

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

Andrea Dincher 1,20

- <sup>1</sup> Institute for Sports Sciences, RPTU Kaiserslautern-Landau, Fortstr. 7, 76829 Landau, Germany; dincher@uni-landau.de
- <sup>2</sup> Institute of Sports Sciences, Saarland University, 66123 Saarbrücken, Germany

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

## 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



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**Copyright:** © 2023 by the author. Licensee MDPI, Basel, Switzerland. This article is an open access article distributed under the terms and conditions of the Creative Commons Attribution (CC BY) license (https:// creativecommons.org/licenses/by/ 4.0/). 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 metaanalyses (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<sup>2</sup> 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<sup>2</sup> = 25%), may represent moderate heterogeneity (I<sup>2</sup> = 50%), and may represent high heterogeneity (I<sup>2</sup> = 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	Туре	Frequency	Sets (Total Time)	Control Group	PEDro
Arias et al., 2009 [26]	multiple	WBV	6 Hz	$5 \times 60$ s, $60$ s rest $\times$ 12 sessions (3600 s)	Placebo	5
Corbianco et al., 2018 [27]	multiple	WBV	26 Hz	$20 \times 60 \text{ s}, 60 \text{ s rest} \times 16 \text{ sessions} (19,200 \text{ s})$	Treadmill	5
Dincher, 2021 [28]	single	WBV	6, 12, 18 Hz	$5 \times 60$ s, $60$ s rest (300 s)	Placebo	9
Dincher et al., 2021 [29]	single	WBV	6, 12, 18 Hz	$5 \times 60$ s, $60$ s rest (300 s)	Placebo	10
Dincher and Wydra, 2021 [30]	single	WBV	6, 12, 18 Hz	$5 \times 60$ 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	$5 \times 60$ s, $60$ s rest $\times$ 12 sessions (3600 s)	Placebo	8
Guadarrama et al., 2021 [32]	multiple	WBV	20 Hz	$8 \times 20$ s, 30–60 s rest $\times$ 20 sessions (3200 s)	Physiotherapy, Combi	6
Haas, Turbanski et al., 2006 [13]	single	rWBV	6 Hz	$5 \times 60$ s, $60$ s rest (300 s)	Control	5
Haas, Buhlmann et al., 2006 [33]	single	rWBV	6 Hz	$5 \times 60$ s, $60$ s rest (300 s)	Control	6
Kapur et al., 2012 [34]	multiple	WBV	30–500 Hz	$1 \times 1800 \times 28$ sessions (50,400 s)	Placebo	8
Kaut et al., 2011 [35]	multiple	rWBV	6.5 Hz	$5 \times 60$ s, $60$ s rest $\times$ 3 sessions (900 s)	Placebo	7
Kaut et al., 2016 [3]	multiple	rWBV	7 Hz	$5 \times 60$ s, $60$ s rest $\times$ 4 sessions (1200 s)	Placebo	9
Koebel et al., 2015 [36]	multiple	WBV	40 Hz	$\begin{array}{c} 1\times1500\times36 \text{ sessions} \\ (54,000 \text{ s}) \end{array}$	Placebo	7
Spieß, 2014 [37]	multiple	rWBV	6–7 Hz	$5 \times 60$ s, $60$ s rest $\times$ 3 sessions (900 s)	Placebo	8
Turbanski et al., 2005 [18]	Single	rWBV	6 Hz	$5 \times 60$ 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.

