The effects of neck muscle vibration on postural orientation and spatial perception: A systematic review

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COMPREHENSIVE REVIEW

The effects of neck muscle vibration on postural orientation and spatial perception: a systematic review

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Abstract

Background: Neck muscle vibration (NMV) is increasingly used for its modulation of body orientation and spatial perception, but its mechanisms of action are still not well known. **Objectives:** to describe the effects of NMV on postural orientation and spatial perception, in both healthy people and patients with disturbed balance potentially related to distorted body orientation perception. **Methods:** following the PRISMA guidelines, a systematic search was performed using the databases MEDLINE, EMBASE, Cochrane library and PEDrO with the key words ((Postural balance) OR (Spatial reference)) AND (Neck muscle vibration) for articles published through to July 2016. **Results:** 67 articles were assessed; these exhibited wide heterogeneity and generally poor quality methodology. In healthy subjects, under bilateral NMV, the body tilts in the anterior direction (Level of Evidence LoE II). Under unilateral NMV, the visual environment moves towards the side opposite the vibration (LoE II) and the subject's experience of "straight ahead" is shifted towards the side of the vibration (LoE II). NMV also modulates both spatial and postural bias among stroke and vestibular patients. **Discussion:** NMV modulates both spatial and postural bias and could thus be proposed as a tool in rehabilitative therapy. However, due to the heterogeneity of published data and the various significant shortfalls highlighted, current research does not allow clear guidelines to be proposed.

Keywords

Neck muscle vibration, postural orientation, review, spatial perception

Running title

Effects of Neck muscle Vibration

Introduction

Postural orientation requires integration of vestibular, visual, and somatosensory information in order to develop perception of the body in space and thus both maintain a position and allow the body to move [3, 28]. This postural orientation can be altered by nervous system pathology, especially stroke or vestibular disease. By modulating one or more of the sources of input information, sensorial stimulation is known to manipulate the subject's posture [6].

Focusing on proprioceptive input, muscle vibration has been extensively used in two different approaches. The first is vibration applied to a specific tendon or muscle, termed "focal vibration", and the second is global stimulation of the body based on a vibrating platform referred to as "Whole body vibration" [84]. This review will focus on the former approach.

Several postural muscles, such as muscles of the trunk and the lower limbs, have been subjected to vibration in order to modulate postural orientation [20, 25]. The neck muscles are unique for their localization between the head and the trunk. Their proprioceptive receptors play a crucial role in the detection of the position of the head in relation to the trunk [65]. Together with visual and vestibular inputs [5], the neck muscles are particularly involved in the perception of the body in space [5, 40, 44, 65]. This perception of body in space can be captured by measuring the perception of allocentric space representation such as the vertical misperception (Subjective Visual Vertical) [7, 66] and the egocentric space representation such as the body midsagittal misperception (Subjective Straight Ahead) [19]. By vibrating the neck muscles, a shift of the visual environment is observed, expressed clinically as the illusion of movement of a visual target [41]. As a consequence of this anatomical configuration, neck muscle vibrations (NMV) are used not only for their postural effect but also for their action on spatial perception. It is therefore essential to gather in-depth qualitative information on the effects of NMV on the perception of space as well as the effect on posture, in order to understand its action. Our objective was to conduct a systematic review of the characteristics and findings of these studies, and to assess the effects of neck muscle vibration (NMV) on postural orientation and spatial perception in both healthy people and patients with disturbed balance, in order to understand the potentially corrective effect of NMV in the patient population.

Methods

This review followed the PRISMA guidelines (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) [55]. Details of the protocol for this systematic review were registered on PROSPERO (CRD42016045392). Studies were only considered eligible if they involved the effect of NMV on either balance or spatial perception, with or without comparators. Studies in which the primary outcome was postural orientation evaluated by posturography in standing or sitting position were included, as were those with assessment of spatial perception (subjective straight ahead (SSA), subjective visual vertical (SSV), subjective haptic vertical (SHV), longitudinal body axis (LBA), pointing task or visual target).

A systematic search was performed using the databases MEDLINE, EMBASE, the Cochrane library and PEDrO. The keywords used in the search were ((postural balance*) OR (Spatial reference*)) AND (Neck muscle vibration). With the exception of reviews and meta-analyses, only studies published in French and in English up to July 2016 were considered. Lastly, a manual search was carried out on Google Scholar, Research Gate and clinical trial.gov for on-going studies. The reference lists of manuscripts and the bibliography of relevant reviews and meta-analyses were also searched.

After having eliminated all duplicates, an eligibility examination for the remaining studies was performed independently by two researchers (KJ and SL) on the basis of titles and abstracts. In the event of divergence between them, this was resolved by a third reviewer (IB). Data extraction was assessed by one reviewer (KJ) and then evaluated by a second (SL) for final validation. Any disagreement between them was resolved by a third reviewer (IB). Valid information was extracted from each eligible study on the basis of the following criteria: 1) Characteristics of the study – authors, year of publication and the type of design. 2) Characteristics of the trial participants - age, number of people involved in the analysis and the population analyzed. 3) Type of intervention - muscle vibrated, the side treated, duration and frequency, 4) Outcome measure: postural orientation, evaluated by posturography in standing or sitting position, and spatial perception (subjective straight ahead (SSA), subjective visual vertical (SSV), subjective haptic vertical (SHV), longitudinal body axis (LBA), pointing task and visual target. 5) Status of the main results - the effect of the vibration; under vibration, the immediate effect as soon as the vibrator stops and the lasting effect at a distance from the vibration.

The methodological quality of both the randomized control trials (RCTs) and the cross-over trials (CO) was assessed using the PEDro scale [21, 51]. This scale is based on 11 items scored out of 10: namely, eligibility criteria, randomization, concealed allocation, blinding (subjects, therapists, and assessors), follow-up, intention-to-treat analysis, between-group comparisons, point estimates and variability [57, 63]. This scale gives a classification of quality with different cut-off score possibilities whereby 9 to 10 is considered excellent; 6 to 8 good; 4 to 5 fair; and < 4 poor quality [54, 57, 63]. Other studies were assessed by way of the Quality Assessment Tool for Before–After (Pre-Post) Studies with No Control Group [61] based on 12 items : objective clearly stated, eligibility criteria described, representative patient population, all eligible participants enrolled in the study, adequate sample size, intervention described, outcome measure specified, outcome assessors blinded, loss to follow-up, statistical analysis of outcome measure before and after intervention, interrupted time-series design and individual data used for group effects. According to the guidelines, the rating quality was considered to be good, fair or poor. The efficiency of NMV was scored according to the level of evidence (LoE) following the Sackett *et al* guidelines [14, 70] for each outcome. For LoE I: large RCTs with clear results (only RCTs with a PEDro score of 6/10 or more), for LoE II: small RCTs with unclear results (poorer quality RCTs with a PEDro score under 6/10), for LoE III: cohort and case-control studies, for LoE IV: historical cohorts or case-control studies, for LoE V: case series, studies with no controls [54]. The quality of methodology was assessed independently by two researchers (KJ and SL) and in the event of a disagreement between them, this was resolved by a third reviewer (IB).

Results

In this systematic review, 290 references were identified, to which 15 references were added thereafter by way of a manual search (Fig.1). Only 92 articles met the eligibility criteria and their full texts were requested. In the end, 67 articles, published between 1979 and May 2016, were included in this review, divided into 41 articles concerning postural orientation, 27 articles on spatial perception, and one article was included in both categories. These 67 articles covered a total of 74 experimental sessions, of which 56 (75%) were related to cross-over designs with median quality on the PEDro scale of 5/10 [min=3/10; max=6/10] (table 1) and 18 (25%) to other study designs (Quality Assessment Tool for Before–After (Pre-Post) Studies with No Control Group), most of these being studies of fair to poor quality (table 2).

A total of 21 out of 75 were of good quality (i.e. above the PEDro cut-off of 6/10), among which 4 experimental sessions were based on spatial perception and the others (17) on postural orientation (table 1).

A total of 1522 participants [min=4; max=104] were included in this systematic review, among whom 958 were healthy subjects, 235 were patients with vestibular lesions and 158 were stroke patients (table 3). All the characteristics of the interventions are presented in table 4. The median frequency and amplitude applied by the vibrator was 90Hz [min=20; max=140] and 0.8mm [min=0.13; max=1.4]. The most common muscle sites were the dorsal neck muscles for 23 studies (31%) with the identification of posterior or paravertebral or paraspinal neck muscles. Vibration was performed on one side (either right or left) for 20 studies (27%) and bilaterally for 21(28%) studies. In most cases, muscle tracking was either not performed (46%) or established by anatomical location (40%) for the studies on postural balance; for spatial perception, however, most authors used the illusion of movement of a visual target to position the vibrator (59%). The median duration of the vibration was 20s [min=1s; max=28min].

Postural orientation (tables 5 and 6)

The results for the effect of NMV on postural orientation are presented in table 5. Concerning bilateral NMV in healthy subjects, authors were in agreement, and many good-quality studies reported that the body tilted in the anterior direction (LoE II) [50, 56, 58, 62, 75, 81]. Further to this, two studies (one of fair quality and the other of poor quality) described body tilt as soon as the vibrator was switched on, within the first milliseconds of onset of the vibration, generating first a backward body tilt and only thereafter a forward tilt at 250ms [1, 80]. One fair-quality study described a vectoral additive effect when vibrating back and oblique neck muscles: the body tilted in both the antero-posterior and the medial-lateral direction and when the vibrators were placed on two antagonist muscles; the effect vanished and no displacement was found [42].

Unilateral NMV applied to healthy subjects tilted the subject either in the anteroposterior plane or in the medial-lateral plane, depending upon which muscle was vibrated or the manner in which the vibrator was placed on the back of the neck (LoE IV). In the medial-lateral plane, bearing in mind that studies were only of fair quality, most of them found that subjects usually tilted in the direction opposite the vibrated side [11, 20, 42]. Only three

studies of poor quality found that subjects could also tilt forward in the anteroposterior plane [46, 69] (table 5).

With regard to the retention effects after the vibrator was switched off, the systematic review highlights some disagreement. Only one study, albeit of good quality, did not observe any retention effect as their test subjects returned to their initial position after a short-duration bilateral NMV (1s-4s) [13]. In the case of unilateral NMV, three fair-quality articles found variability from one subject to another after stopping the vibration [16, 22, 82]. The length of the effect after stopping NMV was dependent on each individual experiment, for example, Wierzbicka *et al.* [82] described a retention effect between 3 minutes up to 3hours, while this was attained for at least 5 minutes for Leplaideur *et al.* [16] and 13 minutes for Duclos *et al.* [22]. Besides this, a variability was also observed in the direction of the retention effect as Duclos *et al.* [22] found a long lasting effect which was a tilt towards the NMV side for half of the healthy subjects while the other half, the tilt was in the opposite direction.

This being said, three studies of fair to poor quality observed that when vibrating with different eye, head or trunk orientations, the body tilted towards the orientation of gaze rather than head or trunk orientation [29, 33, 34]. Five studies of good quality showed that vibrating with the eyes open had little or no effect on postural orientation (LoE II) [26, 56, 62, 64, 81] and one study (good quality) showed that the effect of vibration can be reduced or even suppressed by finger contact on a stable surface [10]. One good-quality study described an increase in the effect after successive sessions [13]. Magnusson *et al.* [50] (good quality) found that the amplitude of the tilt was related to the amplitude of the vibration, with a greater effect when the vibration amplitude was increased.

Results for patients are summarized in table 6. For patients with vestibular lesions, this systematic review showed some disagreement. Among studies on patients with unilateral vestibular lesions, two studies of fair to very poor quality put forward the idea that unilateral NMV on the contra-lesional side tilted the body forward, whereas unilateral NMV on the ipsi-lesional side tilted the body in the medial plane towards the side of the lesion [45, 67]. Controversially, one study of fair quality did not find any effect, and this is possibly due to a longer time-lapse since the lesion, to which they refer in their article [24]. Focusing on bilateral NMV in the case of unilateral vestibular lesions, two studies of fair to poor quality found that the body tilted towards the side of the lesion (LoE V) [79, 83]. In the case of bilateral vestibular lesions, only one study of fair quality found no effect [45]. Regarding the retention effect, only one study of fair quality [83] focused on the effect after 15 seconds of

vibration and found that patients moved gradually back to their initial position. Therefore, on the basis of these studies, this systematic review provides a low level of evidence (V) for the efficacy of NMV on unilateral and bilateral vestibular lesions.

For stroke patients, three studies of fair quality observed that unilateral NMV on the contra-lesional side resulted in a medial-lateral tilt towards the contralesional side, i.e. the hemiplegic side, in both right and left brain damaged groups [17, 18, 48] with a greater body tilt among the stroke patients who experienced the illusion of movement of a visual target under vibration [48]. On the other hand, only one study of good quality showed that bilateral NMV in standing position led to a forward tilt [58]. This systematic review revealed the absence of studies focusing on the retention effect amongst stroke patients.

