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Pelvic Floor Stimulation: What Are The Good Vibrations?

Monika Lauper,[1] Annette Kuhn,[2]* Regina Gerber,[3] Helena Luginbühl,[4] and Lorenz Radlinger[4]
[1] *Physiotherapy Research, University Hospital Bern, Bern, Switzerland*
[2] *Women's Hospital, University Hospital Bern, Bern, Switzerland*
[3] *Physiotherapy Women's Hospital, University Hospital Bern, Bern, Switzerland*
[4] *Bern University of Applied Sciences, Health, Bern, Switzerland*

Objective: The aim of this study was to determine if two different whole body vibration, sinusoidal vibration (SV) and stochastic resonance vibration (SRV), using various intensities lead to a reactive activation of pelvic floor muscles. **Study Design:** We compared the pelvic floor muscle response of a healthy control group with that of a post partum group with weakened pelvic floor contraction. Activation effects of stochastic resonance vibration and sinusoidal vibration with six increasing vibration intensities were investigated using pelvic floor EMG and compared to activity during rest and maximum voluntary contraction. **Results:** Both whole body vibration systems were able to activate pelvic floor muscles significantly depending on vibration intensity. Generally, the SRV achieved a significantly higher activation than maximum voluntary contraction, especially in women post partum and using a frequency of 6–12 Hz. **Conclusion:** SRV, compared to SV, leads to higher pelvic floor muscle activation in subjects with weakened pelvic floor muscles and achieves higher pelvic floor activation than maximum voluntary contraction alone. *Neurourol. Urodynam. 28:405–410, 2009.* © 2009 Wiley-Liss, Inc.

Key words: correlation; prospective; sinusoidal; stochastic; whole body vibration

INTRODUCTION

Urinary incontinence is a common problem in women with a prevalence of approximately 20−30%, depending on age.[1,2]

Vaginal delivery may initiate damage to the continence mechanism by direct injury to the pelvic floor muscles, damage to their sensory and motor innervation, or both. Additional denervation may occur with aging, resulting in a functional disability many years after the initial trauma.[3]

Vaginal delivery causes partial denervation of the pelvic floor muscles[4] in most women having their first baby[5] with consequent re-innervation. Pelvic muscle strength is impaired shortly after vaginal birth,[6] but for most women it returns after cessation of breast feeding.[7] For a few, the impairment is severe and may be associated with urinary or fecal incontinence.[7]

For some women it is likely to be the first step leading to stress incontinence and other pelvic floor disorders such as prolapse and/or sexual dysfunction.[8]

There is a growing body of evidence that multiparity, forceps delivery, prolonged duration of the second stage of labour, third degree perineal tear and high birth weight >4,000 g are important factors leading to pudendal nerve damage.[9–11]

Pelvic muscle strength and power are significantly reduced after vaginal birth but not in women after caesarean section.[9,12]

It is still an open question how to address pelvic floor muscle reactivity and proprioception after delivery; pelvic floor muscle proprioception is poor because pelvic floor muscles and sphincters lack several sensory input mechanisms as skin and visual input and therefore the brain is not "well informed" on their status.[13]

The primary endings of skeletal muscle spindles are exceptionally sensitive to small induced length changes in their parent muscle, and muscle receptors, particularly Ia and II afferent fibers, are known to be stimulated by vibration.[14] There is some evidence that stochastic or sinusoidal whole body vibration is as efficient as physical fitness training and is widely investigated in sports medicine,[15,17] however, this is discussed controversial. The effects of whole body vibration on the pelvic floor muscles have not been investigated.

Stochastic vibration also known as stochastic resonance (SR), is commonly understood as the enhancement of a nonlinear system to a weak input signal by noise.[16] It has been shown that the sensitivity of muscle spindle receptors to a weak movement signal is enhanced when a particular level of noise is introduced through the tendon of the parent muscle.[16] Additionally, it has been demonstrated that monosynaptic reflex response elicited by Ia afferents is optimized by the noisy stretching of a synergistic muscle.[17] Positive effects of sinusoidal and stochastic whole body vibration on power and strength of the skeletal muscles have been demonstrated in various studies.[16,17] An improvement, particularly of muscular power, is the ideal treatment goal in women with weak pelvic floor muscles and incontinence as velocity and power of muscular contractions are essential in situations where intra-abdominal pressure is suddenly increased (coughing, sneezing, laughing, stepping down, jumping, or running) and stress incontinence may occur if abdominal pressure surpasses urethral pressure. Whole body vibration could have the potential to activate pelvic muscles and improve their function through better activation patterns and more power.

