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Effect of whole body vibration on cervical (neck) proprioception in young, healthy individuals serving as their own control: a pilot study

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Objective: *The objective of this pilot study is to determine the effects of whole body vibration on head repositioning accuracy.*

Methods: *Twenty-one participants had a bicycle helmet with an attached laser pointer placed on their heads while standing on a vibration platform. After aligning the laser beam to their determined neutral position on wall-mounted chart paper, they were instructed to close their eyes, flex their neck maximally then return to their perceived neutral position. The point where the laser beam stopped as close to the neutral position as possible was marked on the chart and the sequence was repeated for extension, left and right rotation and left and right lateral flexion. The vibration platform was then activated and the process was repeated for the same six neck movements.*

Results: *T-tests showed significant differences (p < 0.01) for head repositioning errors between normal and vibration data for all neck movements (in mm),*

Objectif : *La présente étude pilote vise à examiner les effets de la vibration transmise* à l'ensemble du corps sur la précision du repositionnement de la tête.

Méthodologie : *On a demandé à vingt et un participants de se tenir en station debout sur une plateforme vibrante en portant un casque de cycliste équipé d'un pointeur au laser. Après avoir aligné le faisceau laser avec leur position neutre sur un tableau à feuilles mural, on a demandé aux participants de fermer les yeux, de fléchir le cou au maximum et de revenir* à la position qu'ils percevaient comme neutre. *Le point auquel le faisceau laser s'est arrêté le plus près possible de la position neutre a été marquée sur le tableau; on a recommencé la séquence pour l'extension, la rotation vers la gauche et vers la droite et la flexion latérale vers la gauche et vers la droite. On a mis en service la plateforme vibrante et repris la séquence pour les six mêmes mouvements du cou.*

Résultats : *Les tests T ont révélé d'importants écarts (p < 0,01) pour ce qui est des erreurs de repositionnement entre les données normales et les*

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except flexion, with vibration trials exhibiting greater re-positioning errors. Data tabulated from the four Cartesian quadrants demonstrated a preponderance of overshoot re-positioning errors in which the laser stopped in individual Cartesian quadrants for each movement and each subject.

Conclusions: *Whole body vibration contributes to greater head repositioning errors in young, healthy, asymptomatic individuals. Larger scale trials should establish a normal data base for head re-positioning with vibration. Future studies might investigate the relationship between whole body vibration on neck proprioception as an indicator of therapeutic efficacy in neck disorders.*

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KEY WORDS: neck, proprioception, whole body vibration, re-positioning errors

données sur la vibration pour tous les mouvements du cou (en mm), sauf la flexion, les essais avec vibration étant ceux pour lesquels les erreurs de repositionnement étaient les plus graves. Les données totalisées à partir des quatre quadrants cartésiens révélaient une prépondérance d'erreurs de repositionnement lorsque le faisceau laser s'arrêtait dans les quadrants cartésiens individuels pour chaque mouvement et chaque sujet.

Conclusions : *La vibration transmise à l'ensemble du corps contribue à une hausse du nombre d'erreurs de repositionnement de la t*ête chez des sujets jeunes, en bonne santé et *asymptomatiques. On devrait faire des essais à plus grande échelle pour créer une base de données sur le repositionnement de la tête après l'exposition à des vibrations. On pourrait faire d'autres études sur le lien existant entre la vibration transmise* à l'ensemble du corps et la *proprioception cervicale servant d'indicateur de l'efficacité des traitements dans les troubles de la colonne cervicale.*

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MOTS-CLÉS : cou, proprioception, vibration transmise à l'ensemble du corps, erreurs de repositionnement

Introduction

Proprioception is the sense of the position of the body and its parts, and is crucial to body balance and posture. This awareness depends on various specialized neuroreceptors located in muscles, tendons, skin and fascia. The afferent information provided by various proprioceptors helps the body perform its coordinated movements and involuntarily control posture.[1-3]

Static proprioception is concerned with orientation of one body part to another, while dynamic proprioception involves neuromuscular feedback about the rate and direction of movement to allow for proper joint function and reflexive stabilization of joints. Information regarding position and movement of the head in relation to the trunk is provided in part by neck proprioceptors.

Vestibular reflexes are influenced by visual information, neck proprioceptors, auditory reflexes and the cerebellum. All of this sensory information helps in the stabilization of eye, head and body posture and in maintaining proper spatial orientation to the environment.[4,5] If visual, vestibular and neck proprioceptors provide conflicting sensory information, a sensory mismatch occurs.[6] Ligament injury may cause direct or indirect alterations in sensory information from mechanoreceptors and/or proprioceptors.[5] Neck injury, especially whiplash, can result in a variety of symptoms, including oculomotor dysfunction. This is explained by alteration of the neck proprioceptive system.[6] Damaged muscular and articular receptors can affect afferent integration and motor output, as can neuroreceptors in fascia[7], a structure often overlooked in soft tissue injuries.

