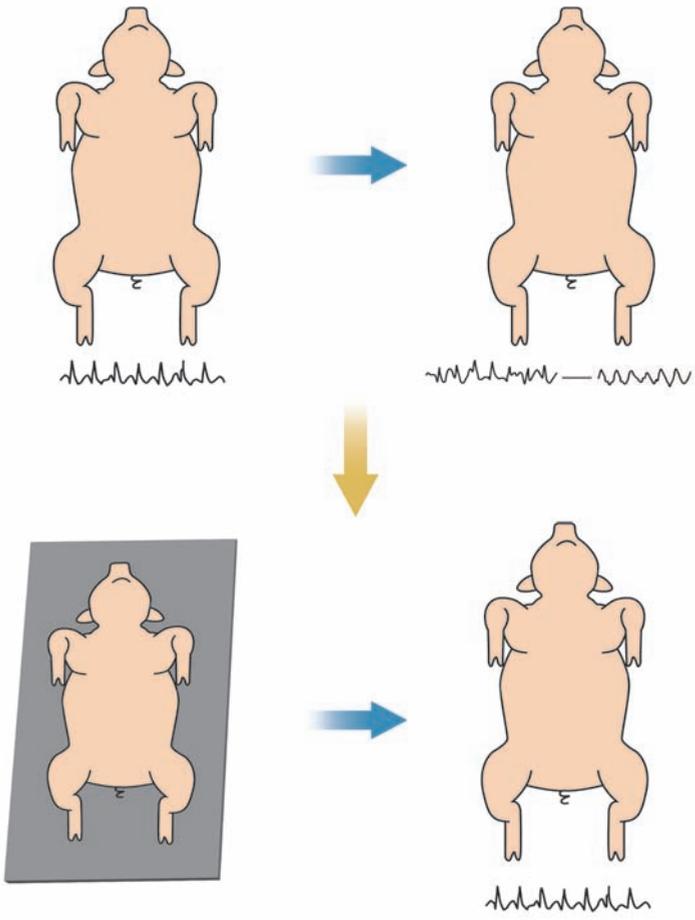
Based on the animal model, we can conclude if WBPA were used in patients with heart disease periodically, their conditions can improve. Even for the patients with myocardial infarction, WBPA can prevent the recurrence and improve the prognosis.

Why can WBPA improve cardiovascular function and ameliorate its damage? Dr Jose Lopez from Brigham and Women's Hospital, Boston, US, examined the rat's heart muscle. He confirmed that **after WBPA increased nitric oxide release, it improved calcium balance, reduce cell membrane depolarization, thus to protect heart from myocardial ischemia.**

Accordingly, we can see that WBPA is an innovative, effective, non-invasive approach to protect the heart from myocardial ischemia.<sup>(156)</sup>



Part 2: Whole Body Horizontal Vibration or Whole body Periodic Acceleration (WBPA)



(Figure 69) WBPA applied to pigs before or after cardiac arrest could reduce damage of heart and other organs



### **27.4.2 Therapeutic WBPA used after cardiopulmonary resuscitation (CPR)**

Now, we know if we used WBPA before cardiopulmonary resuscitation (CPR), cardiovascular organs can be protected. But what if WBPA is given after cardiopulmonary resuscitation? Does it still work? Asphyxia shock was induced in 20 pigs. After cardiac arrest appeared, the cardiopulmonary resuscitation was performed. 15 minutes after return of spontaneous circulation (ROSC), the animals were randomized to receive WBPA or not. Pigs with WBPA got better results on cardiovascular indicators such as (1) ejection fraction; (2) ratio of fractional shortening; (3) wall motion score index; (4) biochemical indices of reperfusion injury like TNF-alpha, IL-6, and Troponin I, and myeloperoxidase activity. Thus, delayed postconditioning with WBPA ameliorates acute post resuscitation reperfusion injury and improves myocardial dysfunction after asphyxia-induced shock. <sup>(158)</sup>

The application of 2 Hz WBPA increased cardiac output in ventricular fibrillation pigs. The benefit is proportional to the intensity of WBPA. The intensity is plateaued at 0.7g. <sup>(165)</sup>

