2. METHODS

2. METHODS

The system for imparting mechanical chin taps employed in this project is shown as a line diagram in Figure: 5a and supported on the subject's chin in Figure: 6b. It consisted of a solenoid (Model No. 16, 50 Hz, 8 amps, pull type operation, Oliver Electric Company, Alexandria, N.S.W. Australia), the core (B) being extended as a plunger (G) via a shaft (D) which on activation contacted a freely movable chin plate (I) positioned in the path of travel (Figure: 5a). This chin plate was supported by guide rods (F) running on nylon bearings, and the distance between plunger and chin plate was adjustable via locking rings (E) which modified the magnitude of the impulse imparted to the chin. Friction was reduced within the housing of the apparatus by employing nylon bearings. With sequential reduction in the distance between plunger tip and chin plate, the magnitude of the impulse imparted to the chin progressively increased due to the interruption of plunger travel at an earlier stage. An electronic switch (Fig.5b) activated the system repetitively at a controlled frequency by incorporating a variable electronic timer. This was usually set at once every one and a half seconds during menton taps. The duration of pulse activation was able to be varied but was set at the smallest time that would be sufficient to consistently drive the plunger. This time, assessed electronically, was calculated to be 3-4msec. The system

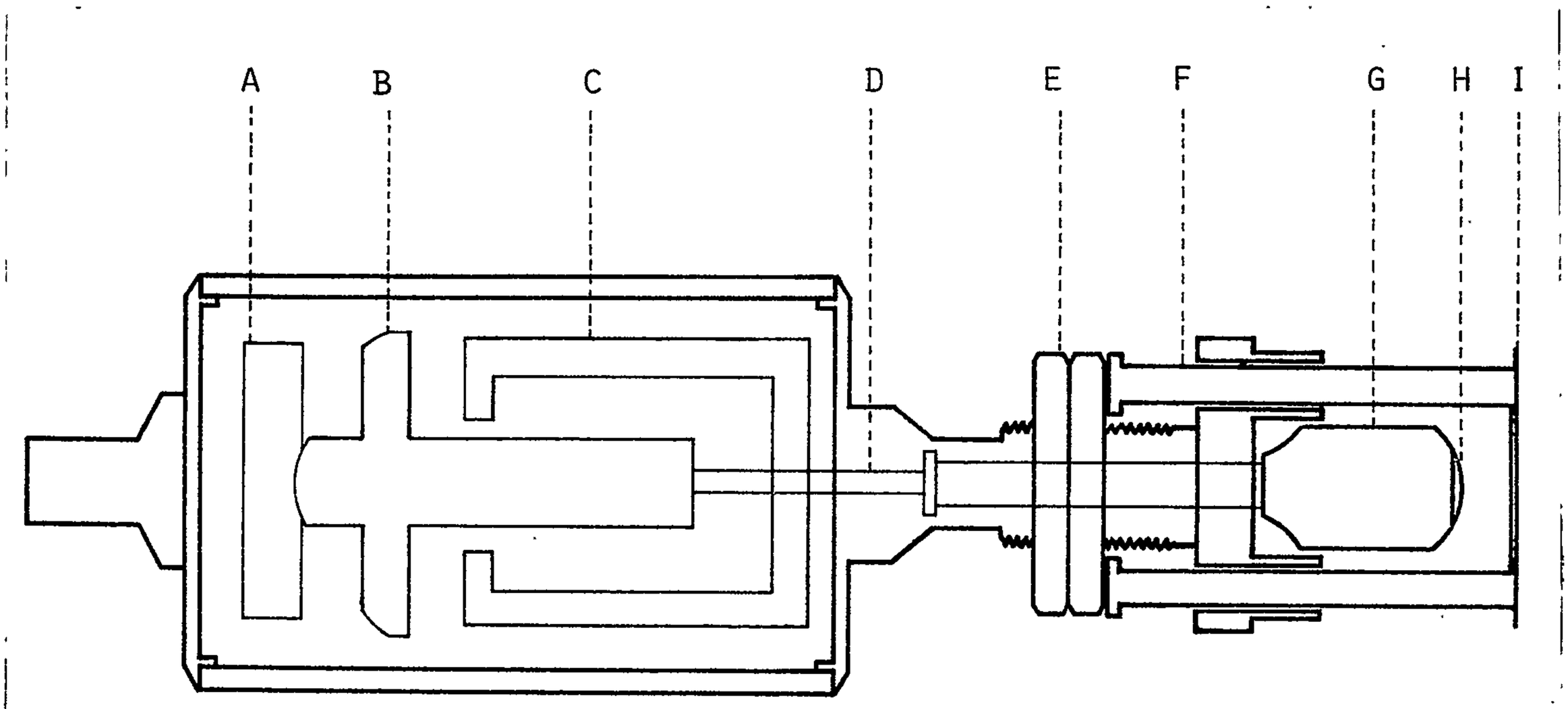


FIGURE: 5a

Line drawing of essential components of the plunger system that delivers reproducible mechanical menton taps for evoking jaw reflexes. A: set microswitch, B: core laminations, C: armature, D: plunger shaft, E: adjustable locking rings, F: guide rods supporting chin plate, G: plunger, H: reset microswitch, I: chin plate.

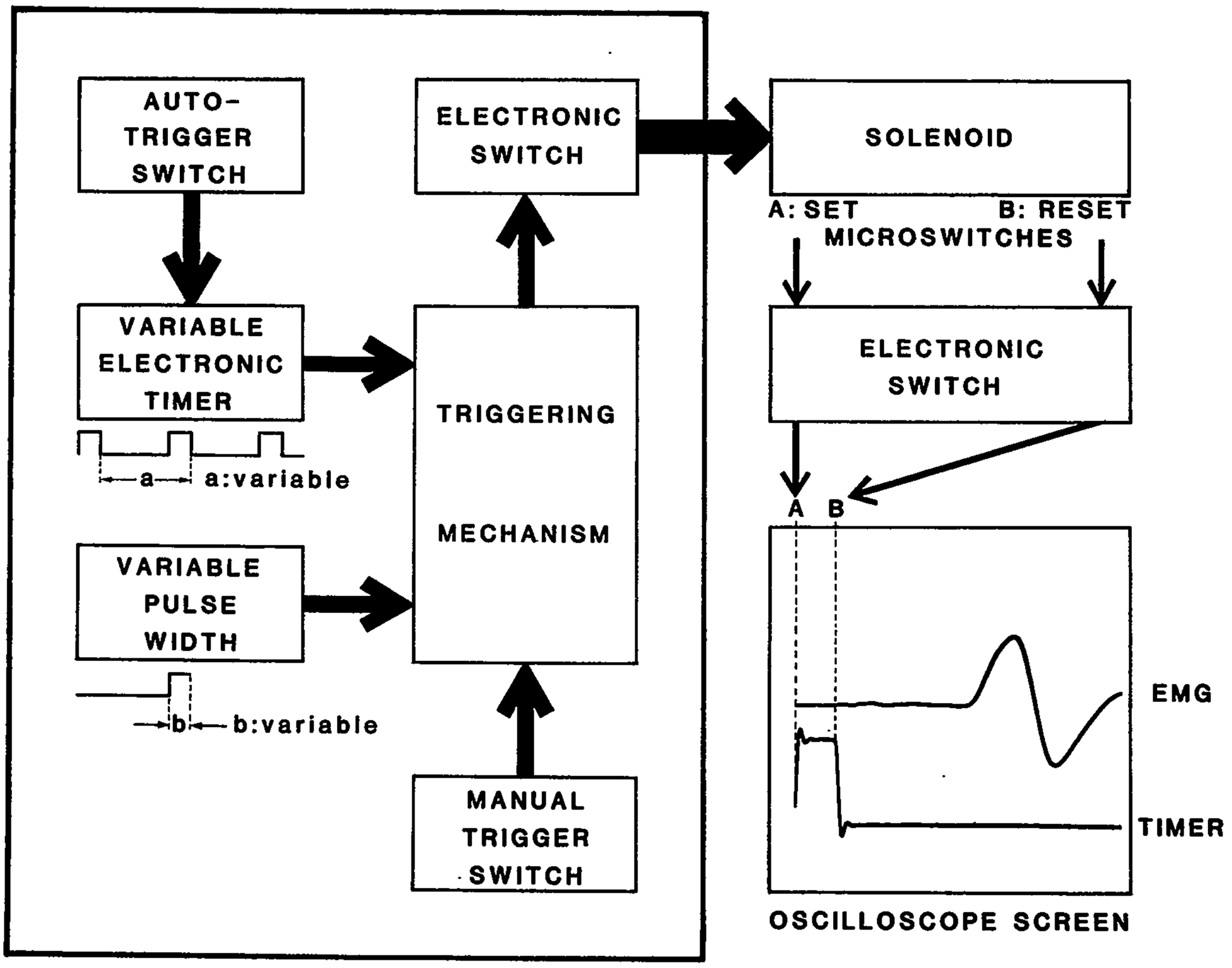
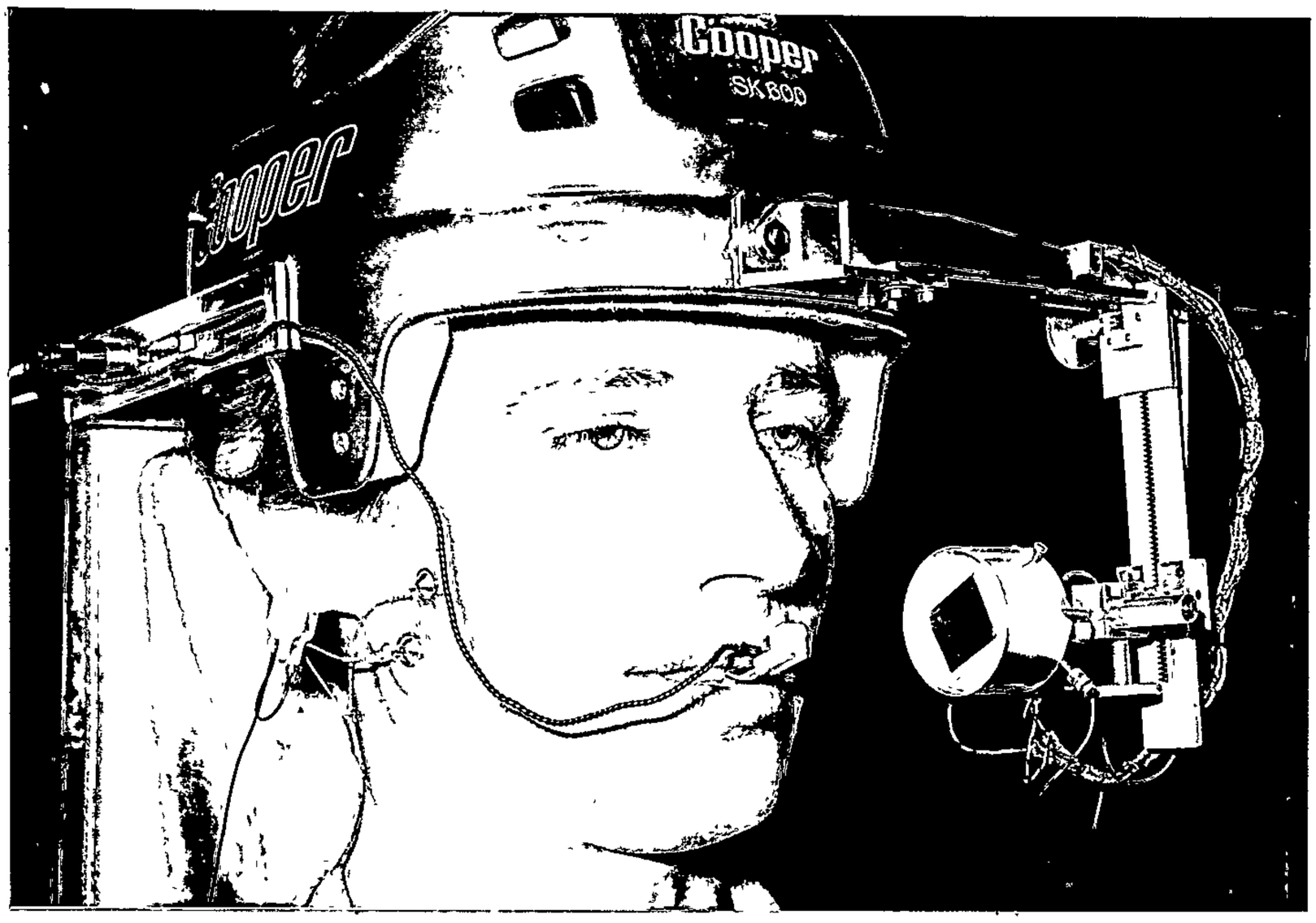
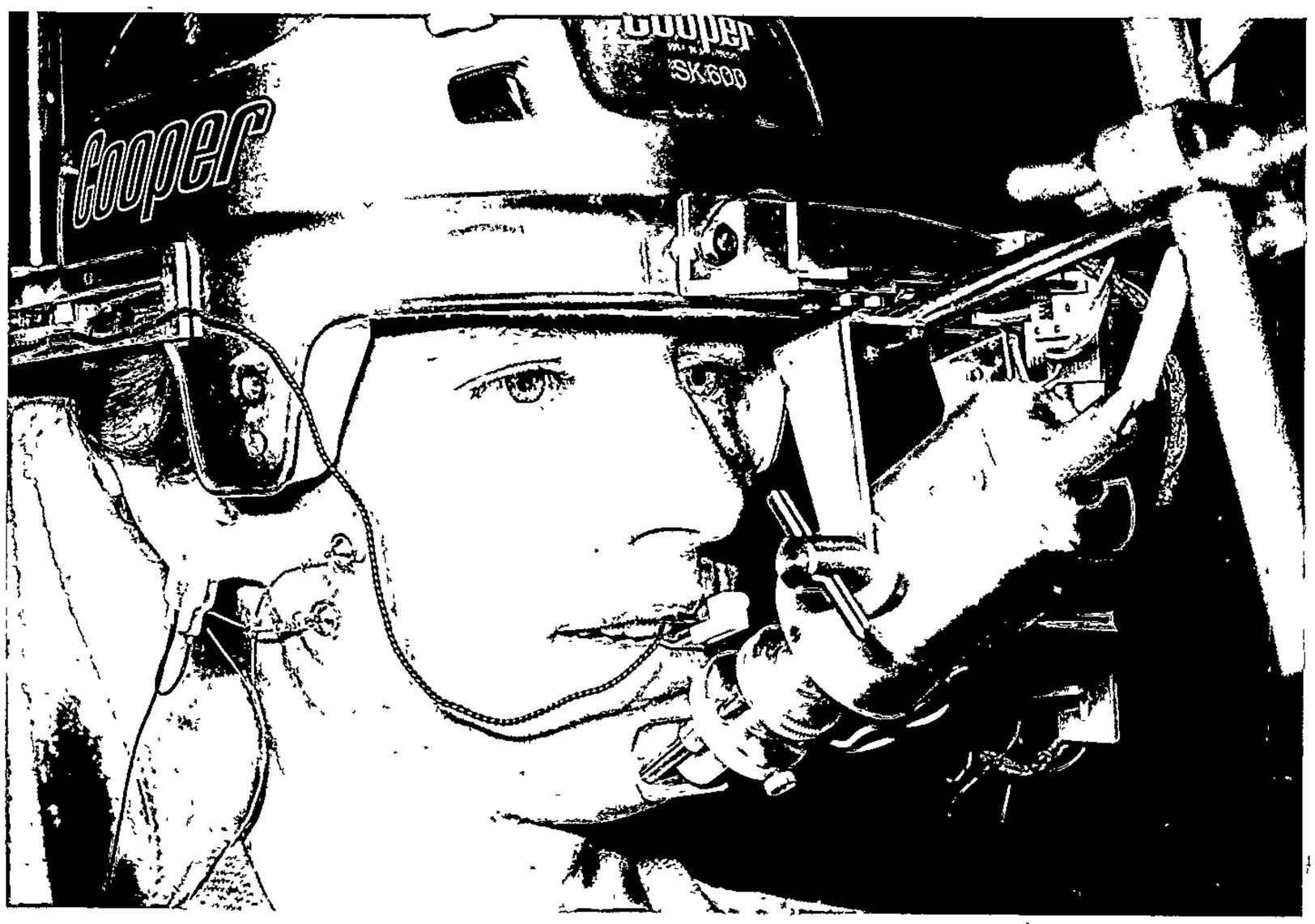


FIGURE: 5b

Block diagram of electronic switching mechanism and timer employed with the menton-tapping plunger system. The solenoid incorporated into the plunger system could be activated by an electronic switch either manually (manual trigger switch) or automatically (auto-trigger switch) at a variable frequency (variable electronic timer - period between successive activations equivalent to distance "a"). Variations in pulse width (b) modified the duration of solenoid activation, which was set to the shortest possible time (about 3-4 msec) producing consistent activation of the triggering mechanism. A microswitch (A) incorporated into the plunger system housing, which was activated at the commencement of plunger travel, triggered an oscilloscope beam. The circuit was reset at the moment of plunger-chin plate contact and this time is precisely indicated by B.



a



b

FIGURES: 6a and 6b

(a) Subject seated in dental chair with head-frame supporting light sensor for tracking jaw displacement in position. A miniature lamp is attached to the lower anterior teeth with acrylic and cyano-acrylate adhesive.
(b) Identical set-up as in (a), with the standardised system for evoking reflex responses in position also.

could also be activated manually to deliver single pulses as required and this facility was used initially to accustom subjects to the equipment. As shown in Figure: 5b, the initiation of plunger travel was signalled by a micro-switch (A) incorporated into the aluminium housing, and the moment of plunger-chin plate contact by a second microswitch (B) which reset a timer circuit; both of these pulses were recorded on tape along with the electromyographic responses. The system was bolted to the headrest of a dental chair by a rigid adjustable framework which also aided in stabilising head position by supporting a restraint that could be lowered onto the subject's head (Figure: 9).

The reproducibility of the system was assessed by monitoring in the sagittal plane the rate and magnitude of jaw displacement, during the application of chin taps of different force magnitude, employing an opto-electronic tracking system (Luschei, personal communication; Figure: 6a and 6b). This consisted of a light sensor (Quadrature Pin Diode, PIN SC/25; active area: 3.5 cm^2; field of view: 155^{o}; maximum frequency response: 2kHz; United Detector Technology Inc., Santa Monica), mounted on a headframe by light-weight rigid bars with fine vertical and horizontal adjustments, which monitored a miniature halogen cycle lamp (General Electric, Lamp No. 2600 - 3.5V; 2.5W; 2.9 candle power; length 13.2mm; diameter 4.8mm) secured to the lower anterior teeth (Figure: 6a). This was achieved

by moulding self-cure acrylic, which coated the cross-bar of a T-shaped aluminium support, against the labial surfaces of the lower anterior teeth (Figure: 7). After the acrylic cured, the beam that projected in the sagittal plane and which supported the miniature lamp was adjusted to accommodate soft tissue contour. The framework was then fixed securely to the lower anterior teeth with cyanoacrylate adhesive. The sensor is a light sensitive diode overlying a uniform film of resistive material with an electrode at each end of the vertical and horizontal axes. Differential voltage changes across the electrodes are proportional to the relative location of the light source provided this remains near the centre of the sensor. Manufacturer's specifications indicated reproducibility to within a two per cent error over an 80mm field, with barrel-type distortion occurring principally at the periphery of the field rather than over the central zone where jaw displacement was monitored. The tracking system was calibrated for vertical displacement in each subject by monitoring the magnitude of light source movement with the interposition between the teeth of plastic shims of known thickness. The degree of linearity was assessed under in vitro conditions by monitoring output from the sensor for a given movement of the light source (Figure: 8). The sensor was secured in a stable position at a known distance from the light source and this was varied in different experiments to produce distances of 20mm, 30mm, 40mm, and 50mm. At each distance between light source and

FIGURE: 7

Index used to attach halogen cycle lamp (left upper of photograph) to lower anterior teeth. The index consists of a short rigid bar secured to the teeth with acrylic resin and cyanoacrylate adhesive.

