

# Isometric bite force and its relation to dimensions of the facial skeleton

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Maximum voluntary isometric bite force was recorded at the incisors and at the molars in 29 healthy females aged 19—23 years. The relationships between the variations in bite force and dimensions of the facial skeleton were studied by means of linear simple and multiple regression analyses.

There was a high correlation between incisor and molar bite force. Bite force was mainly associated with a long mandible and a small gonion angle. 49% of the variation in incisor bite force could be explained by variations in the length of the mandible, the gonion angle and the length of the anterior cranial base. 56% of the variation in molar bite force could be explained by variations in the length of the mandible, the gonion angle and a long maxilla.

*Key-words:* Facial morphology; bite force

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Many studies have been carried out with the object of calculating the bite force. Surveys of investigations in this field are given by e.g. *Brawley & Sedwich* (1940), *Strenger* (1949) and *Jenkins* (1966). There is a wide range of maximum values for bite force reported by different authors. Disparities in the materials investigated and differences in the techniques and instruments used may account for this. Large interindividual variations in bite force were found in most studies, but few attempts have been made to explain these variations. *Linderholm & Wennström* (1970) found no correlation between bite force and general muscle force or body build in young males; in children 12 years of age only weak correlations were seen

for these relationships (*Linderholm et al.*, 1971). In adults, aged 20—69, part of the interindividual variation in bite force could be explained by the variables sex and age (*Ringqvist & Ringqvist*, in preparation).

Body build and muscle force of the extremities and of the trunk are positively correlated (e.g. *Lindegård*, 1953; *Asmussen & Heebøll-Nielsen*, 1961; *Ringqvist*, 1966). Analogously, one could expect correlations between bite force and dimensions of the facial skeleton. The purpose of this study was therefore to analyse the relationships between variations in bite force and facial morphology in a material homogeneous as regards age and sex.

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## MATERIAL AND METHODS

The investigation was performed on 29 female student nurses, aged 18—23, from a class consisting of 31 subjects. One nurse did not participate because of large fillings in the central incisors, and the other was excluded because of an earlier injury with multiple fractures in the middle face.

The girls were subjectively healthy. They had a complete or nearly complete dentition, only rather small fillings in their teeth and no serious malocclusion. In 8 subjects one or more of the first premolars had been extracted for orthodontic reasons and in 5 subjects one or more of the first or second molars had been extracted for orthodontic reasons or because of caries. At the time of the examination none of the subjects had symptoms or signs of functional disturbances in the masticatory apparatus except for clicking and attrition facets. Clicking was observed in 9 subjects and had generally not been noticed before by the individuals themselves. Only two were aware of grinding their teeth periodically. In connection with periods of bruxism, one of them sometimes had symptoms from the temporal muscles.

Body height, weight and wrist width were registered for characterization of the material (Table I).

*Clinical examination*

Clinical examination was performed with special regard to the function of the masticatory apparatus. The masticatory muscles and the temporomandibular joints were examined according to *Schwarz & Chayes* (1969). The range of maximal mandibular movements was measured according to *Ingervall* (1970) with slight modifications. Each movement was regis-

tered 3 times and the highest value obtained was regarded as representative for maximum opening, lateral movement or protrusion. Overjet and overbite were measured by the methods of *Lundström* (1948).

*Bite force measurements*

The maximum voluntary isometric bite force was recorded at the incisors (incisor bite force) and at the molars on the right side (molar bite force). The equipment used has been described by *Linderholm & Wennström* (1970). Individually produced acrylic splints, in the front covering 13—23 and 43—33, in the molar region 17—15 and 47—45, protected the teeth. The incisor splints together were on an average 6 mm high, the molar splints 4 mm. The incisor bite force was recorded with the incisors in the biting off position, the molar bite force in the habitual closing position. Generally 5—6 recordings of maximum bite force were made for each region. The highest value obtained in the front or molar region was used as an expression of maximum voluntary isometric bite force in the given region. The recordings of the incisor bite force and the molar bite force were preceded by thorough instructions and preliminary attempts at biting. The dynamometer was regularly calibrated with known weights.

