

The effects of whole body vibration on mobility and balance in children with cerebral palsy: a systematic review with meta-analysis

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Abstract

Objective: We performed a meta-analysis to evaluate the effects of whole-body vibration on physiologic and functional measurements in children with cerebral palsy. **Design and methods:** We searched MEDLINE, Cochrane Controlled Trials Register, EMBASE, Scielo, CINAHL (from the earliest date available to November 2014) for randomized controlled trials, that aimed to investigate the effects of whole-body vibration versus exercise and/or versus control on physiologic and functional measurements in children with cerebral palsy. Two reviewers independently selected the studies. Weighted mean differences (WMDs) and 95% confidence intervals (CIs) were calculated. **Results:** Six studies with 176 patients comparing whole-body vibration to exercise and/or control were included. Whole-body vibration resulted in improvement in: gait speed WMDs (0.13 95% CI: 0.05 to 0.20); gross motor function dimension E WMDs (2.97 95% CI: 0.07 to 5.86) and femur bone density (1.32 95% CI: 0.28 to 2.36). The meta-analysis also showed a nonsignificant difference in muscle strength and gross motor function dimension D for participants in the whole-body vibration compared with control group. No serious adverse events were reported. **Conclusions:** Whole-body vibration may improve gait speed and standing function in children with cerebral palsy and could be considered for inclusion in rehabilitation programs.

Keywords: Cerebral Palsy, Exercise, Whole-body Vibration, Mobility

Background

The development of alternative techniques and therapeutic resources to improve disability and quality of life in children with cerebral palsy is challenging¹. The use of external devices such as treadmills and weight machines is increasing in treatment settings^{2,3}. Whole-body vibration training was proposed as a new therapeutic modality for the treatment of the gross motor function, balance and functional performance⁴⁻⁷.

Whole-body vibration is a neuromuscular training which uses oscillatory motion around an equilibrium point. This technique may be a effective stimulus to improve neuromus-

cular performance and balance in healthy individuals^{8,9}. In patients with Parkinson disease has demonstrated limited, but beneficial effects on balance stability and mobility¹⁰. However, another review reported that whole-body vibration training only improves strength in neurological patients and balance/ mobility in patients with musculoskeletal or metabolic disorders¹¹. So, the effects of whole-body vibration are not consensual in the literature, what deserves some concern. No systematic review with meta-analysis has been performed to investigate the effects of whole-body vibration in children with cerebral palsy.

The aim of this systematic review was to analyze the published randomized controlled trials (RCTs) that investigated the effects of whole-body vibration on motor function and functional performance in children with cerebral palsy.

Methods

This review was planned and conducted in accordance with PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) guidelines¹¹.

The authors have no conflict of interest.

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Study	1*	2	3	4	5	6	7	8	9	10	11	Total
1 Ibrahim et al, 2014 ¹⁸	✓	✓		✓						✓	✓	4
2 El-Shamy et al, 2014 ¹⁹	✓	✓	✓	✓			✓	✓	✓	✓	✓	8
3 Lee & Chon, 2013 ²⁰	✓	✓	✓	✓			✓	✓		✓	✓	7
4 El-Shamy et al, 2012 ²¹	✓	✓		✓						✓	✓	4
5 Ruck et al, 2010 ²²	✓	✓	✓	✓						✓	✓	5
6 Wren et al, 2010 ²³	✓	✓	✓	✓			✓	✓		✓	✓	7

1: eligibility criteria and source of participants; 2: random allocation; 3: concealed allocation; 4: baseline comparability; 5: blinded participants; 6: blinded therapists; 7: blind assessors; 8: adequate follow-up; 9: intention-to-treat analysis; 10: between-group comparisons; 11: point estimates and variability. *Item 1 does not contribute to the total score.

Table 1. Study quality on the PEDro scale.

Eligibility criteria

This systematic review included all RCTs that studied the effects of whole-body vibration on motor function and functional performance in children with cerebral palsy.

Studies were considered for inclusion regardless of their publication status, language or size. Trials enrolling children with cerebral palsy were included in this systematic review. To be eligible, the trial should have randomized cerebral palsy patients to, at least, one group of whole-body vibration. The main outcomes of interest were motor function and functional performance.

