Effects
of stochastic resonance therapy
on postural control in the
elderly population (Pilot Study)

Proposal

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1 Introduction

1.1 Objective

This thesis is intended to examine the effect of whole body vibration with stochastic resonance (SR-WBV) on postural control in the elderly population.

1.2 Relevance

Life expectancy in industrialized countries has doubled over the last hundred years resulting in an increase in the number of elderly in our society. A logical consequence for the future is that medicine, physiotherapy and sports science will be required to deal more with older people and their health problems.

Aging processes are associated with physical and cognitive changes (Kaeding, 2009). Amongst other things, these changes manifest themselves in physical function loss. In any situation, the human body must always have the ability to maintain a vertical posture against gravitational force.

In the literature, postural control is described as having two main functions. Firstly, to build up posture against gravity and ensure that balance is maintained. Secondly, to fix the orientation and position of the body segments that serve as a reference frame for perception and action with respect to the external world. This means that when in the process of standing, sitting, or walking a person must be able to adequately respond to destabilizing forces in order to maintain balance. (Howe, Rochester, Jackson, Banks, & Blair, 2007; Woollacott & Shumway-Cook, 2002).

Loss of this ability in old age increases the risk of falls, limits activities of daily living and negatively affects quality of life. In addition, there is a risk for progression of degenerative diseases (osteoarthritis, heart, circulation, etc.) caused by decreased physical activity in everyday life (Bauer & Sieber, 2008; Kaeding, 2009; Muhlberg & Sieber, 2004; van den Berg et al., 2008).

Falls are extremely common in old age: about 30% of people over 65 years of age fall at least once a year, almost half of them twice or more, usually with dire consequences (Tinetti, Speechley, & Ginter, 1988).

The annual fall rate increases to 40 - 50% for people over 80 years of age and to 50% for those older than 90 years (Rubinstein, Josephson, & Robbins, 1994). For institutionalized elderly the fall ratio is even higher, ranging between 0.5-3.7 (medium 1.6) falls per bed per year for those in hospital and 0.2-3.6 (average 1.4) for residents of nursing homes (Rubinstein et al., 1994).

In five percent of the fallen, it comes to fractures while further ten to fifteen percent carry other serious injury there from (Granacher, 2004). According to international data, there is an annual mortality rate of 22-24% following a hip fracture (Lu-Yao, Baron, Barrett, & Fisher, 1994; Pfeifer, Wittenberg, Würtz, & Minne, 2001).
Exercise therapy plays an important role in health promotion, preservation of physical function and in preventing loss of independence among the elderly (Snow, 1999). They work beside an improvement in postural control, a positive effect on metabolic and cardiovascular disorders, reducing falls, osteoporosis, colon cancer, breast cancer, depression, anxiety, and the general well-being.

Appropriate exercise therapy programs for the elderly include elements of strength, endurance, balance and mobility (Bertram & Laube, 2008; Granacher, 2004; Granacher, Gollhofer, & Strass, 2006; Hakkinen & Hakkinen, 1995; Hakkinen et al., 1998; Hakkinen, Kraemer, Newton, & Alen, 2001; Hakkinen, Pakarinen et al., 2001; Swanenburg, de Bruin, Favero, Uebelhart, & Mulder, 2008; Taube, Gruber, & Golliofer, 2008; Williams, Burke, MCClenaghan, & Hirth, 1997).

ProFaNE (Prevention of Falls Network Europe), a thematic network funded by the European Union, has highlighted in a systematic review the conditions for successful interventions in the field of multifactorial fall prevention. The result showed that in addition to the strength training component, successful and effective fall prevention programs should also include challenging balance exercises and twice weekly training. These results are based on 44 randomized trials with a total of 9'603 participants, which makes them rugged and broadly generalizable (Sherrington et al., 2008).

Sensory disorders are a widespread feature in old age. Just as often, deficits occur in muscle activation capability. These can be independent of specific diseases which cause afferents and/or efferent problems resulting in movement uncertainty, especially for complex movements such as those used for gait or postural control (Haas, 2006, 2008b).

A stimulus occurring with a mechanical vibration setting may be associated with the development of muscular reflex responses. Depending on the type, location, duration, etc. there is the possibility of stimulus application restoring functional movement patterns.