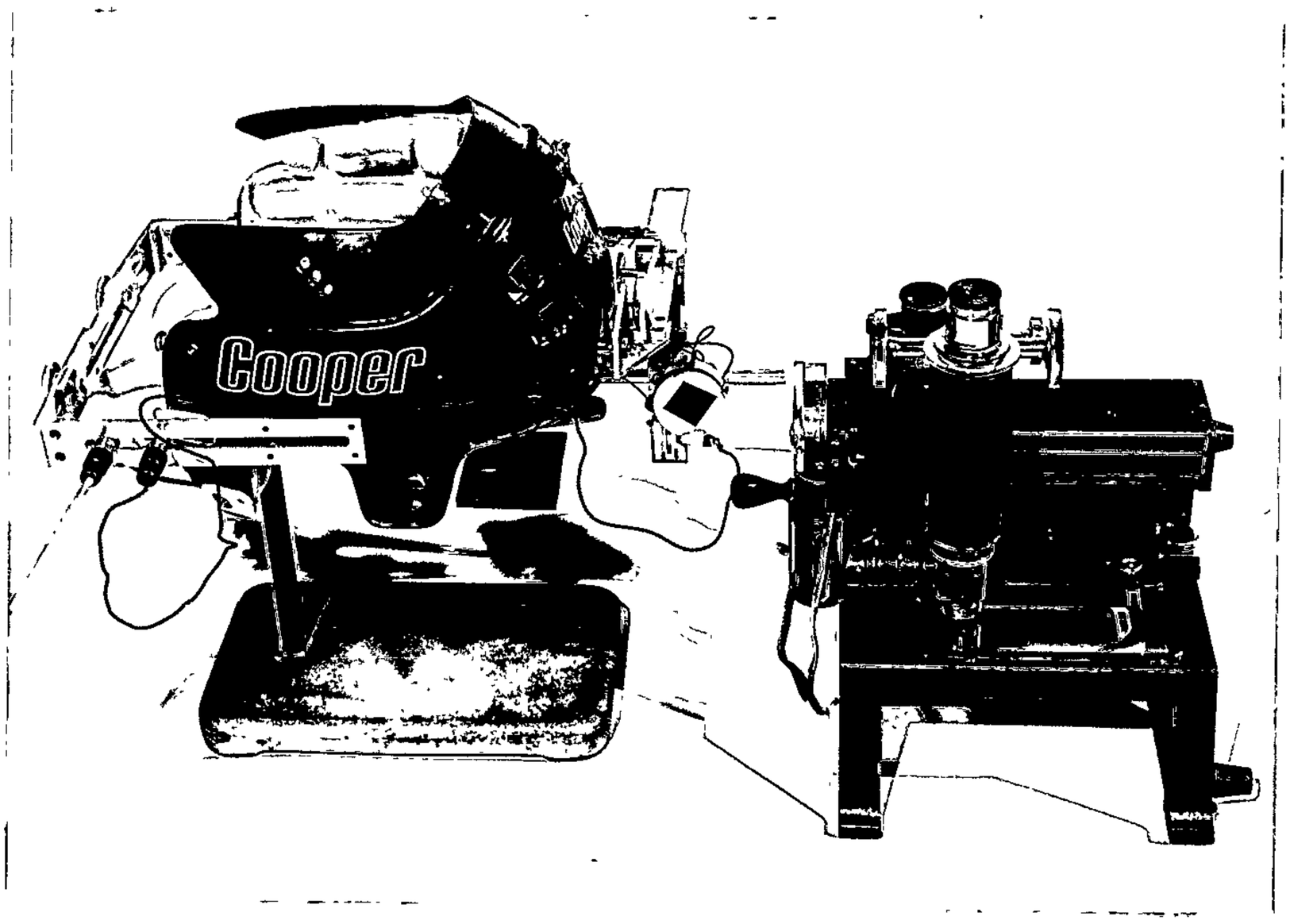


FIGURE: 8

Assessment of linearity of opto-electronic tracking system (left of photograph and mounted on a laboratory stand). Light sensor monitored incremental displacement of lamp secured to travelling microscope (right of photograph; Beck, England).

sensor, the light, secured to a travelling microscope (Beck, England), was moved a certain displacement in line with that axis of the sensor used for detecting vertical jaw displacement. Sensor output, which was recorded and measured on a polygraph (Model 7D, Grass Instrument Company, Quincy, Massechusetts), was then plotted against light source displacement, and the correlation co-efficient was statistically assessed. The distance between light source and light sensor during actual recordings on a subject was between 40 and 50mm.

An approximation of the force delivered was quantified by correlating the displacement during the delivery of a stimulus and as recorded by the tracking system, with that occurring during the application of a known force to the mandible via a hand-held dial gauge (Haldex AB, Sweden). The forces were applied and released as rapidly as possible and in random order of force magnitude in a manner similar to that for the delivery of an impulse to the chin from the plunger system. The maximum displacement of the lower teeth during this manual procedure at a particular force level as indicated by the dial gauge was assessed. This allowed the generation of a force-displacement conversion curve and from this, additional force values at different levels of jaw displacement were interpolated and extra-polated. Therefore, the displacement-time curves recorded during actual stimulus delivery to the menton region could be converted to force-time curves. From these graphs, the

range of forces delivered and the associated rates of force change during the menton tap were evaluated at each particular tap force level. The stresses generated through the chin plate were also quantified following estimation of the area of contact between chin and chin plate.

Subjects were randomly selected from dental students on the basis of their agreement to participate in the study, and informed consent was obtained following approval by the Faculty Ethical Review Committee. The general nature of the investigation and the procedures and equipment involved were explained and demonstrated to each subject. Recordings were made during the delivery of at least ten standardised perturbations to the menton region at one and a half second intervals for each subject at postural jaw position. This latter position was established by calmly having the patient relax to allow the jaw to approximate postural position. Discomfort, sudden noise or a high rate of stimulation has been shown to inhibit reflex responses in the masseter following intraoral stimulation (Achari and Thexton, 1974) and following the delivery of chin taps (Godaux and Desmedt, 1975b). These observations emphasise the need for a stable, comfortable experimental environment and careful attention to stimulus delivery. Therefore, in order to ensure that environmental variables were maintained as optimal as possible during recordings at postural jaw position, the following procedures were carried out:

(a) each subject was seated comfortably in a dental chair with light support for head posture and with

the alar-tragus line parallel with the horizontal plane;

(b) recordings were carried out in a quiet room with fluorescent lighting and at a constant air-conditioned temperature;

(c) before any recordings were made subjects were allowed to familiarise themselves with the clinic environment and equipment;

(d) a preliminary series of at least twenty perturbations at gradually increasing intensity levels were carried out to accustom the subjects to the stimulus delivery system; and

(e) the electromyogram was monitored whilst the subject was relaxed and the absence of any recordable muscle activity over and above background noise suggested that the jaw position at the time of recording closely approximated postural position.

Employing this standardised instrumentation, three series of experiments were carried out. In the first series, groups of perturbations evoked jaw-closing reflexes in four individuals, lacking symptoms of muscle-joint pain or dysfunction, at several different levels of tap force. These perturbations were delivered at an inclination of about 35^{o} to the superficial masseter fibres (Figure: 6b). This series was carried out to assess the effect of variation in tap force on the evoked reflex response parameters and thus to evaluate whether a reproducible system is necessary to achieve consistent reflex responses.

In the second experimental series, recordings were made from thirty-two subjects during the delivery of at least ten standardised perturbations to the menton region of each subject at postural jaw position. The system delivered stimuli at the same setting for all subjects. Of the thirty-two subjects tested, twenty-five exhibited measurable jaw-closing reflexes. These latter were divided into three groups: group A consisted of ten subjects who were completely free of signs and symptoms of muscle-joint dysfunction; i.e. limitation of jaw movement, joint sounds (clicking, popping), pain or tenderness in the temporomandibular joints or the oro-facial musculature. This did not include the presence of certain occlusal features such as a small slide from retruded position to intercuspal position; mild bruxofaceting; mild mediotrusive interferences. Group B consisted of ten subjects who exhibited mild to moderate clinical evidence of dysfunction i.e. the overt presence of one or more of the foregoing signs and symptoms, and group C consisted of five patients referred for treatment of orofacial pain and who exhibited moderate to severe clinical evidence of pain and/or dysfunction. This experimental series was carried out to assess whether characteristics of jaw-closing reflexes could be correlated with the presence or absence of muscle-joint pain and dysfunction.

In the third experimental series, an attempt was made to understand further the respective roles of stretch and vibration in the aetiology of the jaw-closing reflex. Thus,

in an additional five subjects the jaw was firmly supported with acrylic indices between maxillary and mandibular teeth, and with bilateral hand support by the subject during the application of chin taps (Figure: 9a). The indices (Figure: 10a and 10b) were constructed by placing autopolymerising acrylic resin between opposing teeth whilst the subject sat upright, with the head unsupported and in the absence of recordable emg activity in the masseter muscles. This captured a position closely approximating postural jaw position. After curing and during stimulus delivery, the subject was instructed to exert just sufficient manual pressure to prevent jaw opening. In contrast with this manual support manoeuvre, stimuli were also delivered whilst the mandible was rigidly secured in close proximity to postural jaw position, again without emg evidence of voluntary elevator muscle contraction, by luting the indices to the maxillary and mandibular posterior teeth with cyanoacrylate adhesive (Figure: 9c). The evoked reflex responses were compared with those elicited at postural jaw position at the same level of tap force. In addition, stimuli were delivered to the rigidly supported mandible during the classic Jendrassik manoeuvre, that is, a near maximum upper limb contraction attempting to separate hands which were locked together (Figure: 9b). The evoked reflex responses were compared visually with those elicited at postural jaw position at the same level of tap force.

Prior to electrode placement the skin was prepared to remove surface dirt and to abrade superficial dermal layers

FIGURES: 9a, 9b and 9c

FIGURES: 9a, 9b and 9c

Subject seated in dental chair with framework assembly supporting the chin-tapping system in place. Acrylic resin indices positioned in the mouth i whilst the subject exerts firm pressure on the lower border of the mandible as a resistance against displacement (9a); ii during the Jendrassik manoeuvre (9b); and iii with the indices luted in place with cyanoacrylate adhesive (9c). These figures also show the restraint positioned on the subject's head.

9a

9b

9c

10a

10b

FIGURES: 10a and 10b

Indices constructed in autopolymerising resin and located between the teeth with the jaw approximating postural position. These indices were used during subjective chin support, to lute the maxillary and mandibular teeth together and during Jendrassik reinforcement manoeuvres.

in an attempt to minimise movement artefact and provide a stable skin impedance (Tam and Webster, 1977). This was achieved by cleansing where necessary with a swab soaked in water and a small quantity of soap, and then lightly rubbing the skin ten times with 1200 Garnet paper (3M Company). Bipolar surface disc electrodes (Grass Instrument Company, Quincy, Massachusetts) were located 10mm behind the anterior border of the superficial masseter bilaterally in the direction of the muscle fibres and separated by 20mm centre-to-centre (Goldberg, 1971; Figure: 11). An earclip electrode was used as an earth. A calibrated grid of horizontal and oblique intersecting lines scribed onto a perspex sheet (1.5mm thick, 20cm x 20cm) at 5mm intervals aided in the localisation of electrodes (Figure: 12). The oblique lines numbered and approximating the inclination of the superficial masseter were aligned at 45^{o} to the tragal-outer canthus line. The template was aligned along the tragal-outer canthus line with a teflon ear piece located in the external ear. Perforation holes at the points of intersection of the lines allowed a mark to be placed on the skin at particular co-ordinates representing the appropriate electrode position. The documentation of these coordinates for one side aided electrode positioning in about the same relative location to the innervation zone of the masseter muscle on the contralateral side (polygraph bandwidth: $10\text{-}10^{3}$ Hz).

The evoked reflexes, jaw displacement and stimulus indicator were recorded on FM tape (HP 3968A) and analysed

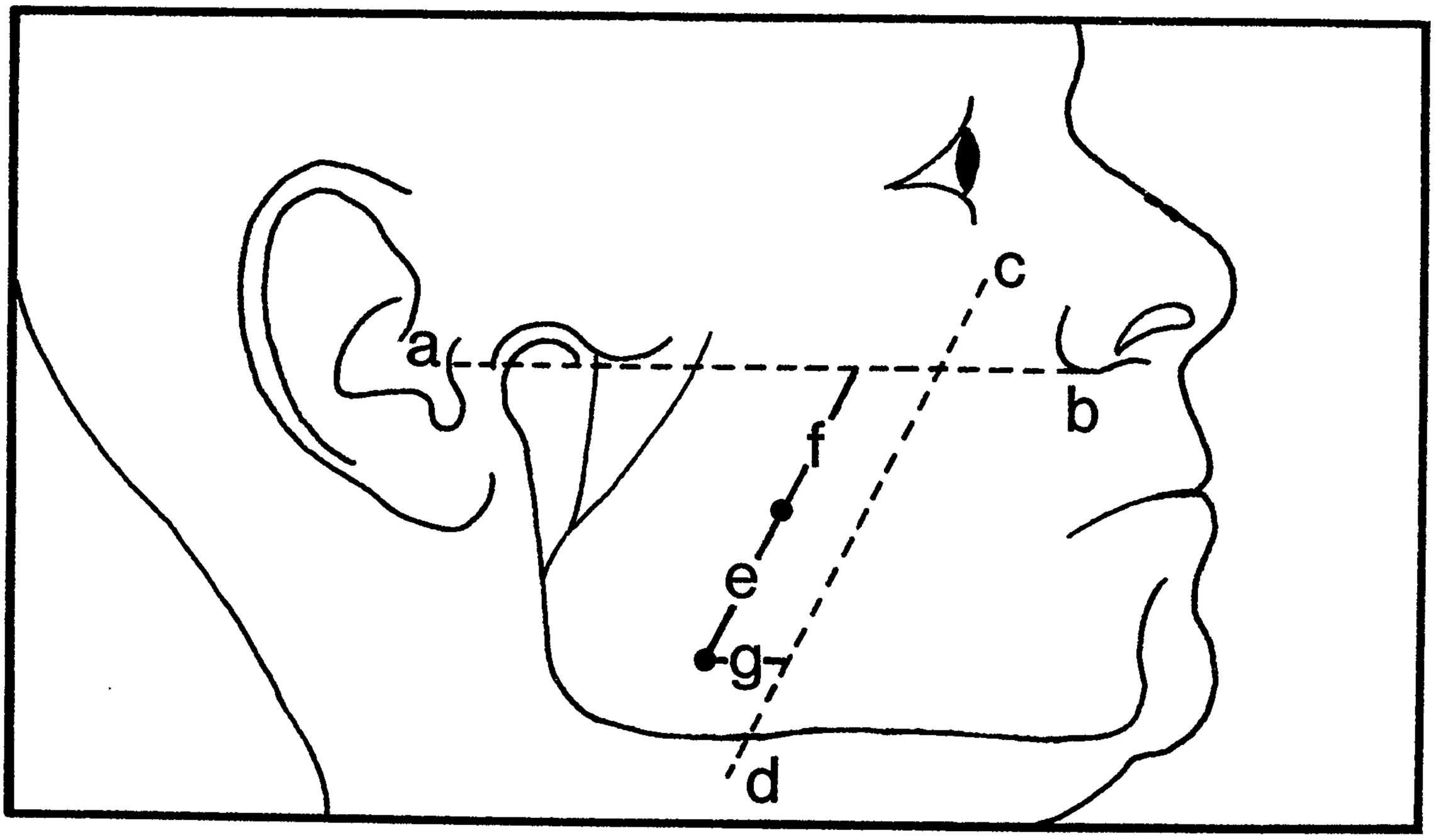


FIGURE: 11

Diagram illustrating electrode placement over masseter muscle. a-b: alar-tragus line; c-d: line parallel to and superimposed over anterior border of superficial masseter; d: 20 mm inter-electrode distance centre-to-centre and parallel to line c-d; f: 20 mm; g: 10 mm.

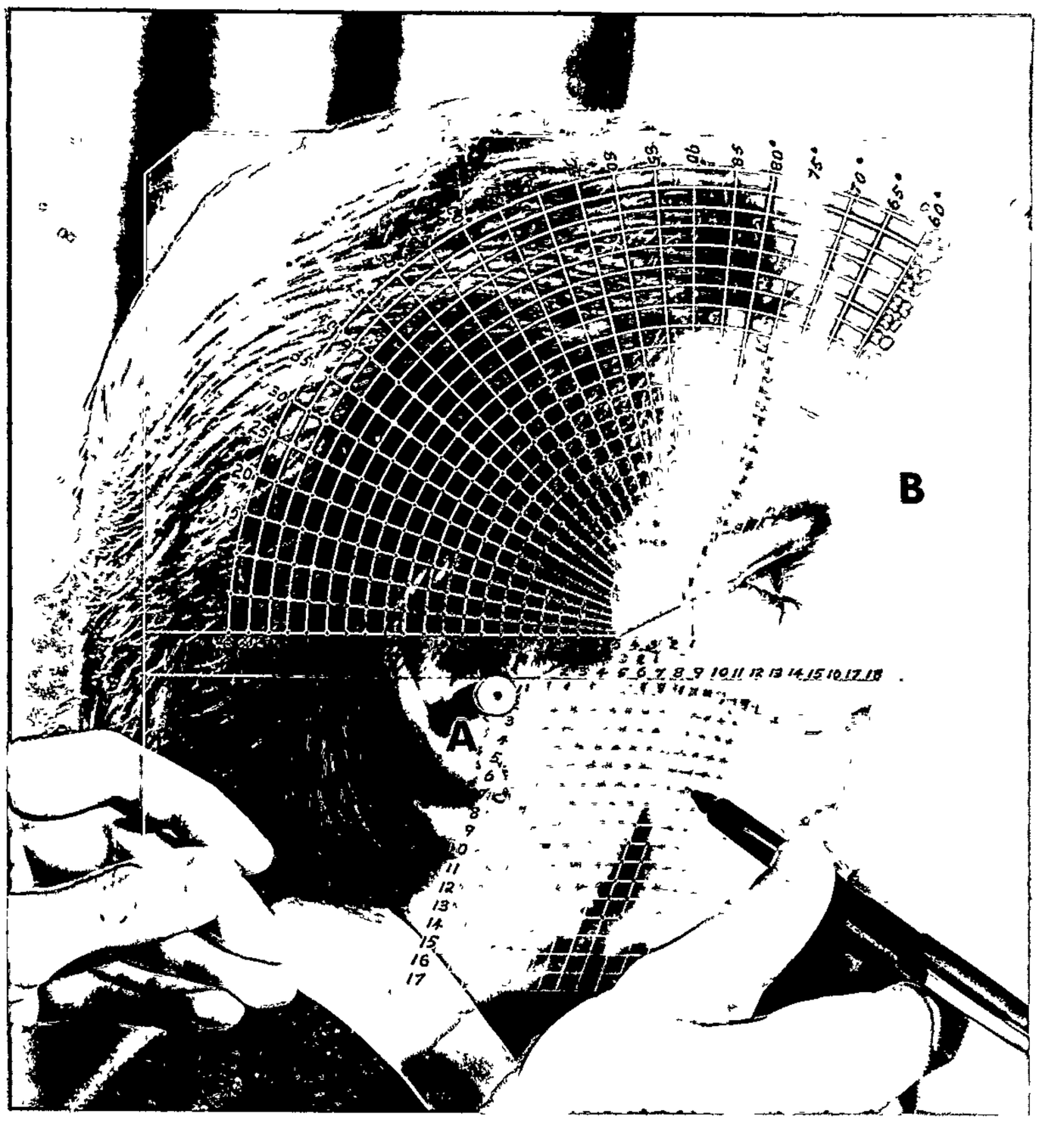


FIGURE: 12

Perspex grid for standardised electrode placement consisting of horizontal and oblique intersecting lines overlying masseter and concentric arcs and radii overlying temporalis. Localisation of grid was achieved by engaging the external ear with a teflon ear-piece (A) and orienting the line AB along the tragal-outer canthus line. Having determined appropriate electrode locations, the coordinates are read from the grid corresponding to the intersection of grid lines overlying each electrode position. This allows electrodes to be placed on each side in the same location relative to the innervation zone of the masseter muscle.

following oscilloscope (Tektronix 5111) replay at reduced speed. The following measurements were made (Figure:13;p.155): jaw-closing reflex latency was assessed from the moment (B) at which the plunger (G in Figure: 5a) contacted the chin plate (I in Figure: 5a) to the first major deflection (D) as part of the diphasic monosynaptic response. Spindle stretch would be expected to commence at C, that is, at the commencement of jaw displacement, which occurs after the plunger has contacted the chin plate resting against the subject's chin. Values assessed from the moment of plunger-chin plate contact (B) may therefore be corrected by subtracting a latency adjustment factor. Variations in this factor relate to individual variations in soft tissue displaceability and the inherent inertia of the mandible supported by muscle protein and fibroelastic connective tissues. Duration was measured from the end-point of latency (D) to the peak of the last major deflection (E), and amplitude was assessed peak-to-peak along the Y-axis (F to G). The latency of chin movement (B to C), the magnitude of light displacement (H to I) and the duration of plunger travel (A to B) were also assessed. Reflexes were assessed only from those responses exhibiting clearly discernible measuring points. The maximum error of measurement was estimated to be 0.05msec, 0.01mV and 0.01mm for the time, voltage and dimensional characteristics respectively. Mean and standard deviation values were calculated and where appropriate the presence of trends was tested using linear regression analysis (Snedecor and

Cochran, 1980); correlations were evaluated using Pearson's co-efficient (Brown and Hollander, 1977); and estimations of significance of differences were evaluated using Student's t-Test (Spiegel, 1961). Results were considered significant at the ninety-five percent level or greater.

