EJPMR, 2026, 13(6), 284-290 **Research Article** **Impact Factor: 8.158**

EUROPEAN JOURNAL OF PHARMACEUTICAL AND MEDICAL RESEARCH

www.ejpmr.com

ISSN (O): 2394-3211
ISSN (P): 3051-2573
Coden USA: EJPMAG

OPTIMAL FREQUENCY AND INTENSITY OF WHOLE-BODY VIBRATION TRAINING IN DIABETIC PERIPHERAL NEUROPATHY REHABILITATION

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DOI: https://doi.org/10.5281/zenodo.20443780

How to cite this Article: Sheela Angel I.[1]*, Dr. Sandhiya M.[2], Dr. Senthil Selvam P.[2]. (2026). Optimal Frequency and Intensity Of Whole-Body Vibration Training In Diabetic Peripheral Neuropathy Rehabilitation. European Journal of Pharmaceutical and Medical Research, 13(6), 284–290.

Article Received on 28/04/2026 **Article Revised on 18/05/2026** **Article Published on 01/06/2026**

ABSTRACT

Background: Diabetic Peripheral Neuropathy is a common complication of Type II Diabetes Mellitus associated with impaired proprioception, balance deficits, and reduced functional mobility, leading to increased risk of falls and decreased quality of life. Whole-Body Vibration Training (WBVT) has emerged as an effective rehabilitation approach for improving neuromuscular activation and postural control. However, the optimal frequency and intensity of WBVT for individuals with DPN remain unclear. **Aim:** The study aimed to determine the optimal frequency and intensity of WBVT for improving balance and functional mobility in individuals with DPN. **Methodology:** A randomized controlled trial was conducted among 45 participants with Type II Diabetes Mellitus and Diabetic Peripheral Neuropathy aged between 50–65 years. Participants were randomly allocated into three groups: low-frequency WBVT, moderate-frequency WBVT, and high-frequency WBVT. All groups underwent WBVT three sessions per week for six weeks. Outcome measures included the Berg Balance Scale (BBS), Functional Reach Test (FRT), and Timed Up and Go Test (TUG). Pre-test and post-test assessments were performed and analyzed using paired t-test and one-way ANOVA. **Results:** All groups demonstrated significant improvement in balance and functional mobility following intervention ($p < 0.05$). However, the moderate-frequency WBVT group showed greater improvement in BBS, FRT, and TUG scores compared to the low-frequency and high-frequency groups. **Conclusion:** Moderate-frequency and moderate-intensity WBVT was found to be more effective in improving balance and functional mobility in individuals with Diabetic Peripheral Neuropathy and may be considered a safe and beneficial rehabilitation intervention.

KEYWORDS

- Diabetic Peripheral Neuropathy
- Whole-Body Vibration Training
- Balance
- Functional Mobility
- Postural Control
- Rehabilitation

INTRODUCTION

Diabetic Peripheral Neuropathy is one of the most common chronic complications of diabetes mellitus and affects nearly 50% of individuals with long-standing diabetes.[1,2,3] It is characterized by progressive damage to peripheral nerves resulting in sensory loss, impaired proprioception, muscle weakness, reduced reflexes, and gait abnormalities.[2,3] These impairments significantly affect postural stability and functional mobility, thereby increasing the risk of falls, injuries, and reduced quality of life.[4,5] Among the sensory deficits, loss of vibration perception and impaired plantar sensation are particularly associated with poor balance control and altered movement strategies.[6,7]

Balance maintenance requires proper integration of visual, vestibular, and somatosensory inputs.[8] In individuals with DPN, impaired peripheral sensory feedback disrupts this integration, leading to delayed neuromuscular responses and compromised postural control.[7,9] As a compensatory mechanism, patients often adopt slower gait patterns, wider base of support, and cautious movement strategies.[10,11] Despite these adaptations, individuals with DPN continue to experience higher fall incidence and reduced confidence during daily activities.[4,11] Therefore, effective rehabilitation strategies targeting balance, proprioception, and neuromuscular activation are essential.