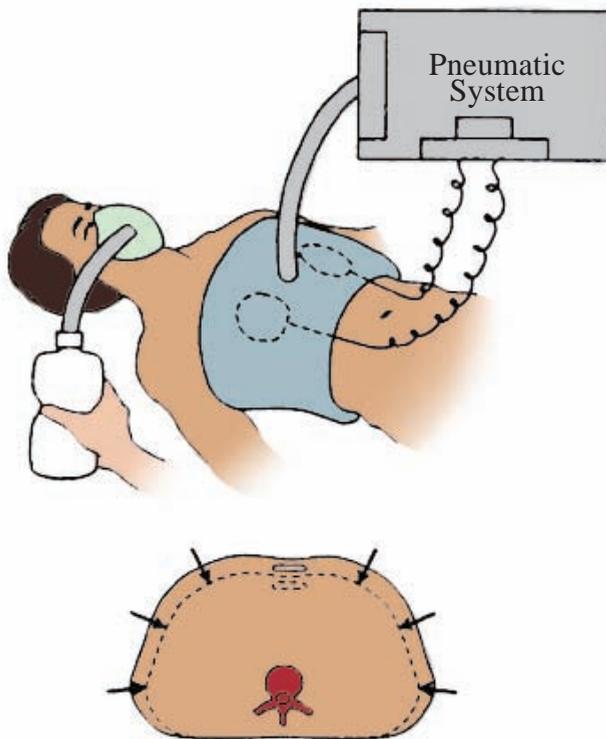
Another study was also in induced cardiac-arrest pigs. CPR and defibrillation were applied to these pigs. 30 minutes after return of spontaneous circulation (ROSC), WBPA was used in these pigs. Scientist noted there was obvious increase in NO synthases. Not only did they have had less myocardial stunning (lower Troponin I), but blood flow in major organs like heart, brain, kidneys, ileum and stomach all increased. Delayed post-conditioning WBPA did not only protect heart against early myocardial stunning by improving microcirculatory blood flow, but also protects other vital organs through this mechanism. <sup>(159)</sup>

### **27.4.3 Therapeutic WBPA used during cardiopulmonary resuscitation (CPR)**

From theories and experiments, WBPA is proved to assist physicians to save the patients with cardiac arrest, increase survival rate and reduce damages of vital organs from hypoxia. What if WBPA is used together with CPR? A medical team in Miami Hospital did a series of research on this topic. First, 12 pigs were electric shocked to cardiac arrest. 3 minutes after cardiac arrest, pigs were divided into 2 groups. Study group received 15 minutes WBPA and the control group didn't. Checking the

condition after 18 minutes, he found pigs received WBPA all return of spontaneous circulation (ROSC) and survived. In opposition, all pigs without WBPA died. the pigs were then randomized to receive 10 min of WBPA or standard CPR with a commercial device,

They also compared WBPA with Thumper CPR, a device common used in emergency room for resuscitation. Thumper CRP is a machine vest worn by the patient, and supports them with automatic pneumatic chest compression.(Figure 70)



(Figure 70) Thumper CPR, a device common used in emergency room for resuscitation

The team used 16 pigs for experiment. They induced these pigs to asphyxia (means choking) cardiac arrest. Then these pigs received either Thumper CPR or WBPA for 10 minutes to see whether there was difference. The results showed that there was no significant difference in survival rate or hemodynamic profiles between two groups.<sup>(160)</sup>



Another research also showed similar results. The only difference was that pulmonary artery pressure in WBPA group was substantially lower than Thumper CPR group (20mm Hg vs. 46mmHg) : Plus, WBPA performed better because rib fracture was much less. (0% vs. 25%)<sup>(161)</sup>

These studies are conducted in pigs with asphyxia (means choking) cardiac arrest. How about to those cardiac arrest not induced by asphyxia? For non-asphyxia cardiac arrest pigs that are caused by other reasons, experiment showed that WBPA group is better than the Thumper CPR group. The rate of returning to spontaneous circulation (ROSC) was higher in the WBPA group (7 in 8 pigs, 88%) compared to control group (5 in 8 pigs, 62%). WBPA also had better results in fraction ejection and %fractional shortening of left ventricle (both are function indices of heart). Cardiac sonography also displayed that with Wall Motion Score Index, (WSMI) in thumper CPR group pigs were much worse because damage. In the opposite, pigs in the WBPA group remained no damage after 6 hours from CPR.<sup>(162)</sup>

Major organs might suffer from hypoxia even though they were successfully resuscitated from cardiac arrest. It means that returning to spontaneous circulation (ROSC) did not promise the patients healthy. Most of time, the major organs like brain, heart, kidney or other vital organs could be actually damaged during the period from cardiac arrest to ROSC. So we need to check the function and blood flow of these organs after CPR to see its prognosis.

