applied sciences

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The Influence of Stochastic Resonance Whole-Body Vibration on Women over 50 Years of Age—Preliminary Studies Based on Patients' Own Experiences

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Abstract: Background: During menopause, a woman's health often deteriorates, and various methods are sought to prevent this decline. The aim of this study was to determine the influence of SR-WBV training on the health and wellbeing of women over 50 years of age. Methods: SR-WBV training was performed twice a week for six weeks using the SRT Zeptor® Medical-plus noise device. Forty-two women were trained on the D program (7–9 series, lasting 45–60 s each), and 23 women on the O program (9–11 series, lasting 50–60 s each). The frequency ranged from 2 to 8 Hz. Due to health problems, 12% of the women did not complete the study protocols. Results: The remaining women declared an improvement in mental state (51%), physical activity (68%), and general well-being (72%), as well as a reduction in lower limb pain (21%), back pain (14%), and urinary incontinence symptoms (17%). Conclusion: The benefits of SR-WBV training include improvement in general well-being and physical fitness, reduction of lower limb and back pain, and reduction of urinary incontinence symptoms. SR-WBV training can provoke or aggravate back pain and lower limb pain and cause other side effects, so the optimization of training parameters for SR-WBV is required.

Keywords: women over 50 years of age; stochastic resonance whole-body vibration; pain symptoms; urinary incontinence; SR-WBV side effects

Citation: Hartman-Petrycka, M.; Lebiedowska, A.; Stolecka-Warzecha, A.; Szumski, A.; Błońska-Fajfrowska, B. The Influence of Stochastic Resonance Whole-Body Vibration on Women over 50 Years of Age—Preliminary Studies Based on Patients' Own Experiences. *Appl. Sci.* **2021**, *11*, 3980. https://doi.org/10.3390/app11093980

Academic Editor: Redha Taiar

Received: 6 April 2021
Accepted: 26 April 2021
Published: 27 April 2021

1. Introduction

The aging process is inevitable for everyone. Involution changes are observed throughout the body, and the rate of progress varies according to gender; comorbidities; socioeconomic conditions; and lifestyle, including diet. The severity of the aging process in women is strongly related to menopause, which occurs at around 50 years of age, or the presenile period of life, according to the World Health Organization (WHO) [1,2]. During this period, cardiovascular, respiratory, and immune disorders, as well as the rate of civilization disorders, such as being overweight, obesity (as a result of a decreased rate of metabolic changes and carbohydrate and hormone disorders), hypertension, and diabetes, all increase [3,4]. For many years, the female population in Poland has been larger than the male population (51.7%), and the average life expectancy of women is still increasing slightly and currently stands at 81.8 years [5]. Socioeconomic changes have also impacted Polish women's status, giving them many new opportunities, but also requiring specific social roles, which are often mutually exclusive. For older women, in particular, the fulfillment of such changes is challenging and requires good mental and physical health [6].

The 21st century has brought about the development of technology and the computerization of everyday life. Unfortunately, along with the increase in a number of civilization

diseases, a decrease in physical activity among women is observed. Non-invasive methods to prevent involution changes that are available to most of the population, and, above all, that are effective, are constantly being sought. Stochastic resonance is one of the therapeutic methods that is still studied. In 2003, Calim et al. described how noise could benefit neurons or other nonlinear systems [7].

Whole-body vibration (WBV) improves strength and power in healthy people. There are two basic forms of whole-body vibration: sinusoidal whole-body vibration (S-WBV) and stochastic resonance whole-body vibration (SR-WBV). During S-WBV, the device vibrates vertically or laterally, alternately, with frequencies from 20 to 50 Hz and amplitudes from 2 to 6 mm. During SR-WBV, participants stand on two platforms that vibrate independently with frequencies from 1 to 12 Hz [8].

