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From:
The Institute of Applied Psychology,
University of Stockholm;
the Department of Oral and Jaw Diseases,
the Department of Physical Medicine,
Karolinska Sjukhuset, Stockholm,
and the Department of Prosthetics,
University of Gothenburg, Sweden

HORIZONTAL ISOMETRIC MUSCLE FORCES OF THE MANDIBLE

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

GUSTAF MARKLUND
CARL MOLIN

The aim of the investigation was to study isometric protrusive, retrusive, and laterotrusive mandibular muscle forces produced at »maximum» as well as at submaximum levels as defined in subjective terms (a simple rating scale). Special attention was paid to differences between subjects with and without manifest mandibular pain dysfunction syndrome (MPD).

31 female subjects with manifest MPD constituted the patient group and 30 healthy females the control group.

The mandibular forces were transmitted via an acrylic splint on the mandibular teeth to a transducer and recorded.

A good reliability of the measurements, especially on high levels, was obtained in both groups. This indicates that the discriminating capacity is unaffected by the disorder.

On low force levels, corresponding to those used in every day life, only small group differences in force were found for all directions studied. On »maximum» levels, however, the forces produced by the patients constantly were only about half those produced by the controls. This seems to be an effect of the higher degree of pain experienced by the patients. In the control group »maximum» laterotrusive forces to the left significantly exceeded those to the right.

In contrast to the great number of studies concerning biting forces, rather few investigations have been performed regarding the horizontal mandibular forces, *i.e.* the muscle forces acting in protrusive, retrusive, and laterotrusive directions. The few earlier studies of the horizontal muscle forces have generally dealt with the problem of calculating the maximum level on the basis of anatomico-mechanical analyses (*Carlsöö*, 1956; *Schumacher*, 1961; *Honée*, 1970). A survey of the literature on this subject has not revealed any investigation utilizing direct measurements of these forces.

The main reason why the horizontal mandibular forces have been studied less than the biting forces is probably the fact that the latter have been considered to be of more practical interest to the dental clinician, especially to the prosthodontist (*e.g. Black*, 1895; *Eckermann*,

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1911; *Howell & Manly*, 1948; *Uhlig*, 1953; *Eichner*, 1963). However, the study of the horizontal mandibular forces, seems to be motivated since the muscles acting in these directions, and especially the lateral pterygoid, may be of particular interest in cases of mandibular pain dysfunction syndrome (MPD), (*Vaughan*, 1943, and 1955; *Kruse*, 1962; *Franks*, 1965; *Molin*, 1967; *Vestergård-Christensen*, 1967; *Greene* et al., 1969). This syndrome, also called the temporomandibular joint paindysfunction syndrome, manifests itself by certain symptoms (pain, clicking, subluxation, tenderness and limitation of movement) involving the mandibular joint and its musculature. Although some controversy still exists concerning the etiology and the pathogenesis of this disorder, the part played by the muscles and their response to nervous tension seems to be increasingly accepted (*Schwartz*, 1955, 1959; *Molin & Levi*, 1966; *Laskin*, 1969; *Doms et al.*, 1969; *Agerberg et al.*, 1969; *Carlsson et al.*, 1970; *Thomson*, 1971).

By studying the performance of the horizontally acting mandibular muscles it therefore may be possible to obtain further information about this type of disorder. Besides studying maximum forces, measurements at submaximum levels seem to be informative for this purpose. Furthermore, submaximum levels make assessments of the subject's discriminating capacity possible. It has been demonstrated by *Borg and Wennström* (1962 a, b, c, and 1967) that a psychophysical approach is useful in investigations of bite force. Although psychophysical theory is beyond the scope of this paper, a few brief points will be made: Within most sense modalities the psychophysical function may be described by a power function (*Stevens*, 1957, 1966; *Stevens & Galanter*, 1957; *Ekman*, 1958, 1964). A general expression of the power function is $R = a + c\,(S\text{-}b)^n$, where R is the intensity of the perception, S the stimulus intensity, c a measure constant, a and b indicate the starting point of the curve and n the exponent (*Borg*, 1961, 1962).

Experiments concerning the determination of perceived force (perceived pedal resistance) in short time work on a bicycle ergometer have been performed by *Borg & Dahlström* (1959, and 1960), *Borg* (1962), *Borg, Edström & Marklund* (1970). A positively accelerating function has been obtained with the exponent 1.6. This can be compared with the exponent 1.7 which has been obtained for apparent force of hand grip (*Stevens & Mach*, 1959) and the exponent 1.7 for apparent foot pressure (*Eisler*, 1962).

In their studies *Borg* and *Wennström* (1962 a, b, c) demonstrated the possibility of determining the relation between subjective and objective bite force by means of a psychophysical ratio scaling (fraction) method. A simple rating scale was also used for production of bite force values.

The psychophysical experiments showed that the relation between perceived and physically registered bite force could also be described as a simple power function with a linear relationship between these two factors (*Borg & Wennström*, 1962c). The experiment with the rating scale demonstrated that a positively accelerating function was obtained when physical bite force values were plotted as a function of subjective force values according to the rating scale (*Borg & Wennström*, 1967).

The aim of the present investigation was to study levels, variations, intra-, and intercorrelations of isometric protrusive, retrusive, and laterotrusive mandibular muscle forces produced at maximum as well as at submaximum intensities as defined in subjective terms. Special attention is paid to differences between subjects with and without manifest mandibular pain dysfunction syndrome (MPD).