Note :

The error of 0.05msec quoted on page 151 should read 0.2msec. This difference is in each standard deviation value and will not influence the significance of the statistical tests.

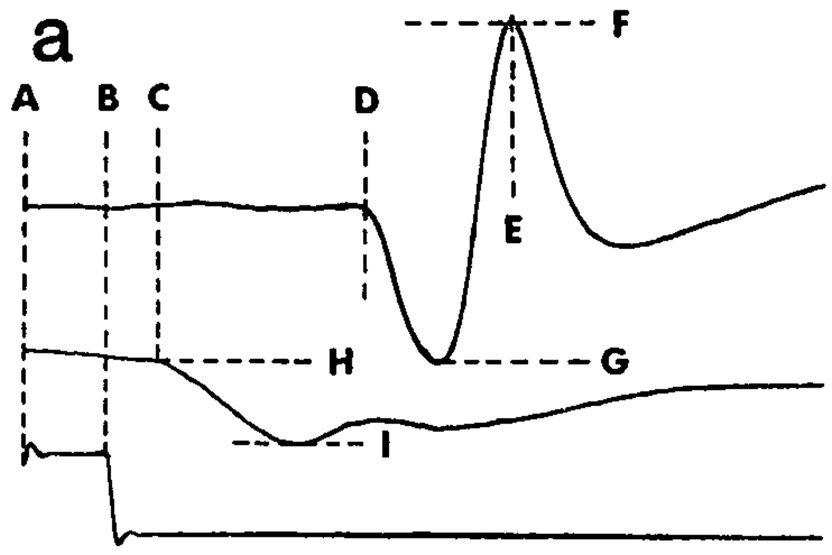
3. RESULTS

In the first experimental series, stimuli were delivered at different levels of tap force in four individuals. With sequential adjustment of the plunger system characteristics, a progressive decrease in tap force was reflected by a reduction in the magnitude of jaw displacement (Figure: 13f, g and h). In a representative subject, jaw displacement was recorded during menton tapping at different levels of force ranging from the lightest tap that could be barely felt to the strongest that the subject could tolerate. In this subject an estimate of the magnitude of force imparted to the chin was made by delivering impulses of known magnitude to the lower teeth employing a hand-held dial gauge. The maximum displacement recorded at each impulse delivery was recorded and used to derive a force-displacement relation (Figure: 14a). Assuming this function to be linear, a straight line of best fit was derived mathematically by linear regression analysis (Snedecor and Cochran, 1980). The resultant function was: $y = 0.91 + 0.67x$, where 'x' represents displacement in millimetres at the light source secured to the lower anterior teeth, and 'y' represents the maximum force imparted corresponding with that particular displacement. Note that the displacement actually occurring at the teeth would be less than that recorded at the light source due to the short distance (about 12mm) separating the lamp from the lower teeth. The correlation coefficient

FIGURE: 13

FIGURE: 13

(a) Measurement criteria for electromyogram (emg), jaw displacement and stimulus timer (upper, middle and lower traces respectively): A-B, duration of plunger travel; B-C, latency of jaw movement; C-D, latency of jaw-closing reflex based on the moment of commencement of jaw displacement; D-E, duration of jaw-closing reflex; F-G, amplitude of jaw-closing reflex; H-I, amplitude of jaw displacement. (b) and (c) Five consecutive superimposed traces of right and left masseter emg (upper two traces in each figure), jaw displacement (middle traces) and stimulus timer (lower traces) elicited at postural jaw position (b) and during chin support at postural position rigidly maintained with acrylic and adhesive (c). (d) and (e) Emg, jaw displacement and stimulus timer recorded during five consecutive standardised menton taps (d) and during the delivery of five non-standardised taps (e). (f), (g) and (h) Emg response and jaw displacement recorded at three decreasing levels of tap force, respectively, to the menton region. (i) Right and left masseter emg (upper two traces respectively) elicited at constant tap force to show difference in jaw-closing reflex latency values between sides and the more variable jaw-closing reflex amplitude evoked in the right masseter. Calibration data: vertical bar represents the following for each group of traces from upper to lower within a group - (a) 0.22 mV, 2.16 mm; (b) and (c) 0.51 mV, 0.42 mV, 0.75 mm; (d) 0.15 mV, 0.55 mm; (e) 0.39 mV, 0.55 mm; (f), (g) and (h) 0.12 mV, 1.10 mm; (i) 0.38 mV, 0.32 mV, 2.75 mm. No calibration is given for the stimulus timer. Horizontal bar: (a) - (c): 2.50 msec; (d) - (i): 2.00 msec.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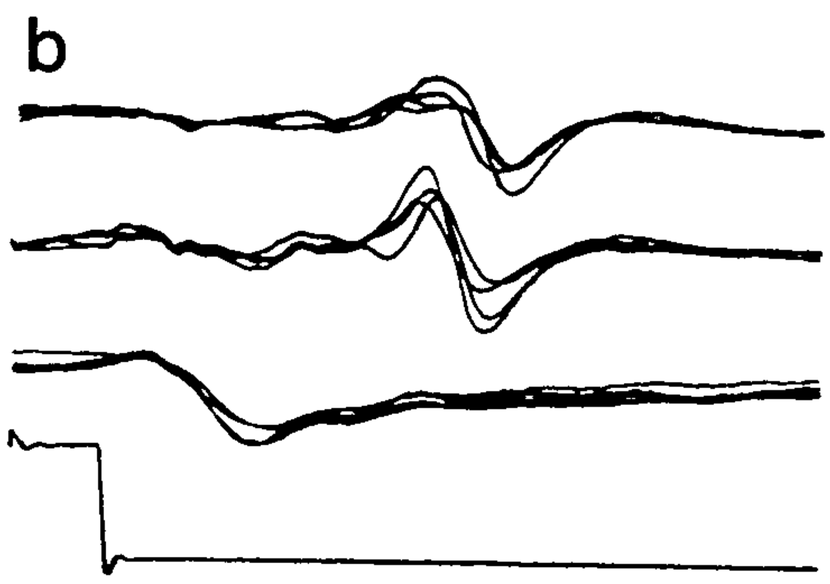
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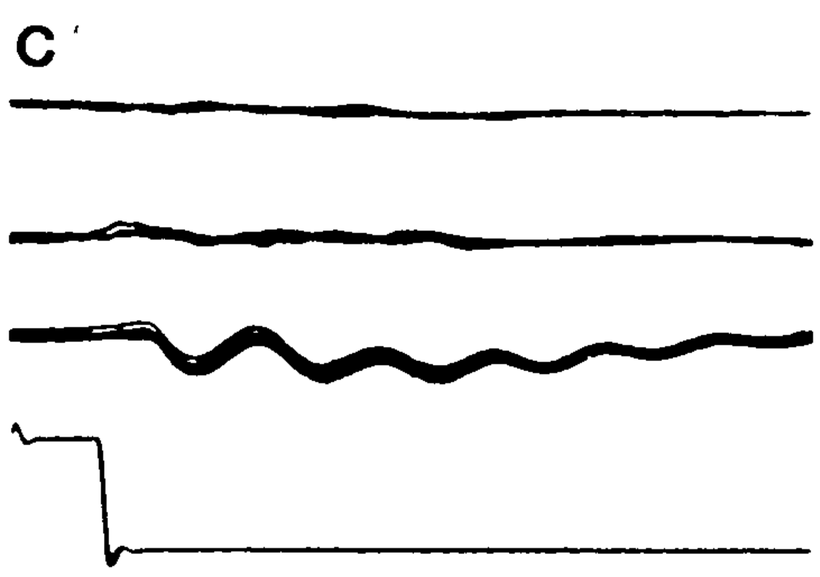
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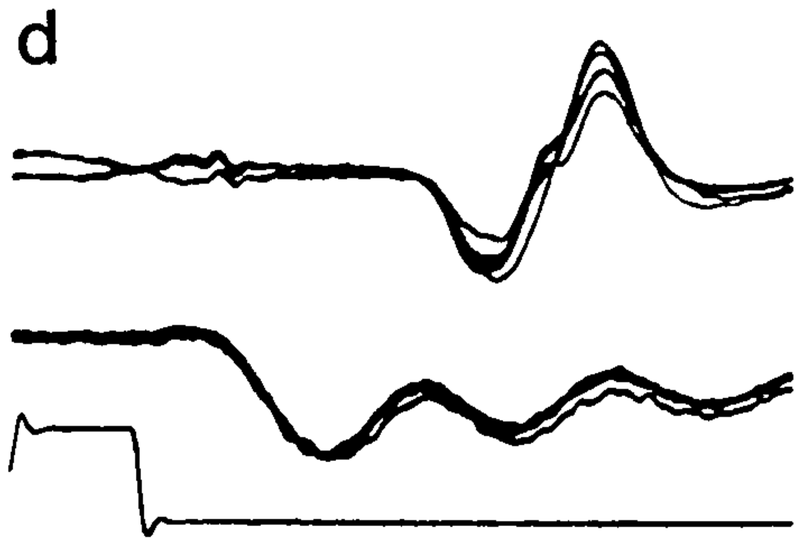
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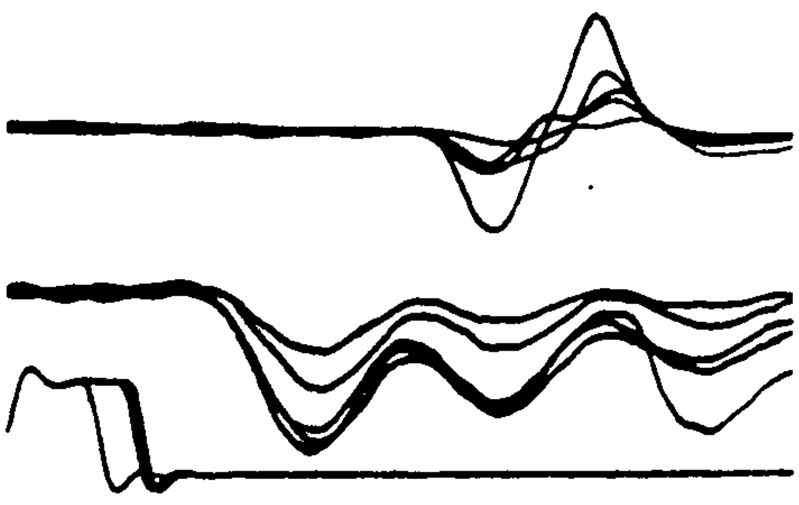
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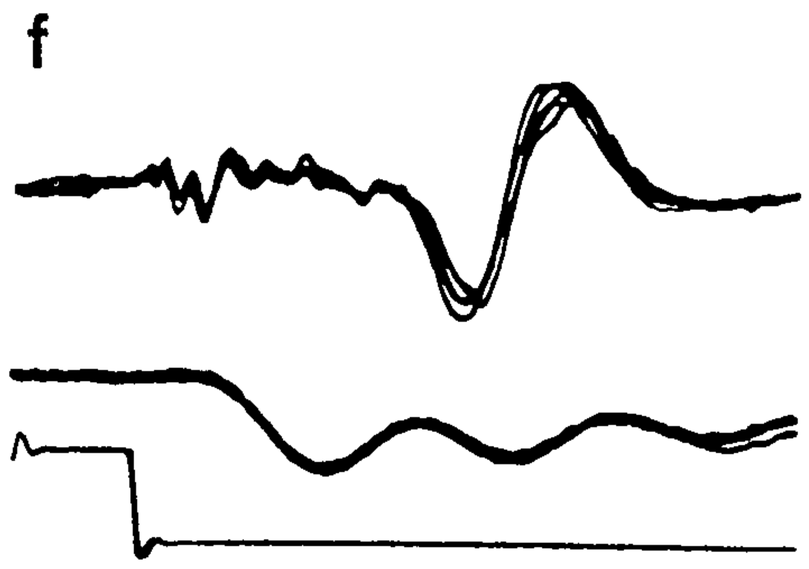
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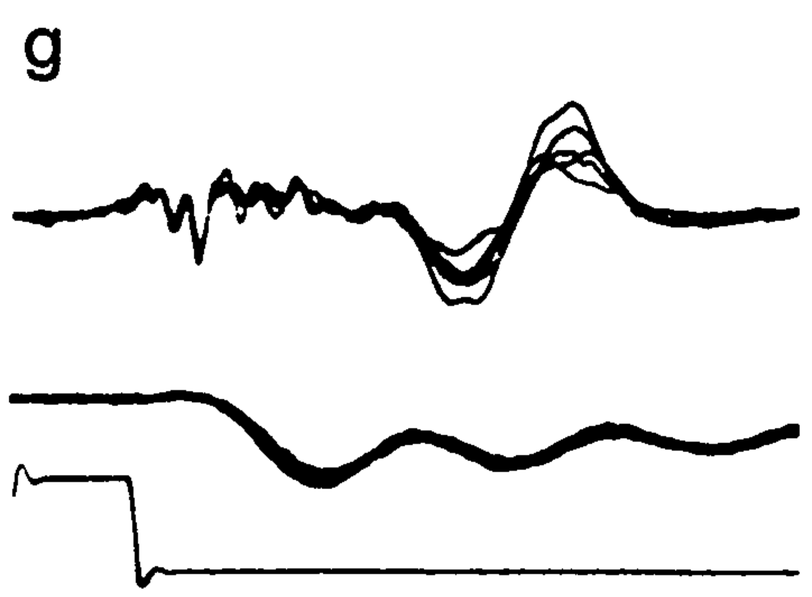
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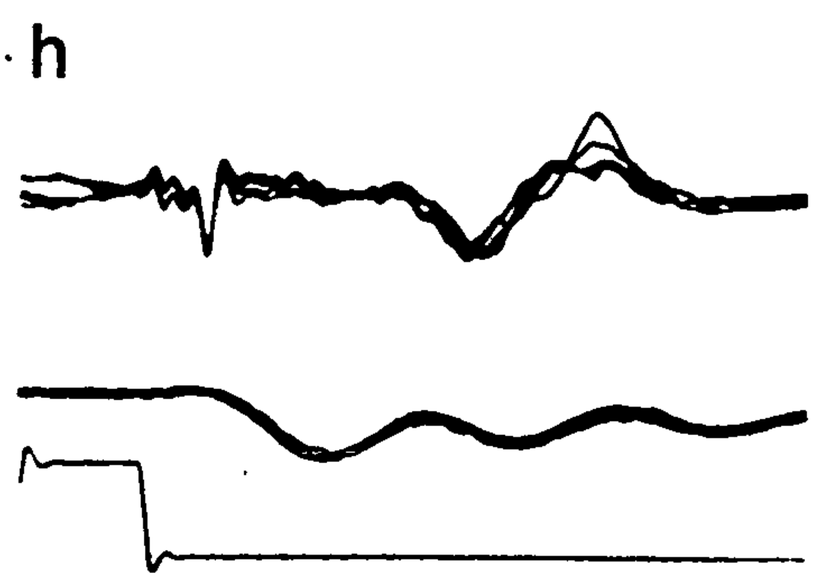
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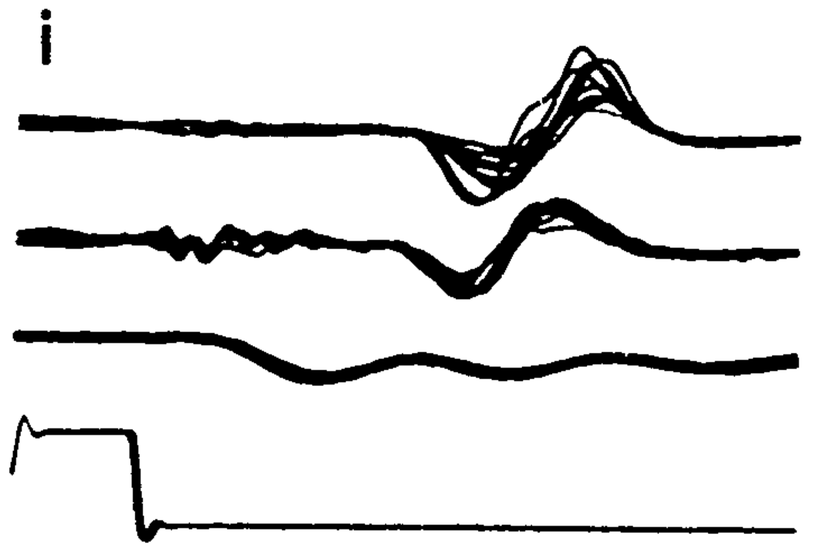

i

was 0.97. Extrapolation of the force-displacement line to the force axis suggested that at very light load levels jaw displacement would not occur.

