

Efficacy of whole-body vibration on hormonal responses in individuals with hormonal disorders: A systematic review and meta-analysis

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Objective. This systematic review aims to examine the current literature on the effects of whole-body vibration on hormonal levels in individuals with hormonal disorders.

Methods. A systematic search was performed on six electronic databases to retrieve studies examining the effects of whole-body vibration on hormonal levels in individuals with hormonal disorders. The retrieved studies were assessed against predetermined eligibility criteria in two stages: title and abstract filtration and full-text filtration. The quality of the studies included was assessed using the physiotherapy evidence based (PEDro) scale and their data were summarized in a data extraction sheet. A pooled statistical analysis was conducted in studies that showed homogeneity.

Results. The included studies assessed hormonal level in individuals with hormonal disorders across various pathological conditions including fibromyalgia, multiple sclerosis, obese hypothyroid females, diabetes mellitus, and individuals with renal diseases. The effect of whole-body vibration was statistically significant on thyroid hormones, prolactin, cortisol, and irisin, while other studies showed no effect for whole-body vibration on insulin, gonadal hormones, ghrelin and leptin, adiponectin, parathyroid hormone, and insulin-like growth factor 1 in women with fibromyalgia.

Conclusion. The whole-body vibration training may have an action in endocrine system as observed by the alteration of plasma concentration of thyroid hormones, prolactin, cortisol and irisin. It is possible that long-term, repeated mechanical vibration could directly or indirectly affect the levels of other hormones.

Keywords: hormones, vibration therapy, whole-body vibration, thyroid, multiple sclerosis, fibromyalgia, obesity

Hormones play multiple and crucial roles in the regulation of the body functions. For instance, insulin and glucagon regulate blood glucose, cortisol reduces inflammation across the whole body, the thyroid gland hormones control the metabolic rate, and the gonadal hormones are essential regulators of

the sexual functions of the human body (Boron and Boulpaep 2017).

Hormonal imbalance and dysfunction are a common systemic manifestation across various pathological conditions. For example, obesity may affect several parts of the endocrine system, specifically

the blood glucose regulating hormones are the main affected hormones causing insulin resistance leading to the occurrence of type II diabetes mellitus (T2DM) (Golacki et al. 2022). In addition, published literature has linked fibromyalgia with altered insulin-like growth factor (IGF) (Atamer et al. 2023). Also, due to the likelihood of multiple sclerosis (MS) to affect female individuals, research has correlated the disturbance in gonadal hormones and the incidence of MS (Sparaco and Bonavita 2021).

Whole-body vibration (WBV) training is a non-invasive method of transmitting mechanical vibrations to the entire body of the subject through a vibrating platform (Van Heuvelen et al. 2021). It is reported to improve muscle strength and flexibility and it may enhance musculoskeletal performance (Bidonde et al. 2017).

Whole-body vibration training was hypothesized to have an impact on hormones levels. For example, it was reported that a single session of WBV training increased the testosterone levels in healthy participants. Also, it was reported that WBV training may have an impact on plasma concentrations of parathyroid hormone (PTH), adrenaline, insulin-like growth factor-1 (IGF-1), and growth hormones (Paineiras-Domingos et al. 2017; Sa-Caputo et al. 2023).

Numerous clinical trials have investigated the effect of WBV training on hormones (Bosco et al. 2000; Di Loreto et al. 2004; Cardinale et al. 2010; Chen et al. 2015; da Cunha Sa-Caputo et al. 2015). The effect of WBV training on body hormones has been investigated in numerous clinical trials. However, to the best of our knowledge, only one systematic review has examined the effectiveness of WBV training on growth hormones, and the population was mostly healthy participants (Paineiras-Domingos et al. 2017).

To the best of our knowledge, there is no other systematic review published, which has investigated the effect of WBV training on hormonal levels in individuals with pathological conditions. Only one systematic review examined the impact of WBV training on growth hormone concentration on healthy participants concluding that WBV may play an important role in promoting neuroendocrine function of the human body (Paineiras-Domingos et al. 2017).

This systematic review aims to evaluate the effects of WBV training on various body hormones, including thyroid and parathyroid hormones, gonadal hormones, IGF-1, and irisin, in pathological conditions such as fibromyalgia, obesity, MS, and diabetes mellitus.