Spatial perception (tables 7 and 8)

Illusion of movement of a visual target (VT)

Sixteen articles focused on VT with a total of 304 subjects, of whom 92 were patients, for the most part stroke patients (n=72). The six articles, of fair quality, without exception all found that during unilateral NMV in healthy subjects, the VT shifted towards the direction opposite to the vibrated side (LoE II) [31, 37, 41, 47, 52, 68]. This systematic review found two means of assessing the illusion of movement of a VT; the first was to ask the subject to give a self-report on whether there was an illusion of movement of the VT and to define its direction [37] and the second was the administration of a pointing task [52]. One poor quality study found that the illusion of motion was consistent whether the subject was pointing towards it or just viewing it [5]. Two studies of fair to poor quality observed that in a few cases the illusion could also move on the vertical plane [5, 41].

Four studies of poor quality highlighted that this illusion was not consistent [5, 38, 74, 77]. Biguer *et al.* [5] specified that whatever the side of vibration, only 78% of the healthy subjects were found to be susceptible to visual illusions. A greater amplitude of deviation was found when the vibration amplitude was increased [5]. Regarding the effect after the cessation of the vibration, the most relevant studies were found to be of poor quality with authors in disagreement on the topic; some authors stated that the VT could reverse its direction to return to its initial position [5, 74], while others claimed that for some subjects [31] the VT continued in the same direction after the vibration was switched off. The same effect was observed in both sitting and supine positions [68] (fair quality).

Concerning stroke patients, apart from the poor quality of most studies, 3 authors reported a frequency of illusion of movement of the VT (LoE IV) identical to the proportion found among healthy subjects [35, 37, 48] (table 8). Unilateral spatial neglect did not influence this proportion [37, 38]. In the vestibular lesion population, no studies on the effect of NMV on the illusion of VT movement were found.

Mid-sagittal plane perception : Subjective Straight Ahead (SSA)

Eleven articles focused on SSA with a total of 271 trial subjects, of whom 60 were patients, stroke patients for the most part. Two good quality articles and the others of fair to poor quality found that the SSA shifted towards the vibrated side whatever the method used (visual or haptic condition), in both healthy subjects (LoE II) (table 7) [15, 40] and stroke patients, independently from the side of the brain damage [39, 48, 72, 73] (LoE II). Only one study of fair quality focused on patients with vestibular lesions and found a shift towards the side of the vestibular lesion [76] (table 8). In addition, some studies of fair quality [30, 41] found that the healthy subjects who deviated on SSA were those who were susceptible to the illusion of movement of the VT.

Biguer *et al.* [5] reported that increasing the amplitude of vibration led to a greater amplitude of SSA deviation. Karnath *et al.* (fair quality) showed that the duration of the vibration resulted in an effect maintained over time [40]. The same effect was found when vibrating in both upright and sitting positions, but when the body was maintained tilted in the roll plane, the SSA deviation was greater (fair quality) [15].

Gravitational perception: Subjective Vertical (SV)

Five articles with a total number of 140 subjects were included in the analysis, 76 of whom were healthy subjects (table 7) and the rest vestibular patients(table 8). There was one good quality study [53]. Regarding the healthy subjects, unilateral vibration on either the sternocleidomastoid (SCOM) or other dorsal neck muscles induced a tilt in the roll plane of SVV towards the vibrated side [53] as compared to the subjective visual horizontal where the effect was absent (fair quality) [4, 36]. NMV with the head-roll tilt to the opposite side induced a greater tilt of the SVV towards the side of the vibration (the Müller effect) [53]. This result, found in the sitting position, was also found in the standing position [27] (fair quality). This systematic review revealed the absence of studies focusing on the retention

effect. Similarly, this systematic review pointed out, that no studies provided evidence on evaluating the effect of NMV on the SV in the stroke population

Among patients with vestibular lesions, three studies of fair quality showed that, independently from the time-lapse since the lesion, both contralesional and ipsilesional NMV increased the abnormal ipsilesional SV tilt with a greater effect when vibrating the ipsi-lesional side (LoE IV) [4, 36, 43]. In addition, compared to healthy subjects, this effect was influenced by the head orientation in the roll plane, given that it increased when the head was tilted towards the contra-lesional side, but not towards the ipsi-lesional side (fair quality) [4].

Discussion

To our knowledge, there have been only a limited number of reviews on the subject of neck muscle vibration [59, 65]. In the perspective of moving towards better understanding of the mechanism of action of NMV on postural orientation and body perception in space, this review differs from others: first by its systematic methodology, secondly, the fact that it takes both postural orientation and spatial perception into account, and thirdly, the fact that it includes both healthy subjects and patients with a disturbed balance, in order to evaluate the potentially corrective effect of NMV in the patient population.

This review highlights the fact that the effect of NMV has been studied extensively, with literature on this research going as far back as 1979 and continuing to be substantial. It can be noted that the effect of NMV on postural balance has been studied more widely than its effect on spatial perception. It must however be recalled that only 56 experimental sessions out of 74 were based on cross-over trial designs, while the remaining 25% were experimental designs, translating into poor methodological quality for these studies. The Pedro Scale and the Quality Assessment Tool for Before–After (Pre-Post) Studies with No Control Group also confirmed this conclusion. Consequently, some results should be interpreted with caution. This being said, our findings could help get a better understanding of the mechanism of action of NMV on postural muscles.

This systematic review has outlined some general points for healthy subjects, with a good level of evidence; first under bilateral NMV, the body tilts in the anterior direction, and secondly, under unilateral NMV, the external visual environment (VT) has repeatedly been found to move towards the side opposite the vibrator whereas the subject's experience of straight ahead was found to be shifted towards the vibrated side, so that the environment

appears to move relative to the body mid-sagittal plane. Furthermore, albeit to a lesser extent, a body tilt is produced under unilateral NMV, but the direction is not always the same. This can be explained by the very heterogeneous methodologies used for the localization of the vibrated muscle. Moreover, the muscle is not always clearly identified, which could confuse the postural results. Therefore, the method of muscle location should be carefully defined in future studies. Some authors have suggested the use of the illusion of displacement of a visual target [41, 48]. This method can be used to identify the muscle that causes the most marked environmental-lateral shift. In addition, the patients who perceived the illusion of the displacement of a visual target responded better on both spatial perception and postural balance, with an adequate level of evidence [30, 41, 48]. However, this method does have some limitations: firstly, the illusion is inconstant (78% in both healthy subjects and patients) and secondly, the link between a visual illusion and postural effects is still under discussion in the literature [78].

With regards to the effect once the vibration was switched off, no clear consensus was found in the literature. A retention effect had been identified only in healthy subjects for postural orientation. Karnath *et al.* showed that increasing the duration of the vibration resulted in an effect maintained over time [40]. However, the duration of the effect was subject-dependent and the direction of the effect after end of vibration was variable. The retention effect on the spatial perception seems to stop after its use. Regretfully, due to the limited number of studies which dealt with the topic of the retention effect and in particular, rehabilitation of patients with postural disorders, it is difficult to draw any noteworthy conclusion. A second retention effect was observed after several sessions as a cumulative effect. This retention effect appeared more intensive as the sessions progressed repeated. Indeed, Bove *et al.* described an increase in the effect after successive sessions [13], which suggests the implication of chronic vibration use in future studies involving patients with postural disorders in rehabilitation. This should however be confirmed by experimental studies.

In order to gain a better understanding of the specificity of neck muscle vibration, we chose to highlight the specificities of neck muscle vibration compared to vibration of other muscles. Interestingly, some points differ. First, the direction of the body tilt under bilateral neck muscle vibration is in the opposite direction to that obtained under back postural lower limb vibration (triceps surae) [82]. Moreover, unlike lower limb vibration in the sitting or the upright position [2], the effect of NMV is constant regardless of the position. Indeed, the reaction to vibration of the triceps surae results in a backward tilt in upright position [23, 62]

and a forward tilt in sitting position [82] whereas the forward shift is produced regardless of the body position for NMV [62, 82]. This is also the case for space perception under NMV; the same effect was repeatedly obtained whatever the position, sitting or standing [68]. This difference between NMV and lower limb muscle vibration supports the notion of a different frame of reference involved in the perception of body in space, i.e. body-referenced for lower limb vibration, and head-referenced for NMV [68]. In our opinion, this is due to the particular configuration of the neck muscles between the head and the trunk and their close relationship with other sensory receptors. In the case of NMV, the forward tilt is the response to the illusion of the body tilting backwards relative to the head, due to the absence of stimulation of the vestibular receptor, since the head is the reference [34, 65]. This explanation is further supported by the fact that the effect of NMV was found to be influenced either by the orientation of the head or by the direction of gaze [33] which was found for postural balance [32, 33], spatial perception (SSA [15], SVV [27, 53] and VT [68]. An additional point is, as expected, that NMV modulates body orientation and also the perception of space. When compared to other forms of sensorial stimulation such as vestibular or visual stimulations, the modulation of NMV on body mid-sagittal plane perception (SSA) [37, 72], on external environment perception (VT) [38] or on gravitational environment perception (SV) [36], was similar. In addition, the effect of NMV can also be altered by external sensorial information [10], which shows with a fair level of evidence that it is more relevant to carry out vibration either with eyes closed or in a dark room [5, 12, 13, 68, 80]. In general, this suggests that NMV, like any other stimulation, acts on supramodal cerebral centers, and especially in areas where the representation of the body in space is elaborated [49, 60, 71]. Indeed, Bottini *et al.,* who studied NMV during position emission tomography scans, confirmed brain activity particularly in the areas of multisensory integration where the egocentric representation of space is involved [9]. Therefore, our hypothesis is that the interconnected information by way of the neck or oculomotor muscle proprioceptive receptors and/or vestibular receptors is probably processed in addition to the proprioception information contributed by NMV.

This modulation of both body orientation and space perception therefore supports the use of this modulation among patients with altered postural and spatial perception. In fact, for stroke patients, both postural orientation and spatial perception shift towards the side opposite the vibrator and more precisely towards the contra-lesional side, with good evidence for SSA. Therefore, the findings of this review are in favor of the application of vibration to the contra-lesional side of the neck in order to correct the ipsi-lateral bias in both postural and spatial

perception. Interesting results were found for the correction of misperceptions of the body in space for subacute patients [37, 48], but no articles have confirmed these results relating to either long term studies or for stroke patients at a chronic stage.

Similarly, vestibular patients are of particular interest, as their asymmetrical behaviors could be at least partially due to body misorientation in space in acute disorders, as a result of imbalance of left and right vestibular inputs [8]. For unilateral vestibular patients, unilateral NMV induces a body tilt either in the antero-posterior plane or towards the lesional side, translating into the misinterpretation of vestibular information, which is not corrected [45, 67]. In the case of bilateral vestibular or compensated vestibular lesion, no effect was found. Regrettably, the small number of studies, often of low quality and with small numbers of patients, does not enable us to firmly conclude to the interest of NMV.

There are several limitations to this review. Although this review yielded interesting results with an adequate level of evidence, some results need to be confirmed with better quality designs and larger population samples. These limitations open a new avenue for further studies, especially since this review has highlighted the small number of studies on the subject in relation to studies entailing comparisons of NMV with other muscles and also the very small number of studies on stroke and vestibular lesions. The findings require confirmation by way of better quality studies. Therefore, the effect of NMV on both postural orientation and spatial perception still remains a subject for research and for future studies.

Conclusion

The strength of this original review is that it highlights the specific characteristics of NMV for modulating both postural orientation and spatial perception in healthy subjects and patients, in that NMV induces body shifts and deviations in spatial perception. This review has provided some interesting results with an adequate level of evidence, but some results need to be confirmed with better-quality designs and larger populations. As a consequence, the effect of NMV on postural orientation and spatial perception remains a subject for further research studies with improved methodological quality.

Disclosure of interest

The authors have no competing interests to report.