The stochastic resonance whole-body vibration (SR-WBV) is efficiently used in rehabilitation. One method of stochastic resonance vibration training is contrary to the traditional understanding of motion control mechanisms. Usually, disturbances that cause imbalance are avoided, and individuals attempt to limit the negative effects of vibration. However, during vibration training, some disturbances are created intentionally to train the motion control mechanisms of the body and to increase movement control in everyday life [8,9]. It has been proven that stochastic vibrations are an effective way to improve walking, coordination, posture, and manual performance in patients with locomotive diseases [10]. Donocik et al. [11] performed SR-WBV training (frequency: 2–8 Hz; amplitude: 0.5–3.5 mm; duration: 6 weeks, 2 times a week) in women and showed the improvement in maintaining balance and postural control. Stochastic vibrations (frequency: 3–6 Hz; amplitude: 4 mm; level of noise: 4; duration: 8 weeks) also contribute to muscle strength and bone structure improvement [12], which can affect bone density, physical fitness, and improve comfort in an individual's general life [13]. This method may also provide other therapeutic effects.

The aim of this study was to determine the effect of SR-WBV on the well-being and health of women over 50 years of age based on descriptions of the patients' own experiences after they had completed the training. These data will help form an understanding of the basic risks and benefits of SR-WBV and will determine the direction of further, more detailed research using objective measurement methods.

2. Materials and Methods

The study was conducted in accordance with the Helsinki Declaration. Every participant provided written consent after being informed about the aim, protocol, and methodology of the study. The Bioethics Committee of the University approved the research project.

Health interviews were conducted before vibration training among volunteers. The participants in this study were women over 50 years of age. They were either excluded from the study or qualified for one of the two vibration programs offered by the equipment: the disbalance program (D) or the osteoporosis program (O). Inclusion criteria were completion of the participation agreement, being over 50 years old, and having the ability to move without support. The D program was intended for women with little or no health problems, while the O program was for women whose health issues were assessed as a medium risk. Exclusion criteria were acute inflammations, fresh surgical wounds, serious injuries, thrombosis, cancer, severe arthritis, advanced discopathy, severe pain (especially in a knee, hip joint, or spine), heart pacemaker, severe arrhythmia, severe coronary heart disease, serious unregulated hypertension, retinal detachment, nausea and malaise, and dizziness. Forty-two women were trained on the D program (7–9 vibration series, lasting 45–60 s each), and 23 women on the O program (9–11 vibration series, lasting 50–60 s each). Of these women, 12% did not complete the study protocols due to health problems (Table 1).

Table 1. Information about women quitting SR-WBV training. N = 8 (12% of all participants).

No.	Program	Number of Sessions/Level	Age	Health Problem in Medical History	Reason for Quitting the Training
1 D	Disbalance	1/Medium, 1/High	52	No medical history of health problems	Back pain
2 D		1/Medium	52	Surgery for hernia and vermiform appendix	Hyperthyroidism
3 D		4/Low	74	Overweight, knee pain when climbing stairs, arterial hypertension treated pharmacologically, heart arrhythmia	Heart arrhythmia (hospitalization)
4 D		3/Low	62	Class II obesity	Knee pain, dizziness
1 O	Osteoporosis	2/Low	65	Obesity, thoracic and cervical back pain, knee pain caused by weather changes, depression, dizziness, hypertension, arrhythmia	Knee pain
2 O		4/Low	60	Overweight, discopathy with no current pain, hypertension, diabetes	Nausea and vomiting
3 O		4/Low	70	Overweight, displaced fractures of left lower leg, lower extremity edema, hypertension, arrhythmias, removed varicose veins, urinary incontinence	Back pain, numbness of hands
4 O		1/Low	57	Musculoskeletal pain, degenerative changes in the spine	Arthritis