Exercise therapy has been widely recommended as a non-pharmacological intervention for DPN rehabilitation.[12,13] Aerobic exercise, strengthening exercises, balance training, and sensorimotor interventions have shown positive effects on functional mobility and glycemic control.[14,15] In recent years, Whole-Body Vibration Training (WBVT) has emerged as an innovative therapeutic modality for improving neuromuscular performance and balance in neurological and metabolic disorders.[16,17]

WBVT involves standing or exercising on a vibrating platform that generates mechanical oscillations transmitted through the body. These vibrations stimulate muscle spindles and Ia afferent fibers, producing reflexive muscle contractions known as the tonic vibration reflex.[18] This neuromuscular stimulation may improve muscle activation, proprioceptive feedback, circulation, postural control, and functional mobility.[16,17] Additionally, WBVT is considered a low-impact intervention that can be safely performed by individuals with reduced exercise tolerance.[19]

Several studies have demonstrated beneficial effects of WBVT in individuals with DPN, including improvements in balance, gait speed, lower limb strength, plantar sensation, and quality of life.[16,20] WBVT has also been shown to enhance circulation and reduce neuropathic symptoms by increasing peripheral blood flow and sensory stimulation.[17,19] Due to these effects, WBVT is increasingly being integrated into physiotherapy rehabilitation programs for diabetic neuropathy.

However, despite promising outcomes, there is currently no standardized WBVT protocol for individuals with DPN.[17,21] Existing studies vary considerably in terms of:

- Vibration frequency (Hz)
- Amplitude (mm)
- Intensity
- Session duration
- Treatment frequency and progression

This lack of consistency makes it difficult to determine the most effective and safest WBVT parameters for clinical practice. Some studies suggest that low-frequency vibration improves sensory awareness and circulation, while moderate-frequency vibration may provide greater neuromuscular activation and balance improvement.[16,17] Conversely, excessively high vibration frequencies and amplitudes may lead to discomfort, fatigue, instability, or adverse effects in individuals with impaired sensation and balance deficits.

Determining the optimal frequency and intensity of WBVT is therefore clinically important to maximize therapeutic benefits while minimizing risks. Standardized WBVT parameters may improve rehabilitation efficiency, patient adherence, and functional outcomes in DPN populations.[17,20] Furthermore, identifying optimal dosage parameters could contribute to evidence-based physiotherapy guidelines and enhance the integration of WBVT into routine diabetic neuropathy management.

Hence, the present study aimed to determine the optimal frequency and intensity of Whole-Body Vibration Training for improving balance and functional mobility in individuals with Diabetic Peripheral Neuropathy.

AIM

To determine the effect of different frequencies and intensities of Whole-Body Vibration Training on balance and functional mobility in individuals with Diabetic Peripheral Neuropathy.

OBJECTIVES

1. To evaluate the effect of low-frequency Whole-Body Vibration Training on balance and functional mobility in individuals with DPN.
2. To evaluate the effect of moderate-frequency Whole-Body Vibration Training on balance and functional mobility in individuals with DPN.
3. To compare the effectiveness of different frequencies and intensities of Whole-Body Vibration Training on balance using: Berg Balance Scale (BBS) & Functional Reach Test (FRT)
4. To compare the effectiveness of different frequencies and intensities of Whole-Body Vibration Training on functional mobility using: Timed Up and Go Test (TUG)
5. To determine the optimal WBVT frequency and intensity that produces maximum improvement in balance and functional mobility in individuals with DPN.

Hypothesis

Null Hypothesis (H_0)

There will be no significant difference between different frequencies and intensities of Whole-Body

Vibration Training on balance and functional mobility in individuals with Diabetic Peripheral Neuropathy.

Alternative Hypothesis (H_1)

Different frequencies and intensities of Whole-Body Vibration Training will produce significant improvements in balance and functional mobility in individuals with Diabetic Peripheral Neuropathy.

METHODOLOGY

- **Study design** : Randomized Controlled Trial
- **Study type** :Comparative Study
- **Sample size** : 45 participants
- **Study setup** : Physiotherapy Outpatient Unit- Dhanam Health Care and Diabetic Centre, Chennai
- **Sampling method** : Simple random sampling
- **Treatment duration** : 6 weeks
- **Treatment frequency** : 3 sessions per week
- **Session duration** : 15–20 minutes per session

Procedure

The present study was conducted to determine the optimal frequency and intensity of Whole-Body Vibration Training (WBVT) on balance and functional mobility in individuals with Diabetic Peripheral Neuropathy. Ethical clearance was obtained from the Institutional Ethical Committee prior to the commencement of the study. Participants were recruited from the Dhanam Health Care and Diabetic Centre-Physiotherapy outpatient unit, based on the inclusion and exclusion criteria. The purpose and procedure of the study were explained clearly to all participants, and written informed consent was obtained before participation.