The methodological errors in recording the bite force were calculated from the two last determinations of all subjects. Expressed as a coefficient of variation, the methodological error was 5.8 % for the incisor bite force and 5.3 % for the molar bite force.

*Cephalometric measurements*

Profile cephalometric radiographs were taken with the mandible in intercusp-

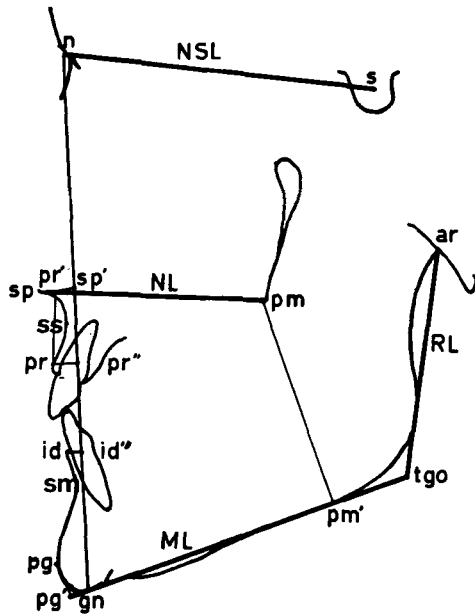


Fig. 1. Reference points and lines used in the cephalometric analyses.

position. The film-focus distance was 155 cm and the film-median plane distance 18 cm. Two films were taken of each subject on separate occasions.

In analysing the profile radiographs, reference points and lines used were defined according to *Solow* (1966) with the following points added:  $sp'$ ,  $pr''$  and  $id''$ , projections of the spinal point, prosthion, and infradentale respectively on the line nasion-gnathion;  $pg'$  and  $pm'$ , projections of pogonion and pterygo-maxillare respectively on the mandibular line (Fig. 1). The measurements were performed according to *Björk & Solow* (1962). For the measurements of distance, calipers were used and the measurements were read to the nearest tenth of a millimeter. The angles were measured with a protractor and read to the nearest half degree. The values obtained were not corrected for linear magnification. The methodological errors for the cephalo-

metric analyses were determined by duplicate measurements made with a time interval of about 3 weeks on radiographs of 22 subjects taken on separate occasions. Expressed as a coefficient of variation, the methodological error varied between 1.1 % ( $n-s$ ) and 1.9 % ( $ar-tgo$ ).

#### Statistical methods

Conventional statistical methods were used for calculation of the mean and standard deviation (e.g. *Snedecor*, 1959). The relationships between two variables were studied by means of simple linear correlation (e.g. *Snedecor*, 1959).

As the variation in the dependent variable (regressand) may be due to the variations of many other variables (regressors) multiple regression analyses (*Dra-per & Smith*, 1967) were performed to calculate the influence of each single regressor on the regressand and to determine whether a higher explanatory value could be obtained with many variables present. The regression coefficients, the constant, the residual standard deviation ( $S.D._e$ ) and the square of the multiple correlation coefficient ( $R^2$ ) were calculated.  $R^2$  and  $S.D._e$  were chosen as parameters indicating the explanatory values of the equations obtained. The regressors were included stepwise in the equations in free order. Only regressors significant at least at the 5 % level were considered. The variables used are listed in Table I.

To study the importance of different groups of variables in explaining the variation in bite force, various sets of variables were tested with bite force as regressand, viz.

