Strength effects after whole-body vibration in elderly population – a systematic review and meta-analysis

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1. Background

Decrease of muscle strength, gait ability and balance are the main factors for about 26% of falls in nursing homes. The risk of falling rises by up to 6.2 times after strength loss in the leg muscles (1). Strength training and exercise are traditional intervention methods in the field of sport and physical therapy. In recent years, whole body vibration was introduced as a new, attractive and efficient training method for improving power and strength (2-4). Due to the influence of WBV on the neuromuscular system and the triggering of reflex responses, mechanical vibrations have the potential to improve muscle strength (5-7).

Several studies have demonstrated that WBV improves strength in elderly healthy people. Trans et al. (8) showed a beneficial effect after 8 weekly WBV training sessions focused on strengthening the knee extensors and flexors. Bogaerts (9) described similar positive effects on the knee extensors. Furthermore, one training session can be completed in a short time; also, it seems to have the similar ability to increase muscle strength as conventional strength training. Another positive aspect may be that WBV training showed no side effects.

However, while most WBV studies show varying results in strength or power, these results must be interpreted with caution. Thus, according to Colson et al. (10), no effects on students were examined after a WBV intervention.

Furthermore, it should be mentioned that many of the studies published have methodological flaws. One explanation for the contradictory results could be attributed to the inconsistent training parameters used for the WBV training. The frequency, amplitude, duration of one vibration session, the number of vibration interventions (sessions per week), are all treatment parameters that need to be considered when applying WBV. The duration of the rest period between vibration sessions also seems to play an important role (11, 12). A pertinent question arises as to the strength of the evidence in the scientific literature for this type of intervention.

The purpose of this systematic review is to provide an overview of the evidence currently available for the use of WBV to improve strength or power in elderly people. Following aspects should be clarified in particular: 1) assessment of the quality and
internal validity of the studies reviewed; 2) description of the assessments used to document the effect of WBV on maximal voluntary contraction, power and force development rate; 3) composition of the WBV training parameters; and 4) conclusion about the clinical relevance. Furthermore, this re-view should produce some more conclusive insight into the effect of WBV on the strength and power in the elderly by summarizing the available studies in a meta-analysis.
2. Research question

The aim of this systematic review and meta-analysis is to establish the best evidence regarding whole-body vibration on strength, power, rate of force development and functional strength in elderly population. Specifically, the research questions are

1. What are the effects after whole-body Vibration training on the muscle strength in elderly people aged 65 years?
2. Are there differences on muscle strength between whole-body vibration and conventional strength training in elderly people aged 65 years?
3. Methods

3.1. Searching design

This systematic review and meta-analysis follows the PRISMA guideline. The search strategy aims to find published studies and articles. Following databases was conducted until November 2013:

- Cochrane Register of Controlled Trials,
- Physiotherapy Evidence Database (PEDro)
- PubMed
- Science direct.

Hand search:

- Unpublished International Clinical Trials Registry Platform from the World Health Organization (WHO).
- Google scholar
- Manual search of the reference lists of retrieved publications was conducted.

3.2. Search strategy

3.2.1 Database

Cochrane Register of Controlled Trials

Search terms: “WBV”, „whole body vibration”, „whole body vibrations”, “whole-body vibration” and „vibration training”

PEDro

Search terms: „WBV”, „whole body vibration“, „whole-body vibration“ und „vibration training“.

PubMed

Search terms: (((((elderly) OR age) OR frail)) AND ((((((((((((strength)) OR ((power))) OR ((rate of force development))) OR ((force))) OR (((functional strengh) OR (force)))) OR (propriocept*))) OR (sensori-motor))) OR (gait stability))) OR (dynamic stability))) OR ((postural stability))) OR (postural balance))) OR ((postural balance))) OR (gait stability))) OR (dynamic stability))) OR (propriocept*))) OR (sensori-motor))) OR
((sensorimotor))) AND (("whole body vibration") OR ("whole body vibrations") OR (Vibration Training[tiab])) OR (stochastic stimulation) OR (stochastic training) OR (stochastic vibration) OR (Whole-Body Vibration) OR (Whole-Body-Vibration) OR (Whole-Body Vibrations) OR (Whole-Body-Vibrations) OR (WBV) OR (sinusoidal vibration) OR (noise vibration AND (therapy OR treatment OR training OR exercise)) OR (stochastic resonance therapy) OR (stochastic resonance treatment)))

Science direct


3.2.2 Hand search

International Clinical Trials Registry Platform and Google scholar „whole body vibration“, „WBV“ und „vibration“
4. Study selection

In the first round five reviewers (CJ, CN, NJS, SR, RH) screened title and abstract. Published randomised and non randomised controlled studies were eligible for inclusion. The studies examined the effects of whole-body vibration on isometric maximally voluntary contraction, rate of force development, power and functional strength. Exclusion criteria was current vibration, vibration via insoles, participants < 65 years and participants with diseases.