From numerous studies it is known that harmonic vibration stimuli can lead to an increase in short-term neural and muscular activity, after a certain time (medium term) would have a monotonic determine habituation and an accompanying reduction in neuronal activity (Haas & Schmidtbleicher, 2005).

Several neuroscientific studies have shown that biopositive adjustment processes can be achieved primarily through randomized or stochastic peripheral stimulus (Haas & Schmidtbleicher, 2005).

The Zeptor med® has the condition for the stochastic peripheral stimuli. In reports relating to the improvement of postural control in multiple sclerosis and Parkinson’s disease the use of stochastic peripheral stimuli with this device has been found to be reasonably successful. The use of a stimulus with stochastic resonance pattern provided with a harmonic signal has the advantage that only a small intensity mechanical stimulus is needed to produce the corresponding sensory and neuromuscular activity states. Due to the very small movements of the vibrating plate on a Zeptor med® can be used without major risks early in the reconditioning therapy of older persons and thereby offer a challenging form of balance exercises.
There is preliminary evidence to indicate that balance can be trained in the elderly using vibration therapy (Costa et al., 2007; Delecluse et al., 2004; Gravelle et al., 2002; Hijmans, Geertzen, Schokker, & Postema, 2007; Kawanabe et al., 2007). The impact of this therapy on the body is low according to indicators of physical stress (blood pressure, heart rate, lactate, O2 uptake) (Herren & Radlinger, 2008; Rittweger, Beller, & Felsenberg, 2000; Rittweger et al., 2002).

Permanent changes in health care increasingly require evidence of sustainability of training or treatment methods. It stands to reason that these changes must be accompanied by an increase in physical performance with an optimization of the training quality. Once implemented, the equivalent or better results are achieved in the same amount of training time or less.

Here, this pilot study attempts to recognize conducted or to explain a meaningful use of vibration training. Both forms of vibration (sinusoidal and stochastic) in addition to a meaning to increase muscle strength (Bogaerts et al., 2007; Delecluse, Roelants, & Verschueren, 2003; Jordan, Norris, Smith, & Herzog, 2005) (Roelants, Delecluse, Goris, & Verschueren, 2004; Roelants, Delecluse, & Verschueren, 2004; Sarabon, Haas, Wirth, & Schmidtbleicher, 2002) also improve postural control on the balance in Parkinson's disease (Haas, 2008a, 2008b; Haas & Schmidtbleicher, 2002; Schmidtbleicher, Turbanski, & Haas, 2004), multiple sclerosis (Schuhfried, Mittermaier, Jovanovic, Pieber, & Paternostro-Sluga, 2005), stroke patients (A. A. Priplata et al., 2006) and a reduction of osteoporosis (Tanaka, Alam, & Turner, 2002).

In this dissertation, the "Zeptor med ®" system of "Swiss Frei AG" company is used.

The use of SR-WBV in the elderly population has shown to be a simple and effective treatment in the areas of balance and mobility. It would be very desirable to investigate these factors further in order to provide evidence for the delivery of sustainability of training methods.

Thus, the goal of this pilot study is to test whether in the elderly population there are acute long-term improvements in both the static and dynamic balance, reaction time and mobility with the use of whole body vibration therapy with stochastic resonance.

Precision of the research project is made in the following chapters. This study is registered in the NIH database (ClinicalTrials.gov) with the ID NCT01045746.
Problems

There is a lack of published data using SR-WBV in the elderly on their effectiveness for postural control.

There are numerous studies and results of the use of SR-WBV in Parkinson's disease, multiple sclerosis, orthopedic and spinal cord injury. These investigation results have shown that the SR-WBV has a positive effect on postural control. Are these results transferable to the elderly?

Furthermore, the literature shows that SR-WBV and partial-body vibration, via electrode application or the use of vibrating insoles, in elderly people can improve postural control. Are these results transferable to SR-WBV?

There is a general lack of scientifically based guidelines for weight bearing normative (frequency, amplitude, duration) series. The methodological design of an effective WBV is therefore based mostly on experience. Transfer to the subjects, this means: What weight bearing normative must be chosen so that SR-WBV may have positive effects on postural control?
2 Background

Aging is a biological progression and that affects every living being. Aging processes are predetermined and cannot be undone. The question of when the aging process begins, whether directly after birth or in the middle of twenty is not clear as opinions are divided (van den Berg et al., 2008).

