vibration

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Review

Effects of a Single Session of Whole Body Vibration Compared to Multiple Sessions—An Updated Review and Meta-Analysis

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Abstract: Parkinson's disease is an incurable neurological disease. Only the symptoms can be treated with medication or exercise therapy. The present analysis is intended to show how whole-body vibration training affects the symptoms of Parkinson's disease, distinguishing between acute and long-term effects. Methods: online databases (EMBASE, PubMed, PEDro) were searched for reviews, meta-analyses and new studies since the previous most recent review/meta-analysis. Studies with at least a medium methodological quality (PEDro score at least 5 points) were selected. Results were presented as forest plots that indicated standardized mean differences with 95% confidence interval. Results: Sixteen studies were found with a PEDro-score of at least 5 points. Of these, three studies were excluded from the qualitative analysis because the necessary data, such as standard deviation or control group results, were missing. The effect sizes are very mixed. In some parameters there is no effect, in others a very strong effect. The effects in the comparison between single and multiple treatments are similar. Discussion: The different effects may be partly due to the different vibration frequencies or sentence durations, as well as to different valid test procedures. Conclusions: Since the study situation still does not show clear results, further studies must follow that compare different frequencies, sentence durations and vibration types with each other, so that training recommendations can be given on this basis.

Keywords: Parkinson's disease; whole body vibration; rehabilitation; training therapy

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1. Background

Parkinson's disease affects approximately 9.4 million people worldwide [1]. This disease is due to a degeneration of dopaminergic neurons in the substantia nigra and an impairment of nigrostriatal projections. This results in symptoms such as tremor, rigidity, and akinesia, and lesions in the supplementary motor cortex lead to hypokinesia [2]. Most of these symptoms are thought to be caused by abnormal neuronal beta oscillations [3]. In addition, neurotrophic factor deficiency may be a possible cause of PD [4]. Due to the defect in dopamine neurotransmission, dopamine substitution is most commonly used as a medical therapy. At the same time, the motor symptoms of the disease are treated with occupational and physical therapy. To date, there is limited evidence for the positive benefits of whole-body vibration training as a form of physical therapy [5]. There are some studies showing that physical exercise of any kind can improve symptoms such as freezing, walking, mobility, or balance. After physical exercise or therapy, some of these symptoms may even improve to clinically significant levels [6].

Vibration therapy is applied either to the whole body or to individual body parts. Whole-body vibration (WBV) is vibration that is transmitted to the body via a stand or seat [7]. Here, a distinction is made between vertical, sinusoidal vibrations around a central axis (originating from rotating motors on the left and right sides) and vertical, synchronous vibrations (originating from motors with eccentric mass centered under the platform) [8], see Figure 1. These vibrations can be harmonic or random, with random noise interspersed

during sinusoidal vibrations in randomized vibration [9]. WBV is increasingly used to treat symptoms of various neurological disorders [10]. However, the underlying mechanism of action of these therapies is not yet fully understood. WBV is thought to stimulate subcutaneous proprioceptors, inducing a tonic vibratory reflex [11]. Animal studies found that striatal dopamine levels and the neurotrophic factor BDNF increased in the striatum and regeneration of dopaminergic neurons increased after treatment with WBV [4].

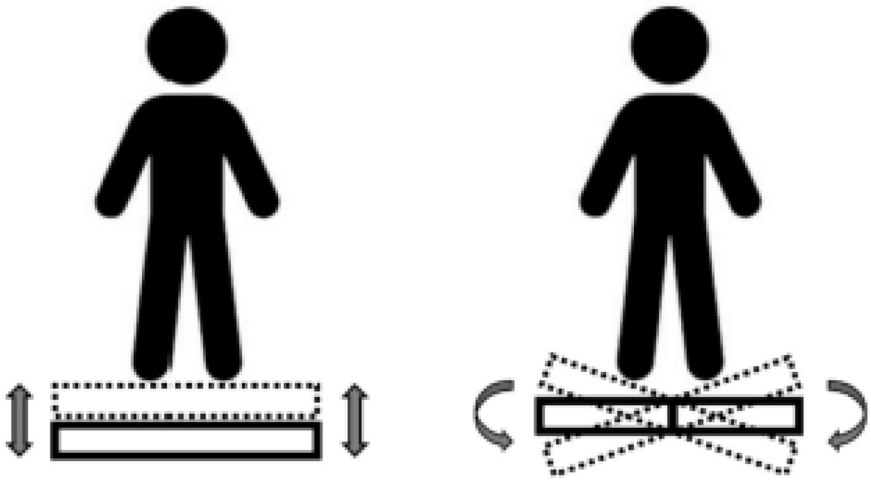

Figure 1. Vertical (**left**) versus side-alternating (**right**) vibration platform system [12].

The effects of WBV on the upper body could be understood as adaptations of the peripheral nervous system, and on the lower body as changes in cortical and subcortical functions [13,14]. It is also thought that treatment with WBV could induce abnormal neuronal beta oscillations [3]. WBV could be an effective method for treating symptoms in PD patients by using it in addition to conventional therapy. There are studies that found significant differences in motor symptoms between treatment and control groups after a single application [13,15,16]. Group differences in gait and postural parameters were mostly not significant when compared with placebo. The effects were also often not as clear-cut [13,17,18]. Although some studies indicated a positive effect of WBV on individual variables [3,19], the effect of WBV on PD symptoms does not seem to be as clear yet [20]. Many studies have already examined the effect of WBV, but most of them have poor methodological quality, making them unsuitable for quantitative analysis. Since it has been some time since the last review, it is warranted to present a new analysis of the effects of WBV, taking into account only high-quality studies. Therefore, this article addresses the effects of WBV on the motor symptoms of Parkinson's disease in studies with at least good methodological quality. Studies are included that have examined the effects of WBV on gait, balance, flexibility, mobility, freezing response, Parkinson's motor symptoms and physiological parameters.

2. Methods

Search strategy: online data base (EMBASE, PubMed, PEDro) publications up to May 2023, were searched with the search terms Parkinson, whole body vibration, review, and meta-analysis. Reviews or meta-analyses that investigated whole body vibration in Parkinson's Disease, as well as newer studies were included up to 2020.