Materials and Methods

The current review followed PRISMA (the preferred reporting items for systematic reviews and meta-analysis) guidelines (Page et al. 2021). The protocol was registered in PROSPERO (the International prospective register of systematic reviews) on 27th October 2024 (CRD42024598841).

Data sources and search strategy. Systematic search by two authors (AFS and HM) was conducted across six electronic databases which are PubMed, Scopus, Cochrane Central, Google Scholar, Web of Science and PEDro (the Physiotherapy Evidence Database) till 20th October 2024. The detailed search strategy is available in Appendix 1 (data available on request from the authors).

Study selection. Eligible studies for inclusion included randomized controlled trials assessing the effectiveness of WBV on any hormone. Studies that were not peer reviewed or were written in languages other than English were excluded.

The identified records were imported to Rayyan web platform (Ouzzani et al. 2016) for screening, duplicate records were removed, and the remaining studies went title and abstract screening by two authors independently (MMS and YMH) followed by another round of screening through the full text of the retrieved records by another two authors independently (HE and AFS). The senior author (SE) resolved conflicts arising during the screening process.

Quality assessment. The PEDro Scale was used to assess the quality of the included studies (Cashin and McAuley 2020). In the PEDro scale, the quality of the studies included is assessed across 11 criteria. However, the first criterion is not counted making the total score out of 10.

Data extraction. The following elements were extracted from each included study, which are the study ID i.e., the first author's name and year of publication, the included participants' characteristics, the parameters of the intervention and control procedures, the outcomes and results.

Data synthesis. Using the Review manager software (RevMan – V5.4.1, The Nordic Cochrane Center, The Cochrane Collaboration, Copenhagen, Denmark, 2021), the eligible studies were analyzed. A pooled statistical analysis for all available outcomes was conducted if the data were sufficient.

The mean difference (MD) with 95% CI was used to express continuous effect measures. We calculated the MD for studies reporting pre and post mean and SD by direct subtraction where the SD of the difference was calculated by Follman equation (Follmann et al.

1992; Abrams et al. 2005). The statistical heterogeneity between the included studies was assessed using the I^2 test and its results determined the model used in the analysis. If the heterogeneity was significant ($p < 0.05$) or I^2 was $> 50\%$, the Der Simonian and Laird random-effects model was employed, otherwise the fixed-effect model was the default (DerSimonian and Laird 1986). It was considered 2-sided statistical analysis testing, setting the α -error level at 0.05.

Results

Study selection. Figure 1 shows the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analysis) of the study. The systematic search yielded 659 records with additional three articles retrieved through citation searching, i.e., snowballing. One hundred and fifty-seven duplicates were removed, 502 research papers were screened in the title and abstract filtration, and 21 of them went through full text filtration. Finally, 10 studies have the eligibility for inclusion in this systematic review (Alentorn-Geli et al. 2009; Behboudi et al. 2011; Bellia

et al. 2014; Eftekhari et al. 2014; Ebrahimi et al. 2015; Manimmanakorn et al. 2017; Rajapakse et al. 2017; Tubic et al. 2019; Abdel-Latif et al. 2021; Dos Santos et al. 2023). The exclusion reasons are cited individually in Appendix 2 (data available on request from the authors).

Quality of the included studies. The PEDro scale was used to assess 10 included articles, two poor quality studies (Alentorn-Geli et al. 2009; Bellia et al. 2014), four studies had fair quality (Ebrahimi et al. 2015; Manimmanakorn et al. 2017; Rajapakse et al. 2017; Tubic et al. 2019), three studies had good quality (Behboudi et al. 2011; Ebrahimi et al. 2015; Dos Santos et al. 2023) and one study was considered to be of excellent quality (Abdel-Latif et al. 2021) (Table 1). The main weakness points were regarding intention-to-treat analysis, allocation concealment and subject and therapist blinding.

