Original Paper

A study of the relationship between posterior unilateral biting tasks and body sway

Toshikazu Ishikawa, Shinji Iyama, Yoshihiro Tsukiyama and Kiyoshi Koyano

Section of Removable Prosthodontics, Faculty of Dental Science, Kyushu University

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Abstract: The influences of head and body posture on physiologic rest position, range of functional movements and initial tooth contact have previously been reported. The purpose of this study was to investigate whether the posture of the body can be modified by alterations in the stomatognathic system. Postural sway was assessed in 8 healthy subjects. We recorded the subjects' center of gravity (CG) during natural standing in physiologic rest position (with eyes open or closed), while biting on one sheet of occlusal registration paper without clenching on the left and the right sides (with eyes closed). The dominant side of the velocity vector of CG (DSVV) was determined by comparing the total value of magnitudes in right and left ingredients of the velocity vector. In each subject, the DSVV coincided with the side for which the subject presented a smaller value of total sway length of center of gravity (LNG). The LNG values with eyes open were significantly smaller than those with eyes closed. The LNG values obtained when subjects were biting on the occlusal registration paper placed on the ipsilateral side to the DSVV were significantly smaller than those obtained when they were biting on the contralateral side to the DSVV. The results suggest that there could be a dominant side for the CG in normal subjects and this condition might be more stabilized with biting on the ipsilateral side of DSVV.

I. Introduction

The functional relationship between dental occlusion and systemic body condition has been of interest to many researchers in recent years. It has been well documented that a change of head/body posture influences the position and movement of the mandible¹⁻⁴⁾. Conversely, changes in mandibular position could influence activities of neck muscles and head posture. They could also affect activities of upper limb and antigravity muscles⁵⁻⁷⁾. The posture of the body might be modified by alterations in the stomatognathic system.

It has been reported that objective measurements of body sway are useful for characterizing the dynamics of the postural control system associated with maintaining balance during quiet standing⁸⁻¹⁰⁾. The sway paths of the center of gravity (CG) can be dynamically measured with the subject standing on a force plate for a period of time. CG is used to approximate the shifts of the center of gravity of the body in antero-posterior and lateral directions. It is known that the individual CG indicates a peculiar pattern in direction, i.e., the subject generally stands asymmetrically associated with one's own habitual posture, and the dominant directional deviation of CG is observed.

Recently, Bracco, et al.¹¹⁾ evaluated the effect on body sway of three different jaw positions - centric occlusion, rest position and myocentric position. However, it is unclear how the information derived from these previous studies, especially the dominant directional deviation of CG, is related to body equilibrium.

In this study, CG of healthy individuals was measured at three different jaw positions, i.e., physiologic rest position (with eyes open or closed), biting on one sheet of occlusal registration paper on the left side without clenching (with eyes closed), and biting on one sheet of occlusal registration paper on the right side without clenching (with eyes closed). Furthermore the dominant side of the velocity vector of CG (DSVV) was determined. All information on body sway was analyzed from the point of view of DSVV. The aim of this study was to provide new information about the relationships between posture and occlusal contacts.

II. Materials and methods

1. Subjects

Twelve healthy dental students aged 18-24 years old participated in the study. Informed consent was obtained from each subject prior to the experiment, provided that all subjects were blinded with regard to the outcome from each subject's measurement. Information on age, height, body weight, and past and present illness was collected through a questionnaire. Then oral and dental study cast examinations were carried out. The subjects with a history of spine, lower limb or temporomandibular disorders (TMD), any otologic, or neurologic problems were excluded. Inclusion criteria were that the subject had complete dentition excluding third molars, without removable or fixed partial dentures, bilateral Angle class I occlusion, no previous or current orthodontic treatment, absence of anterior or lateral reverse articulation, and no open occlusal relationship. As the result of examination, four subjects were excluded from the study. One had been suffering from a foot injury, two had dental arch problems, and one had chronic pain of TMD. Therefore, eight subjects completed the study.