Heikkala[8] showed that whiplash patients were less able to relocate initial head position for all neck movements. Improvement in proprioception in sports injuries and back pain has been used as one criterion for treatment success and proprioceptive rehabilitation in musculoskeletal complaints has been concerned with protecting the affected joint from future injury, while maximizing a return to normal function.[5] Laskowski[4] showed that low back pain patients had greater postural sway and were less able to balance themselves than subjects who had no low back pain, while Persson[9] demonstrated the positive effects of neck surgery on aberrant neck proprioception secondary to cervical root compression. In his study, Persson[9] postulated that the decrease in muscular tension was due to a reduction of neck pain after surgery and the normalization of neck proprioception. This resulted in improved postural control.

The objective of this pilot study was to investigate whether whole body vibration affects neck proprioception in healthy, asymptomatic participants. Vibration or vibratory sense is not a specific sensory modality, but rather a temporal summation of rapidly repeating tactile sensations. Vibration travels in the same afferent pathway as proprioception, i.e. the gracile and cuneate fasciculi, and thus may interfere with proprioception. This theory is supported in studies by Brumagne[10], Radovanovic[11], Patel[12] and Shanahan[13]. Motor control disorders may be caused or influenced by altered proprioception[14] and how patients adapt to proprioceptive disturbances such as vibration, initially and following therapy, may be useful in diagnosis and in assessing therapeutic efficacy.[15]

Methods

This study was approved by the Institutional Review Board of Southern California University of Health Sciences. Male and female participants were recruited from the college staff, students and faculty and those participating were informed of the risk that normal neck movements, as performed in this experiment, could possibly lead to complications ranging from mild transient soreness to stroke involving the vertebra-basilar artery (VBA).[16-19]

To manage the theoretical risk of VBA stroke, a methodology offered by the Canadian Chiropractic Association (CCA)[20] was used in this study. It provided a partial list of exclusion criteria. Participants with any of the following were excluded:

- History of cervical artery dissection
- History of stroke
- Acute neck, occipital or head pain that is severe and unlike any previously experienced
- Active or existing vertebral artery disease (VAD) as evidenced by at least 1 of 4 signs or symptoms of neurovascular impairment: unilateral paresthesia of the face, objective cerebellar defects, lateral medullary signs or symptoms (such as dysphagia, dysphonia, dysarthria, diplopia, ataxia, vertigo, nystagmus, hemianesthesia or unilaterally narrow pupil) or visual field defects
- Active cervical spine cord injury
- Acute cardiac disease
- Past history of, or current smoking.
- Current or recent neck pain

In addition, no one was accepted as a participant if there was a history of any of the following:

- Cervical radiculopathy or myelopathy
- Cervical arthritis of any type
- Vestibular dysfunction
- Sensorimotor disease
- Tumors or infection of the cervical spine

All participants recruited were informed of the risks of neck motion, were required to sign a form indicating that they had none of the exclusion criteria and were required to sign an informed consent form before beginning the study. All participants signed a form allowing their data to be used in a future publication.

Data Collection Procedure

Each participant was instructed to wear comfortable clothing that would not inhibit movement, especially of the head and neck region. The only restriction was removal of shoes so vibration would not have to pass through footwear. Each participant was assigned a number and was identified only by that number, not by name. In the study laboratory, a bicycle helmet with mounted laser pointer was fitted onto the participant's head, as per the method devised by Revel.[21] The participant then stood, without shoes, on the vibration platform (Power Vibe Pro II Whole Body Vibration (Figure 1, manufactured by PowerVibe LLC)), with hands on the platform handles and facing a Cartesian coordinate chart mounted on the wall. The platform was situated so that all study participants were 60 cm from the wall. The participant was instructed to place his/her head in the neutral position (looking straight ahead). The Cartesian chart was adjusted to the participant's neutral position so that the laser beam was at a 90

Table 1.
Summary of the study procedure.

Step	Description
1	Helmet/laser pointer fastened on participant's head.
2	Participant stands on vibration platform without shoes – vibration off.
3	Laser beam centered on 0,0 point on wall chart.
4	Participant closes eyes.
5	Participant told to flex head maximally.
6	Participant told to bring head back to perceived neutral 0,0, point.
7	Laser beam point marked with a blue pen dot
8	Head re-positioned to 0,0 point by study investigator.
9	Same procedure repeated for other five neck movements.
10	Procedure for six neck movements repeated – points marked with red pen.
11	Procedure for six neck movements repeated – points marked with blue pen.
12	Now, three sets of neck movements have been collected.
13	Entire procedure for three sets of neck movements repeated with vibration platform turned on to 20 Hz.

degree angle to the Cartesian chart and focused on the 0, 0 point. The participant was instructed to keep his/her eyes closed during each of the six neck movements, then to flex the head as far as possible and return to what he/she felt was neutral. All participants moved their head at their preferred speed.