According to the WHO definition someone who had reached 65 years of age is considered old people (WHO).

Change in Age
Looking at the aging process, it can be stated that it is associated with many physiological structural changes. These changes can be found in the:
1. sense organs (Hüter-Becker et al., 2005; van den Berg et al., 2008):
   • eyes (decreased prescription values)
   • ears (decreased auditory intensity)
   • exteroception (decreased sensory sensation)
   • proprioception (or loss)
2. connective tissue (Hüter-Becker et al., 2005; van den Berg et al., 2008):
   • skin (loss of elasticity)
   • bone (loss of bone density)
   • muscle (increased stiffness)
3. muscle tissue (loss of muscle strength and muscle mass ==) for sarcopenia, frailty) (Hüter-Becker et al., 2005; van den Berg et al., 2008)
4. nerve function (Hüter-Becker et al., 2005; van den Berg et al., 2008).

Due to these various changes in age, there will be reduced adaptation to change with intrinsic and extrinsic factors.

2.1 Exercise therapy in the aged

Aging in the neuromuscular system affects not only the power but also the reflex behavior. In everyday life, e.g. walking, it makes itself apparent by a reduced capacity.

Strength and reflex loss can be positively influenced by training. In particular, the effect of power and sensorimotor training can cause a delayed degradation of the neuromuscular system.

2.1.1 Sensorimotor training

The literature shows that sensorimotor training not only has an influence on the reflexes, but also on the strength behavior. It has been shown that in addition to an improvement in maximal and explosive strength (Gollhofer, 2003; Granacher, 2004; Gruber, Gollhofer, Alt, Lohrer, & Bruhn, 2003), reflex activity (Granacher, 2004; Granacher et al., 2006), ability to balance (Granacher, 2004) and walking speed (Granacher, 2004) significantly improved.
2.1.2 Strength training

Numerous studies on strength training in old age has shown changes in maximum muscle strength and an improvement in quickness which resulted from hypertrophy and adaptation processes (Gruber et al., 2007; Hakkinen, Alen, Kallinen, Newton, & Kraemer, 2000; Hakkinen & Hakkinen, 1995; Hakkinen, Pakarinen et al., 2001). An improvement in the balance capability and a reduction of falls were also demonstrated.

2.1.3 SR-WBV

There are few scientific studies on the effects of SRT in humans. Of those, the results have shown that muscle reflexes can be induced by externally generated stimuli (Haas, 2008a; Haas, Turbanski, & Schmidtleicher, 2007).

Several research groups have studied the effect of SRT and partial-body vibration with SR.

Two research groups have dealt with SRT. The research group at the Johann-Wolfgang-Goethe University led by Prof. Schmidtleicher and the group at the Berne University of Applied Sciences led by Dr. Radlinger.


The research group at the Bern University of Applied Sciences found that during and after SR application in stroke patients there were lower demands on the body as was indicated by blood pressure, heart rate, lactate, and subjective stress ratings (Herren & Radlinger, 2008). Other research involving postpartum healthy female volunteers, showed a more pronounced acute higher activation of the pelvic floor muscles during the SR-WBV (on the Zeptor med ®) compared to the sinusoidal vibration (on the Galileo ®) (Lauper, Kuhn, Gerber, Luginbühl, & Radlinger, 2008).

In addition, various working groups have noted improved postural control after SR with partial body vibration Collins et al. (Boston) (Gravelle et al., 2002; A. Priplata et al., 2002; A. A. Priplata, Niemi, Harry, Lipsitz, & Collins, 2003) and Ross (Virginia) (Ross, Arnold, Blackburn, Brown, & Guskiewicz, 2007; Ross & Guskiewicz, 2006).
2.2 What we know about SR-WBV:

- various research groups
- two research groups with SR-WBV ==> Frankfurt and Bern
- other research groups with electrodes or vibrating insoles
- good potential in various diseases with SR-WBV
- good potential use of electrical SR in elderly people for postural control and sensitivity
- SR-WBV improved quickness ability
- many stress stimuli in a few seconds and small strain parameters (heart rate, RR, lactate)
- economical, requires little space