Another study with 16 pigs explored the above question. These pigs were artificially led to ventricular fibrillation (VF) and lasted for 18 minutes. Comparing to the pigs in Thumper CPR group, WBPA group pigs (received 15mins horizontal vibration) exhibited (1) higher ejection fraction and less ventricular wall mobility disorder; (2) All hemodynamic indicators returned to normal in 3 hours while the Thumper CPR group remained high; (3) Initially, they are pretty similar but 30 minutes after ROSC, there was much higher blood flows in brains, hearts, and kidneys in WBPA group; (4) Significant lower tissue inflammation reaction measured in myeloperoxidase (MPO), plasma creatine phosphokinase (CPK), cardiac troponin I, TNF- $\alpha$  and IL-6 in WBPA group.

**These experiments proved that in cardiopulmonary resuscitation (CPR), WBPA had less damage than Thumper CPR did.**

## 27.5 WBPA used in acute stroke or cerebrovascular accident (CVA)

### Introduction

A stroke or cerebrovascular accident (CVA) is a severe emergent disease, often leads to permanent neurological damage or even death. Symptoms include aphasia (difficulty with verbal expression), swallowing disturbance, memory or cognition disorder, seizures, and uncontrolled gestures. The severe case may lead to persistent vegetative state. Research showed that WBPA has neuroprotective effects to stroke accidents. This is because:

- (1) It reduces the subsequent brain complications after cardiopulmonary resuscitation (CPR) from cardiac arrest;
- (2) It can diminish the ischemic or necrotic area of brain after CVA
- (3) it can influence the intracellular signal to cell deaths proteins like Bcl-2, Bax and reduce brain cells death
- (4) it can increase the regeneration protein like BDNF and enhance the damage neurons to regeneration and connection.

Therefore, WBPA showed it is a promising approach to prevent or treat CVA patients.

During cardiopulmonary resuscitation (CPR), the priority is to help patients recover the automatic heartbeat and return the spontaneous circulation. But even after they returned to normal, vital organs may have suffered from hypoxia, and ischemic damage. These vital organs include brain, heart, kidney, liver and intestines. Brain is the most oxygen sensitive and critical organ. If brain is wounded, even after returning to normal circulation, it will still produce dysfunctions of cognition, memory, speech, swallowing, motion or posture. It could even lead to a persistent vegetative state or death. So, does WBPA help these patients with stroke?

Martinez-Murillo R's team from Spain did a study in rats. They performed artery ligation in rats to induce brain ischemia. This induced a focal brain ischemia in rats. Then WBPA was used in half of these rats for 3 hours immediately after the onset of ischemia. Half of the rats used as control group without WBPA. Brain damage was assessed with magnetic resonance imaging (MRI) and two biochemical markers beclin 1 and fractin. 7 days after brain ischemia, he noted that WBPA rats had 82% less brain atrophy compared to control group. Furthermore, WBPA rats had significantly lower levels of beclin 1 and fractin. Both intracellular proteins beclin 1 and fractin are index of brain cell apoptosis. (apoptosis means cell programmed death) Lower beclin 1 and fractin indicated less brain cells death.



So Martinez-Murillo concluded,” WBPA proves to be an innovative, affordable, non-invasive therapeutic option for treatment of stroke.”<sup>(166)</sup>

Jose A Adams’ team in Miami also obtained similar outcomes. They conducted experiments in pigs 2003. Pigs are induced to cardiac arrest. And after 3 minutes after cardiac arrest, 15 minutes of WBPA was given to half of pigs. Their neurological functions were evaluated 24 hours after CPR. Compared to control pigs, WBPA pigs exhibited no abnormal neurological findings. These maintained normal observed until 48 hours.<sup>(164)</sup>

In 2010, they studied the brain regulatory proteins of rats following asphyxial cardiac arrest. After anesthetized, vibration group of rats received 60 minutes of WBPA, and then they were paralyzed and blocked their airway for 5 min, followed by resuscitation until return of circulation and recovery for 4 hrs. 4 hours after return of spontaneous circulation, brain cells from these rats’ frontal lobe were removed and examined. Then they analyzed the regulatory proteins involved in initiation protein (Bax) or inhibition of apoptosis (pAkt, Bcl-2, high Bcl-2/Bax ratio) in (apoptosis means programmed death of cells).

