J Korean Soc Phys Ther Vol.26, No.3, June 2014
pISSN 1229-0475 · eISSN 2287-156X
The Journal of Korean Society of Physical Therapy
Original articles

The Effect of Different Head Positions with Whole Body Vibration on Muscle Activation related to Postural Stability in Standing

Hye-Jung Seo[1], Joong-Hwi Kim[2], Kuk-Kyung Son[3]

[1]Department of Physical Therapy, General Graduate School, Catholic University of Daegu, [2]Department of Physical Therapy, College of Medicine Science, Catholic University of Daegu, [3]Department of Physical Therapy, Bobath Children's Hospital

Purpose: The purpose of this study was to investigate muscle activation related to postural stability depending on different head positions with whole body vibration (WBV) in standing.

Methods: Eighteen healthy subjects voluntarily participated in this single-group, repeated-measures study in which the surface electromyography (EMG) data from upper trapezius, rectus abdominis, external oblique abdominis, erector spinae, gluteus maximus, rectus femoris, semitendinosus, medial gastrocnemius were collected over 3 different frequencies (0-10-20Hz) and 4 different head positions (neutral, flexion, extension, chin tuck) for each subject on WBV while standing.

Results: The results of this study demonstrated that the EMG activity of all recorded muscles shows significant difference between three different frequencies and four head positions of WBV while standing ($p<0.05$). In the multiple comparison, significant differences could be observed for most of different frequency conditions except 0-10Hz of RA, 10-20Hz of ST. In contrast, no significant difference showed the comparison of the EMG activity depending on different head positions ($p<0.05$).

Conclusion: These findings suggest that different head positions on WBV do not activate muscles related to postural stability. However, higher frequency on WBV is highly effective to activate whole body muscles included postural muscles regardless of different head positions.

Key Words: Whole body vibration, Frequency, Head position, Standing, Muscles activation, Electromyography

I. Introduction

Stabilization of the head with respect to the environment is considered as fundamental in the control of whole body balance and co-ordination during the performance of several motor actions, such as daily-life locomotor tasks. One of the primary goals of postural control is to stabilize the head in space.[1] The sensory organs for visual and vestibular systems are embedded in the head, making refined head control of critical importance for both orientation and balance.[2-6] Potential mechanisms for controlling stabilization of the head and neck include voluntary movements, vestibular (VCR) and proprioceptive (CCR) neck reflexes, and system mechanisms.[7]

Studies of head control have shown increased head movement during transitions between postures, during reaching and even when making visual saccades.[3,4,7,8] Berthoz and Pozzo studied head stability during postural tasks and found that the head is oriented to vertical and the amplitude of motion is kept to a minimum. The types of postural tasks included free walking, walking in place, running in place, and hopping and single-leg standing on a balance beam and bilateral stance on a rocking platform.[3]

Received May 16, 2014 Revised Jun 9, 2014
Accepted Jun 13, 2014
Corresponding author Joong-Hwi Kim, charmpt@gmail.com

Scientific researches with respect to proper head posture have been studied for a long time. Many previous studies have reported that proper head posture is considered to be a state of musculoskeletal balance that involves minimizing the stresses and strains acting on the upper body.[8,9] Kwon et al. investigated whether different sitting positions natural and ideal head postures, have an effect on head and shoulder posture and muscle activity during the forward overhead reaching.[9] Kogler et al. evaluated postural control in five head positions in standing. As such, there were numerous studies about interaction of proper head position and postural control during various body positions.[10]

Recently, whole-body vibration (WBV) training has been used as one of methods for muscle strengthening.[11-13] The variability in the vibration-training protocols used by different investigators may be an important reason for the inconsistent results that are reported in the scientific literature.[14-19] The vibration protocols can vary in the vibration characteristics (i.e., frequency and amplitude) that are used, the body position and movement performed during the exposure to vibration, the duration of the exposure, and the length of time between the cessation of the vibration treatment and the post treatment measurements. It is mainly used to practice on a vibrating platform where the person is standing in a static position or moving in dynamic movements.[20,21]

Further, neck muscle vibration has prominent effects on sway and inclination and can modify the anticipatory postural adjustment (APA) during a voluntary arm movement.[22] In particular, when applied to the posterior neck it induces forward sway, whereas when applied laterally on the sternocleidomastoid it induces roll to the opposite side.[23,24] Julius et al. reported that the local and global effects of neck muscle vibration during upright standing seemed to affect both at the level of individual joints and on whole-body postural coordination.[25]