The position where the participant first stopped was marked with a dot and a vertical line, using a blue pen for later identification. The participant's head was then manually returned to the neutral position by the investigator. Next, the participant was told to extend the head and return to the neutral position. This point was marked with a dot and an associated horizontal blue line. Left rotation and return to neutral was marked with a \ blue line, right rotation and return was marked with a / blue line, left lateral flexion and return was marked with a left-facing bracket symbol] in blue and right lateral flexion and return was marked with a right-facing bracket symbol [in blue. The same procedure was repeated, with all six neck movements marked with a red pen. Then, the same procedure was repeated a third time, but six neck movements were marked with a pencil. The participant was then instructed to open his/her eyes, the laser was turned off, and the marked and labelled chart taken down.

The above steps were then repeated using vibration, so that three complete trials were done. Vibration was set at 20 Hertz (Hz), the lowest possible frequency setting. The setting of 20 Hz and all protocols were initially determined by trial, using the authors as subjects. Both authors reported that vibration was felt in the neck. In addition, all study participants verified that vibration was felt in their neck region prior to continuing with the trial. When finished, the helmet was removed and the inside cleaned with alcohol. Each participant was then scheduled for 3 more sessions at weekly intervals.

Because any point marked on a Cartesian chart has unique x and y coordinate, the x and y values for each study participant were recorded in millimeters and entered into an Excel spreadsheet for later analysis. Data was later changed to centimeters, for statistical analysis and presentation.

Figure 1.
The vibration platform used in the study.

Data Analysis

All participants were free from neck pain and served as their own control. Since active ranges of neck motion were not being measured and no participant had neck pain, neck ranges of motion were not taken.

The x and y coordinates previously marked on the participant's Cartesian chart, were used to calculate the distance between the 0,0 starting point and the point where the study participant stopped, i.e. the position that the participant felt was the starting neutral position. These x and y values were squared and added, and the square root of their sum was calculated, as per the Pythagorean method. This value was a straight line and hence represented the actual direct distance between the 0,0 point and where the study participant stopped his/her movement. This distance in cm was the repositioning error. It was the length of this repositioning error that allowed for a statistical comparison between normal head repositioning and that done under whole body vibration.

Twelve columns of neck motion data were collected, one each for extension (EX), flexion (FL), right rotation (RR), left rotation (LR), right lateral flexion (RLF) and left lateral flexion (LLF), first without vibration, then the same 6 movements in the whole body vibration mode. Each column of data contained 252 samples (12 for each study participant x 21 participants = 252). For clarity, when referring to rotation in general, R will be used and when referring to lateral flexion in general, LF will be used.

The reliability of the measurement device, a laser pointer mounted on a bicycle helmet, was dependent upon the laser attachment to the helmet and the rigidity of the helmet fit to the participant's head. Ideally, the head/helmet/laser unit should move as one. The laser pointer used in this study was rigidly attached to the helmet with layers of gorilla tape, which were checked after each trial, but remained unchanged throughout the study. The helmet had internal webbing with adjustable chin straps and an external ratchet device to secure the helmet's internal lining to the head.

Results

Transformation of Raw Data

Observation of histograms showed that our initial raw data was not normally distributed and variances were unequal. This raw data could have been analyzed via non-parametric methods; however, there are several reasons for preferring parametric analysis over non-parametric analyses:

1) drawing inferences about population distribution and predictability regarding future outcomes are only met with parametric statistical analysis;
2) parametric statistics have greater power;
3) parametric statistics are robust to modest violations of normality (non-equality of variances, samples from non-normally distributed populations) and thus can be used with non-normal distributions, as long as the normality violations are not excessive.

It was decided to transform the data via square roots, an acceptable technique when desiring to shift the data towards a normal distribution.[22] The square root transformed data proved to be much closer to normal distributions than the raw data.

Skewness is an asymmetric distribution of data along the horizontal x axis and is negative if concentrated to the right and positive if concentrated to the left.[22] All sets of raw data exhibited considerable positive skewness. As can be seen in Table 2, the skewness was reduced in the transformed normal data by 75%, and in the transformed vibration data by 79%.

Table 2.
Skewness and kurtosis comparison between normal and transformed data.

	Mean – Normal Raw Data N = 1512	Mean – Normal Transformed Data N = 1512	% Reduction	Mean – Vibration Raw Data N = 1512	Mean – Vibration Transformed Data N = 1512	% Reduction
Skewness	0.88	0.22	75%	0.87	0.18	79%
Kurtosis	4.14	2.66	36%	4.1	2.77	32%

Kurtosis, the flatness or peakedness of a distribution[22], occurs along the y axis and was also evident in the raw data. The raw study data, both normal and vibratory, were platykurtotic. As can be seen from Table 2, the platykurtotic nature of both the normal and vibratory raw data was reduced by 36% and 32% respectively, in the transformed data.

Coefficients of variation (standard deviation/mean) for all 12 neck movement columns (six normal and six vibration) are shown in Table 3. As large standard deviations can affect statistical analysis, the large standard deviations and coefficients of variation seen in the original data were reduced considerably, post- square root data transformation. Coefficients of variation averaged 54.5% of the mean in the normal raw data and were reduced to 28.3% of the mean in the transformed data. Coefficients of variation averaged 52.5% of the mean in vibration raw data and were reduced to 27.2% of the mean in the transformed data.

