

Keywords

Biting force  
Masticatory muscle  
Muscle contraction  
Temporomandibular joint

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## VERTICAL ISOMETRIC MUSCLE FORCES OF THE MANDIBLE

### A COMPARATIVE STUDY OF SUBJECTS WITH AND WITHOUT MANIFEST MANDIBULAR PAIN DYSFUNCTION SYNDROME

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The aim of the investigation was to study isometric biting forces at 'maximal' as well as at submaximal levels as defined in subjective terms. Special attention was paid to differences between subjects with and without manifest mandibular pain dysfunction syndrome (MPD). Thirty-one female subjects with manifest MPD constituted the patient group and 30 healthy females the control group. The reliability of the measurements was tested and the results obtained in both groups indicated that the discriminating capacity was not affected by the disorder. Except for the lowest force level (approximating the absolute threshold), substantial force differences between the groups were obtained. These differences increased with the force levels, and the patients generally produced only one-half to two-thirds of the forces produced by the control subjects. No significant differences were found between forces produced on the right and left sides respectively in the control group, nor were such differences found in the patient group between forces produced on the disordered or on the non-disordered side. Reasons for this were considered, and a comparison between the vertical and the horizontal forces of the mandible was made and discussed.

Studies of biting forces generally have been performed in close bite near intercuspal position (*i.e.*, approx. in the muscular position) either by placing measuring devices between the teeth of the upper and lower jaw or by mounting transducers in single crowns, bridges or removable dentures (*e.g.*, Black, 1895; Eckermann, 1911; Haber, 1927 a, b; Howell & Manly, 1948; Anderson, 1953; Uhlig, 1953; Eichner, 1963; Nyquist & Öwall, 1968; Linderholm & Wennström, 1970; Dette & *al.*, 1971).

The relation between biting force and general muscle force was also studied in the above mentioned paper by Linderholm and Wennström (1970). They found that the maximal biting force in adults did not, or only slightly, covariate with the force of muscles involved in *e.g.*, flexion of trunk

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Received for publication, May 2, 1972.

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and neck, elbow flexion and hand grip, or with anthropometric data such as height, weight, width of the wrist (skeletal dimension). Nor was there any statistically significant difference in bite force between adult males and females, though there was a statistically highly significant positive correlation between general muscle force and skeletal dimensions.

Most of the above-mentioned authors have been aware of certain distinct disadvantages in the maximal level assessment methods. Generally their discussion has centered around the detrimental effect of local, dental factors as carious, 'brittle' teeth as well as pain sensations from periapical or marginal inflammations on the performance capacity of the subjects. Thus *Müller* (1928) made a distinction between 'Kaudruck' (biting force) and 'Zahnschmerzhaftigkeitsdruck', *i.e.*, bite pressure hard enough to produce pain in the teeth and/or the periodontium. The first attempt to evade the disadvantages inherent in the maximal level methods, was made by *Borg* and *Wennström*, who presented a method of measuring biting forces on submaximal levels utilizing a psychophysical approach (*Borg & Wennström*, 1962 a, b, c, 1967).

Only sparse information is available concerning the relation between mandibular forces produced in different directions. In an investigation performed in parallel with the present one *Marklund* and *Molin* (1972), made a study of voluntary isometric muscle forces acting in protrusion, retrusion, and laterotrusion of the mandible. The principal results are summarized in Table I.

The aim of the present investigation was to study levels, variations, intra-, and intercorrelations of voluntary isometric biting forces at maximal as well as at submaximal intensities as defined in subjective terms, and to study correlations between these forces and corresponding forces produced in protrusion, retrusion and laterotrusion. Special attention was paid to differences between subjects with and without manifest mandibular pain dysfunction syndrome (MPD).

#### MATERIAL AND METHOD

*Subjects.* The experimental group consisted of the same 31 female patients from the Department of Oral and Jaw Diseases, Karolinska Sjukhuset, Stockholm, who had taken part in the study of the horizontal mandibular forces (*Marklund & Molin*, 1972). Their age range was 16–45 with a mean of 18.3 years. All of them had manifest mandibular pain dysfunction syndrome (MPD), (*Molin*, 1973a).