MATERIAL AND METHOD

Subjects. Thirty-one female patients, aged 16—45 with a mean age of 28.3 years, from the Department of Oral and Jaw Diseases at the Karolinska sjukhuset, Stockholm, constituted the patient group. They all had clinically manifest MPD (*Molin*, 1972b). Thirty healthy female subjects (no history or sign of MPD), aged 18—28 with a mean age of 22.1 years, acted as controls. They included dental nurses, student dental nurses and student physiotherapists who were paid for their participation. Neither the patients nor the controls had any previous experience in this kind of investigation.

Only subjects with fairly normal bite conditions, except for the MPD in the patient group, were chosen since an acrylic splint was to be affixed on the mandibular teeth to connect the mandible with the measuring device.

Apparatus. The measurements of the pro-, re-, and laterotrusive muscle forces were performed on an ordinary otorhinolaryngological examination chair, where the standard head rest was exchanged for a specially designed head frame (Fig. 1).

The head frame formed the base for a force transducer and held the head of the subject steadily during the measurements. Hence the cranial part of the head and the frame acted as one unit in relation to the movable mandible.

A bar connected to an individually produced acrylic splint transmitted the mandibular forces to the transducer. The splint was attached to the teeth in the lower jaw with the help of temporary cement.

In principle the force transducer (Fig. 2) was a cantilever beam with four electrical strain-gauges. The mandibular force caused a bending moment in the beam and the strain-gauges formed a Wheatstone-bridge sensitive to this moment. The electrical signal from the bridge was recorded on an ordinary potentiometer-recorder. The wiring circuit was arranged so that it automatically compensated for forces produced by temperature changes as well as for other parasitic forces.

The relation between the mandibular force and the recorded information was calibrated by applying known forces to the bar between the flexible joint on the transducer and the splint (Fig. 2b). The maximum error of the measuring system was less than $\pm$ 0.1 kp. The flexibility of the frame and the transducer did not influence the force measurements even if it somewhat changed the position of the jaw between the unloaded and the loaded conditions. The position changes were always less than $\pm$ 1 mm as measured from photographs taken during these different conditions. The force measurements thus have been performed under essentially isometric conditions.

The rating scale. A simple rating scale (category scale) was used to obtain measurements of physical forces corresponding to different subjectively perceived ones (*Borg & Wennström*, 1967).

The categories were defined verbally and numerically in the following way:

1 = Very weak (only just perceptible)
2 = Weak

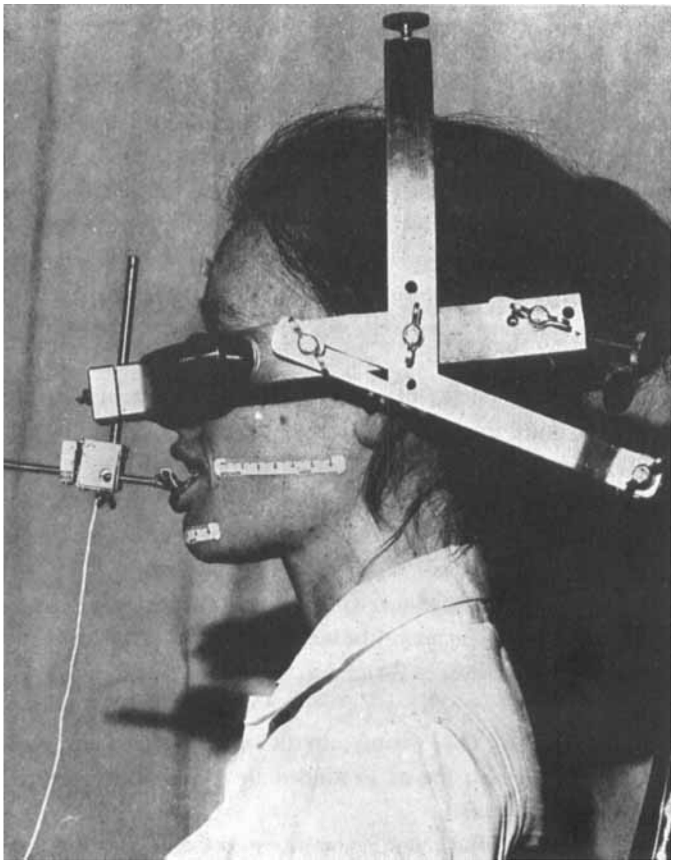
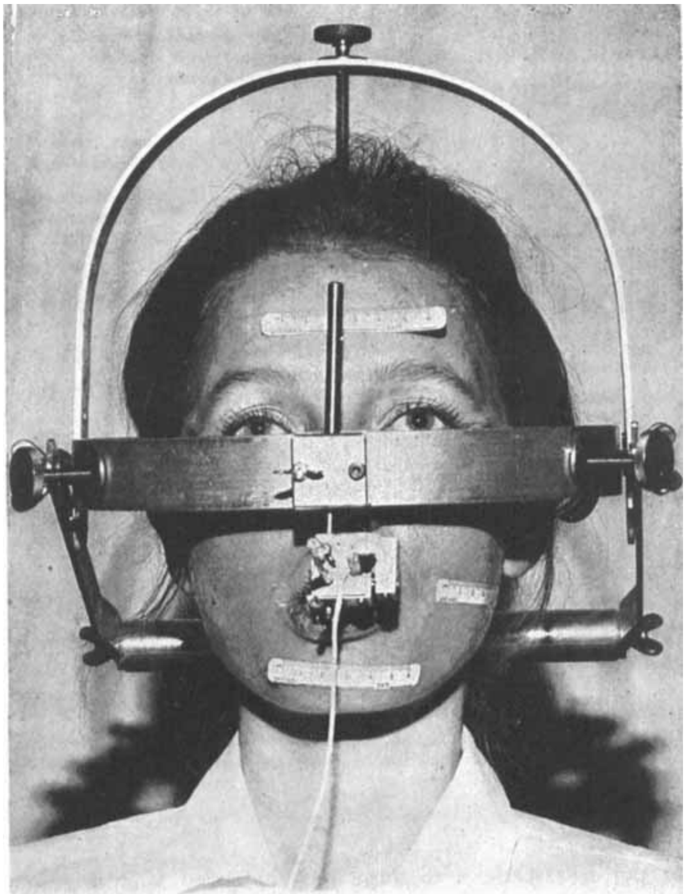