Characteristics of the included studies. Seventeen hormones were measured in 10 included studies, which were performed on six pathological conditions, including obesity (Bellia et al. 2014; Tubic et al. 2019), fibromyalgia (Alentorn-Geli et al. 2009; Dos Santos et

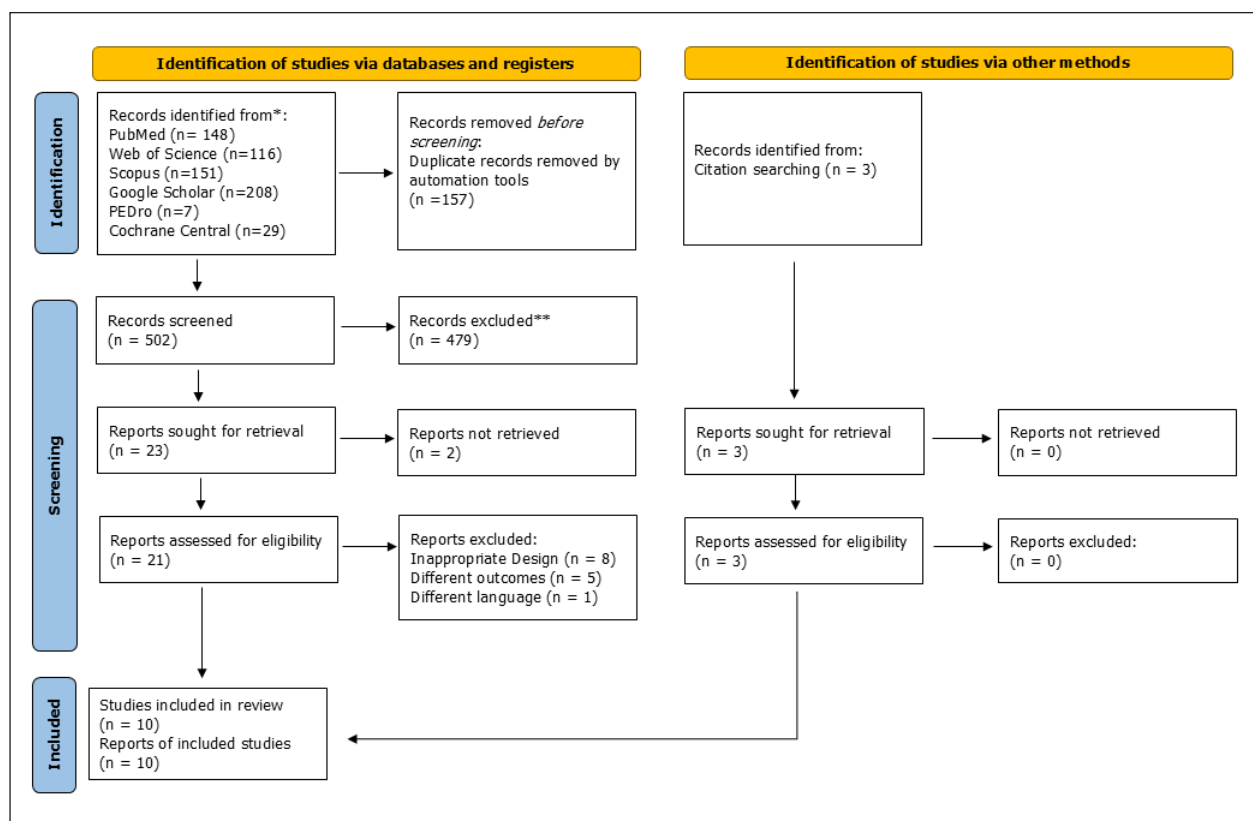


Figure 1. PRISMA flow diagram.

Table 1
Quality score of the included studies

Study	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	Q11	Total (0–10)
Alentorn-Geli et al. (2009)	Yes	1	0	0	0	1	0	1	0	0	0	3
Bellia et al. (2014)	Yes	1	0	1	0	0	0	1	0	1	1	5
Tubic et al. (2019)	Yes	1	0	1	0	0	0	0	0	1	1	4
Rajapakse et al. (2017)	No	1	1	1	1	1	1	1	1	1	1	10
Manimmanakorn et al. (2017)	Yes	1	1	1	0	0	1	1	0	1	1	7
Ebrahimi et al. (2015)	Yes	1	0	1	0	0	1	1	0	1	1	6
Eftekhari et al. (2014)	Yes	1	0	1	0	0	0	1	0	1	1	5
Dos Santos et al. (2023)	Yes	1	1	1	0	0	1	1	0	1	1	7
Behboudi et al. (2011)	Yes	1	0	0	0	0	0	0	0	1	1	3
Abdel-Latif et al. (2021)	Yes	1	0	1	0	0	0	0	0	1	1	4

al. 2023), T2DM (Behboudi et al. 2011; Manimmanakorn et al. 2017), MS (Eftekhari et al. 2014; Ebrahimi et al. 2015), end-stage renal disease (Rajapakse et al. 2017), and hypothyroidism in obese postmenopausal women (Abdel-Latif et al. 2021).