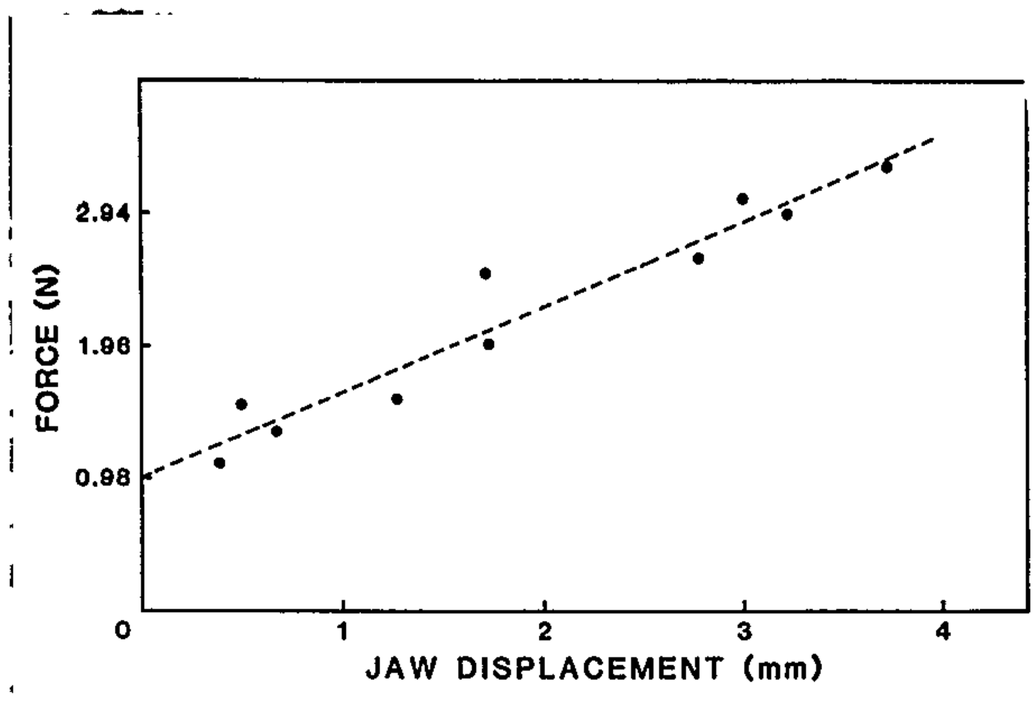
Using this function, displacement-time curves recorded during menton tapping at different settings of the plunger system were converted into force-time curves and from these the associated rates of force change were calculated. The maximum force delivered at each plunger system setting is graphically displayed in Figure: 14b with continuous curves being represented in Figure: 14c. Individual values for force and rates of force change are listed in Table: 2. In this table, time values represent the period from the beginning of plunger travel to the moment at which a particular force value was assessed. Force values represent the instantaneous forces developed at a particular point in time during the menton tap. The rate at which forces imparted change was calculated by dividing the instantaneous force increment by the corresponding increment in time. From these results it is apparent that with sequential adjustment of the plunger system so that the chin plate interrupts plunger travel at a progressively earlier stage, both the force and the rate of change of force imparted to the chin increased. Maximum forces delivered for all settings ranged from 1.52N to 2.45N and the maximum rates of force change ranged from $0.23 Nmsec^{-1}$ to $0.68 Nmsec^{-1}$. The approximate skin contact area of the chin plate was

FIGURE: 14

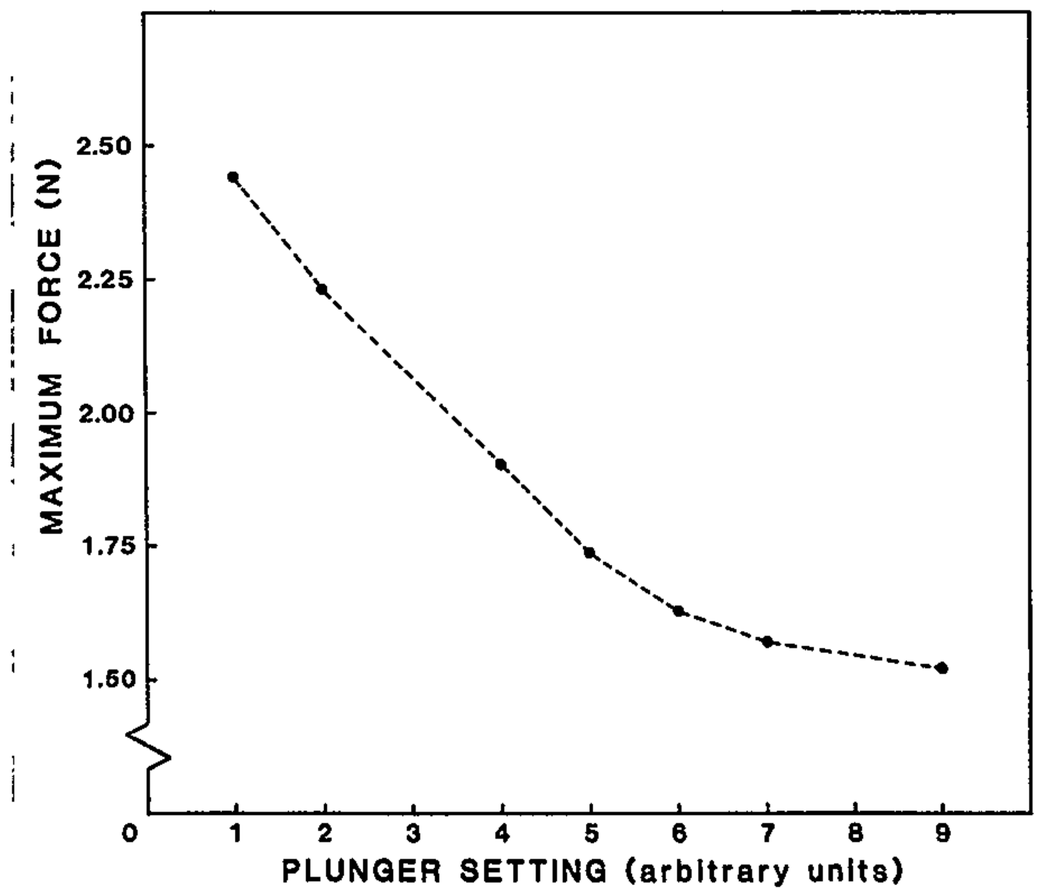
FIGURE: 14

(a) Straight line of best fit ($y = 0.67x + 0.91$, $r = 0.97$), drawn through plot of jaw displacement against load applied to the mandible, used to calibrate the menton-tapping system. (b) Maximum force in newtons developed at seven separate plunger system settings. (c) Force against time curves plotted for each of seven separate plunger system settings. Time begins when the first microswitch is activated at the moment the plunger shaft commences its travel from the back of the apparatus housing. (d) In one subject for a single trial, individual jaw-closing reflex latency, duration and amplitude values are plotted against the tap number in a consecutive series of nine taps.

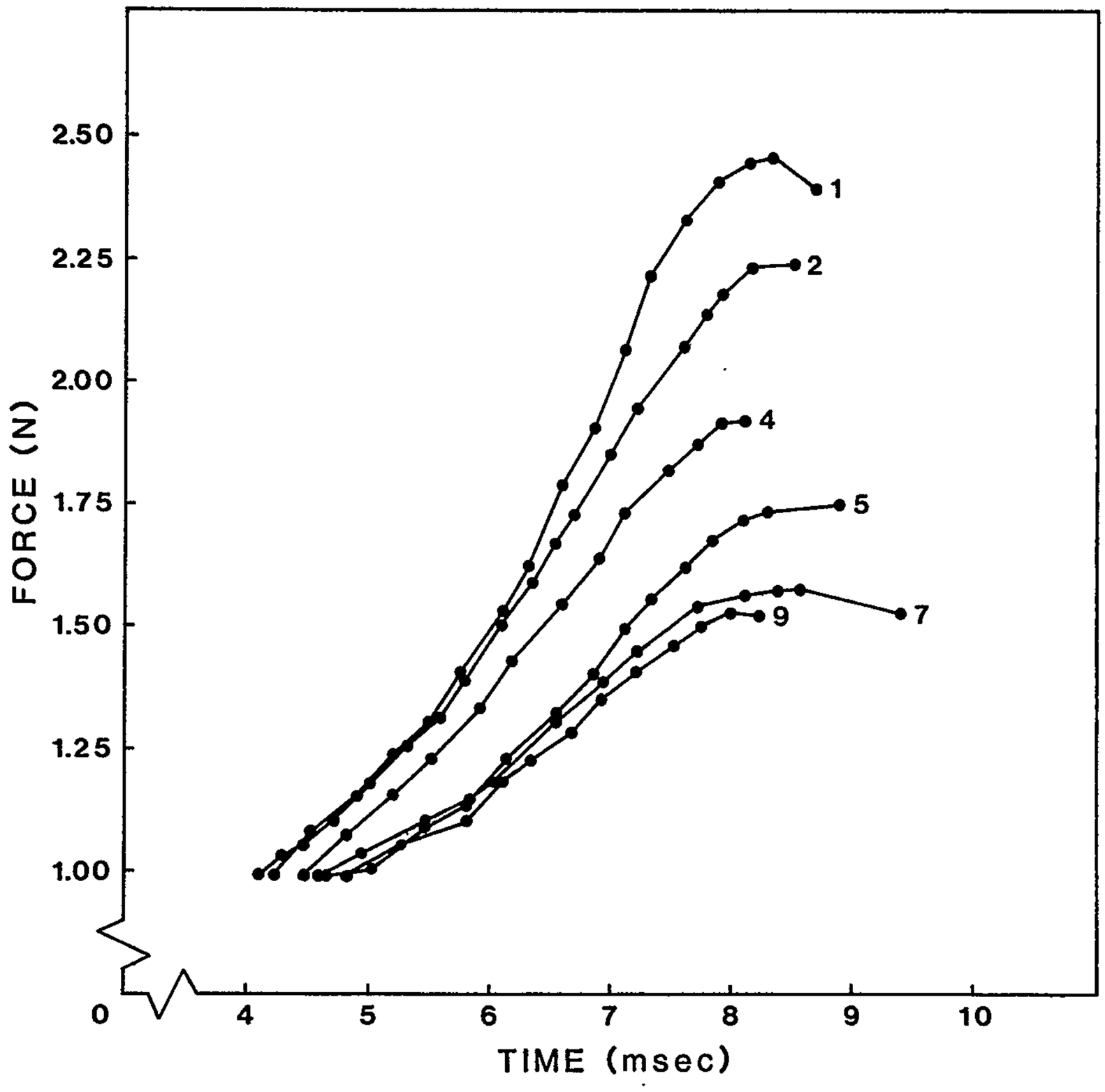
14a



14b



14c



14d

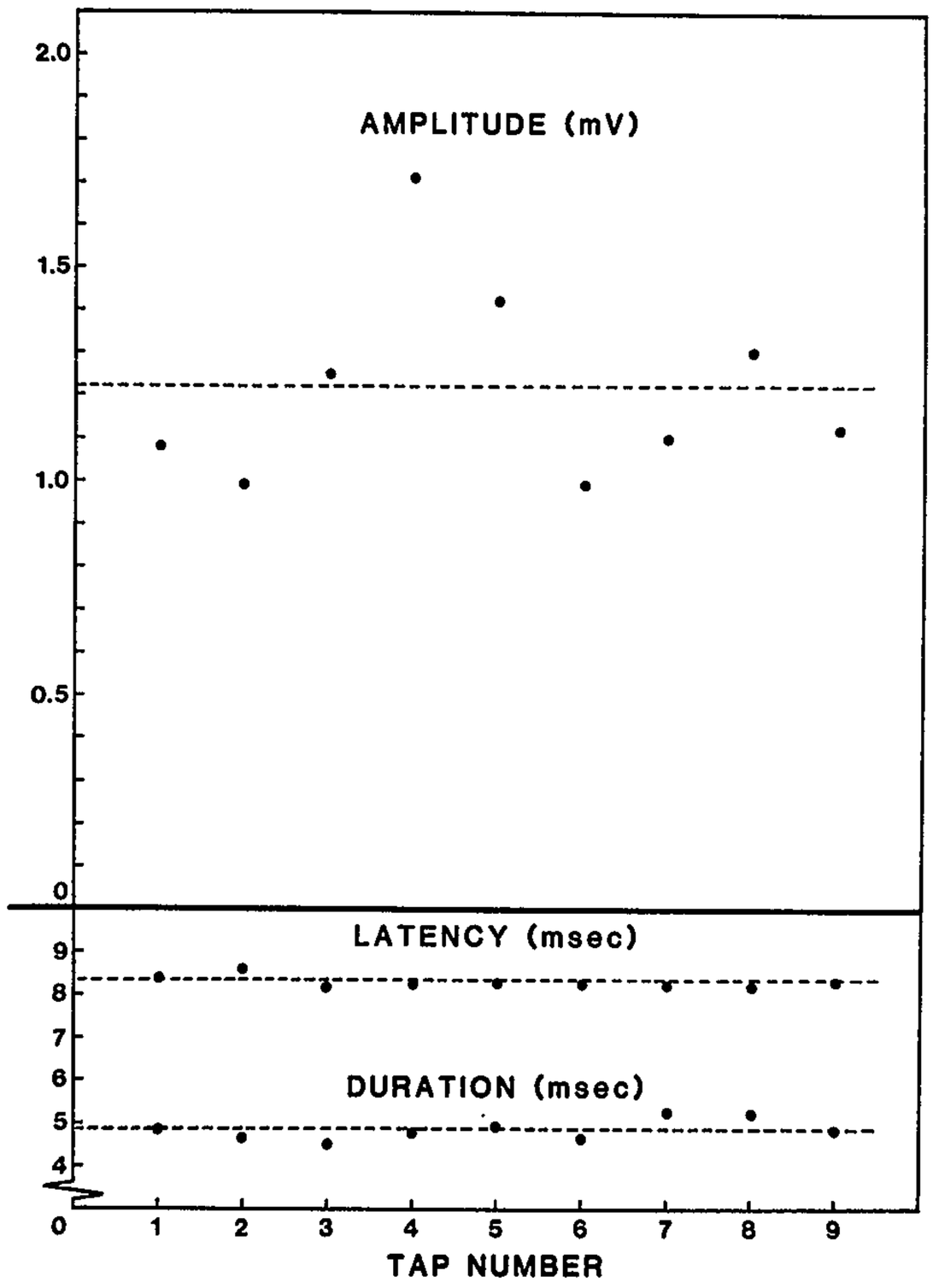


Table 2. Composite table listing forces and rates of change of forces that were calculated to be imparted to the menton region from the chin-tapping system in a representative subject.

1.

Time(msec)	Force(N)	Rate of Force Change($Nmsec^{-1}$)
4.11	0.99	0.19
4.52	1.07	0.23
4.86	1.15	0.24
5.21	1.23	0.25
5.47	1.30	0.38
5.72	1.39	0.34
6.09	1.52	0.45
6.31	1.62	0.62
6.57	1.78	0.45
6.84	1.90	0.62
7.11	2.06	0.68
7.33	2.21	0.45
7.60	2.33	0.24
7.87	2.40	0.16
8.16	2.44	0.03
8.36	2.45	-0.21
8.70	2.38	
MAX	2.45	0.68

2.

Time(msec)	Force(N)	Rate of Force Change($Nmsec^{-1}$)
4.01	0.99	0.14
4.25	1.03	0.10
4.47	1.05	0.20
4.72	1.10	0.27
5.01	1.17	0.27
5.30	1.25	0.18
5.60	1.31	0.38
5.79	1.38	0.39
6.09	1.50	0.32
6.35	1.58	0.42
6.55	1.66	0.42
6.72	1.73	0.39
6.99	1.84	0.45
7.21	1.94	0.34
7.58	2.06	0.35
7.77	2.13	0.26
7.94	2.17	0.25
8.16	2.23	0.00
8.53	2.23	
MAX	2.23	0.45

4.

Time(msec)	Force(N)	Rate of Force Change($Nmsec^{-1}$)
4.45	0.99	0.24
4.79	1.08	0.20
5.18	1.15	0.21
5.52	1.22	0.30
5.87	1.33	0.30
6.18	1.42	0.31
6.57	1.54	0.33
6.87	1.64	0.36
7.09	1.72	0.26
7.43	1.81	0.20
7.70	1.86	0.23
7.89	1.91	0.03
8.09	1.91	
MAX	1.91	0.36

5.

Time(msec)	Force(N)	Rate of Force Change ($Nmsec^{-1}$)
4.62	0.99	0.04
5.01	1.01	0.17
5.43	1.08	0.18
5.77	1.14	0.23
6.16	1.23	0.24
6.52	1.32	0.28
6.82	1.40	0.32
7.06	1.48	0.27
7.33	1.55	0.24
7.58	1.61	0.25
7.82	1.67	0.14
8.09	1.71	0.12
8.28	1.73	0.02
8.90	1.74	
MAX	1.74	0.32

6.

Time(msec)	Force(N)	Rate of Force Change ($Nmsec^{-1}$)
4.79	0.99	0.11
4.94	1.01	0.20
5.21	1.06	0.11
5.52	1.10	0.20
5.79	1.15	0.11
6.18	1.20	0.20
6.50	1.26	0.13
6.79	1.30	0.31
7.01	1.36	0.30
7.28	1.45	0.18
7.60	1.50	0.24
7.87	1.57	0.12
8.14	1.60	0.10
8.36	1.62	0.13
8.53	1.64	-0.06
8.72	1.63	
MAX	1.64	0.31

7.

Time(msec)	Force(N)	Rate of Force Change ($Nmsec^{-1}$)
4.57	0.99	0.09
4.94	1.03	0.13
5.47	1.10	0.16
6.04	1.19	0.24
6.52	1.30	0.19
7.21	1.44	0.18
7.72	1.53	0.07
8.09	1.56	0.06
8.38	1.57	0.03
8.55	1.58	-0.07
9.38	1.52	
MAX	1.58	0.24

9.

Time(msec)	Force(N)	Rate of Force Change ($Nmsec^{-1}$)
4.81	0.99	0.13
5.25	1.05	0.11
5.79	1.11	0.22
6.09	1.17	0.21
6.33	1.22	0.20
6.65	1.28	0.23
6.92	1.35	0.21
7.21	1.41	0.19
7.50	1.46	0.13
7.77	1.50	0.14
7.97	1.52	0.02
8.19	1.52	
MAX	1.52	0.23

$1.4cm^2$ and thus stresses generated through the plate ranged from $1.07Ncm^{-2}$ to $1.79Ncm^{-2}$.

As part of the first experimental series, groups of perturbations were delivered to the menton region at different settings of the plunger system that were each shown to impart different levels of force. In the second and third experimental series, the plunger system was fixed at a constant setting for all subjects. This corresponded to a maximum force delivery, as assessed previously, of 1.74N.