Table I.

Means ( $\bar{x}$ ), and standard deviations (S) for protrusion, retrusion, and laterotrusion to the right (R) and to the left (L) sides for the control group given in kp. For the patient group are values for laterotrusion to the disordered (DO) and to the nondisordered (NDO) sides given, skewness (s),  $p \leq .05$

Variable	Init.		S		C		A		L		E		L		E		V		E		L	
	max. meas		1		2		3		4		5											
	I	II	I	II	I	II	I	II	I	II	I	II	I	II	I	II	I	II	I	II	I	II
<i>Controls</i>																						
Protrusion	$\bar{x}$	5.5	6.0	.5 <sup>s</sup>	.7 <sup>s</sup>	1.0 <sup>s</sup>	1.0	1.4 <sup>s</sup>	1.7 <sup>s</sup>	3.4	3.4	5.4	6.1									
	S	(3.0)	(3.1)	(.6)	(1.3)	(1.1)	(.8)	(1.1)	(1.5)	(2.5)	(2.1)	(2.8)	(2.6)									
Retrusion	$\bar{x}$	2.9	3.3	.5	.7	.8	.9	1.4	1.4	2.3	2.4	3.6	4.0									
	S	(1.4)	(1.3)	(.6)	(.5)	(.7)	(.7)	(1.2)	(1.1)	(1.7)	(1.4)	(1.6)	(2.0)									
Lat. R	$\bar{x}$	2.9	3.2	.4 <sup>s</sup>	.5	.7	.9	1.1	1.3	1.9 <sup>s</sup>	2.1	3.1	3.4									
	S	(1.5)	(1.6)	(.4)	(.3)	(.6)	(.7)	(.6)	(.8)	(1.2)	(1.3)	(1.7)	(1.8)									
Lat. L	$\bar{x}$	3.6	3.7	.4	.5	.7	.8	1.2	1.3	2.1	2.5	4.2	4.3									
	S	(1.9)	(1.9)	(.3)	(.4)	(.5)	(.5)	(.6)	(.8)	(1.1)	(1.6)	(2.1)	(2.3)									
<i>Patients</i>																						
Protrusion	$\bar{x}$	2.7	3.2	.4 <sup>s</sup>	.6 <sup>s</sup>	.6 <sup>s</sup>	.8	.9 <sup>s</sup>	1.0	1.7 <sup>s</sup>	2.0	3.5	3.7									
	S	(1.8)	(2.2)	(.6)	(.6)	(.7)	(.7)	(.7)	(.8)	(.9)	(1.4)	(2.3)	(2.5)									
Retrusion	$\bar{x}$	1.6	2.3	.4	.4	.6	.6	.7	.9	1.1	1.2	1.9	2.3									
	S	(.9)	(2.0)	(.3)	(.3)	(.5)	(.7)	(.5)	(.7)	(.8)	(.9)	(1.8)	(1.7)									
Lat. DO	$\bar{x}$	1.4	1.5	.3	.3	.4	.5 <sup>s</sup>	.7	.8 <sup>s</sup>	1.0	1.2	1.6	1.8									
	S	(.9)	(1.1)	(.3)	(.3)	(.3)	(.5)	(.6)	(.7)	(.8)	(.9)	(1.2)	(1.5)									
Lat. NDO	$\bar{x}$	1.6	1.6	.3 <sup>s</sup>	.4 <sup>s</sup>	.5 <sup>s</sup>	.6 <sup>s</sup>	.7 <sup>s</sup>	.8	.9	1.0	1.6	1.8									
	S	(1.2)	(1.1)	(.3)	(.4)	(.4)	(.5)	(.5)	(.7)	(.6)	(.8)	(1.2)	(1.3)									

The control group consisted of the same 30 healthy females (dental nurses, student dental nurses and student physiotherapists) who also participated in the previous investigation. They were aged 18–28 with a mean age of 22.1 years. The control subjects were paid. None of the subjects had appreciable bite defects or periodontal disease.