Insulin was measured in four studies (Behboudi et al. 2011; Bellia et al. 2014; Manimmanakorn et al. 2017; Tubic et al. 2019), testosterone (Eftekhari et al. 2014; Ebrahimi et al. 2015), adiponectin and leptin (Bellia et al. 2014; Tubic et al. 2019) in two studies each, while thyroid-stimulating hormone (TSH) (Abdel-Latif et al. 2021), follicle-stimulating hormone (FSH) (Eftekhari et al. 2014), luteinizing hormone (LH) (Eftekhari et al. 2014), prolactin, free thyroxine (FT4) (Abdel-Latif et al. 2021), free triiodothyronine (FT3) (Abdel-Latif et al. 2021), PTH (Rajapakse et al. 2017), cortisol (Eftekhari et al. 2014), estradiol (Eftekhari et al. 2014), progesterone (Eftekhari et al. 2014), ghrelin (Ebrahimi et al. 2015), irisin (Dos Santos et al. 2023), and IGF-1 (Alentorn-Geli et al. 2009) were measured in one study (Table 2).

Hormones are classified based on organ of origin and the results of WBV effect on each hormone in each pathological condition are reported.

Effect of WBV on gonadal hormones. Testosterone level was assessed in individuals with MS in two studies including 54 participants (Eftekhari et al. 2014; Ebrahimi et al. 2015). Pooled statistical analysis showed no statistically significant difference in testosterone level between WBV and control groups (MD 0.00 [−0.12, 0.13, P=0.96]) (Figure 2). The same scenario was applied to estradiol and progesterone levels, which were assessed in one study in individuals with MS (Eftekhari et al. 2014).

Effect of WBV on adipokines. Two studies (Bellia et al. 2014; Tubic et al. 2019) investigated WBV effect on adiponectin level in 59 patients with obesity. The results of pooled statistical analysis of two above-mentioned studies showed no significant statistical difference in adiponectin level between WBV and control groups (MD 1.10 [−1.92, 4.13, P=0.47]) (Figure 3). This applies also to leptin and IGF-1 levels, which showed no statistical difference between WBV and control intervention in individuals with MS (Ebrahimi et al. 2015) and fibromyalgia (Alentorn-Geli et al. 2009).

Effect of WBV on pituitary gland hormones. In one study (Abdel-Latif et al. 2021), TSH level was

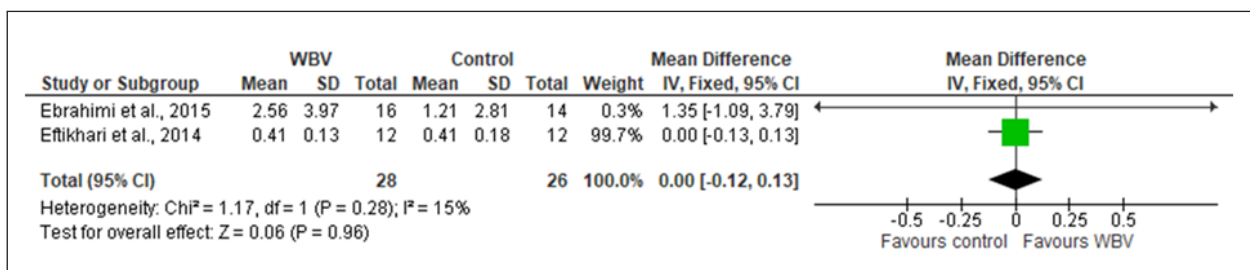


Figure 2. Comparison of testosterone levels between whole-body vibration (WBV) group and the control group.