In summary, the square root transformed data reduced the skewness and kurtosis in the raw data, modified the differences in normal and vibratory variances in the raw data, decreased standard deviations in the raw data and altered the distribution curves in the raw data, allowing them to more closely approximate normal curves.

Main Study Findings and Statistical Analysis

There were 21 study participants, 14 men and 7 women. Mean age was 29.14 (4.3) years, mean height was 68.7 (3.9) inches or 1.745 (0.099) meters and mean weight was 167.3 (34.1) lbs. or 75.89 (15.47) kg.

The original raw data were positively skewed and not normally distributed. Acceptable corrections include data transformation techniques. Different transformations were tried and it was found that square root transformation was best for moving the data towards a more normal distribution. Therefore, it was decided to use parametric

Table 3.
Coefficients of variation.

Movement	Coefficients of variation raw data normal	Coefficients of variation square root data normal	Coefficients of variation raw data vibration	Coefficients of variation square root data vibration
Extension	57%	28%	56%	28%
Flexion	53%	29%	47%	25%
Right rotation	54%	29%	54%	28%
Left rotation	54%	28%	50%	27%
Right lateral flexion	52%	27%	56%	28%
Left lateral flexion	57%	29%	52%	27%
Averages	**54.5%**	**28.3%**	**52.5%**	**27.2%**

Table 4.
Pairwise comparisons showing statistically significant repositioning errors.

Movement	Greater or Lesser	Comparison Movement	Statistical Significance (p)
Extension	<	Flexion	.003
Extension	>	Left lateral flexion	.047
Flexion	>	Left rotation	.001
Flexion	>	Left lateral flexion	.001
Right rotation	>	Left lateral flexion	.001
Left rotation	<	Right lateral flexion	.045
Left rotation	>	Left lateral flexion	.035
Right lateral flexion	>	Left lateral flexion	.001

tests, since they are robust to minor violations of normality assumptions.

Normality tests (Kolmogorov – Smirnov and Shapiro-Wilk) demonstrated that only two (FL normal and FL vibrating) out of 12 variables failed normality tests ($p = .01$, $p = .02$ respectively).

Repeated measures ANOVAs were run under two separate conditions. In the first condition, the means were calculated of the 12 repetitions per study participant, ($N = 252$; 12 repetitions per participant x 21 participants) for each of the 6 neck movements, in both normal and vibration conditions. A two-way ANOVA was used to assess the main effects (condition, movement) and interaction effects. In the second condition, the same procedure was used as in the first condition with repetition number being used as an additional factor. A three-way ANOVA was used to assess the main effects (condition, movement, repetition) and interaction effects. For the first condition, the assumption of sphericity (verified by Mauchly's W test) was violated ($p = .002$), therefore, Greenhouse-Geisser adjusted statistics are reported.

No statistically significant interaction effect was found – $F(4.74,1189.15) = 1.33$, $p = .25$. This suggests the difference between normal and vibration modes does not depend on movement type. Re-running repeated measure ANOVA with only main effects, showed that there was a statistically significant difference between normal and vibration modes, $F(1,251) = 42.52$, $p < .001$, partial $\eta^2 = .15$. We observed that repositioning error is significantly higher for vibration than for normal.

There were also statistically significant differences between movements, $F(5,1194.19) = 12.34$, $p < .001$, partial $\eta^2 = .05$. A pairwise comparison (Table 4) showed statistically significant differences in repositioning errors between the following movements, regardless of vibration.

In summary, LLF movement resulted in the smallest repositioning error compared to all other movements. The effect size for platform vibration (vs normal) is larger than the effect size for movement, suggesting that the repositioning error is more related to vibration than to type of movement. ANOVA under the second condition – with 3 factors; normal vs vibration, movement type (6 levels), and repetition number (12 levels), was performed. The repetition effect was used to see if repetitions had any effect based on fatigue or learning. Experiments in which study participants must perform a number of tasks can lead to fatigue, or to a learning effect. Both of these can affect results.

The assumption of sphericity (verified by Mauchly's W test) was violated ($p = .04$ and $p < .001$ for movement and repetition respectively); therefore, Greenhouse-Geisser adjusted statistics are reported.

A statistically significant difference was found between normal and vibration mode, $F(1,20) = 15.87$, $p = .001$, partial $\eta^2 = .44$. A pairwise comparison indicated that repositioning error is significantly higher for vibration mode compared to normal mode and a statistically significant difference between movements was also indicated – $F(5,71.11) = 3.34$, $p = .018$, partial $\eta^2 = .14$. Pairwise comparison showed statistically significant differences in repositioning errors between the following movements regardless of vibration:

- FL has larger repositioning error than LR, $p = .018$
- FL has larger repositioning error than LLF, $p = .015$

The repetition number was not statistically significant, $F(11,88.92) = 1.95$, $p = .10$. This suggests no difference in