*Apparatus.* The biting force transducer was designed according to principles outlined by Linderholm and Wennström (1970). In principle the transducer consisted of two cantilever beams with electrical strain-gauges cemented close to the fixed ends. To improve the comfort of the experimental subjects and to avoid the fear of damaging their teeth during biting, the tips of the beams were covered with small gutta-percha plates.

In a transducer of this kind the strain underneath the strain-gauge is proportional to the bending moment in the beams (bending moment =

biting force  $\times$  distance between the teeth and the centre of the strain-gauges). For this reason the biting forces were always applied to approximately the same spot of the gutta-percha covered plates.

The strain-gauges formed a Wheatstone-bridge connected to a potentiometer-recorder. The relation between the bite force and the recorded information was calibrated by applying known forces to the plates of the transducer. Unloaded the distance between the bite plates was about 4 mm, and loaded with 75 kp this distance was reduced to about 3 mm. The biting force measurements thus have been performed under essentially isometric conditions.

*The rating scale.* To obtain measurements of the physical forces corresponding to different subjectively perceived ones a simple rating scale (category scale) was used (Borg & Wennström, 1967). The categories were numerically and verbally defined in the following way:

- 1 = Very weak (only just perceptible)
- 2 = Weak
- 3 = Neither weak nor strong (optimal)
- 4 = Strong
- 5 = Maximum

*Procedure.* The investigation took place in the same quiet laboratory that previously had been used for the study of the horizontal muscle forces, and was conducted by the same test leader, a female physiotherapist (Marklund & Molin, 1972).

As described in that paper the subject was informed of the purpose of the investigation and given instruction and an opportunity to acquaint herself with the equipment by performing some trials on different biting force levels.

The premolars were chosen as experimental teeth, since the dynamic conditions when closing restrict the selection to molars and premolars, of which only the latter ones were present in all the subjects. Furthermore, the measuring device is easily handled in this region and there produces the least discomfort to the subject. The biting force was exerted with the mandible in the habitual closing path and the teeth about 4 mm below the intercuspal position, this bite-opening depending on the apparatus used.

During the measurements the subject was sitting in an upright position without headrest. The testleader showed a neutral attitude throughout the investigation, and the subject did not gain any feedback concerning her performance.

The subject was instructed to perform close bites in accordance with the rating scale. The scale was placed in front of the subject, and the test leader pointed out the requested biting force category. The subject was asked to bite intermittently for periods of about 3 seconds with 10 seconds rest intervals. To keep the effects of experimental praxis, fatigue and memory errors under control, the order of the biting force levels was rotated at random.

Preceding the rating scale series, measurements of 'maximum' biting force were conducted twice on each side with 30 seconds rest between each attempt.

In the rating scale series the subject produced four bitings at each level on each side, altogether 40 bitings. Only the first two of these four produced on each level were taken into consideration in the statistical analysis. The reason for having the subjects produce so many bitings was the desire to get a similar experimental design as in the study of the horizontal forces (*Marklund & Molin, 1972*).

#### RESULTS

Tables II—IV present means, medians and standard deviations for each group concerning the initial 'maximum' measurements as well as for the forces produced in accordance with the different levels of the rating scale. The mean values are graphically represented in Figs. 1 and 2.

Test- and retest-values (in the following referred to as I-, and II-values) are given for each level, as well as test-retest correlations. Differences of means represent the differences between the groups. These differences were tested for statistical significance by means of Student's t-test, and the various levels of significance are specified. In some instances where skewness appears, reservations must be made for the validity of the t-test.

As may be seen from Tables II—IV and Figs. 1 and 2, the biting forces, *i.e.*, the vertical forces of the mandible, increased as a positively accelerating function with rising values on the rating scale. Test-retest correlations were with a few exceptions generally higher on the high force levels than on the low ones. The II-values were always slightly higher than the I-values, except for the initial 'maximum' measurements in the control group. Values obtained at the initial 'maximum' measurements were consistently lower than 'maximum' (level 5) values obtained in the rating production series.