Search methods for identification of studies

We searched for references on MEDLINE, LILACS, EMBASE, SciELO, Cumulative Index to Nursing and Allied Health (CINAHL), PEDro, and the Cochrane Library up to November 2014 without language restrictions. A standard protocol for this search was developed and whenever possible, controlled vocabulary (Mesh term for MEDLINE and Cochrane and Emtree for EMBASE) were used. Key words and their synonyms were used to sensitize the search.

For the identification of RCTs in PUBMED/MEDLINE the optimally sensitive strategy developed for the Cochrane Collaboration was used¹². To identify the RCTs in EMBASE, a search strategy using similar terms was adopted. In the search strategy, there were four groups of keywords: study design, participants, interventions, and outcome measures as such: “randomized controlled trials”, “Cerebral palsy”, “exercise”, “whole-body vibration” and “mobility”, using Boolean operators and/or.

All eligible articles for this meta-analysis had their references lists analyzed in order to detect other potentially eligible studies. For ongoing studies or when the confirmation of any data or additional information was needed, the authors were contacted by e-mail.

Data collection and analysis

The previously described search strategy was used to obtain titles and abstracts of studies that might be relevant for this re-

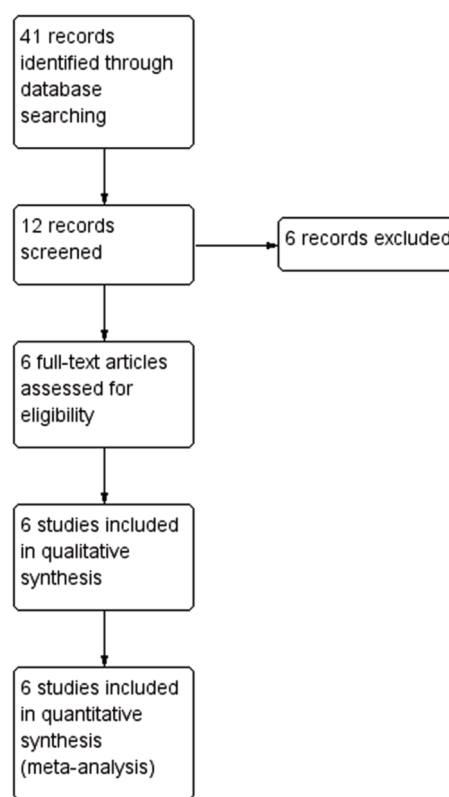


Figure 1. Search and selection of studies for systematic review according PRISMA.

view. Each abstract identified in the search was independently evaluated by two authors. If at least one of the authors considered one reference eligible, the full text was obtained for complete assessment.

In a similar fashion, two authors independently evaluated full text articles for eligibility and filled inclusion and exclusion criteria in a standard form. A standardized data extraction form was used to inclusion and exclusion criteria. In case of any disagreement, the authors discussed the reasons for their decisions and a final decision was made by consensus.

Study	Patients (diagnosis, N analysed, age, gender)	Intervention groups		Outcome measures	Results
		Treatment	Control		
1 Ibrahim et al ¹⁸	Spastic Diplegia, 30 children; 9.93 years.	Conventional Therapy + WBV	Conventional Therapy	Knee extensor strength Walking Speed Walking Balance GMFM	Knee extensor strength, Walking Speed and GMFM (E) was significantly increase only WBV group
2 El-Shamy et al ¹⁹	Spastic Diplegia, 30 children; 9.93 years; 76,6% male.	Conventional Therapy + WBV	Conventional Therapy	Knee extensor strength Balance and postural stability	Increase the gains in muscle strength and balance
3 Lee & Chon ²⁰	Cerebral Palsy, 30 children; 10 years; 50% male.	Conventional Therapy + WBV	Conventional Therapy	Gross motor function Leg muscle thickness Three-dimensional gait analyses	Improve mobility in children with cerebral palsy Positive effect on the leg muscles
4 El-Shamay et al ²¹	Spastic Diplegia; 30 children; 10-13 years; GMFCS = I, II.	Conventional Therapy + WBV	Conventional Therapy	Bone densitometry Anthropometry	Improvements in Bone densitometry
5 Ruck et al ²²	Cerebral Palsy, 20 children, 18 analysed, 6.2 to 12.3 years, 70% male; GMFCS = II-IV.	Conventional Therapy + WBV	Conventional Therapy	Walking ability Gross motor function Bone densitometry	Improve mobility function Without detect a positive treatment effect on bone
6 Wren et al ²³	Cerebral Palsy; 36 children; 9.4 years; 42% male; GMFCS = I-IV.	WBV	Stand up without WBV	Bone densitometry and Muscle strength	Did not result from increases in muscle mass or strength. No effect was seen on bone

GMFM=Gross motor function; GMFCS= Gross Motor Function Classification System.