SR-WBV training was performed using the SRT Zeptor® Medical-plus noise device (Figure 1). This device consists of two plates emitting vibrations of varied direction and power. During training, a volunteer would put both feet (without shoes) on the plates of the device and stand straight with slightly bent knees. After running a selected program, plate units started to move in a disorganized way, gradually increasing in frequency and amplitude, until the desired intensity had been reached. The participant was relaxed, with their torso and head remaining as calm as possible. During a break between series of vibrations, the participant could maintain any comfortable position. The vibration frequency ranged from 2 to 8 Hz. The vibration amplitude ranged from 0.5 to 3.5 mm. In the D program, depending on the level, there were 7 to 9 vibration series that lasted 50 to 60 s each, and, in the O program, there were 9 to 11 series that lasted 50 to 60 s each, with 40 to 60 s breaks between series. In the O program, compared to the D program, vibrations were noticed less by the women due to a lower vibration amplitude and a different type of imposed stochastic noise. The first training session was always performed using a low or medium level of vibrations. If women did not report negative feelings after the first session and gave their consent, the vibration level was raised during the next sessions. At the low and medium level, the maximum vibration frequency is 6 Hz, and at the high level, it is 8 Hz. During each training session, the weakest vibrations characterized the first and last series, while the middle ones were the strongest. Depending on the programs and vibration levels used, each training session lasted between 10 and 22 min. A full cycle of vibrations consisted of 12 sessions, two times a week, with at least a one-day break between sessions. The entire study lasted six weeks. A more detailed description of training programs is provided in Supplement 1. Detailed information about the number of participants, programs used, and vibration levels is shown in Figure 2.

Figure 1. The SRT Zeptor® Medical-plus noise device.

To determine the effect of SR-WBV therapy on the human body, a non-validated questionnaire was used. After participation in the entire cycle of SR-WBV, each woman recorded what changes she had observed in her body, using a 10 cm linear analog scale (with "improvement" at one end and "deterioration" at the other, and "no change" in the center). Using the first three scales, all the women over 50 years of age recorded how their general well-being, mental state, and physical fitness had changed. On the last linear scale, participants listed any additional noticeable post-training changes that occurred, if this was applicable (Figure 3).

Statistical Analysis

The data were collected using Microsoft Excel. To determine the most frequent effects of vibration, descriptive statistics were used. The percentage of women over 50 with an improvement or deterioration in a particular aspect of their health was calculated, as well as the percentage of women where the severity of symptoms did not change (Figure 4). The χ^2 test was used to compare the responses of women participating in the D and O programs. Statistical significance was set at $p < 0.05$.