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Table 1:

Quality of methodology of randomized control trials and cross-over trials with Pedro scale

Title	Author	1	2	3	4	5	6	7	8	9	10	11	Total/10
Adaptation of a bimodal integration stage: Visual input needed during neck muscle vibration to elicit a motion aftereffect (experiment 2)	Seizova-Cajic et al.	X	0	0	0	0	0	0	1	1	1	0	3
Eye movements cannot explain vibration-induced visual motion and motion after-effect.	Seizova-Cajic et al.	X	0	0	0	0	0	0	1	1	1	0	3
Time course of gaze influences on postural responses to neck proprioceptive and galvanic vestibular stimulation in humans	Grasso et al.	X	0	0	1	0	0	0	1	1	0	0	3
Effects of neck muscle vibration on subjective visual vertical: Comparative analysis with effects on nystagmus	Kawase et al.	X	0	0	1	0	0	0	1	1	1	0	4
Adaptation of a bimodal integration stage: Visual input needed during neck muscle vibration to elicit a motion after-effect (experiment 1)	Seizova-Cajic et al.	X	0	0	1	0	0	0	1	1	1	0	4
Neck muscle vibration modifies the representation of visual motion and direction in man (Experience 2)	Biguer et al.	X	0	0	1	0	0	0	1	1	1	0	4
Changes in apparent body orientation and sensory localization induced by vibration of postural muscles: vibratory myesthetic illusions (Experience 3)	Lackner et al.	X	0	0	1	0	0	0	1	1	1	0	4
Asymmetric vestibular function in the elderly might be a significant contributor to hip fractures	Kristinsdottir et al.	X	0	0	1	0	0	0	1	1	1	0	4
Vibration-induced postural post-effects	Wierzbicka et al.	X	0	0	1	0	0	0	1	1	1	0	4
The Subjective Visual Vertical and the Subjective Haptic Vertical Access Different Gravity Estimates	Frase et al.	X	0	0	1	0	0	0	1	1	1	1	5
Prism adaptation and neck muscle vibration in healthy individuals: Are two methods better than one?	Guinet et al.	X	0	0	1	0	0	0	1	1	1	1	5
Neck muscle vibration in full cues affects	McIntyre et al.	X	0	0	1	0	0	0	1	1	1	1	5

pointing.													
Effects of neck muscles vibration on the perception of the head and trunk midline position (experience 1)	Ceyte et al.	X	0	0	1	0	0	0	1	1	1	1	5
Convergent and divergent effects of neck proprioceptive and visual motion stimulation on visual space processing in neglect	Schindler et al.	X	0	0	1	0	0	0	1	1	1	1	5
The perception of body orientation after neck-proprioceptive stimulation: Effects of time and of visual cueing (Experience0)	Karnath et al.	X	0	0	1	0	0	0	1	1	1	1	5
Vibration-induced shift of the subjective visual horizontal: A sign of unilateral vestibular deficit	Karlberg et al.	X	0	0	1	0	0	0	1	1	1	1	5
Neck muscle vibration alters visually-perceived roll after unilateral vestibular loss	Betts et al.	X	0	0	1	0	0	0	1	1	1	1	5
Visual and oculomotor responses induced by neck vibration in normal subjects and labyrinthine-defective patients	Popov et al.	X	0	0	1	0	0	0	1	1	1	1	5
Changes of visual localization induced by eye and neck muscle vibration in normal and strabismic subjects	Han et al.	X	0	0	1	0	0	0	1	1	1	1	5
Ocular exploration of space as a function of neck proprioceptive and vestibular input - Observations in normal subjects and patients with spatial neglect after parietal lesions	Karnath et al.	X	0	0	1	0	0	0	1	1	1	1	5
Properties of eye movements induced by activation of neck muscle proprioceptors	Lennerstrand et al.	X	0	0	1	0	0	0	1	1	1	1	5
The interactive contribution of neck muscle proprioception and vestibular stimulation to subjective 'straight ahead' orientation in man	Karnath et al.	X	0	0	1	0	0	0	1	1	1	1	5
Subjective body orientation in neglect and the interactive contribution of neck muscle proprioception and vestibular stimulation	Karnath et al.	X	0	0	1	0	0	0	1	1	1	1	5
Clinical interest of postural and vestibulo-ocular reflex changes induced by cervical muscles and skull vibration in	Dumas et al.	X	0	0	1	0	0	0	1	1	1	1	5

compensated unilateral vestibular lesion patients													
Vibration-induced post-effects: A means to improve postural asymmetry in lower leg amputees?	Duclos et al.	X	0	0	1	0	0	0	1	1	1	1	5
Neck proprioception and spatial orientation in cervical dystonia	Bove et al.	X	0	0	1	0	0	0	1	1	1	1	5
Neck vibration causes short latency electromyographic activation of lower leg muscles in postural reactions of the standing human	Andersson et al.	X	1	0	1	0	0	0	1	1	1	0	5
Neck muscle vibration disrupts steering of locomotion	Bove et al.	X	0	0	1	0	0	0	1	1	1	1	5
Methods for evaluation of postural control adaptation	Fransson et al.	X	0	0	1	0	0	0	1	1	1	1	5
Neck muscle vibration makes walking humans accelerate in the direction of gaze	Ivanenko et al.	X	0	0	1	0	0	0	1	1	1	1	5
Influence of vibration to the neck, trunk and lower extremity muscles on equilibrium in normal subjects and patients with unilateral labyrinthine dysfunction.	Yagi et al.	X	0	0	1	0	0	0	1	1	1	1	5
From balance regulation to body orientation: Two goals for muscle proprioceptive information processing?	Kavounoudias et al.	X	0	0	1	0	0	0	1	1	1	1	5
Postural responses to vibration of neck muscles in patients with uni- and bilateral vestibular loss	Lekhe et al.	X	0	0	1	0	0	0	1	1	1	1	5
Analysis of adaptation in anteroposterior dynamics of human postural control	Fransson et al.	X	0	0	1	0	0	0	1	1	1	1	5
Postural responses to vibration of neck muscles in patients with idiopathic torticollis	Lekhe et al.	X	0	0	1	0	0	0	1	1	1	1	5
Effects of neck muscles vibration on the perception of the head and trunk midline position (experience 2)	Ceyte et al.	X	1	0	1	0	0	0	1	1	1	1	6
Neck Muscle Vibration Alters Visually Perceived Roll in Normals	McKenna et al.	X	1	0	1	0	0	0	1	1	1	1	6
Neck muscle vibration induces lasting recovery in spatial neglect	Schindler et al.	X	1	0	1	0	0	0	1	1	1	1	6

The perception of body orientation after neck-proprioceptive stimulation: Effects of time and of visual cueing (Experience1)	Karnath et al.	X	1	0	1	0	0	0	1	1	1	1	6
Differences in the use of vision and proprioception for postural control in autism spectrum disorder	Morris et al.	X	1	0	1	0	0	0	1	1	1	1	6
Effect of neck muscles and gluteus medius vibrations on standing balance in healthy subjects	Challois et al.	X	1	0	1	0	0	0	1	1	1	1	6
Neck muscle vibration can improve sensorimotor function in patients with neck pain	Beinert et al.	X	1	0	1	0	0	0	1	1	1	1	6
Role of proprioceptive information to control balance during gait in healthy and hemiparetic individuals	Mullie et al.	X	1	0	1	0	0	0	1	1	1	1	6
Effects of manipulations with visual feedback on postural responses in humans maintaining an upright stance	Smetanin et al.	X	1	0	1	0	0	0	1	1	1	1	6
Local and global effects of neck muscle vibration during stabilization of upright standing	Verrel et al.	X	1	0	1	0	0	0	1	1	1	1	6
Interaction between vision and neck proprioception in the control of stance (Experience 1)	Bove et al.	X	1	0	1	0	0	0	1	1	1	1	6
Interaction between vision and neck proprioception in the control of stance (Experience 2)	Bove et al.	X	1	0	1	0	0	0	1	1	1	1	6
Effects of ageing on adaptation during vibratory stimulation of the calf and neck muscles	Patel et al.	X	1	0	1	0	0	0	1	1	1	1	6
Stance- and locomotion-dependent processing of vibration-induced proprioceptive inflow from multiple muscles in humans	Courtine et al.	X	1	0	1	0	0	0	1	1	1	1	6
The postural disorientation induced by neck muscle vibration subsides on lightly touching a stationary surface or aiming at it (experience 1)	Bove et al.	X	1	0	1	0	0	0	1	1	1	1	6
The postural disorientation induced by neck muscle vibration subsides on lightly	Bove et al.	X	1	0	1	0	0	0	1	1	1	1	6

touching a stationary surface or aiming at it (experience 2)													
Cervical muscle afferents play a dominant role over vestibular afferents during bilateral vibration of neck muscles	Magnusson et al.	X	1	0	1	0	0	0	1	1	1	1	6
Head stabilization on a continuously oscillating platform: The effect of a proprioceptive disturbance on the balancing strategy	De Nunzio et al.	X	1	0	1	0	0	0	1	1	1	1	6
Effect of gaze on postural responses to neck proprioceptive and vestibular stimulation in humans	Ivanenko et al.	X	1	0	1	0	0	0	1	1	1	1	6
Postural and symptomatic improvement after physiotherapy in patients with dizziness of suspected cervical origin	Karlberg et al.	X	1	0	1	0	0	0	1	1	1	1	6
Effects of vibrations on gait asymmetry: a prospective randomized controlled study in patients with chronic stroke	Leblong et al.	X	1	0	1	0	0	0	1	1	1	1	6

1/ the eligibility criteria were specified, 2/ subjects were randomly allocated to groups, 3/ allocation was concealed, 4/ the groups were similar at baseline regarding the most important prognostic indicators, 5/ there was blinding of all subjects, 6/ there was blinding of all therapists who administered the therapy, 7/ there was blinding of all assessors who measured at least one key outcome, 8/ measures of at least one key outcome were obtained from more than 85% of the subjects initially allocated to groups, 9/ all subjects for whom outcome measures were available received the treatment or control condition as allocated or, where this was not the case, data for at least one key outcome was analyzed by "intention to treat", 10/ the results of between-group statistical comparisons are reported for at least one key outcome, 11/ the study provides both point measures and measures of variability for at least one key outcome.

Table 2:

Quality methodology of experimental studies with the Quality Assessment Tool for Before–After (Pre-Post) Studies with No Control Group;

Titles	Authors	1	2	3	4	5	6	7	8	9	10	11	12	Rating quality
Short-term effect of neck muscle vibration on postural disturbances in stroke patients	Leplaideur et al.	Y	Y	Y	Y	NR	Y	Y	N	Y	Y	Y	NA	FAIR
Neck muscle vibration and stroke patients	Challois et al.	Y	Y	Y	Y	NR	Y	Y	N	Y	Y	Y	NA	FAIR
Short term effects of neck muscle vibration on balance control of stroke patients: A preliminary study	Challois-Leplaideur et al.	Y	Y	Y	Y	NR	Y	Y	N	Y	Y	Y	NA	FAIR
Discrepancy between the directions of body sway and gaze during simultaneous optokinetic and posterior neck muscle vibration stimulation	Tsutsumi et al.	Y	N	N	NR	NR	Y	Y	N	Y	Y	N	NA	FAIR
Postural responses to continuous unilateral neck muscle vibration in standing patients with cervical dystonia	Bove et al.	Y	N	Y	NR	NR	Y	Y	N	Y	Y	Y	NA	FAIR
Postural reactions to neck vibration in Parkinson's disease	Valkovic et al.	Y	N	Y	NR	NR	Y	Y	N	Y	Y	N	NA	FAIR
Role of dorsal neck proprioceptive inputs to vestibular compensation in humans.	Yagi et al.	Y	N	Y	NR	NR	Y	Y	N	Y	Y	N	NA	FAIR
Postural responses to vibration of neck muscles in patients with unilateral vestibular	Popov et al.	Y	N	Y	NR	NR	Y	Y	N	Y	Y	N	NA	FAIR

lesions														
Lasting amelioration of spatial neglect by treatment with neck muscle vibration even without concurrent training	Johannsen et al.	Y	Y	Y	NR	NR	Y	Y	N	Y	Y	Y	NA	FAIR
The perception of body orientation after neck-proprioceptive stimulation: Effects of time and of visual cueing (Experience2)	Karnath et al.	Y	N	N	NR	NR	Y	Y	N	Y	Y	Y	NA	FAIR
Subjective straight-ahead during neck muscle vibration: Effects of ageing	Strupp et al.	Y	N	N	NR	NR	Y	Y	N	Y	Y	Y	NA	FAIR
Perceptual and oculomotor effects of neck muscle vibration in vestibular neuritis. Ipsilateral somatosensory substitution of vestibular function	Strupp et al.	Y	Y	N	NR	NR	Y	Y	N	Y	Y	Y	NA	FAIR
Pattern of postural changes after symmetric neck muscle vibration	Valkovic et al.	Y	N	N	NR	NR	Y	Y	N	Y	NR	N	NA	POOR
Is muscle spindle proprioceptive function spared in muscular dystrophies? A muscle tendon vibration study	Ribot-Ciscar et al.	Y	N	Y	NR	NR	Y	Y	N	Y	NR	N	NA	POOR
The influence of head rotation on human upright posture during balanced bilateral vibration	Gurfinkel et al.	Y	N	N	NR	NR	Y	Y	N	Y	N	N	NA	POOR
Decrease of contralateral neglect by neck muscle	Karnath et al.	Y	N	N	NR	NR	Y	Y	N	Y	Y	N	NA	POOR

vibration and spatial orientation of trunk midline														
Illusions of head and visual target displacement induced by vibration of neck muscles.	Taylor et al.	Y	N	N	NR	NR	Y	Y	N	Y	Y	N	NA	POOR
Neck muscle vibration modifies the representation of visual motion and direction in man (Experience 1)	Biguer et al.	Y	N	N	NR	NR	Y	Y	N	Y	N	N	NA	POOR

1/objective clearly stated, 2/eligibility criteria described, 3/representative patient population, 4/all eligible participants enrolled in the study, 5/sufficient sample size, 6/intervention described, 7/outcome measure specified, 8/outcome assessors blinded, 9/loss to follow-up, 10/statistical analysis of outcome measure before and after intervention, 11/interrupted time-series design, 12/individual data used for group level effects. Yes (Y), No (N), Not Reported (NR), Not Available (NA). Quality Good, Fair, Poor.