2.3 What we do not know about SR-WBV:

- There is a RCT study on electrical vibration and postural control (static equilibrium) in elderly (AA Priplata et al., 2003).
- There are no RCT studies using SR-WBV and postural control in older people.
- There are no studies using WBV and the static balance in older people.
- There are no studies using WBV and the dynamic balance in older people.
- There are no studies of SR’s effects on the latency period prior to a glitch in the elderly.
- EMG recordings are not yet sufficiently available: - Postural condition: trunk muscles, leg muscles
  In elderly people, we see an increased co-contraction of agonists and antagonists.
  There are no investigations into whether and how far co-contraction can influence them.
- There are no studies on SR-effects on mobility in ADL.
- There are no studies on SR and the effects on the explosive power capacity in the elderly.
- There are no studies of SR’s effects on the dynamic muscular strength in everyday life among the elderly.
- There are no studies about SR’s effects on locomotion in older people.
- Many studies have been conducted with small samples.
- There is general lack of valid strain parameters (Normativa).
- Long-term effects are missing.
- Contraindications are not defined.
2.4 Objectives, questions and hypotheses

Investigation into whether SR-WBV is a positive influence on:
- the static balance
- the dynamic balance
- on the reaction time
- mobility in everyday life in older people.

Items to be analyzed and interpreted:

1. the static balance:
   - means of a clinical testing: Functional Reach Test (Duncan, Weiner, Chandler, & Studenski, 1990)
   - using biomechanical testing ==> 2x 20 seconds Semi- Tandem- stand (Ritchie, Trost, Brown, & Armit, 2005) by means of a Kistler® - force plate (Kistler Instrumente AG, Winterthur, Switzerland).

2. the dynamic balance:
   - using Dual Task Costs (Beauchet et al., 2009) and an acceleration sensor, DynaPort® Minimod (McRoberts BV, The Hague, Netherlands).
   - using Expanded Timed Up and Go test (Botolfsen, Helbostad, Moe-Nilssen, & Wall, 2008; Wall, Bell, Campbell, & Davis, 2000).
   - using biomechanical testing ==> after an activity (Karinkanta, Heinonen, Sievanen, Uusi-Rasi, & Kannus, 2005), (standardization) transferring from a chair to standing position, without armrests, as soon as possible and keep their balance once again as calmly as possible, stand 20 seconds on a Kistler® - force plate and an acceleration sensor (DynaPort® Minimod?).
   - If using questionnaires Efficacy Scale-International Version (FES-I) (Dias et al., 2006)

3. reaction time:
   - using a hand –held reaction timer and a light at the stimulus and depression of a switch by finger and the foot as the response (Lord, Menz, & Tiedemann, 2003)

4. mobility:
   - using the StepWatch™ Activity Monitor (SAM) (Cyma Corporation, Sättler, USA) (pedometer) (Coleman, Smith, Boone, Joseph, & del Aguila, 1999)
   - If using questionnaires EQ-5D (Rabin & de Charro, 2001)
From this I can derive the central question, the subqueries and working hypotheses.

**Does SR-WBV has an influence on postural control in elderly people?**

Subqueries
1. Does SR-WBV has an influence on balance?
   1.1 Does SR-WBV has an acute exercise control over the static balance?
   1.2 Does SR-WBV has a long-term influence on the static balance?
   1.3 Does SR-WBV has an acute impact on the dynamic balance?
   1.4 Does SR-WBV has a long-term influence on the dynamic balance?
2. Does SR-WBV has an influence on the reaction time?
3. Does SR-WBV has a long-term impact on mobility?

The general hypothesis regarding the central question is:

**H0:** SR-WBV vibration shows no effect on postural control in older people.

Hypotheses (H0) to the subqueries:

**H0-1:** SR-WBV shows no acute effect on the static balance.

**H0-2:** SR-WBV shows no long-term influence on the static balance.

**H0-3:** SR-WBV shows no acute effect on the dynamic balance.

**H0-4:** SR-WBV shows no long-term influence on the dynamic balance.

**H0-5:** SR-WBV shows no effect on the reaction time.

**H0-6:** SR-WBV shows no effect on mobility.
3 Development

- To data create a systematic review.
- Methodological work: Criterion validity for transfer-seat to stand
- A study with acute effects on the static and dynamic balance and reaction time should be disciped.
- A cross-over trial (RCT) is made after 4 weeks with a change of the interventions in the two groups (3x per week, 48 hrs break)
- A follow up to this study