A total of 45 participants diagnosed with Type II Diabetes Mellitus with Diabetic Peripheral Neuropathy were selected for the study. Baseline demographic data including age, gender, body mass index (BMI), duration of diabetes, and medical history were recorded. Participants were screened to ensure they met the inclusion criteria, including the ability to walk independently and follow verbal instructions.

Pre-intervention assessment was carried out for all participants using the Berg Balance Scale (BBS), Functional Reach Test (FRT), and Timed Up and Go Test (TUG). These outcome measures were selected to assess static balance, dynamic balance, and functional mobility respectively.

Following the baseline assessment, the participants were randomly allocated into three groups using simple random sampling:

- Group A – Low-frequency WBVT group
- Group B – Moderate-frequency WBVT group
- Group C – High-frequency WBVT group

All participants underwent Whole-Body Vibration Training using a vibration platform under the supervision of a physiotherapist. During the intervention, participants were instructed to stand on the vibration platform in a semi-squat position with approximately 20–30 degrees of knee flexion and feet placed shoulder-width apart. Hand support was provided initially when required to ensure safety and stability.

Group A received low-frequency vibration training at 10–15 Hz with an amplitude of 1–2 mm. Group B received moderate-frequency vibration training at 20–30 Hz with an amplitude of 2–4 mm. Group C received high-frequency vibration training at 35–40 Hz with an amplitude of 4–5 mm. The intervention was administered three sessions per week for a duration of six weeks.

Each treatment session lasted approximately 20–30 minutes and consisted of warm-up exercises, WBVT intervention, and cool-down exercises. The warm-up session included active range of motion exercises and gentle stretching exercises for the lower limbs for about five minutes. This was followed by WBVT exposure for 10–20 minutes depending on the participant's tolerance and progression level. Cool-down exercises consisting of relaxation and stretching exercises were performed for five minutes after the intervention.

The intensity and exposure duration of WBVT were progressively increased throughout the study period. During the initial weeks, participants received lower vibration exposure to allow adaptation and minimize discomfort. As the intervention progressed, vibration frequency, amplitude, and duration were gradually increased based on the participant's tolerance and safety.

Throughout the intervention period, participants were closely monitored for adverse effects such as dizziness, pain, fatigue, instability, or discomfort. Adequate rest intervals were provided whenever necessary. Safety precautions including therapist supervision and support rails were maintained during all sessions.

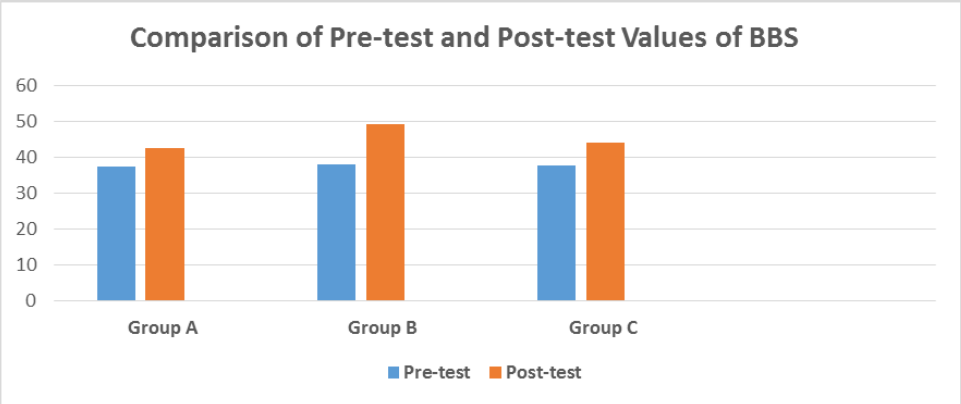
At the end of the six-week intervention period, all participants underwent post-intervention assessment using the same outcome measures: Berg Balance Scale (BBS), Functional Reach Test (FRT), and Timed Up and Go Test (TUG). The obtained data were tabulated and statistically analyzed using SPSS software to compare the effects of different WBVT frequencies and intensities on balance and functional mobility in individuals with Diabetic Peripheral Neuropathy.