Table 3:

Characteristics of the population (Right brain damage (RBD), Left brain damage (LBD), Parkinson Disease (PD))

Charateristics Population	Numbers	%
Population Total	1522	
Healthy subjects	958	62.6
Vestibular lesion	235	15.4
*Unilateral lesions	184	
*Bilateral lesions	51	
Strokes	154	10.1
*RBD	87	
RBD with Neglect	15	
*LBD	58	
*Unknown	9	
Neck pain	30	1.9
Cervical dystonia	28	1.8
PD	26	1.7
Hip fractures Subjects	19	1.2
Spasmodic torticoli	19	1.2
Strabismic patients	16	1
Lower limb amputation	14	0.9
Autism spectrum disorders	12	0.7
Muscular dystrophia	11	0.7

Table 4:

Characteristics of the intervention

Characteristics	Studies	%	Characteristics	Studies	%
Muscles			**Postural orientation**	**43**	
Dorsal neck muscles	23	31	***Muscle tracking***		
Trapezius	9	12.3	Not Available	19	44
Neck muscles	8	10	anatomical location	17	39.5
Splenius	8	10	Illusion movement visual target	4	9
SCOM	6	8	Illusion of movement of head	3	7
Splenius and Trapezius	5	6.7			
Splenius and Trapezius and SCOM	5	6.7	***Position***		
Splenius and Semispinalis and Trapezius	3	4	Standing position	31	75
Splenius and Semispinalis	2	2.7	Sitting position	5	11
Splenius and SCOM	2	2.7	Standing with different head position and eyes position	3	7
Trapezius and Dorsal neck muscles	1	1.3			
Trapezius and Semispinalis and SCOM	1	1.3			
Splenius or SCOM or Trapezius	1	1.3	Standing with hand contact	2	4.6
			Standing with different head position	1	2.3
Side vibrated					
Bilateral	21	28	Not Available	1	2.3
Right and left side	20	27.3			
Left side	14	19.1	**Spatial perception**	**32**	
Contralesionnel side	5	6.7	***Muscle tracking***		
Right side	3	4	Illusion movement visual target	19	59
Symmetrical to the supine	3	4	anatomical location	7	21
Bilateral and right side and left side	3	4	Muscle palpation	3	9
Bilateral and left side	1	1.3	Not Available	3	9
Bilateral and right side	1	1.3			
Painful side	1	1.3	***Position***		
Amputation side	1	1.3	Sitting position	25	78
NA	1	1.3	Sitting position with different head position	2	6
			Standing position	2	6
Eyes			Sitting and supine position	1	3
Eyes Open (EO)	31	41	Standing with body tilt	1	3
Eyes Closed (EC)	22	30.1	Standing and lying side position	1	3
EO and EC	20	27.3			
NA	1	1.3	***Room light***		
			Dark	23	25
Vibrator			Dark/Light	8	3
Duration= mean 20s (min=1s; max=28min)	53	70	Light	1	
Amplitude = mean 0.8mm (min=0.13mm; max=1.4mm)	50	66			
Frequency = mean 90Hz (min:20Hz; max:140Hz)	72	96			

Table 5:

Effect of neck muscle vibration (NMV) on postural orientation of healthy subjects

Author	Design/ score	S1/ number/ Age (Years)	S2/ number/ Age (Years)	Zone or muscles vibrated	Muscle tracking /side	Frequency (Hz) / Amplitude (mm)	Duration (s)/ repetition	Vibration EO/EC - position	Comparator	Adjuvant	Protocol	Effect of vibration (S1)	Effect of vibration (S2)	comparator /adjuvant
Morris et al. 2015	CO (6/10)	Healthy 20/23.4±5.1		Dorsal neck muscles	anatomical location / Bilateral	NA / NA	5	EO/EC - standing	-	-	pre-test(15s) /test under vibration(5s)	antero-postero plane = no effect EO. effect EC with shift forward		
Challois et al. 2015	CO (6/10)	Healthy 13/23		Splenius and semispinalis	VTI / left	70 / NA	300	EC-standing	GMV Right side	-	pre-test(52s)/test under vibration (5min)/ post-test (5min)	medio-lateral plane = effect not significant (EC). Shift toward the left side in 5/13 subjects. Effect maintained in time		Comparator = effect significant with shift toward the left side in 9/13. effect not maintained in time
Beinert et al. 2015	CO (6/10)	Healthy 10/21.8		Neck muscles	anatomical location painful side/right/left	100 / 1	30	NA-NA	-	-	pre-test(60s)/vibration (30s)/post test (immediate)	no effect		
Mullie et al. 2014	CO (6/10)	Healthy 12		Dorsal neck muscles	NA / Bilateral	80 / 0.5	NA	EC-sitting	TSV paretic /non dominant side	-	pre-test(10s) /test under vibration(20s)	antero-postero plane = effect (EC)		Comparator = effect (EC) with a shift

Author	Design/ score	S1/ number/ Age (Years)	S2/ number/ Age (Years)	Zone or muscles vibrated	Muscle tracking /side	Frequency (Hz) / Amplitude (mm)	Duration (s)/ repetition	Vibration EO/EC - position	Comparator	Adjuvant	Protocol	Effect of vibration (S1)	Effect of vibration (S2)	comparator /adjuvant
												with a shift forward		backward
Dumas et al. 2013	CO (5/10)	Healthy 9/43±15		Trapezius	anatomical location / right/left	85 / NA	10	EO/EC-standing	Mastoid vibration. TSV Left/Right	-	test under vibration (25.6s)	no effect		Comparator = TSV effect with a shift backward in healthy and medio-lateral in unilateral vestibular lesion
Valkovic et al. 2012	CS (POOR)	Healthy 12/20–35		Splenius and trapezius	anatomical location / Bilateral	70 / 1.4	2	EC-standing	-	-	test under vibration	antero-postero plane = effect (EC) with a shift backward shift (106 ms) then forward (359 ms)		
Smetanin et al. 2011	CO (6/10)	Healthy 11/men 46.6±9.6 and women 54.0±6.2		Trapezius	anatomical location / Bilateral	70-100 / 1	4	EO/EC-standing	TAV bilateral	-	pre-test(9-10s)/vibration (4s)/post test (5s)	antero-postero plane = effect (EC>EO2=EO3D) with a shift forward		Comparator = NMV greater than TAV
Verrel et al. 2011	CO (6/10)	Healthy 8/21.4±2.4		Dorsal neck muscles	NA / Bilateral	100 / 0.8	10	EO/EC-standing	-	-	pre-test(10s) /test under vibration(10s)	antero-postero plane = effect		

Author	Design/ score	S1/ number/ Age (Years)	S2/ number/ Age (Years)	Zone or muscles vibrated	Muscle tracking /side	Frequency (Hz) / Amplitude (mm)	Duration (s)/ repetition	Vibration EO/EC - position	Comparator	Adjuvant	Protocol	Effect of vibration (S1)	Effect of vibration (S2)	comparator /adjuvant
												(EC>EO) with a shift forward		
Bove et al. 2009	CO (6/10)	Healthy 6/26.7±2.5		Splenius and semispinalis and trapezius	anatomical location / Bilateral	100 / 0.8	5 X 10	EO/EC-standing	-	-	pre-test(15s)/vibration (5s)/post test (15s)	antero-postero plane = effect (ECEC>EOEC /ECEO>EOEO) shift forward during vibration then return to initial. Effect Increasing with successive vibration pulses		
Bove et al. 2009	CO (6/10)	Healthy 6/26.2± 2.6		Splenius and semispinalis and trapezius	anatomical location / Bilateral	100 / 0.8	5 X 10	EO/EC-standing	-	-	pre-test(15s+ 3s/6s/9s)/vibration (5s)/post test (15s)	antero-postero plane = increasing duration EO reduce effect/ increasing duration EC increase		

Author	Design/ score	S1/ number/ Age (Years)	S2/ number/ Age (Years)	Zone or muscles vibrated	Muscle tracking /side	Frequency (Hz) / Amplitude (mm)	Duration (s)/ repetition	Vibration EO/EC - position	Comparator	Adjuvant	Protocol	Effect of vibration (S1)	Effect of vibration (S2)	comparator /adjuvant
												effect. Effect with shift forward during vibration then return to initial		
Patel et al. 2009	CO (6/10)	Healthy (young) 18/29.1±7.8	Healthy (old) 16/71.5±3.9	Dorsal neck muscles	NA / Bilateral	85 / 1	50 /(PRBS)	EO/EC-standing	TSV bilateral	-	pre-test(30s) /test under vibration(PRBS)	antero-postero plane and mediolateral = Decrease effect EO/ increase effect EC. When repetition = Adaptation on antero-postero plane and lateral	antero-postero plane and lateral = Decrease effect EO/ increase effect EC. When repetition =Adaptation on antero-postero plane not on lateral	Comparator = TSV lager effect on antero-postero plane and lateral
Duclos et al. 2007	CO (5/10)	Healthy 18/37±10		Trapezius	Illusion head movement / left side/amputation side	80 / 0.5-0.8	30	EC-sitting	GMV left side/amputation	-	pre-test(2X60s)/vibration (30s)/post test (immediate	medio-lateral plane = effect with a shift to one side (half subject) and		Comparator = no difference CP shift amplitude. no difference in

Author	Design/ score	S1/ number/ Age (Years)	S2/ number/ Age (Years)	Zone or muscles vibrated	Muscle tracking /side	Frequency (Hz) / Amplitude (mm)	Duration (s)/ repetition	Vibration EO/EC - position	Comparator	Adjuvant	Protocol	Effect of vibration (S1)	Effect of vibration (S2)	comparator /adjuvant
											until 13min)	to the opposite side (half of subject). Effect maintained 13min		CP shift between two groups
Tsutsumi et al. 2007	CS (FAIR)	Healthy 8/21.4±2.4		Dorsal neck muscles	NA / Bilateral	50 / 0.2	NA	EO-standing	-	OKS	pre-test /test under vibration	no effect		Adjuvant = the direction of CoP translation was related to OKS velocity
Bove et al. 2007	CS (FAIR)	Healthy 12/51±15.5		SCOM	NA / right/left	90 / NA	NA	EC-standing	-	-	test under vibration (51.2s)	medio-lateral plane = effect with a shift toward the right with left vibration and to the left with right vibration.		
Courtine et al. 2007	CO (6/10)	Healthy 8/26–58		Splenius or SCOM or trapezius	anatomical location / left	80 / 0.8	60	EC-standing	TH. LU. AB. GL. RF. BF. TI. TE. TA. SOL. AI. AE vibration	-	pre-test (60s)/test under vibration (60s)	antero-postero plane and mediolateral = effect with a shift toward		Comparator = Effect in the mediolateral plane =Lu. TI. TE. AI. AE. Sol.

