# Maximal bite force and its association with signs and symptoms of craniomandibular disorders in young Finnish non-patients

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Maximal bite force values and subjective symptoms and clinical signs of craniomandibular disorders (CMD) were recorded for a non-patient sample of 129 young adults, 56 men and 73 women. The signs and symptoms of CMD were classified on the basis of Helkimo's clinical dysfunction index. The two genders reported equally frequently subjective symptoms of CMD, but women had significantly more severe clinical signs of CMD than did men. Mean maximal bite force values for men were 909 N (SD, 177) in the molar region and 382 N (SD, 133) in the incisal region and thus significantly higher than corresponding figures for women, 777 N (SD, 168) in the molar, 325 N (SD, 116) in the incisal region, suggesting that separate evaluation of the genders would be advisable in future studies involving bite force assessments. Neither subjective symptoms nor clinical signs of CMD correlated significantly with maximal bite force values. The bite force values measured were in line with theoretical calculations. □ *Bite force; mandible; temporomandibular disorders*

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The maximal human bite force values have been estimated with mathematical models based on cross-sectional areas and estimated intrinsic strength of jaw closing muscles and skull shape. The estimated maximal bite force values have varied in the molar region from 753 N to 1030 N and in the incisal region from 687 to 743 N (1–3). However, the measured maximal bite force values have in general been notably smaller (4). We have studied bite forces with a new bite force recorder equipped with a unilateral 14-mm-thick housing for the sensory element. Special attention was paid to bite comfort, to reduce the subjects' fear of dental damage and to deliver the force to several teeth. The dental students selected in that study were healthy and free of craniomandibular disorders (CMD). Indeed, the recorded maximal bite forces for both genders were greater than those previously reported (5). In our following study concerning endurance of masticatory muscles several subjects preferred a thinner housing (10 mm) compared with the 14-mm-thick housing (6).

Patients with CMD have been reported to have lower maximal bite force values than healthy subjects (7–9), and the weakness of masticatory muscles has been considered to be a factor predisposing for CMD (10). An increase in bite force up to 'normal' levels has been reported to follow successful treatment of CMD (8), but there are also results contradictory to this (11). However, maximal bite force values have not always been found to be lower for CMD patients than for healthy controls (12, 13). The association between maximal bite force values and the presence of CMD has not been studied in an unselected non-patient population.

The purpose of this study was to measure maximal bite force values in molar and incisal regions for a large group of young Finnish adults, using the new bite force recorder equipped with a 10-mm-thick housing. An additional aim was to ascertain whether, with regard to maximal bite force, there is any difference between subjects with and without signs and symptoms of CMD and to study the possible association between gender or body size and maximal bite force.

## Materials and methods

The 129 subjects were included from among those ($n$ = 137) participating in a longitudinal study of dental development and oral health at the Department of Pedodontics and Orthodontics, University of Helsinki, Finland (14). Three subjects were unwilling to participate in bite force measurements owing to fear of dental damage, and two were undergoing active orthodontic treatment and had sore teeth. Three subjects with multiple enamel fractures and/or severe erosion in the incisal teeth were prohibited by the examiner from biting with the incisors, because of evident risk of dental damage. With these eight subjects excluded, those participating in this study comprised 56 men and 73 women. Before the examinations the subjects gave their informed consent in accordance with the Helsinki Declaration of 1975. For both genders mean age was 23

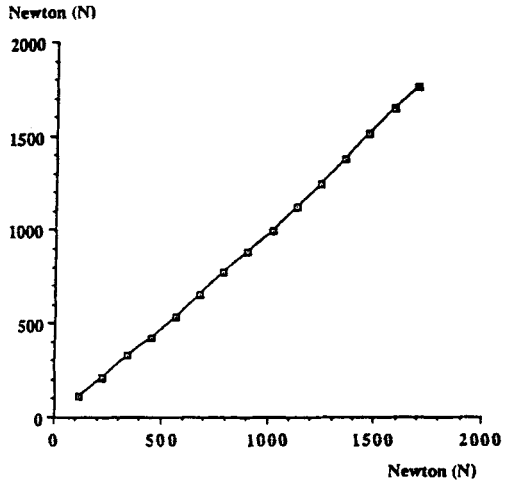


Fig. 1. Calibration curve. X-axis shows force used for calibration test, and y-axis reading on display of the bite force recorder. Each value is mean of 10 measurements.

years (range, 20–25 years). The mean height and weight for men were 182 cm (range, 163–196 cm) and 76 kg (range, 60–119 kg). The corresponding values for women were 167 cm (range, 151–183 cm) and 59 kg (range, 45–85 kg). All subjects had continuous dental arches with at least two pairs of occluding molars bilaterally. After the subjects had answered a questionnaire concerning subjective symptoms of CMD, they were clinically examined by an experienced professional (author M. Könönen), using routine stomatognathic methods (15, 16). Subjects were classified on the basis of Helkimo's clinical dysfunction index ($D_i$) (17).

