Whole body vibration training & motor control

Dr. Ramona Ritzmann
I What is Whole Body Vibration (WBV)?

II How does WBV affect the nervous system?

III Functional implication?
What is Whole Body Vibration (WBV)?
I – What is Whole Body Vibration?

WBV

Performance

Structural components

Flexibility

Muscle

Blottner et al. 2006, Buehring et al. 2011

Strength

Bone

Belavy et al. 2010, Armbrecht et al. 2010

Force

Di Giminiani et al. 2010

Ness and Field-Fote 2009, Semler et al. 2007, Haas et al. 2007

Blottner et al. 2006, Buehring et al. 2011

Mahieu et al. 2006, Ruiter et al. 2003


Sports & Therapy

Motor control
I – What is Whole Body Vibration?

**Biomechanics**

Transmission of mechanical oscillation
(Pel et al. 2009, Pollock et al 2010)

High acceleration (up to 9g) causes high forces
(Rittweger 2010)

Dampening by the muscle-tendon complex
(Cochrane et al. 2009, Abercromby et al 2007)
I – What is Whole Body Vibration?

**Neuromuscular**

- Dorsiflexion moment
- Muscle stretch
  - (Cochrane et al. 2009)
- Stretch Reflex
  - (Gollhofer & Rapp 1993)

**Relevant factors**

- Frequency
- Amplitude
- Muscle group (extensor / flexor)
- Proximity to the vibration device
I – What is Whole Body Vibration?
I – What is Whole Body Vibration?

Sensory
Sensory Perception
Receptors - Afference

Motor
Force control
Efference - Muscles
I – What is Whole Body Vibration?

Nervous System

Movement
How does WBV affect the nervous system (NS)?
II – WBV and the NS

II Supraspinal level

III Receptors

Muscle spindle

I Spinal level

(Modified Squire et al. 2002)

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II – WBV and the NS

II Supraspinal level

III Receptors

Muscle spindle

Spinal level

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II – WBV and the NS – spinal level

Peripheral nerve stimulation

Facilitation
Inhibition

H-reflex

(Modified Squire et al. 2002)

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II – WBV and the NS – spinal level

Peripheral nerve stimulation
Facilitation
Inhibition

H-reflex

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II – WBV and the NS – supraspinal level

Transcranial magnetic stimulation

(Modified Squire et al. 2002)
II – WBV and the NS – supraspinal level

WBV Training

Mileva et al. 2008

Double pulse TMS (ICI, ICF)
Intracortical processes
Cortical silent period prolonged

(Modified Squire et al. 2002)

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n = 44 (16f/ 28m, age 26 ±3 years)

Protocol 1
Corticospinal excitability

Protocol 2
Spinal excitability

WBV
1 min
2 mm/ 30 Hz

$t_0$ & $t_1$
pre

$t_2$
post

$t_3$
2’

$t_4$
4’

$t_5$
10’

Krause et al. 2016 in revision
II – WBV and the NS

1

MEP

$1 \text{ min } WBV$

$t_0 \quad t_1 \quad t_2 \quad t_3 \quad t_4 \quad t_5$

$(2') \quad (4') \quad (10')$

$0.5 \text{ mV } | 10 \text{ ms}$

2

H-reflex

$1 \text{ min } WBV$

$t_0 \quad t_1 \quad t_2 \quad t_3 \quad t_4 \quad t_5$

$(2') \quad (4') \quad (10')$

$0.4 \text{ mV } | 10 \text{ ms}$
**SOL**

Mean values up to +22% (P<0.05)

Mean values up to -21% (P<0.05)

**Time course of corticospinal excitability increased**

**Time course of spinal excitability decreased**

**PERSISTENT EFFECTS**

For a minimum of 10 min after WBV
WBV Training

Supraspinal level

Supraspinal level

Krause et al. 2016 in revision, Mileva et al. 2008

WBV Training

Spinal level

Spinal level

II – WBV and the NS – Receptors

Microneurography

Reduction in muscle spindle sensitivity

Roll et al. (1989), Hayward et al. (1986), Ribot-Ciscar et al. (1998)
Functional implication?
Neurorehabilitation
Patients suffering from spasticity