In the WBPA group, all rats recovered spontaneous circulation, while the control group only had 60% of rats survived. WBPA group had higher Bcl-2/Bax ratio (1.92 vs. 0.62,  $p=0.001$ ) and pAkt (124 vs. 34,  $p=0.001$ ). The higher of Bcl-2/Bax ratio means fewer of brain cells death. Akt is a protein within cells and inhibit apoptosis of cells. It means more Akt proteins exist, more brain cells survive. In conclusion, WBPA preconditioning in a rat model, may provide significant protection from apoptotic neuronal injury and therefore be a valuable neuroprotective strategy prior to procedures likely to involve hypoxia/ischemia.<sup>(167)</sup>

### **27.5.1 WBPA used in neuron regeneration and reconnection**

Besides prevention of neuron damage or death, can WBPA help nerve regeneration and reconnection? Adams’ team did another rats research. This time they evaluated the results with two neurotrophins (means the neuron nutrition proteins), “brain cell line derived neurotrophic factors, BDNF” and “glial cell line derived neurotrophic factors, GDNF”.



Neurotrophins like BDNF and GDNF, are factors to control signaling pathways and guide synaptic, axonal and neuronal circuits in brain plasticity and neurogenesis. They improve cognitive performance, promote angiogenesis, and cell survival. The rats with one hour WBPA for 2 weeks expressed 30% higher BDNF and 26% higher GDNF ( $p < 0.001$ ) than the rats without WBPA. Thus, WBPA helps recover brain function from cerebral hypoxia-ischemia condition.<sup>(168)</sup>

## 27.6 WBPA used to treat peripheral vascular diseases

### Introduction

*Vascular disease is not limited to heart or brain. They can also happen in the limbs. These are called peripheral vascular diseases or peripheral arterial disorders, which often come along with diabetes or atherosclerosis. They often do not lead to death, but cause discomfort or disable. Most common signs include intermittent claudication, pain, pale, numbness and cyanosis of upper or lower limbs, fingers or toes.*

*Research showed that WBPA improve peripheral vascular diseases. They can (1) increase blood flow volume, reduce the ischemia induced pain and intermittent claudication; (2) increase NO syntheses and angiogenic growth factor, which help dilate the vessels and accelerate new blood vessel formation. Therefore, WBPA is a new effective therapy for peripheral vascular diseases through improving blood circulation and reducing hypoxia ischemia.*

Vascular disease is not limited to heart or brain. They can also happen in the distant limbs. These are called peripheral vascular diseases or peripheral arterial ischemic disorders, which often come along with diabetes or atherosclerosis. They will not lead to death, but often cause discomfort or disable. Most common signs include intermittent claudication, pain, pale, numbness and cyanosis of upper or lower limbs, fingers or toes.

Professor Rokutanda Taku from Kumamoto University in Japan studied how WBPA can influence ischemic peripheral vascular disease. He ligated hind-limb artery of 28 rats and divided them into two groups- WBPA group and the control group. The experiment rats received WBPA 45 minutes a day for 7 days. He noted blood flow volume in ligated hind-limb increased much more in the WBPA group



than in the control group. In addition, there were significant increase in NO synthases and angiogenic growth factor expression as well. Angiogenic growth factors such as VEGF, FGF2, SDF-1 and PDGF-B all raised. These growth factors are important signaling proteins involved in both vasculogenesis ( the de novo formation of the embryonic circulatory system) and angiogenesis (the growth of blood vessels from pre-existing vasculature).<sup>(169)</sup>

Two other experiments exhibited similar outcomes. In diabetes rats, WBPA accelerated blood flow of rat's hindlimb while insulin and blood sugar remained intact. Another study with 10 patients suffered from peripheral artery occlusion, a single WBPA (140 cpm, 45 min) significantly improved the ischemic/non-ischemic ratio of blood flow from 74% to 87% in the lower limbs ( $p < 0.05$ ).<sup>(170)</sup>