Fig. 1. Subject connected to head frame and transducer.
A, Lateral view: transducer in position for protrusive and retrusive force measurements (see also Fig. 2 B).

3 = Neither weak nor strong
4 = Strong
5 = Maximum

Procedure. The investigation took place in a quiet laboratory belonging to the Department of Physical Medicine at the Karolinska sjukhuset, Stockholm. The same test leader, a female physical therapist instructed and tested all subjects. As far as possible the measurements were obtained in the same part of the day.

Prior to the force measurements each subject was informed about the purpose and the procedure of the investigation. The rating scale and the apparatus to be used were carefully demonstrated.



B, Frontal view: transducer in position for laterotrusive force measurements (see also Fig. 2C).

The subject was then installed in the chair, the splint with the protruding bar was cemented to her mandibular teeth and the head frame was adjusted as tightly as possible without hurting. The bar was connected to the transducer in a position either for protrusive/retrusive or for laterotrusive measurements depending on the rotation schedule (see below). Care was taken to obtain a right angle between the direction of force and the measuring device. Before measurements of laterotrusive forces were performed, the distance from the transducer to the midpoint of the intercondylar axis was estimated *i.e.* the moment arm for the laterotrusive forces. The registered lateral forces were then transformed to values corresponding to a moment arm of 8.0 cm. In this way the forces exerted in the premolar zone were estimat-

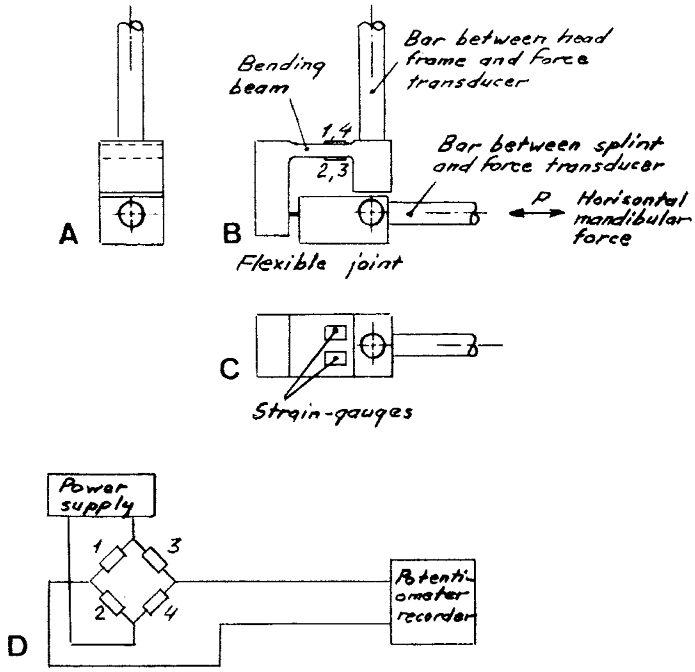


Fig. 2. Schematic of the transducer.
A, Frontal view.
B, Lateral view: position for protrusive and retrusive force measurements.
C, From above: position for laterotrusive force measurements.
D, The bridge circuit.

ed, *i.e.* in the area where bite force was measured later on (see *Molin*, 1972).

In order to acquaint the subject with the equipment and the test conditions, the actual study was preceded by a few trials on submaximum levels.

The subject was then asked to produce the maximum force twice at random for protrusion, retrusion, laterotrusion right and left with a 30 sec. rest period after each measurement. In this way an interval of approx. 2 min. was obtained between the measurements in the same direction. (In the following these measurements are referred to as Initial »maximum» measurements.)

Thereafter the subject was instructed to produce forces in specified directions in accordance with levels pointed out on the rating scale. These forces were produced intermittently for periods of about 3 sec. and at intervals of approx. 20 sec. For each force direction and force level two randomly positioned measurements were recorded (test and retest).

Table I.