The aim of the present study was to determine if whole body vibration actually leads to an increased activation of normal and weakened pelvic floor muscles and if there is a difference in efficiency between sinusoidal and stochastic whole body vibration patterns.

Conflicts of interest: none.
Chris Winters led the review process.
*Correspondence to: Annette Kuhn, Zentrum für Urogynäkologie, Effingerstr.102, CH−3010 Bern, Switzerland. E-mail: annette.kuhn@insel.ch
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Additionally, the question is if different whole body vibration intensities will result in different pelvic floor muscle activation levels.

METHODS

This study was designed as a prospective experimental cross section case control study and was approved by the ethics Committee of the Canton of Bern (Switzerland; No. 71/06, Mai 15th 2006). Subjects gave informed consent.

We performed a power analysis prior to the study. To detect a 10% difference of pelvic floor activity and $\alpha = 0.05$ 21 subjects in each group were required (*t*-test; StatMate version 4.0 for Windows).

Post-partum women with pelvic floor muscle weakness as well as healthy women were tested at six different vibration intensities on two different vibration platforms each.

Twenty-three healthy controls and 26 subjects post-partum women with pelvic floor muscle weakness were included in this study. The pelvic floor muscle contraction was graded according to the modified Oxford grading system:[18] 0, no contraction; 1, flicker; 2, weak; 3, moderate; 4, good; and 5, strong.

To be selected, the post-partum women had to be 8 weeks to 12 months after vaginal delivery, aged 18–40 with a pelvic floor testing score of M0–M3, whereas women of the control group had to be aged 18–40, nulliparae or with a period of at least 2 years since their last delivery, without any history of pelvic floor dysfunction and with a pelvic floor testing score of at least M4. Pregnancy, lactation, and menstruation were defined as exclusion criteria.

Each study participant was instructed to perform a maximum voluntary isometric pelvic floor contraction (MVC) before the tests on the vibration platforms; pelvic floor muscle testing was performed according to the Oxford grading system in the sitting position (six categories, range M0–M5, 18).

During the MVC test and during VIB and VIB + MVC, subjects were standing on the floor or on the vibration platforms respectively with slightly bent knees and neutral hip position.

Two different whole body vibration platforms were used: Galileo 900® (REMEDA GmbH, Horgen, Switzerland) with sinusoidal vibrations (SV) and Zeptor med® (Idiag AG, Fehraltorf, Switzerland) with stochastic resonance vibrations (SRV). The Galileo 900® has a single footplate which vibrates side alternating like a see saw. Its vibration amplitude ranges continuously from 1 to 10 mm and the frequency ranges from 5 to 30 Hz. The Zeptor med® has two separate footplates which vibrate vertically and independently with a fixed amplitude of 3 mm and frequencies from 1 up to 12 Hz.

Activation of pelvic floor muscles was measured with an intravaginal surface EMG-electrode (Periform, Parsenn-Produkte AG, Switzerland) similar to the one described by Madill and McLean.[19] The response of the pressure transducer is linear from 0 to 125 cm.

H_2O and Repeatable ($r = 0.99$)

The reference electrode was fixed on the anterior part of the tibia. The EMG was sampled at a rate of 1 kHz, the cut-off-frequency of the low pass filter (Butterworth, 24 dB/Oct) was set at 500 Hz. Expecting vibration artifacts in the EMG, no high pass filter was applied in order to detect the fundamental frequency of vibration as well as the harmonic content in the EMG signal.

The activation of pelvic floor muscles was measured during standing without voluntary contraction and during MVC, each measurement lasting 5 sec.

Afterwards, pelvic floor activity at six different intensities was measured on two different vibration platforms (SRV: 2, 4, 6, 8, 10, and 12 Hz; SV: 5 Hz 2 mm, 5 Hz 4 mm, 15 Hz 2 mm, 15 Hz 4 mm, 25 Hz 2 mm, and 25 Hz 4 mm). At each intensity, the EMG activity was measured during 5 sec vibration only (VIB) and during 5 sec vibration combined with MVC (VIB + MVC). The application of SRV and SV took place at two test occasions within 1 week. The order of test settings and the order of the six intensities at each test were randomized.

Vibration artifacts of fundamental frequency and harmonic content in the EMG's raw signal were spectrum analyzed by Fast Fourier Transformation (FFT) and removed by notch filtering. The EMG was calculated with the RMS-algorithm and was MVC-normalized (MVC = 100 EMG%).