- 1) cephalometric variables (no 6—26)
- 2) body build variables (no 3—5)
- 3) overjet, overbite, splint variables (no

Table I Mean values ( $\bar{x}$ ), standard deviations (S.D.) and range of variation for the variables recorded

No	Variable	$\bar{x}$	S.D.	Range of variation
1	Max. incisor bite force, kg	29.9	6.0	20.5— 45.7
2	Max. molar bite force, kg	47.7	9.4	30.8— 69.3
3	Body height, cm	164.6	5.2	155.0—176.0
4	Wrist width, cm	50.9	2.5	45.3— 54.7
5	Body weight, kg	55.0	6.2	43.0— 64.0
6	pg'—ar, mm, length of the mandibular base	114.7	4.8	106.5—125.6
7	pg'—tgo, mm, length of the mandibular body	80.5	5.5	68.0— 92.0
8	ar—tgo, mm, height of the ramus	51.2	4.9	41.6— 59.2
9	id'—gn, mm, height of the mandibular alveol. process	29.7	2.5	27.2— 34.1
10	n—pr", mm, height of the maxilla	67.2	3.8	60.2— 74.5
11	sp'—pr", mm, height of the maxillary alveolar process	15.0	2.7	10.7— 20.4
12	pr'—pm, mm, length of the maxillary body	53.8	2.9	47.7— 57.8
13	n—s, mm, length of the anterior cranial base	71.4	2.7	62.5— 75.7
14	n—gn, mm, anterior height of the face	118.1	6.1	102.5—128.3
15	sp'—gn, mm, anterior height of the jaws	66.2	5.0	54.6— 73.3
16	s—tgo, mm, posterior height of the face	82.2	5.8	68.8— 95.0
17	pm—pm', mm, posterior height of the jaws	44.7	4.3	34.4— 51.8
18	NSL/ML <sup>o</sup> inclination of the mandible in relation to the anterior cranial base	28.7	5.9	17.5— 45.0
19	NL/ML <sup>o</sup> vertical intermaxillary relation	22.7	6.7	7.5— 37.0
20	ML/RL <sup>o</sup> gonion angle	121.6	7.8	109.0—138.0
21	s—n—ss, <sup>o</sup> maxillary prognathism	84.0	3.7	76.0— 91.5
22	s—n—sm, <sup>o</sup> } mandibular	81.3	3.5	75.5— 86.5
23	s—n—pg, <sup>o</sup> } prognathism	83.2	4.1	77.5— 93.5
24	ss—n—sm, <sup>c</sup> sagittal intermaxillary relation	2.8	3.6	8.0— 9.5
25	n—s—ar, <sup>o</sup> curvature of the cranial base	122.5	6.2	112.0—140.5
26	s—ar—tgo, <sup>o</sup> inclination of the ramus	144.2	8.0	131.0—164.0
27	Overjet, mm	2.5	1.6	1.0— 5.5
28	Overbite, mm	3.3	1.5	1.0— 7.5
29	Incisor splint thickness, overbite added, mm	9.2	1.9	5.0— 13.5
30	Max. opening, mm	54.8	4.7	41.0— 62.0
31	Lateral movement, left, mm	10.6	1.7	6.5— 14.0
32	Lateral movement, right, mm	10.6	1.9	7.0— 16.0
33	Protrusion, mm	8.2	2.1	4.0— 12.0

27—29) and variables expressing the range of maximal mandibular movements (no 30—33)

- 4) cephalometric and body build variables simultaneously.

The computer program used for the statistical calculations was BMDO2R — stepwise regression — version of June 2, 1964, Health Sciences Computing Facility, UCLA (University of California, Los Angeles).

## RESULTS

Dimensions of the facial skeleton, overjet, overbite, range of movement of the mandible and body build (mean values and standard deviations) were in agreement with those found for other series. (Ingervall, 1971; Linderholm & Wennström, 1970; Ringqvist, T., 1966).

The means, standard deviations and ranges of variation for the variables recorded are given in Table I. Incisor bite

force and molar bite force were on the average, 30 kg and 48 kg (standard deviation 6.0 and 9.4) respectively.