Data extraction: data was summarized the from the existing reviews and meta-analyses (number of sessions, vibration type, vibration frequency, sets, control condition and PEDro score).

Data analysis: Only studies with a PEDro score of five or higher were included in the quantitative analysis [21]. Standardized mean differences (SMD) with 95% confidence intervals (CI) were calculated for continuous outcomes, to indicate a small (SMD < 0.3), moderate (SMD > 0.5), or large (SMD > 0.8) effect. These effects were presented as forest

plots [22], that distinguished between single session and multiple session treatment studies. Random-effects models were also used, as the effects varied across studies. I^2 was used for assessing heterogeneity between studies, because it can be calculated and compared across meta-analyses of different study sizes and types and can use different types of outcome data. The magnitude of heterogeneity was categorized into the following categories: might show low heterogeneity (I^2 = 25%), may represent moderate heterogeneity (I^2 = 50%), and may represent high heterogeneity (I^2 = 75%) [23,24]. The level of significance was set at $p < 0.05$.

Table 1 shows all studies identified through the reviews found with a PEDro score of five and higher.

Table 1. Studies identified from the reviews found (sessions = single or multiple treatment, type WBV = whole body vibration, type rWBV = randomized whole body vibration, sets in seconds, PEDro = study quality) [12,25].

Study	Sessions	Type	Frequency	Sets (Total Time)	Control Group	PEDro
Arias et al., 2009 [26]	multiple	WBV	6 Hz	5 × 60 s, 60 s rest × 12 sessions (3600 s)	Placebo	5
Corbianco et al., 2018 [27]	multiple	WBV	26 Hz	20 × 60 s, 60 s rest × 16 sessions (19,200 s)	Treadmill	5
Dincher, 2021 [28]	single	WBV	6, 12, 18 Hz	5 × 60 s, 60 s rest (300 s)	Placebo	9
Dincher et al., 2021 [29]	single	WBV	6, 12, 18 Hz	5 × 60 s, 60 s rest (300 s)	Placebo	10
Dincher and Wydra, 2021 [30]	single	WBV	6, 12, 18 Hz	5 × 60 s, 60 s rest (300 s)	Placebo	9
Ebersbach et al., 2008 [31]	multiple	WBV	25 Hz	2 × 900 s × 30 sessions (27,000 s)	Physiotherapy	5
Gaßner et al., 2014 [19]	multiple	rWBV	6 Hz	5 × 60 s, 60 s rest × 12 sessions (3600 s)	Placebo	8
Guadarrama et al., 2021 [32]	multiple	WBV	20 Hz	8 × 20 s, 30–60 s rest × 20 sessions (3200 s)	Physiotherapy, Combi	6
Haas, Turbanski et al., 2006 [13]	single	rWBV	6 Hz	5 × 60 s, 60 s rest (300 s)	Control	5
Haas, Buhlmann et al., 2006 [33]	single	rWBV	6 Hz	5 × 60 s, 60 s rest (300 s)	Control	6
Kapur et al., 2012 [34]	multiple	WBV	30–500 Hz	1 × 1800 × 28 sessions (50,400 s)	Placebo	8
Kaut et al., 2011 [35]	multiple	rWBV	6.5 Hz	5 × 60 s, 60 s rest × 3 sessions (900 s)	Placebo	7
Kaut et al., 2016 [3]	multiple	rWBV	7 Hz	5 × 60 s, 60 s rest × 4 sessions (1200 s)	Placebo	9
Koebel et al., 2015 [36]	multiple	WBV	40 Hz	1 × 1500 × 36 sessions (54,000 s)	Placebo	7
Spieß, 2014 [37]	multiple	rWBV	6–7 Hz	5 × 60 s, 60 s rest × 3 sessions (900 s)	Placebo	8
Turbanski et al., 2005 [18]	Single	rWBV	6 Hz	5 × 60 s, 60 s rest (300 s)	Control	5

In total, 16 studies were found that reached a total PEDro score of five or higher. Six of them investigated a single session of WBV [13,18,28–30,33], the rest investigated multiple sessions. Seven of the studies found investigated randomized WBV [3,13,18,19,33,35,37], the rest investigated WBV without noise. The total time of treatment ranged from 300 s [13,18,28–30,33] to 54,000 s [36]. Only three studies had a real control group without intervention [13,18,33], used a placebo treatment [3,19,26,28–30,34–37], while the rest investigated WBV compared to a conventional treatment.

3. Results

Figure 2 shows the effects of the single session treatment of WBV on balance, flexibility, freezing, reaction time and proprioception parameters as a forest plot.