Descriptive statistics, differences between the six dependent intensities (Friedman's ANOVA), differences between independent groups (Mann–Withney-*U*) and differences between devices (Wilcoxon) were calculated with SPSS (15.0). Probability was set at $P = 0.05$ and for repeated measurements the Bonferroni-correction was applied ($P = 0.05/n$).

Spectrum analysis of raw EMG data during MVC was calculated by FFT. Median frequency was taken from the power density spectrum.

RESULTS

Forty nine women (23 controls, 26 post-partum) were included in the study. Two women of the control group were excluded because of pelvic floor muscle weakness (testing < M4) and nine post-partum subjects because there was no pelvic floor weakness (testing > M3). Baseline descriptive statistics of the participants are shown in Table I nine women of the control group were nullipareous and two were pareous. For age and height, there was no significant difference between groups, but for bodyweight, testing and number of delivery, groups differed significantly. Seven of 17 post-partums thought their pelvic floor muscles were weak.

None of the post-partum subjects with pelvic floor muscle weakness had a zero line EMG. While controls showed a mean rest activation level of their pelvic floor muscles of 30.1% during standing, the muscles of post-partum subjects achieved a significantly higher ($P < 0.001$) mean activation level of 52.8% (Figs. 1–4).

Figure 1 shows means and 95%-confidence intervals of EMG activity during frequency dependant vibration only for SRT

TABLE I. Baseline Descriptive Statistics of Groups

	Age (years), Mean (SD)	Height (m), Mean (SD)	Weight (kg), Mean (SD)	Testing (M0–5), Median (IQR)	Births, Mean (SD)
Controls, n = 21	30.0 (4.7)	1.66 (0.06)	59.6 (7.6)	5 (1)	0.3 (0.9)
Post-partum, n = 17	31.7 (3.4)	1.70 (0.07)	66.4 (7.7)	3 (0)	1.3 (0.5)
Significance, *P*	0.294	0.128	0.014	0.000	0.000

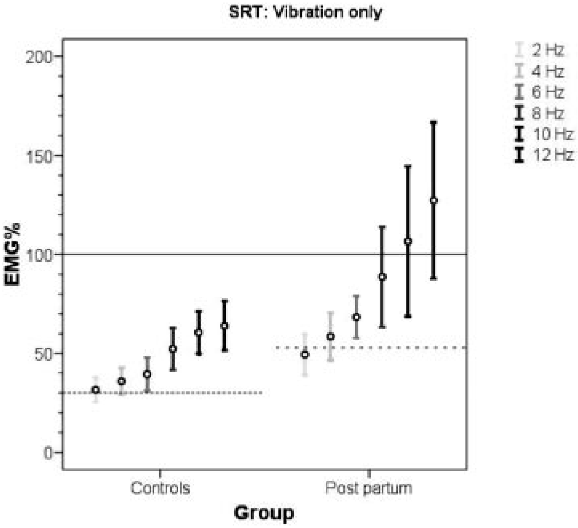

Fig. 1. Means and 95%-confidence intervals of EMG% during vibration only for stochastic resonance vibration and both groups from 2 to 12 Hz. — = 100 EMG% during MVC-test; – – – = EMG% during standing for controls; - - - = EMG% during standing for post-partum subjects.

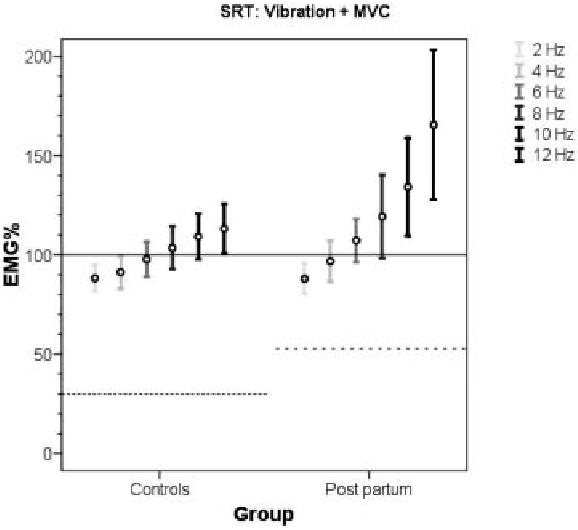

Fig. 3. Means and 95%-confidence intervals of EMG% during vibration and additional maximum voluntary contraction (MVC) for stochastic resonance vibration and both groups from 2 to 12 Hz. — = 100 EMG% during MVC-test; – – – = EMG% during standing for controls; - - - = EMG% during standing for post-partum subjects.

and both groups. The horizontal uninterrupted line shows 100% EMG activity during MVC without vibration, the dotted lines show EMG percentages of pelvic floor muscles during standing without vibration.

