

# English translation

## Vibrationstraining in der Therapie unter besonderer Berücksichtigung der Stochastischen Resonanz

The structure follows the pages of the original presentation. Diagrams and figures were not redrawn; their text content and captions are translated as descriptions.

### 1. Vibration Training in Therapy

- with special consideration of stochastic resonance
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### 2. Vibration

- The common feature of all such interventions is external mechanical stimulation in which oscillations are transmitted through the body.
- The body reacts to this stimulation as, from a mechanical point of view, a multiple mass-and-spring-coupled oscillator system with numerous adaptation mechanisms. A prerequisite for these mechanisms is the function of the body as a frequency-selective filter for endogenous vibration transfer [Haas et al., 2004].
- When a high proportion of body weight is involved, for example when standing, sitting or lying on a vibrating surface, whole-body vibration is present. When the proportion is lower, for example when holding a vibrating object, partial-body vibration is applied [Haas et al., 2004].
- As a rule, a bipedal stance is assumed; the training and stimulating effects mainly act on the lower extremities [Huber, 2006].

### 3. Influencing Factors in Vibration Training

- Type of vibration.
- Amplitude and frequency.
- Body position on the platform.
- Load parameters: training duration, load density, training volume and frequency.
- With or without additional weight.
- Principle of individuality.
- Diagnosis.

### 4. Acute Short-Term Effects

- Strength gains of 5-10% after a training protocol of 10 times one minute at 26 Hz [Bosco et al., 2000; Cochrane and Stannard, 2005; Issurin and Tenenbaum, 1999].
- Increased secretion of testosterone and growth hormone (up to 460%) [Bosco et al., 2000].

### 5. Tonic Vibration Reflex (TVR)

- The central triggering mechanism of the effects of vibration training is the TVR [Matthews, 1966; Hagbarth and Eklund, 1966].

- Cyclic vibration loading triggers muscle stretch reflexes via muscle spindles and Golgi organs. This leads to increased recruitment and simultaneous activation of the motor units addressed by the training.
- Muscle spindles play a central role in muscular stabilization of upright posture. Vibrations trigger muscular activity and subsequent adaptation processes.
- This creates an interaction between afferent Ia fibers, which continuously report length changes in the stimulated muscles, and efferent gamma fibers.
- The aim is to dampen and compensate for the vibration and thereby maintain constancy of upright posture [van Diemen, 2002].

## 6. Tonic Vibration Reflex (TVR)

- It can be considered established that vibration training via the TVR leads to increased force development during training, depending on the selected frequency and training form.
- In this context, numerous publications are available that demonstrate performance optimization through vibration training [Cochrane and Stannard, 2005; Delecluse et al., 2003].

## 7. Adaptations of the Neuromuscular System

- Optimization of motor control and improved recruitment of previously unused motor units are the central mechanisms of vibration training [Issurin and Tenenbaum, 1999] -> TVR.
- Targeted vibration stimuli release biochemical substances - neurotrophic factors - that counteract degeneration and loss of function of nerve cells and promote new connections between neuronal networks [Haas et al., 2006].

## 8. Adaptations of the Neuromuscular System

- The original slide shows a motor-control loop: action goal, programming, target-actual comparison, control/regulation, storage in motor memory, processing of afferent information, movement execution, internal and external control circuits, and environmental factors.
- Source of the diagram: Meinel and Schnabel, 1998, p. 42.

## 9. Bone Adaptations

- The quality and quantity of bone structure depend on compression and traction stimuli exerted by the relevant muscles, as well as on torsional forces and gravity - stretching and compression [Torvinen, 2003].
- Vibration stimuli appear to be particularly suitable for triggering this osteogenetic effect.
- Basic animal studies show that intensive vibration training (20 minutes, 5 times per week) can achieve a 32% increase in bone density in the trabecular structures of the femur.
- Vibration training at 25 Hz almost completely stopped the loss of bone density in 70 postmenopausal women after one year of training, whereas bone density in the control group decreased by more than 2% [Rubin et al., 2004].
- Verschueren et al. [2004] even reported an increase in bone density after more intensive training at 35 Hz.

