Maximal bite force and its associations with spinal posture and craniofacial morphology in young adults

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Maximal bite force (MBF) and its associations with craniofacial morphology and spinal posture were studied in a group of young adults (46 M and 38 F) aged 21 to 23 years. MBF was recorded in molar and incisal regions. Sagittal spinal posture was measured by spinal pantography and trunk asymmetry at thoracic and lumbar levels by a forward-bending test. Craniofacial variables and posture of the cervical spine were examined from lateral cephalograms taken in a natural head position. No statistically significant correlations existed between MBF and spinal posture, but significant correlations did exist between MBF and craniofacial variables, especially in women. □ *Bite force; craniofacial morphology; spinal posture*

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Associations between bite force (BF) and craniofacial morphology have been investigated previously with most based on variables measured from lateral cephalograms (1–6). These studies have shown associations between facial form and BF, especially with regard to the shape of the mandible and other variables connected with masseter muscle activity.

An association between BF and head posture has been shown (7), but there seem to be no studies covering the association between BF and spinal posture. Hellsing & Hagberg (7) examined the alteration in individual BF in association with extension of the head from its habitual posture and observed an increase in the BF in the extended position. This was explained by the close interrelationship between the masticatory muscle system and muscles supporting the head. Evidence of muscular interrelationship has also been shown by Huggare & Raustia (8) in patients with craniomandibular disorders; treatment of craniomandibular disorders in some cases altered the inclination of the cervical spine. These observations aroused our interest in possible associations between the magnitude of BF and spinal posture, the latter being examined not merely at the cervical level but also at thoracic and lumbar levels.

The aim of the present study was to investigate molar and incisal maximal bite force among young adults as related to their spinal posture and position, as well as the associations between MBF and craniofacial morphology.

Subjects and methods

The 84 subjects of this study belonged to a subgroup of 91 (51 M, 40 F) selected from a population-based cohort of 430 young Finnish adults (222 M, 208 F), ages ranging from 21 to 23 years. The investigation was part of a cohort

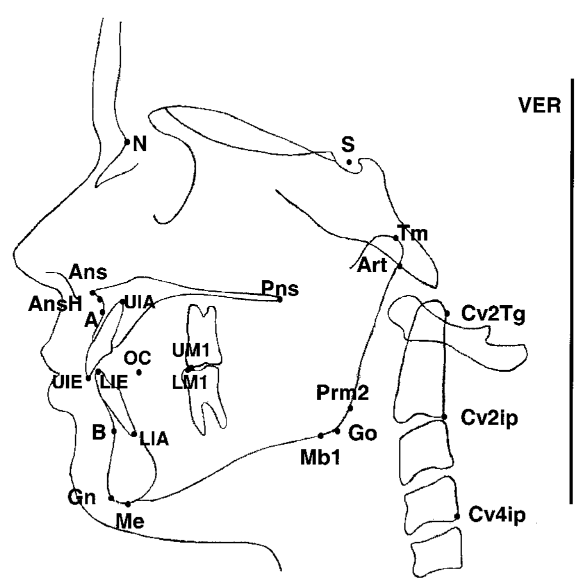

Fig. 1. Cephalometric reference points used in this study.

Table 1. Correlations (r) of maximal bite forces with spinal and craniofacial variables