In the control group (Table II and Fig. 1) there were with a few exceptions, no significant differences between the forces produced on right and left sides respectively, neither in the initial 'maximum' measurements nor on

Table II.

*Bite force. Controls. Bite force on the right (R) and on the left (L) sides; means ( $\bar{x}$ ), medians (Md), and standard deviations (S D) given in kp; test-retest correlations ( $r_{I, II}$ ); differences between R and L described by mean differences ( $M_R - M_L$ ), Student's test (t), and levels of significance (p),  $p < .05 = X$ ;  $p < .01 = XX$ ;  $p < .001 = XXX$ ; skewness (S),  $p \leq .05$*

Force level	x		Md		S		$r_{I, II}$		$M_R - M_L$	t	P	$\frac{M_R + M_L}{2}$
	R	L	R	L	R	L	R	L				
Init. max.												
meas. :I	32.4	31.9	32.0	31.7	11.2	13.1	.92		.5	.42	—	32.2
→ :II	30.9	30.9	29.1	30.8	11.9	13.7			.96	.0	-.03	—
Scale level 1:I	3.3	3.2	3.6	2.6	2.1	2.6	.81		.1	.61	—	3.2
→ 1:II	3.8	2.8	3.6	2.7	2.7	1.7			.72	1.0	2.72	x
→ 2:I	7.3	7.1	7.3	7.1	4.4	5.5	.83		.2	.25	—	7.2
→ 2:II	7.7	6.5	7.7	6.0	4.1	3.9			.88	.7	2.06	x
→ 3:I	13.1	12.0	12.7	11.5	8.4	8.4	.82		1.1	.57	—	12.5
→ 3:II	15.0	13.2	14.1	11.1	8.8	9.0			.75	1.8	1.44	—
→ 4:I	22.0 <sup>a</sup>	21.2	21.8	20.5	11.6	13.1	.80		.8	.72	—	21.6
→ 4:II	24.8	22.9	22.3	18.6	12.7	13.4			.88	1.9	1.09	—
→ 5:I	33.4	33.8	32.9	33.5	12.0	14.3	.95		-.4	-.23	—	33.6
→ 5:II	34.2	35.9	34.4	36.4	12.7	14.2			.96	-1.7	-1.15	—

Table III.

*Bite forces on the disordered (DO), and the nondisordered (NDO) sides; means ( $\bar{x}$ ), medians (Md), and standard deviations (S) given in kp; test-retest correlations ( $r_{I, II}$ ); difference between DO and NDO described by mean differences ( $M_{DO} - M_{NDO}$ ), Student's test (t), and levels of significance (p),  $p \leq .05 = X$ ;  $p \leq .01 = XX$ ;  $p \leq .001 = XXX$ ; skewness (S),  $p \leq .5$*

Force level	x		Md		S		$r_{I, II}$		$M_{DO} - M_{NDO}$	t	P
	DO	NDO	DO	NDO	DO	NDO	DO	NDO			
Init.max.meas. :I	19.1	18.6	18.9	17.3	8.1	9.4	.91		.5	-.32	—
→ :II	19.1	19.0	19.2	17.7	7.8	8.7			.96	.1	-.02
Scale level 1:I	2.1	2.6	2.2	1.9	1.7	2.6	.76		-.5	1.29	—
→ 1:II	2.4	3.0	2.4	2.1	1.8	3.7			.83	-.6	.95
→ 2:I	3.8	4.3	3.3	3.5	2.7	3.9	.80		-.5	1.05	—
→ 2:II	4.2	4.7 <sup>a</sup>	3.2	3.4	3.2	4.4			.90	-.5	.80
→ 3:I	6.2	6.7	6.3	5.0	3.3	5.2	.63		-.5	.55	—
→ 3:II	8.1 <sup>a</sup>	8.4	7.6	7.2	6.1	5.8			.83	-.3	.28
→ 4:I	10.2	12.0	10.0	10.3	5.3	7.5	.76		-1.8	1.40	—
→ 4:II	11.2	12.0	11.2	11.2	5.4	7.0			.91	-.8	.69
→ 5:I	19.5	19.6	19.3	19.0	9.4	9.0	.97		-.1	.06	—
→ 5:II	20.5	20.2	19.8	20.2	9.4	9.5			.98	.3	-.16

Table IV.