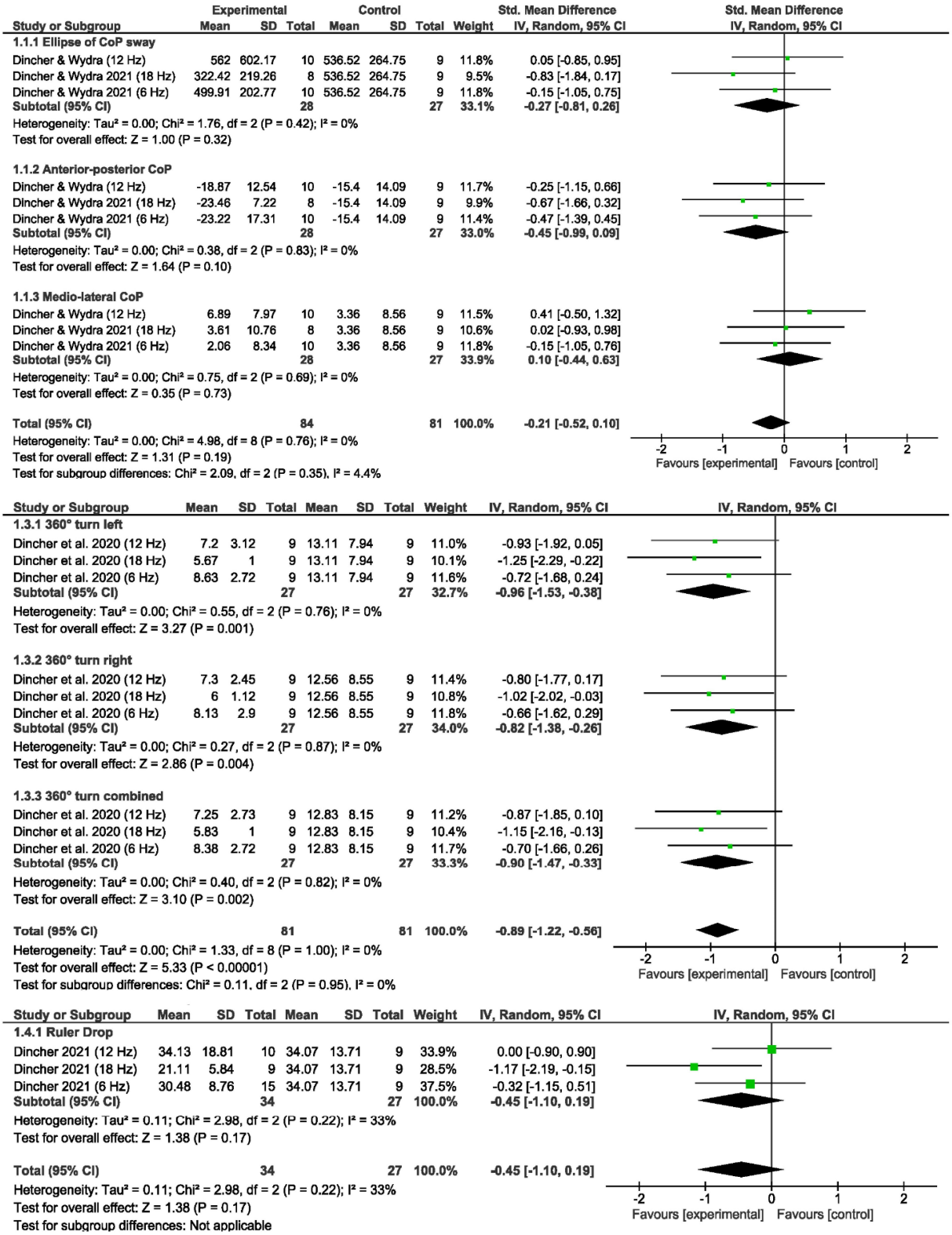

Figure 2. Effects—standardized mean differences (SMD) and their 95% confidence intervals (CI) for a single session treatment of WBV on balance, freezing, and reaction time (score minimizing assessments).

Values for heterogeneity of the subgroups/studies (I^2) range from 0% to 33% (ruler drop).

Effects range from −1.25 on 360° left turn at 18 Hz favoring the experimental group, to 0.41 on medio-lateral CoP at 12 Hz in Dincher and Wydra (2021) [30] favoring the control group. The total effect for balance shows a value of −0.21, for freezing −0.89, and reaction −0.45, all favoring the experimental group.

The following Figure 3 shows the effects of a single treatment session of WBV on flexibility and proprioception parameters as a forest plot.

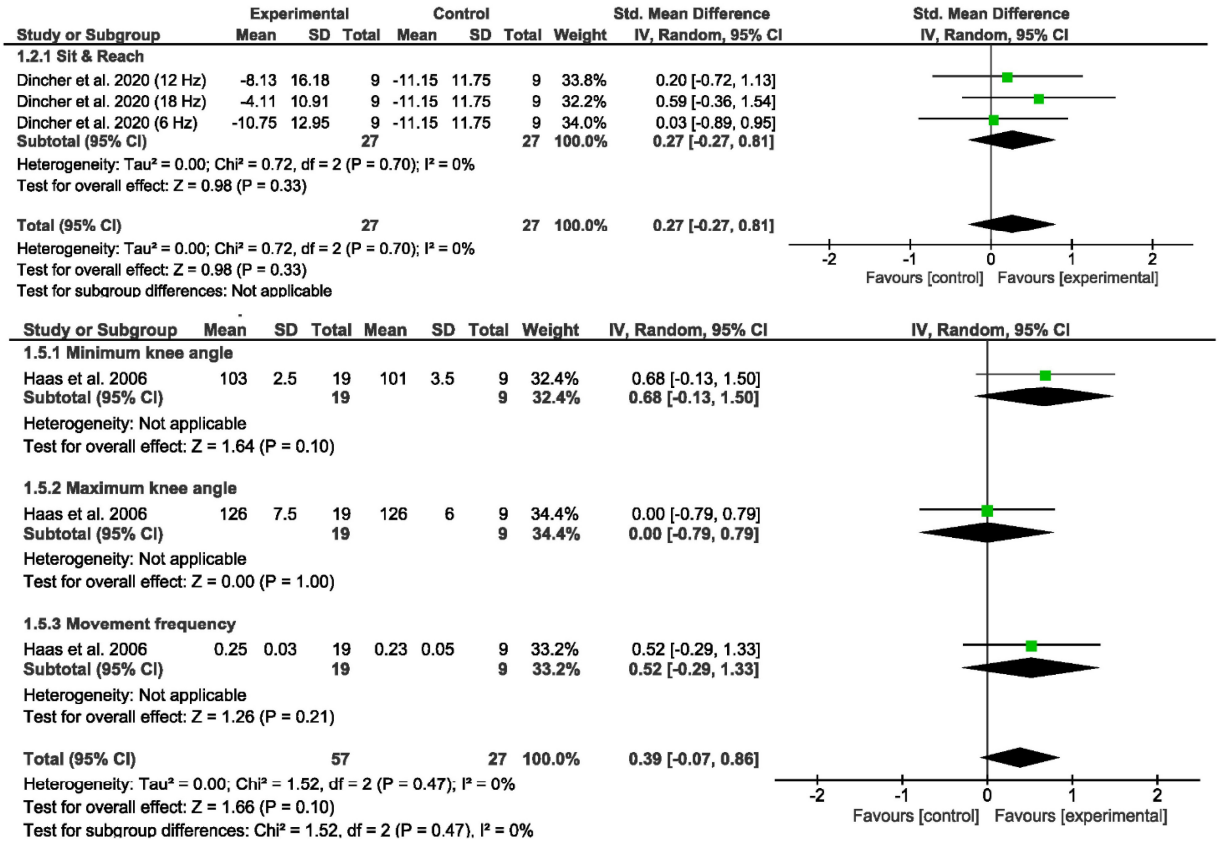

Figure 3. Effects—standardized mean differences (SMD) and their 95% confidence intervals (CI) for a single session treatment of WBV on flexibility, and proprioception parameters (score maximizing assessments).