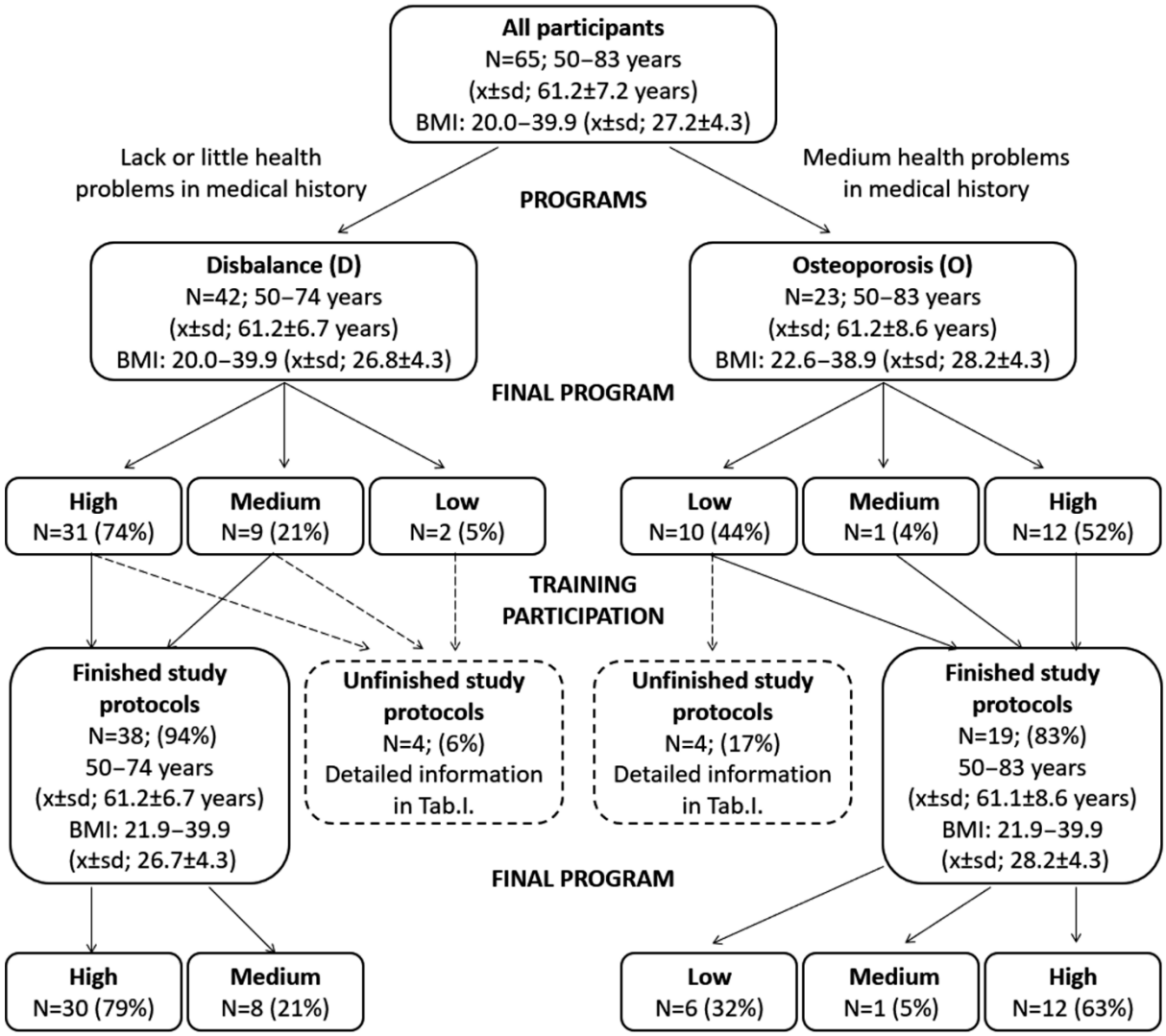

Figure 2. Diagram showing number (N), age and BMI of studied women (x ± sd, mean ± standard deviation), type and final level of the program used, and information about completion or quitting the training. A dashed line represents quitting the training.

The effect of the SR-WBV therapy on the human body **Current Date** ……

Name…… **Date of Birth** ……

1. General well-being ← deterioration no change improvement →

……

2. Mental state ← deterioration no change improvement →

……

3. Physical fitness ← deterioration no change improvement →

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4. …… ← deterioration no change improvement →

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5. …… ← deterioration no change improvement →

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Figure 3. Questionnaire: The effect of SR-WBV therapy on the human body.