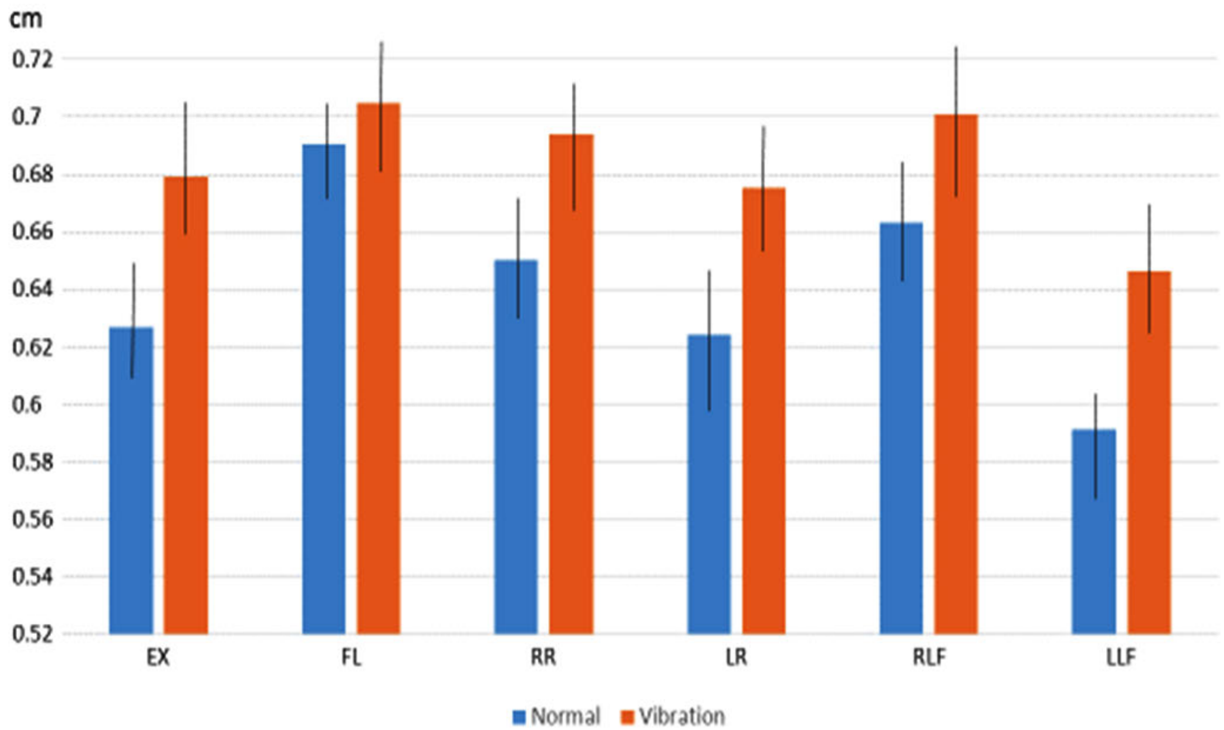

Figure 2.
Comparison of means of repositioning errors for all six neck movements. Error bars are for standard deviations.

repositioning error between repetitions; thus there was no fatigue or learning effect.

Finally, a statistical analysis of the 6 neck movements was done, treating each paired movement of normal with vibration individually, i.e., NEX vs VEX only, NFL vs VFL only, etc. A one-tailed, paired sample T-test was performed (Table 5). Since each neck movement was independent of the other movements, no Bonferroni correction was used.

Secondary Findings

The Cartesian chart used to mark data points is divided into 4 quadrants, with each quadrant assigned a number (Figure 3).

After preliminary analysis of the square root transformed data, it was noticed that each Cartesian quadrant in which individual study participants had repositioned their heads, could be determined. It was decided to tabu-

Table 5.
p-values for each paired neck movement.

Movement Comparison	P Value
NormalEX vs. VEX	$p < .01$
NFL vs. VFL	$p = .20$
NRR vs. VRR	$p < .01$
NLR vs. VLR	$p < .01$
NRLF vs. VRLF	$p = .01$
NLLF vs. VLLF	$p < .01$

Legend: Conditions that begin with an 'N' are under normal conditions, those that begin with a 'V' are under vibration conditions.

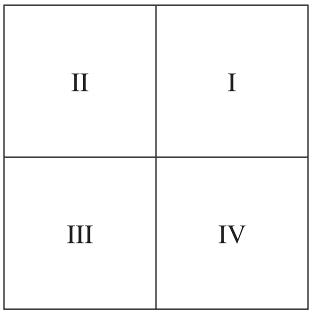

Figure 3.
Numbering of the Cartesian coordinate system.

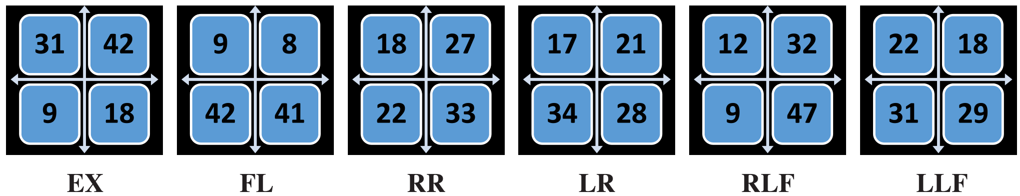

Figure 4.
Normal quadrant summary data (%).