1. Pulsed focused ultrasound treatment of muscle mitigates paralysis-induced bone loss in the adjacent bone: A study in a mouse model.
   PMID: 24181660 [PubMed - in process]
   Related citations

2. Whole-Body Vibration Versus Eccentric Training or a Wait-and-See Approach for Chronic Achilles Tendinopathy: A Randomized Clinical Trial.
   Horstmann T, Jud HM, Fröhlich V, Mündermann A, Grau S.
   PMID: 24175595 [PubMed - in process]
   Related citations

3. Responsiveness of muscle size and strength to physical training in very elderly people: A systematic review.
   Stewart VH, Saunders DH, Greig CA.
   PMID: 24151875 [PubMed - as supplied by publisher]
   Related citations

4. Variations in neuromuscular activity of thigh muscles during whole-body vibration in consideration of different biomechanical variables.
   Perchthaler D, Horstmann T, Grau S.
   Related citations

5. Low-intensity whole-body vibration training to reduce fall risk in active, elderly residents of a retirement village.
   Calder CG, Mannion J, Metcalf PA.
   PMID: 23937498 [PubMed - indexed for MEDLINE]
   Related citations

   Spiliopoulou SI, Amiridis IG, Tsigganos G, Hatzitaki V.
   PMID: 23914911 [PubMed - in process]
   Related citations
7. Effects of whole body vibration training on balance in adolescents with and without Down syndrome.
Villarroya MA, González-Agüero A, Moros T, Gómez-Trullén E, Casajús JA.
PMID: 23872530 [PubMed - in process]
Related citations
8. Effect of whole-body vibration exercise on mobility, balance ability and general health status in frail elderly patients: a pilot randomized controlled trial.
Clin Rehabil. 2013 Jul 17. [Epub ahead of print]
PMID: 23864514 [PubMed - as supplied by publisher]
Related citations
9. Short-term Effects of Whole-Body Vibration on Functional Mobility and Flexibility in Healthy, Older Adults: A Randomized Crossover Study.
Tsuji T, Kitano N, Tsunoda K, Himori E, Okura T, Tanaka K.
J Geriatr Phys Ther. 2013 Jul 8. [Epub ahead of print]
PMID: 23838625 [PubMed - as supplied by publisher]
Related citations
10. Long-term impact of strength training on muscle strength characteristics in older adults.
Kennis E, Verschueren SM, Bogaerts A, Van Roie E, Boonen S, Delecluse C.
PMID: 23831385 [PubMed - in process]
Related citations
11. Effects of whole-body vibration exercise training on aortic wave reflection and muscle strength in postmenopausal women with prehypertension and hypertension.
Figueroa A, Kalfon R, Madzima TA, Wong A.
PMID: 23823582 [PubMed - as supplied by publisher]
Related citations
Ross SE, Linens SW, Wright CJ, Arnold BL.
PMID: 23724774 [PubMed - indexed for MEDLINE]
Related citations
13. Whole-body vibration exercise training reduces arterial stiffness in postmenopausal women with prehypertension and hypertension.
Figueroa A, Kalfon R, Madzima TA, Wong A.
Menopause. 2013 May 24. [Epub ahead of print]
PMID: 23715407 [PubMed - as supplied by publisher]
Related citations
14. Effects of 3 months of short sessions of controlled whole body vibrations on the risk of falls among nursing home residents.
Beaudart C, Maquet D, Mannarino M, Buckinx F, Demonceau M, Crielaard JM, Reginster JY, Bruyère O.
Related citations
15. Effects of whole-body vibration on muscle architecture, muscle strength, and balance in stroke patients: a randomized controlled trial.
Marín PJ, Ferrero CM, Menéndez H, Martín J, Herrero AJ.
PMID: 23636085 [PubMed - in process]
Related citations
16. Acute effect of whole-body vibration at optimal frequency on muscle power output of the lower limbs in older women.
PMID: 23552332 [PubMed - indexed for MEDLINE]
Related citations
17. Vibration or balance training on neuromuscular performance in osteopenic women.
Stolzenberg N, Belavý DL, Rawer R, Felsenberg D.
PMID: 23549694 [PubMed - in process]
Related citations
Ferguson SL, Kim E, Seo DI, Bemben MG.
J Strength Cond Res. 2013 Mar 8. [Epub ahead of print]
PMID: 23478479 [PubMed - as supplied by publisher]
Related citations
19. The acute effects of whole-body vibration on gait parameters in adults with cerebral palsy.
Dickin DC, Faust KA, Wang H, Frame J.
Related citations
Söderpalm AC, Kroksmark AK, Magnusson P, Karlsson J, Tulinius M, Swolin-Eide D.
Related citations
21. Precision control of trunk movement in low back pain patients.
Willigenburg NW, Kingma I, Hoozemans MJ, van Dieën JH.
PMID: 23427936 [PubMed - indexed for MEDLINE]
Related citations
22. Ten-week whole-body vibration training improves body composition and muscle strength in obese women.
Milanese C, Piscitelli F, Zenti MG, Moghetti P, Sandri M, Zancanaro C.
Related citations
23. Whole-body vibration versus proprioceptive training on postural control in postmenopausal osteopenic women.
Stolzenberg N, Belavý DL, Rawer R, Felsenberg D.
PMID: 23375357 [PubMed - in process]