	Men				Women			
	Molar MBF (n = 46)		Inc MBF (n = 42)		Molar MBF (n = 38)		Inc MBF (n = 38)	
	r	Sign.	r	Sign.	r	Sign.	r	Sign.
Postural, spinal								
OPT/CVT (Cv2Tg-Cv2ip/Cv2Tg-Cv4ip)	−0.11	NS	−0.11	NS	0.16	NS	−0.02	NS
Thoracic kyphosis	0.06	NS	−0.04	NS	−0.28	NS	−0.24	NS
Lumbar lordosis	−0.09	NS	−0.20	NS	0.09	NS	−0.04	NS
Thoracic hump	0.16	NS	−0.14	NS	−0.05	NS	−0.27	NS
Lumbar prominence	0.03	NS	0.07	NS	0.03	NS	0.18	NS
Positional								
NSL/VER (N-S/VER)	0.03	NS	0.16	NS	0.22	NS	0.34	*
CVT/VER (Cv2Tg-Cv4ip/VER)	−0.19	NS	−0.29	NS	−0.23	NS	−0.28	NS
ML/VER (Me-Mb1/VER)	0.28	NS	0.31	*	0.39	*	0.58	***
Postural, craniofacial								
NSL/CVT (N-S/Cv2Tg-Cv4ip)	−0.15	NS	−0.13	NS	−0.07	NS	−0.03	NS
ML/CVT (Me-Go/Cv2Tg-Cv4ip)	0.09	NS	0.04	NS	0.14	NS	0.27	NS
Cranial base								
Saddle angle (N-S-Art)	0.08	NS	0.21	NS	−0.30	NS	−0.33	*
Cranial base angle (Sphen/Clivus planes)	0.05	NS	0.17	NS	0.09	NS	0.04	NS
Craniofacial sagittal								
SNA angle	0.13	NS	−0.07	NS	−0.07	NS	0.05	NS
SNB angle	0.09	NS	−0.03	NS	0.06	NS	0.16	NS
ANB angle	0.06	NS	−0.07	NS	−0.20	NS	−0.18	NS
Craniofacial vertical								
Craniomaxillary angle (S-N/Ans-Pns)	−0.10	NS	0.16	NS	0.25	NS	0.19	NS
Craniomandibular angle (S-N/Me-Mb1)	−0.29	*	−0.21	NS	−0.23	NS	−0.34	*
Maxillomandibular angle (Ans-Pns/Me-Mb1)	−0.24	NS	−0.28	NS	−0.34	*	−0.41	*
Mandibular angle (Art-Prm2/Me-Mb1)	−0.29	NS	−0.09	NS	−0.14	NS	−0.09	NS
Lower gonial angle (Me-Go-S)	−0.31	*	−0.27	NS	−0.16	NS	−0.23	NS
Post./Ant. facial height (S-Go:N-Me)	0.33	*	0.17	NS	0.32	*	0.38	*
Lower/Ant.facial height (Ans-Me:N-Me)	−0.08	NS	−0.18	NS	−0.22	NS	−0.34	*
Dimensions of jaws								
Maxillary length (Tm-AnsH)	0.22	NS	0.18	NS	0.29	NS	0.28	NS
Mandibular length (Tm-Gn)	0.07	NS	0.03	NS	0.34	*	0.24	NS
Mandibular base length (Go-Me)	0.20	NS	0.11	NS	0.16	NS	0.08	NS
Ramus height (Art-Go)	0.32	*	0.10	NS	0.44	**	0.43	**
Dental relationship								
Upper incisor inclination (UIE-UIA/Ans-Pns)	0.12	NS	0.02	NS	0.01	NS	−0.01	NS
Lower incisor inclination (LIE-LIA/Me-Mb1)	0.20	NS	−0.09	NS	−0.15	NS	−0.26	NS
Upper inc. alveolar height (UIE_I_ Ans-Pns)	−0.09	NS	−0.15	NS	−0.02	NS	−0.19	NS
Upper mol. alveolar height (UM1_I_ Ans-Pns)	−0.17	NS	−0.11	NS	0.35	*	0.12	NS
Lower inc. alveolar height (LIE1_I_Me-Mb1)	−0.11	NS	−0.29	NS	−0.03	NS	−0.19	NS
Lower molar alveolar height (LM1_I_Me-Mb1)	0.06	NS	−0.12	NS	0.16	NS	−0.06	NS
Interincisal angle (UIA-UIE/LIE-LIA)	−0.09	NS	0.27	NS	0.29	NS	0.40	*
Overbite (UIE-LIE on N-Me)	0.18	NS	0.27	NS	0.13	NS	0.23	NS
Overjet (UIE-LIE on OC-LM1)	0.11	NS	−0.10	NS	−0.10	NS	0.09	NS

* $P < 0.05$, ** $P < 0.01$, *** $P < 0.001$.