## 10. Adaptations of Vessels and Metabolic Processes

- Trainees report a perceived widening of blood vessels after vibration application.
- It is assumed that an increase in peripheral resistance leads to opening of capillary vessels in order to maintain energy supply and metabolic processes in the addressed muscles [Mester et al., 2006].
- Stewart et al. [2005] demonstrated significantly improved fluid flow - arterial and venous blood flow as well as lymph flow - after vibration training.

## 11. Model of Influencing Factors in Vibration Training

- The original model describes whole-body vibration training in a bipedal stance.
- Controlling parameters: static or dynamic execution, with or without additional load, training volume, training duration, pause structure, training position, frequency and amplitude.
- Systems affected: neuromotor system, muscles, bones, vessels, neuroendocrine system.
- Potential target areas: osteoporosis, back pain, posture and balance, neurological diseases, incontinence and other indications.
- Model source: Huber, 2006, p. 48.

## **12. Stochastic Resonance Vibration**

- Stochastic resonance vibration follows the physical law according to which signals are better understood by the body and cells when these signals - stimuli - are noisy.
- A characteristic bundle of vibration stimuli is transmitted into the body.
- A weak basic stimulus - the carrier signal - is amplified by so-called noise, that is, a chaotic additional signal.

## **13. Stochastic Resonance Vibration**

- The original slide compares two types of signal: a sinusoidal signal and a stochastic resonance signal.
- The sinusoidal signal is shown as a regular wave, while stochastic resonance is shown as an irregular, noisy vibration signal.

## **14. Nerve Cell Model**

- A nerve cell model is stimulated with sinusoidal signals (circles) and SR signals (triangles).
- While sinusoidal stimuli remain subthreshold, stochastic resonances trigger action potentials.

## **15. Stochastic Resonance (SR) Vibration**

- The continuous but unpredictable change in SR signals leads to constant, small disturbances of balance.
- Through repetition, the person learns to generate muscular activation patterns to compensate for these disturbances as successfully as possible.
- If vibration stimuli were always the same, for example sinusoidal vibrations, the responses of receptors in muscles, tendons and joints would also always be the same, and the information would become uninteresting for the brain.
- Furthermore, sinusoidal vibrations train only a very narrow activation pattern that hardly meets the variable demands of daily life.

## **16. Stochastic Resonance (SR) Vibration**

- SR vibration signals also interact with stochastic functional parameters of the nervous system, resulting in resonance-like behavior.
- The stochastic component of SR signals enters into a short-term quasi-resonance with the stochastic behavior of the nerve cell.
- In this way, unlike a linear signal, excitation thresholds of nerve cells can be exceeded more easily.
- Even low stimulus intensities are therefore perceived by the patient and generate neuromuscular activity.
- Liu et al. [2002] and Khadhiar [2003] showed that the perception of mechanical SR stimuli in older persons, stroke patients and neuropathy patients is increased by 16-34% compared with sinusoidal signals.

## **17. Nerve Cell Model**

- Repeat of the original diagram: a nerve cell model is stimulated with sinusoidal signals and SR signals.

- Sinusoidal stimuli remain subthreshold, whereas stochastic resonances trigger action potentials.

## **18. Stochastic Resonance (SR) Vibration**

- There are indications that peripheral stimulation can lead to biochemical reactions in supraspinal structures.
- Stimulation of muscle spindles, which show high sensitivity to SR stimuli, may release neurotrophic factors such as dopamine [Fallon et al., 2004].
- These substances primarily fulfil neuroprotective and neurorestorative functions, creating potential for better control and therapy of neurodegenerative disorders such as Parkinson's disease, multiple sclerosis or amyotrophic lateral sclerosis.