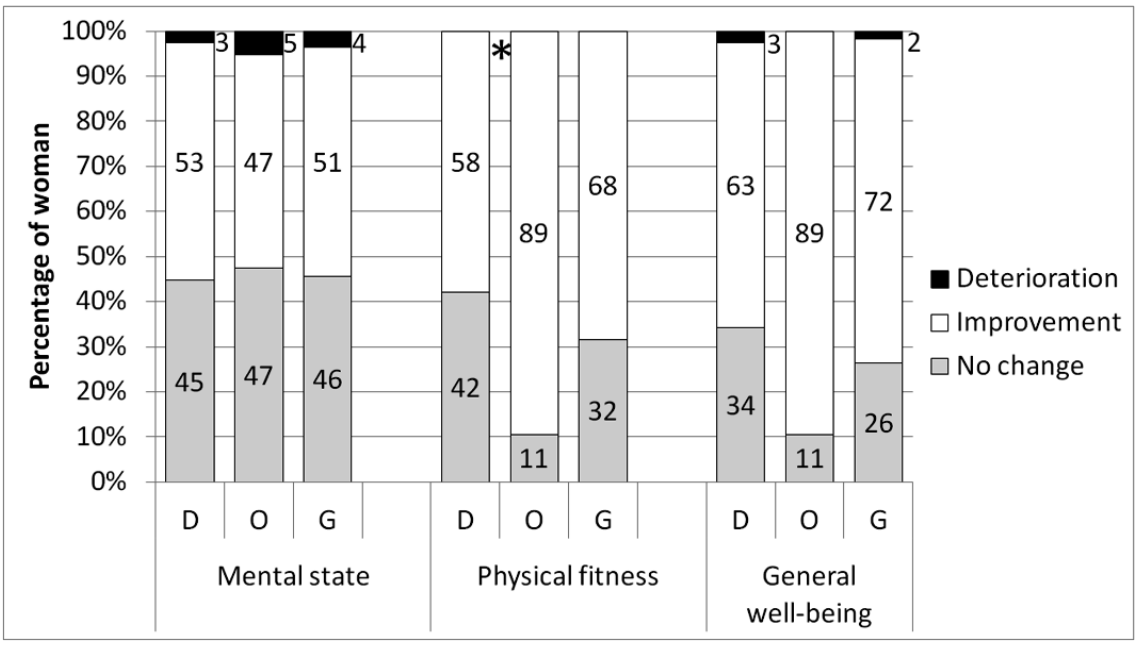

Figure 4. Percentage of women declaring different effects of SR-WBV training on individuals in the D program (N = 38), O program (N = 19), and altogether—G (the entire group of women) (N = 57); * $p < 0.05$.

3. Results

Women who completed the entire training cycle declared improvement in their mental state (51%), physical fitness (68%), and general well-being (72%) (Figure 4). Only a small percentage of women declared deterioration of mental state (4%) and general well-being (2%). There was a statistically significant difference in physical fitness after the D and O training programs ($p < 0.05$). The declared improvement in physical fitness after the O program was reported in 89% of women, and in 58% of women after the D program. Changes in mental state and general well-being after the D and O programs were not statistically significant.

After SR-WBV training, some women declared changes in pain syndromes. Before training, lower limb pain was reported by 25% of all participants. After training, lower limb pain was reported as reduced in 21% of women and intensified in 2% of women (Figure 5). Of the 28% of women who had reported back pain before training, 14% experienced a reduction of this symptom. Originally, 16% of women reported experiencing shoulder and hand pain, which decreased by 5% after training. There were no statistically significant differences in the effects of vibration in the D and O programs on the area of sensation of pain.