In former study, there were numerous researches that the neuromuscular activation during WBV was shown to be closely related to the frequency of vibration: the higher the frequency, the higher the EMG activity.[14-20,26,27] Also, there were numerous studies about interaction of different vibration frequencies in WBV depending on different body position, especially angle of knee and ankle.[14-16,28] But study of interaction between head position and vibration frequency during standing was not found in the literature. Therefore, we hypothesized that different head position in WBV would affect on postural control during standing, which has not been studied. The objective of this study was to investigate muscle activation related to postural stability depending on different head position and frequency of WBV while standing.

II. Method

1. Subjects

18 volunteers participated in this study. The participants were physically healthy and have worked in the Bobath Children's Hospital (9 males and 9 females, age 27.7±4.1, weight 59.7±11.7, height 165±7.7 and body mass index 21.7±2.5) (Table 1). They were informed about the aim and experimental aspects of research prior to the study. The exclusion criteria included a history of any cardiovsacular, respiratory, abdominal, urinary, gynaecologinal, neurological, musculoskelectal, or other chronic disease.

2. Experimental design

In order to examine the influence of three vibration frequencies of whole body vibration and four head positions, a single-group, repeated measures and crossed-study design was used. For that purpose, the EMG activity of 8 trunk muscles was analyzed with respect to a progressive increase in three vibration frequencies (0-10-20Hz) and four head positions (neutral, flexion, extension, chin tuck).

3. Surface electromyographic recording

The surface EMG activity of all eighteen subjects was measured at eight muscles by a WEMG-8 (LXM5308, LAXTHA, Korea). Bipolar surface electrodes were placed over the muscle bellies approximately in the midway between the center of the innervation zone and the further tendon. Before attaching the electrodes, the skin was carefully shaved, rubbed and cleaned with alcohol. The eight sites on the dominant side were as follows: 1) the upper trapezius(UT) muscle, one half the distance lateral between the cervical spine at C-7 and

Table 1. Characteristics of subjects (N=18)

Subjects	Age (yrs)	Height (cm)	Weight (kg)	BMI
9 males	29.3 ± 3.9	170.9 ± 4.9	68.8 ± 9.0	23.5 ± 1.9
9 females	25.6 ± 3.5	159.2 ± 4.9	50.7 ± 4.9	20.0 ± 1.7
Total	27.7 ± 4.1	165.1 ± 7.7	59.7 ± 11.7	21.7 ± 2.5

BMI: Body Mass Index

Table 2. The mean comparison of %RVC of neuromuscular activation at the different applied vibration frequencies and head positions.

Variable	Frequency	Neutral	Flexion	Extension	Chin Tuck	F	p
	0Hz	100	110.07 ± 33.61	128.03 ± 56.92	117.74 ± 48.09		
UT	10Hz	194.35 ± 142.04	216.25 ± 211.54	213.45 ± 285.91	138.18 ± 56.44	2.000	0.030*
	20Hz	300.64 ± 299.84	270.33 ± 253.88	327.04 ± 567.88	242.47 ± 163.21		
	0Hz	100	125.73 ± 61.28	93.73 ± 25.41	92.14 ± 26.84		
ES	10Hz	152.32 ± 63.28	206.22 ± 101.10	119.15 ± 48.11	116.58 ± 46.65	7.490	0.000*
	20Hz	276.34 ± 199.32	252.15 ± 122.49	233.56 ± 158.01	241.78 ± 188.01		
	0Hz	100	105.54 ± 14.10	108.94 ± 17.54	117.40 ± 59.62		
RA	10Hz	237.32 ± 142.81	273.19 ± 242.12	259.79 ± 142.55	204.99 ± 113.78	6.899	0.000*
	20Hz	417.08 ± 327.88	487.96 ± 490.27	251.40 ± 162.99	335.73 ± 195.33		
	0Hz	100	122.23 ± 34.68	115.11 ± 47.06	124.99 ± 43.77		
EO	10Hz	262.07 ± 218.83	209.96 ± 90.86	208.04 ± 104.47	211.41 ± 136.78	6.472	0.000*
	20Hz	337.07 ± 208.74	371.39 ± 276.72	355.27 ± 251.41	315.02 ± 239.19		
	0Hz	100	130.21 ± 46.92	115.89 ± 37.24	110.67 ± 25.35		
GM	10Hz	381.11 ± 280.36	353.92 ± 256.99	266.65 ± 157.51	293.93 ± 253.98	8.388	0.000*
	20Hz	846.89 ± 800.55	720.22 ± 740.95	445.91 ± 191.80	472.31 ± 194.93		
	0Hz	100	219.23 ± 259.19	163.03 ± 186.71	183.10 ± 226.83		
RF	10Hz	1380.97 ± 1299.33	1004.64 ± 1226.30	937.14 ± 1034.93	1015.52 ± 1143.37	5.147	0.000*
	20Hz	2345.78 ± 2360.42	2020.55 ± 2278.33	1746.80 ± 2204.28	1661.55 ± 2084.57		
	0Hz	100	270.93 ± 216.43	249.54 ± 259.76	184.20 ± 126.13		
ST	10Hz	1159.12 ± 1265.22	807.13 ± 452.46	709.67 ± 366.65	582.78 ± 356.22	8.700	0.000*
	20Hz	1138.63 ± 808.74	1136.34 ± 628.56	891.81 ± 542.61	928.92 ± 624.73		
	0Hz	100	121.95 ± 52.26	145.99 ± 67.27	121.26 ± 61.63		
MS	10Hz	453.06 ± 469.71	386.34 ± 294.71	370.10 ± 217.94	351.12 ± 209.14	8.289	0.000*
	20Hz	1076.67 ± 1232.73	740.27 ± 468.15	683.28 ± 340.29	733.43 ± 500.10		

