Taylor & Francis
Taylor & Francis Group

Somatosensory & Motor Research

ISSN: 0899-0220 (Print) 1369-1651 (Online) Journal homepage: http://www.tandfonline.com/loi/ismr20

Effect of tongue position on postural stability during quiet standing in healthy young males

Ahmad H. Alghadir, Hamayun Zafar & Zaheen A. Iqbal

To cite this article: Ahmad H. Alghadir, Hamayun Zafar & Zaheen A. Iqbal (2015) Effect of tongue position on postural stability during quiet standing in healthy young males, Somatosensory & Motor Research, 32:3, 183-186, DOI: 10.3109/08990220.2015.1043120

To link to this article: http://dx.doi.org/10.3109/08990220.2015.1043120

Published online: 23 Sep 2015.

Somatosensory & Motor Research

http://informahealthcare.com/smr
ISSN: 0899-0220 (print), 1369-1651 (electronic)

Somatosens Mot Res, 2015; 32(3): 183–186

DOI: 10.3109/08990220.2015.1043120

Taylor & Francis
Taylor & Francis Group

ORIGINAL ARTICLE

Effect of tongue position on postural stability during quiet standing in healthy young males

Ahmad H. Alghadir[1], Hamayun Zafar[1,2], & Zaheen A. Iqbal[1]

[1]Department of Rehabilitation Sciences, College of Applied Medical Sciences, King Saud University, Riyadh, Saudi Arabia and [2]Department of Odontology, Clinical Oral Physiology, Umea University, Umea, Sweden

Abstract

Background and aims: Role of the neck and jaw sensory motor system in control of body balance has been established. Tongue is an integral part of jaw sensory motor system and helps in execution of purposeful and precise motor tasks like eating, drinking and speaking. The purpose of this study was to evaluate the possible effects of tongue position on the postural control system.
Materials and method: We compared the mean center of gravity (COG) velocity during quiet standing on an unstable surface with eyes closed during two test conditions: (i) with habitual jaw resting position and (ii) with instructed tongue positioned against the upper incisors. One hundred and sixteen normal healthy male subjects (average age 31.56 ± 8.51 years and height 170.86 ± 7.26 cm) participated in the study. Their COG velocity (deg/s) was measured using the NeuroCom® Balance Master version 8.5.0 (Clackamas, OR, USA).
Results and conclusions: The results show that COG velocity decreased significantly while tongue was positioned against upper incisors in comparison to the habitual jaw resting position. Our findings suggest that the tongue positioning can modulate postural control mechanisms. Tongue positioning against the upper incisors can enhance the postural stability during upright standing on an unstable surface and in the absence of vision in healthy young adults. Our findings can be of value for evaluation and rehabilitation protocols for postural control dysfunction.

Keywords

Balance, COG velocity, postural stability, tongue position

History

Received 7 December 2014
Revised 15 March 2015
Accepted 10 April 2015
Published online 9 September 2015

Introduction

Provocation of the neck position in cases of neck pain and subjective postural instability has shown to cause imbalance (Alund et al., 1993). Similarly, in cases of neck trauma (whiplash associated disorders), the patients show symptoms of gait disturbances, dizziness and balance impairments. (Abrahams, 1977; Kogler et al., 2000) These studies point to the important role of neck sensory motor system in the control of body posture and balance.

A close functional, anatomical, biomechanical, neurological and physiological link has been reported between jaw and neck regions (Brodie, 1950; Chang et al., 1988; Abrahams et al., 1993; Ertekin et al., 1996). Co-activation of muscles of jaw and neck-shoulder complex has been observed during mandibular movements and clenching. (Davies, 1979; Widmalm et al., 1988; Clark et al., 1993) This shows the existence of neural connections between trigeminal and the neck sensory and motor systems. (Eriksson et al., 1998; Zafar et al., 2000) Neck trauma is also shown to derange integrated jaw and neck behavior showing the functional coupling between the jaw and neck motor systems. (Eriksson et al., 2004; Haggman-Henrikson and Eriksson, 2004) Role of the jaw sensory motor system in control of body balance has also been shown. (Alghadir et al., 2014)