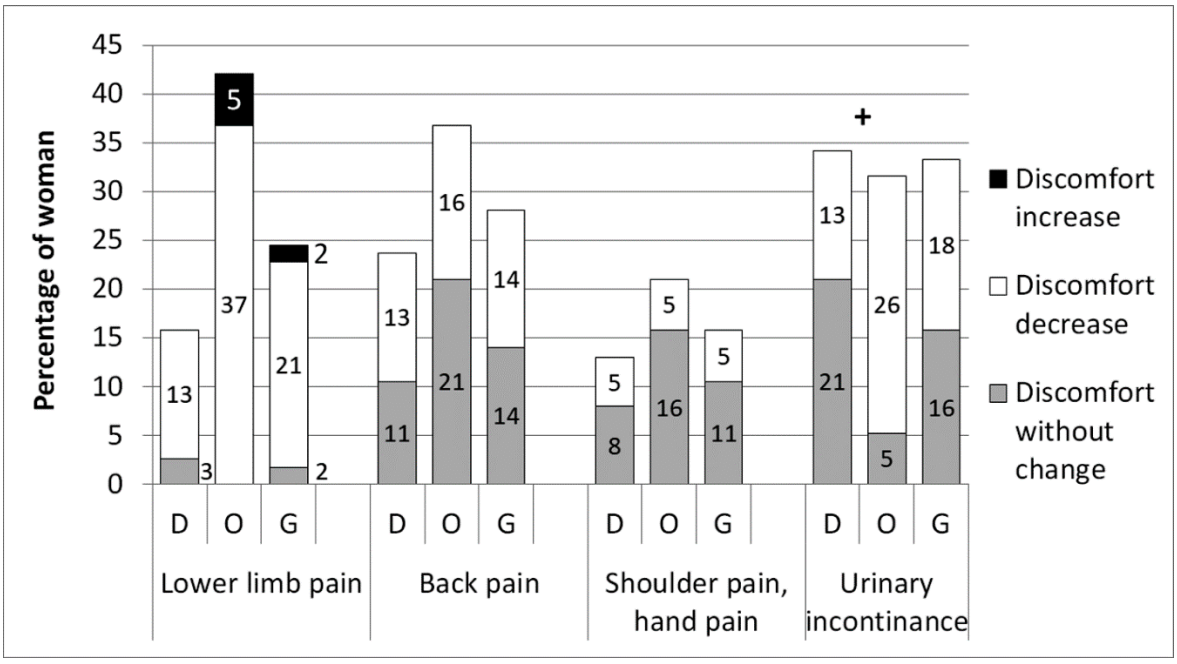

Figure 5. Percentage of women declaring different effects of SR-WBV training on pain syndromes and urinary incontinence in the D program (N = 38), O program (N = 19), and G (the entire group of women) (altogether, N = 57); $^{+}$ $p = 0.068$.

The urinary incontinence symptom was reported by 33% of women before SR-WBV training (Figure 5). After training, reports of urinary incontinence decreased in 17% of women, with 16% experiencing no change. A more frequent incontinence improvement was observed in women on the O program compared to women on the D program ($p = 0.068$). Among women on the O program, 31% experienced incontinence symptoms, and in 26% of the women, the symptoms decreased. Of the 34% of women on the D program that reported experiencing incontinence, 13% reported a decrease in this symptom.

Among other effects, the most frequently mentioned by women after SR-WBV training were an increase in energy and physical condition (11%), skin firming and cellulite reduction (11%), and improvement in sleep quality and in falling asleep (7%) (Table 2).

Table 2. Percentage of women declaring different effects of SR-WBV training in the D program (N = 38), O program (N = 19), and G program (altogether, N = 57).

Effects Listed by Women after SR-WBV Training	D		O		G	
	N	%	N	%	N	%
Increase in energy and physical condition	3	8	3	16	6	11
Skin firming, cellulite reduction	5	13	1	5	6	11
Improvement in sleep quality and in falling asleep	2	5	2	11	4	7
Concentration improvement	2	5	-	-	2	4
Calming and silencing effect	2	5	-	-	2	4
Quicker bruises healing	1	3	1	5	2	4
Less headaches	1	3	1	5	2	4
Less severe headaches and menstrual cramps during menstruation	-	-	1	5	1	2
Balance improvement while climbing stairs	1	3	-	-	1	2
Dizziness reduction while rising from bed	1	5	-	-	1	2
Reduction in tingling and tickling of the skin	-	-	1	5	1	2
Lower hypertension	1	5	-	-	1	2
Lower body weight	1	5	-	-	1	2
Hemorrhoids reduction	1	5	-	-	1	2
Sharpen eyesight	1	5	-	-	1	2
Constipation improvement	-	-	1	5	1	2
Easier breathing	-	-	1	5	1	2
Higher hypertension	-	-	1	5	1	2

4. Discussion

This study could represent that 12 sessions of SR-WBV intervention have beneficial effects on physical fitness and reduce knee and back pain in women experiencing menopause. However, the inadequate adjustment of the stimulus power to the health condition of each examined person may cause negative effects.

Decreased cell proliferation, increased degeneration, and a decline in physical fitness occur in the human body with age. Involution changes in the musculoskeletal system, along with degenerative changes, pains, and imbalance occur in addition as a result of the deterioration of visual function, vestibular function, weight loss, muscle strength loss, and prolongation of reaction time [14,15]. The results of this study show that, among all the women who had completed the entire stochastic resonance vibration training cycle, the improvement in physical fitness was 68%. Positive changes in the musculoskeletal system under the influence of SR-WBV trainings include increased energy and physical condition (11%) and balance improvement while climbing stairs (2%). Zhang et al. [16] also described the positive effect of SR-WBV on the muscular system. The muscle strength of the knee rectifiers improved after eight weeks of training in the elderly. Similarly, Rogan and Herren et al. [17,18] demonstrated an improvement in functional muscle strength after the SR-WBV intervention in less active older adults. SR-WBV was also shown to play a role in improving women's ability to maintain balance [11].