Mean ± SD of %RVC. * $p<0.05$
UT: upper trapezius, ES: extensor spinea, RA: rectus abdominalis, EO: external oblique,
GM: gluteus maximus, RF: rectus femoris, ST: semitendinosus, MG: medial gastrocnemius

the acromion, 2) the erector spinae (ES) muscles, 1–2 finger widths lateral from the L1 spinous process, 3) the rectus abdominis (RA) muscle, at the level of the anterior superior iliac spine, 1–2 cm lateral to the midline, 4) the external oblique (EO) muscle, just below the rib cage at the inferior angle of the rib, 5) the gluteus maximus (GM) muscle, 50% of

Table 3. The multiple comparison for interaction between vibration frequencies and head positions.

	UT	ES	RA	EO	GM	RF	ST	MS
Frequency								
0-10Hz	0.154	0.035*	0.000*	0.000*	0.001*	0.001*	0.000*	0.002*
0-20Hz	0.000*	0.000*	0.000*	0.000*	0.000*	0.000*	0.000*	0.000*
10-20Hz	0.049*	0.000*	0.000*	0.000*	0.000*	0.002*	0.074	0.000*
Head position								
Neutral-Flexion	1.000	1.000	1.000	1.000	1.000	1.000	1.000	0.905
Neutral-Extension	1.000	1.000	1.000	1.000	0.092	1.000	0.597	0.630
Neutral-Chin tuck	1.000	1.000	1.000	1.000	0.170	1.000	0.209	0.662
Flexion-Extension	1.000	0.167	1.000	1.000	0.092	1.000	1.000	1.000
Flexion-Chin tuck	1.000	0.196	0.521	1.000	0.170	1.000	0.602	1.000
Extension-Chin tuck	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000

* $p<0.05$

the distance from sacral vertebrae to the greater trochanter, at the greatest prominence of the middle buttocks, parallel to a line from the posterior superior iliac spine to the middle posterior thigh, 6) the rectus femoris (RF) muscle, 50% of the distance from the anterior superior iliac spine to the superior patella, 7) the semitendinosus (ST) muscle, 50% of the distance from the ischial tuberosity to the medial tibial epicondyle, and 8) the medial gastrocnemius (MG) muscle, distal from the knee and 2 cm apart medial to the midline. The reference electrode was placed on the pectoral major muscle.

The EMG signals were preamplified, filtered (input impedance; 1012 Ω, CMRR (common mode rejection ratio); 110 dB, bandpass digital filter; 50–300 Hz) and sampled at 1,024 Hz. The raw EMG data were converted into root mean squre(RMS) data using TeleScan program (version 2.0). For normalization, reference contraction (no vibration while standing on the WBV platform) was used and EMG data expressed as a percentage of reference voluntary contraction (%RVC).