Table 2. Characteristics of the included studies.

Two authors independently extracted data from the published reports using standard data extraction forms adapted from the Cochrane Collaboration's¹² model for data extraction, considering: 1) aspects of the study population, such as the average age and sex; 2) aspects of the intervention performed (sample size, frequency, and duration of each session); 3) follow-up; 4) loss to follow-up; 5) outcome measures; and 6) presented results. Disagreements were resolved by one of the authors. Any further information required from the original author was requested by e-mail.

Risk of bias of included studies

The risk of bias of included studies was assessed independently by two authors using The Cochrane Collaboration's 'Risk of bias' tool¹². The following criteria were assessed: Random sequence generation, allocation concealment, blinding of participants and personnel, blinding of outcome assessment, incomplete outcome data, selective reporting, intention-to-treat analysis and completeness of follow-up.

Quality of meta-analysis evidence

The quality of evidence generated by this meta-analysis was classified using the PEDro scale. There are several scales for assessing the quality of RCTs. The PEDro scale assesses the

methodological quality of a study based on important criteria, such as concealed allocation, intention-to-treat analysis, and the adequacy of follow-up. These characteristics make the PEDro scale a useful tool for assessing the quality of physical therapy and rehabilitation trials¹³.

Methodological quality was independently assessed by two researchers. Studies were scored on the PEDro scale based on a Delphi list¹⁴ that consisted of 11 items. One item on the PEDro scale (eligibility criteria) is related to external validity and is generally not used to calculate the method score, leaving a score range of 0 to 10¹⁵. Any disagreements were resolved by a third reviewer.

Statistical assessment

Pooled-effect estimates were obtained by comparing the least square mean percentage change from baseline to study end for each group, and were expressed as the weighted mean difference between groups. When the SD of change was not available, the SD of the baseline measure was used for the meta-analysis. Calculations were done using a random-effects model. One comparison was made: whole-body vibration versus control group. An α value of 0.05 was considered significant. Statistical heterogeneity of the treatment effect among studies was assessed using Cochran's Q-test and the inconsistency I^2 test, in which values above 25 and 50% were considered indicative of moder-

Study	Modality	Intensity/ duration (wk)	Volume	Frequency (x per Wk)	Time (min)	Length (wk)	Supervision
1 Ibrahim et al ¹⁸	Whole Body Vibration	12-18 Hz 2-6 mm	3 min of WBV 3 min of rest 3 min of WBV 3 min of rest 3 min of WBV	3	60	12	Yes
2 El-Shamy et al ¹⁹	Whole Body Vibration	12-18 Hz	3 min of WBV 3 min of rest 3 min of WBV 3 min of rest 3 min of WBV	5	18	12	Yes
3 Lee & Chon ²⁰	Whole Body Vibration Without shoes	5-25 Hz	3 min of 5-8 Hz 3 min of 10-15 Hz 3 min of 15-20 Hz 3 min of 20-25 H 3 min of 15-20 Hz 3 min of 10-15 Hz	3	60	8	Yes
4 El Shamay et al ²¹	Whole Body Vibration	0,3 g 25 Hz 1,7 mm	5 min of warming up 10 min of WBV	5	10	24	Yes
5 Ruck et al ²²	Whole Body Vibration With shoes	12-18 Hz	3 minutes of WBV 3 minutes rest 3 minutes of WBV 3 minutes rest 3 minutes of WBV	5	18	24	Yes
6 Wren et al ²³	Whole Body Vibration	30 Hz	10 minutes of WBV	7	10	24	No

WBV= Whole Body Vibration.

Table 3. Characteristics of the experimental intervention in the trials included in the review.

ate and high heterogeneity, respectively¹⁶. If a meta-analysis was not possible due to clinical heterogeneity, data were analysed descriptively. All analyses were conducted using Review Manager Version 5.0 (Cochrane Collaboration)¹⁷.