Effects range from 0.00 for maximum knee angle to 0.68 for minimum knee angle in Haas, Buhlmann et al. (2006) [33]. Total effect for mobility is 0.27, and for proprioception 0.39, both favoring the experimental group.

The following Figures 4 and 5 shows the effects of a multiple session treatment of WBV on mobility and balance parameters as forest plots.

Values for heterogeneity of subgroups/studies range from 0% (mobility) to 82% (posturography).

Effects range from −1.68 for posturography in Ebersbach et al. (2008) [31] favoring the experimental group, to 0.26 for posturography in Kaut et al. (2016) [3] favoring the control group. The total effect for balance is −0.48 and for mobility parameters −0.39, both favoring the experimental group.

Effects range from 1.01 for functional reach, favoring the experimental group in Arias et al. (2009) [26], to −0.48 for the one leg stance, favoring the control group in Gaßner et al. (2014) [19]. The total effect for mobility is 0.75 and for balance 0.16, both favoring the experimental group.

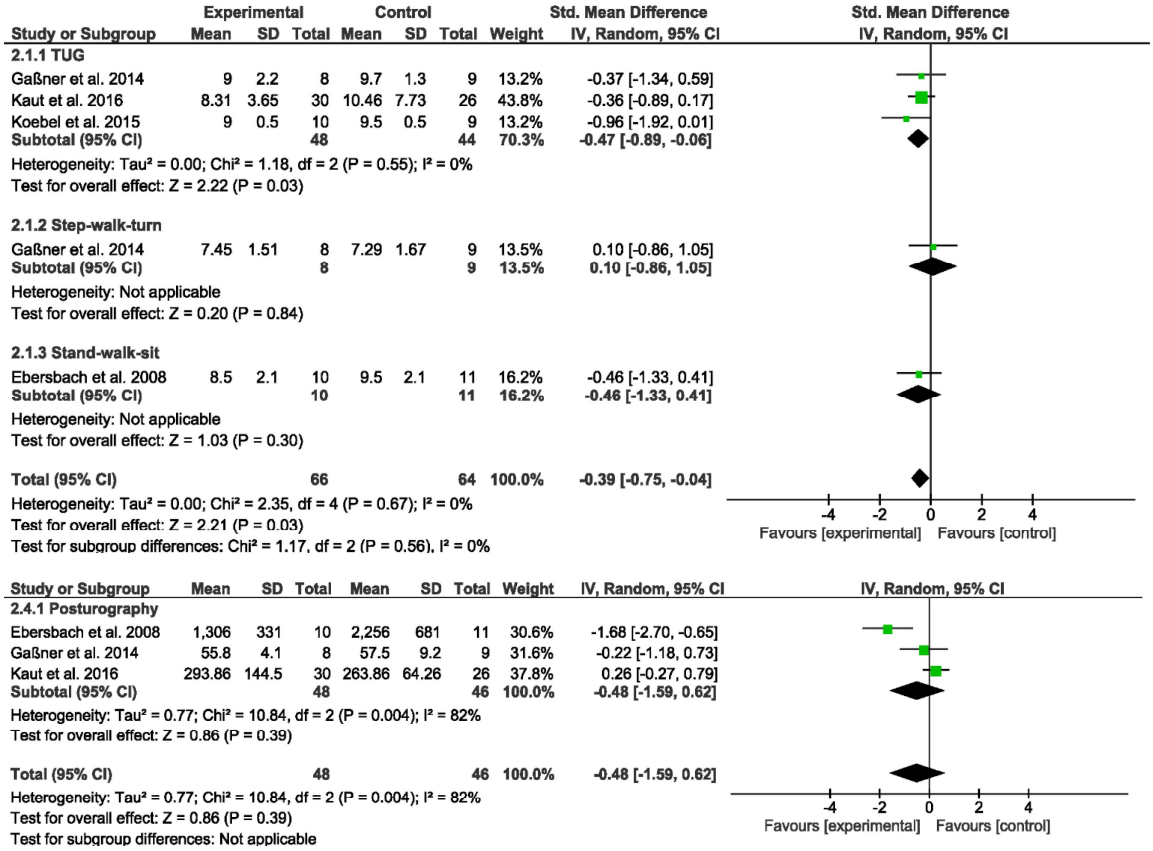

Figure 4. Effects—standardized mean differences (SMD) and their 95% confidence intervals (CI) for a multiple session treatment of WBV on mobility and balance parameters (score minimizing assessments).