Table 2
Characteristics of the included studies

Study	Design	Diagnosis	Population		Intervention			Outcome Measure		Dropout	Results
			N (C)	Gender (M:F)	Age	SG	CG	WBV Duration			
Alentorn-Geli et al. (2009)	RCT	Fibromyalgia	SG: 12 CG: 12	24 F	54.96±2.96	Static and dynamic exercise on WBV platform F: 30 Hz A: 2 mm	Static and dynamic exercise on placebo WBV	21 min/session, 2 sessions/week, 6 weeks	Serum IGF-1	0	Not statistically significant difference between groups (p<0.05).
Belia et al. (2013)	RCT	IR/obesity	SG: 18 (15) CG: 15 (14)	15:14	42.48±4.99	Hypocaloric diet + Static squat on WBV platform F: 30 Hz A: 2 mm On:Off 1:1	Hypocaloric diet	20 min/session, 3 sessions/week, 8 weeks	- Insulin - Leptin - Adiponectin	5	Statistically significant difference was found favoring SG regarding adiponectin only (p=0.021); however, insulin and leptin were non-significant (p=0.11 and p=0.22, respectively).
Tubic et al. (2019)	RCT	Obesity	SG: 19 (16) CG: 17 (14)	14:16	12.61±2.80	Static squat with balance support on WBV platform F: 16-24 Hz A: 2 mm	No intervention	7–10 min/session, 3 sessions/week, 12 weeks	- Insulin - Adiponectin	6	Not statistically significant difference was observed between groups regarding insulin (p=0.87) and adiponectin (p=0.50).
Rajapakse et al. (2017)	RCT	ESRD	SG: 15 (14) CG: 15 (15)	17:12	49.17±10.46	Standing on WBV platform F: 30 Hz A: 0.09 mm	Placebo WBV	20 min/daily, 24 weeks	Parathyroid	1	No significant difference between groups was observed regarding serum parathyroid (p=0.60).
Manimmanakorn et al. (2017)	RCT	T2DM	SG: 20 (17) CG: 20 (19)	13:23	63.2±7.7	Different squat positions on WBV platform F: 30-40 Hz A: 2-4 mm	No intervention	12 min/session, 3 times/week, 12 weeks	Insulin	4	Not statistically significant difference in insulin level between groups (p=0.996).
Ebrahimi et al. (2015)	RCT	MS	SG: 17 (16) CG: 17 (14)	7:23	38.78±9.49	Different static positions on WBV platform F: 2-20 Hz A: 2 mm On:Off 1:1	No intervention	7.5:30 min/session, 3 times/week, 10 weeks	- Ghrelin - Leptin - Testosterone	4	No significant difference between groups regarding ghrelin, leptin and testosterone (p=0.17, p=0.34, and p=0.44, respectively).

Table 2
Continued . . .

Study	Design	Diagnosis	Population		Intervention		CG	WBV Duration	Outcome Measure	Dropout	Results
			N (C)	Gender (M:F)	Age	SG					
Eftekhari et al. (2014)	Quasi-experimental	MS	SG: 12 CG: 12	24 F	34.41±6.05	Multiple static positions on WBV platform F: 2-20 Hz A: 0.1-2 mm + Low intensity resistance training	No intervention	2.5 min/session, 3 times/week, 8 weeks	- FSH - LH - Estradiol - Progesterone - Testosterone - Prolactin - Cortisol	0	Significant differences were observed favoring SG regarding testosterone, prolactin and cortisol levels (p=0.04, p=0.02 and p=0.00, respectively); however, no differences existed between groups regarding FSH, LH, estradiol or progesterone (p=0.63, p=0.27, p=0.18 and p=0.08, respectively).
Dos Santos et al. (2023)	RCT	Fibromyalgia	SG: 20 CG: 20	40 F	54.71±6.97	Dynamic squats on WBV platform F: 35-40 Hz A: 4 mm	No intervention	3 to 10.6 min/session, 3 times/week, 6 weeks	Irisin	0	There was a statistically significant difference favoring the SG (p=0.009).
Behboudi et al. (2011)	RCT	T2DM	SG: 10 CG1: 10 CG2: 10	30 M	51.53±5.74	Static squats on WBV platform F: 30 Hz A: 2 mm + Aerobic exercise	CG1: Aerobic exercise 30 – 60 min CG2: No intervention	16 to 24 min/session, 3 times/week, 8 weeks	Insulin	0	No significant differences were observed between groups (p<0.05).
Abdel-Latif et al. (2021)	RCT	Obese PMP	SG: 15 CG: 15	30 F	51.83±1.68	WBV training F: 20 – 100 Hz + Thyroxine tablets + Hypocaloric diet	Thyroxine tablets + hypocaloric diet	40 min/session, 3 times/week, 8 weeks	- FT3 - FT4 - TSH	0	Statistically significant differences favoring the SG regarding T3, T4 and TSH levels (p≤0.0001).