Results

Description of selected studies

The initial search led to the identification of 12 abstracts, from which six studies were considered as potentially relevant and were retrieved for detailed analysis. Only six papers met the eligibility criteria. Figure 1 shows the PRISMA flow diagram of studies in this review.

The remaining six articles were fully analyzed and approved by both reviewers and had the extraction of data from each RCT. Each of the papers was assessed using the PEDro scale methodology by both reviewers. The results of the assessment of the PEDro scale are presented individually in Table 1.

Study characteristics

The final sample ranged from 17²¹ to 30^{18,19,20,22}, and mean age of participants ranged from 8.2 to 9.8 years. All studies included patients of both genders, but there was a predominance

of male. Table 2 presents summary data from the two RCTs eligible for this systematic review.

Characteristics of intervention programs

The parameters used in the application of whole-body vibration have been reported in the searched studies, and the progressive nature of the programs was described.

The duration of whole-body vibration programs ranged from 8²⁰ to 24²¹⁻²³ weeks. Regarding the session duration, there was a variation from 10^{21,23} to 60^{18,20} minutes. The frequency ranged from 3^{18,20} to 7²³ times per week. The characteristics of the intervention programs are in Table 3.

Gait speed

Two studies^{20,22} assessed gait speed as an outcome. A significant improvement in gait speed of 0.13 m/s (95% CI: 0.05, 0.2, N=46) was found for participants in the whole-body vibration group compared with control group (Figure 2).

Muscle strength

Three studies^{18,19,23} assessed muscle strength as an outcome. Due to the difference between the instruments used in the

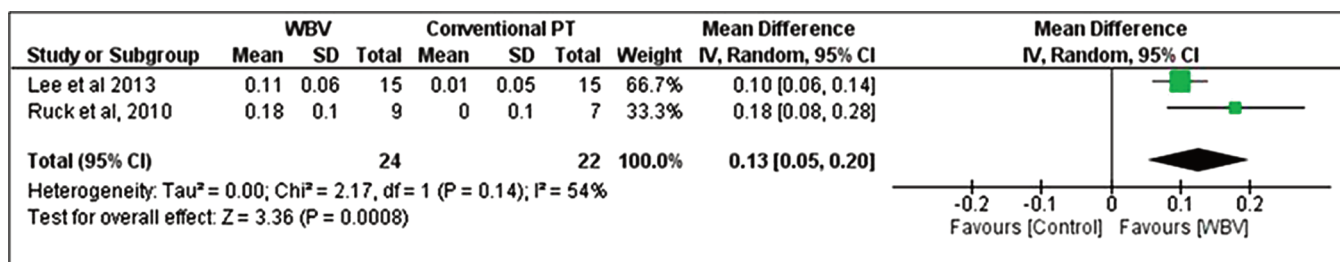


Figure 2. WBV versus Control: Gait Speed. Review Manager (RevMan). Version 5.2 The Cochrane Collaboration, 2013.

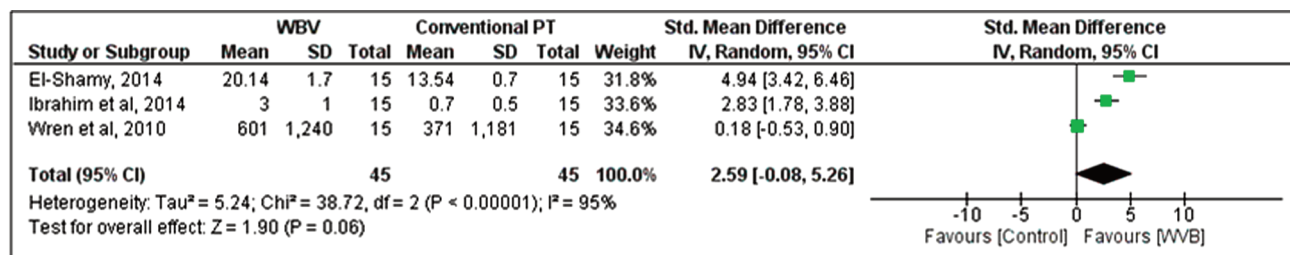


Figure 3. WBV versus control: Muscle Strength. Review Manager (RevMan). Version 5.2 The Cochrane Collaboration, 2013.