Mean values ( $\bar{x}$ ) for bite force on disordered (DO) and on nondisordered (NDO) in the patient group, and mean values of mean values for bite force on the right and the left sides ( $M_{R, L}$ ) in the control group; differences between the groups are described by mean differences ( $M_{R, L}-DO$  and  $M_{R, L}-NDO$ ) respectively; Student's test ( $t$ ), and levels of significance ( $p$ ),  $p \leq .05 = X$ ;  $p \leq .01 = XX$ ;  $p \leq .001 = XXX$ ; skewness ( $S$ ),  $p \leq .05$

Force level	$\bar{x}$		$M_{R, L}-$		t	P	$\bar{x}$		$M_{R, L}-$		t	P
	DO	$M_{R, L}$	DO				NDO	$M_{R, L}$	NDO			
Init. max. meas.	:I	19.1	32.2	13.1	4.98	xxx	18.6	32.2	13.6	4.91	xxx	
	:II	19.1	30.9	11.8	4.39	xxx	19.0	30.9	11.9	4.28	xxx	
Scale level	1:I	2.1	3.2	1.1	2.13	x	2.6	3.2	.6	.95	—	
→	1:II	2.4	3.3	.9	1.71	—	3.0	3.3	.3	.38	—	
→	2:I	3.8	7.2	3.4	3.37	xx	4.3	7.2	2.9	2.56	xx	
→	2:II	4.2	7.1	2.9	3.13	xx	4.7 <sup>s</sup>	7.1	2.4	2.23	x	
→	3:I	6.2	12.5	6.3	3.92	xxx	6.7	12.5	5.8	3.28	xx	
→	3:II	8.1 <sup>s</sup>	14.1	6.0	3.08	xx	8.4	14.1	5.7	2.97	xx	
→	4:I	10.2	21.6	11.4	4.73	xxx	12.0	21.6	9.6	3.69	xx	
→	4:II	11.2	23.8	12.6	4.97	xxx	12.0	23.8	11.8	4.43	xxx	
→	5:I	19.5	33.6	14.1	4.87	xxx	19.6	33.6	14.0	4.90	xxx	
→	5:II	20.5	35.1	14.6	4.94	xxx	20.2	35.1	14.9	5.02	xxx	

the higher levels of the rating scale (levels 4–5). In the patient group this type of comparison was not meaningful, due to the generally unilateral character of their disorder (30 out of 31 in the present patient group).

For that reason a comparison was made between the forces obtained on the disordered and the nondisordered sides (Table III). Only very small differences were thus found. Although the values obtained at levels 1–4 in the rating production series on the nondisordered side were slightly higher than those on the disordered side, three out of four of the 'maximum' values (initial 'maximum' measurements and scale level 5) were higher on the disordered side. No differences, however approached a significant level.

When the patients were compared with the control subjects (Table IV), it can be seen that there were progressively increasing force differences between the groups with rising values on the rating scale. The degree of significance also increased with rising force levels. On level 2 all group differences were significant ( $p \leq .05$ ), and on levels 3–4,  $p \leq .01$ . For level 5 and the initial 'maximum' measurements all the group differences were significant ( $p \leq .001$ ).