Tongue is closely related to the jaw sensory motor system, (Rocabado, 1983) and due to its location near landmarks like teeth, palate, and upper and lower jaws, the information about its location and movement is constantly available in the mechanoreceptor system supplying the region. (Carleton, 1938; Trulsson and Essick, 1997) Execution of purposeful and precise motor tasks like eating, drinking, speaking, and protrusion in specific direction require information about tongue position and movements. (Trulsson and Essick, 1997) Tongue has been proposed to be idle site for electrical stimulation due to presence of electrolyte rich saliva and high tactile acuity on its tip compared to other body regions, (Rath and Essick, 1990; Lozano et al., 2009; Wildenberg et al., 2010) and used in various studies for sensory substitution in the absence of other source (Tyler et al., 2003).

We propose that additional sensory feedback from tongue just by touching the hard palate behind the upper incisors may modulate posture control during standing either via its connections to the jaw system and neck sensory motor

Correspondence: Zaheen A. Iqbal, Department of Rehabilitation Sciences, College of Applied Medical Sciences, King Saud University, PO BOX 10219, Riyadh 11433, Saudi Arabia. Tel: 00966569086528. Fax: 014693589. E-mail: z_iqbal001@yahoo.com

system or through its possible indirect connections to the vestibular system. We studied the effect of tongue position (TP) against the upper incisors on the velocity of Center of Gravity (COG) during quite standing. The findings of this study can be helpful to understand postural control mechanisms and to develop rehabilitation protocols for the management and treatment of patients with balance impairments.

Materials and methods

Subjects

One hundred and twenty five healthy male subjects (average age 31.76, SD 8.45 years; height 170.95, SD 7.29 cm) participated in this study. The data on the same group of subjects has previously been reported in our other study (Alghadir et al., 2014) were included. All subjects were informed about the aims and procedures of study and written consent was obtained in accordance with the Declaration of Helsinki. Before the study, subjects were subjectively and objectively assessed for any signs or symptoms of balance, temporomandibular joint disorders and skeletal anomalies including face, neck and jaw. Based on these criteria, nine subjects were excluded. The study fully complied with the ethical standards for human research of our University.

COG velocity assessment

The COG velocity was assessed using the NeuroCom® Balance Master version 8.5.0 (Clackamas, OR, USA) which measures force using variable inductance compression load cells. It includes a $46 \times 152\,cm^2$ force platform interfaced to a computer (Liston and Brouwer, 1996; Newstead et al., 2005; Chien et al., 2007). The Balance Master was automatically calibrated before each testing session in the automatic mode. The subjects were asked to stand as still as possible on a soft relatively unstable surface (a foam block of 50 cm by 50 cm by 15 cm, provided by the manufacturer) with their feet comfortably together as marked on the force platform with normal angle of 4–7 degrees of toe out, eyes closed and arms by their sides. The COG velocity (deg/s) during test was measured by the system with eyes closed during the two conditions: (i) with habitual jaw resting position, i.e., natural jaw position without any instructions and (ii) the instructed tongue positioned against the upper incisors (TP). Each recording was started 10 s after the subject assumed the test condition. The data on COG velocity (deg/sec) during resting jaw position was collected in a different session on the same day with same recording conditions and as has been previously reported (Alghadir et al., 2014).

The duration for each test run for both test conditions was 10 s. Each test condition was repeated three times for each subject, and a rest of about 30 seconds was allowed between the trials. The COG velocity (deg/s) of the natural sway while trying to stand as still as possible was sampled at a frequency of 100 Hz and the mean for the three trials was used for analyses.

Data analysis

Data was analyzed using Graph-Pad Instat 3.0 (GraphPad Software, San Diego, CA, USA). Means and SD were used for descriptive statistics. The effect size was calculated using Hedges' (adjusted) g [$g = M_1 - M_2/S_{pooled}$; where M_1 and M_2 are the mean score of condition 1 and 2, S_{pooled} is the estimate of the population standard deviation]. The hypothesis of no difference in COG velocity during the habitual resting jaw position and while TP was tested by the Friedman test. The null hypothesis was rejected at the 0.05 level of significance.