	Expe	erimen	tal	Co	ontrol			Std. Mean Difference	Std. Mean Difference
Study or Subgroup	Mean	SD	Total	Mean	SD	Total	Weight	IV, Random, 95% Cl	IV, Random, 95% CI
2.1.1 TUG									
Gaßner et al. 2014	9	2.2	8	9.7	1.3	9	13.2%	-0.37 [-1.34, 0.59]	
Kaut et al. 2016	8.31	3.65	30	10.46	7.73	26	43.8%	-0.36 [-0.89, 0.17]	
Koebel et al. 2015	9	0.5	10	9.5	0.5	9	13.2%	-0.96 [-1.92, 0.01]	
Subtotal (95% CI)			48			44	70.3%	-0.47 [-0.89, -0.06]	$\bullet$
Heterogeneity: Tau <sup>2</sup> = 0	.00; Chi	² = 1.18	8, df = 2	2 (P = 0.	55); l²	= 0%			
Test for overall effect: Z	: = 2.22 (	P = 0.0	)3)						
2.1.2 Step-walk-turn									
Gaßner et al. 2014	7.45	1.51	8	7.29	1.67	9	13.5%	0.10 [-0.86, 1.05]	
Subtotal (95% CI)			8			9	13.5%	0.10 [-0.86, 1.05]	+
Heterogeneity: Not appl	licable								
Test for overall effect: Z	: = 0.20 (	P = 0.8	84)						
2.1.3 Stand-walk-sit									
Ebersbach et al. 2008	8.5	2.1	10	9.5	2.1	11	16.2%	-0.46 [-1.33, 0.41]	
Subtotal (95% CI)			10			11	16.2%	-0.46 [-1.33, 0.41]	◆
Heterogeneity: Not appl	licable								
Test for overall effect: Z	= 1.03 (	P = 0.3	80)						
Total (95% CI)			66			64	100.0%	-0.39 [-0.75, -0.04]	•
Heterogeneity: Tau <sup>2</sup> = 0	.00; Chi	2 = 2.35	i, df = 4	I (P = 0.	67); l²	= 0%		-	
Test for overall effect: Z	: = 2.21 (	P = 0.0	3)						Favours (experimental) Eavours (control)
Test for subgroup different	ences: C	;hi² = 1.	.17, df	= 2 (P =	0.56).	l² = 0%			
Study or Subgroup	Mean	SD	Total	Mean	S	) Tota	Weight	t IV, Random, 95% CI	IV, Random, 95% Cl
2.4.1 Posturography									
Ebersbach et al. 2008	1,306	331	10	2,256	681	1 11	30.6%	-1.68 [-2.70, -0.65]	
Gaßner et al. 2014	55.8	4.1	8	57.5	9.2	2 9	31.6%	-0.22 [-1.18, 0.73]	
Kaut et al. 2016	293.86	144.5	30	263.86	64.26	5 26	37.8%	0.26 [-0.27, 0.79]	-
Subtotal (95% CI)			48			46	100.0%	-0.48 [-1.59, 0.62]	-
Heterogeneity: Tau <sup>2</sup> = 0. Test for overall effect: Z	77; Chi² : = 0.86 (P	= 10.84 ' = 0.39	, df = 2 )	(P = 0.0	04); l²	= 82%			
Total (95% CI)			48			46	100.0%	-0.48 [-1.59, 0.62]	
Heterogeneity: Tau <sup>2</sup> = 0.	77: Chi <sup>2</sup> :	= 10.84	. df = 2	(P = 0.0)	04); l²	= 82%			
Test for overall effect: Z	= 0.86 (P	= 0.39	)	. 5.0	,, .				
Test for subgroup differe	nces: No	t applic	able						Favours [experimental] Favours [control]

**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).

	Expe	eriment	al		Co	ntrol			Std.	Mean Difference	Std. Mean Difference