2. Equipment

Stabilometry recordings were performed with a strain-gauge-type force platform (Stabilometer EB1101, NEC medical systems, Tokyo) at a sampling frequency of 20 Hz. The information collected by the sensors was transferred into a personal computer (personal computer PC-9821Bp, NEC, Tokyo), where the data were processed by software (Stabilometer 98II, NEC medical systems, Tokyo) that provides graphic and numerical information on the location and relative amount of pressure applied on the platform.

3. Experimental protocol

The subjects were instructed according to the Japan Society for Equilibrium Research recommendations as well as the following: "Please relax when you stand, since the human body naturally moves". The subjects were asked to stand barefoot on the force platform with feet parallel and hands at their sides, and to look straight ahead at a visual reference point that was put 1.5 meters in front of the subject. The point was mounted on a wall at each subject's eye level. The experimental setting is illustrated in Figure 1.

During the trial, the measurement sequence was as follows:

1) physiologic rest position with eyes open, 2) physiologic rest position with eyes closed, 3) biting on one sheet of

Fig. 1 Block diagram of the experiment

occlusal registration paper (Articulating paper, GC, Tokyo) on the left side without clenching (with eyes closed) and 4) biting on one sheet of occlusal registration paper on the right side without clenching (with eyes closed). These four measurements were made while each subject stood on forth platform. The thickness of the occlusal registration paper was $100\mu\text{m}$.

The occlusal registration papers were cut to $1\text{ cm} \times 1\text{ cm}$ size, and placed between the occlusal surfaces of upper and lower mandibular second molars. Each measurement lasted 60 seconds, and a 30-second rest, quietly seated on a chair, was given to the subject between measurements.

4. Data analysis

First, the individual "dominant side of the velocity vector of CG (DSVV)" was defined according to the whole image of the velocity vector, that was visualized projecting radially in 8 directions from the center to the periphery in 45° increments between 0° and 359° . Six out of eight vector directions were divided into right components (0° , 45° , 315°) and left components (135° , 180° , 225°), and the vector directions 90° and 270° were excluded because they do not represent any lateral components. As a result, DSVV (represented by right or left) was determined by comparing the total value of right and left components. Then the following body sway parameters were calculated: the total sway length of CG (LNG), envelope area (ENV), root mean square area (RMS), and rectangle area (REC).

The mean values and SD of 4 measurements were calculated. The values were compared by one-way repeated mea-

asures of analysis of variance. When test results were significant, Fisher's PLSD were further performed. The value of statistical significance was set at $P=0.05$.

III. Results

1. DSVV

Table 1 presents the data of the velocity vector. Seven subjects showed right side deviation in DSVV, and one subject showed left side deviation.

2. Body sway parameters

Table 2 shows the results of measurements when the occlusal registration paper was placed on the mandibular second molar on either the left or right side. In each subject, the DSVV coincided with the side for which subjects presented a smaller value of LNG. However, the rates of coincidence for ENV, RMS and REC were 62.5%, 37.5% and 50%, respectively.

Table 1 Magnitudes of velocity vector and DSVV

Subject number	Left side				Right side				DSVV
	135°	180°	225°	Total	0°	45°	315°	Total	
1	232.52	294.56	177.34	704.42	353.28	153.63	224.27	731.18	Right
2	128.05	114.38	212.68	455.11	106.57	202.52	136.56	445.65	Left
3	138.69	126.55	140.67	405.91	183.05	162.37	150.03	495.45	Right
4	110.00	157.02	96.66	363.68	210.51	114.35	119.29	444.15	Right
5	205.42	188.47	234.35	628.24	217.91	206.9	237.51	662.32	Right
6	188.78	145.13	114.56	448.47	238.85	134.59	171.34	544.78	Right
7	102.35	181.34	208.43	492.12	266.27	225.95	102.11	594.33	Right
8	130.42	129.93	141.57	401.92	190.6	137.99	136.37	464.96	Right

The individual DSVV were determined by comparing the total magnitudes on right and left side.

unit, cm/s; DSVV, dominant side of the velocity vector of center of gravity.