On level 1 about the same forces were produced in both groups, while on levels 2–4 the patients produced only about half those produced by the

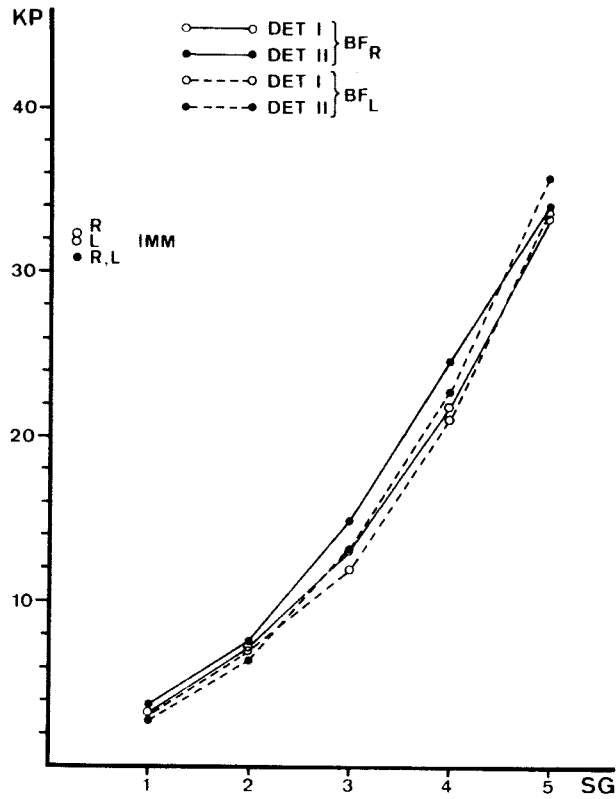


Fig. 1. Means of biting forces on the right (BFR) and on the left side (BFL) in kilopond (KP) produced in accordance with different levels of the rating scale (SG) in the control group. Initial 'maximum' measurements (IMM).

Table V.

*Intercorrelations between biting forces produced on different levels of the rating scale. *I*-values reported. Control group*

Right					Left				
2	.56				2	.78			
3	.30	.70			3	.54	.84		
4	.21	.69	.59		4	.62	.83	.74	
5	.11	.57	.67	.70	5	.28	.61	.63	.75
	1	2	3	4		1	2	3	4

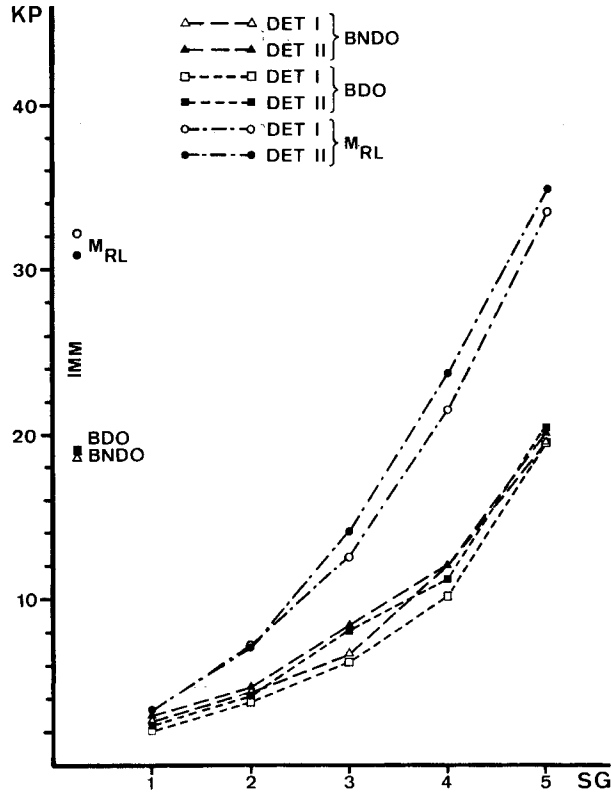


Fig. 2. Means of biting forces in kilopond (KP) on the disordered (BDO) and on the non-disordered side (BNDO) in the patient group, and mean of biting forces on the right and left sides (MRL) in the control group. Initial 'maximum' measurements (IMM).

Table VI.

*Intercorrelations between biting forces produced on different levels of the rating scale. II-values reported. Patient group*

Nondisordered side					Disordered side				
2	.93				2	.75			
3	.72	.85			3	.59	.77		
4	.63	.79	.81		4	.41	.61	.54	
5	.38	.58	.71	.76	5	.29	.57	.59	.79
	1	2	3	4		1	2	3	4

Table VII.