Study or Subgroup	Mean	SD	Total	Me	an	SD	Total	Weig	ht IV	, Random, 95% Cl	IV, Random, 95% Cl
2.2.1 Functional React	۱										
Arias et al. 2009	324.08	52.65	10	257	.24	72.45	11	52.5	5%	1.01 [0.08, 1.93]	
Gaßner et al. 2014	0.92	0.08	8	0.	.89	0.04	9	47.5	%	0.46 [-0.51, 1.43]	
Subtotal (95% CI)			18				20	100.0	9%	0.75 [0.08, 1.41]	◆
Heterogeneity: Tau <sup>2</sup> = 0	.00; Chi	² = 0.64	, df = 1	l (P =	0.42	); l² = (	)%				
Test for overall effect: Z	= 2.19	(P = 0.0	3)								
Total (95% CI)			18				20	100.0	)%	0.75 [0.08, 1.41]	◆
Heterogeneity: Tau <sup>2</sup> = 0	.00; Chi	² = 0.64	, df = 1	I (P =	0.42	); I² = (	)%			_	
Test for overall effect: Z	= 2.19	(P = 0.0	3)								-4 -2 0 2 4 Eavours [control] Eavours [experimental]
Test for subgroup different	ences: N	lot appl	icable								
Study or Subgroup			Mean	SD	Tota	Mea	n SD	Total	Weight	IV, Random, 95% Cl	IV, Random, 95% Cl
2.3.1 One leg stance											
Gaßner et al. 2014			31.5	17.1	8	3 40.	8 19.6	9	10.8%	-0.48 [-1.45, 0.49]	
Subtotal (95% CI)					1	3		9	10.8%	-0.48 [-1.45, 0.49]	-
Heterogeneity: Not applicat		0.00									
Test for overall effect: $Z = 0$	).97 (P =	0.33)									
2.3.2 Tinetti											
Ebersbach et al. 2008			12.8	1.9	10	) 11.	5 2.4	11	13.2%	0.57 [-0.30, 1.45]	+
Kaut et al. 2016			24.24	3.3	30	21.9	2 7.61	26	36.2%	0.40 [-0.13, 0.93]	<b>T</b>
Subtotal (95% CI)					40	)		37	49.4%	0.45 [-0.01, 0.90]	•
Heterogeneity: Tau <sup>2</sup> = 0.00	; Chi <sup>2</sup> = 0	0.11, df =	1 (P =	0.74);	$l^2 = 0^2$	%					
lest for overall effect: Z = 1	.93 (P =	0.05)									
2.3.3 Berg Balance Scale											
Guadarrama-Molina et al. 2	2020		51.3	2.6	15	5 51.	3 3.4	15	19.9%	0.00 [-0.72, 0.72]	+
Guadarrama-Molina et al. 2	2020 (+PI	nysio)	51.13	3.4	15	5 51.	3 3.4	15	19.9%	-0.05 [-0.76, 0.67]	<u>+</u>
Subtotal (95% CI)					30	)		30	39.8%	-0.02 [-0.53, 0.48]	•
Heterogeneity: Tau <sup>2</sup> = 0.00	; Chi <sup>2</sup> = 0	.01, df =	1 (P =	0.92);	l <sup>2</sup> = 0 <sup>6</sup>	%					
lest for overall effect: $Z = 0$	).09 (P =	0.92)									
Total (95% CI)					78	3		76	100.0%	0.16 [-0.16, 0.48]	•
Heterogeneity: Tau <sup>2</sup> = 0.00	; Chi² = 3	.82, df =	4 (P =	0.43);	$ ^{2} = 0^{4}$	%					
Test for overall effect: Z = 0	.98 (P =	0.33)	•	.,,							-4 -2 0 2 4 Eavours [control] Eavours [avoerimental]
Test for subgroup differenc	es: Chi² =	= 3.70, df	f = 2 (P	= 0.16	5), <b> </b> ² =	45.9%					ravous (control] ravous [experimental]