Table 2 Data of the body sway parameters

Subject number	DSVV	LNG (cm)		ENV (cm ²)		RMS (cm ²)		REC (cm ²)	
		L	R	L	R	L	R	L	R
1	Right	89.00	83.61*	6.12	5.84*	4.32	3.45*	16.96	11.97*
2	Left	72.47*	73.71	2.45	1.94*	1.36	0.83*	4.18	4.12*
3	Right	61.00	57.72*	2.63*	3.34	1.35*	2.21	4.95*	7.12
4	Right	64.35	61.58*	3.59	3.51*	1.43*	1.50	5.27*	7.02
5	Right	94.95	85.58*	7.83	4.81*	4.15	3.06*	17.61	13.86*
6	Right	79.74	72.89*	3.32	3.28*	1.28*	1.72	6.32	6.24*
7	Right	94.99	76.61*	4.24*	4.78	2.19*	2.42	10.24*	11.12
8	Right	49.00	43.86*	2.62	1.71*	1.54	0.79*	6.00	3.45*
The rates of coincidence		100%		62.5%		37.5%		50.0%	

L or R represents the side on which an occlusal registration paper was placed.

DSVV, dominant side of the velocity vector of center of gravity; LNG, total sway length of CG; ENV, envelope area; RMS, root mean square area; REC, rectangle area; *, smaller value as a result of comparison between L and R.

DSVV, dominant side of the velocity vector of center of gravity; n = 8.

Fig. 2 Group mean value of LNG

The LNG value with eyes open was significantly smaller than that with eyes closed (Fisher's PLSD test, $*P<0.05$). The LNG values obtained when subjects were biting on the occlusal registration paper placed on the ipsilateral side to the DSVV were significantly smaller than those when they were biting on the contralateral side to the DSVV.

Figure 2 shows mean values of LNG recorded at physiologic rest position (with eyes open or closed), biting on the ipsilateral side to the DSVV (with eyes closed), and on the contralateral side (with eyes closed). Post-hoc Fisher's PLSD intervals revealed that the LNG value with eyes open was smaller than that with eyes closed. Also the LNG values obtained when subjects were biting on the occlusal registration paper placed on the ipsilateral side to the DSVV were significantly smaller than those when they were biting on the contralateral side to the DSVV.

IV. Discussion

Computerized stabilometry has been developed to assess equilibrium disturbance. Using this dynamic method for evaluation of body posture, the effect of various types of modifi-

cations on body posture have been investigated⁸⁻¹⁴. Because this method is simple and non-invasive, and requires only a short time for measurement, it is introduced not only for clinical use but also for epidemiological studies investigating sub-clinical abnormal findings related to the nervous system¹⁵⁻¹⁷.

One of the issues demonstrated in this study was that each subject tends to show its own peculiar pattern of the CG, i.e., there is one's own DSVV. The DSVV was determined by comparing the lateral components of the velocity vector. The reproducibility of the direction of DSVV was very high in our preliminary experiments (data not shown). For instance, most people are aware of their dominant hand/eye, and usually control the body movements with hand/eye coordination. The authors consider the existence of the preferred chewing side to affect the body balance as the dominant hand/eye. This might be important to know because it can relate to the prediction about possible breakdown of dental prosthesis in the future. In this study, the subjects have no difference between the two biting sides (right or left) visually. However, we speculate the one's own preferred chewing side affect the body balance, especially lateral direction, if the stomatognathic system was normal and even if she or he does not aware of the preferred chewing side. This is one of the reasons why we paid attention to DSVV. It is not clear exactly what the described DSVV indicates. At the moment, we simply consider it as the dominant side of body sway in the lateral direction.