4. General procedure

The subjects were positioned in standing on the WBV platform (Novotec Medical, Pforzheim, Germany), instructed to direct their head and eyes forward and distribute their weight equally on both feet. They were instructed to perform the motion maximally in each of 4 different head positions of neutral, flexion, extension and chin tuck for the following conditions: 0 Hz, 10 Hz, and 20 Hz. Vibration exposure during a single trial was limited to 10s with at least 10s of rest in between trials. Three trials of each position and condition were recorded.

5. Statistical analysis

The analysis of all data was executed using SPSS for Window (Ver. 19.0). The level of significance was set to 0.05. All data were expressed as the mean and standard deviation. To analyze the differences in EMG data, the two-way analysis of variance was used. The dependent variables in all statistical tests were EMG values measured from the muscles UT, ES, RA, EO, GM, RF, ST, and MG. The independent variables were vibration frequency and head position. In order to test hypothesis and to detect interaction effects between the independent variables, a two-way ANOVA with Bonferroni corrected post hoc tests was used.

III. Results

The study demonstrated that the EMG activity of all recorded muscles (UT, ES, RA, EO, GM, RF ST, and MG) show significant difference between three different frequency and four head position of WBV while standing ($p<0.05$)(Table 2). In the multiple comparison, significant differences could be observed for most of the different frequency conditions except 0–10 Hz of UT, 10–20 Hz of ST. In contrast, no significant difference showed the comparison of the EMG activity of all recorded muscles depending on different head position (Table 3).

IV. Discussion

Whole-body vibration training (WBVT) is a new therapeutic strategy in sports, rehabilitation and preventive medicine.[29] Many positive effects of vibration on the human body have also been reported in physiotherapeutic and clinical settings in which vibration has been used for pain management and to elicit muscle contractions in spastic and paretic muscles.[13,17,21,30] At present, research is being performed examining the use of whole-body vibration in the treatment and prevention of osteoporosis.[11,13,17,21,29–31]

It is well known that muscle vibration alters postural orientation in quiet stance through the production of abnormal spindle input. Former study investigated whether it would also affect either postural orientation during stance on a translating surface or body stabilization and dynamic coordination between the upper and lower body, or both.[17] It is clear that vibration protocols used by investigators have been varied according to the frequency, amplitudes, duration of exposure, and body position during the exposure to vibration.[31] Generally, the training consists of mild physical exercises the patient performs while standing on a vibrating platform.[29]

Therefore, we studied to investigate muscles activation related to postural stability depending on different head position and frequency of WBV during quiet standing and to identify the most effective training conditions that cause highest neuromuscular responses.

As a result, the main findings were that (1) all recorded muscles (UT, ES, RA, EO, GM, RF, ST, and MG) were affected by 3 different frequencies and 4 different head positions (Table 2) and (2) no significant difference showed the comparison of the EMG activity of all recorded muscles depending on different head position.

In this study, the EMG activity increased in response to a progressive increase in vibration frequency in all recorded muscles (Table 2). These observations are in line with the finding of previous study; they documented a linearly increased EMG activity as a function of the vibration frequency. In the multiple comparison of 3 different vibration frequencies (Table 3), a significant difference could be observed for most different frequencies except 0–10 Hz of UT, 10–20 Hz of ST. Based on this result, we suggest that it applies higher frequency on WBV in order to strengthen most muscles.

On the other hand, in the multiple comparison of 4 different head positions, no significant difference showed the comparison of the EMG activity of all recorded muscles. This result proved that head position was no influence on muscle activation related on postural stability in WBV during standing. A reason why this study reported outcome was that vibration energy was diminished as head is far away from vibration plate. Our results are in agreement with previous studies, in which muscles adjacent to vibration plate were more activated and muscles far away from vibration plate were less activated because of the loss of vibration energy.[18–20]

The other reason was that we subjected various postural muscles to continue mechanical vibration during the mobile-platform task, in order to assess the relative weight of proprioceptive information from distal or proximal sites.[24] In fact, based on the information in the literature, the perturbing effect could have different features depending on the muscle vibrated.[22,23] For this reason, we studied to investigate muscle activation related to postural stability depending on 4 different head position with WBV during standing. Our findings of no or only small changes on muscle activation indicate that WBV training depending on head position is not an efficient training method. The explanation of this opinion is in line with the finding of Hamid, in which head position is of no large importance for equilibrium performance.[4]