Statistical Analysis

The collected data were analyzed using SPSS software version 25.0. Descriptive statistics such as mean and standard deviation were calculated for all outcome measures. Paired t-test was used to compare pre-test and post-test values within each group, while one-way ANOVA was used to compare post-test values between the three groups. The level of significance was set at p < 0.05.

Table 1: Comparison of Pre-test and Post-test Values of Berg Balance Scale (BBS).

Group	Pre-test Mean ± SD	Post-test Mean ± SD	Mean Difference	t-value	p-value
Group A	37.4 ± 3.2	42.6 ± 2.9	5.2	5.12	<0.001*
Group B	38.1 ± 3.5	49.3 ± 2.7	11.2	10.84	<0.001*
Group C	37.8 ± 3.4	44.1 ± 3.0	6.3	6.28	<0.001*

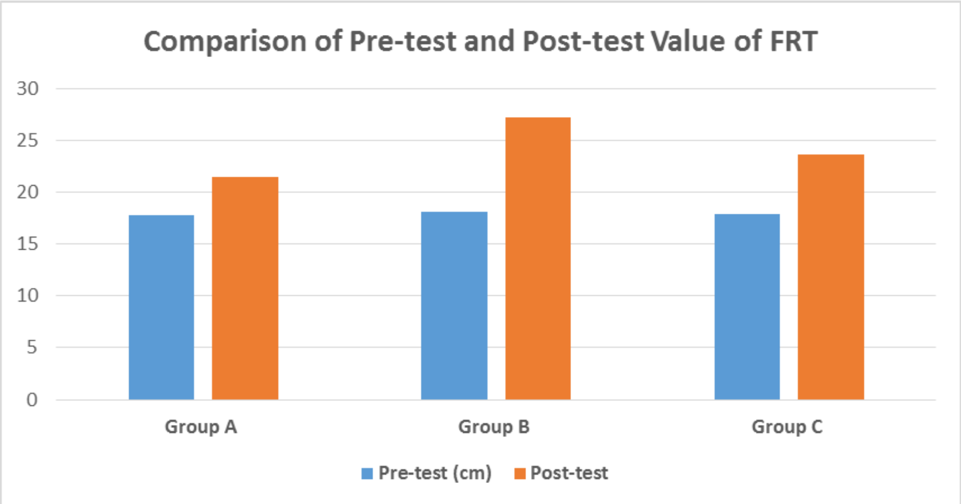


All three groups showed significant improvement in BBS scores following intervention. However, Group B demonstrated the greatest improvement in static and dynamic balance.

Table 2: Comparison of Pre-test and Post-test Values of Functional Reach Test (FRT).

The findings suggest that moderate-frequency and moderate-intensity WBVT may be the optimal training parameter for improving postural control and functional mobility in individuals with Diabetic Peripheral Neuropathy.

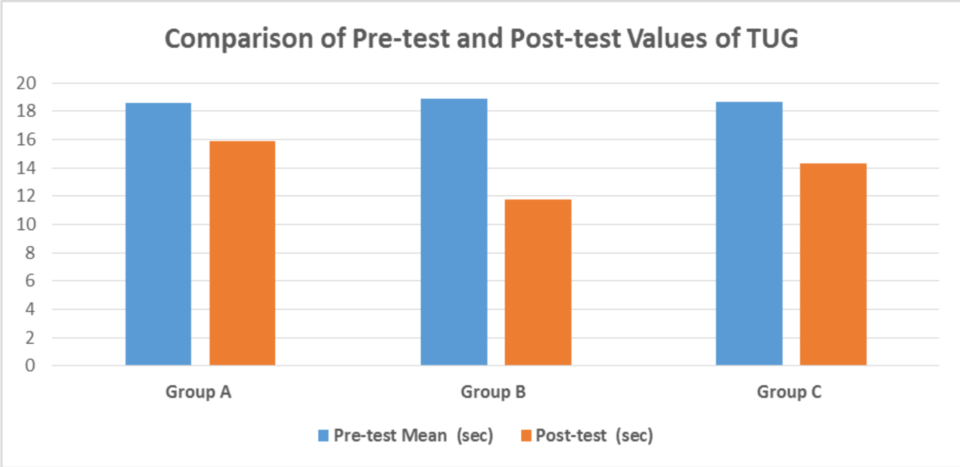
Group	Pre-test Mean ± SD (cm)	Post-test Mean ± SD (cm)	Mean Difference	t-value	p-value
Group A	17.8 ± 2.3	21.5 ± 2.1	3.7	4.96	<0.001*
Group B	18.1 ± 2.5	27.2 ± 2.4	9.1	9.88	<0.001*
Group C	17.9 ± 2.4	23.6 ± 2.2	5.7	6.12	<0.001*