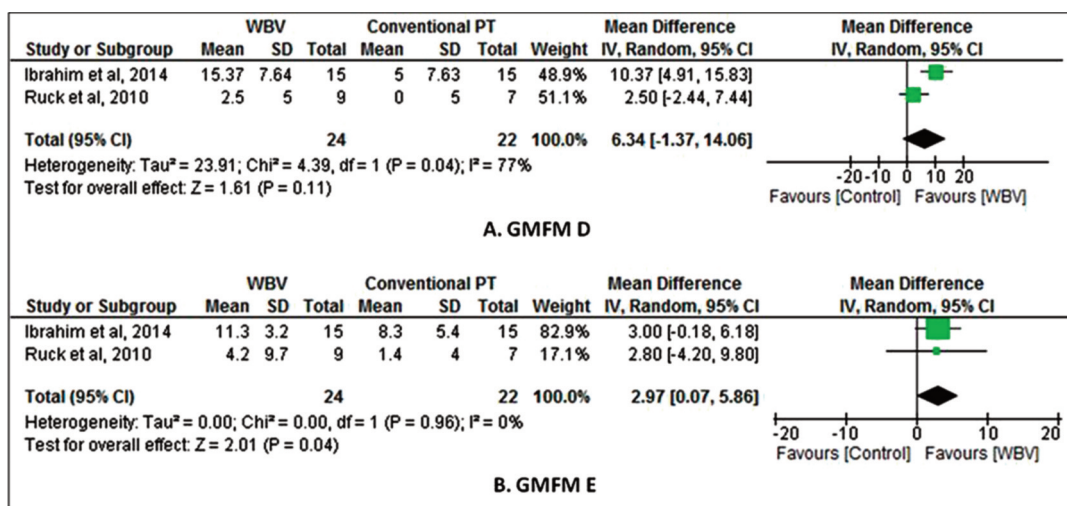


Figure 4. WBV versus control: (A) GMFM D and (B) GMFM E. Review Manager (RevMan). Version 5.2 The Cochrane Collaboration, 2013.

measurement of muscle strength, a meta-analysis using standardized mean difference was performed. A nonsignificant improvement in muscle strength of 2.59 (95% CI: -0.08, 5.26, N=90) was found for participants in the whole-body vibration group compared with control group (Figure 3).

Gross motor function

Two studies^{18,22} assessed gross motor function D and gross motor function E as outcomes. A nonsignificant improvement in gross motor function D of 6.34 (95% CI: -1.37, 14.06, N=46) was found for participants in the whole-body vibration

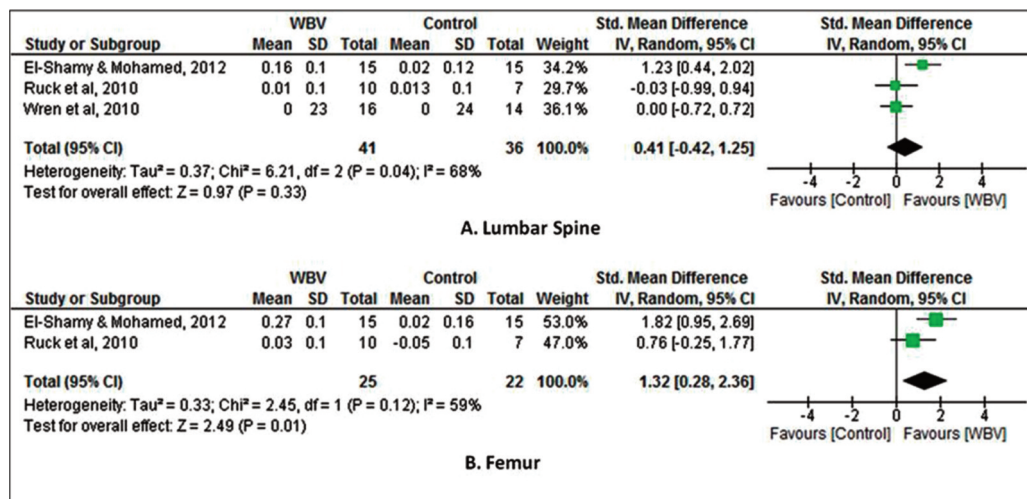


Figure 5. WBV versus control: (A) Lumbar Spine bone density and (B) Femur bone density. Review Manager (RevMan). Version 5.2 The Cochrane Collaboration, 2013.

group compared with control group. Considering gross motor function E, a significant improvement of 2.97 (95% CI: 0.07, 5.86, N=46) was found for participants in the whole-body vibration group compared with control group (Figure 4).