Although postural sways in the antero-posterior direction are usually greater than those in the lateral direction, we focused on the lateral direction because asymmetric lateral deviations were reported to be more important indications in normal subjects¹⁴, patients with ankle sprain¹⁸ and edentulous patients using complete dentures¹⁹. Dietz and Berger¹⁴ reported there was a right-left coordinated leg muscle EMG activity during balancing and this was mediated by a spinal coordinating mechanism. Maruya et al.¹⁹ compared the body sways of edentulous patients under four conditions: centric occlusion, during clenching in centric occlusion, and in physiologic rest position with and without dentures. They reported that the standard deviation in the lateral direction of body sway in physiologic rest position without dentures was significantly larger than that in physiologic rest position with dentures, in centric occlusion, or during clenching in centric occlusion. However, they found no difference in the antero-posterior direction among these four conditions. They sug-

gested that the movement of CG in the lateral direction might reflect the changes of subjects's body sway more sensitively than that in the antero-posterior direction.

In each subject, the DSVV coincided with the side for which they presented the smaller value of LNG. The occlusal registration paper used in this study was 100 μ m in thickness. It might not be thick or hard enough to disturb the subject's intercuspatation of occlusion. Therefore it may be supposed that the mechanical stimulation to the periodontal ligament and to the proprioception of masticatory muscles modulated the subject's body sways. In this study, the occlusal registration paper was placed between upper and lower second molar region. On the contrary, when the occlusal registration paper was placed between upper and lower premolar region, the coincidence of DSVV was low in our preliminary experiments. It's unclear why they show different levels of coincidence.

The other measurement scores (ENV, RMS and REC) did not show such a high coincidence as the LNG. Taguchi²⁰⁾ described the importance of measuring LNG, and FitzGerald et al.²¹⁾ indicated that LNG was the most sensitive method to detect changes in body sway. On the contrary, Goto.²²⁾ suggests that parameters such as ENV and REC are well suited for comparing the body sways in older individuals. Since the subjects examined in this study were healthy young adults, it is reasonable to speculate that the data on these subjects were within normal limits. It is unclear why these scores did not show high levels of coincidence. However, it might be related to the sensitivity to differences in stability. It is probable that these scores may be useful in cases in which the sway range is large, but may not reflect a delicate movement of CG.

Our results showing that the LNG values with eyes closed were larger than those with eyes open were consistent with those in previous studies. Several studies have reported a greater lateral body sway with eyes closed than with eyes open^{23, 24)}. This highlights the importance of vision in maintaining postural stability²³⁾. It is known that vision is used in conjunction with proprioceptive and vestibular signals for spatial orientation and balance control²⁵⁾. In this study, the individual DSVV was defined with eyes closed so that visual stimulus would have little effect on body sway.

Additional information concerning the life style of the subjects, such as dominant hand, preferred chewing side, and more detailed assessment of the various factors of postural control would be needed for further investigations.

V. Conclusion

The center of gravity (CG) was measured at three different jaw positions: physiologic rest position (with eyes open or closed), biting on one sheet of occlusal registration paper on the left side without clenching (with eyes closed), and biting on one sheet of occlusal registration paper on the right side without clenching (with eyes closed), and the dominant side of the velocity vector of CG (DSVV) was determined.

The results obtained were as follows:

1. In each subject, the DSVV coincided with the side for which the subject presented a smaller value of LNG.
2. The LNG value with eyes open was smaller than that with eyes closed.
3. The LNG values obtained when subjects were biting on the occlusal registration paper placed on the ipsilateral side to the DSVV were significantly smaller than those when they were biting on the contralateral side to the DSVV.

VI. Reference

- 1) Tingey, E.M., Buschang, P.H. and Throckmorton, G.S.: Mandibular rest position: a reliable position influenced by head support and body posture, *Am J Orthod Dentofacial Orthop*, 120: 614-622, 2001.
- 2) Makofsky, H.W.: The influence of forward head posture on dental occlusion, *Cranio*, 18: 30-39, 2000.
- 3) Kibana, Y., Ishijima, T. and Hirai, T.: Occlusal support and head posture, *J Oral Rehabil*, 29: 58-63, 2002.
- 4) Robson, F.C.: The clinical evaluation of posture: relationship of the jaw and posture, *Cranio*, 19: 144, 2001.
- 5) Ferrario, V.F., Sforza, C., Serrao, G., et al: The influence of different jaw positions on the endurance and electromyographic pattern of the biceps brachii muscle in young adults with different occlusal characteristics, *J Oral Rehabil*, 28: 732-739, 2001.
- 6) Miralles, R., Dodds, C., Manns, A., et al: Vertical dimension. Part 2 : the changes in electrical activity of the cervical muscles upon varying the vertical dimension, *Cranio*, 20: 39-47, 2002.
- 7) Zuniga, C., Miralles, R., Mena, B., et al: Influence of variation in jaw posture on sternocleidomastoid and trapezius electromyographic activity, *Cranio*, 13: 157-162, 1995.