1. Reduction of spasticity
2. Improved motor control

Clinical setting
Breast cancer patients
during chemotherapy and radiation
In-patient stay

Increased voluntary muscle control

Healthy subjects and athletes

1. Flexibility
2. Strength and Power
Neurorehabilitation

*Patients suffering from spasticity*

1. Reduction of spasticity
2. Improved motor control

Clinical setting

*In-patient stay*

*Breast cancer patients during chemotherapy and radiation*

Increased voluntary muscle control

Healthy subjects and athletes

1. Flexibility
2. Strength and Power
Spasticity

- Exaggerated reflex activity
- Strong Co-contraction
  Coactivation of antagonistic muscles
- Joint rigidity
  Impaired movement control
III – Functional implication – Neurorehabilitation

- **Spinal cord injury**
  Ness & Field-Fote 2009

- **Chronic stroke**
  Pang et al. 2013; Tankisheva et al. 2014

- **Multiple sclerosis**
  Schyns et al. 2009

- **Cerebral palsy**
  Ahlborg et al. 2006; Katusic et al. 2013

**TABLE 1**

<table>
<thead>
<tr>
<th>Grade</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>no increase in muscle tone</td>
</tr>
<tr>
<td>1</td>
<td>slight increase in muscle tone, manifested by a catch, followed by minimal resistance throughout the remainder (less than half) of the ROM</td>
</tr>
<tr>
<td>2</td>
<td>more marked increase in muscle tone through most of the ROM, but affected part(s) easily moved</td>
</tr>
<tr>
<td>3</td>
<td>considerable increase in muscle tone, passive movement difficult</td>
</tr>
<tr>
<td>4</td>
<td>affected part(s) rigid in flexion or extension</td>
</tr>
</tbody>
</table>

**Gross motor function (GMFM)**

Ahlborg et al. 2006; Katusic et al. 2010, 2013

**Gait parameters**

(fast, dynamic ankle range of motion) ↑

Dickin et al. 2013; Lee & Chon 2013

**Balance** ↑

El-Shamy 2013

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**WBV reduces spasticity**

**WBV improves functional skills**
### Protocol 1 – Stretch Reflex
- Stretch reflex of SOL (amplitude)

### Protocol 2 – Maximal voluntary contraction (MVC)
- Electromyographic (EMG) activity
- Goniometry

### Protocol 3 – Active Range of Motion
- Co-activation (agonist/antagonist)
- Goniometry

Krause et al. 2016 submitted
1. Stretch Reflex amplitudes

2. EMG during MVC

Krause et al. 2016 submitted
3. Active range of motion

Co-activation = \( \frac{\text{agonist}}{\text{antagonist}} \)

Krause et al. 2016 submitted
### Protocol 1
- Stretch reflex amplitude is reduced

### Protocol 2
- Maximal voluntary contraction is elevated

### Protocol 3
- Active range of motion is increased
- Co-activation is improved

Subjects suffering from spasticity profit from WBV on a neuromuscular basis
III – Functional implication – Neurorehabilitation

II Supraspinal level

III Receptors

Muscle spindle

I Spinal level

(Modified Squire et al. 2002)

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Neurorehabilitation
*Patients suffering from spasticity*

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Neurorehabilitation

Patients suffering from spasticity

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Clinical setting

In-patient stay

Breast cancer patients
during chemotherapy and radiation

Increased voluntary muscle control
In-patient stay
Breast cancer patients - Oncology
Chemotherapy medication Taxane

- Negative effects for the sensory and motor system
- Polyneuropathy: structural and functional changes in the NS