Significant improvement in dynamic balance was observed in all groups. Group B showed maximum improvement in Functional Reach Test values compared to Groups A and C.

Table 3: Comparison of Pre-test and Post-test Values of Timed Up and Go Test (TUG).

Group	Pre-test Mean ± SD (sec)	Post-test Mean ± SD (sec)	Mean Difference	t-value	p-value
Group A	18.6 ± 2.1	15.9 ± 1.8	2.7	4.52	<0.001*
Group B	18.9 ± 2.4	11.8 ± 1.6	7.1	9.96	<0.001*
Group C	18.7 ± 2.3	14.3 ± 1.9	4.4	5.87	<0.001*



Functional mobility significantly improved in all groups after intervention. Group B demonstrated the greatest reduction in TUG time, indicating superior improvement in mobility and balance.

Table 4: Between-Group Comparison of Post-test Values (One-Way ANOVA).

Outcome Measure	F-value	p-value	Inference
Berg Balance Scale (BBS)	18.62	<0.001*	Significant
Functional Reach Test (FRT)	16.48	<0.001*	Significant
Timed Up and Go Test (TUG)	20.14	<0.001*	Significant

RESULTS

The results of the present study demonstrated that all three Whole-Body Vibration Training protocols produced significant improvements in balance and functional mobility in individuals with Diabetic Peripheral Neuropathy. However, the moderate-frequency WBVT group (20–30 Hz) showed significantly greater improvement in Berg Balance Scale, Functional Reach Test, and Timed Up and Go Test scores compared to the low-frequency and high-frequency groups.

DISCUSSION

The present study was conducted to determine the optimal frequency and intensity of Whole-Body Vibration Training (WBVT) on balance and functional mobility in individuals with Diabetic Peripheral Neuropathy. The findings of the study demonstrated significant improvements in balance and functional mobility in all three intervention groups following six weeks of WBVT. However, the moderate-frequency WBVT group (20–30 Hz) showed greater improvement in Berg Balance Scale (BBS), Functional Reach Test (FRT), and Timed Up and Go Test (TUG) scores compared to the low-frequency and high-frequency WBVT groups.

Diabetic Peripheral Neuropathy is associated with impaired proprioception, reduced plantar sensation, muscle weakness, delayed postural responses, and gait instability, all of which contribute to balance impairment and increased fall risk. Recent literature emphasizes that impaired sensory integration and neuromuscular control are major contributors to postural instability in DPN. The improvements observed in the present study may be attributed to enhanced neuromuscular activation and proprioceptive stimulation induced by WBVT.

Whole-Body Vibration Training stimulates muscle spindles and Ia afferent fibers through rapid mechanical oscillations, producing tonic vibration reflexes that facilitate muscle activation and postural responses. Moderate-frequency vibration appears to provide optimal sensory stimulation without causing excessive fatigue or instability. In the present study, participants in the moderate-frequency group demonstrated the greatest improvement in BBS scores, indicating superior enhancement in static and dynamic balance. This finding supports previous studies which reported that WBVT significantly improves balance and postural control in individuals with diabetic neuropathy.

The significant improvement in Functional Reach Test values observed in the moderate-frequency group suggests enhanced dynamic stability and improved limits of stability. WBVT may have improved postural adjustments and weight-shifting ability by increasing lower limb muscle activation and proprioceptive feedback. Similar findings were reported in a systematic review by Akbari et al., which concluded that exercise therapy and sensory stimulation interventions positively influence balance and postural control in DPN.