**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).

Std. Mean Difference Experimental Std. Mean Difference Contro Study or Subgroup 2.5.1 UPDRS III SD Total Mean SD Total Weight IV, Random, 95% CI IV, Random, 95% CI Mean Ebersbach et al. 2008 17.6 4.5 13 10 16.9 5 11 3.1% 0.14 [-0.72, 1.00] Gaßner et al. 2014 18 6 9 2.6% 0.86 [-0.15, 1.87] 27 8 7.58 12 2.9% 3.7% -0.68 [-1.58, 0.23] -0.48 [-1.15, 0.18] Kapur et al. 2012 30.6 9.3 10 36.6 10 17 24 19 Kaut et al. 2011 19 8 30 21.44 10.79 10 36.5 5.5 26 9 Kaut et al. 2016 18.86 12.53 4.2% -0.22 [-0.74. 0.31] 29 2.5% -1.50 [-2.55, -0.46] Koebel et al. 2015 -0.34 [-0.99, 0.32] -0.31 [-0.73, 0.11] Spieß 2014 Subtotal (95% CI) 19.6 9.4 18 105 24 15.5 18 3.7% 100 22.7% Heterogeneity: Tau<sup>2</sup> = 0.16; Chi<sup>2</sup> = 12.25, df = 6 (P = 0.06); |<sup>2</sup> = 51% Test for overall effect: Z = 1.44 (P = 0.15) 2.5.2 Postural stability Ebersbach et al. 2008 1.17 0.72 10 -0.25 [-1.11, 0.61] 1.32 0.4 11 3.1% 0.4 0.3 0.7 0.3 2.7% 2.6% Gaßner et al. 2014 1.1 8 19 0.7 9 0.65 [-0.33, 1.64] Kaut et al. 2011 1 2 17 -3.26 [-4.29, -2.23] 26 18 81 -0.36 [-0.89, 0.17] -0.09 [-0.74, 0.57] -0.63 [-1.65, 0.39] 30 18 Kaut et al. 2016 1.1 0.93 1.48 1.15 4.1% Spieß 2014 Subtotal (95% CI) 0.9 1.18 0.9 1.1 3.7% 85 16.2% Heterogeneity: Tau<sup>2</sup> = 1.17; Chi<sup>2</sup> = 34.81, df = 4 (P < 0.00001); l<sup>2</sup> = 89% Test for overall effect: Z = 1.21 (P = 0.23) 2.5.3 Rigidity Gaßner et al. 2014 2.8 2.1 1.6 0.9 5.8 2.6% 0.88 [-0.13, 1.89] 0.7 19 17 3.6% Kaut et al. 2011 1.5 -0.73 [-1.41. -0.05] 30 2.04 18 2.18 75 Kaut et al. 2016 2.17 2.92 2.52 26 4.2% 0.05 [-0.48, 0.57] Spieß 2014 Subtotal (95% CI) 18 3.7% 14.1% -0.31 [-0.97, 0.34] -0.10 [-0.65, 0.45] 1.6 1.3 2.2 70 Heterogeneity: Tau<sup>2</sup> = 0.19; Chi<sup>2</sup> = 7.62, df = 3 (P = 0.05); l<sup>2</sup> = 61% Test for overall effect: Z = 0.37 (P = 0.71) 2.5.4 Tremor Gaßner et al. 2014 1.3 1.5 0.21 [-0.75, 1.16] 1.4 2.3 2.8% 1 3.7% Kaut et al. 2011 1.5 0.8 19 2 17 -0.41 [-1.08, 0.25] 0.13 [-0.39, 0.66] 30 18 75 4.2% 3.7% Kaut et al. 2016 2.69 1.24 1.78 26 1.55 18 0.01 [-0.65, 0.66 Spieß 2014 1.9 1.9 1.88 3.1 Subtotal (95% CI) 70 -0.02 [-0.35, 0.30] Heterogeneity: Tau<sup>2</sup> = 0.00; Chi<sup>2</sup> = 1.90, df = 3 (P = 0.59); l<sup>2</sup> = 0% Test for overall effect: Z = 0.14 (P = 0.89) 2.5.5 Bradykinesia Gaßner et al. 2014 1.2 0.71 [-0.28, 1.70] 1.8 0.9 8 0.7 2.7% 9 19 14.4 30 11.32 18 14.71 75 17 26 18 70 2.2 5.78 3.2% 4.2% -2.03 [-2.85, -1.21] -0.26 [-0.79, 0.26] Kaut et al. 2011 9.5 2.5 Kaut et al. 2016 9.65 6.65 Spieß 2014 Subtotal (95% CI) 10.28 4.5 5.8 3.6% -0.83 [-1.52, -0.15] 13.6% -0.62 [-1.57, 0.33] Heterogeneity: Tau<sup>2</sup> = 0.79; Chi<sup>2</sup> = 20.36, df = 3 (P = 0.0001); l<sup>2</sup> = 85% Test for overall effect: Z = 1.28 (P = 0.20) 2.5.6 Speech & facial Kaut et al. 2016 2.17 1.25 30 2.36 1.38 26 4.2% -0.14 [-0.67, 0.38] 3.7% 7.9% Spieß 2014 Subtotal (95% CI) 1 18 2.29 48 0.8 18 44 0.12 [-0.54, 0.77] 2.4 Heterogeneity: Tau<sup>2</sup> = 0.00; Chi<sup>2</sup> = 0.37, df = 1 (P = 0.54);  $I^2 = 0\%$ Test for overall effect: Z = 0.19 (P = 0.85) 2.5.7 Raising from chair Spieß 2014 0.7 0.8 18 0.71 0.8 18 3.7% 3.7% -0.01 [-0.67. 0.64] Subtotal (95% CI) 18 -0.01 [-0.67, 0.64] Heterogeneity: Not applicable Test for overall effect: Z = 0.04 (P = 0.97) 2.5.8 Posture Spieß 2014 18 1.12 18 0.9 0.8 0.4 18 18 3.7% 3.7% -0.34 [-1.00, 0.32] -0.34 [-1.00, 0.32] Subtotal (95% CI) Heterogeneity: Not applicable Test for overall effect: Z = 1.01 (P = 0.31) 2.5.9 Gait Spieß 2014 Subtotal (95% CI) -0.28 [-0.94, 0.38] -0.28 [-0.94, 0.38] 0.8 1.29 1.1 18 0.5 18 3.7% 3.7% 18 18 Heterogeneity: Not applicable Test for overall effect: Z = 0.83 (P = 0.41) Total (95% CI) 517 489 100.0% -0.29 [-0.52, -0.06] Heterogeneity: Tau<sup>2</sup> = 0.26; Chi<sup>2</sup> = 86.82, df = 28 (P < 0.00001); l<sup>2</sup> = 68% Test for overall effect: Z = 2.47 (P = 0.01) 7 -5 4 5 Favours fexp Favours [control] Test for subgroup differences: Chi<sup>2</sup> = 3.84, df = 8 (P = 0.87), l<sup>2</sup> = 0%

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).