## **19. Stochastic Resonance (SR) Vibration**

- With regard to stimulating bone growth, SR vibration stimuli lead to approximately four times greater growth processes than low-frequency mechanical sinusoidal vibrations with the same carrier frequency.
- This is apparently due to stochastic functioning of calcium and other ion channels, which in turn play a central role in the formation of bone cells - osteoblasts. This is relevant to osteoporosis and fracture risk.

## **20. SRT - Zeptoring: Selected Mechanisms of Action**

- Stochastic resonance: variable, non-anticipatable stimulation; enables different sensor systems to be addressed; improves the perceptual ability of sensor systems; improves neural information selection and processing; improves bone strength.

## **21. SRT - Zeptoring: Selected Mechanisms of Action**

- Theta carrier frequency (3.5-7.5 Hz): stimulates the release of neuronal growth factors - neurotrophic factors - and promotes nerve cell growth; avoids kinesthetic illusions, meaning perceptual disturbances.

## **22. SRT - Zeptoring: Selected Mechanisms of Action**

- Alpha carrier frequency (7.5-12.5 Hz): training under time pressure; promotes rapid muscular response; optimizes rapid initiation of protective contractions in critical everyday situations, such as falls.

## **23. SRT - Zeptoring: Selected Mechanisms of Action**

- Multidimensional stimulation: multiple degrees of freedom provide stimuli in all three spatial dimensions, allowing ideal transfer of training effects to motor demands in daily life and sport.

## **24. SRT - Zeptoring: Selected Mechanisms of Action**

- Bypassing: involuntary, reflex-like activation of muscles; enables effective training stimuli even when voluntary activation is limited or absent.

## **25. Examples of Indications and Effects**

### **26. SRV Effects for Fall Prevention**

- Improved processing of sensory signals.
- Increased movement safety.
- Improved balance regulation and gait pattern.
- Increased voluntary activation potential.
- SRV: 30% better perception compared with sinusoidal vibration.
- High movement safety in everyday life: SRV score 1.3 on a 1-6 scale.

### **27. SRV Effects in Osteoporosis**

- Massive increase in bone metabolism and strength.
- Change in bone structure through multidimensional mechanical stimulation.
- Reflex triggering through neuromuscular stimulation.
- Increased movement safety and reduced risk of falls.
- Improved balance regulation.
- Improved gait pattern.
- Reduced fracture risk.
- SRV: 390% greater bone growth compared with sinusoidal vibration.

## **28. Caution**

- Spinal X-ray and bone-density measurement are prerequisites for SR therapy so that conditions such as osteoporotic fractures and malignant processes can be excluded. In such cases, SR therapy is contraindicated.
- No pain during SR therapy.
- No pain one hour or days as a reaction to SR therapy.
- First changes in bone density are detectable after 6-12 months.

## **29. SRV Effects in Chronic Pain**

- Clear pain reduction.
- Improved body perception.
- Generation of involuntary muscular activations.
- Optimization of unconscious interaction between different muscle groups.
- Prevention of secondary damage.
- High effectiveness in reducing chronic back pain: SRV score 1.7 on a 1-6 scale.

## **30. SRV Effects in Orthopedic Lesions**

- Improved balance regulation.
- Faster muscular activation.
- Improved processing of sensory signals.
- Increased voluntary activation potential.
- Increased movement safety.
- Improved gait pattern.
- SRV: 35% better medial/lateral balance compared with conservative therapy.
- SRV: 43% better anterior/posterior balance compared with conservative therapy.

## **31. Fractures**

- Regular X-ray checks are mandatory.
- Femoral neck fractures managed conservatively: partial weight-bearing is a prerequisite for SRT.
- Patellar fracture: SRT only in full knee extension or hyperextension; start 14 days after trauma or surgery.
- Fractures near the knee joint: special standing positions can unload the fracture areas.
- Lower-leg fractures managed surgically or conservatively: SRT possible when partial weight-bearing begins.
- Fractures in the foot area: SRT possible when partial weight-bearing begins.