The bite force recorder has previously been described in detail (5). The metallic housing of the bite force sensor was 10-thick and covered on both sides with 2-mm-thick rubber plates mounted with double-sided adhesive tape. To prevent moisture from reaching the piezoelectric sensory unit, the housing was covered with a latex finger cot. The 'bite-comfortable' design of the housing/sensor system delivers bite force to a large supportive tissue area. The calibration curve for the 10-mm housing is shown in Fig. 1.

Before maximal bite force trials, each subject was asked to bite the housing without any measurements being made, so as to become familiar with the equipment. Each subject made three attempts in each region (right molar, left molar, and incisal region) in random order, to bite as hard as possible. The subjects were advised to increase their bite force steadily in a few seconds to maximum and then release (6). Each subject was allowed a 1-min recovery between these attempts. After all recordings the highest values (the highest peak value of three bites) were registered for each region for maximal bite force analysis. The subjects were then asked what had been the major factor limiting their biting. The following alternatives were given: pain in teeth or in their supportive structures, pain in the muscles, pain in the temporomandibular joint (TMJ) area, or lack of greater muscular strength.

Table 1. Maximal bite force-limiting factors in men ($n = 56$) and in women ($n = 73$) in molar and incisal regions

| | Male | | Female | |
|---|---|---|---|---|
| Limiting factor | Molar, % | Incisal, % | Molar, % | Incisal, % |
| Pain in muscles | 9 | 0 | 6 | 0 |
| Pain in TMJ area* | 0 | 0 | 6 | 1 |
| Pain in teeth or in supportive structures | 4 | 75 | 10 | 89 |
| Lack of greater muscular strength | 88 | 25 | 80 | 10 |

* TMJ = temporomandibular joint.

Statistical analysis of differences in maximal and averaged bite force between men and women was performed with the $t$ test. To test whether $D_i$ or number of palpation-tender spots are associated with maximal bite force, ANOVA was used. Statistical analysis with regard to differences in maximal bite force values between subjects with CMD ($D_i$II and $D_i$III) and those practically CMD-free ($D_i$0 and $D_i$I) was done with the $t$ test. Similarly, possible association of each sign or symptom of CMD with maximal bite force was tested against maximal bite force values of subjects without this particular sign or symptom. Male and female subgroups are tested separately. The chi-square test was used to test gender differences in signs and symptoms of CMD. The association of maximal bite force with body size (height and weight) was studied using Pearson's product moment correlation coefficient. The level of statistical significance is given when $P \leq 0.05$.

## Results

The mean maximal bite force of men was 918 N (SD, 192 N) in the right and 900 N (SD, 173 N) in the left molar region. The corresponding values for women were 774 N (SD, 166 N) and 780 N (SD, 178 N). The averaged maximal bite force values in the molar region were greater for men (909 N; SD, 177 N) than for women (777 N; SD, 168 N) ($P = 0.0001$). The mean maximal incision force for men was 382 N (SD, 133 N) and for women 325 N (SD, 116 N) ($P \leq 0.01$). The averaged mean values of all three measurements in the molar region was 847 N (SD, 177 N) for men and 723 N (SD, 165 N) for women ($P = 0.0001$). In the incisal region averaged values of all three measurements were 337 N (SD, 129 N) for men and 282 N (SD, 107 N) for women ($P \leq 0.01$). Table 1 shows the reported maximal

Table 2. Percentage distribution of subjective symptoms in men ($n$ = 56) and women ($n$ = 73)

| Symptom | Men (%) | Women (%) | $P$ |
|---|---|---|---|
| Headache more than once a week | 5 | 10 | NS |
| Sounds from TMJ* | 27 | 33 | NS |
| Cannot open mouth sufficiently | 7 | 10 | NS |
| Difficulties when opening mouth wide | 5 | 6 | NS |
| Facial pain | 4 | 4 | NS |
| Tiredness of jaws | 9 | 7 | NS |
| Forceful trauma to jaws | 13 | 11 | NS |
| One or more of the above symptoms | 49 | 39 | NS |

* TMJ = temporomandibular joints.

Table 3. Percentage distribution of clinical signs of craniomandibular disorders in men ($n$ = 56) and women ($n$ = 73)

| Clinical findings* | Men, % | Women, % | $P$ |
|---|---|---|---|
| Tenderness to palpation | | | |
| Masticatory muscles | 20 | 36 | 0.05 |
| TMJ laterally | 5 | 14 | NS |
| TMJ dorsally | 0 | 0 | NS |
| TMJ clicking | 34 | 32 | NS |
| Painful mandibular movements | 5 | 7 | NS |

* TMJ = temporomandibular joint.

bite force-limiting factors. In the molar region main bite force-limiting factor was lack of more muscular strength, and in the incisal region pain in teeth or in their supportive structures.