*Correlations between biting forces and forces produced in different horizontal directions on levels 1, 3, and 5 of the rating scale. The table is based on II-values. Protrusion (Prot.), retrusion (Ret.), laterotrusion to the right (LR), and to the left (LL), close bite on the right (BR) and on the left (BL) sides. Control group*

Level 1.					
Retr.	.44				
LR	.24	.50			
LL	.40	.48	.43		
BR	-.12	.40	.19	-.04	
BL	-.16	.43	.44	.13	.68
	Prot.	Retr.	LR	LL	BR
Level 3.					
Retr.	.86				
LR	.27	.40			
LL	.58	.79	.64		
BR	.00	.05	-.17	-.07	
BL	.03	.09	-.06	-.05	.71
	Prot.	Retr.	LR	LL	BR
Level 5.					
Retr.	-.06				
LR	-.06	.40			
LL	.11	.29	.76		
BR	.41	.21	.21	.32	
BL	.23	.28	.17	.23	.82
	Prot.	Retr.	LR	LL	BR

control subjects. The 'maximum' forces (initial 'maximum' measurements and recordings at scale level 5) produced by the patients were all between two-thirds and half of those produced by the control subjects.

Correlations for the biting forces produced on the different levels are presented for the control group in Table V and for the patient group in Table VI. In the latter group the values for right and left sides are, as mentioned above, not valid, and consequently the correlations are based on whether the forces were produced on the disordered or the nondisordered side. They generally were of a moderate or fairly high magnitude, and higher between levels that were close to each other than between more distant ones.

Finally, the correlations between the biting forces and the different horizontal mandibular forces are presented. Tables VII and VIII give these correlations for forces produced at levels 1, 3 and 5 according to the rating

Table VIII.

Correlations between biting forces and forces produced in different horizontal directions on levels 1, 3, and 5 of the rating scale. The table is based on *r*-values. Protrusion (Prot.), retrusion (Ret.), laterotrusion to nondisordered (LNDO), and to disordered (LDO) sides, close bite on the nondisordered (BNDO), and on the disordered (BDO) sides. Patient group

Level 1.					
Retr.	.16				
LNDO	.50	.16			
LDO	.71	.48	-.25		
BNDO	.19	-.06	.03	-.08	
BDO	.49	.11	.24	.18	.50
	Prot.	Retr.	LNDO	LDO	BNDO
Level 3.					
Retr.	.28				
LNDO	.43	.09			
LDO	.57	.22	.55		
BNDO	.06	-.02	.16	-.02	
BDO	.13	.01	.12	-.07	.76
	Prot.	Retr.	LNDO	LDO	BNDO
Level 5.					
Retr.	-.05				
LNDO	.86	-.05			
LDO	.81	-.01	.85		
BNDO	-.09	.36	-.03	-.11	
BDO	-.03	.23	-.13	-.10	.50
	Prot.	Retr.	LNDO	LDO	BNDO

scale. Also here these correlations for the patient group are based on whether they were produced on the disordered or nondisordered side. These correlations were of a moderate or low magnitude.

DISCUSSION

The curves describing the relation between subjective and objective biting forces are similar to those obtained in earlier investigations (*Borg & Wennström, 1962 a, b, c, 1967*). They also accord well with the general shape of the corresponding curves obtained for horizontal mandibular forces by *Marklund and Molin (1972)*. Thus the underlying psychophysical functions will probably also have the same general shape, *i.e.*, a power function with the

exponent approximately = 1. The more theoretical psychophysical aspects fall, however, as previously stated beyond the scope of the present investigation.

The high correlations between I- and II-values indicate both the reliability of the measurements and the subjects' discriminating capacity on the different levels. That these correlations are somewhat lower on low than on high force levels may partly be due to the fact that the measurement errors caused by the apparatus become relatively greater on the low force levels.

The generally slightly higher means and medians for II-values in comparison to those for I-values may be an effect of the subjects' adjustment to the apparatus and the test situation. This will probably also explain the fact that all 'maximum' performance values, with the exception of the initial ones in the control group, are rising up to assessment II on level 5 in the rating production series. The increasing 'maximum' values may also be regarded as an indication that effects of fatigue are negligible.