### **32. Capsule, Ligament and Tendon Injuries of the Lower Extremities**

- Meniscus injuries: SRT can begin just a few days postoperatively at 10-15 degrees of knee flexion.
- Cruciate ligament injuries: SRT starts 6 weeks postoperatively at 10-15 degrees of knee flexion; no full extension.
- Ligament reconstruction of the ankle: SRT starts 3 weeks postoperatively.
- Operatively treated Achilles tendon rupture: SRT starts 6 weeks postoperatively.

### **33. Hip and Knee Joint Endoprostheses**

- Hip and knee joint endoprostheses.
- With cemented prostheses, SRT can begin 14 days postoperatively.
- With cementless prostheses, SRT can begin 6 weeks postoperatively.
- No pain during treatment.
- Regular X-ray checks.

### **34. Morbus Sudeck**

- Synonym: sympathetic reflex dystrophy.
- Local metabolic dysregulation with particular involvement of neuronal structures in the upper or lower extremities, triggered by various causes such as trauma or surgery.
- SRT can positively influence the disease by activating and increasing the release of neurotrophic substances and by reactivating neuronal networks.
- Depending on the condition of the affected extremity, SRT can be performed under partial or full weight-bearing.
- If the arms are affected, they can be supported on the standing surfaces.

### **35. SRV Effects in Neuropathy and Diabetes**

- Improved sensory perception.
- Improved reflex control.
- Improved balance.
- Restoration of walking ability.
- Fall prevention.
- SRV: 34% better perception compared with conservative therapy.

### **36. SRV Effects After Stroke and Traumatic Brain Injury in Paresis**

- Increased voluntary muscular activation potential.
- Improved sensory perception.
- Generation of involuntary muscular activations.
- Restoration and improvement of walking ability and balance.
- Promotion of reorganization of neural cell networks.
- Neuroprotection.
- SRV: 40% better activation ability compared with conservative therapy.

### **37. SRV Effects in MS and ALS**

- Improved balance.
- Improved reflex control.

- Improved walking ability.
- Fall prevention.
- Neuroprotection - protection of the nervous system.
- Improved functionality of neural cell networks.
- SRV: 27% better balance compared with conservative therapy.

### **38. SRV Effects in Parkinson's Disease**

- Reduction of rigidity and tremor.
- Massive improvement in movement safety and quality of life.
- Improvement of gait and balance.
- Reduction of bradykinesia/akinesia.
- SRV: 24% reduced rigidity compared with conservative therapy.
- SRV: 25% reduced tremor compared with conservative therapy.

### **39. Contraindications: Orthopedic Aspects**

- Acute inflammation.
- Recent herniated disc.
- Recent fracture.
- Recently implanted endoprotheses.
- Severely advanced osteoporosis with acute fracture risk.

### **40. Contraindications: Neurological and Psychiatric Aspects**

- Deep brain stimulation in Parkinson's disease.
- Schizophrenia.
- Epilepsy.
- Perceptual disturbances.
- Dizziness.

### **41. Contraindications: Cardiology Aspects**

- Pacemaker.
- Severe hypertension or hypotension.
- Aneurysm - arterial vessel dilatation.
- Severe cardiac arrhythmias.

### **42. Contraindications: Other Aspects**

- Nausea and malaise.
- Tumors/metastases.
- Pregnancy.

### **43. SR Vibration: In-House Indications**

- Osteoporosis.
- Spinal complaints with muscular imbalance.

- Fractures, provided full weight-bearing is possible and callus formation is present: patella, fractures in the knee-joint area, lower-leg fractures and fractures in the foot area.
- Capsule-ligament injuries of the knee joint: 6 weeks postoperatively.
- Capsule-ligament injuries of the ankle: 3 weeks postoperatively.
- Meniscus injuries: 3 weeks postoperatively.
- Condition after Achilles tendon rupture: 6 weeks postoperatively.
- Arthrosis of the lower extremities.
- Morbus Sudeck.
- Incomplete spinal cord lesions.
- Ataxia and balance disorders, including after traumatic brain injury.

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