study focusing on the growth of the spine and a long-term evaluation of trunk asymmetry, initially comprising 1060 children aged 11 (9, 10). Of the group of 91, the BF was successfully measured in 84 subjects (46 M, 38 F) comprising the study group. The ethics committee of Helsinki City Health Board approved the study. A physiatrist measured trunk asymmetry and sagittal spinal posture, the asymmetry by a forward-bending test at thoracic and lumbar levels, according to Vercauteren et al. (11) and Nissinen et al. (9). Spinal posture was measured with a spinal pantograph according to Nissinen et al. (9) and Willner (12). In the present study, the criteria for trunk asymmetry (hump exceeding 10 mm) and sagittal spinal posture (hyperkyphosis >50 degrees and hypokyphosis <20 degrees) were the same as used in the study on associations between thoracic kyphosis, head posture, and craniofacial morphology in young adults by Zepa et al. (13).

Lateral cephalometric radiographic examination of the head and cervical spine was done for 84 subjects having either trunk asymmetry (n = 73) or thoracic hyper- (n = 14) and hypokyphosis (n = 13); 11 with hypokyphosis and 4 with hyperkyphosis also showed trunk asymmetry.

The cephalograms were taken in a natural head position according to the fluid-level method (14–16). The habitual sagittal head orientation was determined before the exposure, and repeated when positioning the subject in the cephalostat as indicated by the fluid-level device attached to the temple. For imaging of the gravity vertical, a plumb wire was suspended from the cephalostat in front of the film cassette.

A total of 24 landmarks were identified from the lateral cephalograms (Fig. 1); for definitions, see references 17 to 20. We used these points to landmark the skeletal, dental, and cervical structures.

The cephalometric landmarks were digitized with a computer-connected digitizer (X-Metrix, SmartSystems, 1996), which calculated 13 cephalometric linear and 19 angular variables. All linear dimensions were corrected for the radiographic enlargement (10%).

To detect the possible errors in landmark identification, 20 cephalograms were redigitized after 2 months. The error of method was calculated by the Dahlberg formula: $S(i) = \sqrt{(\sum d^2/2\ N)}$, where d is the difference between the first and second digitization and N is the number of the double digitizations. The range of error variance between two digitizations varied from 0.02 to 1.76 degrees for the angular and 0.30 to 1.38 mm for the linear measurements. These errors were considered acceptable.

Maximal bite force was measured as described previously by Waltimo & Könönen (21). During recording, the patients were sitting in an upright position without head support, and the maximal bite force was measured for the right and left molar regions and incisally, twice in each area. With regard to molar MBF, the higher value (right/left) was chosen to represent the variable for the subject. MBF was not measured in subjects having large fillings or enamel fractures in molar or incisal areas or severe erosion of incisal teeth, for fear of dental damage, or in subjects with orthodontic appliances. The number of subjects for the final analysis thus fell from 91 to 84 with regard to molar MBF and to 80 with regard to incisal MBF.

The statistical significance for differences between MBF values for men and women was analyzed using with Student's *t*-test for unpaired samples. Correlation coefficients (*r*) for simple regression analysis of MBF and spinal, positional, and craniofacial variables were calculated with the statistical computer program Statview.

Results

Men showed significantly higher MBF than women, especially with regard to molar areas; their mean molar MBF was 844 N (range 210–1257, *s* 213.35), with 683 N (range 50–1054, *s* 196.12) in women. The mean incisal MBF was 286 N (range 77–550, *s* 98.06) in men and 237 N (range 32–467, *s* 109.63) in women (*s* = standard deviation).

The results of correlation analysis of maximal incisal and molar bite force with spinal and craniofacial variables are given in Table 1. Owing to the great number (140) of correlations made and the statistical level ($P < 0.05$) taken into account, some of the reported statistically significant findings may be caused by chance. No statistically significant correlations appeared between MBF and the variables characterizing spinal posture. With regard to the positional variables, however, horizontal orientation of the mandibular line correlated significantly with incisal MBF in both genders; in women it also correlated with molar MBF.