However, perturbation of neck proprioception, by means of neck muscle vibration (NMV), is known to affect postural control during upright quiet standing.[25] The abundance of receptors sensitive to mechanical influences may be regarded as the physiological basis of sensory illusion and postural responses evoked by stimulation of the neck, similar to stimulation of postural muscles.[22] Several previous researchers suggested a hypothetical explanation for the postural response to neck vibration, based on the concept that sensory data is interpreted with respect to a postural schema.[32-34] That is, when vibration is applied to the posterior surface of the neck muscles of a blindfolded standing subject, the vibration selectively activates muscle spindle receptors signaling the brain that the neck muscles are lengthening.[22,32] Also, the NMV-induced perceived neck lengthening is hypothesized to be interpreted by the postural control system as a backward leaning that would lead to a corrective response, i.e., the observed forward leaning of the body.[25] Therefore, we think that it is more efficient to stimulate directly on neck muscle than using WBV during standing.

It has been proposed that frequent correction to an upright neutral postural position serves two functions: first, that may provide a regular reduction of adverse loads on the cervical joints induced by poor spinal, cervical and scapular postures. Second, it may train the deep postural stabilizing muscles of the spine in their functional postural supporting role.[9] Hence, we can assume that the proper head posture is a common treatment approach. In former studies, most of authors proposed that head extension increases postural sway in normal subjects. This pattern, according to the authors, indicates that head extension causes deterioration of both visual and vestibular cues and increases the dependence of the proprioceptive input.[2]

In this study, although not statistically significant, it was higher activation of muscles related postural stability during neural head position and head flexion than the other two positions. On the other hand, although not statistically significant, it was higher activation of UT during head extension. Those results revealed that the primary or secondary muscles related on head extension were more activated than other muscles on WBV during standing. But, this study did not measure the neck flexor. For this reason, we did not study to investigate muscle activation of neck flexor depending on different head position. This is one of limitations of this study to be discussed. Another limitation was to studying the effect of the 4 head position among various head position and 3 vibration frequencies on certain muscle group related in postural stability. The other limitation was small sample size and subjects were located in certain region. Future studies are needed to do study using various head position including rotation and segmental vibration frequency.

It was concluded from this study that the different position of head may be not affect to muscle activation related to postural stability with WBV during standing, but it is more beneficial to activate specific muscles related on postural stability, using a higher WBV frequency. Therefore, we recommend that it is more efficient to stimulate neck muscles vibration directly than WBV during standing for stabilizing of head and postural stability.

References

1. Pozzo T, Berthoz A, Lefort L. Head stabilization during various locomotor tasks in humans. Experimental Brain Research. 1990;82(1):97-106.
2. Barin K, Seitz CM, Welling DB. Effect of head orientation on the diagnostic sensitivity of posturography in patients with compensated unilateral lesions. Otolaryngol Head Neck Surg. 1992;106(4):355-62.
3. Berthoz A, Pozzo T. Head stabilization during various locomotor tasks in humans. Exp Brain Res. 1990;82(1):97-106.
4. Hamid MA. Effects of head position on posture during altered visual and proprioceptive orientation: Preliminary report. J Vestib Res. 1994;4(6):481-3.
5. Pozzo T, Berthoz A, Lefort L. Head stabilization during various locomotor tasks in humans. Experimental Brain Research. 1990;82(1):97-106.
6. Nashner L, Shupert C, Horak F. Head-trunk movement coordination in the standing posture. Prog Brain Res. 1988;76:243-51.
7. Keshner E, Peterson B. Mechanisms controlling human head stabilization. I. Head-neck dynamics during random rotations in the horizontal plane. J Neurophysiol. 1995;73(6):2293-301.
8. Caneiro JP, O'Sullivan P, Burnett A et al. The influence of different sitting postures on head/neck posture and muscle activity. Man Ther. 2010;15(1):54-60.
9. Kwon JW, Nam SH, Choi YW et al. The effect of different head positions in sitting on head and shoulder posture and muscle activity. J Korean Soc Phys Ther. 2013;25(4):217-23.