#### Simple linear correlation analyses

The results of the simple linear correlation analyses appear from Table II. There was a highly significant positive correlation between *incisor bite force* and *molar bite force* ( $r = +0.81$ ). Both *incisor bite force* and *molar bite force* were systematically positively associated with variables representing the size of the mandible (var. 6, 7, 8), a small gonion angle (var. 20), a small inclination of the mandible in relation to the anterior cranial base (var. 18) and the posterior height of the face (var. 16). *Incisor bite force* was probably significantly positively correlated to mandibular prognathism (var. 23), and *molar bite force* significantly positively correlated to anterior jaw rotation (var. 19). No statistically significant correlations were seen between bite force and variables representing the size of the maxilla (var. 10, 11, 12). *Incisor bite force* was probably significantly, and *molar bite force* significantly positively correlated to body height (var. 3). There were no statistically significant correlations between bite force and variables influencing the position of the mandible at biting (var. 27, 28, 29) or between bite force and the range of movement of the mandible (var. 30, 31, 32, 33).

#### Stepwise multiple regression analyses

The results of the regression analyses are presented in Table III.

1) Forty-nine % of the variations in *incisor bite force* could be explained by the variations in mandibular base length, the gonion angle and the length of the anterior cranial base. The

Table II Simple linear correlation coefficients ( $r$ ) for the variables listed in Table I as regressors and incisor bite force or molar bite force as regressand. Asterisks indicate level of statistical significance for  $r$

Regressors	Regressand	
	Incisor bite force $r$	Molar bite force $r$
No variable		
1 Incisor bite force	—	0.81***
2 Molar bite force	0.81***	—
3 Body height	0.41*	0.53**
4 Wrist width	0.04	0.06
5 Body weight	0.22	0.35
6 pg'—ar	0.48**	0.55**
7 pg'—tgo	0.47*	0.52**
8 ar—tgo	0.40*	0.45*
9 id"—gn	0.25	0.21
10 n—pr"	0.003	—0.12
11 sp'—pr'	—0.17	—0.35
12 pr'—pm	0.04	0.18
13 n—s	0.33	0.25
14 n—gn	0.17	0.10
15 sp'—gn	0.06	—0.09
16 s—tgo	0.46*	0.42*
17 pm—pm'	0.33	0.34
18 NSL/ML	—0.39*	—0.43*
19 NL/ML	—0.30	—0.47**
20 ML/RL	—0.39*	—0.42*
21 s—n—ss	—0.02	—0.21
22 ss—n—sm	—0.31	—0.31
23 s—n—pg	0.37*	0.29
24 s—n—sm	0.30	0.10
25 n—s—ar	—0.18	0.06
26 s—ar—tgo	0.25	0.09
27 Overjet	—0.05	—0.13
28 Overbite	0.10	0.10
29 Incisor splint thickness	—0.04	0.01
30 Max. opening	—0.07	0.08
31 Lateral movement left	0.09	0.06
32 Lateral movement right	0.03	0.004
33 Protrusion	0.04	0.02

\*  $p < 0.05$ ; \*\*  $p < 0.01$ ; \*\*\*  $p < 0.001$

residual standard deviation was 4.6 (eq. no 1). 56 % of the variations in *molar bite force* could be explained by the

Table III *Multiple regression equations for different sets of regressors with incisor bite force (IB) or molar bite force (MB) as regressand*

Sets of regressors	Equations for bite force no	S.D. <sub>e</sub>	R <sup>2</sup>
Cephalometric variables	1 IB = 0.47* mandibular base length (pg'—ar) — 0.38** gonion angle (ML/RL) + 0.76* anterior cranial base length (n—s) — 31.8	4.6	0.49
	2 MB = 1.12*** mandibular base length (pg'—ar) — 0.59** gonion angle (ML/RL) + 0.90* maxillary body length (pr'—pm) — 57.6	6.6	0.56
Variables representing body build	3 IB = 0.48* body height — 48.5	5.6	0.17
	4 MB = 0.95** body height — 108	8.2	0.27
Cephalometric and body build variables simultaneously considered	5 As above, eq no 1		
	6 MB = 0.84** mandibular base length (pg'—ar) — 0.53*** gonion angle (ML/RL) + 1.11** maxillary body length (pr'—pm) + 0.65** body height — 150	5.9	0.67