Muscle forces in protrusion in patients (P), and controls (C). Means ($\bar{x}$), medians (Md), and standard deviations (SD) given in kp; test-retest correlations ($r_{I,\ II}$); differences between C and P described by mean differences (M_c—M_p), Student's test (t), and levels of significance (p), $p \leq 0.05$ = x; $p \leq 0.01$ = xx; $p \leq 0.001$ = xxx; skewness (s), $p \leq 0.05$

Force level	$\bar{x}$		Md		SD		$r_{I,\ II}$		M_C-M_P	t	p
	P	C	P	C	P	C	P	C			
Init.max.meas.: I	2.7	5.5	2.4	5.0	1.8	3.0	0.93	0.91	2.8	4.51	xxx
» : II	3.2	6.0	2.6	6.2	2.2	3.1			2.8	4.12	xxx
Scale level 1 : I	0.4^s	0.5^s	0.3	0.3	0.6	0.6	0.70	0.92	0.1	0.16	—
» 1 : II	0.6^s	0.7^s	0.4	0.5	0.6	1.3			0.1	0.67	—
» 2 : I	0.6^s	1.0^s	0.5	0.7	0.7	1.1	0.53	0.58	0.4	1.73	—
» 2 : II	0.8	1.0	0.5	0.8	0.7	0.8			0.2	1.22	—
» 3 : I	0.9^s	1.4^s	0.7	1.1	0.7	1.1	0.71	0.78	0.5	1.96	—
» 3 : II	1.0	1.7^s	0.7	1.3	0.8	1.5			0.7	2.22	x
» 4 : I	1.7^s	3.4	1.5	2.7	0.9	2.5	0.50	0.81	1.7	3.63	xxx
» 4 : II	2.0	3.4	1.5	2.9	1.4	2.1			1.4	3.00	xx
» 5 : I	3.5	5.4	3.6	5.8	2.3	2.8	0.94	0.81	2.3	3.58	xxx
» 5 : II	3.7	6.1	3.2	6.0	2.5	2.6			2.4	3.58	xxx

To reduce effects of experimental praxis, fatigue and memory errors the presentation order of the force directions and the categories was rotated at random intra- as well as interindividually.

The test leader showed a neutral attitude during the investigation, and the subject did not gain any feed back concerning her performance.

RESULTS

Tables I—V present means, medians, and standard deviations for each group concerning the initial »maximum» measurements and the forces produced in accordance with the different levels of the rating scale. The mean values are graphically represented in Figs. 3—6.

For each level test- and retest values (in the following referred to as I- and II-values) as well as test-retest correlations are given. Differences between the groups are represented by differences of means, which are tested for statistical significance with the help of Student's t-test. The levels of significance are specified. In those instances, where skewness appears, reservations must be expressed for the validity of the t-test.

Table II.

Muscle forces in retrusion in patients (P) and controls (C). Means ($\bar{x}$), medians (Md), and standard deviations (SD) given in kp; test-retest correlations ($r_{I,\ II}$); differences between C and P described by mean differences (M_c—M_p), Student's test (t), and levels of significance (p), $p \leq 0.05$ = x; $p \leq 0.01$ = xx; $p \leq 0.001$ = xxx; skewness (s), $p \leq 0.05$

Force level	$\bar{x}$		Md		SD		$r_{I,\ II}$		M_c-M_p	t	p
	P	C	P	C	P	C	P	C			
Init.max.meas.: I	1.6	2.9	1.3	2.9	0.9	1.4	0.51	0.80	1.3	4.22	xxx
» : II	2.3^{s}	3.3^{s}	1.6	3.1	2.0	1.3			1.0	2.40	x
Scale level 1 : I	0.4	0.5^{s}	0.3	0.4	0.3	0.6	0.41	0.55	0.1	1.19	—
» 1 : II	0.4	0.7	0.3	0.6	0.3	0.5			0.3	3.23	xx
» 2 : I	0.6	0.8^{s}	0.4	0.6	0.5	0.7	0.59	0.76	0.2	1.13	—
» 2 : II	0.6^{s}	0.9	0.5	0.7	0.7	0.7			0.3	1.58	—
» 3 : I	0.7	1.4^{s}	0.6	1.1	0.5	1.2	0.54	0.88	0.7	3.05	xx
» 3 : II	0.9^{s}	1.4	0.7	1.2	0.7	1.1			0.5	2.54	x
» 4 : I	1.1^{s}	2.3^{s}	0.9	1.9	0.8	1.7	0.77	0.76	1.2	3.60	xxx
» 4 : II	1.2^{s}	2.4	1.1	2.2	0.9	1.4			1.2	3.91	xxx
» 5 : I	1.9^{s}	3.6	1.5	3.5	1.8	1.6	0.85	0.91	1.7	3.82	xxx
» 5 : II	2.3^{s}	4.0	1.5	4.0	1.7	2.0			1.7	3.65	xxx

Table III.

Muscle forces in the controls proup. Laterotrusion to the right (LR) and to the left (LL) sides; means ($\bar{x}$), medians (Md), and standard deviations (SD) given in kp; test-retest correlations ($r_{I,\ II}$); differences between LR and LL described by mean differences (M_{LR}-M_{LL}), Students' test (t), and levels of significance (p), $p \leq 0.05$ = x; $p \leq 0.01$ = vv; $p \leq 0.001$ = xxx; skewness (s), $p \leq 0.05$