Abbreviations: A - amplitude; CG - control group; ESRD - end-stage renal disease; F - females; F - frequency; FSH - follicle-stimulation hormone; FT3 - free triiodothyronine; FT4 - free thyroxine; IGF-1 - insulin-like growth factor-1; IR - insulin resistance; LH - luteinizing hormone; M - males; MS - multiple sclerosis; PMP - post menopause; RCT - randomized controlled trial; SG - study group; T2DM - type II diabetes mellitus; TSH - thyroid-stimulating hormone; WBV - whole-body vibration.

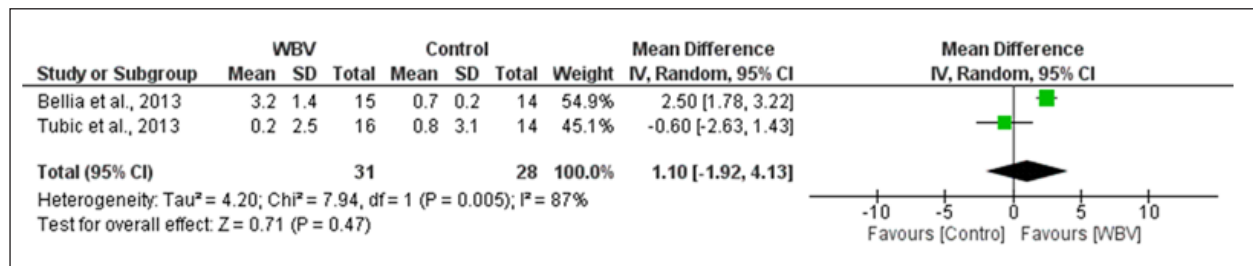


Figure 3. Comparison of adiponectin levels between whole-body vibration (WBV) group and the control group.

measured in obese hypothyroid postmenopausal women and showed a significant decrease of TSH level in group performed WBV training in addition to thyroxine tablets and hypocaloric diet compared to group received thyroxine tablets and hypocaloric diet alone. Another study (Eftekhar et al. 2014) has found a significant increase of prolactin level in WBV plus low intensity resistance training group compared to no intervention group; however, this was not the case regarding FSH and LH levels.

Effect of WBV on thyroid and parathyroid hormones. One study (Abdel-Latif et al. 2021) assessed the effect of combining WBV training to thyroxine tablets and hypocaloric diet on FT3, FT4 and showed that there was a significant increase compared to thyroxine tablets and hypocaloric diet alone, while the PTH was assessed in one study (Rajapakse et al. 2017) showing no significant statistical difference between WBV and placebo WBV groups.

Effect of WBV on adrenal gland hormones. Cortisol was assessed in one study (Eftekhar et al. 2014) and showed a significant decrease following WBV plus low intensity resistance training, compared to no intervention.

Effect of WBV on pancreatic hormones. Four studies (Behboudi et al. 2011; Bellia et al. 2014; Manimmanakorn et al. 2017; Tubic et al. 2019) investigated the effects of combining squat WBV to either hypocaloric diet or aerobic exercise on insulin level in individuals with obesity (Bellia et al. 2014; Tubic et al. 2019) and patients with T2DM (Behboudi et al. 2011; Manimmanakorn et al. 2017); however, no statistically significant difference was observed regarding insulin level in both populations.

Effect of WBV on gastrointestinal hormones. Ebrahimi et al. (2015) have found no effect of WBV plus low intensity exercise on ghrelin compared to no intervention in patients with MS. The only significant effect of WBV was found on irisin level, which was statistically significantly increased following WBV

compared to no intervention in individuals with fibromyalgia.

Discussion

This systematic review showed that WBV has a beneficial effect on several hormones in various pathological conditions. The effect of WBV on hormones included TSH, FT4, and FT3 in obese hypothyroid postmenopausal women (Abdel-Latif et al. 2021), prolactin and cortisol in patients with MS (Eftekhar et al. 2014), irisin in females with fibromyalgia (Dos Santos et al. 2023).