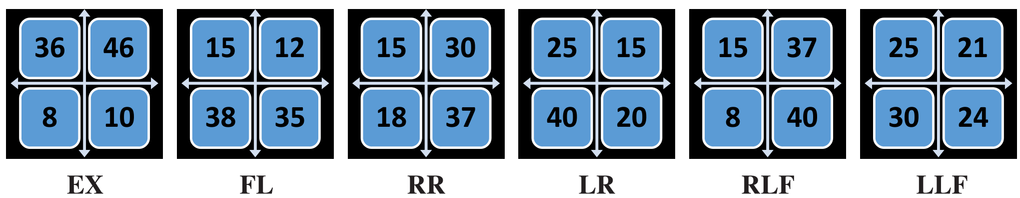

Figure 5.
Vibration quadrant summary data (%).

late the number of times repositioning had ended in each of the 4 quadrants (Figures 4 and 5). It was thought that this might provide additional useful data to the data related to main study objective.

Data extracted from these figures was used to show head repositioning errors of overshoot or undershoot of the 0,0 neutral point. Each repositioning attempt involves specific muscle groups. From the above, which neck muscle groups were used most often (flexors, extensors, etc.), can be determined.

The first Cartesian diagram in Figure 4 is for NEX. It can be seen that in 73% of cases, the repositioning error was in quadrant 1 or 2, and in 27% of cases, the repositioning error was in quadrant 3 or 4. An EX trial ending in either quadrant 1 or 2 would indicate a repositioning error involving the neck extensor muscles, since the laser pointer would be up above the x axis. An EX trial ending in either quadrant 3 or 4 would indicate a repositioning error involving the neck flexor muscles, since the laser pointer would be below the x axis.

The third Cartesian diagram in Figure 4 is for NRR. In 60% of the cases, the repositioning error was in quadrant 1 or 4, to the right of the Y axis, and in 40% of the cases, the repositioning error was in quadrant 2 or 3, to the left of the Y axis. A RR trial ending in either quadrant 1 or 4 would indicate a repositioning error of the right neck rotators/right lateral flexors, since the laser pointer would be to the right of the y axis, while a RR rotation trial ending in either quadrant 2 or 3 would indicate a repositioning error of the left neck rotators/left lateral neck flexors, since the laser pointer would be to the left of the y axis.

Overshoot or undershoot of the 0,0 target in head repositioning is useful for demonstrating which neck muscle groups come into play most often.

Discussion

Our study appears to be the first one reported in which healthy, asymptomatic participants were tested without vision for their accuracy in returning their heads to a neutral position, under normal conditions and while experiencing whole body vibration. Part of the method used in this study, a laser pointer mounted on a bicycle helmet, has been used successfully in previous studies.[21, 23-25]

Previous studies have also confirmed that vibration af-

Table 6.
Percentage of time trials stopped in individual quadrants.

Movements	Percent in quadrants above or below x axis	Neck muscles used	Percent in quadrant to right or left of y axis	Neck muscles used
NEX	73% (1,2)	Extensors	42% (1)	Right Rotators / Lateral flexors
VEX	82% (1,2)	Extensors	46% (1)	Right Rotators / Lateral flexors
NFL	83% (3,4)	Flexors	42% (3)	Left Rotators / Lateral flexors
VFL	73% (3,4)	Flexors	38% (3)	Left Rotators / Lateral flexors
NRR	60% (1,4)	Right rotators	33% (4)	Flexors
VRR	67% (1,4)	Right rotators	37% (4)	Flexors
NLR	51% (2,3)	Left Rotators	34% (3)	Flexors
VLR	65% (2,3)	Left Rotators	40% (3)	Flexors
NRLF	79% (1,4)	Right Lateral Flexors	47% (4)	Flexors
VRLF	77% (1,4)	Rightt Lateral Flexors	40% (4)	Flexors
NLLF	53% (2,3)	Left Lateral Flexors	31% (3)	Flexors
VLLF	55% (2,3)	Left Lateral Flexors	30% (3)	Flexors
Legend: Conditions that begin with an 'N' are under normal conditions, those that begin with a 'V' are under vibration conditions.				

fects proprioception[10-13] and that proprioception is diminished in injury[4,6-9]. Vibration, by travelling in the same pathway as proprioception, can alter muscle spindle output and may affect efferent output and contribute to aberrant motion patterns, such as increasing head re-positioning errors.[1-6]

Statistical results in this study showed that head re-positioning errors were statistically significantly different (greater) in whole body vibration in EX, RR, LR, RLF AND LLF. Only FL failed to show a statistically significant difference when comparing normal vs vibration. Repeated measure ANOVA demonstrated that these statistically significant differences were not due to interaction of movement type, fatigue or numbers of repetitions, but to whole body vibration. These results justified the use of a one-tailed, paired sample T-test to determine the p value for comparing the normal vs. vibration trials for each of the 6 movements. These values are seen in Table 5.