During VIB only, controls as well as post-partums needed a minimal intensity of 6 Hz for SRV and 15 Hz 4 mm for SV to attain a significantly higher activation than in rest ($P < 0.001$). With increasing vibration intensities, there was a significant increase of muscular activation during VIB on each vibration device and for each group ($P < 0.001$). Notably in post-partum subjects stochastic vibration alone leads to peak activation higher than during MVC (12 Hz = 127.2%). Peak values during sinusoidal vibration reached a significantly lower activation ($P < 0.001$; 25 Hz 4 mm = 74.6%). This result is similar to that of the control group where peak activation during SRV (12 Hz = 63.9%) differed significantly from sinusoidal vibration ($P < 0.001$; 25 Hz 4 mm = 49.9%; Figs. 1 and 2).

Figure 2 demonstrates means and 95%-confidence intervals of EMG activity during frequency dependant vibration only for SV and both groups. Again, 100% EMG activity at MVC without vibration is marked as uninterrupted horizontal line. With sinusoidal vibration only, the control group and the post-partum group show lower EMG activity than MVC.

Figures 3 and 4 show the results of vibration with additional MVC during vibration.

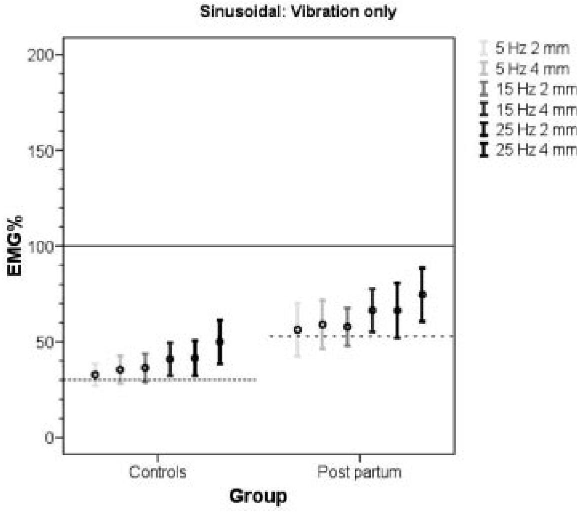

Fig. 2. Means and 95%-confidence intervals of EMG% during vibration only for sinusoidal vibration and both groups from 5 Hz 2 mm to 25 Hz 4 mm. — = 100 EMG% during MVC-test; – – – = EMG% during standing for controls; - - - = EMG% during standing for post-partum subjects.

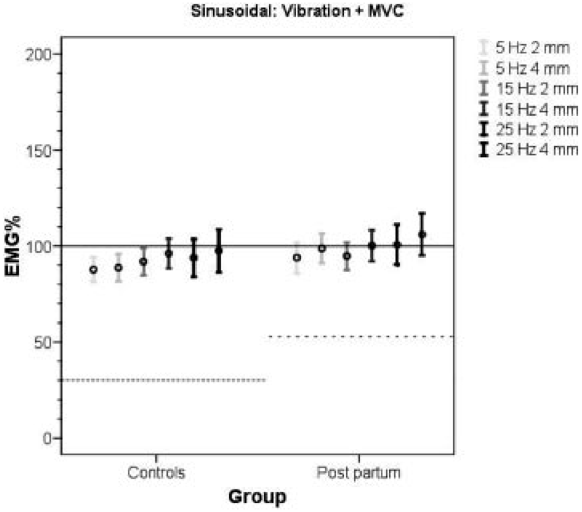

Fig. 4. Means and 95%-confidence intervals of EMG% during vibration and additional maximum voluntary contraction (MVC) for sinusoidal vibration and both groups from 5 Hz 2 mm to 25 Hz 4 mm. — = 100 EMG% during MVC-test; – – – = EMG% during standing for controls; - - - = EMG% during standing for post-partum subjects.