Force level	x		Md		SD		$r_{I,\ II}$		M_{LR}-M_{LL}	t	p
	LR	LL	LR	LL	LR	LL	LR	LL			
Init.max.meas.: I	2.9	3.6	2.7	3.0	1.5	1.9	0.82	0.86	—0.7	—2.64	x
» : II	3.2	3.7	2.6	3.3	1.6	1.9			—0.5	—2.26	x
Scale level 1 : I	0.4^{s}	0.4	0.3	0.3	0.4	0.3	0.55	0.59	0.0	0.36	—
» 1 : II	0.5	0.5	0.4	0.4	0.3	0.4			0.0	—0.61	—
» 2 : I	0.7	0.7	0.6	0.6	0.6	0.5	0.56	0.56	0.0	0.47	—
» 2 : II	0.9	0.8	0.7	0.8	0.7	0.5			0.1	0.90	—
» 3 : I	1.1	1.2	1.0	1.1	0.6	0.6	0.69	0.63	—0.1	—0.80	—
» 3 : II	1.3	1.3	1.1	1.2	0.8	0.8			0.0	0.12	—
» 4 : I	1.9^{s}	2.1	1.7	2.0	1.2	1.1	0.78	0.78	—0.2	—1.10	—
» 4 : II	2.1	2.5	1.7	2.1	1.3	1.6			—0.4	—2.46	x
» 5 : I	3.1	4.2	2.6	3.7	1.7	2.1	0.87	0.81	—1.1	—4.81	xxx
» 5 : II	3.4	4.3	3.1	4.4	1.8	2.3			—0.9	—3.62	xx

Table IV.

Muscle forces in the patient group. Laterotrusion to the disorder (LDO), and the nondisorder (LNDO) sides; means ($\bar{x}$), medians (Md), and standard deviations (SD) given in kp; test-retest correlations ($r_{I,\ II}$); difference between LDO and LNDO described by mean differences (M_{LDO}-M_{LNDO}), Student's test (t), and levels of significance (p), $p \leq 0.05$ = x; $p \leq 0.01$ = xx; $p \leq 0.001$ = xxx; skewness (s), $p \leq 0.05$

Force level	$\bar{x}$		Md		SD		$r_{I,\ II}$		M_{LDO}-M_{LNDO}	t	p
	LDO	LNDO	LDO	LNDO	LDO	LNDO	LDO	LNDO			
Init.max.meas.: I	1.4	1.6	1.2	1.3	0.9	1.2	0.90	0.90	—0.2	—1.05	—
» : II	1.5	1.6	1.3	1.3	1.1	1.1			—0.1	—0.56	—
Scale level 1 : I	0.3	0.3^s	0.2	0.2	0.3	0.3	0.73	0.55	0.0	—0.21	—
» 1 : II	0.3	0.4^s	0.3	0.3	0.3	0.4			—0.1	—1.27	—
» 2 : I	0.4	0.5^s	0.3	0.3	0.3	0.4	0.70	0.75	—0.1	—1.00	—
» 2 : II	0.5^s	0.6^s	0.4	0.3	0.5	0.5			—0.1	—0.61	—
» 3 : I	0.7	0.7^s	0.5	0.6	0.6	0.5	0.84	0.62	0.0	—0.38	—
» 3 : II	0.8^s	0.8	0.6	0.6	0.7	0.7			0.0	0.12	—
» 4 : I	1.0	0.9	0.7	0.8	0.8	0.6	0.83	0.69	0.1	0.14	—
» 4 : II	1.2	1.0	1.0	0.8	0.9	0.8			0.2	0.14	—
» 5 : I	1.6	1.6	1.3	1.3	1.2	1.2	0.90	0.92	0.0	0.89	—
» 5 : II	1.8	1.8	1.4	1.5	1.5	1.3			0.0	0.42	—

Table V.

Mean values ($\bar{x}$) for laterotrusion to disordered (LDO) and to nondisordered (LNDO) sides in the patient group, and mean values of mean values for laterotrusion to the right and to the left sides (M_{RL}) in the control group; differences between the groups are described by mean differences (M_{RL}-LDO) and (M_{RL}-LNDO), respectively, Student's test (t), and levels of significance (p), $p \leq 0.05$ = x; $p \leq 0.01$ = xx; $p \leq 0.001$ = xxx, skewness (s), $p \leq 0.05$

Force level	$\bar{x}$		M_{RL}-LDO	t	p	$\bar{X}$		M_{RL}-LNDO	t	p
	LDO	M_{RL}				LNDO	M_{RL}			
Init.max.meas.: I	1.4	3.3	1.9	5.10	xxx	1.6	3.3	1.7	4.32	xxx
» : II	1.5	3.5	2.0	5.03	xxx	1.6	3.5	1.9	4.80	xxx
Scale level 1 : I	0.3	0.5	0.2	0.84	—	0.3s	0.5	0.2	0.67	—
» 1 : II	0.3	0.5	0.2	1.93	—	0.4s	0.5	0.1	0.96	—
» 2 : I	0.4	0.7	0.3	2.35	x	0.5s	0.7	0.2	2.03	x
» 2 : II	0.5^s	0.9	0.4	2.92	xx	0.6s	0.9	0.3	1.85	—
» 3 : I	0.7	1.2	0.4	2.60	x	0.7s	1.2	0.5	3.08	xx
» 3 : II	0.8^s	1.4	0.6	2.47	x	0.8	1.4	0.6	2.60	x
» 4 : I	1.0	2.1	1.2	5.10	xxx	0.9	2.1	1.2	4.51	xxx
» 4 : II	1.2	2.4	1.2	3.33	xx	1.0	2.4	1.3	4.28	xxx
» 5 : I	1.6	3.7	2.1	4.79	xxx	1.6	3.7	2.1	4.78	xxx
» 5 : II	1.8	3.9	2.1	5.21	xxx	1.8	3.9	2.1	4.52	xxx