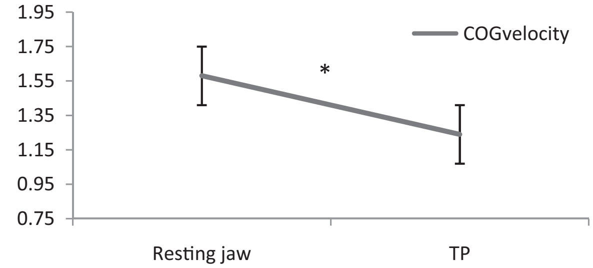

Figure 1. Mean of COG velocity (deg/s) and 95% confidence interval values of all subjects ($n = 116$) for quiet standing on relatively unstable surface with eyes closed during two test conditions. Note significant differences ($p < 0.0001$) in COG values between the test conditions (*) and the lesser mean value for the tongue positioned against the upper incisors (TP).

Results

COG velocity during two test conditions

The mean COG velocity values during quiet standing on a relatively unstable surface varied between the two test conditions. The mean COG velocity (deg/sec) values of 1.58 (SD 0.64) and 1.24 (0.43) were found for 'habitual resting jaw' and 'TP' test conditions, respectively. Effect size was 0.624 with 95 % CI 0.36LL and 0.88 UL. It corresponds to medium effect size.

In comparison to the 'habitual resting jaw' condition, the mean COG velocity was significantly less in the 'TP' test condition ($p < 0.0001$) (Figure 1).

Discussion

We studied if an additional sensory feedback from positioning of the tongue placed against the upper incisors could modify the subjects' ability to control postural stability. We measured velocity of center of gravity in normal healthy subjects with eyes closed while standing on a foam surface during habitual resting jaw position and with instructed tongue position against the upper incisors (TP). Results showed that the COG velocity was significantly different during the two test conditions, with least mean value during TP condition.

Tactile sensations have potential to free the visual and auditory channels to utilize unexploited sensory channel to convey information about posture control. (Wall et al., 2001) A biofeedback system supplying the subject with supplementary sensory information related to foot sole pressure distribution through a tongue placed tactile output device has been studied. (Bach-y-Rita et al., 1998; Vuillerme and Chenu, et al. (2007a); Vuillerme and Chenu, et al. (2007b); Vuillerme and Chenu, et al. (2007c); Wildenberg et al., 2010) Such an artificial tongue placed tactile biofeedback can efficiently be integrated with other sensory cues for improving the postural control system. (Vuillerme and Chenu, et al. (2007a)) Tongue is located in a protected environment of the mouth and is invisible to others raising its potential to be used as a mean of feedback, (Vuillerme et al., 2009) to which body can react to control its posture during rest and motion. (Kaczmarek et al., 1991) Our study shows that sensory motor mechanisms related to tongue positioning against the upper incisors can help modulate the postural control on unstable surface.

A sound balance system requires an assessment of body position or motion in space and a timely reaction to control it. (Massion, 1994) Cutaneous information from foot sole, (Kavounoudias et al., 1998; Meyer et al., 2004) visual, (Collins and De Luca, 1995) vestibular, (Horak and Hlavacka., 2001; Wardman et al., 2003), and somatosensory (Fransson et al., 2000; Rogers et al., 2001; Fransson et al., 2003) channels are widely studied sources of such information. Besides these, postural stability is also affected by various neural inputs and cognitive tasks (Rankin et al., 2000; Dault et al., 2001). With aging, these sources lose their sensitivity (Kenshalo, 1986) and increase the risk of fall. (Lord et al., 1991) Sensory biofeedback systems using vestibular, vision and hearing sensations are widely used in rehabilitation. (Chiari et al., 2005; Pinsault and Vuillerme, 2008) Such a sensory feedback help when one of its inputs become weak or absent, or when we just want to enhance it for better balance control if the chances of falls are high. But these may lead to multi-tasking deficit with vision or hearing being preoccupied. (Vuillerme et al., 2009)