The positive effects of stochastic resonance therapy have also been observed in women with urinary incontinence, another common health problem among older women. Urinary incontinence mostly occurs in postpartum women, menopausal women, and women older than 50 years of age, and is considered to be a basic health problem by the WHO. At present, preventive and therapeutic measures are necessary for treating urinary incontinence [19–21].

Urinary incontinence symptoms decreased among 50% of women who had reported symptoms before the therapy (84% on the O program, 38% on the D program). Lauper et al. [22] also reported positive effects of stochastic vibrations on urinary incontinence. The increase in pelvic floor muscle activation was observed after using both stochastic and sinusoidal vibrations. Runge et al. [23] assessed the effect of sinusoidal vibrations on urinary incontinence and also noted symptom relief in patients with incontinence. Luginbuehl et al. analyzed the effect of SR-WBV vibrations of different durations (continuous, 60 s, and intermittent, 15 s) on the pelvic floor muscles. When there were no statistically significant differences found, continuous vibrations were recommended (60 s), which is consistent with the methodology used in this study [24].

There are no studies available about the effect of SR-WBV on mood or mental state. In the present study, 51% of all women who completed the training cycle declared an improvement in their mental state and 72% in their general well-being. Most likely, this is due to a general improvement in health and reduction in pre-existing symptoms. An improvement in health and life quality will improve mood and general well-being. After SR-WBV training, only two patients reported mental state deterioration. In one patient, it was most likely related to the death of the patient's brother and not to the therapy, while, in the other person, it was associated with the therapy because, at the end of the procedure, knee pain appeared.

Most respondents declared an improvement in health problems. Eighty-four percent of women with lower limb pain declared improvement, and only about 3% (N = 1) reported deterioration. As for back pain, an improvement was noticed in about 50% of women and, in the case of shoulder and hand pain, in about 31% of women experiencing such symptoms. Elfering et al. [25,26] also investigated the effect of SR-WBV on muscle pain. Participants of the study reported slight improvements immediately after the first stochastic resonance training session, which gradually progressed with further trainings. The most frequently reported positive effects after SR-WBV were skin firming and cellulite reduction (11%) and improvement in sleep quality and in falling asleep (7%).

In the present study, a greater improvement in physical fitness and urinary incontinence symptoms was found in the group of women using the O program compared to those enrolled in the D program. These differences may be attributed to two reasons: (1) The highest vibration level (9 vibration series) on the D program was used, which, together with the breaks, lasted 16 min. However, on the O program, 11 vibration series were used, which, together with breaks, lasted 22 min. Although in the O program, due to the type of noise and amplitude, vibrations are less noticeable, the increased number of series seems to be important in the effectiveness of the training. (2) The fact that the qualification for training on each particular program was not randomized may also have played a role in the higher effectiveness of the O program. Women with worse overall health and pain symptoms were referred to the O program. These women were more likely to be susceptible to vibration than those with a lack of or little health problems in their medical history, who were primarily referred to the D program.

If used improperly, SR-WBV training can cause negative effects. In the available literature, it is not easy to find information about the adverse effects of SR-WBV. In 2007, Monteleone et al. [27] described an acute renal colic episode after a single WBV cycle in a patient with asymptomatic kidney stones. Bogaerts et al. [28] excluded five out of ninety-four people who had developed knee pain. However, side effects described in the literature refer to studies using sinusoidal vibrations.

Due to the variable vibration characteristic and the type of "noise" applied in SR-WBV training, lower frequency and lower amplitude vibrations may be used, compared to the typical WBV training where sinusoidal vibrations are applied. In this study, during SR-WBV training, vibration frequencies ranged from 2 to 8 Hz, and those trained at medium- or low-level frequencies did not exceed 6 Hz. For comparison, in the WBV training with sinusoidal vibrations in the studies of Bogaerts et al. [28], the frequency at various training stages ranged from 30 to 40 Hz. The lower vibration frequency in SR-WBV allows it to