Related citations
24. Therapeutic impact of low amplitude high frequency whole body vibrations on the osteogenesis imperfecta mouse bone.
Vanleene M, Shefelbine SJ.

Related citations
Eftekhari E, Mostahfezian M, Etemadifar M, Zafari A.

Related citations
26. Relationship between vibrotactile detection threshold in the Pacinian channel and complex mechanical modulus of the human glabrous skin.
Yildiz MZ, Gϋçlü B.
PMID: 23323828 [PubMed - indexed for MEDLINE]

Related citations
27. Temporal correlations in postural sway moderate effects of stochastic resonance on postural stability.
Kelty-Stephen DG, Dixon JA.
PMID: 23317679 [PubMed - indexed for MEDLINE]

Related citations
28. Study protocol: the effect of whole body vibration on acute unilateral unstable lateral ankle sprain- a biphasic randomized controlled trial.
Baumbach SF, Fasser M, Polzer H, Sieb M, Regauer M, Mutschler W, Schieker M, Blauth M.

Related citations
29. Effects of a short-term whole body vibration intervention on physical fitness in elderly people.
Gómez-Cabello A, González-Agüero A, Ara I, Casajús JA, Vicente-Rodríguez G.
PMID: 23312489 [PubMed - as supplied by publisher]

Related citations
30. Effects of fitness and vibration training on muscle quality: a 1-year postintervention follow-up in older men.
Kennis E, Verschueren SM, Bogaerts A, Coudyzer W, Boonen S, Delecluse C.
PMID: 23254274 [PubMed - indexed for MEDLINE]

Related citations
31. Effect of whole-body vibration on delayed onset muscular soreness, flexibility, and power.

Related citations
32. Low-volume whole-body vibration lasting 3 or 6 months does not affect biomarkers in blood serum of rats.

Related citations
33. [Effect of an 8-week vibration training program in the elderly].

Related citations
34. Risk of lumbar spine injury from cyclic compressive loading.

Related citations
35. Vibration platform training in women at risk for symptomatic knee osteoarthritis.

Related citations

Related citations
37. Improved sensorimotor performance via stochastic resonance.

Related citations
38. Whole body vibration exercise improves body balance and walking velocity in postmenopausal osteoporotic women treated with alendronate: Galileo and Alendronate Intervention Trail (GAIT).

Related citations
39. Whole body vibration effects on body composition in the postmenopausal korean obese women: pilot study.
Related citations
40. Effects of combining whole-body vibration with exercise on the consequences of detraining on muscle performance in untrained adults.
Osawa Y, Oguma Y.
PMID: 22739330 [PubMed - in process]

Related citations
41. Baseline-dependent effect of noise-enhanced insoles on gait variability in healthy elderly walkers.
PMID: 22739049 [PubMed - indexed for MEDLINE]

Related citations
42. [Neurological lower torso function test. A new assessment].
Merkert J, Butz S, Niecezaj R, Steinhaugen-Thiessen E, Eckardt R.
PMID: 22733479 [PubMed - indexed for MEDLINE]

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43. Stochastic resonance training reduces musculoskeletal symptoms in metal manufacturing workers: a controlled preventive intervention study.
Burger C, Schade V, Lindner C, Radlinger L, Elfering A.
PMID: 22699194 [PubMed - indexed for MEDLINE]

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44. The effect of whole body vibration on balance, mobility and falls in older adults: a systematic review and meta-analysis.
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PMID: 22609157 [PubMed - indexed for MEDLINE]