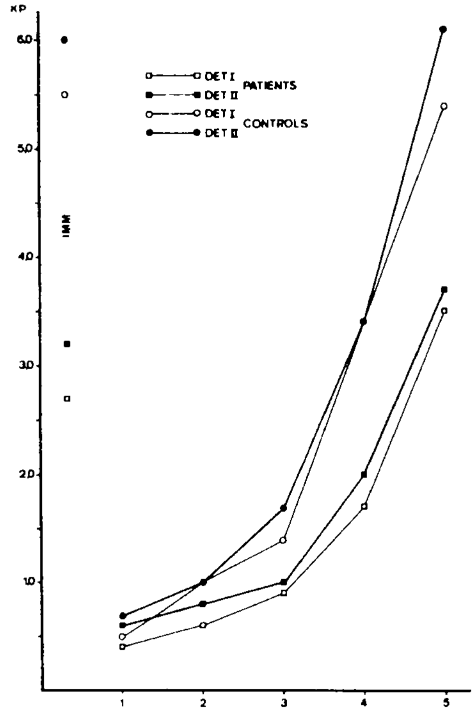


Fig. 3. Means of protrusive forces in kilopond (KP) produced in accordance with the different levels of the rating scale. Initial »maximum» measurements (IMM).

As may be seen from Tables I–V and Figs. 3–6, the horizontal forces of the mandible increase as positively accelerating functions with rising values on the rating scale. Test-retest correlations generally are higher on the high force levels than on the low ones. II-values constantly are slightly higher than I-values. Values obtained at the initial »maximum» measurements generally are lower than »maximum» (level 5) values obtained in the rating production series. At the initial »maximum» measurements as well as at levels 4 and 5 considerably higher values are recorded for protrusion than for retrusion and for laterotrusion.

In the control group (Table III and Fig. 5) the initial »maximum» values obtained for laterotrusion to the left exceeded those obtained to the right ($p \leq 0.05$). This fact also held true for the forces corresponding to the highest values on the rating scale ($p \leq 0.001$ and $p \leq 0.01$). For the patient group this type of comparison is not meaningful since the actual disorder generally is of a unilateral character (30 of 31 in the present patient group).

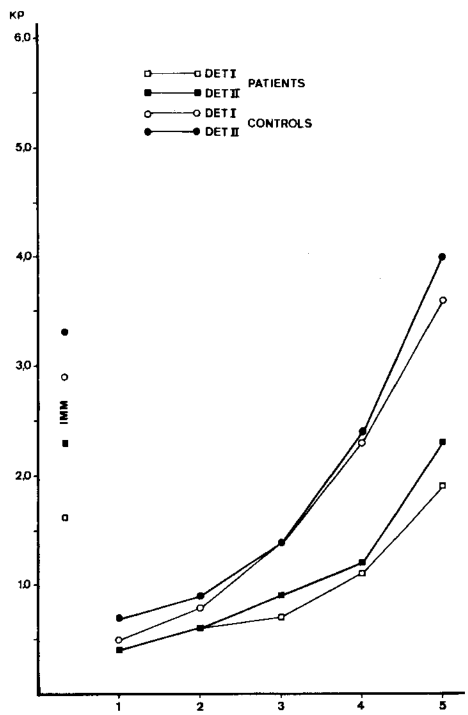


Fig. 4. Means of retrusive forces in kilopond (KP) produced in accordance with the different levels of the rating scale. Initial »maximum» measurements (IMM).

When the patients are compared with the controls, it can be seen that in the directions studied, there are progressively increasing force differences between the groups with rising values on the rating scale. On levels 3—5 all differences but one are significant ($p \leq 0.05$) and on levels 4—5 $p \leq 0.001$ in all cases but two. For the initial »maximum» measurements all the group differences are significant, $p \leq 0.001$, except one ($p \leq 0.05$).

On level 1 the two groups roughly produced the same forces, while on level 5 and at the initial »maximum» measurements the forces produced by the patients were only about half those produced by the controls.

Very small differences were found in the patient group when a comparison was made between the forces produced to the disordered and to the non-disordered side (Table IV and Fig. 6). A comparison between these forces and mean values calculated for laterotrusive forces produced to the right and to the left in the control group (side differences eliminated) resulted in

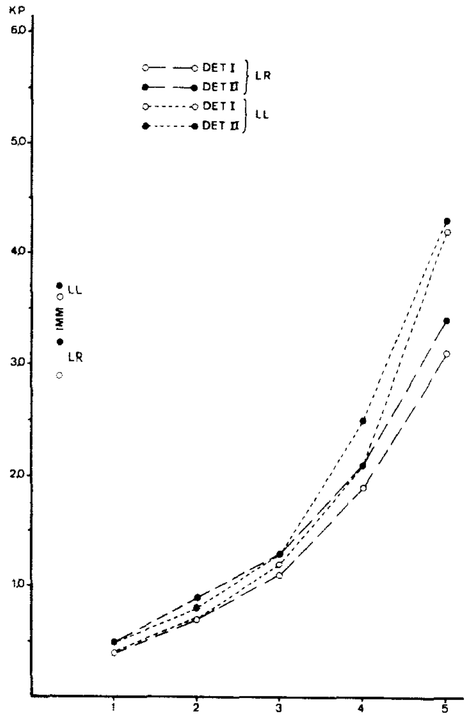


Fig. 5. Means of laterotrusive forces to the right (LR) and to the left (LL) in kilopond (KP) produced in accordance with different levels of the rating scale in the control group. Initial »maximum» measurements (IMM).

a similar group relation (Table V and Fig. 6) as demonstrated for protrusion and retrusion.