be used in a larger group of people and in patients with a history of health problems. Despite the higher safety of SR-WBV training compared to WBV training, it can also cause side effects. In this study, there were eight (12%) unfinished study protocols, 6% in the D program and 17% in the O program. Symptoms that had become the reason for quitting the training appeared most often in the evenings on the day of the training, and never during the vibration session. The most common reasons for resigning were back pain and knee joints pain (four women, 6%). There were also three de novo cases, and there was one case with a history of knee pain. One woman reported the development of arthritis, but she had had degenerative changes in spinal joints and a minor arthralgia before the study. SR-WBV training also negatively affected a participant with episodes of arrhythmias in their medical history and exacerbated the symptoms. The manifestation of back pain, knee joint pain, and arthritis, as well as the severity of arrhythmias, were certainly related to the vibration training, but not all participants could directly associate the training with new symptoms. One woman quit the training due to nausea and vomiting, and another participant reported hyperthyroidism. Nausea and vomiting might appear independently of the training, e.g., due to food poisoning, because symptoms occurred late in the evening on the day of the vibration, not directly after or during the training. It has not been described yet how vibration training affects thyroid function. The occurrence of hyperthyroidism in one participant might have been a coincidence, but it could also be hypothesized that SR-WBV training increased blood flow through the thyroid and increased its hormonal activity.

Limitations of the Study

The main limitation of the study was that the research assumption focused on a wide variety of possible effects and side effects of the vibration training. The selection of the participants was random, most of them being students of The University of the Third Age, and it did not target a specific disease. This is the reason why it does not have a typical medical experiment construction in which we can observe a given symptom using the most objective measurement methods possible, preferably in a randomized controlled trial scheme. We do not have detailed before and after measurements, only questions about the patients' experiences. As a result, we can provide only descriptive statistics of the patients' responses after the vibration training. We cannot conclude that vibrations with a specific type of parameter are definitely effective, but based on the patients' statements, we can plan further research on the efficacy of vibrations with specific parameters for a particular dysfunction based on the inferred effectiveness seen in this study. The descriptions of the patients' subjective experiences also allow us to raise awareness of the possible side effects during recruitment for any future experiments.

5. Conclusions

Positive changes in the body and the appearance of side effects observed by women indicate that SR-WBV training, using the programs described in this paper, generates sufficient stimuli to influence a woman's body. The most commonly mentioned benefits of SR-WBV training included improvement in general well-being and physical fitness, reduction in lower limb and back pain, and a reduction in urinary incontinence symptoms. SR-WBV training can provoke or aggravate back pain and lower limb pain and causes other side effects, so optimizing the training parameters and detailing the eligibility criteria for SR-WBV training are required. In addition to the changes mentioned above, the influence of SR-WBV training on mental state, skin, and thyroid hormone activity are potential directions for further research on the usefulness of SR-WBV.

Author Contributions: Conceptualization, M.H.-P.; A.L.; A.S.-W.; A.S. and B.B.-F.; methodology, M.H.-P.; A.S.; B.B.-F.; software, M.H.-P.; B.B.-F.; validation, M.H.-P.; A.L.; A.S. and B.B.-F.; formal analysis, M.H.-P.; A.L.; A.S.-W.; A.S. and B.B.-F.; investigation, M.H.-P.; A.L.; A.S.-W.; resources, B.B.-F.; data curation, M.H.-P.; writing—original draft preparation, M.H.-P.; A.S.-W.; A.S.; writing—review and editing, A.L.; and B.B.-F.; visualization, M.H.-P.; supervision, B.B.-F.; project administration, B.B.-F.; funding acquisition, B.B.-F. All authors have read and agreed to the published version of the manuscript.

Funding: Medical University of Silesia; contract KNW-2-001/N/7/N.

Institutional Review Board Statement: The study was conducted according to the guidelines of the Declaration of Helsinki, and approved by the Ethics Committee of Medical University of Silesia (KNW/0022/KB1/49/II/13/18; 17.04.2018).

Informed Consent Statement: Informed consent was obtained from all subjects involved in the study.

Data Availability Statement: The data presented in this study are available on request from the first author (mhart-man@sum.edu.pl).

Conflicts of Interest: The authors have no competing interests to declare.

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