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45. Functional performance and inflammatory cytokines after squat exercises and whole-body vibration in elderly individuals with knee osteoarthritis.
PMID: 22546535 [PubMed - indexed for MEDLINE]

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46. Effects of supplemental training on fitness and aesthetic competence parameters in contemporary dance: a randomised controlled trial.
Angioi M, Metsios G, Twitchett EA, Koutedakis Y, Wyon M.
PMID: 22543316 [PubMed - indexed for MEDLINE]

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47. Anaerobic power in road cyclists is improved after 10 weeks of whole-body vibration training.
Oosthuyse T, Viedge A, McVeigh J, Avidon I.
PMID: 22531614 [PubMed - indexed for MEDLINE]
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48. Alternative Exercise Technologies to Fight against Sarcopenia at Old Age: A Series of Studies and Review.
  Kemmler W, von Stengel S.
Related citations
49. The assessment of postural control with stochastic resonance electrical stimulation and a neoprene knee sleeve in the osteoarthritic knee.
  Collins AT, Blackburn JT, Olcott CW, Jordan JM, Yu B, Weinhold PS.
PMID: 22425291 [PubMed - indexed for MEDLINE]
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50. Stochastic resonance whole-body vibration training for chair rising performance on untrained elderly: a pilot study.
  Rogan S, Hilfiker R, Schmid S, Radlinger L.
PMID: 22425243 [PubMed - indexed for MEDLINE]
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51. Weight bearing through lower limbs in a standing frame with and without arm support and low-magnitude whole-body vibration in men and women with complete motor paraplegia.
PMID: 22407161 [PubMed - indexed for MEDLINE]
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52. Effects of training on bone mass in older adults: a systematic review.
  Gómez-Cabello A, Ara I, González-Agüero A, Casajús JA, Vicente-Rodríguez G.
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53. Whole-body vibration and resistance exercise prevent long-term hindlimb unloading-induced bone loss: independent and interactive effects.
PMID: 22371114 [PubMed - indexed for MEDLINE]
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54. Whole-body vibration training for patients with neurodegenerative disease.
PMID: 22336858 [PubMed - indexed for MEDLINE]
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55. Whole-body vibration has no effect on neuromotor function and falls in chronic stroke.
  Lau RW, Yip SP, Pang MY.
Whole body vibration improves the single-leg stance static balance in women with fibromyalgia: a randomized controlled trial.


Whole-body vibration in addition to strength and balance exercise for falls-related functional mobility of frail older adults: a single-blind randomized controlled trial.


Effect of whole-body vibration exercise on balance in women with fibromyalgia syndrome: a randomized controlled trial.


No specific effect of whole-body vibration training in chronic stroke: a double-blind randomized controlled study.


Effects of whole-body vibration with or without localized radiofrequency on anthropometry, body composition, and motor performance in young nonobese women.


Characterization of the tendon vibration reflex response in hemi-spastic stroke individuals.


Acute effect of whole-body vibration on power, one-repetition maximum, and muscle activation in power lifters.


Practice of contemporary dance promotes stochastic postural control in aging.

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Osawa Y, Oguma Y.
81. Effects of whole-body vibration and resistance training on knee extensors muscular performance.
82. Stochastic resonance therapy in Parkinson's disease.
83. Effects of vibrotherapy on postural control, functionality and fatigue in multiple sclerosis patients. A randomised clinical trial.
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84. Effects of whole body vibration therapy on main outcome measures for chronic non-specific low back pain: a single-blind randomized controlled trial.
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86. Physical and psychosocial ergonomic risk factors for low back pain in automobile manufacturing workers.
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87. Effects of a 6-week periodized squat training with or without whole-body vibration upon short-term adaptations in squat strength and body composition.
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88. Combined whole body vibration and balance training using Vibrosphere®: improvement of trunk stability, muscle tone, and postural control in stroke patients during early geriatric rehabilitation.
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Kasturi GC, Adler RA.
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90. [Incontinence after radical prostatectomy and cystectomy: are combined training with mechanical devices and whole body vibration effective?].
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PMID: 21472620 [PubMed - indexed for MEDLINE]

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91. Improving balance function using vestibular stochastic resonance: optimizing stimulus characteristics.
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92. Proprioceptive impairment and postural orientation control in Parkinson's disease.
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PMID: 21419506 [PubMed - indexed for MEDLINE]

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93. The effect of 8 mos of twice-weekly low- or higher intensity whole body vibration on risk factors for postmenopausal hip fracture.
Beck BR, Norling TL.
PMID: 21403595 [PubMed - indexed for MEDLINE]

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94. The acute effect of different frequencies of whole-body vibration on countermovement jump performance.
Turner AP, Sanderson MF, Attwood LA.
PMID: 21358422 [PubMed - indexed for MEDLINE]

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95. Changes in balance, functional performance and fall risk following whole body vibration training and vitamin D supplementation in institutionalized elderly women. A 6 month randomized controlled trial.
Bogaerts A, Delecuse C, Boonen S, Claessens AL, Milisen K, Verschueren SM.
The effect of 6-week exercise programme and whole body vibration on strength and quality of life in women with fibromyalgia: a randomised study.