	Expe	eriment	al	C	ontrol			Std. Mean Difference	Std. Mean Difference
Study or Subgroup	Mean	SD	Total	Mean	SD	Total	Weight	IV, Random, 95% CI	IV, Random, 95% Cl
2.7.1 Velocity (m/s)									
Gaßner et al. 2014	1.17	0.14	8	1.2	0.13	9	11.9%	-0.21 [-1.17, 0.74]	
Kaut et al. 2016	1.31	0.43	29	1.23	0.26	25	37.8%	0.22 [-0.32, 0.75]	
Koebel et al. 2015 Subtotal (95% Cl)	1.23	0.35	10 47	1.24	0.4	9 43	13.4% 63.1%	-0.03 [-0.93, 0.88] 0.09 [-0.33, 0.50]	•
Heterogeneity: Tau <sup>2</sup> =	0.00; Ch	ni² = 0.6	6, df =	2 (P =	0.72);	l² = 0%			
Test for overall effect:	Z = 0.40	(P = 0.	69)						
2.7.2 Step length (m)									
Gaßner et al. 2014	0.61	0.09	8	0.6	0.04	9	12.0%	0.14 [-0.81, 1.09]	_ <del>_</del>
Koebel et al. 2015	0.67	0.18	10	0.65	0.17	9	13.4%	0.11 [-0.79, 1.01]	<u>+</u>
Subtotal (95% CI)			18			18	25.3%	0.12 [-0.53, 0.78]	•
Heterogeneity: Tau <sup>2</sup> = Test for overall effect:	0.00; Ch Z = 0.37	ni² = 0.0 ' (P = 0.	0, df = 71)	1 (P =	0.96);	l² = 0%			
2.7.3 Single support	(s)								
Gaßner et al. 2014 Subtotal (95% Cl)	0.4	0.05	8 8	0.38	0.03	9 9	11.6% 11.6%	0.47 [-0.50, 1.44] 0.47 [-0.50, 1.44]	<b>★</b>
Heterogeneity: Not ap	plicable								
Test for overall effect:	Z = 0.95	(P = 0.	34)						
Total (95% CI)			73			70	100.0%	0.14 [-0.19, 0.47]	<b>•</b>
Heterogeneity: Tau <sup>2</sup> =	0.00; Ch	ni² = 1.1	7, df =	5 (P =	0.95);	$l^2 = 0\%$		-	
									4 2 2 4
Test for overall effect:	Z = 0.83	(P = 0.	41)	- 1	,.				-4 -2 0 2 4 Fayours [control] Fayours [experimental]
Test for overall effect: Test for subgroup diffe	Z = 0.83 erences:	(P = 0. Chi² = 0	41) ).51, d	f = 2 (P	= 0.78	3),  ² = (	)%		-4 -2 0 2 4 Favours [control] Favours [experimental]
Test for overall effect: Test for subgroup diffe Study or Subgroup	Z = 0.83 erences: Mean	(P = 0. Chi <sup>2</sup> = 0 SD	41) ).51, d Total	f = 2 (P Mean	= 0.78 SD	3),  ² = ( Total	)% Weight	IV, Random, 95% Cl	-4 -2 0 2 4 Favours [control] Favours [experimental] IV, Random, 95% Cl
Test for overall effect: Test for subgroup diffe Study or Subgroup 2.9.1 Free fatty acid (	Z = 0.83 erences: <u>Mean</u> mmol/l)	(P = 0. Chi <sup>2</sup> = 0 SD	41) ).51, d Total	f = 2 (P Mean	= 0.78 SD	3),  ² = ( Total	)% Weight	IV, Random, 95% Cl	-4 -2 0 2 4 Favours [control] Favours [experimental] IV, Random, 95% Cl
Test for overall effect: Test for subgroup diffe Study or Subgroup 2.9.1 Free fatty acid ( Corbianco et al. 2018 Subtotal (95% CI)	Z = 0.83 erences: <u>Mean</u> mmol/l) 0.42	(P = 0. Chi <sup>2</sup> = 0 <u>SD</u> 0.02	41) ).51, d <u>Total</u> 10 10	f = 2 (P <u>Mean</u> 0.55	= 0.78 SD 0.05	3),   <sup>2</sup> = ( <u>Total</u> 10 <b>10</b>	0% Weight 32.1% 32.1%	IV, Random, 95% Cl -3.27 [-4.70, -1.84] -3.27 [-4.70, -1.84]	-4 -2 0 2 4 Favours [control] Favours [experimental] IV, Random, 95% Cl
Test for overall effect: Test for subgroup diffe Study or Subgroup 2.9.1 Free fatty acid ( Corbianco et al. 2018 Subtotal (95% CI) Heterogeneity: Not app	Z = 0.83 erences: <u>Mean</u> mmol/l) 0.42 plicable	(P = 0. Chi <sup>2</sup> = 0 <u>SD</u> 0.02	41) ).51, d <u>Total</u> 10 10	f = 2 (P <u>Mean</u> 0.55	= 0.78 SD 0.05	3),  ² = ( <u>Total</u> 10 <b>10</b>	0% <u>Weight</u> 32.1% 32.1%	IV, Random, 95% Cl -3.27 [-4.70, -1.84] -3.27 [-4.70, -1.84]	-4 -2 0 2 4 Favours [control] Favours [experimental] IV, Random, 95% Cl