The Timed Up and Go Test (TUG) results in the present study demonstrated significant reduction in mobility time following intervention, particularly in the moderate-frequency group. This indicates improvement in functional mobility, gait stability, and movement coordination. WBVT may improve functional mobility by enhancing lower limb muscle strength, neuromuscular coordination, and reaction time. Previous randomized controlled trials have also demonstrated that WBVT combined with balance exercises improves functional mobility and lower limb performance in patients with DPN.

The findings of the present study suggest that low-frequency WBVT produced improvement in balance and mobility; however, the magnitude of improvement was comparatively lower than the moderate-frequency group. Low-frequency vibration may primarily improve circulation and sensory awareness but may not provide sufficient neuromuscular stimulation for optimal balance enhancement. Conversely, although the high-frequency WBVT group demonstrated improvement, the outcomes were less favourable than the moderate-frequency group. Excessively high vibration frequencies may increase muscular fatigue, discomfort, or instability in individuals with impaired sensation and reduced postural control.

The superior outcomes observed in the moderate-frequency group may indicate that moderate vibration parameters provide an ideal balance between sensory stimulation and neuromuscular activation. Moderate-frequency WBVT likely enhances proprioceptive integration and motor unit recruitment without producing excessive mechanical stress. This observation is consistent with recent evidence indicating that moderate-intensity balance-oriented interventions are more effective for improving postural control in DPN populations.

Another possible explanation for the observed improvements is neuroplastic adaptation. Repeated vibration exposure may improve sensory-motor integration and central processing of proprioceptive input. WBVT may also increase peripheral circulation and stimulate mechanoreceptors, thereby improving sensory feedback from the lower limbs. These physiological adaptations could contribute to improved balance confidence and reduced fall risk.

The present study also supports the growing body of evidence favouring multimodal sensory stimulation approaches in diabetic neuropathy rehabilitation. A recent randomized controlled trial by Jamal et al. demonstrated that WBVT significantly improved pain, balance, proprioception, and quality of life in individuals with painful diabetic neuropathy. Similarly, Albert et al. reported that WBVT improved balance and proprioception in diabetic foot neuropathy patients.

The findings of this study have important clinical implications. Identifying the optimal WBVT frequency and intensity may help physiotherapists design safer and more effective rehabilitation programs for individuals with DPN. Moderate-frequency WBVT can be considered a practical and non-invasive intervention for improving postural control and functional mobility while minimizing fall risk.

Despite the positive findings, certain limitations were observed in the present study. The sample size was relatively small, and the duration of intervention was limited to six weeks. Long-term retention of treatment effects was not assessed. Additionally, objective neurophysiological measures such as nerve conduction studies and electromyography were not included.

Future studies are recommended to investigate long-term effects of WBVT, include larger sample sizes, and compare WBVT with other rehabilitation interventions such as sensorimotor training and dual-task training. Further research may also focus on combining WBVT with aerobic exercise or gait training to enhance rehabilitation outcomes in individuals with DPN.

CONCLUSION

The present study concluded that Whole-Body Vibration Training (WBVT) significantly improved balance and functional mobility in individuals with Diabetic Peripheral Neuropathy. Significant improvements were observed in Berg Balance Scale (BBS), Functional Reach Test (FRT), and Timed Up and Go Test (TUG) scores following six weeks of intervention in all three groups.

Among the different vibration parameters, the moderate-frequency and moderate-intensity WBVT group (20–30 Hz) demonstrated greater improvement in static balance, dynamic balance, and functional mobility compared to the low-frequency and high-frequency WBVT groups. The findings suggest that moderate-frequency WBVT provides optimal neuromuscular stimulation and proprioceptive enhancement without causing excessive fatigue or instability.

Therefore, moderate-frequency WBVT may be considered an effective, safe, and clinically useful rehabilitation intervention for improving postural control and mobility in individuals with Diabetic Peripheral Neuropathy.

Limitations

- Sample size of the study was relatively small.
- Long-term follow-up was not performed.
- The study included only individuals between 50–65 years of age; therefore, results may not be applicable to younger or older populations.

Recommendations

- Studies can be conducted with larger sample size.
- Long-term follow-up studies can be done.
- Future research may compare WBVT with other rehabilitation approaches
- Studies combining WBVT with aerobic exercise or gait training may be conducted to evaluate additional functional benefits.
- Further research is recommended to determine individualized WBVT protocols based on severity of neuropathy, age, and functional status.
- Multicenter trials with extended intervention duration can be done

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