To a certain extent the values obtained on level 1 in the rating production series, may be considered as 'absolute threshold' values. However, they were assessed only in ascending series, and therefore probably overestimated. Furthermore, the equipment was not designed for absolute threshold measurements, so this problem cannot be further discussed in this context.

The measured 'maximum' force values, *i.e.*, maximal voluntary contractions (MVC), are considerably below those calculated on anatomical bases. They are probably also below values obtainable with a more active attitude on the part of the test leader. Her neutral attitude, however, was intended to keep the motivational conditions as constant as possible.

Concerning the quotient between the 'maximum' voluntary muscle force and the theoretically available muscle force a figure of .65 is given by *Hettinger* (1964). However, as has been pointed out already under the heading Survey of literature, so many complicated factors are involved in the control of biting forces — most of them beyond the scope of this investigation — that the discussion here will be limited to the differences found between the patient group and the control group.

The existing age differences are not considered to be a differentiating factor (*Hettinger*, 1964).

On the lowest scale grade the force difference between the two groups is not a striking one. On all other levels, including the initial 'maximum' measurements, the differences between the groups are impressive, the patients reaching only little more than half the force values produced by the control subjects. This corresponds well with the results obtained for horizontal mandibular forces with the same subject groups (*Marklund &*

*Molin*, 1972). As in this study, the lower forces produced by the patients may be interpreted as a result of the more intense pain that they experienced on their disordered side, as reported towards the testleader during the experimental session.

It would seem that this explanation is contradicted by the fact that no significant differences were found between the forces produced on the disordered and on the nondisordered side. However, due to the bilateral articulation of the mandible, forces exerted on one side will, in all probability, also influence the other side. Furthermore, it is known that the lateral pterygoid muscle acts as a stabilizer of the moving parts (condyle and disc) of the temporomandibular joint. Since it has also been demonstrated that this muscle is increasingly active with increasing bite forces (*Carlsöö*, 1956; *Molin*, 1973c), the pain experienced by the patients may well be explained by the involvement of the disordered muscle.

Regarding the test-retest correlations no considerable group differences were found. Consequently, the discriminating capacity of the patients seems to be unaffected in spite of their manifest MDS.

A good possibility of predicting 'maximum' values on the basis of sub-maximal measurements is indicated by the fairly high correlations between forces produced on the three highest force levels (3, 4 and 5). This may imply certain clinical applications.

From a clinical point of view, however, the maximum biting forces seem to be rather uninteresting, since they hardly ever are used in chewing (e.g., *Tholuck*, 1925; *Anderson*, 1956 a, b; *Eichner*, 1963). Far more important are those forces used in every day life; it is just these forces that can be assumed to correspond well with levels 1—3 on the rating scale, as stated by *Marklund* and *Molin* (1972) concerning the horizontal forces.

When the vertical forces are compared to the corresponding horizontal mandibular forces produced by the same groups (Tables I—III) it can be seen that the vertical forces exceed the horizontal ones substantially. Thus in the 'normal' range, scale levels 1—3 where the biting forces reach values up to 15 kp, the horizontal forces are only about one-tenth thereof.

However, even if these horizontal forces are of a modest magnitude, the role they play in mastication is very important by reducing the occlusal loads required to chew hard and tough food. In this context it may be of interest to mention *Gysi's* experiment (*Uhlig*, 1953) in which he demonstrated that a vertical force of 7 kp was required to cut a hemp string, while 2 kp was enough if a sliding movement of a few mm was made simultaneously.

*Acknowledgements.* To Professor G. Borg and Dr G. Marklund for valuable theoretical discussions in the planning of this study. To Professor H. Brodin for placing the laboratory

and to Assistant Professor A. Wennström for placing the measuring device at my disposal and to Mrs. I. Sandell-Jacobson for acting as test leader. To Professors G. E. Carlsson, B. Hedegård and G. Mårtensson for constructive criticism. The investigation was supported by a research grant from the Karolinska Institutet.

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