Tongue, owing to its neurophysiological characteristics, dense mechanoreceptors, (Picard and Olivier, 1983; Trulsson and Essick, 1997) and large somatosensory cortical representations, (Picard and Olivier, 1983) has always been focus of research. Deep mechanoreceptors located in lingual nerve have the capacity to signal tongue movements even in the absence of its physical contact. (Trulsson and Essick, 1997) It has been shown to convey higher resolution information than skin (Sampaio et al., 2001) and that the plantar based, tongue-placed tactile biofeedback improves postural control during quiet standing. (Vuillerme and Chenu, et al. (2007a); Vuillerme and Chenu, et al. (2007b); Vuillerme and Chenu, et al. (2007c) Electrical stimulation of the tongue has been shown to modulate a region within pons and explain its association with postural stability. (Wildenberg et al, 2011) However, this is the first study to use sensory feedback from tongue without any electrical stimulation.

It is interesting to note that despite deprivation of visual input and more challenging situation to stand on relatively unstable foam surface, (as used in our study) the subjects showed decrease in COG velocity with changes in tongue position. This indicates that tongue position within jaw system is capable of modulation of postural control system in the same way as body stabilization reported by its stimulation and different jaw positions. (Alghadir et al., 2014; Wildenberg et al., 2011)

Dependence on a sensory input for postural control may vary with individual capacity, depending on availability, accuracy, reliability and inconsistency between signals. Vuillerme and Chenu, et al. (2007a); Young healthy adults could have relied more on additional sensations from tongue to cope up with the changing environment, to improve their postural control by decreasing their COG velocity as central nervous system.

Conclusion

Our findings suggest that the tongue positioning can modulate postural control mechanisms. In the absence of vision, the positioning of tongue against the upper incisors can enhance the postural stability during upright standing on an unstable surface in healthy young adults. Our findings can be of value for evaluation and rehabilitation protocols for postural control dysfunction.

Limitation

We have used only COG velocity as a parameter for posture and balance. Future studies with additional parameters in both genders and different age groups can be helpful to further understand the role of tongue positioning in postural control.

Acknowledgment

The authors would like to extend their sincere appreciation to the Deanship of Scientific Research at King Saud University for funding this research through the research group NO. RGP-VPP-209.

Declaration of interest

The authors report no conflicts of interest. The authors alone are responsible for the content and writing of the paper.

References

Abrahams VC. 1977. The physiology of neck muscles; their role in head movement and maintenance of posture. Can J Physiol Pharmacol 55(3):332–338.

Abrahams VC, Kor AA, Loeb GE, Richmond FJ, Rose PK, Keirstead SA. 1993. Facial input to neck motoneurons: trigemino-cervical reflexes in the conscious and anaesthetised cat. Exp Brain Res 97(1):23–30.

Alghadir A, Zafar H, Whitney SL, Iqbal ZA. 2014. Effect of chewing on postural stability during quiet standing in healthy young males. Somatosens Mot Res 1–5.

Alund M, Ledin T, Odkvist L, Larsson SE. 1993. Dynamic posturography among patients with common neck disorders. A study of 15 cases with suspected cervical vertigo. J Vestib Res 3(4):383–389.

Bach-y-Rita P, Kaczmarek KA, Tyler ME, Garcia-Lara J. 1998. Form perception with a 49-point electrotactile stimulus array on the tongue: a technical note. J Rehabil Res Dev 35(4):427–430.

Brodie AG. 1950. Anatomy and physiology of head and neck musculature. Am J Orthod 36(11):831–844.

Carleton A. 1938. Observations on the Problem of the Proprioceptive innervation of the Tongue. J Anat 72(Pt 4):502–507.

Chang CM, Kubota K, Lee MS, Iseki H, Sonoda Y, Narita N, Shibanai S, Nagae K, Ohkubo K. 1988. Degeneration of the primary snout sensory afferents in the cervical spinal cords following the infraorbital nerve transection in some mammals. Anat Anz 166(1–5):43–51.