\*  $p < 0.05$  \*\*  $p < 0.01$ ; \*\*\*  $p < 0.001$ ;

Asterisks indicate level of statistical significance for the regression coefficients. Residual standard deviation (S.D.<sub>e</sub>), the square of the multiple correlation coefficient, R<sup>2</sup>.

- variations in the mandibular base length, the gonion angle and the length of the maxillary body. The residual standard deviation was 6.6 (eq. no 2).
- 2) When testing the variables representing body build, only the coefficients for body height gave significant values. According to the multiple correlation coefficients, 17 % of the variation in *incisor bite force* and 27 % of the variation in *molar bite force* could be explained by the variation in body height (eq. no 3 and 4).
- 3) No significant influence on the bite force of overjet, overbite and splint thickness or of variables representing the range of maximal mandibular movements was found.
- 4) When the body build and cephalometric variables were simultaneously considered, no significant influence of

body build variables on the *incisor bite force* was found. Only the cephalometric variables had any explanatory value (eq. no 5). As regards *molar bite force*, however, body height had a significant value. 67 % of the variation in molar bite force could be predicted by the mandibular base length, the gonion angle, the length of the maxillary body and the body height. The residual standard deviation was 5.9 (eq. no 6).

#### DISCUSSION

Dimensions within the facial skeleton are associated with the length of the extremities (Lindegård, 1953). Consequently the importance for the variation of bite force of some factors representing body build were tested in the analyses along with the

cephalometric variables. Variations in the position of the mandible during biting influence the bite force (*Boos*, 1940; *Leff*, 1966) and the activity of masticatory muscles (*Garret, Angelone & Allen*, 1964; *Møller*, 1966). The effect on maximum bite force of variations in the position of the mandible due to splint thickness, overbite and overjet was therefore also taken into consideration.

The mean value for incisor bite force was in good agreement with that for a similar female age group investigated with the same technique (*Ringqvist & Ringqvist*, in preparation). Incisor as well as molar bite force were somewhat higher than the values found by *Linderholm & Wennström* (1970) and can probably be ascribed to an effect of the splints used in the present study.

Among the cephalometric variables investigated by means of simple linear correlation, the size and inclination of the mandible were most strongly correlated to bite force. The relationships found between bite force and shape and position of the mandible corresponded well with the findings of *Møller* (1966) that the muscle activity during maximal bite is positively correlated to mandibular prognathism, anterior inclination of the mandible and a small gonion angle. The association between a small gonion angle and a high activity of the masticatory muscles during chewing has earlier been observed by *Ahlgren* (1966).

There were no significant relationships between bite force and maximal mandibular movements. In healthy individuals bite force and mobility of the mandible thus seem to be functions independent of each other. Nor were there any significant relationships analogous to those found by *Boos* (1940), *Garret et al.* (1964) and *Leff* (1966) between bite force and variables

influencing the position of the mandible. The variations in these factors may have been too small to give a significant explanatory value for the variation in bite force.

When the body build variables were considered, height was positively correlated to bite force. Body height was also systematically associated with some distances within the facial skeleton (var. 6, 7, 14 and 16), all of which probably constitute measures of a length factor. The association between body height and bite force was not in agreement with observations by *Linderholm & Wennström* (1970), a discrepancy which may be due to a sex difference, as their correlation analyses were made on a male series.