Author	Design/ score	S1/ number/ Age (Years)	S2/ number/ Age (Years)	Zone or muscles vibrated	Muscle tracking /side	Frequency (Hz) / Amplitude (mm)	Duration (s)/ repetition	Vibration EO/EC - position	Comparator	Adjuvant	Protocol	Effect of vibration (S1)	Effect of vibration (S2)	comparator /adjuvant
												opposite of the vibrated side. Effect in the mediolateral plane = Splenius /SCOM /Trapezius and Antero-Post plane=Spleni us.		Effect in the Antero-posterior plane =Th. Lu. AB. GL. RF.BF. TA. Sol
Bove et al. 2006	CO (6/10)	Healthy 7/28.4±6.7		SCOM	NA / Bilateral/right/l eft	100 / NA	60	EC-standing and hand contact	-	-	pre-test/test under vibration/post test	antero-postero plane and lateral = Light Finger Touch (LFT) during vibration or post-vibration reduce effect. LFT has more effect in plane of the deviation		
Bove et al. 2006	CO (6/10)	Healthy 5/27±6.4		SCOM	NA / Bilateral/left	100 / NA	5	EC-standing	-	-	pre-test/test under	antero-postero plane		

Author	Design/ score	S1/ number/ Age (Years)	S2/ number/ Age (Years)	Zone or muscles vibrated	Muscle tracking /side	Frequency (Hz) / Amplitude (mm)	Duration (s)/ repetition	Vibration EO/EC - position	Comparator	Adjuvant	Protocol	Effect of vibration (S1)	Effect of vibration (S2)	comparator /adjuvant
								and hand contact			vibration/post test (2/5s)	and mediolateral = LFT before vibration suppress effect. intended reduce effect		
Magnusson et al. 2006	CO (6/10)	Healthy 10/16-27		splenius	NA / Bilateral	55/85 / 0.4/1	1X10	EC-standing	mastoid vibration	-	pre-test (30s)/test under vibration (110s)	antero-postero plane = effect with vibration on = backward then forward and when vibration switched off opposite effect. Effect larger with higher intensity		Comparator = lower and less effect
Valkovic et al. 2006	CS (FAIR)	Healthy 13/63.9±11.3		Splenius and trapezius	anatomical location / Bilateral	80 / 1	3X10	EO/EC	-	-	test under vibration (60s)	antero-postero plane = Effect wit a shift backward (119ms to		

Author	Design/ score	S1/ number/ Age (Years)	S2/ number/ Age (Years)	Zone or muscles vibrated	Muscle tracking /side	Frequency (Hz) / Amplitude (mm)	Duration (s)/ repetition	Vibration EO/EC - position	Comparator	Adjuvant	Protocol	Effect of vibration (S1)	Effect of vibration (S2)	comparator /adjuvant
												123ms) than forward (250ms to 400ms). Effect EC>EO. With repetitive vibration no effect EO and decrease effect EC		
De Nunzio et al. 2005	CO (6/10)	Healthy 14/33±11.3		Splenius	anatomical location / Bilateral	90 / 0.9	30	EO/EC-standing	QV. TAV. BFV. TSV bilateral	-	test under vibration (30s)	antero-postero plane = Effect with a shift forward. EC>EO		Comparator = Effect forward =Q/TA and backward for TS/BF
Bove et al. 2004	CO (5/10)	Healthy 12/51.6±15.5		SCOM	anatomical location / right/left	90 / NA	51.2	EC-standing	-	-	pre-test (51.2s)/test under vibration (51.2s)	medio-lateral plane = Effect with a shift to the left with right vibration and to the right with left vibration		
Ribot-Ciscar et al. 2004	CS (POOR)	Healthy 10/35.1±10.2		Splenius	anatomical location / left	80 / 0.5	2	EC-standing	TAV bilateral / TSV bilateral	-	pre-test(0.5s)/test under	antero-postero plane = Effect with		Comparator = Effect with a shift forward

Author	Design/ score	S1/ number/ Age (Years)	S2/ number/ Age (Years)	Zone or muscles vibrated	Muscle tracking /side	Frequency (Hz) / Amplitude (mm)	Duration (s)/ repetition	Vibration EO/EC - position	Comparator	Adjuvant	Protocol	Effect of vibration (S1)	Effect of vibration (S2)	comparator /adjuvant
											vibration (20s)/post test (immediate)	a shift forward		for TAV and backward for TSV
Andersson et al. 2002	CO (5/10)	Healthy 10/37		Splenius	NA / Bilateral	85 / 1	0.25	EC-standing	-	-	test under vibration (1s/4s)	antero-postero plane = Effect with a shift forward (250ms) then backward (350ms). Same effect for 1s or 4s		
Bove et al. 2001	CO (5/10)	Healthy 9/32.5		Neck muscles	anatomical location / right	70 / NA	NA	EO/EC-standing	-	-	pre-test(51.2s)/test under vibration (51.2s)/post test (60s)	medio-lateral plane = Effect both during and before vibration. More effect during than before and EC>EO		
Kristinsdottir et al. 2000	CO (4/10)	Healthy 28/72		Dorsal neck muscles	NA / Bilateral	60 / 1	PRBS	EO/EC-standing	TSV bilateral	-	pre-test(30s)/test under vibration (PRBS)	no effect		Comparator = TSV EC S1(8/19) S2(1/28)
Fransson	CO	Healthy		Dorsal	NA / Bilateral	60 / 1	PRBS	EO/EC-	TSV bilateral	-	pre-	antero-		Comparator =

Author	Design/ score	S1/ number/ Age (Years)	S2/ number/ Age (Years)	Zone or muscles vibrated	Muscle tracking /side	Frequency (Hz) / Amplitude (mm)	Duration (s)/ repetition	Vibration EO/EC - position	Comparator	Adjuvant	Protocol	Effect of vibration (S1)	Effect of vibration (S2)	comparator /adjuvant
et al. 2000	(5/10)	10/37.5		neck muscles				standing			test(30s)/test under vibration (PRBS)	postero plane = EC>EO		more sway
Ivanenko et al. 2000	CO (5/10)	Healthy 7/22-39		Splenius and trapezius	anatomical location / Symmetrical to supine	80 / 0.8	0.75	EO/EC-standing with different head position and eye position	-	-	pre-test(5s)/test under vibration (6/8s)	antero-postero plane = effect to the side of head position but more influenced by to eye position. EO effect toward the visual target and EC toward the imaginary target		
Yagi et al. 2000	CO (5/10)	Healthy 59/25.6		Trapezius and dorsal neck muscles	NA / Bilateral	100 / 1	20	EC-standing	-	-	pre-test(20s)/test under vibration (20s)	antero-postero plane = Effect maximum with the upper dorsal neck. with a shift in the sagittal plane.		-

Author	Design/ score	S1/ number/ Age (Years)	S2/ number/ Age (Years)	Zone or muscles vibrated	Muscle tracking /side	Frequency (Hz) / Amplitude (mm)	Duration (s)/ repetition	Vibration EO/EC - position	Comparator	Adjuvant	Protocol	Effect of vibration (S1)	Effect of vibration (S2)	comparator /adjuvant
Grasso et al. 1999	CO (3/10)	Healthy 4/33±7		Splenius and trapezius	anatomical location / Symmetrical to supine	50 / 0.8	NA	EO/EC-standing with different head position and eye position	galvanic vestibular stimulation	-	pre-test(5s)/test under vibration (2min)	medio-lateral plane = Effect with a shift toward the eyes position when EO and toward to the imaginary eye position when EC. Effect with latency 2s and stable at 5s. When repetitive neck vibration effect with a shift opposite eye deviation		Comparator = same effect
Ivanenko et al. 1999	CO (6/10)	Healthy 13/20-39		Splenius and trapezius	anatomical location / Symmetrical to supine	50 / 0.8	15	EO/EC-standing with different head position and eye position	galvanic vestibular stimulation	-	pre-test(5s)/test under vibration (15s)	antero-postero plane = Effect with a shift toward the eyes position when EO and toward to the imaginary eye position when		Comparator = Effect in the medio-lateral plane and biased toward eyes deviation

Author	Design/ score	S1/ number/ Age (Years)	S2/ number/ Age (Years)	Zone or muscles vibrated	Muscle tracking /side	Frequency (Hz) / Amplitude (mm)	Duration (s)/ repetition	Vibration EO/EC - position	Comparator	Adjuvant	Protocol	Effect of vibration (S1)	Effect of vibration (S2)	comparator /adjuvant
												EC. Effect linked with eyes position> head position = head and trunk position		
Kavounoudias et al. 1999	CO (5/10)	Healthy 11/22-55		Splenius and trapezius and SCOM	NA / right/left	80 / 0.2-0.4	2	EC-standing	TSV. TAV. PV	TSV. TAV. PV	pre-test(1s)/test under vibration (2/3s)/post-test (4s)	medio-lateral plane = Effect with a shift contralateral to the muscle vibrated. When vibration of 2 antagonist muscles. no effect. When vibration of an antero-posterior muscle and lateral one. effect with a shift in the oblique direction. SCOM=		Comparator = Effect with a shift ipsilateral to muscle vibrated / adjuvant = When vibration of 2 antagonist muscles. no effect. When vibration of an antero-posterior muscle and lateral one. effect with a shift in the oblique direction.

Author	Design/ score	S1/ number/ Age (Years)	S2/ number/ Age (Years)	Zone or muscles vibrated	Muscle tracking /side	Frequency (Hz) / Amplitude (mm)	Duration (s)/ repetition	Vibration EO/EC - position	Comparator	Adjuvant	Protocol	Effect of vibration (S1)	Effect of vibration (S2)	comparator /adjuvant
												effect backward. Splenius= effect forward		
Yagi et al. 1998	CS (FAIR)	Healthy 30/29		Dorsal neck muscles	NA / Bilateral	110 / 1	30	EC-standing	-	-	pre-test (15s)/test under vibration (30s)/post-test (15s)	antero-postero plane = Effect with a shift forward		
Lekhe et al. 1998	CO (5/10)	Healthy 19/33.8±10	Unilateral vestibular lesion 13/49±15	Trapezius	NA / right/left	90 / 0.5	35/PRBS	EC-standing	-	-	pre-test (4/5s)/test under vibration (35s/PRBS)/post-test (2/40s)	antero-postero plane = When vibration on = effect with a shift backward then forward. When the vibration is switched off = shift goes back to initial		
Wierzbicka et al. 1998	CO (4/10)	Healthy 12/23-59		Splenius and trapezius and SCOM	NA / Bilateral	80 / 0.2	30	EC-sitting	TAV bilateral / TSV bilateral	-	pre-test(60s)/vibration (30s)/post-test (19min)	antero-postero plane = Effect with a shift backward		Comparator = Effect with shift forward for Soleus = forward and

Author	Design/ score	S1/ number/ Age (Years)	S2/ number/ Age (Years)	Zone or muscles vibrated	Muscle tracking /side	Frequency (Hz) / Amplitude (mm)	Duration (s)/ repetition	Vibration EO/EC - position	Comparator	Adjuvant	Protocol	Effect of vibration (S1)	Effect of vibration (S2)	comparator /adjuvant
												when vibration of the front NM and forward when vibration of the back of the neck. Post effect varied across subjects (3min-3H)		backward for TAV. Same effect for post-vibration
Fransson et al. 1998	CO (5/10)	Healthy 12/34.8		Dorsal neck muscles	NA / Bilateral	60 / 1	PRBS	EO/EC-standing	TSV bilateral	-	pre-test(30s)/test under vibration (PRBS)	antero-postero plane = Effect with a shift forward. EC>EO		Comparator = Effect with a shift backward
Lekhe et al. 1997	CO (5/10)	Healthy 19/33.8±10		Trapezius	NA / right/left	90 / 0.5	35/PRBS	EC-standing with different head position	-	-	pre-test (4/5s)/test under vibration (35s/PRBS)/post-test (2/40s)	antero-postero plane = Effect with a shift forward		
Karlberg et al. 1996	CO (6/10)	Healthy 17/36(25-55)		Dorsal neck muscles	anatomical location / Bilateral	20/40/60/80/100 - 0.4	10	EO/EC-standing	-	-	pre-test (10s)/test under	antero-postero plane = Effect with		

Author	Design/ score	S1/ number/ Age (Years)	S2/ number/ Age (Years)	Zone or muscles vibrated	Muscle tracking /side	Frequency (Hz) / Amplitude (mm)	Duration (s)/ repetition	Vibration EO/EC - position	Comparator	Adjuvant	Protocol	Effect of vibration (S1)	Effect of vibration (S2)	comparator /adjuvant
											vibration (10s)	a shift on the antero-postero direction EO/EC and at different frequency		
Popov et al. 1996	CS (FAIR)	Healthy 19		Trapezius	NA / right/left	90 / 0.5	PRBS	EC-standing	-	-	pre-test (30s)/test under vibration (PRBS)	antero-postero plane = Effect with a shift forward and little right side with left vibration and forward and little left side with right vibration. No difference in amplitude of deviation between right/left side vibration		
Gurfinkel et al. 1995	CS (POOR)	Healthy 12		Splenius	Illusion head movement / NA	NA / NA	NA	EC-standing	-	-	NA	medio-lateral plane = effect with a lateral		

Author	Design/ score	S1/ number/ Age (Years)	S2/ number/ Age (Years)	Zone or muscles vibrated	Muscle tracking /side	Frequency (Hz) / Amplitude (mm)	Duration (s)/ repetition	Vibration EO/EC - position	Comparator	Adjuvant	Protocol	Effect of vibration (S1)	Effect of vibration (S2)	comparator /adjuvant
												body tilt		

Abdominal (AB), ankle external (AE), ankle internal (AI) biceps femoris (BF), case-study (CS), cross-over trail (CO), eye open and closed (EO, EC), gluteus (GL), gluteus medius vibration (GMV), not available (NA), optokinetic stimulation (OKS), pseudorandom binary sequence schedule (PRBS), Quadriceps vibration (QV), rectus femoris (RF), soleus (S), Subjects (S1, S2), thigh external (TE), thigh internal (TI), tibialis anterior vibration (TAV), triceps surae vibration (TSV), trunk lumbar (LU), trunk thoracic (TH), visual target illusion (VTI),

Table 6:

Effect of neck muscle vibration on postural orientation of patients with disturbed balance