Both genders experienced almost equally frequent subjective symptoms of CMD (Table 2). Men and women had equally frequent clinical signs, but women had tenderness to palpation of masticatory muscles more often ($P \leq 0.05$) (Table 3). Women had significantly higher Helkimo's $D_i$ values than men ($P \leq 0.05$). None of the subjective symptoms or clinical signs were significantly associated with maximal bite force either in men or in women. Table 4 shows maximal bite force values for men and women on the basis of Helkimo's clinical dysfunction index groups. No significant association was found between maximal bite force and Helkimo's clinical dysfunction index either in men or in women. Neither weight nor height correlated with maximal molar or incisal bite force either in men or in women.

## Discussion

Mean maximal bite forces measured in the present study were higher than those recorded in our previous study for young healthy adult of comparable age (5). The average bite force values of all three measurements were in line with the maximal values, indicating good reproducibility of the method. In the molar region the great majority of subjects were able to exert their maximal muscular potential, indicated by the subjective bite force-limiting factors. In accordance with earlier studies, the difference in maximal bite force values between men and women when biting in the molar region was highly significant (5, 6, 8, 18, 19) and is explained by men's greater muscular potential, even if the size differences of muscles are taken into account (20). The housing used in this study was similar to that in the previous study (5), except for it thickness, which was 10 mm in the present study and 14 mm in the previous one. The interocclusal separation of 10 mm has been found suitable for maximal bite force production in electromyographic (EMG) studies (21, 22). The difference in the maximal incisal bite force values between genders also achieved statistical significance, as might have been assumed on the basis of previous findings (5, 23).

As evidenced by theoretical calculations (1–3), maximal incisal bite force is reduced by biomechanical factors as compared with maximal molar bite force. The present study confirms the earlier finding that maximal incisal bite force is mainly limited by negative feedback control from the tooth-supporting structures (5, 24, 25), and therefore the present method does not record the maximal muscular potential in the incisal region. Nine of every 10 women and 3 of every 4 men reported pain in their teeth or in tooth-supporting structures as the major bite force-limiting factor in the incisal region. It must be emphasized that the biting loaded only the central incisors in the maxilla and their occluding incisors in the mandible. To record the actual muscular potential in the front tooth region, the load of biting must be delivered to a larger periodontal ligament area (25). In the molar region 'lack of more muscular strength' was the dominant bite force-limiting factor. This indicates sufficient delivery of bite force on teeth, and thus the subjects were able to use their full bite strength.

Table 4. Distribution of men and women on the basis of Helkimo's clinical dysfunction index ($D_i$) ($P \leq 0.05$) and mean maximal bite force values in newtons (N) and standard deviations for each $D_i$ group

| | Male | | | Female | | |
|---|---|---|---|---|---|---|
| $D_i$ | $n$ | Molar, N (SD) | Incisal, N (SD) | $n$ | Molar, N (SD) | Incisal, N (SD) |
| $D_i0$ | 27 | 897 (155) | 362 (119) | 21 | 750 (119) | 337 (83) |
| $D_iI$ | 26 | 929 (200) | 401 (149) | 36 | 788 (169) | 328 (129) |
| $D_iII$ | 3 | 841 (187) | 396 (120) | 14 | 745 (186) | 276 (110) |
| $D_iIII$ | 0 | – | – | 2 | 1077 (302) | 483 (57) |

The maximal bite force evidently depends on factors more complex than body size, such as the cross-sectional area of masticatory muscles and jaw biomechanics (26, 27), and thus no significant association between maximal bite force and body size was found.

Confirming earlier studies, women more often than men showed clinical signs of CMD (28–30) and had lower jaw-closing muscle capacity (5, 6, 8, 18, 19). In patient groups with myofascial pain dysfunction or TMJ osteoarthrosis or internal derangement, lower maximal bite force values and shorter endurance of jaw-closing muscles are clearly demonstrated (31–34). However, in the present study no significant correlation was detected between maximal peak bite force and Helkimo's index or between any of the reported symptoms or recorded signs of CMD either in men or in women. Reported soreness of the masticatory muscles when palpating was the most important variable classifying the subjects on the basis of Helkimo's index. It has been shown in experimental exercise studies, however, that soreness itself does not necessarily affect the strength of human skeletal muscles (35). The wide variety of normal bite force evidently covers partly the possible effects of CMD on maximal bite force. Furthermore, similar signs and symptoms of CMD can be found in subjects with different etiologies, confusing the association between maximal bite force and CMD; in this study the two women with $D_iIII$ had extremely strong but sore jaw-closing musculature, probably caused by bruxism. In addition, it must be emphasized that none of the subjects was seeking treatment for CMD, and most of the subjects had mild signs of CMD ($D_iI$).

The maximal bite force values measured in this study are the highest measured for today's Western population and are in line with theoretical calculations for maximal human bite force (1–3). A significant difference in maximal bite force values between genders in both molar and incisal regions was clearly demonstrated, suggesting that separate evaluation of genders would be advisable in future studies involving bite force assessments.

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