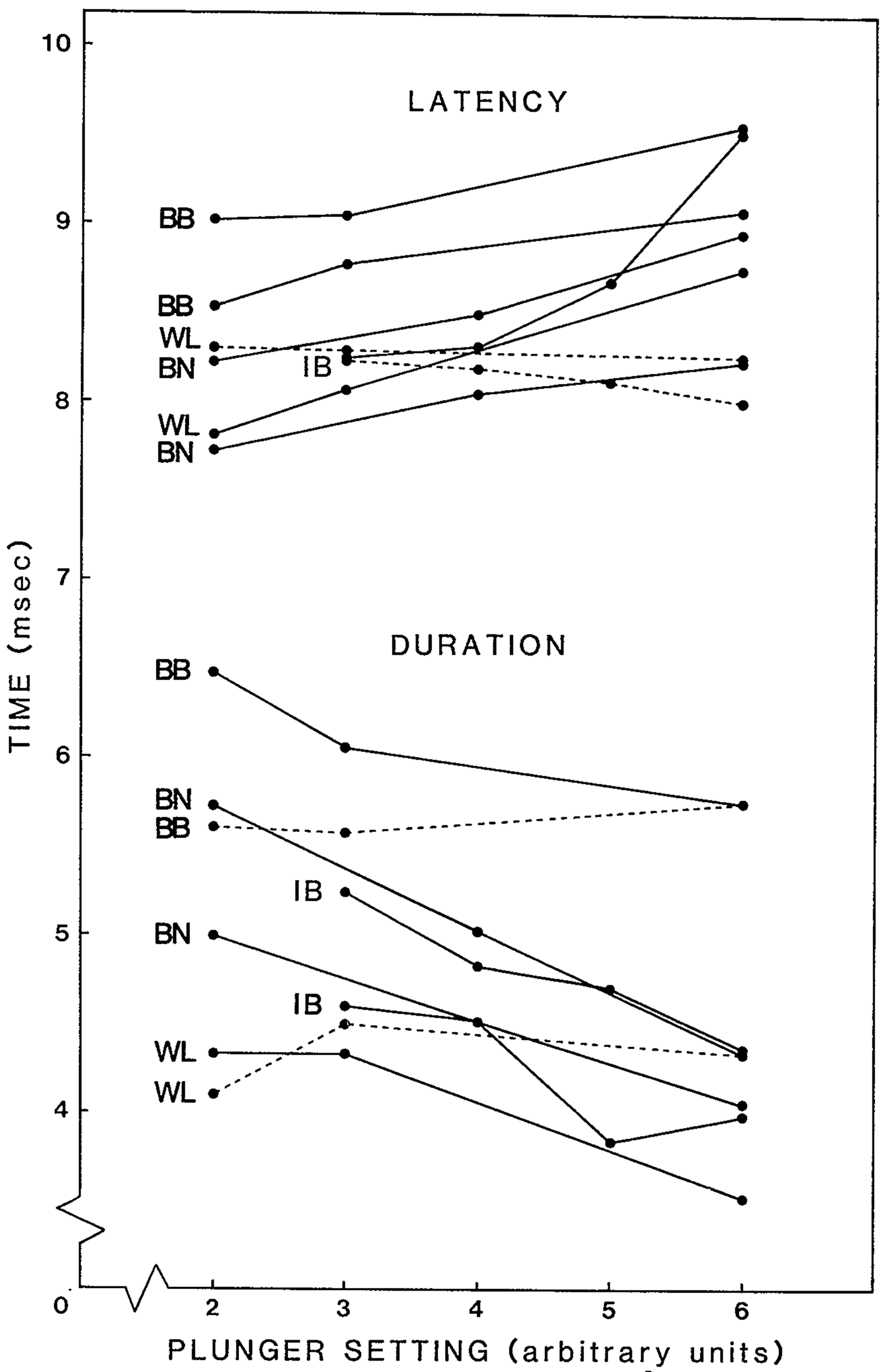
Therefore, in this first series, mean latency, duration and amplitude values were plotted against relative tap force intensity for each muscle in each of the four individuals. For latency (Figure: 15a), six of the eight muscles studied demonstrated significant negative trends with no trend evident in two muscles. Significant positive trends between duration and tap force (Figure: 15a) were evident for six of the eight muscles with none in two muscles. Mean amplitude values (Figure: 15b) demonstrated positive trends in all muscles studied.

The degree of linearity of the tracking system assessed at various distances between light source and light sensor is illustrated in Figure: 16. There is only a slight deviation from linearity at each particular

FIGURES: 15a and 15b

FIGURES: 15a and 15b

Mean latency and duration (a) and amplitude (b) values plotted against plunger setting for both muscles in each of four individuals (BB, WL, IB, BN). A significant trend is indicated by a continuous line; an interrupted line indicates no significant trend.


LATENCY
DURATION
BB
BB
WL
BN
IB
WL
BN
BB
BN
BB
IB
BN
IB
WL
WL
10
9
8
7
6
5
4
0
2
3
4
5
6
TIME (msec)
PLUNGER SETTING (arbitrary units)

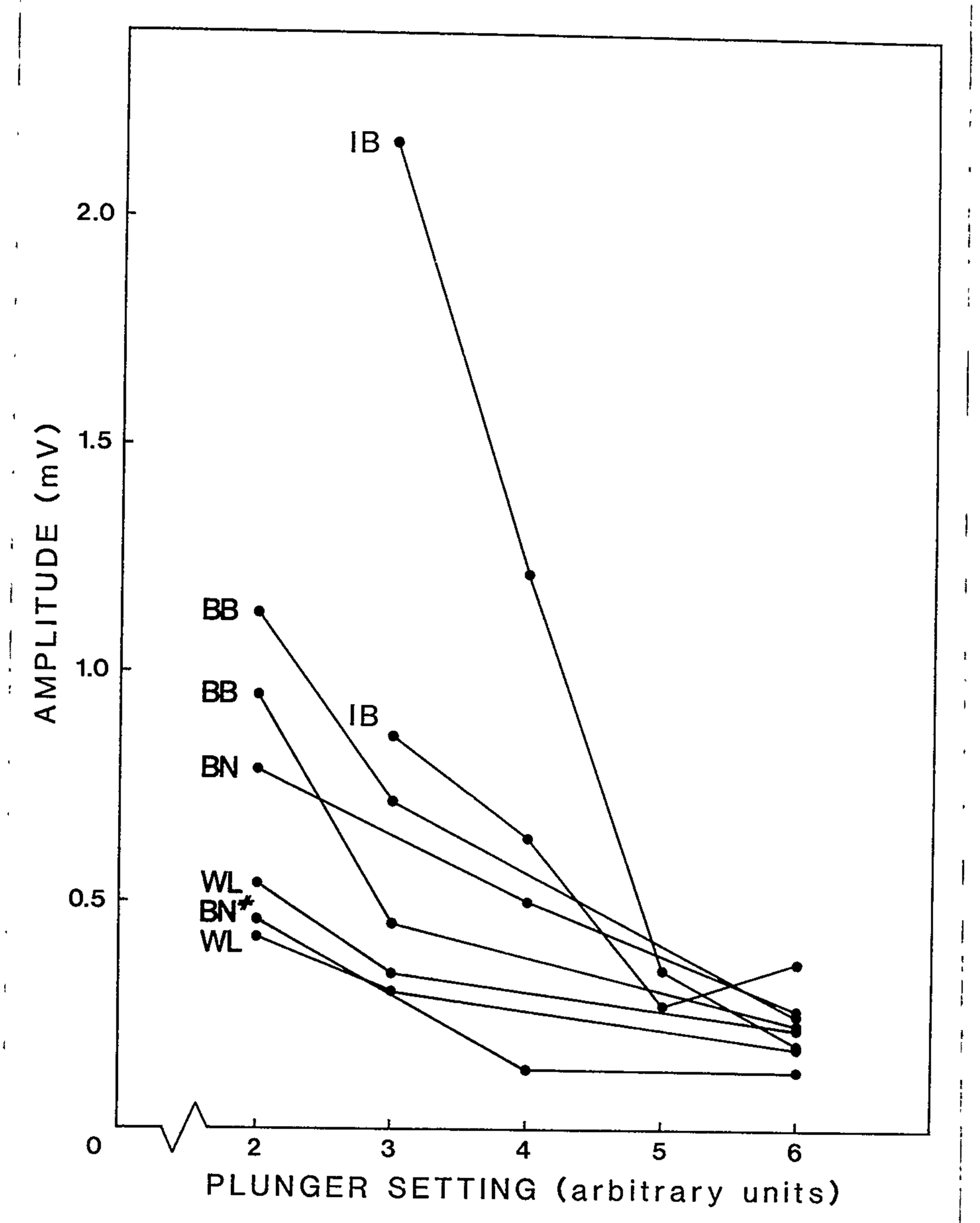
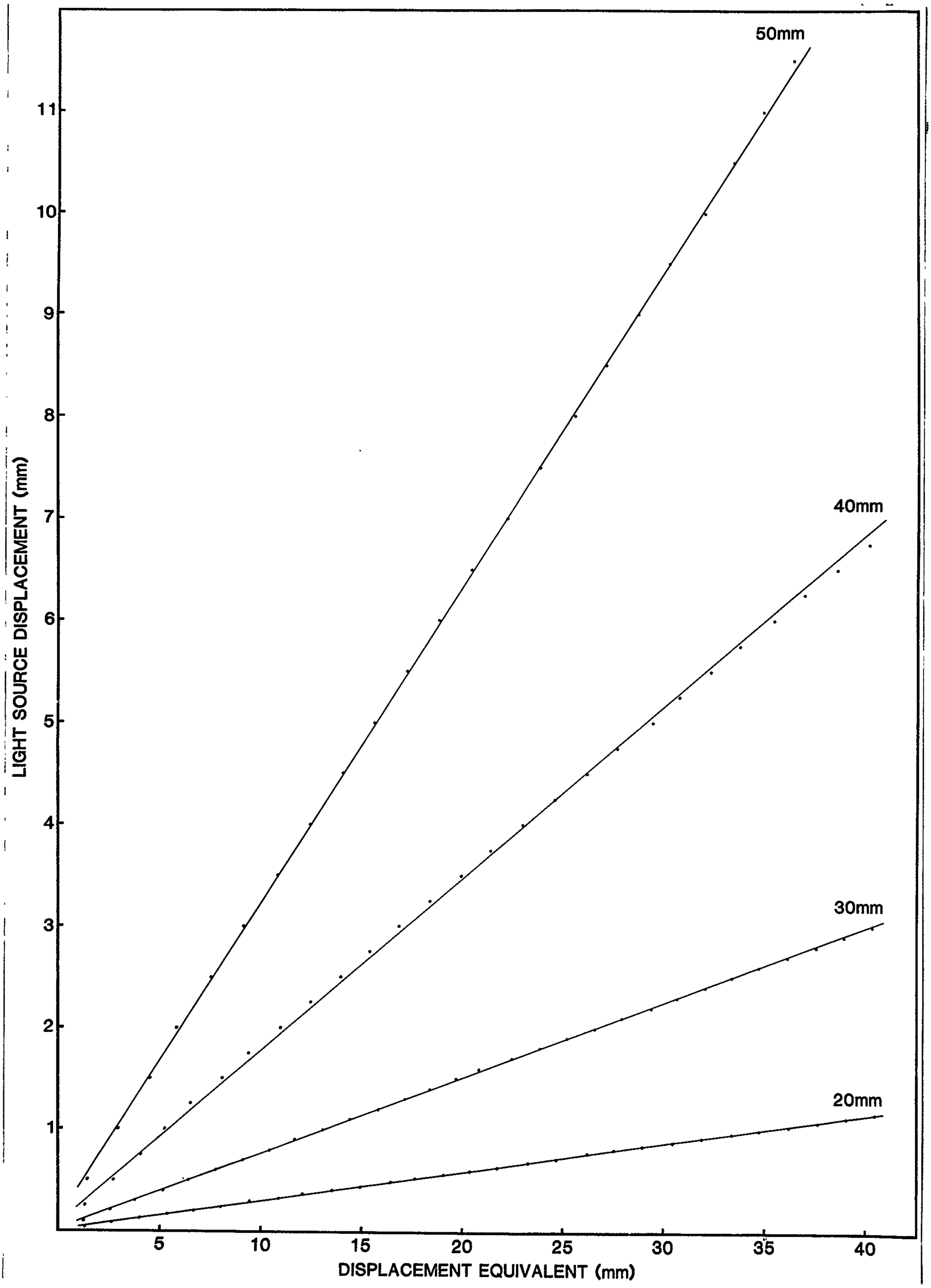

AMPLITUDE (mV)
2.0
1.5
1.0
0.5
0
IB
BB
BB
IB
BN
WL
BN*
WL
2
3
4
5
6
PLUNGER SETTING (arbitrary units)

FIGURE: 16

FIGURE: 16

Results of laboratory calibration of opto-electronic tracking system (see Figure: 8). Straight lines of best fit relating incremental displacements of the light source in the vertical plane with the associated displacement equivalent as derived from the light sensor. Relationships were assessed at four separate distances between light source and sensor: 20 mm, 30 mm, 40 mm, and 50 mm. The light sensor was usually positioned at between 40 mm and 50 mm from the light source on the subject. The high degree of linearity of the tracking system is indicated by the close approximation of the readings to a straight line.


50mm
40mm
30mm
20mm
LIGHT SOURCE DISPLACEMENT (mm)
DISPLACEMENT EQUIVALENT (mm)
1
2
3
4
5
6
7
8
9
10
11
5
10
15
20
25
30
35
40

distance between light source and sensor (correlation coefficients being all 0.99) as shown by the close approximation of the straight lines of best fit with the individual readings.

In the second experimental series, stimuli were delivered to a total of thirty-two subjects, of which twenty-five (78 per cent) exhibited measurable jaw-closing reflexes that were able to be readily elicited from the masseter muscles on both sides. In the remainder, the response was not clearly discernible above background noise; thus in some subjects a small disturbance in the baseline electromyographic level was noted but which could not be satisfactorily measured whilst in others, no apparent modulation was identified (Figure: 17). Immediately following chin tap and before the evoked electromyogram is an oscillation in the baseline which occurs quite distinct from the evoked reflex response and which appears to reflect movement artefact (Figure: 13f, g and h; 17).

Mechanical taps delivered to the menton region at constant force setting evoked consistent output parameters. Five consecutive superimposed tracings of jaw displacement, plunger travel and the evoked jaw-closing reflex elicited at a constant force setting are illustrated in Figure: 13d. The uniformity of jaw displacement (middle trace), plunger

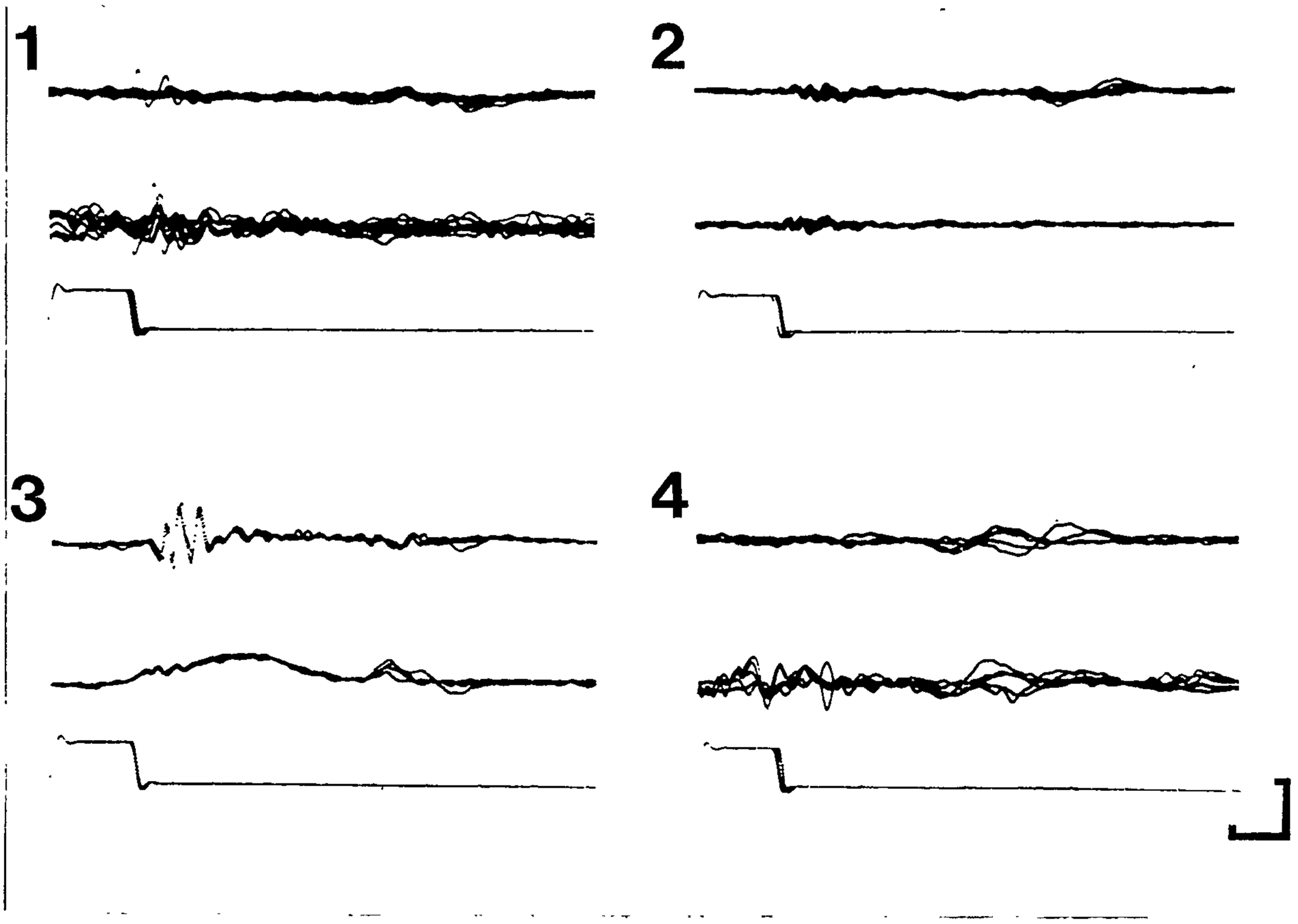


FIGURE: 17

Traces of the electromyogram recorded from the right masseter (upper trace in each group of traces) and left masseter (middle trace in each group of traces) in four subjects (1,2,3, and 4) exhibiting a negligible or poor jaw-closing reflex response to chin tap stimuli. Calibration: vertical bar represents the following voltage magnitudes for the right and left masseter muscle in each group of traces - group 1: 0.02 mV; groups 2,3 and 4: 0.01 mV. Horizontal bar: 2 msec for all traces.

travel (lower trace) and jaw-closing reflex latency, duration and amplitude (upper trace) at consecutive standardised taps contrasts with the variability in the corresponding traces evoked under non-standardised conditions (Figure: 13e). Jaw-closing reflex responses evoked within a subject at one recording session exhibited latency, duration and amplitude characterised by low standard deviation values (Tables: 3, 4 and 5). However, under these apparently standardised conditions, reflex responses with the same absolute numerical values were not consistently evoked between taps within a subject or between subjects.

The degree of variability about a mean is illustrated graphically where individual values for jaw-closing reflex latency, duration and amplitude were plotted against the particular sequence in a series of taps (Figure: 14d). Individual values demonstrate a fairly narrow band of random scatter about a mean value. In addition, reproducibility of jaw-closing reflex parameters as reflected by the size of the standard deviation values was not necessarily the same magnitude, relative to the mean, between subjects or between sides. For example, mean and standard deviation latency values for subject NS from group A were 9.29±0.05msec for the right masseter and 8.99±0.34msec for the left masseter. A visual display of jaw-closing reflex amplitude in one subject shows

Table 3. Mean and standard deviation values for jaw-closing reflex latency for the right and left masseter muscles in ten subjects without evidence of muscle-joint dysfunction (group A); ten subjects with mild to moderate evidence (group B); and five patients with moderate to severe dysfunction (group C).