“Intermittent claudication” is a unique pattern of walking disturbance. Claudication is a Latin word means limping. This feature of “Intermittent claudication” is muscle pain or cramp, mainly in the calf muscle which occurs during exercise, such as walking, and is relieved by a short period of rest. There are two kinds of claudication: (1) Neurogenic claudication (NC) is a common symptom of lumbar spinal stenosis, or inflammation of the nerves emanating from the spinal cord. (2) Vascular claudication, which stems from a circulatory problem, most of time is because of arteriosclerosis. The pulse of foot artery will be very weak and the low limbs are pale and cold. Final diagnosis will rely on the Doppler sonography. This peripheral arterial disease often accompanied with coronary artery disease, brain artery disease or renal artery disease. It is because the vascular pathologic change often occurred in all of vascular system.

Kohler M from University Hospital Zurich in Switzerland conducted a research with congestive heart failure patients. These subjects had their heart condition LVEF < 35% and NYHA stage > 2nd stage. 6 of them had intermittent claudication. WBPA was applied to them 40 minutes a day, 5 days a week for 5 weeks. The results showed that their “6 minute walk distance” increased by 105 meters ( $p < 0.05$ ); Ischemic skin temperatures raised ( $p < 0.05$ ); 4 of the 6 intermittent claudication patients improved on walk distance, quality of life and lower limbs temperature ( $p < 0.05$ ). For those severe congestive heart failure patients combined with intermittent claudication, several weeks WBPA could improve their quality of live and mobility.<sup>(173)</sup>

In summary, these experiments above displayed that WBPA could (1) increase NO synthases signal pathway; (2) increase upregulation of angiogenic growth factors and in turn enhance blood vessel dilation, increase blood flow and boost new blood vessel formation. As a result, WBPA elevated oxygen supply of limbs and ameliorated the ischemia injuries of limbs.

## 27.7 WBPA used to ameliorate pulmonary hypertension

### Introduction

*Pulmonary arterial hypertension (PAH) or pulmonary hypertension is a rare but severe disease. Due to some reasons, the pulmonary artery became very narrow, tense or high resistance, the heart became difficult to pump out blood to the lung. As a result, the oxygen exchange between lung and heart reduced, the patient became feeling shortness of breath, cyanosis, dizziness, fainting, leg swelling and other symptoms. Pulmonary hypertension can develop to severe disease with a markedly decreased exercise tolerance and heart failure.*

*WBPA could stimulate blood vessels to produce more NO and prostacyclin, therefore theoretically WBPA could help pulmonary hypertension. What's the real situation? Experiments on pigs showed that it could lower pulmonary and systemic hypertension. In the future, WBPA may play a role as a non-pharmacologic way to treat pulmonary hypertension.*

Pulmonary artery is an artery connected the heart to lung. After the oxygen was consumed in the tissues and organs, these low oxygen blood will flow back to right heart. Then through the pulmonary artery in right ventricle, these low oxygen blood flow to lung and exchange to saturated oxygen blood. Then the O<sub>2</sub> saturated blood returns back to left atrium through pulmonary vein. Whatever the initial causes are, pulmonary hypertension is because the stricture, narrowing or fibrosis of pulmonary artery. This causes right heart had substantial resistance to pump blood to lungs. This will increase blood pressure within pulmonary artery and impairs their blood flow to lung. In addition, the increased workload of the heart will cause hypertrophy of the right ventricle gradually. It ultimately causes right heart failure. This condition is called “cor pulmonale” in medical terms. Because the blood flow returning to lungs decreases and oxygen exchange is not full, left heart will receive less and hypoxia blood. The situation of inadequate O<sub>2</sub> exchange will cause the patient dyspnea during exercise in the initial stage and dyspnea at rest in the later stage.