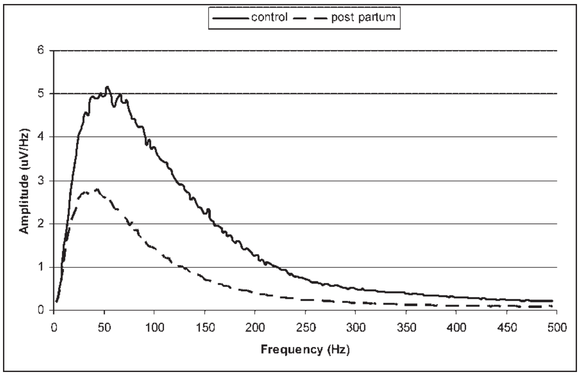

Fig. 5. Fast Fourier transformation of raw EMG during MVC.

During VIB + MVC, all activation levels for each device and each group were significantly higher than activation during rest ($P < 0.001$). During sinusoidal VIB + MVC EMG activity of the control group varied between 87.7% and 97.6% and the post-partum group between 93.9% and 106.0% but there was no increasing activation with increasing intensity ($P > 0.05$). However, the VIB + MVC during stochastic vibrations showed a significant increase with increasing intensity for the controls (from 88.3% to 113.1%) and for post-partums (from 88.0% to 165.5%; $P < 0.001$). The post-partum group showed a substantial peak effect during 12 Hz stochastic resonance; in contrast the sinusoidal vibration caused a significantly lower activation at 25 Hz 4 mm ($P < 0.001$; Figs. 3 and 4).

Spectrum analysis of raw EMG data showed a clear difference in amplitude and a shift to the left for the post-partum group (Fig. 5). The mean median frequency (49.9 ± 5.3 Hz) as well as the absolute mean amplitude of post-partum group's EMG (316.3 ± 51.3 μV) of post-partum group were both significantly ($P < 0.001$) lower than the control's median frequency (61.9 ± 4.7 Hz) and absolute amplitude (709.8 ± 324.0 μV).

DISCUSSION

This study has investigated the influence of various vibration intensities and types of vibrations on the pelvic floor muscles of post-partum subjects and a control group.

To avoid influences from pregnancy and childbirth, it would have been ideal to compose the control group of homogenously nullipareous women; however, 90% of the controls were nullipareous and all subjects in the control group had a pelvic floor digital testing of 4 or more.

Particularly in the post-partum group, SRT reached with vibration alone and a frequency of 10–12 Hz higher EMG activation than maximum voluntary contraction; stochastic vibration with a frequency of 6–12 Hz and additional MCV reaches significantly higher EMG potentials than MCV alone, which may be a therapeutic option for patients with a weakened pelvic floor. In this pilot study, sinusoidal vibration was inferior to stochastic vibration as EMG activity with SV alone did not reach EMG levels of MCV in neither the post-partum group nor the controls. SV vibration with MCV did just reach the same EMG activation level as MCV alone meaning there was no benefit of SV.

As shown in Figures 1–4 by the dotted lines, the post-partum group used about 53% of their maximum pelvic floor muscle activity during standing alone, and this percental activation was about 22% higher than the basic activity in controls. For every day activities this means that patients with weakened pelvic floor muscles after delivery need to activate more pelvic floor muscle fibers than healthy controls. This could mean that post-partum women's pelvic floor muscles are generally prone to more strain and, as a consequence, fatigue more easily.

The lower EMG amplitude and median frequency under condition of maximal contraction showed the reduced ability of women post-partum to muscle fiber synchronization and recruitment and their low maximum strength and power. This correlates with Morin's results[20] who showed that women with pelvic floor muscle weakness have a lower rate of force development and force endurance. Both conditional factors are fundamentally important for the reactive, fast and repetitive muscle contraction to avoid stress urinary incontinence during unexpected or high impacts.

With sinusoidal stimulation, any frequency was sufficient to evoke potentials greater than the activation at rest in the control group. In the post-partum group, at least 15 Hz 4 mm were needed to reach activation levels higher than at rest. However, the evoked potentials were significantly higher with stochastic resonance therapy, particularly in the post-partum group.

With both devices, it was possible to demonstrate a statistically significant improvement of pelvic floor activation between vibration only and vibration plus maximal voluntary pelvic floor muscle activation; however, only with SRV an activation level far above 100% was found, and this was particularly evident in women with impaired pelvic floor muscle function.

Fontana et al.[21] was able to show that low frequency whole body vibration improved proprioception in the lumbosacral area, and Khaodhiar et al.[22] demonstrated an improvement of tactile perception using SRV. We have not tested pelvic floor proprioception in the current study but this subject will be addressed in the future.