Test for overall effect: Test for subgroup diffe Study or Subgroup 2.9.1 Free fatty acid ( Corbianco et al. 2018 Subtotal (95% Cl) Heterogeneity: Not app Test for overall effect:	Z = 0.83 erences: <u>Mean</u> mmol/l) 0.42 plicable Z = 4.48	(P = 0. Chi <sup>2</sup> = 0 <u>SD</u> 0.02 (P < 0.0	41) 0.51, d <u>Total</u> 10 10	f = 2 (P <u>Mean</u> 0.55	= 0.78 <u>SD</u> 0.05	3),  ² = ( <u>Total</u> 10 <b>10</b>	0% Weight 32.1% 32.1%	IV, Random, 95% Cl -3.27 [-4.70, -1.84] -3.27 [-4.70, -1.84]	-4 -2 0 2 4 Favours [control] Favours [experimental] IV, Random, 95% Cl
Test for overall effect: Test for subgroup diffe Study or Subgroup 2.9.1 Free fatty acid ( Corbianco et al. 2018 Subtotal (95% Cl) Heterogeneity: Not app Test for overall effect:	Z = 0.83 erences: <u>Mean</u> mmol/l) 0.42 plicable Z = 4.48	(P = 0. Chi <sup>2</sup> = 0 SD 0.02 (P < 0.0	41) ).51, d <u>Total</u> 10 10 00001)	f = 2 (P <u>Mean</u> 0.55	= 0.78 SD 0.05	3),   <sup>2</sup> = ( <u>Total</u> 10 <b>10</b>	0% Weight 32.1% 32.1%	IV, Random, 95% Cl -3.27 [-4.70, -1.84] -3.27 [-4.70, -1.84]	-4 -2 0 2 4 Favours [control] Favours [experimental] IV, Random, 95% Cl
Test for overall effect: Test for subgroup diffe Study or Subgroup 2.9.1 Free fatty acid ( Corbianco et al. 2018 Subtotal (95% CI) Heterogeneity: Not app Test for overall effect: 2.9.2 VO2average	Z = 0.83 erences: <u>Mean</u> mmol/l) 0.42 plicable Z = 4.48	(P = 0. Chi <sup>2</sup> = 0 SD 0.02 (P < 0.0	41) 0.51, d <u>Total</u> 10 10 00001)	f = 2 (P <u>Mean</u> 0.55	= 0.78 SD 0.05	3),  ² = ( <u>Total</u> 10 10	0% Weight 32.1% 32.1%	IV, Random, 95% Cl -3.27 [-4.70, -1.84] -3.27 [-4.70, -1.84]	-4 -2 0 2 4 Favours [control] Favours [experimental]
Test for overall effect: Test for subgroup diffe Study or Subgroup 2.9.1 Free fatty acid ( Corbianco et al. 2018 Subtotal (95% CI) Heterogeneity: Not ap Test for overall effect: 2.9.2 VO2average Corbianco et al. 2018 Subtotal (95% CI)	Z = 0.83 erences: <u>Mean</u> mmol/l) 0.42 plicable Z = 4.48 13.22	(P = 0. Chi <sup>2</sup> = 0 <u>SD</u> 0.02 (P < 0.0 6.16	41) 0.51, d <u>Total</u> 10 10 00001) 10	f = 2 (P <u>Mean</u> 0.55 13.46	= 0.78 <u>SD</u> 0.05 4.96	3),   <sup>2</sup> = ( <u>Total</u> 10 <b>10</b> 10	0% Weight 32.1% 32.1% 34.3% 34.3%	IV, Random, 95% Cl -3.27 [-4.70, -1.84] -3.27 [-4.70, -1.84] -0.04 [-0.92, 0.84] -0.04 [-0.92, 0.84]	-4 -2 0 2 4 Favours [control] Favours [experimental]
Test for overall effect: Test for subgroup diffe Study or Subgroup 2.9.1 Free fatty acid ( Corbianco et al. 2018 Subtotal (95% Cl) Heterogeneity: Not ap Test for overall effect: 2.9.2 VO2average Corbianco et al. 2018 Subtotal (95% Cl) Heterorgeneity: Not ap	Z = 0.83 erences: <u>Mean</u> mmol/l) 0.42 plicable Z = 4.48 13.22	(P = 0. Chi <sup>2</sup> = 0 <u>SD</u> 0.02 (P < 0.0 6.16	41) 0.51, d <u>Total</u> 10 10 00001) 10 10	f = 2 (P <u>Mean</u> 0.55 13.46	= 0.78 SD 0.05 4.96	3),   <sup>2</sup> = ( <u>Total</u> 10 <b>10</b> 10 10	0% Weight 32.1% 32.1% 34.3% 34.3%	IV, Random, 95% Cl -3.27 [-4.70, -1.84] -3.27 [-4.70, -1.84] -0.04 [-0.92, 0.84] -0.04 [-0.92, 0.84]	-4 -2 0 2 4 Favours [control] Favours [experimental]