Subject	Jaw-closing reflex latency (msec)		Difference between mean values	Significance of difference between sides
	R. Masset.	L. Masset.		
Group A				
1. MB	8.15(0.38)*	7.85(0.52)	0.30	p>0.05
2. SdeB	8.10(0.17)	7.99(0.12)	0.11	p>0.05
3. MC	8.46(0.46)	8.38(0.27)	0.08	p>0.05
4. DH	9.56(0.18)	9.29(0.29)	0.27	0.05>p>0.025
5. GH	8.52(0.28)	8.13(0.27)	0.39	0.001>p
6. WL	8.26(0.59)	8.74(0.39)	0.48	p>0.05
7. RS	8.49(0.46)	8.10(0.33)	0.39	0.05>p>0.025
8. NS	9.29(0.05)	8.99(0.34)	0.30	p>0.05
9. AT	8.33(0.28)	8.45(0.39)	0.12	p>0.05
10. DW	7.82(0.20)	7.97(0.38)	0.15	p>0.05
Mean of means for Group A	8.45(0.47)	8.39(0.48)	0.26(0.14)	p>0.05
Group B				
1. BB	9.60(0.36)	9.13(0.25)	0.47	0.05>p>0.025
2. PB	9.65(0.71)	8.91(0.34)	0.74	0.025>p>0.01
3. SB	10.08(0.58)	9.44(0.53)	0.64	0.01>p>0.001
4. JB	8.20(0.35)	7.33(0.67)	0.87	0.025>p>0.01
5. RC	8.41(0.31)	7.90(0.46)	0.51	0.01>p>0.001
6. RH	8.32(0.52)	7.70(0.36)	0.62	0.025>p>0.01
7. JL	8.75(0.31)	7.92(0.29)	0.83	0.001>p
8. RL	9.02(0.79)	7.86(0.44)	1.16	0.001>p
9. JM	7.80(0.12)	6.95(0.18)	0.85	0.001>p
10. OS	10.99(0.20)	10.38(0.53)	0.61	0.001>p
Mean of means for Group B	9.08(0.99)	8.35(1.07)	0.73(0.21)	p>0.05
Group C				
1. LB	9.05(0.22)	8.54(0.21)	0.51	0.001>p
2. MC	11.16(0.66)	9.37(0.18)	1.79	0.001>p
3. MH	8.43(0.12)	7.36(0.57)	1.07	0.001>p
4. PL	8.25(0.22)	7.73(0.33)	0.52	0.001>p
5. DO	7.94(0.20)	8.52(0.17)	0.58	0.001>p
Mean of means for Group C	8.97(1.29)	8.30(0.78)	0.89(0.55)	p>0.05
Mean of means for groups A, B and C	8.83(0.91)	8.36(0.79)	0.57(0.38)	p>0.05

* Values in parentheses are standard deviations
† Spiegel, 1961

Table 4. Mean and standard deviation values for jaw-closing reflex duration for the right and left masseter muscles in ten subjects without evidence of muscle-joint dysfunction (group A);ten subjects with mild to moderate evidence (group B); and five patients with moderate to severe dysfunction (group C).

Subject	Jaw closing reflex duration(msec)		Difference between mean values	Significance of difference †
	Right Masseter	Left Masseter		
Group A				
1. MB	4.61(0.20)*	4.33(0.44)	0.28	p>0.05
2. SdeB	4.93(0.32)	5.12(0.25)	0.19	p>0.05
3. MC	4.32(0.39)	3.70(0.36)	0.62	0.01>p>0.001
4. DH	4.71(0.43)	4.37(0.15)	0.34	p>0.05
5. GH	6.86(0.13)	6.22(0.25)	0.64	0.001>p
6. WL	4.38(0.70)	3.51(0.52)	0.87	0.05>p>0.025
7. RS	6.02(0.51)	6.13(0.54)	0.11	p>0.05
8. NS	3.84(0.31)	3.66(0.27)	0.18	p>0.05
9. AT	5.25(0.58)	5.42(0.76)	0.17	p>0.05
10. DW	5.22(0.18)	4.34(0.47)	0.88	0.001>p
Mean of means for Group A	5.01(0.88)	4.68(1.00)	0.43(0.30)	p>0.05
Group B				
1. BB	5.76(0.23)	5.75(0.42)	0.01	p>0.05
2. PB	5.21(0.71)	5.40(0.33)	0.19	p>0.05
3. SB	4.66(0.37)	4.43(0.58)	0.23	p>0.05
4. JB	4.79(0.61)	5.45(0.83)	0.66	p>0.05
5. RC	4.43(0.23)	4.66(0.57)	0.23	p>0.05
6. RH	4.41(0.65)	4.80(0.25)	0.39	p>0.05
7. JL	4.81(0.46)	4.94(0.36)	0.13	p>0.05
8. RL	3.81(0.74)	4.29(0.25)	0.48	p>0.05
9. JM	4.13(0.16)	3.73(0.33)	0.40	0.025>p>0.01
10. OS	3.23(0.33)	4.21(0.37)	0.98	0.001>p
Mean of means for Group B	4.52(0.71)	4.77(0.63)	0.37(0.28)	p>0.05
Group C				
1. LB	4.05(0.46)	4.63(0.33)	0.58	0.025>p>0.01
2. MC	3.73(0.65)	4.33(0.30)	0.60	p>0.05
3. MH	4.49(0.14)	5.33(0.63)	0.84	0.001>p
4. PL	4.71(0.17)	4.65(0.18)	0.06	p>0.05
5. DO	5.23(0.24)	4.35(0.20)	0.88	0.001>p
Mean of means for Group C	4.44(0.58)	4.66(0.40)	0.59(0.33)	p>0.05
Mean of means for Groups A, B and C	4.70(0.78)	4.71(0.74)	0.44(0.30)	p>0.05

* Values in parentheses are standard deviation
† Spiegel, 1961

Table 5. Mean and standard deviation values for jaw-closing reflex amplitude for the right and left masseter muscles in ten subjects without evidence of muscle-joint dysfunction (group A); ten subjects with mild to moderate evidence (group B); and five patients with moderate to severe dysfunction (group C).

Subject	Jaw-closing reflex amplitude(mV)		Difference between mean values	Significance of difference†
	Right Masseter	Left Masseter		
Group A				
1. MB	0.66(0.15)	0.38(0.20)	0.28	0.01>p>0.001
2. SdeB	0.53(0.31)	0.74(0.28)	0.21	p≫0.05
3. MC	0.14(0.06)	0.19(0.05)	0.05	p>0.05
4. DH	0.15(0.07)	0.15(0.03)	0.00	p>0.05
5. GH	1.06(0.18)	1.46(0.46)	0.40	0.025>p>0.01
6. WL	0.22(0.13)	0.18(0.04)	0.04	p>0.05
7. RS	0.35(0.05)	0.35(0.08)	0.00	p>0.05
8. NS	0.12(0.03)	0.15(0.05)	0.03	p>0.05
9. AT	0.23(0.08)	0.15(0.06)	0.08	0.01>p>0.001
10. DW	0.33(0.07)	0.79(0.49)	0.46	0.025>p>0.01
Mean of means for Group A	0.38(0.30)	0.45(0.43)	0.16(0.17)	p>0.05
Group B				
1. BB	0.23(0.06)	0.25(0.10)	0.02	p>0.05
2. PB	0.31(0.12)	0.56(0.18)	0.25	0.01>p>0.001
3. SB	0.26(0.11)	0.58(0.21)	0.32	0.001>p
4. JB	0.07(0.02)	0.18(0.07)	0.11	0.001>p
5. RC	0.83(0.34)	0.32(0.10)	0.51	0.001>p
6. RH	0.17(0.13)	1.13(0.64)	0.96	0.01>p>0.001
7. JL	0.43(0.17)	0.65(0.21)	0.22	0.01>p>0.001
8. RL	0.20(0.08)	0.35(0.13)	0.15	0.01>p>0.001
9. JM	0.69(0.20)	0.48(0.17)	0.21	p>0.05
10. OS	0.13(0.02)	0.13(0.04)	0.00	p>0.05
Mean of means for Group B	0.33(0.25)	0.46(0.29)	0.28(0.28)	p>0.05
Group C				
1. LB	0.45(0.16)	1.53(0.62)	1.08	0.001>p
2. MC	0.07(0.01)	0.13(0.05)	0.06	0.025>p>0.01
3. MH	1.56(0.50)	0.82(0.52)	0.74	0.025>p>0.01
4. PL	1.05(0.24)	0.62(0.21)	0.43	0.01>p>0.001
5. DO	0.39(0.10)	0.19(0.07)	0.20	0.001>p
Mean of means for Group C	0.70(0.60)	0.66(0.57)	0.50(0.41)	p>0.05
Mean of means for Groups A, B and C	0.43(0.37)	0.50(0.40)	0.27(0.29)	p>0.05

* values in parentheses are standard deviations
† Spiegel, 1961

greater variability in the right masseter than on the left side (Figure: 13i). Thus even though standardised reproducible stimuli were delivered in each subject, this did not necessarily result in identical reflex responses in different individuals or reflex responses exhibiting identical levels of consistency either in different individuals or in different masseter muscles in the same subject. In addition, when pooling results for all individuals in each group, the variation in each evoked parameter was more marked, especially for amplitude, where the standard deviation was mostly higher than the individual subject results.

3.1 Latency

Highly significant differences in latency values between sides were identified in all subjects exhibiting clinical evidence of muscle-joint pain (groups B and C; Table: 3; Table: 6). A representative series of traces in one subject from group B is illustrated in Figure: 13i, the upper trace of which, representing the right masseter, shows a longer jaw-closing reflex latency than for the left masseter in the lower trace. This contrasted with the results obtained from subjects lacking clinical evidence of muscle-joint dysfunction (group A) in which latency

JAW-CLOSING REFLEX PARAMETER	GROUP	TOTAL NUMBER OF SUBJECTS	PERCENTAGE OF SUBJECTS WITH DIFFERENCES BETWEEN SIDES BEING SIGNIFICANT AT THE 95% LEVEL
LATENCY	A	10	30%
	B	10	100%
	C	5	100%
DURATION	A	10	40%
	B	10	20%
	C	5	60%
AMPLITUDE	A	10	40%
	B	10	70%
	C	5	100%

TABLE: 6

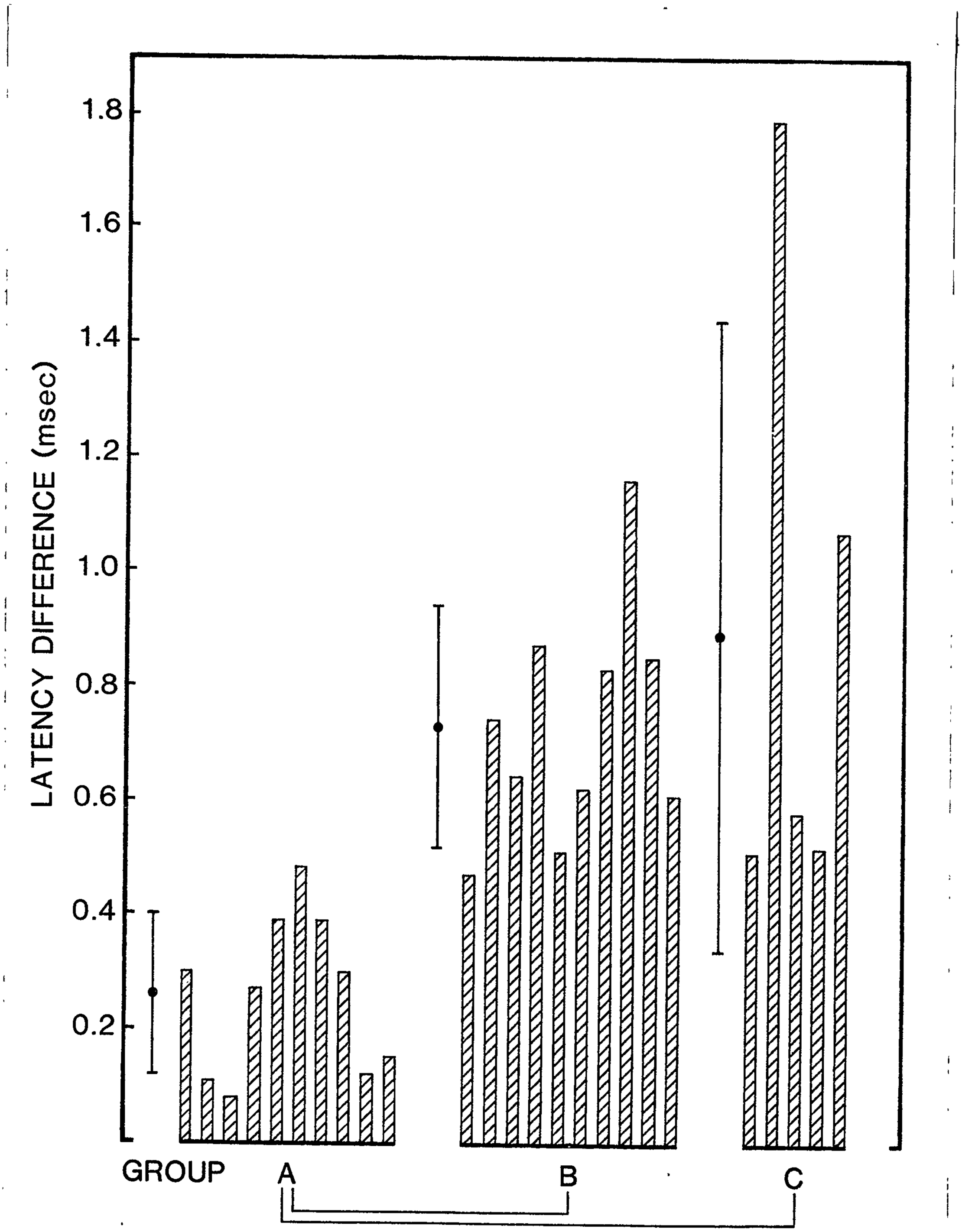
SUMMARY OF DIFFERENCES BETWEEN SIDES FOR EACH JAW-CLOSING REFLEX PARAMETER AND EACH GROUP

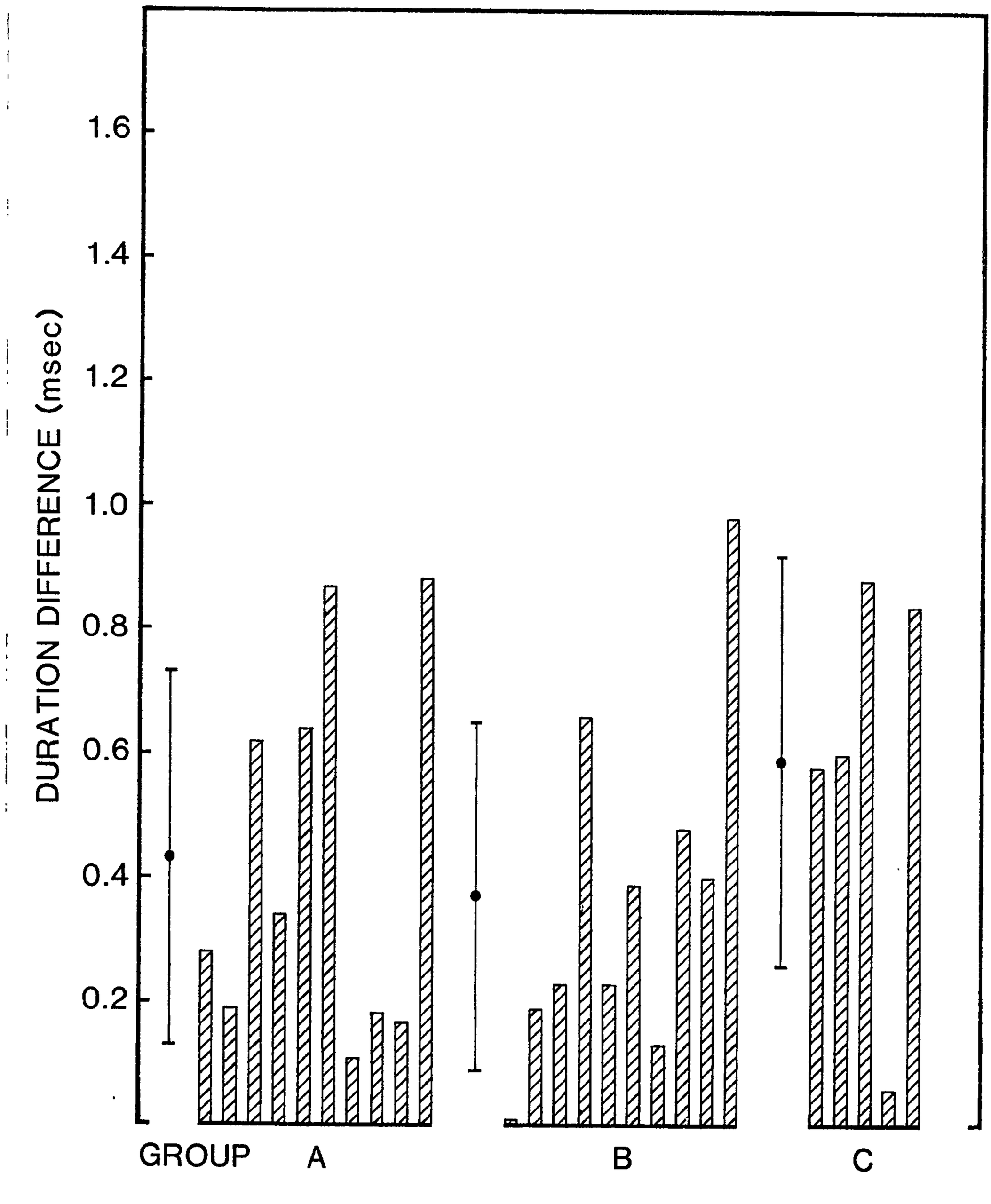
values between sides were more nearly equal in seven out of ten subjects (Table: 3). For each subject, the mean value obtained for latency on one side was subtracted from the corresponding value of the other side. These values were then plotted for each subject within a group and are represented graphically in Figure: 18. The mean difference in each group was calculated and the presence of significant differences amongst groupings assessed. The mean value of the difference between the latencies on both sides for group A was 0.26±0.14msec (range: 0.08 to 0.48msec) which was highly significantly different ($p < 0.001$) from the corresponding value of 0.73±0.21msec (range: 0.47 to 1.61msec) for group B, and 0.89±0.55msec (range: 0.51 to 1.79msec) for group C. Differences between groups identified as being significant at the ninety-five per cent level are indicated by lines joining the respective groups in each graph (Figure: 18). However, when the average mean latency value on the right side for all subjects in group A was compared with the corresponding mean value on the left side, the difference observed was not significant at the ninety-five per cent level (Table: 3). This submergence of significant differences between sides with the calculation of mean values for a group was also apparent with the averaging of latencies on either side in group B, in group C and in the three groups together (Table: 3). The maximum and minimum values recorded from any subject for jaw-

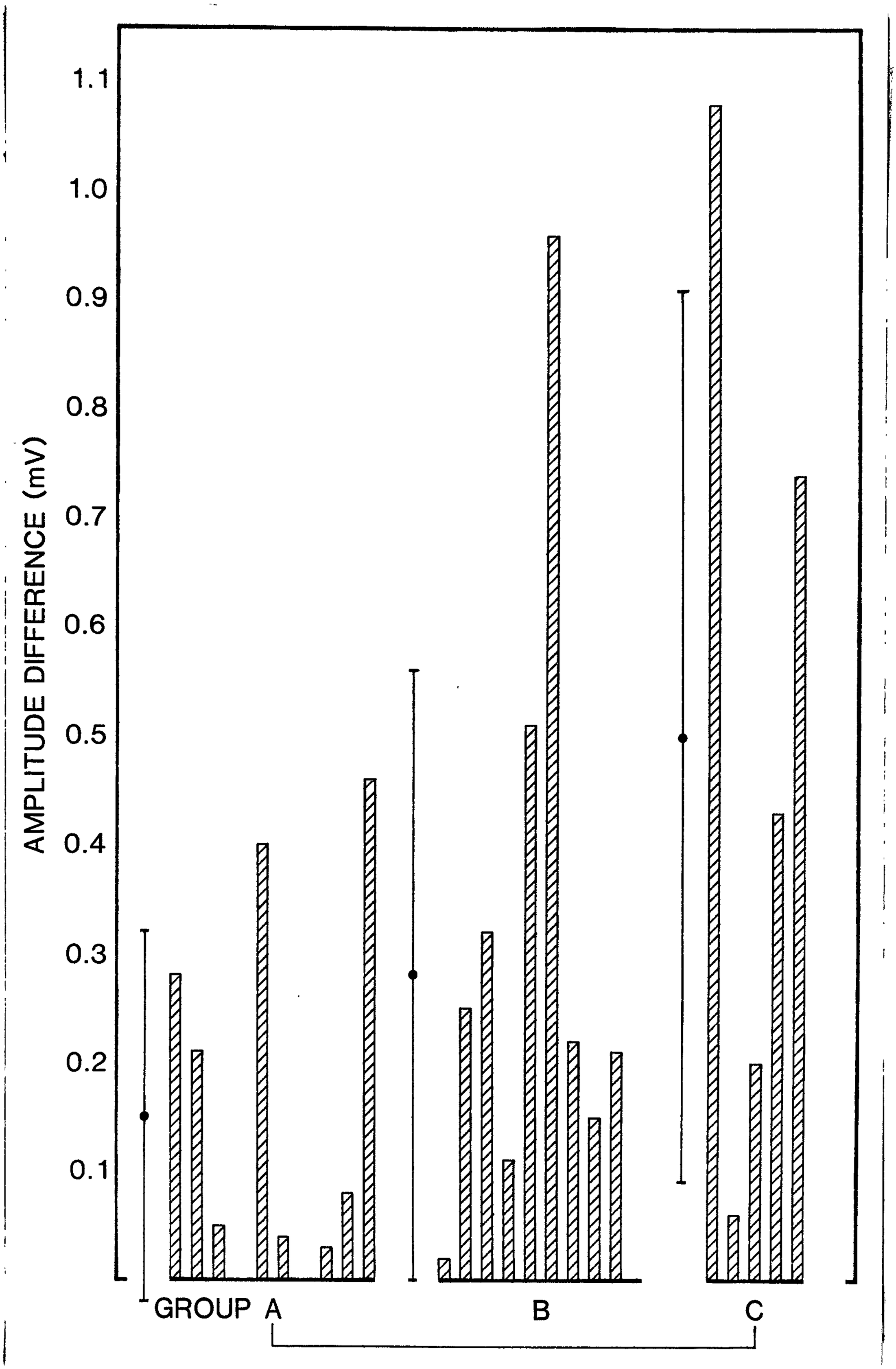
FIGURES: 18, 19 and 20

FIGURES: 18, 19 and 20

For each subject, the mean value obtained for each jaw-closing reflex parameter on one side was subtracted from the corresponding value of the other side. These values have been plotted for each subject within a group and are represented graphically in Figure: 18 (latency differences), Figure: 19 (duration differences) and Figure: 20 (amplitude differences). The mean difference in each group for each parameter was calculated and the presence of significant differences amongst groupings assessed. Differences between groups identified as being significant at the ninety-five per cent level are indicated by lines joining the respective groups in each graph.