Author	Design/ score	S1/ number/ Age (Years)	S2/ number/ Age (Years)	Zone or muscles vibrated	Muscle tracking /side	Frequency (Hz) / Amplitude (mm)	Duration (s)/ repetition	Vibration EO/EC - position	Comparator	Adjuvant	Protocol	Effect of vibration (S1)	Effect of vibration (S2)	difference between groups	comparator /adjuvant
Leplaideur et al. 2016	CS (FAIR)	Stroke (RBD) 15/62.1±8.5	Stroke (LBD) 16/60.9±12	Splenius and semispinalis	VTI / contralesionnel side	80 / NA	600	EC-sitting	-	-	pre-test(50s)/vibration (10min)/post test (immediate)	medio-lateral plane = significant effect with a shift toward the hemiplegic side	medio-lateral plane = significant effect with a shift toward the hemiplegic side	no difference	
Morris et al. 2015	CO (6/10)	Autism spectrum disorders 12/23.6±7.9		Dorsal neck muscles	anatomical location / Bilateral	NA / NA	5	EO/EC - standing	-	-	pre-test(15s) /test under vibration(5s)	antero-postero plane = effect both EO/EC with shift forward			
Beinert et al. 2015	CO (6/10)	Neck pain 13/22.4		Neck muscles	anatomical location painful side/righ	100 / 1	30	NA-NA	-	-	pre-test(60s)/vibration (30s)/post test (immediate)	no effect			

Author	Design/ score	S1/ number/ Age (Years)	S2/ number/ Age (Years)	Zone or muscles vibrated	Muscle tracking /side	Frequency (Hz) / Amplitude (mm)	Duration (s)/ repetition	Vibration EO/EC - position	Comparator	Adjuvant	Protocol	Effect of vibration (S1)	Effect of vibration (S2)	difference between groups	comparator /adjuvant
					t/left										
Challois et al. 2014	CS (FAIR)	Stroke (RBD) 14/61.6	Stroke (LBD) 16/61.6	Neck muscles	VTI / contralesionnel side	80 / NA	600	EC-sitting	-	-	pre-test(50s)/vibration (10min)/post-test (immediate)	medio-lateral plane = effect (EO/EC) with a shift toward the hemiplegic side	medio-lateral plane = effect (EO/EC) with a shift toward the hemiplegic side	no difference	
Mullie et al. 2014	CO (6/10)	Stroke 9/47.8±11.8		Dorsal neck muscles	NA / Bilateral	80 / 0.5	NA	EC-sitting	TSV paretic /non dominant side	-	pre-test(10s) /test under vibration(20s)	antero-postero plane = effect (EC) with a shift forward			Comparator = effect (EC) with a shift backward
Dumas et al. 2013	CO (5/10)	Compensate Unilateral vestibular lesions (left) 12/54± 8		Trapezius	anatomical location / right/left	85 / NA	10	EO/EC-standing	Mastoid vibration. TSV Left/Right	-	test under vibration (25.6s)	no effect		no difference	Comparator = TSV effect with a shift backward in healthy and medio-lateral in unilateral vestibular lesion

Author	Design/ score	S1/ number/ Age (Years)	S2/ number/ Age (Years)	Zone or muscles vibrated	Muscle tracking /side	Frequency (Hz) / Amplitude (mm)	Duration (s)/ repetition	Vibration EO/EC - position	Comparator	Adjuvant	Protocol	Effect of vibration (S1)	Effect of vibration (S2)	difference between groups	comparator /adjuvant
Challois-Leplaideur et al. 2012	CS (FAIR)	Stroke (RBD) 7/60.3	Stroke (LBD) 7/60.3	Neck muscles	VTI / contralesionnel side	80 / NA	600	EC-sitting	-	-	pre-test(50s)/vibration (10min)/post-test (immediate)	medio-lateral plane = effect (EC) with a shift toward the hemiplegic side		effect on RBD only	
Duclos et al. 2007	CO (5/10)	Lower limb amputation 14/43±10		Trapezius	Illusion head movement / left side/amputation side	80 / 0.5-0.8	30	EC-sitting	GMV left side/amputation	-	pre-test(2X60s)/vibration (30s)/posttest (immediate until 13min)	medio-lateral plane = effect with a shift to one side (half subject) and to the opposite side (half of subject). Effect maintained 13min		Effect with a shift larger for Amputees	Comparator = no difference CP shift amplitude. no difference in CP shift between two groups
Bove et al.	CS	Cervical		SCOM	NA /	90 / NA	NA	EC-	-	-	test under	antero-			

Author	Design/ score	S1/ number/ Age (Years)	S2/ number/ Age (Years)	Zone or muscles vibrated	Muscle tracking /side	Frequency (Hz) / Amplitude (mm)	Duration (s)/ repetition	Vibration EO/EC - position	Comparator	Adjuvant	Protocol	Effect of vibration (S1)	Effect of vibration (S2)	difference between groups	comparator /adjuvant
2007	(FAIR)	dystonia 16/60.2±14			right/left			standing			vibration (51.2s)	postero plane = no effect or minor shift			
ValkoviÄ et al. 2006	CS (FAIR)	PD (severe) 13/61.8±9.2	PD (moderately affected) 13/64.2±8.9	Splenius and trapezius	anatomical location / Bilateral	80 / 1	3X10	EO/EC	-	-	test under vibration (60s)	antero-postero plane = Effect with a shift backward (119ms to 123ms) than forward (250ms to 400ms). Effect EC>EO. With repetitive vibration no effect (EO/EC)	antero-postero plane = Effect with a shift backward (119ms to 123ms) than forward (250ms to 400ms). Effect EC>EO. With repetitive vibration no effect EO and decrease effect EC	larger effect in S1	
Bove et al.	CO	Cervical		SCOM	anatomic	90 / NA	51.2	EC-	-	-	pre-test	no effect		weaker	

Author	Design/ score	S1/ number/ Age (Years)	S2/ number/ Age (Years)	Zone or muscles vibrated	Muscle tracking /side	Frequency (Hz) / Amplitude (mm)	Duration (s)/ repetition	Vibration EO/EC - position	Comparator	Adjuvant	Protocol	Effect of vibration (S1)	Effect of vibration (S2)	difference between groups	comparator /adjuvant
2004	(5/10)	dystonia 12/59.6±15			al location / right/left			standing			(51.2s)/test under vibration (51.2s)			effect for S1	
Ribot-Ciscar et al. 2004	CS (POOR)	Muscular dystrophia 11/35.4±13		Splenius	anatomical location / left	80 / 0.5	2	EC-standing	TAV bilateral / TSV bilateral	-	pre-test(0.5s)/test under vibration (20s)/post-test (immediate)	antero-postero plane = Effect with a shift forward		same effect	Comparator = Effect with a shift forward for TAV and backward for TSV
Kristinsdottir et al. 2000	CO (4/10)	Hip fracture subjects 19/72.5		Dorsal neck muscles	NA / Bilateral	60 / 1	PRBS	EO/EC-standing	TSV bilateral	-	pre-test(30s)/test under vibration (PRBS)	antero-postero plane = Effect in EC for 2/19			Comparator = TSV EC S1(8/19) S2(1/28)
Yagi et al. 2000	CO (5/10)	unilateral vestibular lesions 12/55.5		Trapezius and dorsal neck muscles	NA / Bilateral	100 / 1	20	EC-standing	-	-	pre-test(20s)/test under vibration (20s)	medio-lateral plane = Effect with dorsal neck toward the ipsilesional side.		less effect for S1 with the upper dorsal neck	

Author	Design/ score	S1/ number/ Age (Years)	S2/ number/ Age (Years)	Zone or muscles vibrated	Muscle tracking /side	Frequency (Hz) / Amplitude (mm)	Duration (s)/ repetition	Vibration EO/EC - position	Comparator	Adjuvant	Protocol	Effect of vibration (S1)	Effect of vibration (S2)	difference between groups	comparator /adjuvant
												No effect with the trapezius			
Yagi et al. 1998	CS (FAIR)	Unilateral vestibular lesions (compensated) 37/55.5±11.8	Unilateral vestibular lesions(acute) 37/51.9±12.6	Dorsal neck muscles	NA / Bilateral	110 / 1	30	EC-standing	-	-	pre-test (15s)/test under vibration (30s)/post-test (15s)	antero-postero and medio-lateral plane = Effect with a shift forward and toward the lesion side	antero-postero and medio-lateral plane = Effect with a shift forward and toward the lesion side	S1/S2 larger shift then S3	
Lekhe et al. 1998	CO (5/10)	Bilateral vestibular lesions 11/52±14	Unilateral vestibular lesion 13/49±15	Trapezius	NA / right/left	90 / 0.5	35/PRBS	EC-standing	-	-	pre-test (4/5s)/test under vibration (35s/PRBS)/post-test (2/40s)	no effect	antero-postero and medio-lateral plane = Ipsilateral vibration = effect with a shift toward the		

Author	Design/ score	S1/ number/ Age (Years)	S2/ number/ Age (Years)	Zone or muscles vibrated	Muscle tracking /side	Frequency (Hz) / Amplitude (mm)	Duration (s)/ repetition	Vibration EO/EC - position	Comparator	Adjuvant	Protocol	Effect of vibration (S1)	Effect of vibration (S2)	difference between groups	comparator /adjuvant
													side of lesion and backward. Contralesional vibration= effect with a shift forward		
Lekhe et al. 1997	CO (5/10)	Spasmodic torticollis 19/42.4±7	Bilateral vestibular lesions 11/52±13	Trapezius	NA / right/left	90 / 0.5	35/PRBS	EC-standing with different head position	-	-	pre-test (4/5s)/test under vibration (35s/PRBS)/post-test (2/40s)	antero-postero plane = Little effect with a shift forward or no effect	antero-postero plane = Little effect with a shift forward or no effect	S1=S2	
Karlberg et al. 1996	CO (6/10)	Neck pain 17/37(26-49)		Dorsal neck muscles	anatomical location / Bilateral	20/40/60/80/100 - 0.4	10	EO/EC-standing	-	-	pre-test (10s)/test under vibration (10s)	antero-postero plane = Effect with a shift on the antero-postero		Effect significantly greater in S1	

Author	Design/ score	S1/ number/ Age (Years)	S2/ number/ Age (Years)	Zone or muscles vibrated	Muscle tracking /side	Frequency (Hz) / Amplitude (mm)	Duration (s)/ repetition	Vibration EO/EC - position	Comparator	Adjuvant	Protocol	Effect of vibration (S1)	Effect of vibration (S2)	difference between groups	comparator /adjuvant
												direction EO/EC and at different frequency			
Popov et al. 1996	CS (FAIR)	Unilateral vestibular lesions 9		Trapezius	NA / right/left	90 / 0.5	PRBS	EC-standing	-	-	pre-test (30s)/test under vibration (PRBS)	medio-lateral plane = Effect vibration of the contralesional (forward) side higher than ipsilesional side. (backward and rotation to the ipsilesional side)		Effect smaller during vibration of the affected side.	
Leblong and al.	CO (6/10)	Stroke (RBD)	Stroke (LBD)	Dorsal neck	NA / contrales	70 / NA	300	EO-standing	Ipsilesional GMV /	-	pre-test (52s)/test under	no effect	no effect	no difference	Comparator = no effect

Author	Design/ score	S1/ number/ Age (Years)	S2/ number/ Age (Years)	Zone or muscles vibrated	Muscle tracking /side	Frequency (Hz) / Amplitude (mm)	Duration (s)/ repetition	Vibration EO/EC - position	Comparator	Adjuvant	Protocol	Effect of vibration (S1)	Effect of vibration (S2)	difference between groups	comparator /adjuvant
Unpublished		11/63.3±14	10/58.2±11	muscles	ional side				contralesional Biceps Brachial vibration		vibration(5min)/ post-test (2/10min)				

Case-study (CS), cross-over trail (CO), eye open and closed (EO, EC), gluteus medius vibration (GMV), left brain damage (LBD), not available (NA), Parkinson disease (PD), Quadriceps vibration (QV), right brain damage (RBD), Subjects (S1, S2), tibialis anterior vibration (TAV), triceps surae vibration (TSV), visual target illusion (VTI),

Table 7:

Effect of neck muscle vibration (NMV) on spatial perception of healthy subjects.