10. Kogler A, Lindfors J, Ödkvist L et al. Postural stability using different neck positions in normal subjects and patients with neck trauma. Acta Otolaryngol. 2000;120(2):151–5.
11. Lim YH. The study on whole body vibration as a new exercise training prescription method. Coach. 2005;7(4):105–16.
12. Kim TH, Choi HS. EMG activities trunk and lower extremity muscles included by different intensity of whole body vibration during bridging exercise. Korean Research Society of Physical Therapy. 2009;16(4):16–22.
13. Kim JH. The effects of whole body vibration exercise on balance and lower extremity muscle activity in stroke patients. J Korean Soc Phys Ther. 2013;25(5):266–72.
14. Avelar NC, Ribeiro VG, Mezencio B et al. Influence of the knee flexion on muscle activation and transmissibility during whole body vibration. J Electromyogr Kinesiol. 2013;23(4):844–50.
15. Cardinale M, Lim J. Electromyography activity of vastus lateralis muscle during whole-body vibrations of different frequencies. J Strength Cond Res. 2003;17(3):621–4.
16. Di Giminiani R, Masedu F, Tihanyi J et al. The interaction between body position and vibration frequency on acute response to whole body vibration. J Electromyogr Kinesiol. 2013;23(1):245–51.
17. Jordan MJ, Norris SR, Smith DJ et al. Vibration training: An overview of the area, training consequences, and future considerations. J Strength Cond Res. 2005;19(2):459–66.
18. Ritzmann R, Gollhofer A, Kramer A. The influence of vibration type, frequency, body position and additional load on the neuromuscular activity during whole body vibration. Eur J Appl Physiol. 2013;113(1):1–11.
19. Seo HJ, Kim JW. Analysis of muscle activation related to postural stability according to different frequency of whole body vibration during quiet standing. J Korean Soc Phys Ther. 2013;25(5):316–21.
20. Pollock RD, Woledge RC, Mills KR et al. Muscle activity and acceleration during whole body vibration: Effect of frequency and amplitude. Clin Biomech (Bristol, Avon). 2010;25(8):840–6.
21. Bressel E, Smith G, Branscomb J. Transmission of whole body vibration in children while standing. Clin Biomech (Bristol, Avon). 2010;25(2):181–6.
22. Kasai T, Yahagi S, Shimura K. Effect of vibration-induced postural illusion on anticipatory postural adjustment of voluntary arm movement in standing humans. Gait Posture. 2002;15(1):94–100.
23. Kavounoudias A, Gilhodes J, Roll R et al. From balance regulation to body orientation: Two goals for muscle proprioceptive information processing? Exp Brain Res.
24. De Nunzio AM, Nardone A, Schieppati M. Head stabilization on a continuously oscillating platform: The effect of a proprioceptive disturbance on the balancing strategy. Experimental brain research. 2005;165(2):261–72.
25. Verrel J, Cuisinier R, Lindenberger U et al. Local and global effects of neck muscle vibration during stabilization of upright standing. Experimental brain research. 2011;210(2):313–24.
26. Abercromby AF, Amonette WE, Layne CS et al. Variation in neuromuscular responses during acute whole-body vibration exercise. Med Sci Sports Exerc. 2007;39(9):1642–50.
27. Roelants M, Delecluse C, Verschueren SM. Whole-body-vibration training increases knee-extension strength and speed of movement in older women. J Am Geriatr Soc. 2004;52(6):901–8.
28. Cochrane DJ, Loram ID, Stannard SR et al. Changes in joint angle, muscle-tendon complex length, muscle contractile tissue displacement, and modulation of EMG activity during acute whole-body vibration. Muscle Nerve. 2009;40(3):420–9.
29. Vry J, Schubert IJ, Semler O et al. Whole-body vibration training in children with duchenne muscular dystrophy and spinal muscular atrophy. European Journal of Paediatric Neurology. 2014;18(2):140–9.
30. Rauch F. Vibration therapy. Dev Med Child Neurol. 2010;10(1):77–83.
31. Villarroya MA, González-Agüero A, Moros T et al. Effects of whole body vibration training on balance in adolescents with and without down syndrome. Res Dev Disabil. 2013;34(10):3057–65.
32. Roll J, Vedel J, Ribot E. Alteration of proprioceptive messages induced by tendon vibration in man: A microneurographic study. Experimental Brain Research. 1989;76(1):213–22.
33. Popov K, Lekhel H, Bronstein A et al. Postural responses to vibration of neck muscles in patients with unilateral vestibular lesions. Neurosci Lett. 1996;214(2):202–4.
34. Lekhel H, Popov K, Anastasopoulos D et al. Postural responses to vibration of neck muscles in patients with idiopathic torticollis. Brain. 1997;120(4):583–91.