LATENCY DIFFERENCE (msec)
1.8
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
GROUP
A
B
C


DURATION DIFFERENCE (msec)
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
GROUP
A
B
C


AMPLITUDE DIFFERENCE (mV)
1.1
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
GROUP A
B
C

closing reflex latency were 11.73msec and 6.40msec, respectively.

3.2 Latency Adjustment Factor

In several subjects a latency adjustment factor was assessed which represents the time difference between the moment the plunger struck the chin plate resting on the subject's chin and the commencement of jaw movement during the delivery of stimuli at a fixed setting of the plunger system (Table: 7). The mean values ranged from 1.08 to 2.36msec with an overall mean value of 1.63msec. Using this mean value as a correction factor, the corrected mean values for jaw-closing reflex latency for right and left masseter muscles in group A were: 6.82±0.47msec, 6.76±0.48msec; in group B: 7.45±0.99msec, 6.72±1.07msec; in group C: 7.34±1.29msec, 6.67±0.78msec; and in the three groups together were: 7.20±0.91msec, 6.73±0.79msec, respectively; and the corrected maximum and minimum values respectively, recorded from any subject for jaw-closing reflex latency (adjusted values) were: 10.10msec and 4.77msec.

Table 7. Latency adjustment factors: the time difference values between the moment of plunger - chin plate contact and the commencement of jaw displacement in ten subjects.

Subject	Mean latency adjustment factor (msec)
PB	1.66
CF	1.78
JL	1.10
WL	1.08
JM	1.67
KC	1.65
RL	1.79
MW	1.45
DW	1.71
RS	2.36
Mean of means	1.63 ± 0.37 msec

3.3 Duration

The maximum and minimum values recorded from any subject for jaw-closing reflex duration were: 7.00msec and 2.40msec, respectively. Four subjects in group A, two subjects in group B and three subjects in group C exhibited a significant difference between sides (Table: 4; Table: 6). As for latency, the mean duration value for the right side in each subject was subtracted from the corresponding value on the left side. Differences are listed in Table: 4 and plotted in Figure: 19. The mean value of the difference in duration between right and left sides in group A was not significantly different from that value for group B or for group C (Table: 4).

3.4 Amplitude

Amplitude values from four out of ten subjects in group A, seven out of ten subjects in group B and five out of five subjects in group C demonstrated significant differences between sides (Table: 5; Table: 6). These differences, however, were not apparent in the remaining subjects. Although comparisons of amplitude data between sides were not strongly indicative of a particular

group, there were more subjects in the dysfunction groups (groups B and C) than in the non-dysfunction group (four out of ten) exhibiting significantly different amplitude values between sides (Table: 6). As for latency and duration, the mean amplitude value on one side in each subject was subtracted from the corresponding value of the opposite side (Figure: 20). The resultant mean amplitude differences were significant between groups A and C only. Overall differences between sides for individual groups and the entire sample were not significant. The maximum and minimum values recorded from any subject for jaw-closing reflex amplitude were 2.44mV and 0.03mV, respectively.

3.5 Correlations

Tests for correlations between latency and duration, latency and amplitude, and duration and amplitude for the right and left masseter in group A and group B individually and both groups together are listed in Table: 8. Latency and duration exhibited a negative correlation in six out of eight tests but these were significant at the ninety-five per cent level in three tests only. Negative correlations were evident between latency and amplitude bilaterally with four of the correlations being significant

Table 8. Correlations† and significance‡ between the mean values of the three jaw-closing reflex parameters for each masseter muscle in each group and the three groups combined.

Parameters†		Right Masseter		Left Masseter	
		r	Significance	r	Significance
JJL and JJD	Group A	-0.13	p>0.05	-0.36	p>0.05
	Group B	-0.15	p>0.05	0.09	p>0.05
	Group C	-0.87	0.05>p>0.02*	-0.83	0.05>p>0.02*
	Groups A, B &C	-0.37	0.02>p>0.01*	0.02	p>0.05
JJL and JJA	Group A	-0.29	p>0.05	-0.51	0.052>p>0.02*
	Group B	-0.45	0.05>p>0.02*	-0.28	p>0.05
	Group C	-0.58	p>0.05	- 0.33	p>0.05
	Groups A, B &C	-0.39	0.01>p>0.0001*	-0.32	0.05>p>0.02*
JJD and JJA	Group A	0.71	0.001>p *	0.57	0.01>p>0.001*
	Group B	-0.004	p>0.05	-0.05	p>0.05
	Group C	0.32	p>0.05	0.44	p>0.05
	Groups A, B&C	0.26	p>0.05	0.34	0.02>p>0.01*

* Significant at the ninety-five per cent level

† JJL, JJD and JJA: jaw-closing reflex latency, duration and amplitude, respectively.

‡ Brown and Hollander, 1977

at the ninety-five per cent level. Duration and amplitude exhibited positive correlation coefficients in six of the eight tests of which three were significant at the ninety-five per cent level.

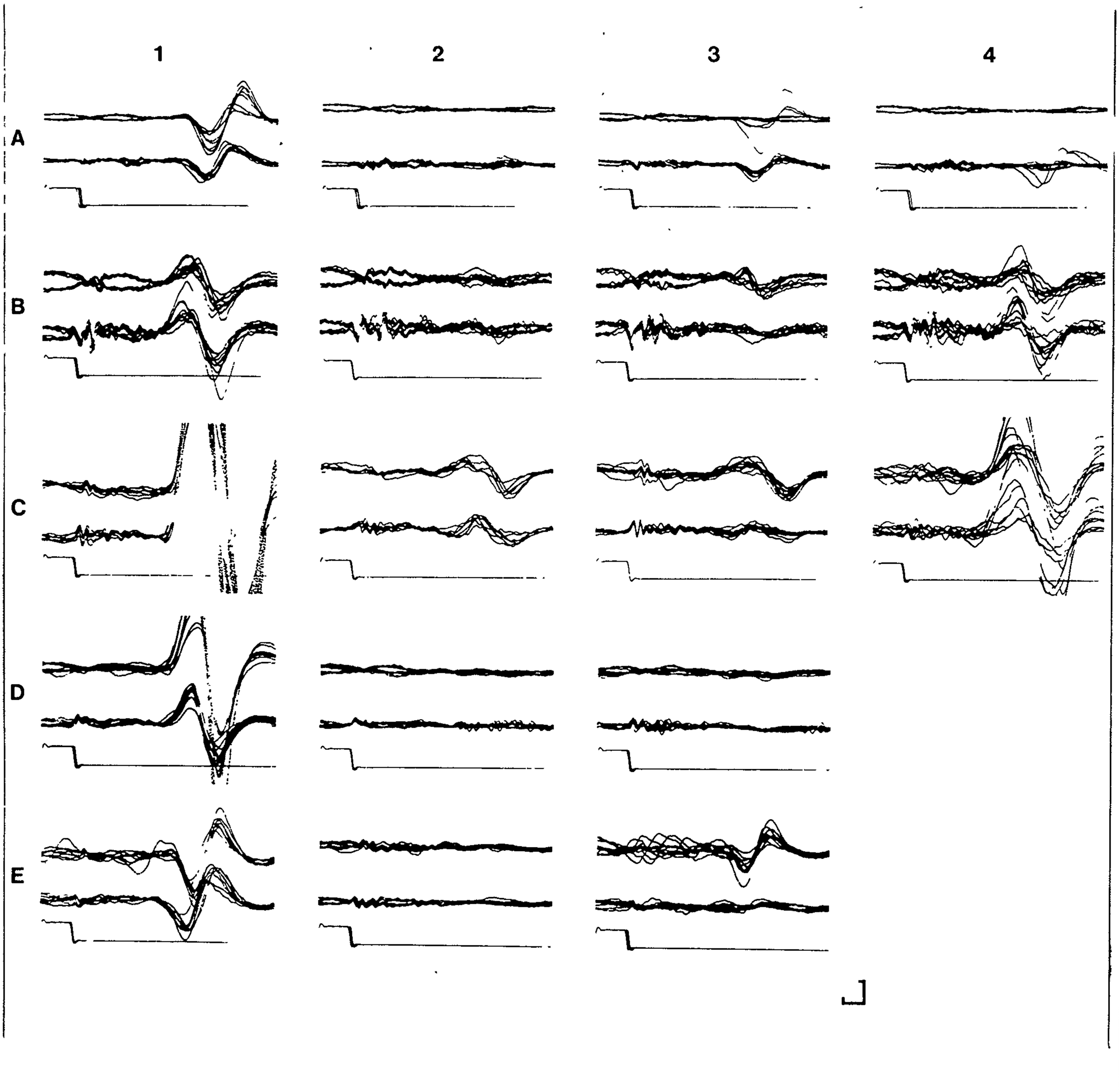
3.6 Chin Support

In the five subjects who supported their chin manually, the amplitude of the jaw-closing reflex, in comparison with that evoked at postural jaw position, was reduced bilaterally in each subject (Figure: 21 - A3, B3, C3 and E3), with a response not being detectable in one subject (Figure: 21 - D3). The jaw-closing reflex amplitude evoked at postural jaw position for the right masseter in subject A showed more variation than in the left masseter and this characteristic was also evident during chin support. However, the degree of variation appeared to be accentuated with no detectable responses being recorded during several trials, and then a large response amplitude was evoked of a magnitude similar to that at postural jaw position. In subject E, reflex amplitudes were roughly equal on both sides at postural position, however during subjective chin support, the response was slightly reduced on the right side but there was no response detectable in the left masseter.

FIGURE: 21

FIGURE: 21

Jaw-closing reflexes evoked in the right (R - upper trace in each display) and left (L - middle trace in each display) masseter muscles of five subjects (rows A,B,C,D and E): with the jaw at postural position (Column 1); with the upper and lower teeth rigidly luted together by acrylic and cyanoacrylate adhesive (Column 2); whilst the subject supported his jaw on the acrylic indices which were not cemented (Column 3); and with indices cemented and during the Jendrassik manoeuvre (Column 4). The lower trace in each display represents the stimulus timer. Calibration data: vertical bar represents the following voltage magnitudes for the right and left masseter muscles respectively in each subject: 0.08 mV and 0.11 mV for subjects A, C and E; 0.04 mV and 0.06 mV for subject B; and 0.10 mV and 0.11 mV for subject D. Horizontal bar - 2 msec for all traces.


1
2
3
4
A
B
C
D
E

With the teeth rigidly luted together at postural jaw position and with relaxed elevator muscles, a jaw-closing reflex was not demonstrable in five out of ten muscles (Figure: 21 - A2, right (R) side; D2, R and left (L) side; E2, R and L). A slight deflection of the baseline emg was observed in three muscles (Figure: 21 - A2, L; B2, R and L) which may represent movement artefact and/or a small jaw-closing reflex. Definite responses were demonstrable in one subject only and this on both sides (Figure: 21 - C2), however this subject also exhibited an unusually large reflex amplitude (1.26mV) for this series at postural jaw position. An oscillation of the light sensor was evident during chin taps at postural position (Figure: 13b) and during the chin support procedure (Figure: 13c).

The classic Jendrassik monoeuvre was carried out in three subjects. In two individuals (Figure: 21 - B4 and C4) the response evoked exhibited a larger amplitude than that during subjective chin support but was smaller than that at postural jaw position. In the other subject (Figure: 21 - A4) a response was not demonstrable in one muscle with a variable response in the other.

At no stage during the recording procedures was pain evoked and all subjects reported that the perturbations were not uncomfortable.

4. DISCUSSION

4. DISCUSSION

The monitoring of jaw-closing reflex parameters allows an insight into the excitability of the trigeminal motoneurone pool. This excitability reflects the level of central and peripheral facilitatory and inhibitory projections, the net effect of which may be modified by inputs from the orofacial area during function and with the development of dysfunctions. A standardised input should be used in eliciting responses in order that subtle variations in motoneurone excitability may be recorded if present. Under such conditions it may be possible to evaluate the effect of these various central and peripheral influences on excitability in the presence of muscle-joint pain dysfunction.

The solenoid-driven plunger system that has been described for eliciting jaw reflexes represents an improvement over both non-standardised and other standardised systems that have been referred to in the literature.

Non-standardised instrumentation results in considerable variability in the parameters of the evoked responses both between and within individuals (Goodwill, 1968; Munro and Griffin, 1971; Munro, 1972a and b).

This is consistent with normal biological variation between subjects and, more importantly, the uncontrolled method of imparting stimuli used in these studies. The influence of controlled alterations in tap force on the parameters of evoked responses emphasises the need for some form of standardised instrumentation (Figure: 15a and b). That is, with progressive increase in tap force, there was an increased jaw displacement which was associated with a reduction in jaw-closing reflex latency and an increase in duration and amplitude values.

Although other standardised systems have purported to impart reproducible stimuli (Ott and Gassel, 1969; Bessette et al., 1971; Hannam, 1972; Bessette et al., 1974; Funakoshi and Amano, 1974; Godaux and Desmedt, 1975a; Lamarre and Lund, 1975; Bailey et al., 1977; Bratzlavsky, 1978; Cox et al., 1982), this ability has not been clearly demonstrated, except with Hannam's (1972) instrumentation where constancy of stimulus and response was evident graphically. The instrumentation described in the present study will deliver consecutive stimuli of reproducible magnitude. This is clearly demonstrated by the consistent durations of plunger travel preceding the stimuli (Figure: 13d, lower trace), consistent magnitudes of jaw displacement following the stimuli (Figure: 13d, middle trace) and consistent

parameters of the evoked jaw-closing reflexes as indicated by the low standard deviation values (Figure: 13d, upper trace; Tables: 3, 4 and 5). However, variations in force at consecutive stimuli, as indicated by the irregular durations of plunger travel and magnitudes of jaw displacement, will evoke highly variable jaw-closing reflex responses (Figure: 13e), even under the controlled environmental conditions cited above.

Sequential reductions in the distance between the plunger tip and the chin plate of the chin-tapping device, effectively interrupted the plunger at an earlier stage in its travel. The progressively greater magnitudes and rates of jaw displacement at each different setting mirror the progressive increase in the forces imparted to the chin (Figure: 14c). In addition, jaw displacement was seen to commence at progressively earlier stages after stimulus delivery (Figure: 14c) and this would contribute to the observed shorter latency values recorded with stronger tap force. Apart from this, an increase in tap force is likely to activate a greater variety of receptors or, at least, recruit higher threshold units, both effects being capable of altering the characteristics of evoked reflex parameters.

The maximum forces assessed at different settings of the plunger system appeared relatively light (1.52N

to 2.45N), however, these forces were imparted over a small area on the chin i.e. 1.4 cm^2 of skin contact surface on average. In addition, the bony contour of the chin is irregular and provides a surface that is unlikely to be evenly contacted by the chin plate. Thus, the plate may, in fact, rest on one or a few small bony protuberances thus effectively increasing the pressure transmitted to the jaw.

Thus a standardised reproducible stimulus to the menton region will evoke jaw-closing reflex responses exhibiting more consistent latency, duration and amplitude than appears to have been achieved in the past. In one individual at a single recording session the consecutive delivery of reproducible stimuli will be likely to activate afferent and efferent pathways in such a way as to produce consistent reflex responses. Thus, in conjunction with controlled environmental influences (noise, light, temperature, physical comfort) spindle excitability, alpha and fusimotoneurone activity and central excitability appear to maintain a relatively constant level of activity and thus constant reflex responses may be expected (Burke, 1980). Alternatively a non-standardised stimulus of varying tap force, results in a highly variable jaw displacement amplitude in any one subject.

As the perturbations were delivered at regular intervals then some subjects may have anticipated delivery. This modulating influence from higher cortical centres has been shown to subliminally facilitate spinal motoneurones to produce a more stable recruitment order than that usually associated with phasic reflex activations (Hannerz and Grimby, 1973). This phenomenon may also apply to the cranial musculature with a more stable recruitment order possibly contributing to the reproducible evoked reflexes.

In seventy-eight per cent of the sample, jaw-closing reflex responses were readily evoked in the masseter muscles bilaterally. This was higher than the figure of sixty to sixty-five per cent reported by Bessette et al. (1971). However, it contrasts with the findings of Lewis et al. (1978), who were unable to detect a response in their group of seven subjects and those of Ferguson et al. (1978) who were able to evoke a response on each occasion for all thirty-two subjects tested. Such marked differences in results may be explained at least in part by:

a. recording variations: equipment employed; magnitude, rate and direction of applied tap (the presence of preceding painful stimulation has been shown to inhibit the masseteric reflex elicited by chin

tap (Godaux and Desmedt, 1975b) and thus an excessively hard tap may be inhibitory); environmental influences: external sounds, lighting and temperature which may influence the central excitatory state.

b. subject variables: small sample sizes biasing the results; sampling from restricted community groupings, such as dental students; age and health of subjects.