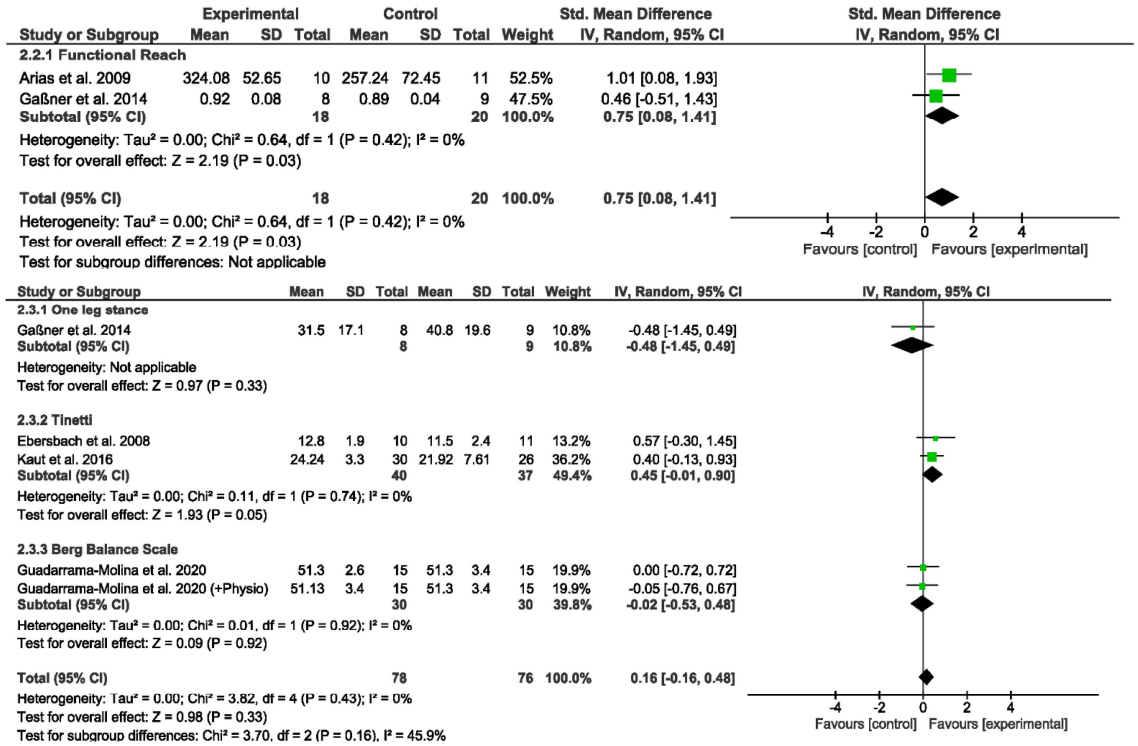

Figure 5. Effects—standardized mean differences (SMD) and their 95% confidence intervals (CI) for a multiple session treatment of WBV on mobility and balance parameters (score maximizing assessments).

The following Figure 6 shows the effects of a multiple session treatment of WBV on PD motor symptoms as a forest plot.

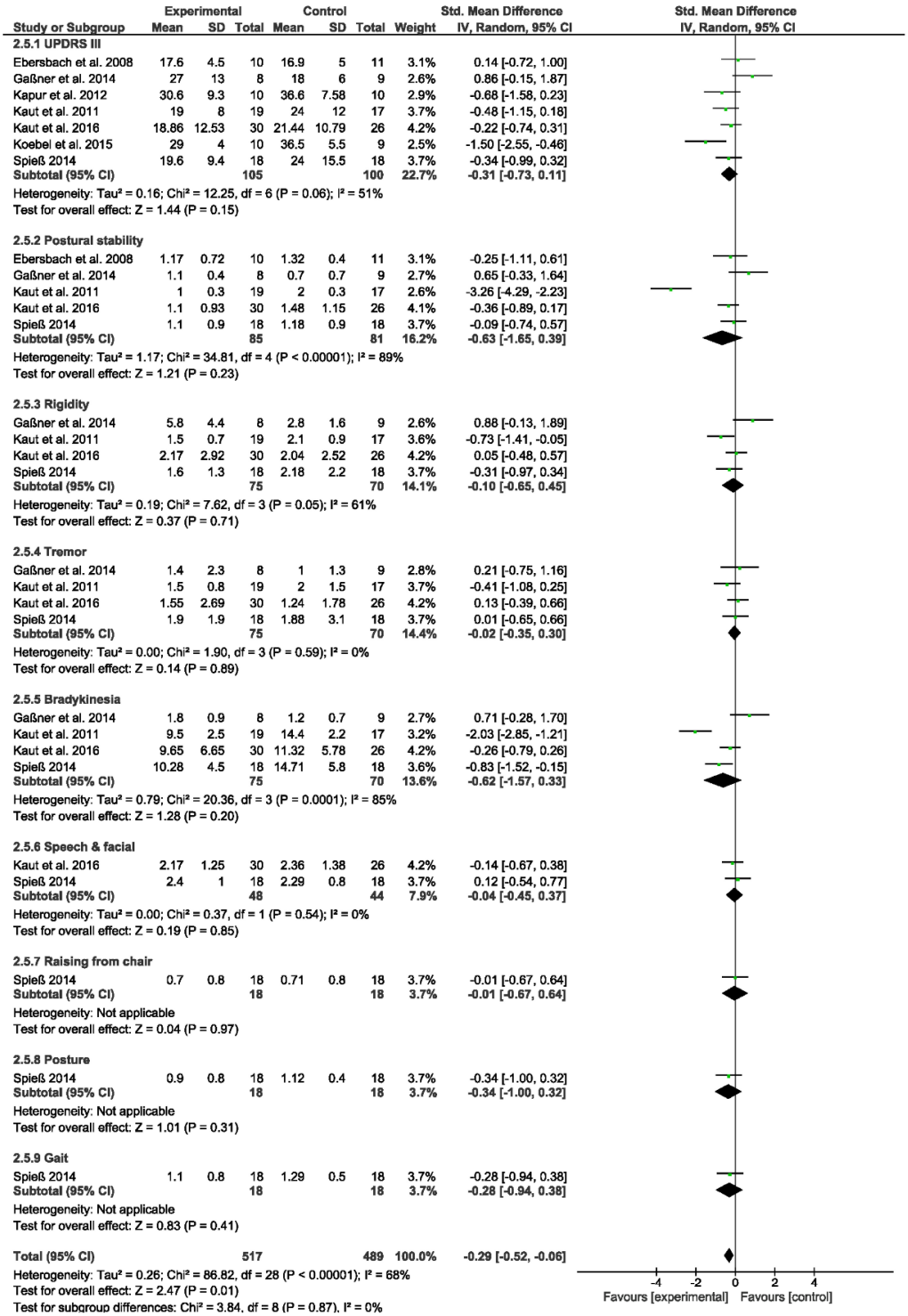

Figure 6. Effects—standardized mean differences (SMD) and their 95% confidence intervals (CI) for a multiple session treatment of WBV on PD motor symptoms.

Values for heterogeneity of subgroups/studies range from 0% to 85% (bradykinesia). Effects range from −3.26 for postural stability in Kaut et al. (2011) [35] favoring the experimental group, to 0.88 for rigidity in Gaßner et al. (2014) [19]. Total effect for PD symptoms reaches a value of −0.29, favoring the experimental group.

The following Figures 7 and 8 show the effects of a multiple session treatment of WBV on gait and physiological parameters as forest plots.