Chiari L, Dozza M, Cappello A, Horak FB, Macellari V, Giansanti D. 2005. Audio-biofeedback for balance improvement: an accelerometry-based system. IEEE Trans Biomed Eng 52(12):2108–2111.

Hu MH, Tang PF, Sheu CF, Hsieh CL. 2007. A comparison of psychometric properties of the smart balance master system and the postural assessment scale for stroke in people who have had mild stroke. Arch Phys Med Rehabil 88(3):374–380.

Clark GT, Browne PA, Nakano M, Yang Q. 1993. Co-activation of sternocleidomastoid muscles during maximum clenching. J Dent Res 72(11):1499–1502.

Collins JJ, De Luca CJ. 1995. The effects of visual input on open-loop and closed-loop postural control mechanisms. Exp Brain Res 103(1):151–163.

Dault MC, Geurts AC. 2001. Postural control and cognitive task performance in healthy participants while balancing on different support-surface configurations. Gait Posture 14(3):248–255.

Davies PL. 1979. Electromyographic study of superficial neck muscles in mandibular function. J Dent Res 58(1):537–538.

Eriksson PO, Zafar H, Haggman-Henrikson B. 2004. Deranged jaw-neck motor control in whiplash-associated disorders. Eur J Oral Sci 112(1):25–32.

Eriksson PO, Zafar H, Nordh E. 1998. Concomitant mandibular and head-neck movements during jaw opening-closing in man. J Oral Rehabil 25(11):859–870.

Ertekin C, Celebisoy N, Uludag B. 1996. Trigemino-cervical reflexes in normal subjects. J Neurol Sci 143(1–2):84–90.

Fransson P, Johansson R, Hafstrom A, Magnusson M. 2000. Methods for evaluation of postural control adaptation. Gait Posture 12(1):14–24.

Fransson PA, Hafstrom A, Karlberg M, Magnusson M, Tjader A, Johansson R. 2003. Postural control adaptation during galvanic vestibular and vibratory proprioceptive stimulation. IEEE Trans Biomed Eng 50(12):1310–1319.

Haggman-Henrikson B, Eriksson PO. 2004. Head movements during chewing: relation to size and texture of bolus. J Dent Res 83(11):864–868.

Horak FB, Hlavacka F. 2001. Somatosensory loss increases vestibulospinal sensitivity. J Neurophysiol 86(2):575–585.

Kaczmarek KA, Webster JG, Bach-y-Rita P, Tompkins WJ. 1991. Electrotactile and vibrotactile displays for sensory substitution systems. IEEE Trans Biomed Eng 38(1):1–16.

Kavounoudias A, Roll R, Roll JP. 1998. The plantar sole is a ‘dynamometric map’ for human balance control. Neuroreport 9(14):3247–3252.

Kenshalo DR., Sr. 1986. Somesthetic sensitivity in young and elderly humans. J Gerontol 41(6):732–742.

Kogler A, Lindfors J, Odkvist LM, Ledin T. 2000. Postural stability using different neck positions in normal subjects and patients with neck trauma. Acta Otolaryngol 120(2):151–155.

Kotsiomiti E, Kapari D. 2000. Resting tongue position and its relation to the state of the dentition: a pilot study. J Oral Rehabil 27(4):349–354.

Liston RA, Brouwer BJ. 1996. Reliability and validity of measures obtained from stroke patients using the Balance Master. Arch Phys Med Rehabil 77(5):425–430.

Lord SR, Clark RD, Webster IW. 1991. Physiological factors associated with falls in an elderly population. J Am Geriatr Soc 39(12):1194–1200.

Lozano C, Kaczmarek KA, Santello M. 2009. electrotactile stimulation on the tongue: intensity perception, discrimination, and cross-modality estimation. Somatosens Mot Res 26:50–63.

Massion J. 1994. Postural control system. Curr Opin Neurobiol 4(6):877–887.

Meyer PF, Oddsson LI, De Luca CJ. 2004. The role of plantar cutaneous sensation in unperturbed stance. Exp Brain Res 156(4):505–512.