On the other hand, some studies have shown no effect of WBV on insulin in patient with obesity (Bellia et al. 2014; Tubic et al. 2019) and individuals with diabetes (Behboudi et al. 2011; Manimmanakorn et al. 2017), estradiol, progesterone, FSH and LH levels in individuals with MS, testosterone, ghrelin and leptin in patients with MS (Eftekhar et al. 2014; Ebrahimi et al. 2015), adiponectin in children with obesity and middle aged obese patients (Bellia et al. 2014; Tubic et al. 2019), PTH in patients with end-stage renal disease (Rajapakse et al. 2017) and IGF-1 in females with fibromyalgia (Alentorn-Geli et al. 2009).

The results of the current systematic reviews showed that WBV has beneficial effect on several hormones including TSH, FT3 and FT4 in obese hypothyroid postmenopausal women (Abdel-Latif et al. 2021). These changes may be possibly elicited by directly mechanical stimulation or through biomolecular transport enhancement. The thyroid hormone is stored in the form of gel-like substance (Yao et al. 2025). Mechanical vibrations release the hormone from the storage form explaining why the thyroid gland is avoided during massage therapy in individuals with hyperthyroidism (Tachi et al. 1990; Wagner et al. 2016).

Notably, WBV yielded a significant inhibitory effect on cortisol in individuals with MS (Eftekhar

et al. 2014). This may be due to exercise adaptation which may decrease the level of cortisol, as exercise temporarily increases cortisol production followed by enhanced catabolism of cortisol, which may be linked to the effect of the neurosecretory centers of the hypothalamus (Rigamonti et al. 2018)

In addition, vibratory movement of WBV may induce relaxation across the body which can lead to reduction in blood and salivary cortisol levels as it reduces stress (Jabraeili et al. 2023; Ahmed and Marinova 2024) Furthermore, Roberge et al. (2007) have proposed that WBV may affect proprioceptive feedback systems and certain neural elements reducing cortisol production by the adrenal gland.

There is also a significant promotive effect of WBV on prolactin in individuals with MS and irisin in women with fibromyalgia. These results may be due to rhythmic muscle contractions caused by vibration stimuli, which have a similar effect to physical exercise. Exercise is thought to stimulate prolactin (Hackney et al. 2016) and irisin (Colaizzi et al. 2017) release, and the extent of cortisol release seems to vary based on the intensity of the exercise.

In addition, Lee et al. (2014) have found that circulating irisin levels are positively associated with shivering in humans exposed to cold conditions. Shivering produces heat via involuntary muscle contractions, suggesting that the rise in irisin likely results from muscle release during thermogenesis. WBV, which triggers forced muscle vibrations, may replicate shivering and thus promote thermogenesis, potentially accounting for the observed effects (Lee et al. 2014).

On the other hand, studies showed no effect of WBV on some hormones including insulin in patients with obesity and T2DM (Behboudi et al. 2011; Bellia et al. 2014; Manimmanakorn et al. 2017; Tubic et al. 2019). This outcome may be attributed to the insufficient intensity or duration of traditional WBV training, which may not be adequate to produce significant changes. Additionally, in diabetic patients, these findings could be due to all participants receiving standard diabetes management, including dietary guidance and medication, throughout the study. Manimmanakorn et al. (2017) have suggested that better results could be obtained from WBV training by increasing the duration of each training session, increasing the frequency of sessions per week and adding weights or performing dynamic exercises during the WBV training.

Santos et al. (2017) have also reported that resistive exercises improve insulin action and glucose hemostasis; however, resistance exercises are an active

form of training, therefore it is debatable whether WBV could induce the same effect as it is considered a passive training modality. This may explain the tendency of many investigators to add certain types of dynamic exercises or positioning to WBV training sessions.

Regarding PTH, studies showed no effect of WBV on PTH in individuals with end-stage kidney failure. These results may explain that these subjects had an elevated PTH level consequently to the renal pathology. A frequent complication of renal failure is increased PTH level resulting from disruptions in the balance of calcium, phosphate, and vitamin D (Yuen et al. 2016).