Values for heterogeneity of subgroups/studies range from 0% (gait parameters) to 94% (physiological parameters).

Effects range from −5.58 for VO2 return to baseline favoring the experimental group to 3.83 for leucine in Corbianco et al. (2018) [27] favoring the control group. The total effect for gait parameters is −0.11 favoring the experimental group, and for physiological parameters 0.52, favoring the control group.

Heterogeneity of subgroups shows values of I^2 = 0% (gait parameters) to 94% (physiology parameters). Effects range from 1.81 for VO2 average peak favoring the experimental group to −3.27 for free fatty acids favoring the control group in Corbianco et al. (2018) [27]. The total effect for gait parameters is 0.14 favoring the experimental group, and for physiology parameters −0.46 favoring the control group.

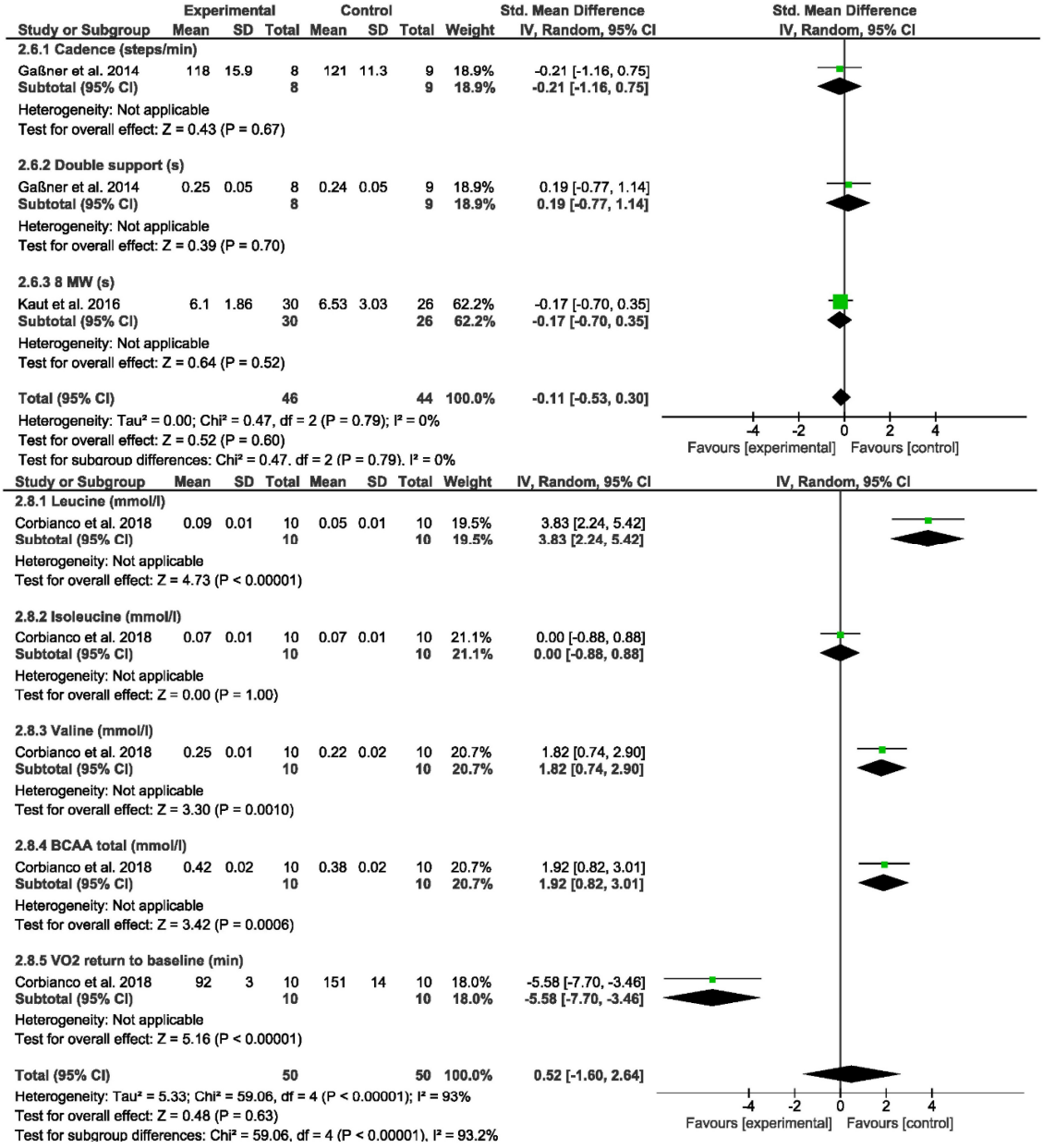

Figure 7. Effects—standardized mean differences (SMD) and their 95% confidence intervals (CI) for a multiple session treatment of WBV on gait and physiological parameters (score minimizing assessments).