Test for overall effect: Test for subgroup diffe Study or Subgroup 2.9.1 Free fatty acid ( Corbiance et al. 2018 Subtotal (95% Cl) Heterogeneity: Not ap Test for overall effect: 2.9.2 VO2average Corbiance et al. 2018 Subtotal (95% Cl) Heterogeneity: Not ap Test for overall effect:	Z = 0.83 erences: <u>Mean</u> mmol/l) 0.42 plicable Z = 4.48 13.22 plicable Z = 0.09	(P = 0. Chi <sup>2</sup> = 0 SD 0.02 (P < 0.0 6.16 (P = 0.§	41) 0.51, d <u>Total</u> 10 10 00001) 10 10	f = 2 (P <u>Mean</u> 0.55 13.46	= 0.78 SD 0.05 4.96	3),   <sup>2</sup> = ( <u>Total</u> 10 10 10 10	32.1% 32.1% 32.1% 34.3% 34.3%	IV, Random, 95% Cl -3.27 [-4.70, -1.84] -3.27 [-4.70, -1.84] -0.04 [-0.92, 0.84] -0.04 [-0.92, 0.84]	-4 -2 0 2 4 Favours [control] Favours [experimental]
Test for overall effect: Test for subgroup diffs Study or Subgroup 2.9.1 Free fatty acid ( Corbianco et al. 2018 Subtotal (95% CI) Heterogeneity: Not app Test for overall effect: 2.9.2 VO2average Corbianco et al. 2018 Subtotal (95% CI) Heterogeneity: Not app Test for overall effect: 2.9.3 VO2average per	Z = 0.83 erences: <u>Mean</u> mmol/l) 0.42 plicable Z = 4.48 13.22 plicable Z = 0.09 ak	(P = 0. Chi <sup>2</sup> = 0 <u>SD</u> 0.02 (P < 0.0 6.16 (P = 0.9	41) 0.51, d <u>Total</u> 10 10 00001) 10 10 10	f = 2 (P <u>Mean</u> 0.55	= 0.78 <u>SD</u> 0.05 4.96	3),   <sup>2</sup> = ( <u>Total</u> 10 10 10	0% Weight 32.1% 32.1% 34.3% 34.3%	IV, Random, 95% Cl -3.27 [-4.70, -1.84] -3.27 [-4.70, -1.84] -0.04 [-0.92, 0.84] -0.04 [-0.92, 0.84]	-4 -2 0 2 4 Favours [control] Favours [experimental]
Test for overall effect: Test for subgroup diffe Study or Subgroup 2.9.1 Free fatty acid ( Corbianco et al. 2018 Subtotal (95% CI) Heterogeneity: Not ap Test for overall effect: 2.9.2 VO2average Corbianco et al. 2018 Subtotal (95% CI) Heterogeneity: Not ap Test for overall effect: 2.9.3 VO2average per Corbianco et al. 2018	Z = 0.83 erences: <u>Mean</u> mmol/l) 0.42 plicable Z = 4.48 13.22 plicable Z = 0.09 ak 20.7	(P = 0. Chi <sup>2</sup> = 0 <u>SD</u> 0.02 (P < 0.0 6.16 (P = 0.9	41) 0.51, dr Total 10 10 00001) 10 10 10 10 33) 10	f = 2 (P <u>Mean</u> 0.55 13.46	= 0.78 <u>SD</u> 0.05 4.96	3),   <sup>2</sup> = ( <u>Total</u> 10 10 10	)% <u>Weight</u> 32.1% 32.1% 34.3% 34.3%	IV, Random, 95% Cl -3.27 [-4.70, -1.84] -3.27 [-4.70, -1.84] -0.04 [-0.92, 0.84] -0.04 [-0.92, 0.84]	-4 -2 0 2 4 Favours [control] Favours [experimental] IV, Randorn, 95% C!
Test for overall effect: Test for subgroup diffe Study or Subgroup 2.9.1 Free fatty acid ( Corbianco et al. 2018 Subtotal (95% Cl) Heterogeneity: Not ap Test for overall effect: 2.9.2 VO2average Corbianco et al. 2018 Subtotal (95% Cl) Heterogeneity: Not ap Test for overall effect: 2.9.3 VO2average per Corbianco et al. 2018 Subtotal (95% Cl)	Z = 0.83 erences: <u>Mean</u> mmol/l) 0.42 plicable Z = 4.48 13.22 plicable Z = 0.09 ak 20.7	(P = 0. Chi <sup>2</sup> = 0 <u>SD</u> 0.02 (P < 0.0 6.16 (P = 0.9 1.17	41) 0.51, dr Total 10 10 00001) 10 10 10 10 10 10 10 10 10 10	f = 2 (P <u>Mean</u> 0.55 13.46	= 0.78 <u>SD</u> 0.05 4.96	3),   <sup>2</sup> = ( <u>Total</u> 10 10 10 10 10	)% Weight 32.1% 32.1% 34.3% 34.3% 33.6% 33.6%	IV, Random, 95% Cl -3.27 [-4.70, -1.84] -3.27 [-4.70, -1.84] -0.04 [-0.92, 0.84] -0.04 [-0.92, 0.84] 1.81 [0.73, 2.88] 1.81 [0.73, 2.88]	-4 -2 0 2 4 Favours [control] Favours [experimental] IV, Random, 95% Cl