According to our results, there is no effect of WBV on adiponectin in children with obesity and middle aged obese patients (Bellia et al. 2014; Tubic et al. 2019). This may be a consequence of the limited role of WBV on body fat, obesity, and body mass index. Theodorou et al. (2015) have reported that WBV induce mild physiological stress to the body as it is a passive modality with a short session.

The lack of effect of WBV on estradiol, progesterone, and testosterone in patients with MS may be due to the fact that these patients were undergoing exogenous ovarian hormone therapy containing estradiol and progesterone. Murgia et al. (2022) have reported that estradiol and progesterone might have a remyelinating and immunomodulating effects in individuals with MS.

These results have coincided with Ahsan et al. (2021) who have reported that the central regulation of gonadal function is located within the hypothalamus and the pituitary gland. Therefore, central diseases in these areas may lead to irregular gonadal hormone secretions and may lead to infertility.

Despite the testosterone close relation to muscle mass, in MS, the muscle atrophy and weakness may reduce the potential for WBV to stimulate testosterone production through muscle contractions (Yuki et al. 2013). Couto et al. (2013) have also reported that increasing exercise intensity results in a higher lactate concentration, which is a precursor to the increase of testosterone level.

The lack of effect of WBV on FSH and LH levels in patients with MS may result from the fact that MS may alter hormonal regulation due the effects of the disease on the neuroendocrine-gonadal axis, which regulates FSH and LH secretion. This disruption may limit the responsiveness of hormone levels to external stimuli like WBV (Ahsan et al. 2020).

Unchanged ghrelin and leptin levels in patients with MS may be due to the fact that chronic inflammation

is characteristic of MS. Inflammatory cytokines may disrupt the signaling pathways involved in the regulation of these hormones reducing their sensitivity to WBV. MS also often leads to changes in body morphology including increased fat mass and reduced muscle mass. These changes can affect how the body produces and responds to ghrelin and leptin, potentially diminishing the impact of WBV.

Furthermore, WBV failed to induce any beneficial effects on IGF-1 levels in females with fibromyalgia. This could be attributed to the lack of sufficient WBV stimuli, as patients with fibromyalgia may be incapable of performing the exercises at the required intensity to stimulate IGF-1 secretion without exacerbating their symptoms (Jones et al. 2007). This assumption is supported by the results reported by de Alcantara Borba et al. (2020) who found that only heavy load exercises induced changes in IGF-1 concentration. Bennett (2002) has also explained this result by increasing somatostatin tone, which inhibit growth hormone release, which is the catalyst to IGF-1 secretion by the liver (Adamek and Kasprzak 2018; Bennett 2002).

Summary

Strengths of the study. To the best of our knowledge, this is the first systematic review to evaluate the efficacy of WBV training on hormonal profiles across various pathological conditions. This study highlights the potential of WBV as a non-invasive complementary or alternative therapy to conventional invasive treatments, particularly for patients who cannot tolerate significant side effects.

Limitations. The current study may have the following limitations. First, limited studies regarding each specific disease and hormone met the inclusion

criteria limiting conclusions that could be drawn. The heterogeneity between studies in terms of populations, interventions, and outcomes precluded quantitative synthesis. Second, is the variability of the intervention parameters and participant characteristics including the age and diagnosis. Additionally, only randomized controlled trials written in English were included due to the inability of the research team to comprehend any other languages.

Implications for clinical practice. Based on the results of our study, WBV could be used as an addition to standard pharmacological and non-pharmacological treatments for individuals with MS, obesity, fibromyalgia, and hypothyroid postmenopausal individuals.

Recommendations for further research. Overall, the findings of this systematic review suggest that more investigations are required to reach a definitive conclusion regarding the effects of WBV training on hormonal levels in pathological conditions. High quality randomized controlled trials are recommended on each subgroup of the included population with larger sample sizes and longer durations of WBV training sessions and programs.

Conclusion

The findings of this review suggest that WBV training may have a significant effect on hormonal levels in pathological conditions. WBV exercises have a significant action in endocrine system as observed by the alteration of plasma concentration of several biomarkers including the stimulation of TSH, FT4, FT3, prolactin, irisin, and inhibition of cortisol. It is possible that long-term repeated vibration could directly or indirectly affect the levels of other hormones.

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