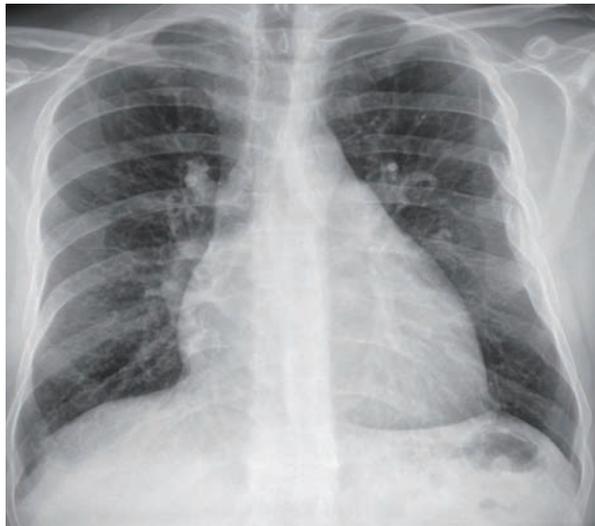
The current treatment for pulmonary hypertension is nitric oxide (NO) inhalation or an oral drug called Epoprostenol (synthetic prostacyclin, marketed as Flolan). Interestingly, WBPA has already shown it stimulates release of NO and prostacyclin, therefore theoretically WBPA may help these patients.

Jose A Adams' team in Miami anaesthetized 8 pigs and gave them L-NAME, which is a chemical can inhibit NO synthases. Those pigs received L-NAME had



higher pulmonary and systemic hypertension. Then they gave pigs 2-4Hz, amplitudes of 0.5-1cm, +/- 0.2-0.8g WBPA. Results showed that WBPA increased NO synthases and offset the effect of L-NAME. After WBPA, these pigs exhibited lower systemic artery and pulmonary artery blood pressure.<sup>(171)</sup>

Another experiment they did was even more creative. Meconium is the first stool of a newborn, composed of materials ingested during the time the fetus stay in the uterus. The scientists infused meconium into these pigs' lungs and led these pigs to meconium-induced aspiration pneumonia. 2 hours after meconium was inhaled, compared to the control group, they found that WBPA group had 30% lower of systemic artery pressure and 100% lower pressure of pulmonary artery pressure. The experiments proved that WBPA could lower both systemic artery and pulmonary artery pressure, especially the latter one.<sup>(172)</sup>(Figure 71)



(Figure 71) Resistance of pulmonary artery will lead to pulmonary hypertension and right ventricular hypertrophy. WPBA can help pulmonary hypertension and right heart failure



## 27.8 WBPA used to improve diabetes

WBPA is also useful for diabetes patients. Sakaguchi M from Osaka University Hospital in Japan tried WBPA in 8 diabetes patients. He examined coronary flow reserve (CFR) before and after WBPA with cardiac sonography. He noted there was 13% increase of coronary flow reserve from 2.3 to 2.6 ( $p=0.02$ ).

In addition, he discovered that WBPA improved the glucose profile. The study exhibited that (1) reduced blood insulin concentration, from 26 to 19 IU/ml ( $p=0.01$ ); (2) increased total adiponectin from 11.6 to 12.5  $\mu\text{g/ml}$  ( $p=0.02$ ) and high molecular weight adiponectin from 4.9 to 5.3 ( $p=0.03$ ). Higher total adiponectin or high molecular weight adiponectin are both associated with a lower incidence of diabetes. (186) We can see that a single WBPA is enough to increase coronary microcirculation and improves glucose profile in patients with type 2 diabetes.<sup>(175)</sup>

In conclusion, WBPA is a novel, effective, non-invasive, non-pharmacological approach to improve cardiovascular diseases, cerebrovascular diseases and peripheral vascular diseases. It can enhance the survival rate and reduce the complications in emergent cardiopulmonary resuscitation. It works even better than current automatic CPR machine -Thumper CPR. It showed substantial benefits whether WBPA is used before, after or during CPR procedure. In addition, it can be used to treat the patients of pulmonary hypertension and diabetes mellitus. WBPV is a non-intervention, non-pharmacologic and cheap, evidences based approach to prevent, improve or ameliorate the cardiovascular diseases.



## How to read this book

In recent years, I have read thousands of articles in the field of whole body vibration. I will say my conclusion first then explain later.

**“Whole body vibration is a magical passive exercise. It influences people in many ways. Thousands of laboratory studies, animal studies and clinical trials have shown that it actually works to improve health.”**

How can I be so sure? Those of you who have tried it or read through the book patiently shall be able to find the reasons in the book. Basic requirement of modern medical science is evidence-based. It means you need to get proof based on scientific studies. In this book, I tried to stick to this medical request. You shall see many references in this book which are almost published papers in famous medical journals. There are total over 180 papers attached in the reference pages.