Author	Design	S1/ number/ Age (Years)	S2/ number/ Age (Years)	Outcome measures	Muscle vibrated	Muscle tracking / side	Frequency (Hz) / Amplitude (mm)	Vibration EO/EC-Duration (s)	Vibration position-Room light	Comparator	Adjuvant	Protocol	Effect of vibration (S1)	Effect of vibration (S2)	Comparator / Adjuvant
Frase et al. 2015	CO (5/10)	Healthy 16/21-60		SVV/SHV	Dorsal neck muscles	Anatomical location / bilateral	30 / NA	EO-NA	standing with body tilt-light	-	-	test under vibration	Effect with a shift opposite body tilt		
Guinet et al. 2013	CO (5/10)	Healthy / 54/25.11±8.28		SSA. VTI	Splenius	VTI / right	80 / NA	EO-150	sitting-dark	prism	prism	pre-test/vibration/post-test	SPA = effect on subjects with illusion of LED in sagittal plane. SVA = no effect		Comparator = Effect / adjuvant = effect
McIntyre et al. 2007	CO (5/10)	Healthy / 11		VTP	Splenius	anatomical location/ muscle palpation/ VTI / right/left	90 / NA	EO-8	sitting-dark/light	-	prism	test under vibration	Effect toward the opposite side of stimulus in dark (11/11) and light (3/11) but		

Author	Design	S1/ number/ Age (Years)	S2/ number/ Age (Years)	Outcome measures	Muscle vibrated	Muscle tracking / side	Frequency (Hz) / Amplitude (mm)	Vibration EO/EC-Duration (s)	Vibration position-Room light	Comparator	Adjuvant	Protocol	Effect of vibration (S1)	Effect of vibration (S2)	Comparator / Adjuvant
													more pronounced in dark		
Seizova-Cajic et al. 2007	CO (4/10)	Healthy / 21		VTP	Splenius and trapezius and SCOM	Anatomical location / right/left	140 / NA	EO-15	sitting-dark/light	-	-	test under vibration(15s)/post-test (15s)	Effect with a shift toward opposite side of the vibration. post Effect in all condition light with less post effect when the VT was not present during the period of vibration		
Seizova-Cajic et al. 2007	CO (3/10)	Healthy / 9		VTP	Splenius and trapezius and SCOM	Anatomical location / right/left	140 / NA	EO-NA	sitting-dark/light	-	-	test under vibration(15s)/post-test (15s)	Post-effect in all condition but smaller when the		

Author	Design	S1/ number/ Age (Years)	S2/ number/ Age (Years)	Outcome measures	Muscle vibrated	Muscle tracking / side	Frequency (Hz) / Amplitude (mm)	Vibration EO/EC-Duration (s)	Vibration position-Room light	Comparator	Adjuvant	Protocol	Effect of vibration (S1)	Effect of vibration (S2)	Comparator / Adjuvant
													VT was absent under the period of vibration		
Ceyte et al. 2006	CO (5/10)	Healthy / 13/27		SSA	Trapezius	muscle palpation / left	100 / 0.2	EO-NA	standing - dark	-	-	test under vibration	Effect with a shift toward the left side (vibrated side)		
Ceyte et al. 2006	CO (6/10)	Healthy /7/30		SSA	Trapezius	muscle palpation / left	100 / 0.2	EO-NA	standing or lying Right/left side-dark	-	-	test under vibration	Effect with a shift toward the left side. Effect larger when lying on the left side than standing. No effect when lying on the right		

Author	Design	S1/ number/ Age (Years)	S2/ number/ Age (Years)	Outcome measures	Muscle vibrated	Muscle tracking / side	Frequency (Hz) / Amplitude (mm)	Vibration EO/EC-Duration (s)	Vibration position-Room light	Comparator	Adjuvant	Protocol	Effect of vibration (S1)	Effect of vibration (S2)	Comparator / Adjuvant
													side		
Seizova-Cajic et al. 2006	CO (3/10)	Healthy / 12		VTP	Trapezius and semispinalis and SCOM	Anatomical location / Bilateral/right	125 / NA	EO-15	sitting-dark	-	-	pre-test (60/2s)/test under vibration (15s)/post-test (15s)	Effect for SCOM upward during vibration. downward during post-vibration and for splenius= left and/or upward during vibration and opposite during post-vibration. Effect in 7/10 subjects.		
McKenna et al. 2004	CO (6/10)	Healthy / 26/36		SVV	Dorsal neck muscles	Anatomical location / right/left	100 / A	EO-NA	sitting with different head position-	left and right mastoid vibration	-	pre-test/test under vibration	Effect with a shift opposite		Comparator = main effect for neck vibration

Author	Design	S1/ number/ Age (Years)	S2/ number/ Age (Years)	Outcome measures	Muscle vibrated	Muscle tracking / side	Frequency (Hz) / Amplitude (mm)	Vibration EO/EC-Duration (s)	Vibration position-Room light	Comparator	Adjuvant	Protocol	Effect of vibration (S1)	Effect of vibration (S2)	Comparator / Adjuvant
									dark				direction head roll-tilt with more effect when vibration on the side of the head opposite to the head tilt.		
Karnath et al. 2002	CO (5/10)	Healthy 18/27.3		SSA	Neck muscles	VTI / left	80 / 0.4	EO-180	sitting-dark	left hand vibration	-	pre-test/test under vibration (3min)	Effect with a shift toward the left side (vibrated side)		Comparator = no effect
Karnath et al. 2002	CO (6/10)	Healthy 6/29.5		SSA	Neck muscles	VTI / left	80 / 0.4	EO-60/300/900/1800	sitting-dark	-	-	pre-test/test under vibration/post-test (3min)	No difference of the duration on the deviation but on the maintaining of the		

Author	Design	S1/ number/ Age (Years)	S2/ number/ Age (Years)	Outcome measures	Muscle vibrated	Muscle tracking / side	Frequency (Hz) / Amplitude (mm)	Vibration EO/EC-Duration (s)	Vibration position-Room light	Comparator	Adjuvant	Protocol	Effect of vibration (S1)	Effect of vibration (S2)	Comparator / Adjuvant
													effect. The more the duration is increased the more the effect is maintained		
Karnath et al. 2002	CS (FAIR)	Healthy 6/27.5	Healthy / 6/25	SSA	Neck muscles	VTI / left	80 / 0.4	EO-1680	sitting-dark	-	visual information	pre-test/test under vibration/post-test (3min)	Effect with a shift toward the left side (vibrated side)		Adjuvant = reduce effect of NMV
Karlberg et al. 2002	CO (5/10)	Healthy 13/32		SVH	SCOM	Palpation muscle / right/left	92 / 0.6	EO-NA	sitting-dark	mastoid bone vibration	-	pre-test/test under vibration	Effect only in 1/13 subjects		Comparator = less effect
Betts et al. 2000	CO (5/10)	Healthy 21/40		SVH	SCOM	Palpation muscle / right/left	100 / 0.4	EO-100	sitting with different head position or standing with whole body tilt - dark	-	-	pre-test (100s)/test under vibration (100s)	no effect		
Strupp et	CS	Healthy		SSA	Dorsal	NA /	100 / 1	EO-20	sitting-dark	-	-	pre-	Effect		

Author	Design	S1/ number/ Age (Years)	S2/ number/ Age (Years)	Outcome measures	Muscle vibrated	Muscle tracking / side	Frequency (Hz) / Amplitude (mm)	Vibration EO/EC-Duration (s)	Vibration position-Room light	Comparator	Adjuvant	Protocol	Effect of vibration (S1)	Effect of vibration (S2)	Comparator / Adjuvant
al. 1999	(FAIR)	30/46.1±12.9			neck muscles	right/left						test/test under vibration	with a shift toward the side of stimulation which increases with the age.		
Popov et al. 1999	CO (5/10)	Healthy 5/25–51		VTI	Trapezius	VTI / right	90 / 0.5	EO-10	sitting and supine position-dark/light	-	-	pre-test(5s)/test under vibration(10s)	Effect with a shift toward the left. Same effect in sitting and supine position. In supine position also a shift in the vertical plane (up or down). No effect when light on		

Author	Design	S1/ number/ Age (Years)	S2/ number/ Age (Years)	Outcome measures	Muscle vibrated	Muscle tracking / side	Frequency (Hz) / Amplitude (mm)	Vibration EO/EC-Duration (s)	Vibration position-Room light	Comparator	Adjuvant	Protocol	Effect of vibration (S1)	Effect of vibration (S2)	Comparator / Adjuvant
Han et al. 1999	CO (5/10)	Healthy 8/32-49		VTP. VTI	Splenius and SCOM	VTI / right/left	70 / 1	EO-8/10	sitting-dark	-	-	pre-test (8/10s)/test under vibration (8/10s)	Effect with a shift to the left when vibration of the left SCOM/right splenius and to the right with right SCOM /left splenius. Vibration off VTI goes back or continue		
Strupp et al. 1998	CS (FAIR)	Healthy 25/49.1±14.2		SSA	Dorsal neck muscles	VTI / right/left	100 / 1	EO/EC-20	sitting-dark	-	prism	pre-test /test under vibration /post-test (1year)	Effect with a shift toward the side of muscle vibrated. No difference		Adjuvant = opposite effect

Author	Design	S1/ number/ Age (Years)	S2/ number/ Age (Years)	Outcome measures	Muscle vibrated	Muscle tracking / side	Frequency (Hz) / Amplitude (mm)	Vibration EO/EC-Duration (s)	Vibration position-Room light	Comparator	Adjuvant	Protocol	Effect of vibration (S1)	Effect of vibration (S2)	Comparator / Adjuvant
													between Right/Left vibration		
Karnath et al. 1996	CO (5/10)	Healthy / 10/50		SSA	Dorsal neck muscles	VTI / left	100 / 0.4	EO-NA	sitting-dark	vestibular stimulation	-	pre-test/test under vibration	Effect with a shift toward the left side		Comparator = same effect
Lennerstrand et al. 1996	CO (5/10)	Healthy 8/29-36		VTI	Splenius and SCOM	NA / Bilateral/right/Left	70 /1	EO-10	sitting-dark/light	-	-	pre-test (10s)/test vibration (10s)/post-test (10s)	Effect with a shift toward the left when vibration of the left SCOM and right splenius. to the right with right SCOM and left splenius. downward with both splenius. No effect in fully		

Author	Design	S1/ number/ Age (Years)	S2/ number/ Age (Years)	Outcome measures	Muscle vibrated	Muscle tracking / side	Frequency (Hz) / Amplitude (mm)	Vibration EO/EC-Duration (s)	Vibration position-Room light	Comparator	Adjuvant	Protocol	Effect of vibration (S1)	Effect of vibration (S2)	Comparator / Adjuvant
													light		
Karnath et al. 1994	CO (5/10)	Healthy 17/31		SSA. VTI	Dorsal neck muscles	VTI / right/left	100 / 0.4	EO-NA	sitting-dark	vestibular stimulation	vestibular stimulation	pre-test/test under vibration	Deviation of SSA only for patients with VTI (9/17). VTI = Effect with a shift toward the right with left NMV vis versa (+/- vertical). SSA = Effect with a shift toward the left with left NMV vis versa		Comparator =Effect with a shift on the right side for 17/17 / Adjuvant = When in the same side=larger effect than alone. When in opposite side= neutralize effect
Karnath et al. 1994	CO (5/10)	Healthy / 10/50		SSA. VTI	Dorsal neck muscles	VTI / right/left	100 / 0.4	EO-NA	sitting-dark/light	vestibular stimulation	vestibular stimulation	pre-test/test under	Effect with a shift		Comparator = Effect in 10/10 /

Author	Design	S1/ number/ Age (Years)	S2/ number/ Age (Years)	Outcome measures	Muscle vibrated	Muscle tracking / side	Frequency (Hz) / Amplitude (mm)	Vibration EO/EC-Duration (s)	Vibration position-Room light	Comparator	Adjuvant	Protocol	Effect of vibration (S1)	Effect of vibration (S2)	Comparator / Adjuvant
												vibration	toward the left and (+/- vertical) with left vibration vis versa and Effect on SSA only on patient with VT motion (10/10)		Adjuvant = same side=larger effect than alone. Opposite side= neutralize effect
Karnath et al. 1993	CS (POOR)	Healthy / 15/46		VTI	Dorsal neck muscles	VTI / right/left	100 / NA	EO-NA	sitting-dark	left hand vibration		pre-test/test under vibration	Effect in 10/15 subjects with a shift to the right with Left NMV and to the left with right NMV		Comparator = no effect
Taylor et al. 1991	CS (POOR)	Healthy 13		VTI	Neck muscles	VTI / left	100 / NA	EO-15	sitting-dark	-	-	test under vibration	Effect in 9/13 subjects		

Author	Design	S1/ number/ Age (Years)	S2/ number/ Age (Years)	Outcome measures	Muscle vibrated	Muscle tracking / side	Frequency (Hz) / Amplitude (mm)	Vibration EO/EC-Duration (s)	Vibration position-Room light	Comparator	Adjuvant	Protocol	Effect of vibration (S1)	Effect of vibration (S2)	Comparator / Adjuvant
													with a shift toward the left (3) and toward the right (6)		
Biguer et al. 1998	CS (POOR)	Healthy 10/25-55		VTP. VTI	Dorsal neck muscles	VTI / left	100 / 0.3	EO-NA	sitting - dark/light	-	-	pre-test/test under vibration	Effect with a shift to the right side (+/- vertical). Relation between VTI and VTP. Effect 9/10 subjects in Dark and middle dark and 2/10 when in light. Vibration off VTI goes initial position		