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Test for overall effect: Test for subgroup diffe Study or Subgroup 2.9.1 Free fatty acid ( Corbianco et al. 2018 Subtotal (95% CI) Heterogeneity: Not app Test for overall effect: 2.9.2 VO2average Corbianco et al. 2018 Subtotal (95% CI) Heterogeneity: Not app Test for overall effect: 2.9.3 VO2average pea Corbianco et al. 2018 Subtotal (95% CI) Heterogeneity: Not app Test for overall effect:	Z = 0.83 erences: <u>Mean</u> mmol/l) 0.42 plicable Z = 4.48 13.22 plicable Z = 0.09 ak 20.7 plicable Z = 3.29	(P = 0.0) (P = 0.0) (P = 0.0) (P < 0.0) (P < 0.0) (P = 0.0) (P = 0.0) (P = 0.0) (P = 0.0)	41) 0.51, d <u>Total</u> 10 10 000001) 10 003) 10 10 001)	f = 2 (P <u>Mean</u> 0.55 13.46 18.55	4.96	3),   <sup>2</sup> = ( <u>Total</u> 10 10 10 10 10 10	9% Weight 32.1% 32.1% 34.3% 34.3% 33.6% 33.6%	IV, Random, 95% Cl -3.27 [-4.70, -1.84] -3.27 [-4.70, -1.84] -0.04 [-0.92, 0.84] -0.04 [-0.92, 0.84] 1.81 [0.73, 2.88] 1.81 [0.73, 2.88]	-4 -2 0 2 4 Favours [control] Favours [experimental] IV, Randorn, 95% Cl
Test for overall effect: Test for subgroup diffe Study or Subgroup 2.9.1 Free fatty acid ( Corbianco et al. 2018 Subtotal (95% CI) Heterogeneity: Not app Test for overall effect: 2.9.2 VO2average Corbianco et al. 2018 Subtotal (95% CI) Heterogeneity: Not app Test for overall effect: 2.9.3 VO2average per Corbianco et al. 2018 Subtotal (95% CI) Heterogeneity: Not app Test for overall effect: Total (95% CI)	Z = 0.83 erences: <u>Mean</u> mmol/l) 0.42 plicable Z = 4.48 13.22 plicable Z = 0.09 ak 20.7 plicable Z = 3.29	$(P = 0.0)$ $Chi^{2} = 0$ $SD$ $0.02$ $(P < 0.0)$ $6.16$ $(P = 0.0)$ $1.17$ $(P = 0.0)$	41) 0.51, d <u>Total</u> 10 10 000001) 10 10 003) 10 10 001) 30	f = 2 (P <u>Mean</u> 0.55 13.46 18.55	4.96	3),   <sup>2</sup> = ( <u>Total</u> 10 10 10 10 10 10 10 10 30	9% Weight 32.1% 32.1% 34.3% 34.3% 33.6% 33.6% 33.6%	IV, Random, 95% Cl -3.27 [-4.70, -1.84] -3.27 [-4.70, -1.84] -0.04 [-0.92, 0.84] -0.04 [-0.92, 0.84] 1.81 [0.73, 2.88] 1.81 [0.73, 2.88] -0.46 [-2.96, 2.05]	-4 -2 0 2 4 Favours [control] Favours [experimental]
Test for overall effect: Test for subgroup diffe Study or Subgroup 2.9.1 Free fatty acid ( Corbianco et al. 2018 Subtotal (95% CI) Heterogeneity: Not app Test for overall effect: 2.9.2 VO2average Corbianco et al. 2018 Subtotal (95% CI) Heterogeneity: Not app Test for overall effect: 2.9.3 VO2average per Corbianco et al. 2018 Subtotal (95% CI) Heterogeneity: Not app Test for overall effect: Total (95% CI) Heterogeneity: Not app	Z = 0.83 arences: <u>Mean</u> mmol/l) 0.42 plicable Z = 4.48 13.22 plicable Z = 0.09 ak 20.7 plicable Z = 3.29	(P = 0.c) (P < 0.c) (P < 0.c) (P < 0.c) (P = 0.c) (P	41) 0.51, d <u>Total</u> 10 10 000001) 10 10 10 33) 10 10 10 33) 30 30 37, df =	f = 2 (P <u>Mean</u> 0.55 13.46 18.55 = 2 (P <	<ul> <li>a. 1.11</li> <li>a. 1.11</li> <li>a. 1.11</li> </ul>	3),  ² = ( <u>Total</u> 10 10 10 10 10 10 10 10 00);  ² = (	9% Weight 32.1% 32.1% 34.3% 34.3% 33.6% 33.6% 33.6% 94%	IV, Random, 95% Cl -3.27 [-4.70, -1.84] -3.27 [-4.70, -1.84] -0.04 [-0.92, 0.84] -0.04 [-0.92, 0.84] 1.81 [0.73, 2.88] 1.81 [0.73, 2.88] -0.46 [-2.96, 2.05]	-4 -2 0 2 4 Favours [control] Favours [experimental]

Test for subgroup differences: Chi<sup>2</sup> = 30.87, df = 2 (P < 0.00001), l<sup>2</sup> = 93.5%

**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<sup>2</sup>. 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<sup>2</sup>. 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 (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 participation. 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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