- 8) Kavounoudias, A., Gilhodes, J.C., Roll, R., et al: From balance regulation to body orientation: two goals for muscle proprioceptive information processing? *Exp Brain Res*, 124: 80-88, 1999.
- 9) Prieto, T.E., Myklebust, J.B., Hoffmann, R.G., et al: Measures of postural steadiness: differences between healthy young and elderly adults, *IEEE Trans Biomed Eng*, 43: 956-966, 1996.
- 10) Kollegger, H., Baumgartner, C., Wober, C., et al: Spontaneous body sway as a function of sex, age, and vision: posturographic study in 30 healthy adults, *Eur Neurol*, 32: 253-259, 1992.
- 11) Bracco, P., Deregibus, A., Piscetta, R., et al: Observations on the correlation between posture and jaw position: A pilot study, *Cranio*, 16: 252-258, 1998.
- 12) Carroll, J.P. and Freedman, W.: Nonstationary properties of postural sway, *J Biomech*, 26: 409-416, 1993.
- 13) Alexander, N.B.: Postural control in older adults, *J Am Geriatr Soc*, 42: 93-108, 1994.
- 14) Dietz, V. and Berger, W.: Spinal coordination of bilateral leg muscle activity during balancing, *Exp Brain Res*, 47: 172-176, 1982.
- 15) Lacour, M., Barthelemy, J., Borel, L., et al, Sensory strategies in human postural control before and after unilateral vestibular neurectomy, *Exp Brain Res*, 115: 300-310, 1997.
- 16) Giacomini, P.G., Bruno, E., Monticone, G., et al: Postural rearrangement in IDDM patients with peripheral neuropathy, *Diabetes Care*, 19: 372-374, 1996.
- 17) Uccioli, L., Giacomini, P.G., Monticone, G., et al: Body sway in diabetic neuropathy, *Diabetes Care*, 18: 339-344, 1995.
- 18) Brunt, D., Andersen, J.C., Huntsman, B., et al: Postural responses to lateral perturbation in healthy subjects and ankle sprain patients, *Med Sci Sports Exerc*, 24: 171-176, 1992.
- 19) Maruya, M., Shimzu, K., Ohnuma, T., et al: The effect of wearing denture and changes of occlusal position on body sway in edentulous patient, *J Jpn Prosthodont Soc*, 44: 781-785, 2000.
- 20) Taguchi, K.: Time course in the position of the center of gravity, *J otolaryngol Jpn*, 80: 217-226, 1977.
- 21) FitzGerald, J.E., Murray, A., Ellicott, C., et al: Comparison of body sway analysis technique, *Acta otolaryngol*, 114: 115-119 1994.
- 22) Goto, A.: effects of eye tracking stimulation on movements of the body's center of gravity and the head in elderly subjects (second report), *J otolaryngol Jpn*, 96: 1270-1278, 1993.
- 23) Brooke-Wavell, K., Perrett, L.K., Howarth, P.A., et al: Influence of the visual environment on the postural stability in healthy older women, *Gerontology*, 48: 293-297, 2002.
- 24) Yamaguchi, I.: Dynamic analysis of high order activities of normal human postural sways, *J Jpn Orthop Assoc*, 63: 764-773, 1989.
- 25) Thurrell, A., Bertholon, P., Bronstein, A.M.: Reorientation of a visually evoked postural response during passive whole body rotation, *Exp Brain Res*, 133: 229-232, 2000.