Correlations between the forces produced on the different levels for the control group are presented in Table VI and in Table VII for the patient group. Each force direction is shown separately. In the patient group values for left-right directions are, as previously mentioned, not taken into consideration. Therefore the correlations in this group are based on whether the forces are produced to the disordered or to the nondisordered side. All these correlations are of a moderate or fairly high magnitude.

Finally the correlations between the different horizontal forces are presented.

Table VIII shows the correlations in the control group for forces produced at levels 1, 3, and 5. Table IX shows these correlations for the patient group where the correlations are based on whether the forces are produced to the disordered or to the nondisordered side. These correlations are of a moderate or low magnitude.

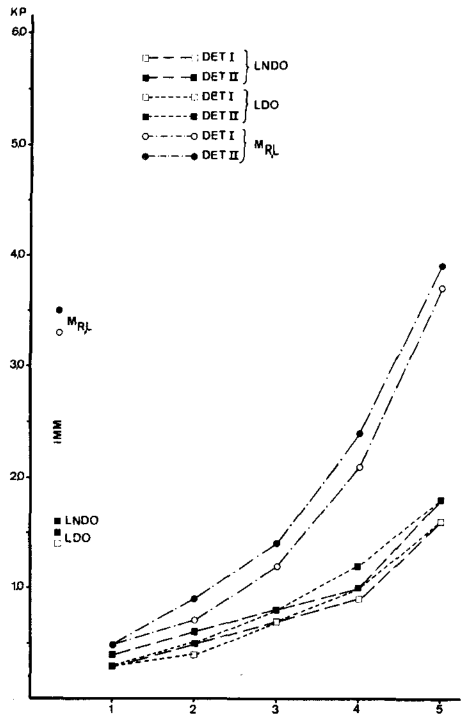


Fig. 6. Means of laterotrusive forces in kilopond (KP) to the disorder (LDO) and to the non-disorder (LNDO) sides in the patient group, and mean of laterotrusion to the left and to the right ($M_{R,L}$) in the control group. Initial »maximum» measurement (IMM).

Table VI.

Correlations between forces produced on different levels of the rating scale. The table is based on II-values for pro-, re-, and laterotrusion. Control group

Protrusion

	1	2	3	4
2	0.68			
3	0.83	0.86		
4	0.41	0.72	0.62	
5	0.22	0.36	0.38	0.75

Retrusion

	1	2	3	4
2	0.70			
3	0.68	0.76		
4	0.52	0.81	0.81	
5	0.36	0.26	0.45	0.45

Laterotrusion to the right

	1	2	3	4
2	0.31			
3	0.43	0.80		
4	0.34	0.55	0.56	
5	0.27	0.47	0.57	0.80

Laterotrusion to the left

	1	2	3	4
2	0.61			
3	0.57	0.82		
4	0.42	0.69	0.47	
5	0.19	0.40	0.55	0.76

Table VII.

Correlations between forces produced on different levels of the rating scale. The table is based on II-values for pro-, re-, and laterotrusion. Patient group

Protrusion

2	0.86			
3	0.80	0.73		
4	0.55	0.61	0.77	
5	0.53	0.41	0.63	0.75
	1	2	3	4

Retrusion

2	0.74			
3	0.54	0.48		
4	0.51	0.69	0.64	
5	0.48	0.49	0.69	0.68
	1	2	3	4

Laterotrusion to the disordered side

2	0.89			
3	0.63	0.75		
4	0.54	0.74	0.84	
5	0.34	0.55	0.70	0.77
	1	2	3	4

Laterotrusion to the nondisordered side

2	0.64			
3	0.66	0.79		
4	0.53	0.72	0.70	
5	0.39	0.67	0.57	0.89
	1	2	3	4

Table VIII.

Correlations between protrusion (P), retrusion (R), laterotrusion to the right (LR), and to the left (LL) sides. Control group

Level 1:II

R	0.44		
LR	0.24	0.50	
LL	0.40	0.48	0.43
	P	R	LR

Level 3:II

R	0.86		
LR	0.27	0.40	
LL	0.58	0.79	0.64
	P	R	LR

Level 5:II

R	–0.06		
RL	0.40	0.50	
LL	0.41	0.41	0.76
	P	R	LR

Table IX.

Correlations between protrusion (P), retrusion (R), and laterotrusion to the disordered (LDO) and to the nondisordered (LNDO) sides. The table is based on II-values on levels 1, 3 and 5. Patient group

Level 1:II

R	0.16		
LDO	0.07	0.38	
LNDO	–0.07	0.19	0.48
	P	R	LDO

Level 3:II

R	0.28		
LDO	0.12	0.04	
LNDO	0.09	–0.03	0.64
	P	R	LDO

Level 5:II

R	–0.05		
LDO	0.00	0.24	
LNDO	–0.10	0.36	0.53
	P	R	LDO

DISCUSSION

The general shape of the curves describing the relations between subjective and objective horizontal mandibular forces corresponds well with curves obtained for bite force (*Borg & Wennström*, 1962 a, b, c, and 1967; *Molin* 1972). This fact indicates that the underlying psychophysical functions probably also have the same general shape, *i.e.* a power function with the exponent approx. = 1 (See *Borg & Wennström*, 1962c). As already mentioned the more theoretical psychophysical aspects fall beyond the scope of the present investigation.

The high or fairly high correlations between I and II values indicate the reliability of the measurements and the subjects' discriminating capacity on different levels. The fact that the correlations are higher on high than on low force levels may partly be explained by the relatively greater errors of measurements on the low levels caused by the equipment.