Every major country in the world is very strict in approving new drug. When I worked in Novartis Pharma AG of Switzerland as a medical director, my major responsibility was to conduct clinical trials and convince the government to approve the new drug. During the period, I had read numerous clinical studies. I can say the level of many researches of the whole body vibration has achieved the standard of new drug studies. Even though some studies didn't show the positive results, scientists still can confirm the efficacy of the whole body vibration. Why? It is because there is obvious discrepancy between clinical trials and physics or chemistry studies. Experiments in physics or chemistry will have the same results as long as the conditions remain the same, like glucose can be fermented to alcohol and carbon dioxide. There is no variation in the process. But in clinical trials studied in humans, it does not perform as perfect as you think. There existed some variations in humans, either genetic or physical conditions. Therefore the results are sometimes not consistent because of these confounding factors.

For example, a pharmaceutical company conducted a research to see if a new sleeping pill works. The objects were divided into 2 groups: the study group taking sleeping pill and the control group taking vitamin. Results may have shown like this: it worked for 75% of the objects in the study group and 61% of the control group; or inversely, it didn't work for 25% of the people in the study group and 39% of the control group. Result like this is not a particular case but actually very common in clinical trials.

How do you explain the result? Is this new sleeping pill effective and can be approved to market? Why 41% of control group who took only vitamin can sleep as sound as the subjects taking new sleeping pills? This is what we called “placebo effect”. Placebo effect works because of people’s subjective expectations. But besides the placebo effect, there are other factors to influence the study outcome, such as personal reasons (genetics or personal predisposition), the dietary habit (people that drink a lot would minimize the effect of a sleeping pill) or emotional reasons (people who are apt to anxious or nervous perhaps not to show the positive effect of sleeping pills).

In addition, the study design and analytic method may cause different results as well. For those studies similar designation but showing different outcomes, we needed to further investigating the possible factors behind. The race, age, genders or the numbers of subjects in experiment could be confounding factors. Plus, the duration of experiment, the investigating variables also can attribute to the inconsistency. You have to keep in mind that inconsistency is actually a feature of clinical trial results when you go to read the articles of whole body vibration.

### **Statistical significant P value**

Due to the reasons mentioned above, medical studies usually use statistical methods to determine if it’s effective or not. The value we use to determine the result is called p value. If p value is less than 0.05, it means that there is a probability of 95% that there is a difference between the experimental group and the control group. Take the sleeping pill case for example, if  $p < 0.05$ , then it means the pill is different from vitamin, so it works. You will see many p values in this book. If  $p < 0.05$  means that there is a difference between the experimental group and the control group and in this book the experimental group represented the vibration group. Thus,  $p < 0.05$  means that there is a difference between the vibration group and the control group.

The tricky part about statistics is that, if there is difference, but the difference is not statistically significant, in order to investigate whether there is difference, scientists need to increase the tested subjects. Take the sleeping pill case; if there were only 100 in the experimental group and 100 in the control group, we might conclude that the sleeping pill doesn’t work. However, if the studied subjects increased to 1000 vs. 1000, the result might turn out to positive result. It is because more subjects in statistics, more chance to find out the smaller difference. But more subjects recruited in the study, more budget needed. The clinical trial is very expensive, therefore most of large scale studies are either conducted by pharmaceutical companies for profits or

government for public health. Most of rehabilitation clinical trials are small scale with limited numbers of subjects. The relative small samples of study may explain why some studies of whole body vibration didn't show positive outcomes.

However, clinical studies of whole body vibration have been done for 4 decades with substantial numbers of research papers. Many papers were published in well-known journals. They were not only excellent in quality and quantity, consistent and reliable, but also in theoretic elaboration. That why, even though some studies did not show positive outcomes, we are confident in the healthy effects of whole body vibration.

Take how vibration helps bone density as example, not only are there research in small animals like rats , large mammals like sheep, but also studies in women, elders, children. There are also further studies in stem cells as well as in the molecular biology. The studies are quite comprehensive in theory, basic studies or clinical trials. And that's why scientists can conclude that " whole body vibration do increase human bone density, reduce osteoporosis and lower the risk of fragile fractures."

I know this is not an easy book for readers who are not physicians or scientists in related fields. However, I hope this book can serve as a tool book for those who need or use whole body vibration devices to improve their health or ameliorate their diseases. Readers can go directly to the specific chapter to look for the data they need or particular information they have questions. For your convenience, there will be a concise introduction in the beginning of every chapter and sections.

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