Newstead AH, Hinman MR, Tomberlin JA. 2005. Reliability of the Berg Balance Scale and balance master limits of stability tests for individuals with brain injury. J Neurol Phys Ther 29(1):18–23.

Picard C, Olivier A. 1983. Sensory cortical tongue representation in man. J Neurosurg 59(5):781–789.

Pinsault N, Vuillerme N. 2008. The effects of scale display of visual feedback on postural control during quiet standing in healthy elderly subjects. Arch Phys Med Rehabil 89(9):1772–1774.

Rankin JK, Woollacott MH. 2000. Cognitive influence on postural stability: a neuromuscular analysis in young and older adults. J Gerontol A Biol Sci Med Sci 55(3):M112–119.

Rath EM, Essick GK. 1990. Perioral somesthetic sensibility: do the skin of the lower face and the midface exhibit comparable sensitivity? J Oral Maxillofac Surg 48(11):1181–1190.

Rocabado M. 1983. Arthrokinematics of the temporomandibular joint. Dent Clin North Am 27(3):573–594.

Rogers MW, Wardman DL, Lord SR, Fitzpatrick RC. 2001. Passive tactile sensory input improves stability during standing. Exp Brain Res 136(4):514–522.

Sampaio E, Maris S, Bach-y-Rita P. 2001. Brain plasticity: ‘visual’ acuity of blind persons via the tongue. Brain Res 908(2):204–207.

Trulsson M, Essick GK. 1997. Low-threshold mechanoreceptive afferents in the human lingual nerve. J Neurophysiol 77(2):737–748.

Tyler M, Danilov Y, Bach-Y-Rita P. 2003. closing an open loop control system: vestibular substitution through the tongue. J of integrative Neurosc 2:159–164.

Vuillerme N, Chenu O, Demongeot J, Payan Y. 2007a. Controlling posture using a plantar pressure-based, tongue-placed tactile biofeedback system. Exp Brain Res 179(3):409–414.

Vuillerme N, Chenu O, Pinsault N, Boisgontier M, Demongeot J, Payan Y. 2007b. Inter-individual variability in sensory weighting of a plantar pressure-based, tongue-placed tactile biofeedback for controlling posture. Neurosci Lett 421(2):173–177.

Vuillerme N, Pinsault N, Chenu O, Boisgontier M, Demongeot J, Payan Y. 2007c. How a plantar pressure-based, tongue-placed tactile biofeedback modifies postural control mechanisms during quiet standing. Exp Brain Res 181(4):547–554.

Vuillerme N, Pinsault N, Chenu O, Fleury A, Payan Y, Demongeot J. 2009. A wireless embedded tongue tactile biofeedback system for balance control. Pervasive and Mobile Computing 5(3):268–275.

Wall C, Weinberg MS, Schmidt PB, Krebs DE. 2001. Balance prosthesis based on micromechanical sensors using vibrotactile feedback of tilt. IEEE Trans Biomed Eng 48(10):1153–1161.

Wardman DL, Day BL, Fitzpatrick RC. 2003. Position and velocity responses to galvanic vestibular stimulation in human subjects during standing. J Physiol 547(Pt 1):293–299.

Widmalm SE, Lillie JH, Ash MM, Jr. 1988. Anatomical and electromyographic studies of the digastric muscle. J Oral Rehabil 15(1):3–21.

Wildenberg JC, Tyler ME, Danilov YP, Kaczmarek KA, Meyerand ME. 2011. High-resolution fMRI detects neuromodulation of individual brainstem nuclei by electrical tongue stimulation in balance-impaired individuals. NeuroImage 56:2129–2137.

Wildenberg JC, Tyler ME, Danilov YP, Kaczmarek KA, Meyerand ME. 2010. Sustained cortical and subcortical neuromodulation induced by electrical tongue stimulation. Brain Imaging and Behaviour 4: 199–211.

Zafar H, Eriksson PO, Nordh E, Haggman-Henrikson B. 2000. Wireless optoelectronic recordings of mandibular and associated head-neck movements in man: a methodological study. J Oral Rehabil 27(3):227–238.