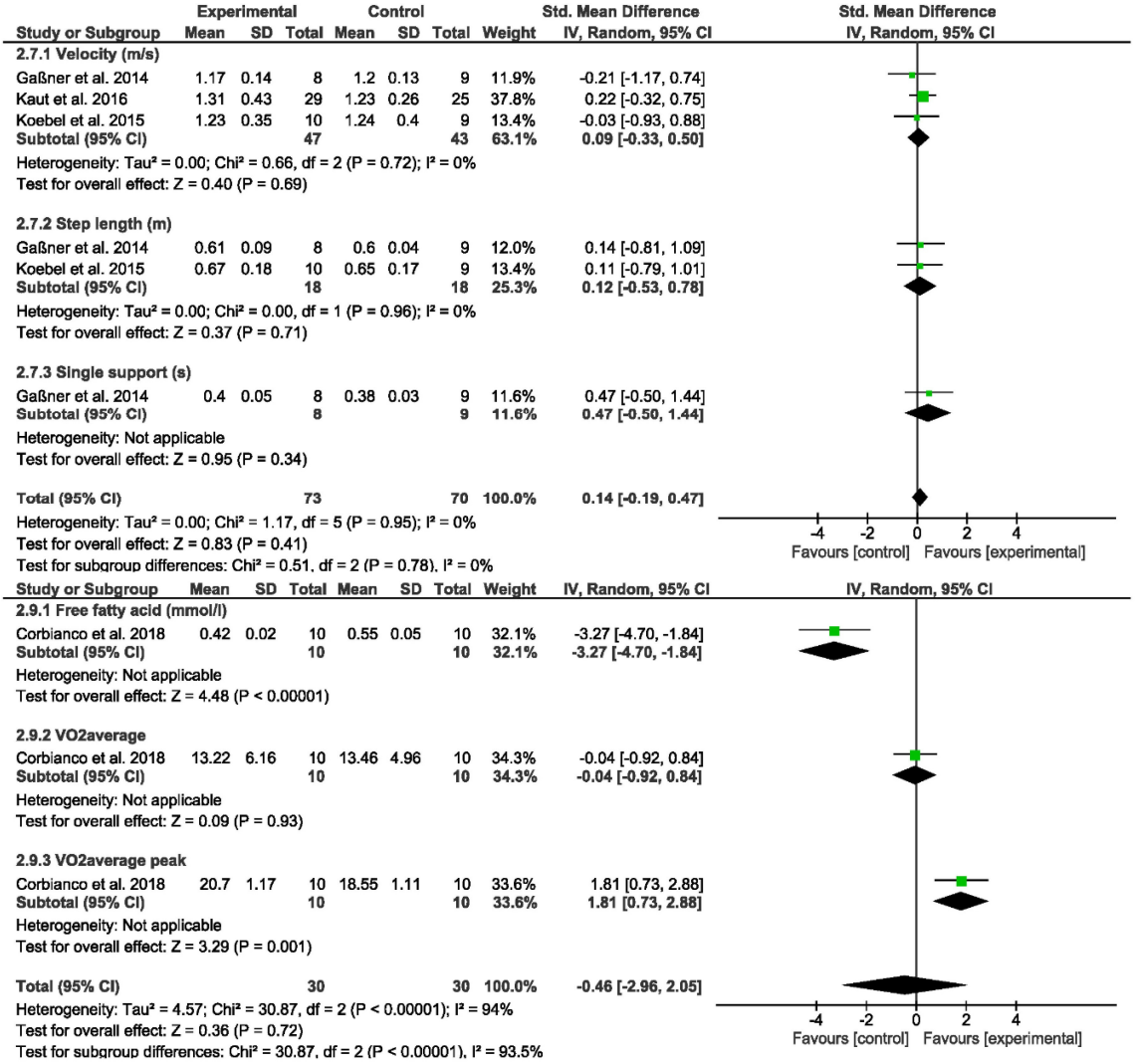

Figure 8. Effects—standardized mean differences (SMD) and their 95% confidence intervals (CI) for a multiple session treatment of WBV on gait and physiological parameters (score maximizing assessments).

4. Discussion

In the present analysis, the effects of a single application of WBV were compared with the effects of multiple applications of WBV using a meta-analysis.

In the quantitative analysis, studies had to be excluded because they either did not report control group results or did not report standard deviations, which are necessary to construct forest plots [13,18].

The studies or subgroups with a single application can be regarded as homogeneous or only very slightly heterogeneous due to their low I^2. However, these are mainly pilot studies with small sample sizes [28–30] in which different frequencies are investigated for their effectiveness. The different effect sizes for the individual parameters here range from "no effect" (ellipse of CoP sway, medio-lateral CoP, Sit and Reach) to "strong effect" (360° turn). For the ellipse of CoP sway, for the anterior–posterior displacement of the CoP, as well as for Sit and Reach, 360° turn and the ruler drop test, the strongest effects are obtained when 18 Hz is applied [30]. This could be attributed to the 18 Hz group being younger on average than the other groups or having a lower Hoehn and Yahr stage.

In the medio-lateral position of CoP, the strongest effect was obtained [30] favoring the control group. This can be attributed to the fact that this group had performed by far the worst in the pretest, but that the period between the two measurement times was possibly

not long enough. The study investigating the effects of WBV on proprioception [33] also has only a small sample size and thus also has a pilot character. Here, "no effect" is obtained for maximum knee angle to "medium effect" (minimum knee angle, movement frequency).

Comparing the studies with each other, it can be seen that the set and pause length, as well as the number of sets are identical in all of them. However, the studies partly differ in the frequency of application (6 Hz vs. 12 Hz vs. 18 Hz) and in the type of vibration: WBV in Dincher (2021) [28], Dincher et al. (2021) [29], Dincher and Wydra (2021) [30] and rWBV in Haas, Buhlmann et al. (2006) [33]. Comparing the studies with 6 Hz WBV vs. 6 Hz rWBV, small to no effects are found for balance and flexibility. Only for freezing is the effect at the upper limit of the medium range. The situation is similar for rWBV. Here too, the values for the effect sizes lie between "no effect" and "medium effect". However, since different areas were studied, it is difficult to make a concrete statement about the effectiveness of WBV versus rWBV. Here, one could imagine replicating the studies with the other type of vibration in each case, i.e., the effect on balance, flexibility, freezing, and reaction with rWBV, the effect on proprioception with WBV. The studies with multiple applications are partly very heterogeneous in the subgroups. This can be attributed to the fact that different measurement methods or durations may have been used for posturography, so that the values differ greatly between the individual studies. In the case of postural stability from UPDRS III, the mean values of the experimental groups are very similar, but one sees greater differences in the standard deviations. However, here it seems more likely that the control groups with their strongly differing mean values caused the high I^2. In the case of bradykinesia, the high heterogeneity is due to the fact that, on the one hand, the results of the complete scale and, on the other hand, the results of subscales or individual items are included in the analysis. In the case of the physiological parameters, the subgroups are also very heterogeneous, which can be attributed to the fact that very different parameters with different scales or basic mean values are combined here.

With the exception of Kaut et al. (2011) [35], Kaut et al. (2016) [3] and Spieß (2014) [37], the studies have only very small sample sizes, so that they also tend to have a pilot character. Summarizing the effects on mobility from score minimization and maximation scales, a medium effect is obtained here. This can be attributed to the fact that different test procedures were used, which may differ in quality. For example, the pull-test as used in Kaut et al. (2016) [3] has only a low test quality. The same applies to the step-walk-turn-test as used by Gaßner et al. (2014) [19], because no psychometric properties exist for this test procedure, so that these results should definitely be viewed critically.