Author	Design	S1/ number/ Age (Years)	S2/ number/ Age (Years)	Outcome measures	Muscle vibrated	Muscle tracking / side	Frequency (Hz) / Amplitude (mm)	Vibration EO/EC-Duration (s)	Vibration position-Room light	Comparator	Adjuvant	Protocol	Effect of vibration (S1)	Effect of vibration (S2)	Comparator / Adjuvant
Biguer et al. 1998	CO (4/10)	Healthy 9		SSA. VTP	Dorsal neck muscles	VTI / left	100 / 0.13/0.29 /0.49	EO-NA	sitting-dark	-	-	pre-test/test under vibration	When increasing the amplitude of vibration. it increases the amplitude of deviation of VTP		
Lackner et al. 1979	CO (4/10)	Healthy 10/25-55		VTI	Splenius and trapezius and SCOM	NA / Bilateral/right/Left	120 / NA	EO-NA	standing - dark/light	muscles vibration		test under vibration	VTI moving according to head change. No effect in fully light		Comparator = moving according to head or body motion

Case-study (CS), cross-over trail (CO), eye open and closed (EO, EC), not available (NA), subjective straight ahead (SSA), subjective visual haptic (SVH), subjective visual vertical (SVV), Subjects (S1, S2), visual target illusion (VTI), visual target pointing (VTP)

Table 8:

Effect of neck muscle vibration (NMV) on spatial perception of patients with disturbed balance

Author	Design	S1/ number/ Age (years)	S2/ number/ Age (years)	Outcome measures	Muscle vibrated	Muscle tracking / side	Frequency (Hz) / Amplitude (mm)	Vibration EO/EC-Duration (s)	Vibration position-Room light	Comparator	Adjuvant	Protocol	Effect of vibration (S1)	Effect of vibration (S2)	Comparator / Adjuvant
Leplaideur et al. 2016	CS (FAIR)	Stroke (RBD) 15/62.1±8.5	Stroke (LBD / 16/60.9±12)	VTI	Splenius and semispinalis	VTI / contralesional side	80 / NA	EO-600	sitting-dark	-	-	test under vibration	Effect toward the opposite side of the stimulus in 11/15 subjects	Effect toward the opposite side of the stimulus in 9/16 subjects	
Kawase et al. 2011	CO (4/10)	unilateral vestibular lesions / 14/54.2		SVV	Dorsal neck muscles	Anatomical location / right/left	110 / NA	EO-NA	sitting-dark	-	-	test under vibration	Effect with a shift toward the ipsilesional side. Effect larger when vibration in the ipsilesional side		
Schindler et al. 2004	CO (5/10)	Stroke (RBD) / 5/44–70		SSA	Splenius	VTI / left	100 / NA	EO-NA	sitting-dark	vibration left dorsal palm and visual motion	-	pre-test/test under vibration	Effect with a shift toward the		Comparator = vibration left dorsal palm= no effect. No

Author	Design	S1/ number/ Age (years)	S2/ number/ Age (years)	Outcome measures	Muscle vibrated	Muscle tracking / side	Frequency (Hz) / Amplitude (mm)	Vibration EO/EC-Duration (s)	Vibration position-Room light	Comparator	Adjuvant	Protocol	Effect of vibration (S1)	Effect of vibration (S2)	Comparator / Adjuvant
										stimulation (left and right)			left side (vibrated side)		difference between VMS and NMV
Johannsen et al. 2003	CS (FAIR)	Stroke (RBD with neglect) / 6/68±9.5		VTI	Dorsal neck muscles	VTI / left	80 / 0.4	EO-120	sitting-dark	-	-	test under vibration	Effect of deviation in 3/6 subjects toward the right		
Schindler et al. 2002	CO (6/10)	Stroke (RBD) 20/48.7±14.3		SSA. VTI	Dorsal neck muscles	VTI / contralesionnel side	80 / 0.4	EO-NA	sitting-dark	-	visual exploration training	pre-test/test under vibration/post-test (2months)	Effect with a shift toward the left side and stable. VTI in all subjects		Adjuvant = more effect
Karlberg et al. 2002	CO (5/10)	Unilateral vestibular lesions 23/53.6		SVH	SCOM	Palpation muscle / right/left	92 / 0.6	EO-NA	sitting-dark	mastoid bone vibration	-	pre-test/test under vibration	Effect with a shift toward the ipsilesional side. Effect larger when vibration in the		Comparator = less effect

Author	Design	S1/ number/ Age (years)	S2/ number/ Age (years)	Outcome measures	Muscle vibrated	Muscle tracking / side	Frequency (Hz) / Amplitude (mm)	Vibration EO/EC-Duration (s)	Vibration position-Room light	Comparator	Adjuvant	Protocol	Effect of vibration (S1)	Effect of vibration (S2)	Comparator / Adjuvant
													ipsilesional side. Effect in 21/23 subjects		
Betts et al. 2000	CO (5/10)	Unilateral vestibular lesions 27/32		SVH	SCOM	Palpation muscle / right/left	100 / 0.4	EO-100	sitting with different head position or standing with whole body tilt - dark	-	-	pre-test (100s)/test under vibration (100s)	More effect when vibration in the ipsilesional side with the head roll-tilt in the contralesional side		
Popov et al. 1999	CO (5/10)	bilateral vestibular lesions 4/43–76		VTI	Trapezius	VTI / right	90 / 0.5	EO-10	sitting and supine position-dark/light	-	-	pre-test(5s)/test under vibration(10s)	Effect with a shift downward. Same effect in sitting and supine position. In supine position		

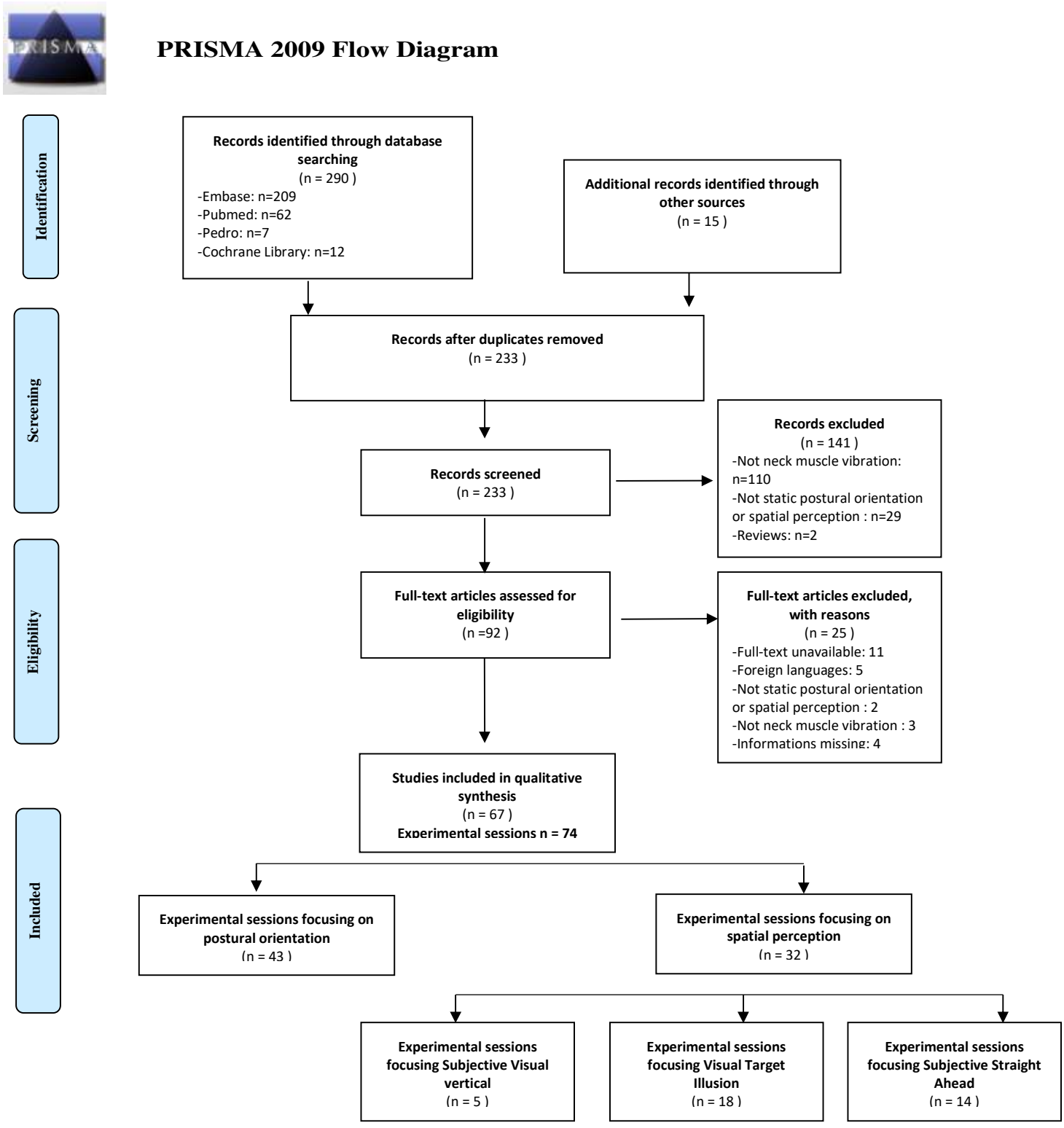
Author	Design	S1/ number/ Age (years)	S2/ number/ Age (years)	Outcome measures	Muscle vibrated	Muscle tracking / side	Frequency (Hz) / Amplitude (mm)	Vibration EO/EC-Duration (s)	Vibration position-Room light	Comparator	Adjuvant	Protocol	Effect of vibration (S1)	Effect of vibration (S2)	Comparator / Adjuvant
													also a shift in the vertical plane (up or down). No effect when light on		
Han et al. 1999	CO (5/10)	strabismic patients 16/26-54		VTP. VTI	Splenius and SCOM	VTI / right/left	70 / 1	EO-8/10	sitting-dark	-	-	pre-test (8/10s)/test under vibration (8/10s)	Effect for good binocular with a shift to the left when vibration of the left SCOM/right splenius and to the right with right SCOM /left splenius. Effect variable for poor binocular		

Author	Design	S1/ number/ Age (years)	S2/ number/ Age (years)	Outcome measures	Muscle vibrated	Muscle tracking / side	Frequency (Hz) / Amplitude (mm)	Vibration EO/EC-Duration (s)	Vibration position-Room light	Comparator	Adjuvant	Protocol	Effect of vibration (S1)	Effect of vibration (S2)	Comparator / Adjuvant
Strupp et al. 1998	CS (FAIR)	unilateral vestibular lesions 25/50.2±12.3		SSA	Dorsal neck muscles	VTI / right/left	100 / 1	EO/EC-20	sitting-dark	-	prism	pre-test /test under vibration /post-test (1year)	Effect with a shift toward the side of the stimulus. Effect ipsilesional side>contralesional side. Effect maintained 60/80d then decreases. No effect with SSA finger EC		Adjuvant = opposite effect
Karnath et al. 1996	CO (5/10)	Stroke (RDB with neglect) 3/61±15		SSA	Dorsal neck muscles	VTI / left	100 / 0.4	EO-NA	sitting-dark	vestibular stimulation	-	pre-test/test under vibration	Effect with a shift toward the left side		Comparator = same effect
Karnath et al. 1994	CO (5/10)	Stroke (RDB with neglect)	Stroke (LBD) 4/50.5	SSA. VTI	Dorsal neck muscles	VTI / right/left	100 / 0.4	EO-NA	sitting-dark/light	vestibular stimulation	vestibular stimulation	pre-test/test under	Left NMV (contralesional side)	Effect with a shift	Comparator = Effect in 17/17 / Adjuvant =

Author	Design	S1/ number/ Age (years)	S2/ number/ Age (years)	Outcome measures	Muscle vibrated	Muscle tracking / side	Frequency (Hz) / Amplitude (mm)	Vibration EO/EC-Duration (s)	Vibration position-Room light	Comparator	Adjuvant	Protocol	Effect of vibration (S1)	Effect of vibration (S2)	Comparator / Adjuvant
		3/61±15										vibration	= correction effect. Right NMV (ipsilesional side)= worsen effect. Effect on SSA only on patient with VT motion (2/3)	toward the left with left vibration vis versa. Effect on SSA only on patient with VT motion (2/4)	same side=larger effect than alone. Opposite side= neutralize effect
Karnath et al. 1993	CS (POOR)	Stroke (RDB with neglect) 3/68±15	Stroke (LBD) / 5/58	VTI	Dorsal neck muscles	VTI / right/left	100 / NA	EO-NA	sitting-dark	left hand vibration		pre-test/test under vibration	Effect in 1/3 subjects with a shift to the right with Left NMV and no effect with right NMV	Effect in 2/5 subjects with a shift to the right with Left NMV and to the left with right NMV	Comparator = no effect

Case-study (CS), cross-over trail (CO), eye open and closed (EO, EC), left brain damage (LBD), not available (NA), Parkinson disease (PD), right brain damage (RBD), subjective straight ahead (SSA), subjective visual haptic (SVH), subjective visual vertical (SVV), Subjects (S1, S2), visual target illusion (VTI),visual target pointing (VTP)

Figure 1: Prisma Flow diagram



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