3.1 Timing schedule, patient samples

Heat one with 15 subjects
January 2010  Preparation / Practice
January 2010  Measurement day 1: 11.01.2010 – 16.01.2010
January 2010  4 weeks, 12 intervention days (group 1 and group 2)
                  18.01-14.02.2010
February 2010 Measurement day 2: 15.02 – 19.02.2010
February 2010  4 weeks, 12 intervention days (group 1 and group 2)
                  22.02 – 21.03.2010
March 2010 Measurement days 3: 22.03 – 27.03.2010

Heat two 5 subjects
March 2010  4 weeks, 12 intervention days (group 1 and group 2)
                  xx.xx – xx.xx.2010
April 2010 Measurement day 2: xx.xx – xx.xx.2010
April 2010  4 weeks, 12 intervention days (group 1 and group 2)
                  22.02 – 21.03.2010
3.2 Acute Effects

Measurement days 1, measurement 1: Randomization: balance, reaction time, Mobility
Measuring days 1, Intervention:
  Randomization: rest or SR-WBV
  • 2 independent groups
  • Blinded Tester
Measurement days 1, measurement 2: randomization, balance, reaction time

<table>
<thead>
<tr>
<th>Measurements before (randomized order)</th>
<th>Intervention (randomized order, Tester blinded)</th>
<th>Measurements after (randomized order)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Questionnaire</td>
<td>Ruhe 9 min</td>
<td>Balance</td>
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<tr>
<td>Balance</td>
<td>oder</td>
<td>Response</td>
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<tr>
<td>Response</td>
<td>SRT 5 Serien à 60 s with 60 s rest</td>
<td></td>
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<tr>
<td>Mobility</td>
<td>break 2 min</td>
<td></td>
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</tbody>
</table>

Tab. 1 Organizational process measurement day 1.
3.3 Long-term effects (longitudinal: RCT)

**Intervention 1: 4 weeks (longitudinal study: RCT)**
- A randomized blind crossover study in two independent groups, in two intervention and two periods:
  - Group 1: Intervention 1 3x week SR-WBV (5 series, 1 Hz, noise 1, 60 "exercise duration, 60" Series rest)
  - Group 2: Intervention 2 3x week SR-WBV (5 series, 5 Hz, noise 4, 60 "exercise duration, 60" series rest)
- After wk 4 to repeat the measurements in Group 1 or Group 2 according to Table 2.

<table>
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<tr>
<th>Measurements (randomized order)</th>
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<tbody>
<tr>
<td>Questionnaire</td>
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<tr>
<td>Balance</td>
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<tr>
<td>Response</td>
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<tr>
<td>Mobility</td>
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</tbody>
</table>

Tab.2 Organizational process measurement day 2.

**Intervention 2: 4 weeks (longitudinal study: RCT)**
- Change of the intervention between the independent groups:
  - Group 1: Intervention 2 3x week SR-WBV (5 series, 5 Hz, Noise 4, 60 "exercise duration, 60" series rest)
  - Group 2: Intervention 1 3x week SR-WBV (5 series, 1 Hz, noise 1, 60 "exercise duration, 60" series rest)
- After wk 4 to repeat the measurements according to Table 3.
### Measurements (randomized order)

| Questionnaire | Balance | Response | Mobility |

Tab. 3 Organizational process measurement day 3.
Follow Up longitudinal study: RCT.

After 4 months, the measurements are repeated according to Table 4.

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<tr>
<th>Follow Up</th>
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<tr>
<td>Questionnaire</td>
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<td>Balance</td>
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<td>Response</td>
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<tr>
<td>Mobility</td>
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Tab. 4 Organizational process measurement day Follow Up.
4 Analysis
The results are published in peer review journals.

1) A systematic review + Meta-analysis: Effects of WBV on postural control
2) Acute effects of SR-WBV on postural control in the elderly population
3) Effects of SR-WBV on postural control in the elderly population after four week training
4) Effects of SR-WBV on postural control in the elderly population after eight week training
5) Effects of SR-WBV on postural control in the elderly population- a Follow up
5 Literature


presented at the European College of Sport Science, Salzburg.


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