The continously slightly higher means and medians for II-values in comparison to those for I-values may be an effect of adjustment to the equipment and the test situation. This probably also explains the successively rising »maximum» performance values from assessment I on the initial measure, ments to assessment II on level 5 in the rating production series. Furthermore. the increasing »maximum» values indicate that effects of fatigue are negligible-

The values obtained on level 1 in the rating production series may be looked upon as »absolute threshold» values assessed in ascending series only, and therefore probably overestimated. However, the equipment used was not designed with enough sensitivity for absolute threshold measurements, and therefore this problem cannot be further discussed here.

The measured »maximum» values, maximum voluntary contractions (MVC), are considerably below those calculated on anatomical bases, and probably also below values obtainable with a more active attitude on the part of the test leader. The reason for her neutral attitude was to have the motivational conditions as constant as possible. With regards to the quotient between the maximum voluntary muscle force and the theoretically available muscle force *Hettinger* (1964) gives a figure of 0.65.

When force values obtained for protrusion and retrusion are compared to those for laterotrusion, it must be remembered that the former are produced by bilateral muscular activity while the latter are mainly produced by unilateral muscular activity.

In spite of the fact that the »maximum» force for protrusion considerably exceeded that for retrusion and for laterotrusion, all forces produced on levels 1—3 were of the same magnitude. These levels may be considered to represent the force levels used in everyday life; hence they may be expected to be in balance.

As shown above for the control group the initial »maximum» force values as well as the force values corresponding to the two highest levels on the rating scale for laterotrusion to the left exceeded those for laterotrusion to the right. The rations between all maximal values obtained to the left and all those obtained to the right is about 1.2. If such a ratio is calculated for the muscular force values reported by *Schumacher* (1961) and by *Honée* (1970), the figures become 1.1—1.2 ($n = 18$) and 1.0 ($n = 5$) respectively. Thus, Schumacher's and Honée's results, based on anatomical studies, are in agreement with our functional measurements. It may be taken into consideration, however, that Honée's material included only five specimens.

When the patients are compared with the controls, the existing age differences are not considered to be a differentiating factor (*Hettinger*, 1960).

On the two lowest scale levels the two groups produced approx. the same forces. On high levels, however, a striking difference between the groups was obtained which may be interpreted as a result of the more intense pain experienced by the patients on their disordered side as reported in a simple questionnaire (five scalegrades verbally and numerically defined) concerning pain during and after the investigation (see Fig. 7). In this context, however, it must be mentioned that all subjects, immediately after the investigation reported here, also took part in a study concerning endurance capacity which may have influenced their pain experience (*Molin*, 1972 a).

This interpretation is seemingly contradicted by the fact that no significant differences were found between forces produced towards and away from the disordered side. However, although laterotrusion towards one side mainly is caused by contraction of the contralateral lateral pterygoid muscle, the corresponding muscle on the ipsilateral side acts as a stabilizer for the joint in which the rotation takes place (*Carlsöö*, 1956; *Honée*, 1970; *Molin*, 1972 c). Thus the disordered muscle may hurt not only in movements directed *away from* but also *towards* the disordered side.

As concerns the test-retest correlations no striking group differences were obtained. Thus, the discriminating capacity of the patients seems to be unaffected in spite of their manifest MPD.

Finally, the fairly high correlations between forces produced on levels 3, 4, and 5 indicate good possibilities of predicting »maximum» values on the basis of submaximum measurements, which may have interesting clinical applications.

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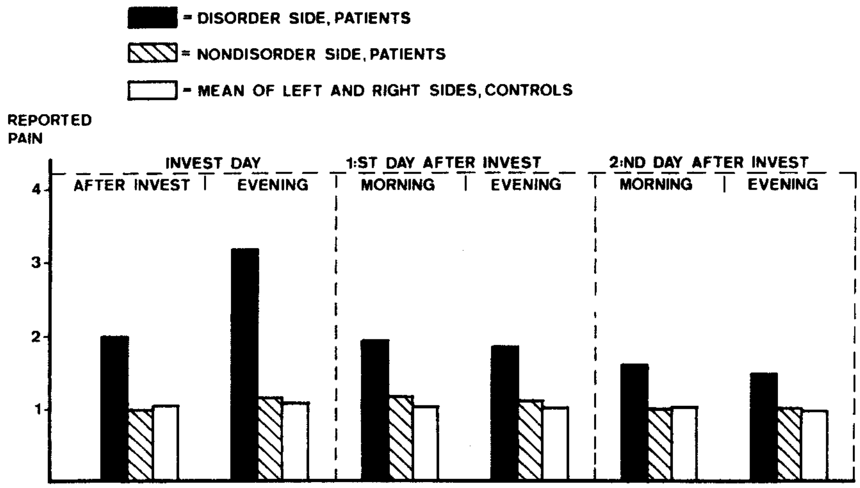

Fig. 7. Mean values of pain reported by the subjects during and after the investigation according to a rating scale with five degrees. For the patients pain on disordered, and nondisordered sides is given separately. For the controls the mean of the pain reported on the left and right sides (almost equal values) is given.

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Addresses:

G. Marklund,
The Institute of Applied Psychology,
University of Stockholm,
Råsundavägen 101,
S- 171 37 Solna,
Sweden

C. Molin,
The Department of Oral and Jaw Diseases,
Karolinska Sjukhuset,
S- 104 01 Stockholm 60,
Sweden