This study was able to prove an activation of the pelvic floor much higher than voluntary peak activation with SRV. This activation was significantly higher than with sinusoidal vibration depending on the frequency. In particular, the SRV frequencies of 6–12 Hz, compared to sinusoidal stimulation, evoked higher EMG potentials in both the control group and, especially, in the post-partum group.

During stair descent the force impact follows within 146 msec[23] and there is a need for fast contracting anaerobic muscle fibers to stabilize the lower limbs. Pelvic floor muscles have to react simultaneously. A contraction time of 146 msec is comparable to a vibration frequency of at least 6.85 Hz. Stress incontinence occurs in situations with a sudden increase of abdominal pressure (as it happens during laughing, coughing, and sneezing), which requires the pelvic floor muscles to react immediately. The expulsive process during sneezing happens within about 150 msec.[24] It has been shown that this reactive contractibility (power) of pelvic floor muscles in women with stress urinary incontinence is significantly reduced.[20] And—again—SRV has been shown to improve fast reactivity and dynamic stability of muscles.[25]

SRV could be an alternative to any vaginal electrical stimulation which is occasionally not appreciated because of cultural or personal reasons. The role of electrical stimulation in pelvic floor muscle strength remains unclear; an improvement of pelvic floor muscle strength was reported in the study by Blowman et al.[26] in both groups comparing pelvic floor muscle training (PFMT) to PMFT with additional electrical stimulation. More improvement in the PMFT with electrical stimulation was reported; however, no statistical tests were performed to test significance. Sand[27] performed pelvic floor muscle strength measurement using a device measuring vaginal squeeze pressure in 35 patients and 17 controls who used identical active and sham stimulation devices before and after treatment; the active group had a significant improvement in vaginal muscle strength compared to controls.

In contrast, another study[28] did not detect any statistically significant differences between electrical and sham electrical stimulation when pelvic floor muscle strength was measured using a device measuring vaginal squeeze pressure. However, if muscle strength was assessed using digital assessment, a statistical significant difference in favor of electrical stimulation was found.

On the more basic part Bø and Talseth found that voluntary contraction of the pelvic floor muscles gave significantly higher increase in urethral pressure than electrical stimulation.[29]

ICI recommendations[30] summarize that overall it appeared that electrical stimulation was better than no treatment.

We chose the Oxford grading system instead of a pressure-measuring device as it has been proven to show very good reliability in various positions for maximum voluntary contractions and excellent intra-class correlation coefficients for squeeze pressure readings.[31] The Oxford grading system has an inter-rater reliability for vaginal palpation of 0.70 measured by Spearman's rho ($P < 0.01$;[18]). In that study, agreement between the physical therapists was documented in 45% of cases only and inter-tester agreement was considered as only fair.

A negative aspect in the methodology is the use of a vaginal surface EMG electrode instead of a needle electrode as needle electrodes are considered more reliable than surface electrodes,[32] which may pick up muscle potentials of muscles other than the pelvic floor. However, we chose surface electrodes in this particularly sensitive area as surface electrodes decrease patients' discomfort[32] and there is some evidence that surface electrodes adequately detect pelvic floor muscle activation.[33]

In conclusion, above all, stochastic but, to a lesser extent, also sinusoidal whole body vibration has beneficial effects concerning the reactive activation patterns and possible treatment outcome of weakened pelvic floor muscles. However, it must be kept in mind that only EMG potentials and acute vibration activation effects have been investigated but not the effects on symptoms or pelvic floor strength after whole body vibration. Higher pelvic floor activation during stimulation does not automatically mean that the activation is also beneficial regarding continence or other dysfunctional pelvic floor states.

To answer the question in the title of the study, the current investigation supports the idea that stochastic resonance vibration is the better type of vibration and leads to higher pelvic floor muscle activation than sinusoidal vibration. However, there are still many unanswered questions: For how long should vibration be applied, and how many training sessions per week over what time period are necessary? Will the clinical effect (e.g., for the treatment of urinary incontinence) correlate with our electrophysiological outcome? Is it wise to use vibration therapy in preparation for pelvic floor exercises? Can the effect of pelvic floor exercises be amplified by simultaneous stimulation? These questions need to be addressed in the future before stochastic resonance whole body vibration can be recommended for treatment of pelvic floor dysfunction. But, as a conclusion from our results, stochastic whole body vibrations in a range between 6 and 12 Hz are the "good" vibrations for the pelvic floor.

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