Since this study is believed to be the first one to use whole body vibration for assessing head repositioning accuracy, it is important to consider whether results obtained with localized vibration applied to the upper thoracic, shoulder or neck areas, can be compared with results seen in whole body vibration, or if such a comparison would be a matter of apples versus oranges. Proprioceptive information from the trunk and lower limbs (T7 and below) is carried to the brainstem via the gracile tract. Proprioceptive information from the arms and from T6 and above is carried to the brainstem via the cuneate tract. Localized vibration applied to the upper thoracic, shoulders or neck area obviously does not travel through feet, legs, and lower to mid-spine, whereas whole body vibration does. Important proprioceptive receptors involving balance, head alignment and postural control are thus bypassed with locally applied vibration above T6. There is also good evidence of the influence of cervical and head receptors on lower limb and trunk activity. Sasaki[26] demonstrated that vibratory stimuli of the neck resulted in an increase in spinal reflex excitability of the triceps surae muscle complex in seated subjects. Parfrey[27] showed that changing cervical and limb positions can change the activation levels of the internal and external oblique muscles. Interestingly, Strimpakos[28] demonstrated that head re-positioning while standing resulted in less variable error than did head re-positioning while sitting. Based on the evidence, it would seem that future vibration trials assessing head re-positioning would be better performed with whole body vibration, so that important sensory information would not be excluded.

A comparative test for head repositioning accuracy, having the same subjects tested by both methods, would shed light on whether results can be compared directly, or whether results varied significantly, making direct comparisons invalid. Until this is done, caution is imperative when comparing results from these two different forms of a similar test, both of which can be used to assess the effects of vibration on head repositioning accuracy.

Before discussing overshoot/undershoot in head re-positioning involving R or LF, it is necessary to discuss coupled neck motions. This study and previous studies using the laser pointer method of Revel[21] or a modification to assess accuracy of head repositioning, have analyzed neck movements separately. One question that needs to be addressed is whether treating neck movements in isolation is in conflict with what is known about coupled neck movements. Coupled movements are defined by Levangie[29] as the consistent association of one motion about an axis, with another motion around a different axis. Motions from neck (cervical) vertebrae C2 through C7 are coupled. FL and EX are coupled with translation, a sliding movement of one vertebrae upon the adjacent vertebra. They are not coupled with R or LF, so it is certainly justified to treat flexion and extension separately.

However, Bergman[30] points out that initiation of LF of the cervical vertebrae is coupled with ipsilateral R. At cervical vertebra C2 there are approximately two degrees of ipsilateral R for every three degrees of LF. This gradually changes so that for every 1 degree of R there are 7.5 degrees of ipsilateral LF at cervical vertebra C7. Similarly, initiation of R of the lower cervical spine results in ipsilateral LF.

The existence of coupled motion of LF and R does not negate assessing these movements separately. They share some motion together, but they also have unique motion. LF to the limit of its range of motion will not result in the neck being rotated to the limit of its range of motion. Standard Kinesiology and Anatomy textbooks show that only three muscles are involved in a single neck movement and most muscles participate in more than one neck movement. Either neck R or LF muscles can cause the head repositioning to deviate to the right or left of the Y axis. Without doing EMG or other studies, we cannot pinpoint which one.

Looking at quadrant data to see the percentage of times head repositioning stopped in each of the four quadrants was not an original objective of this study; however, recording head re-positioning data resulted in Cartesian quadrant data being generated. It was decided to analyze the data and as a result, determine if head repositioning was equally distributed throughout the four quadrants, or if there was a preference. Active motions, such as head/neck movements, depend upon muscle activity and specific movements such as head/neck flexion, depend upon specific muscle groups. At this stage, it appears, with admittedly limited data, that vibration affects only the degree of movement, not the kind of movement, i.e., more re-positioning error, but no change in which quadrants the greater error occurs. Whether our results are normal can only be determined by future, larger scale studies that would establish a normative data base. Future studies may show that not only do people suffering from neck pain show more head re-positioning errors with vibration, but normal quadrant data might also be altered. This could allow rehabilitation plans to place emphasis on the specific muscles involved in the re-positioning error, since quadrant patterns indicate which muscle groups are involved.

The various studies using cervical vibration and head repositioning utilize different methods and thus make comparisons of the different laser/ head repositioning error studies difficult. One other factor that has not been mentioned in previous studies is the influence of subject-target distance on results. Our study used a 60 cm distance between subject and chart, whereas other studies have used 40 cm or 90 cm. When measurements are kept in cm and subject to target distances vary, no direct comparison can be made. The distance between subject and the Cartesian chart target alters the repositioning error, so calculations need to be performed to equalize the study results obtained with different subject-target distances. Standardizing subject to target distances would avoid this problem. Subject to target distance does not affect data derived from studies reporting repositioning errors in radians or degrees.

Reliability is another issue that needs to be addressed in studies involving head repositioning accuracy with the laser pointer method. It is defined as repeat measure testing, the consistency of a measure or method over time[22]. Revel[21], the first to publish a study using the laser pointer method, mentioned two reliability checks used; 1) head repositioning measurements of study participants were checked by two investigators viewing the same participant on the same day; 2) and different investigators measured participants repositioning accuracy on different dates, i.e. investigator one measured participant one's responses on one date and investigator two measured participant one's response on a different date. Unfortunately, there were no details provided about how the study participants' charts were recorded or marked by two investigators.