Bone density

Due to the difference between the instruments used in the measurement of bone density, it was performed a meta-analysis with standardized mean difference. Three studies²¹⁻²³ assessed lumbar spine bone density as an outcome. A nonsignificant improvement in lumbar spine bone density of 0.41 (95% CI: -0.42, 1.25, N=77) was found for participants in the whole-body vibration group compared with control group. Two studies^{21,22} assessed femur bone density as an outcome. A significant improvement in femur bone density of 1.32 (95% CI: 0.28, 2.36, N=47) was found for participants in the whole-body vibration group compared with control group (Figure 5).

Discussion

In the present systematic review, a meta-analysis of four studies demonstrated a significant difference in gait speed, Gross motor function and femur bone density in cerebral palsy children submitted to whole-body vibration. Moreover, whole-body vibration did not show improvements in muscle strength and lumbar spine bone density.

Whole-body vibration is a potential tool in the rehabilitation of elderly and patients with chronic diseases^{9,10,24}. However, no systematic review has been performed concerning whole-body vibration in children with cerebral palsy. This systematic review is important because it analyzes the whole-body vibration as a potential co-adjuvant modality in rehabilitation.

In clinical practice, interventions are rarely applied in iso-

lation and are commonly combined with other therapies for maximum therapeutic benefit. Moreover, the eligibility of gait speed and gross motor function as outcomes in this meta-analysis is important because are complementary measurements in the functional assessment of children with cerebral palsy²⁵. Gait speed and gross motor function are related to daily-life mobility²⁶ and improving the ability to walk is often the essential therapeutic goal for such children²⁷.

Considering gait speed, our meta-analysis showed an improvement of 0.14 m/s (34%) in the whole-body vibration group. We found no studies that estimated the minimum detectable change in children with cerebral palsy. However, Lam et al²⁸, estimate the minimum detectable change in patients with spinal cord injury of 0.13 m/s and 0.1 m/s for patients with stroke²⁹.

The assessment of gross motor function is essential in a cerebral palsy rehabilitation program. The gross motor function for dimension (D), which is related to the standing ability increased in whole-body vibration groups, but showed no significant difference when compared to conventional physical therapy. For dimension (E), which is related to the walking, running and jumping, the results were similar to the gross motor function for dimension (D).

Considering the bone density a significant improvement in femur bone density was found in the whole-body vibration group. The mechanisms involved in this improvement might be related to a greater muscle and bone blood circulation and the offer of nutrients^{30,31}. In spite of the positive results for increasing bone density, our meta-analysis found no significant effect in relation to muscle strength. Our results differ from previous systematic reviews^{32,33} in aging adults who have identified increased muscle strength after whole-body vibration training.

Overall, whole-body vibration seems to be well tolerated among children with cerebral palsy, although the incidence of

long-term hazards requires more research.

It is difficult to make a pragmatic recommendation about whole-body vibration in children with cerebral palsy. Our search strategy found six studies and they used different protocols of whole-body vibration. Different variables must be influencing the effects of the whole-body vibration, such as frequency, intensity and volume. The study by El-Shamy et al¹⁹, for example, used a frequency of the 12- 18 Hz for 18 minutes and the study by Wren et al²³ used a frequency of the 30 Hz for 10 minutes.

Caution is warranted when interpreting the present results given the small amount of studies and the significant heterogeneity in the primary analyses. Further research is required to investigate how to sustain positive effects of WBV over time and to determine essential attributes of whole-body vibration training (mode, rhythm, intensity, frequency and duration).

Considering the available data, our meta-analysis showed that the whole-body vibration should be considered as an alternative method in addition to conventional physical therapy in children with cerebral palsy. Well controlled RCTs are needed to a clear understand of the effects of whole-body vibration in rehabilitation.

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