Kneis et al. (in prep.)
III – Functional implication – Clinical setting

6 Weeks WBV vs. standard physiotherapy

Improved voluntary muscle control

Kneis et al. (in prep.)
III – Functional implication – Clinical setting

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Neurorehabilitation

*Patients suffering from spasticity*

1. Reduction of spasticity
2. Improved motor control

Clinical setting

*In-patient stay* 
*Breast cancer patients during chemotherapy and radiation*

Increased voluntary muscle control

Healthy subjects and athletes

1. Flexibility
2. Strength and Power
III – Functional implication – Healthy subjects

Microneurography

-78%

Reduction in muscle spindle sensitivity

Reduced muscular resistance when stretched

Increased flexibility
III – Functional implication – Healthy subjects

Microneurography

Reduction in muscle spindle sensitivity

Reduced resistance when stretched

Increased flexibility

III – Functional implication – Healthy subjects

1. Acute improvements in countermovement jumps in field hockey players after WBV (26Hz; Cochrane and Stannard 2005)
   - neural potentiation of the stretch reflex loop

2. No improvement in countermovement jumps after long-term training periods
   - of 9 weeks (Kvorning et al. 2006)
   - or 11 weeks (30Hz; de Ruiter et al. 2003)

3. Strength increase after whole body vibration compared with resistance training (35-40Hz; Delecluse et al. 2003)
   - young elite skiers (Mahieu et al. 2006)

4. No improvements in maximal isometric voluntary contraction in young healthy subjects
   - neither after short term (de Ruiter et al. 2003)
   - nor after long-term WBV training (Delecluse et al. 2005)
adaptation to WBV-Training
Nervous system

↑ Supraspinal excitability
↓ Spinal excitability
↓ Receptor sensitivity
Nervous system

↑ Supraspinal excitability

↓ Spinal excitability

↓ Receptor sensitivity
**Nervous system**

- **↑ Supraspinal excitability**
- **↓ Spinal excitability**
- **↓ Receptor sensitivity**

**Functional adaptation**

**Neurorehabilitation**
- ✔ Reduction of spasticity
- ✔ Reduced Co-contraction
- ✔ Improved motor control
  (Posture and locomotion)

**Clinical setting**
- ✔ Improved sensorimotor control
- ✔ Increase in muscle function

**Sports and performance**
- ✔ Improved flexibility
- 🔍 Strength and power
Welcome to Freiburg

THANK YOU


Mileva et al. 2009

Increased TA and SOL SICI and decreased TA ICF in response to paired-pulse TMS during WBV indicate vibration-induced alteration of the intracortical processes as well.

Two interstimulus intervals (ISIs) between the conditioning and the testing stimuli were employed in order to study the effects of WBV on short-interval intracortical inhibition (SICI, ISI=3 ms) and intracortical facilitation (ICF, ISI=13 ms).

**short-interval intracortical inhibition**

**Paired pulse TMS regime (ISI = 3 ms)**

**Tibialis anterior (TA)**

**MEP amplitude**

normalized to single pulse TMS

<table>
<thead>
<tr>
<th></th>
<th>pre-WBV</th>
<th>WBV (+/- vib)</th>
<th>post-WBV</th>
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<tbody>
<tr>
<td><strong>MEP amplitude</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.2</td>
<td>0.9</td>
<td>0.6</td>
<td>0.4</td>
</tr>
<tr>
<td>0.8</td>
<td>0.6</td>
<td>0.4</td>
<td>0.2</td>
</tr>
<tr>
<td>0.4</td>
<td>0.2</td>
<td>0.1</td>
<td>0.0</td>
</tr>
</tbody>
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**intracortical facilitation** (ICF, ISI=13 ms).

**Paired pulse TMS regime (ISI = 13 ms)**

**Tibialis anterior (TA)**

**MEP amplitude**

normalized to single pulse TMS

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<tbody>
<tr>
<td><strong>MEP amplitude</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2.0</td>
<td>1.5</td>
<td>1.0</td>
<td>0.5</td>
</tr>
<tr>
<td>1.5</td>
<td>1.0</td>
<td>0.5</td>
<td>0.2</td>
</tr>
<tr>
<td>1.0</td>
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