The inclusion of examiner reliability assessment in studies involving head re-positioning is lacking in studies by Rix[24], Palmgren[25], Heikkila[8], Beinert[31], and our current study. This is a problem and has been highlighted by Strimpakos[28], who stated that reliable measures and conclusive observations have been lacking in neck proprioception studies. Future studies could include a second trial prior to vibration which would enable the study investigators to calculate reliability.

Our chart for marking repositioning error was a graph sheet, divided into 1 mm squares. The diameter of the dots made by the study investigators' pens/pencils was about 1 mm; thus, our error of measurement would be 1 mm. Figuring this into our data did not alter any of the results. The main criteria for examiner accuracy in marking are good visual acuity and very sharp pencils or small point pens.

Twenty one participants, 14 men and 7 women, entered and completed our study. One question that arose was whether to treat the genders as separate groups, or to combine them into one group. It was decided not to group male and females separately. Differences in muscle use patterns between males and females have been demonstrated in previous studies by Fedorowich[32], Johansen,[33] Tierney[34], and Brophy[35]. Our study did not separate participants by gender because the studies noted involved fatiguing tasks, sports injuries or repetitive tasks carried on for lengthy periods, and these conditions were not present in our study. Demaille-Wlodyka[36] showed that gender had no effect on the ability to return the head to the neutral position under normal conditions, i.e. when these fatiguing or repetitive tasks were not present.

One pattern that has appeared in studies by Heikkila[8], Rix[24], and Palmgren[25] is the fairly large standard deviations seen in raw data. As mentioned previously, this was also seen in the raw data from our current study. Square root data transformation smoothed this study's data considerably and perhaps should be a consideration for researchers in future studies involving head repositioning and laser pointers.

It was noted about 1/5 of the way through the study, that some participants would return their heads to the presumed neutral position, stop, exhibit a small, very brief oscillatory pattern of the head and then move closer to the presumed neutral position. This oscillation seemed more pronounced in the vibratory sessions, but in all sessions observed, it resulted in the participant moving closer to the neutral point on the Cartesian chart. To the best of our knowledge, this oscillatory period has not been previously addressed in head re-positioning studies. Marking this first point of stoppage, part of our protocol, resulted in large standard deviations in our data. Taking this into account, we felt that future experiments could possibly reduce the large standard deviations seen by allowing participants to complete the brief oscillatory period before marking the stopping point. There is a way to incorporate this oscillatory movement/period and help standardize head re-positioning studies – determine a set time for the re-positioning effort. From our experience, two seconds seems a reasonable period. By incorporating a standardized time for re-positioning movements, all trials, whether normal or vibration, will eliminate time variances not addressed in current studies. In a study involving postural control, Arora[37] demonstrated that the normalized time to reach a maximum distance was increased after WBV exposure, confirming our findings

Future studies assessing the effects of vibration on head re-positioning accuracy might also wish to consider the use of whole body vibration, via a vibration platform. As mentioned previously, Strimpakos[28] demonstrated that head re-positioning while standing resulted in less variable error than did head re-positioning while sitting. As long as standardization of methods and statistical analyses are not in agreement, it will be difficult to compare data from different studies investigating the effects of vibration on head repositioning. It is proposed that future work adopt a standardized method of conducting head repositioning/vibration experiments and authors should communicate to standardize procedures. There is potential value in establishing a database of end range of motion deviation with vibration in healthy participants. Further development could lead to the use of vibration as a valuable clinical tool in assessing the response to treatments for various musculoskeletal neck pathologies. The cost of conducting such studies is not prohibitive and the experimental procedure is neither time consuming nor difficult.

Rix[24] alluded to this problem and put it best: "The method of measurement and, in particular, its subjective and non-remote nature inevitably involve a degree of experimenter bias and geometric inaccuracy. On this basis, comparing absolute values between different studies should be done with caution".

Conclusions

The limited data from our pilot study have shown that head re-positioning errors are increased by whole body vibration. This is possibly due to altered proprioceptive input from the elements in the neck muscle spindles. Additionally, tabulation of movements ending in the different Cartesian coordinate quadrants can determine overshoot or undershoot of head re-positioning that identifies which muscle groups are responsible for the overshoot or undershoot errors.

Data transformation was used to help normalize the raw data in this study. Large standard deviations (and variances), as seen in the raw data, can affect statistical analysis and may limit statistical analysis to the use of non-parametric statistics. Transformed data, by approximating a normal distribution, allows the use of more robust parametric statistics. This should be a consideration for future investigators.

With what has been learned in this project and what has been suggested for future research, the investigators feel confident that a database of normal head re-positioning data and vibration re-positioning data can be established. Using this database, future studies could investigate the relationship between whole body vibration on neck proprioception and thus determine if it can be used an indicator of treatment efficacy in neck disorders.

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