The strong systematic correlation between bite force and the size of the mandible may be an expression of a positive correlation between the size of a bone and the size of its muscles. The combination of a long mandibular base and a small gonion angle together with another measure of size (the length of the anterior cranial base or the length of the maxillary body) gave a high explanatory value with respect to bite force. From studies of patients with mandibular prognathism (*Ringqvist*, in preparation) it is suggested, however, that the relationships demonstrated are valid only when dental and/or jaw relations are within normal limits. It is not expected that the relationships found are applicable to subjects with severe malocclusion and large discrepancies in the size of the jaws.

#### REFERENCES

- Agerberg, G.* 1971. Underkåkens rörelseförmåga hos barn och vuxna. Svensk Tandläk.-T. 64, 75—76  
*Ahlgren, J.* 1966. Mechanism of mastication. Acta Odont. Scand. 24, Suppl. 44

- Asmussen, E. & Heebøll-Nielsen, K.* 1961. Isometric muscle strength of adult men and women. Communications from the Testing and Observation Institute of the Danish National Association for Infantile Paralysis. No 11
- Björk, A. & Solow, B.* 1962. Measurements on radiographs. *J. Dent. Res.* 41, 672—683
- Boos, R. H.* 1940. Intermaxillary relation established by biting power. *J. Amer. Dent. Ass.* 27, 1192—1199
- Brawley, R. E. & Sedwick, H. J.* 1940. Studies concerning the oral cavity and saliva. Biting pressure. Measurements of biting pressure in children. *Amer. J. Orthodont. & Oral Surg.* 26, 41—46
- Draper, N. R. & Smith, H.* 1967. *Applied regression analysis.* J. Wiley & Son Inc., New York.
- Garret, F. A., Angelone, L. & Allen, W. I.* 1964. The effect of bite opening, bite pressure and malocclusion on the electrical response of the masseter muscles. *Amer. J. Orth.* 50, 435—444
- Ingervall, B.* 1970. Range of movement of mandible in children. *Scand. J. Dent. Res.* 78, 311—322
- Ingervall, B.* 1971. Variation of the range of movement of the mandible in relation to facial morphology in young adults. *Scand. J. Dent. Res.* 79, 133—140
- Jenkins, G. N.* 1966. *The physiology of the mouth.* Blackwell Scientific Publications, Oxford, pp. 422—426
- Leff, A.* 1966. Gnathodynamics of four mandibular positions. *J. Prosth. Dent.* 16, 844—847
- Lindegård, B.* 1953. Variations in human body-build. *Acta Psychiat. et Neurolog. Suppl.* 86
- Linderholm, H. & Wennström, A.* 1970. Isometric bite force and its relation to general muscle force and body build. *Acta Odont. Scand.* 28, 679—689
- Linderholm, H., Lindqvist, B., Ringqvist, M. & Wennström, A.* 1971. Isometric bite force in children and its relation to body build and general muscle force. *Acta Odont. Scand.* 29, 563—568
- Lundström, A.* 1948. *Tooth size and occlusion in twins.* S. Karger, Basel and New York, p. 52
- Møller, E.* 1966. The chewing apparatus. *Acta Physiol. Scand.* 69, Suppl. 280
- Ringqvist, I. & Ringqvist, M.* Isometric bite force in adults of different ages and its relation to other craniofacial muscle force. In preparation
- Ringqvist, M.* Fibre sizes of human masseter muscle in relation to bite force. In preparation
- Ringqvist, T.* 1966. The ventilatory capacity in healthy subjects. *Scand. J. Clin. Lab. Invest. Suppl.* 88
- Schwartz, L. & Chayes, C.* 1969. *Facial pain and mandibular Dysfunction.* W. B. Saunders Company, Philadelphia
- Snedecor, G. W.* 1959. *Statistical methods.* The Iowa State College Press. Amer. Iowa. U.S.A.
- Solow, B.* 1966. The pattern of craniofacial associations. *Acta Odont. Scand.* 24, Suppl. 46
- Strenger, F.* 1949. *Biting force in man.* Stockholm