Low back pain predict sickness absence among power plant workers.

Does whole-body vibration training have acute residual effects on postural control ability of elderly women?

Whole body vibration therapy in fracture prevention among adults with chronic disease.

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Effects of whole-body vibration training on different devices on bone mineral density.
The effect of warm-up with whole-body vibration vs. cycle ergometry on isokinetic dynamometry.
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PMID: 20570086 [PubMed - indexed for MEDLINE]
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120. Whole body vibration compared to conventional physiotherapy in patients with gonarthrosis: a protocol for a randomized, controlled study.
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121. Muscle activity and acceleration during whole body vibration: effect of frequency and amplitude.

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130. Loads on a spinal implant measured in vivo during whole-body vibration.
Rohlmann A, Hinz B, Blüthner R, Graichen F, Bergmann G.

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131. Predicting discomfort scores reported by LHD operators using whole-body vibration exposure values and musculoskeletal pain scores.
Grenier SG, Eger TR, Dickey JP.
PMID: 20164625 [PubMed - indexed for MEDLINE]

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132. Effects of vibration training on muscle power: a meta-analysis.
Marin PJ, Rhea MR.
PMID: 20145554 [PubMed - indexed for MEDLINE]

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133. The effects of whole-body vibration training in aging adults: a systematic review.
Merriman H, Jackson K.
PMID: 20128338 [PubMed - indexed for MEDLINE]

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134. Effects of 8 weeks of vibration training at different frequencies (1 or 15 Hz) in senior sportsmen on torque and force development and of 1 year of training on muscle fibers.
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135. A systematic review of supported standing programs.
Glickman LB, Geigle PR, Paleg GS.
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136. Vibration as an exercise modality: how it may work, and what its potential might be.
Rittweger J.
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Furness TP, Maschette WE.
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Knopman DS, Jack CR Jr, Kramer JH, Boeve BF, Caselli RJ, Graff-Radford NR, Mendez MF, Miller BL, Mercaldo ND.

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153. Effects of whole body vibration training on cardiorespiratory fitness and muscle strength in older individuals (a 1-year randomised controlled trial).
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154. Fitness efficacy of vibratory exercise compared to walking in postmenopausal women.
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Kaeding TS.
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Berg KE, Kaufman CL, Katsavelis DC, Ratliff KL, Simet JL.
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PMID: 18708849 [PubMed - indexed for MEDLINE]

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176. Ubiquitous crossmodal Stochastic Resonance in humans: auditory noise facilitates
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Lugo E, Doti R, Faubert J.

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Chan RW, Rodriguez ML.

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Armstrong WJ, Nestle HN, Grinnell DC, Cole LD, Van Gilder EL, Warren GS, Capizzi EA.
PMID: 18550962 [PubMed - indexed for MEDLINE]

Related citations
179. Effects of whole body vibration on postural steadiness in an older population.
Rees SS, Murphy AJ, Watsford ML.
PMID: 18550436 [PubMed - indexed for MEDLINE]

Related citations
180. Improved postural control after computerized optokinetic therapy based on stochastic
visual stimulation in patients with vestibular dysfunction.
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5. Data extraction and methodology quality

Five reviewers (CJ, CN, NJS, SR, RH) assessed independently the methodological quality with “The Cochrane Collaboration’s tool for assessing risk of bias”. The criteria list comprised six items. Each item was scored with “+” if the criterion was met, with “-” if the criterion was not met, and with “?” if the information was not provided or was unclear.

Four authors (CJ, CN, NJS, SR) independently abstracted the following information from each of the included studies in the systematic review and meta-analysis: 1) design and sample; 2) inclusion criteria; 3) training parameters; 4) type of vibration plate; 5) change in strength, power and force development rate; 6) conclusions of the studies and statistical significance.

Heterogeneity was assessed by examining forest plots and the $I^2$ statistics. For statistical analysis the standardised mean differences (SMD) as effect measures, and presented as continuous data (mean values and SD or mean changes).
### 6. Time table

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<th>Date</th>
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<td>Management systematic review</td>
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<td>SR &amp; RH</td>
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