For balance, no effect is achieved by such a summary. For motor symptoms, no effect is obtained for many individual symptoms (gait, raising from chair, speech and facial, tremor and rigidity), there is a medium effect for the total UPDRS III scale, for postural stability, bradykinesia and posture. The psychometric properties of the UPDRS III are classified as high quality [25], so that the results obtained can be judged as meaningful. The positive effect on motor symptoms can possibly be attributed to the fact that vibration training prevented or reduced MPTP-induced degradation of dopaminergic neurons in the substantia nigra and upregulated the growth factor BDNF, which an animal study was already able to depict [4]. One study found that the T reflex was suppressed during WBV, as apparently primary spindle afferents were presynaptically inhibited during WBV [38]. To this end, the latency of the muscle reflex triggered by WBV was found to be longer than the latency of the tonic muscle reflex [39]. Possibly, this would also be an explanation for the effects obtained here.

There was no effect on the various gait parameters. For the physiological parameters, there is even a small effect in favor of the control group for all parameters except VO2 return to baseline. It is known that the oxidation of BCAA in skeletal muscle is promoted by physical exercise in general. It is possible that fatty acids could be one of the regulators of BCAA catabolism and that BCAA requirements are increased by exercise [40]. It is quite possible that WBV as a form of physical exercise is not sufficient, i.e., it does not stimulate the muscles intensively enough to achieve the same effect as "classic" physical exercise.

Arias et al. (2009) [26], Gaßner et al. (2014) [19], Kaut et al. (2011; 2016) [3,34], and Spieß (2014) [37] apply the same frequencies at least between 6 and 7 Hz, so that these results can be compared on the basis of this criterion. Within this group, only Kaut et al. (2011) [35] achieve a very strong effect for bradykinesia, as well as Spieß (2014) [37] achieving a medium effect here. For rigidity and postural stability, Kaut et al. (2011) [35] achieve very strong effects. In the comparison of these studies, however, it is noticeable that only Arias et al. (2009) [26] works with WBV, the other studies are mentioned with rWBV. Even though Arias et al. (2009) [26] achieve a strong effect on mobility, it must be taken into account that the other studies examined many more parameters. If one compares the rWBV studies within this group, one sees here that Arias et al. (2009) [25] and Gaßner et al. (2014) [19] only differ in the type of vibration, the duration of application in seconds is identical. In the case of Gaßner et al. (2014) [19], the effects in the area of mobility are only slight, whereas in the case of Arias et al. (2009) [26], the effect here is very strong. In contrast, the effects in Gaßner et al. (2014) [19] on motor symptoms in PD are predominantly in the high range. It is interesting that these low frequencies achieve such good effects, which contrasts with the statements that frequencies below 20 Hz would be ineffective because of the internal organs' own vibrations, which could be attributed to the fact that muscles, joints and bones can absorb these vibrations [41–43]. Likewise, beta oscillations of the basal ganglia in the range of 15 to 13 Hz could trigger abnormal functions such as tremor or bradykinesia, which is why it could be assumed that frequencies below 15 Hz would not be effective [16].

The studies of Kaut et al. (2011) [35], Kaut et al. (2016) [3] and Spieß (2014) [37] differ only slightly in the application duration in seconds for the same type of vibration, so that these results also become comparable. Kaut et al. (2016) [3] achieve weak effects for mobility and balance, as well as for the UPDRS III scales. In contrast, Kaut et al. (2011) [35] achieve strong effects for the UPDRS III scales, and the values for this are in the lower range for Spieß (2014) [37]. The small effect in Kaut et al. (2016) [3] in the TUG could be due to the fact that their experimental group already performed very well in the pretest compared to the other studies. Koebel et al. (2015) [36] have the highest total application time of 54,000 s, but achieve little or no effect. Fatigue and poor performance may be a sign of overtraining, which appears to be a maladaptive response to excessive training without adequate recovery that leads to dysfunction of multiple body systems, including neurological [44]. Exercising too often and too intensively can lead to overload. Therefore, even with a gentle form of training such as WBV, you should try to ensure that the training sessions are not too long and that there are sufficient breaks between the sets or between the training sessions.

Furthermore, it is not known to what extent the study participants continued their conventional therapy (medication, physiotherapy) in parallel with WBV, so that in all the studies listed here this must be taken into account, meaning that the effect achieved is not necessarily 100% attributable to the treatment with WBV.

Additionally, a placebo effect cannot be ruled out. Only Haas, Buhlmann et al. (2006) [33] conduct their study with a real control group, in which only a low overall effect is found. The studies by Dincher (2021) [28], Dincher et al. (2020) [29] and Dincher and Wydra (2021) [30] work with a placebo group for control, but the strong effect clearly speaks for the experimental groups. In the studies with placebo as a control condition by Arias et al. (2009) [26], Gassner et al. (2014) [19], Kaut et al. (2011; 2016) [3,35], Koebel et al. (2015) [36], and Spieß (2014) [37], these effects tend to be in the low range. Thus, it is to be discussed how strong this placebo effect can be.

At this point it would be interesting to continue the studies to find out which application frequency, which type of vibration, which set duration and frequency achieve the strongest effects. More high-quality studies should follow here, or the studies could be replicated with the other type of vibration in each case, with several frequencies and set durations/frequencies compared with each other at the same time. Care must be taken to ensure that participants suspend their conventional treatment for the period of study par-

ticipation. In addition to a real control group, a placebo group should also be investigated in follow-up studies.

5. Conclusions

The effects of single versus multiple applications of WBV and rWBV are mixed. The effect on freezing is particularly strong with single use, and on postural stability and bradykinesia with multiple use. It does not seem to make much difference whether WBV or rWBV is used for training. The amount of application frequency also does not seem to play a major role. It is even possible that it is best if the frequency is individually adjusted to the well-being of the respective person. Therefore, it would be important to conduct further studies to also investigate the underlying mechanisms of WBV/rWBV that cause a change in motor performance or symptomatology.

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