In women, more and stronger correlations existed between craniofacial morphology and MBF (both incisal and molar) than in men. Their head position (NSL/VER) showed a positive correlation with incisal MBF. However, cervical position (CVT/VER) showed no correlation with MBF; neither did MBF and the postural craniofacial variables (NSL/CVT, ML/CVT) display significant correlations. Several craniofacial variables characterizing vertical jaw relationship and mandibular shape showed a correlation, in that subjects with high MBF showed parallelism of the jaws (small craniomandibular and maxillomandibular angles).

Only a few significant correlations appeared between MBF and variables describing dental relationships.

Discussion

In this subgroup of a cohort, the subjects of which were selected for cephalometric radiography based on their moderately deviating spinal posture (13, 22), molar MBF values were in line with previous findings for subjects of corresponding age (6, 21, 23). Both molar and incisal MBF values were significantly higher in men than in women, in line with findings of earlier investigations (4, 6, 23, 24). No associations were found between magnitude of bite forces and variables describing spinal posture. With regard to the positional variables, the significant correlation between incisal MBF and ML/VER in both genders (and also between molar MBF and that angle in women) is probably more a reflection of the vertical jaw relationship than a true positional correlation. Subjects with more horizontally oriented mandibular planes have stronger MBFs; this parallelism of mandibular plane with maxilla has been shown in many investigations to be associated with the strong masseter muscles and small gonial angles (4, 25–27).

In fact, it is questionable whether the correlation between incisal MBF and the angle NSL/VER in women is a true positional correlation. It may be due to the fact that women with a greater NSL/VER angle had greater incisal MBF because of more upright upper incisors as a consequence of the soft-tissue stretch effect known from the study of Solow & Kreiborg (28). Indeed, our women subjects showed a positive correlation between incisal MBF and inter-incisal angle.

We found correlations between MBF and certain pure craniofacial morphological variables. Positive correlations between molar MBF and the ratio PFH/AFH and ramus height, and negative correlations with NSL/ML angle and lower gonial angle in men, may be thought to reflect strong masseter muscles, as also suggested earlier (4, 6, 29). However, the contribution of the masseter muscle to the variation in BF magnitude has been shown to be higher than that of the craniofacial factors. Further, BF magnitude is dependent not only on the size of the masseter, but also on its direction, which in turn is related to variation in craniofacial morphology (5).

Women showed a stronger correlation between facial form and MBF than did men. Ingervall & Minder (30) have also reported stronger correlations in girls than in boys between high MBF and some craniofacial variables, including small mandibular inclination, small gonial angle, and high PFH/AFH ratio.

In a study by Ringqvist (31) on young women comparable to ours, a positive correlation existed not only between MBF and parallelism of the jaws, but also between MBF and length of mandible (pogonion-articulare) and ramus height similar to our results in the women. In our study, only one dentoalveolar variable correlated positively with MBF: the upper molar alveolar height with molar MBF in women. This is in accordance with Braun et al. (2) with regard to the maxillary dentoalveolar height. In contrast to our findings, they found a similar correlation also with mandibular dentoalveolar height in their study group comprising young men and women pooled.

Hellsing & Hagberg (7) showed in adults that higher BF values can be exerted in the extended head posture than in the natural head posture and that the position of the hyoid bone changes by extension. They assumed that the higher BFs are due to a changed interplay between the elevator and depressor muscle groups; by actively stabilizing the hyoid bone, the suprahyoid muscle group could have a less inhibiting effect on the activity in the masseter muscles. Although our study also revealed a higher BF, especially at the incisors, in women with a large NSL/VER angle (elevation of the head), the induced intraindividual elevation of 20 degrees in the study of Hellsing & Hagberg (7) supposedly has a more profound effect on the craniocervical muscular balance. Our subjects were recorded in their habitual craniocervical position, which is an individual long-term musculoskeletal adaptation.

It can thus be concluded that spinal posture, even when mildly deviating from the average, seems to reflect the individual morphology of the spine, and its variability seems not to influence the magnitude of masticatory forces in young adults. However, craniofacial morphology was associated with maximal bite force, especially in women.

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