As well, the recordings of jaw-closing reflex latency, duration and amplitude in this study showed a broad range between subjects even during the delivery of impulses of constant magnitude (6.40 to 11.73 msec; 2.40 to 7.00 msec; and 0.03 to 2.44 mV respectively). These variations may be explained in part on the basis of the results of reflex studies in limb muscle. It has been shown that spindle endings in relaxed limb muscle are not subjected to significant background fusimotor drive (Burke et al., 1976; Burke, McKeon, Skuse and Westerman, 1980; Burke, Skuse and Stuart, 1979). In addition, fluctuations in amplitude and variation in the ease of evoking stretch reflexes between subjects in limb muscles does not appear to be due to changes in background fusimotor drive, but rather to differences in central excitability acting independently of the

fusimotor system (Burke, 1980). In the trigeminal system continuous activity from low threshold, slowly adapting temporomandibular joint mechanoreceptors at postural jaw position (Klineberg, 1971; Wyke et al., 1972) may exert powerful excitatory effects on dynamic fusimotoneurones (Kawamura and Majima, 1964; Freeman and Wyke, 1967) as has been demonstrated in limb muscle (Appelberg et al., 1979). This fusimotor activity may contribute to the observed continuous low level of activity in some motor units at postural jaw position (Lous, Sheikholeslam and Møller, 1970; Lund et al., 1970; Møller, 1976). It may be therefore that spindle endings in jaw elevator muscles are subjected to a more significant background fusimotor drive than in limb muscles. A similar suggestion has recently been made by Riise and Sheikholeslam (1982). Spontaneous activity in fusimotoneurones has been identified in other elevator muscles of lightly anaesthetised cats (Morimoto et al., 1981). Thus the variability encountered in the literature and in this study, concerning the ease of eliciting jaw-closing reflexes and the highly variable amplitude of this response between individuals may relate to variations in fusimotor activity as well as variations in the central excitatory state independent of the fusimotor system. These modulations in excitatory state from higher centres are influenced by the state of the individual at the time. As sleep depresses the

manifestation of proprioceptive reflexes (Chase et al., 1968; Enomoto et al., 1968), then the state of alertness or relaxation of the subject may also have a similar effect.

In addition, a stimulus of a standard magnitude will not necessarily have the same effect on peripheral receptors in different individuals and thus afferent return from these receptors will not necessarily be the same. Soft tissues must be compressed before spindle stretch occurs and as the degree of compression is extremely variable between subjects then the effect of the stimulus on peripheral receptors will be modified accordingly. This variable has been partially overcome by monitoring jaw displacement (Lewis et al., 1978) and assessing a latency adjustment factor which may be used to correct recorded values. However, even with this adjustment, other variables contribute to the lack of reproducibility between subjects, such as: musculo-skeletal morphology in relation to the direction and the magnitude of the applied tap, for example, mandibular body length, orientation of masseter muscle to bone, muscle length, gonial angle, prominence of mental tubercles. Apart from these morphological influences, neurological variables are also likely to be involved, such as normal biological variations in afferent and efferent conduction velocities. Variations in motoneurone

excitability produces alterations in central delay by modifying the ease with which an incoming afferent barrage can evoke a reflex response. Segmental, intersegmental and suprasegmental descending projections, which are likely to be highly variable in different individuals, will establish an environment of motoneurone set that may be characteristic for that person as distinct from someone else. Modulations in reflex response parameters between subjects are to be expected accordingly depending on the current level of motoneurone excitability.

The reproducibility of jaw-closing reflex response parameters was not necessarily of the same order when comparing sides within a subject. Assuming receptors are activated in a consistent manner with a reproducible input stimulus, then the source of this variability presumably lies at the level of the trigeminal motor central synapse. Thus fluctuating influences from higher centres need not necessarily project in a bilaterally symmetrical fashion.

The subjective level of anxiety during the recording procedure may be regarded as an alerting stimulus having a similar reinforcing influence on monosynaptic reflexes as the Jendrassik manoeuvre (Burke, 1982). Different levels of anxiety may therefore modify the

degree of excitability and thus influence the associated parameters of the evoked response. Greater anxiety may correlate with reduced latency and increased duration and amplitude. Although the influence of affect on the results is recognised, great efforts were made to ensure that all subjects were fully aware of the procedures and were not apprehensive. However, irrespective of the level of anxiety that may have been present, this variable would appear to have had a limited influence on the evoked response for consecutive taps within a subject during one recording session. This is suggested by the reproducibility of jaw-closing reflex parameters which reflects a constant modifying influence from reticular formation and limbic structures.

In some individuals a response could not be recorded above background noise levels or could not be clearly measured (Figure: 17). This observation reflects a level of excitability at the trigeminal motoneurone pool that is not conducive to the activation of motor units in sufficient numbers to produce a recordable, or if evoked, measurable response. During menton tapping, discharge from spindle afferents project to the trigeminal motor nucleus, however if the level of surround inhibition is too high, then either motoneurones will not be recruited or, if they are, the evoked potential may be too small to be recorded and measured

above background noise. In addition, electrode position may have been inappropriate for the detection of a reflex response occurring in a related part of the muscle. Thus the observation in some subjects of no apparent modulation in the baseline emg level during menton tap does not necessarily mean that monosynaptic activation of some masseteric motoneurones did not occur.

Recently, mention has been made of a possible contribution to the observed emg from movement artefact (Dubner et al., 1978). In this current study, an early interference was observed in the ongoing emg in close time association with contact of the plunger with the chin but was quite distinct from the evoked reflex response which occurred significantly later (Figure: 13f). This extremely short latency would appear to preclude a neurological aetiology for this initial disturbance and is therefore probably movement artefact. As such it would represent a slight disturbance of surface electrodes from skin movement or vibration transmission occurring simultaneously with the moment of chin tap delivery. It is also possible that movement artefact occurred simultaneously with the evoked reflex itself. However, with the lower teeth rigidly luted to the upper teeth, menton taps evoked the usual early movement artefact, but in the time range for which a monosynaptic

response would be expected to occur (i.e. 6 to 11 msec) there was no observable deflection in the baseline emg in five out of ten muscles (Figure: 21 - A2, R; D2, R and L; E2, R and L). The absence of a deflection in the electromyographic tracing in some subjects indicated that both movement artefact and a neurological response were not detectable above background noise levels. If this result is extrapolated to other subjects then it could be concluded that movement artefact does not contribute significantly to the response evoked at postural jaw position. However, this is not conclusive, since movement artefact may occur in some subjects and not in others depending on variations in the stability of electrodes between individuals. Thus in those subjects for which a baseline deflection was observed with the teeth luted together, this may have been artefact. In addition, without a mechanical constraint preventing jaw movement some additional artefact related to actual jaw opening may have superimposed on the background electromyogram. Nevertheless it is concluded that, employing the chin-tapping system described, movement artefact is not a major contribution to the waveform of the jaw-closing reflex in recordings from most subjects. However no evidence has been presented to indicate that movement artefact would never contribute to the response.

Reflex responses evoked under standardised conditions in different individuals did not necessarily exhibit similar levels of reproducibility (Tables 3, 4 and 5). This observation may reflect influences from one or more of the following variables. In order for the chin tapping system to evoke reproducible reflex responses at postural jaw position, subjects must maintain a constant relationship with the apparatus so that the mandible becomes correctly repositioned after downwards displacement and just prior to each tap. This reorientation depends principally on the visco-elastic characteristics of the muscle-protein supportive elements. On some occasions, however, it was noted that the subject consciously or subconsciously tended to move away from the apparatus thus effectively reducing the magnitude of the impulse imparted. Although subjects were made aware of this and it was closely monitored, some slight net displacement may have occurred altering the relationship with the system and effectively reducing the magnitude of the next perturbation delivered. Evoked reflex response characteristics would therefore be modified accordingly. However, this factor, although it must be recognised, was not considered to play a major role in the observed variability in standard deviation values between individuals for two reasons. Firstly, after a consecutive series of trials each subject was questioned on the reproducibility of taps in the sequence just completed and almost all subjects reported the impulses to be highly consistent; three subjects felt the perturbations

to exhibit slight irregularity, however this was unable to be corrected in subsequent trials. This latter may have reflected a conscious or subconscious movement by these subjects away from the tapping device as previously mentioned. Secondly, the rates and magnitudes of jaw displacement over a sequence of consecutive taps were essentially identical as indicated by the close superimposition of these traces. This reflects the highly reproducible stimulus delivery.

The aetiology of most of the variability that was observed in jaw-closing reflex parameters probably relates, in part, to fluctuating levels of trigeminal motoneuronal excitability. For example, stress and anxiety may, in certain subjects, vary over a short time period during the recording procedure; thus anxiety may change as tapping progresses despite efforts to maintain such levels low and constant. These and other descending projections can influence trigeminal motoneuronal excitability and the manifestations of an evoked response (Yemm, 1971). In addition, a respiratory modulation of proprioceptive reflexes has been demonstrated in limb muscle (Appelberg, et al, 1979) and this may apply to cranial motor systems. In this current study, responses were not evoked in close time association with a particular phase of the respiratory cycle and thus it is conceivable that variations in modulatory influences from the respiratory

centre (located in the reticular formation) could modify trigeminal excitability and alter reflex response parameters. Another factor that may contribute to the variation observed in evoked reflexes at consecutive stimuli is the variable recruitment order of motor units that has been reported to occur in limb muscle with phasic activations despite standardised stimuli (Grimby and Hannerz, 1970). Subliminal facilitations from cerebral cortex can programme the motoneurone pool to recruit in an orderly manner during phasic reflex activity as is normally seen in voluntary contractions and tonic reflex responses (Hannerz and Grimby, 1973). Thus if the subject anticipates stimulus delivery then such subliminal facilitation may produce a stable recruitment order, and this may contribute to more consistent evoked reflexes. Although subjects were instructed to completely relax during stimulus delivery, some anticipation may have occurred and this could also have been somewhat variable in different subjects during the tapping sequence. This could be a source of fluctuating facilitatory projections from higher centres and more variable evoked reflex responses.

An objective means of diagnosis for patients with orofacial pain and dysfunction appears to have largely eluded clinicians. Silent period duration appeared to offer an objective measure of dysfunction (Bessette et al., 1971; Beemsterboer et al., 1976; McCall, Uthman and Mohl, 1978; Helkimo, Bailey and Ash, 1979), however, its variability (Hellsing and Klineberg, 1983) even in the

presence of standardised input stimuli, has clouded its usefulness as a reliable clinical diagnostic tool. Nonetheless, the use of a reflex test to monitor dysfunction is not without a physiological rationale. Levels of motoneurone set and excitability would appear to reflect the unique characteristics of intraoral constraints as encoded by peripheral receptors. A means of monitoring these changing levels of excitability may thus correlate with the functional status of the masticatory system characteristic of that individual and this may provide an accurate measurement for diagnosis. The monosynaptic jaw-closing reflex evoked in a reproducible fashion would appear to serve this purpose as the reflex utilises pathways involved in motor control. Thus jaw-closing reflex latency, duration and amplitude may be indicative of a normal function or the presence of dysfunction. However, the studies by Munro (1972a and b) appear to be the only ones utilising jaw-closing reflex parameters as possible aids in diagnosis of muscle-joint pain dysfunction. The results of this investigation support the above discussion by suggesting:

a. patterns of motoneurone excitability, as indicated by reflex parameter values, are not necessarily identical between sides within a subject;

b. such differences correlate in this investigation with muscle-joint pain and dysfunction.

In particular, the differences between sides observed for latency were greater in subjects from the dysfunction group.

Such differences cannot be completely accounted for by morphological variations such as nerve pathway length discrepancies or asymmetric electrode locations between sides. For example, a nerve fibre conduction velocity of, say, 100 $msec^{-1}$ (Dubner et al, 1978) would require a nerve pathway length difference of several centimetres at least to account for the observed differences. This is unlikely. It is more probable that variations in motoneuronal excitability from incoming segmental and suprasegmental influences would contribute to the observed differences. Asymmetric electrode location in relation to muscle end-palate zones on each side may result in action potentials being recorded from opposing muscles at different times. The observed latency differences would then relate to electrode misplacement rather than to physiological changes in nerve excitability. However, this factor would appear to be less important employing bipolar surface electrodes which summate muscle activity from many motor units. Although the importance of these differences was not apparent, the significant ones were mostly evident in subjects demonstrating evidence of dysfunction (groups B and C). Further investigation is therefore indicated to assess whether differences reflect

dysfunction or whether they relate to other variables, such as side preference as may affect jaw muscles in chewing.

Differences in amplitude between sides did not correlate as well as latency with a particular subject group. However, a trend was evident with more subjects from groups B and C exhibiting differences between sides that were greater and significant at the 95% level more often. This trend towards greater amplitude differences between sides with increased severity of dysfunction does correlate with the similar result observed for latency differences between sides. These trends however were not apparent for duration.

Programmes of jaw muscle coordination encoded in brain-stem centres and based on inputs from peripheral receptors determine characteristic levels of motoneuronal set and excitability. As the form of intraoral relationships are usually not identical between sides, specific demands imposed on muscles of a side may differ from those on the contralateral side. This may especially be so for the excessive demands on muscles that are a source of pain and dysfunction. These demands, of peripheral or central origin or both, may predetermine a level of motoneurone set contrasting with the contralateral side and which evidences as differences in reflex parameter

values between sides. For example, highly restrictive interocclusal relationships may impose specific demands on masseter muscle function of one side. Descending projections related to these requirements may establish patterns of motoneuronal function characteristic for these states and as such may be detectable as alterations in the parameters of evoked reflex responses. When data was pooled for group A, group B, group C and the three groups together, significant differences between sides were not apparent at the ninety-five per cent level (t-Test significance) which emphasises the tendency for these differences to be submerged when values are grouped.

The pattern of change in reflex parameters with variation in tap force is consistent with the correlations observed between overall mean latency, duration and amplitude values. Thus, although not always significant at the ninety-five per cent level, latency tended to be inversely related to duration and amplitude, whilst amplitude was directly related to duration. However, the general level of the correlation co-efficient for latency and duration is somewhat lower than the value quoted by Munro and Griffin (1971).

Some muscles did not demonstrate trends with alterations in tap force and muscles exhibiting this characteristic were not necessarily bilaterally represented in a subject. As the perturbation was delivered in the

midline and, assuming facial morphology is bilaterally similar, then, presumably, stimuli would arrive at the muscle spindles in a similar fashion on both sides. Whether or not the impulse and subsequent afferent discharge produce a similar effect on the trigeminal alpha and fusimotoneurones in each motor nucleus depends on the current levels of surround inhibition on each side. However, motoneurone excitability need not necessarily be identical bilaterally. Changes in the magnitude of the impulse delivered therefore, may or may not manifest as an alteration in evoked reflex characteristics depending on modulating projections to trigeminal motoneurones.

The maximum and minimum values quoted in this study for any of the reflex parameters does not imply that readings outside this range are not possible. The values simply represent a range that has been recorded from this population of subjects all receiving an impulse from the chin tapping system that is kept constant. Thus if stimulus intensity is altered then values larger than the maximums recorded here are possible and this would be consistent with the observed effects of variation in tap force on the evoked reflex responses. Similarly, lower minimum values are also feasible. However, although a much smaller value is theoretically possible for amplitude, the accurate measurement of smaller responses

becomes progressively impaired by background noise levels. In addition, it appears from these results that an identical stimulus magnitude imparted at the same angle in a group of subjects does not necessarily evoke identical monosynaptic reflexes in different subjects from that group. Some possible reasons for this have been discussed previously (see page 196 to 199).

The calculation of latency adjustment factors allow assessment of jaw-closing reflex latency values that more accurately reflect the true physiological delay irrespective of variations in soft tissue compression and the characteristics of microswitches. In the present study, this factor was 1.6 msec. Although it is possible that a portion of this factor could be the result of overcoming the flexibility of the aluminium bar supporting the light source immediately following the commencement of jaw displacement, it was considered unlikely to be the sole cause and that overcoming soft tissue compression would contribute, at least in part, to the discrepancy. Nonetheless, this factor will be different in different studies due to variations in the resistance of the microswitch to closure during impulse delivery. Thus microswitches exhibiting more resistance to closure will trigger at a later stage than those more readily activated. This will effectively result in a shorter recorded latency value. If such corrections were described and made in other

similar studies, then more accurate comparisons of data may be made between and within studies. For example, Goldberg (1971) evoked a periodontal-masseteric reflex with a shorter latency (7.5 ± 0.9 msec) than the jaw-closing reflex (9.9 ± 0.9 msec). Employing a reflex hammer incorporating a microswitch, the former was evoked by directly tapping an upper central incisor, the latter, by tapping the chin. In each case, the timing of microswitch activation in relation to receptor activation is likely to be different. With chin tapping, the microswitch may trigger during soft tissue compression before activation of spindle receptors, and result in a relatively long jaw-closing reflex latency. However, during tooth tapping, microswitch activation would occur closer to the time of receptor activation, and result in a shorter recorded latency.

Significant differences between sides were less consistent for duration values, with four subjects in group A, two subjects in group B and six subjects in group C showing a significant difference. This result seems surprising, in view of the more consistent diferences for latency and as latency and duration have been reported to be inversely related (Munro and Griffin, 1971; Widmalm, 1976; Widmalm and Hedegård, 1976b).

Downwards loading of the jaw without causing jaw opening during isotonic elevator contraction evokes a

monosynaptic reflex (Lamarre and Lund, 1975). The presence of this reflex without the need for spindle stretch suggests concomitant fusimotor activation sensitising primary spindle endings to vibration. This potentiating effect may also be operative with background elevator activity present at postural jaw position due to involvement of fusimotoneurones as described earlier. With manual jaw support provided by the subject, motoneurone excitability is likely to be potentiated by Jendrassik reinforcement, however reflexes were only sometimes evoked under these conditions. Jaw support maintained entirely with acrylic indices (i.e. without manual support and thus Jendrassik reinforcement) and in the absence of elevator muscle contraction, will prevent spindle stretch, but vibration will still occur. The absence or reduction of a response under these conditions of jaw support reflects diminished motoneurone excitability. Thus vibratory oscillations induced during stimulation under these experimental conditions were not sufficient to consistently evoke a jaw-closing reflex at postural jaw position. However, in those subjects exhibiting a large jaw-closing reflex amplitude at postural jaw position, it appears that an enhanced motoneurone excitability existed at the time of stimulus delivery. In the single subject for which responses could be evoked, the level of surround inhibition, as determined by various ascending and descending projections, may be such that smaller peripheral

stimuli can more readily bring motoneurones to threshold. In such individuals, vibration transmission alone to primary spindle endings in relaxed muscle will generate an afferent barrage sufficient to bring motoneurones to threshold and thus evoke a response. When vibration alone is insufficient it may become so in combination with reinforcement from the classical Jendrassik manoeuvre or another procedure having a similar effect e.g. subjective chin support. Menton tapping during the former usually evoked a jaw-closing reflex amplitude greater than that seen during subjective chin support (Figure: 21 -A4; B4; C4). This probably reflects an enhanced descending facilitatory projection onto motoneurones as part of the maximum voluntary effort required during the Jendrassik manoeuvre in contrast to the milder efforts associated with manual chin support. Thus vibration in combination with central descending facilitatory projections can be adequate to bring motoneurones to threshold.

During manual chin support procedures in one subject (Figure: 21 -A3) an increase in the variation of jaw-closing reflex amplitude was noted visually in the right masseter as distinct from that seen in the left masseter which appeared to be more reproducible. This may relate to fluctuating bilateral descending projections onto trigeminal and limb motoneurones as part of the chin support procedure. This was performed with considerable

subjective voluntary effort and although both upper limbs were used, central descending influences may have been neither the same on both sides nor consistent from one moment to the next.

During menton tapping with the teeth luted together, the magnitude of the impact from the plunger system may effectively have been slightly greater than that imparted at postural jaw position, since jaw opening, which helps dissipate the impulse, was prevented. Although no attempt was made to correct for this, it was not considered to invalidate the results as a heavier force, that does not cause pain (Godaux and Desmedt, 1975c), appears to be more likely to evoke a monosynaptic reflex and yet this only occurred clearly in one subject (Figure: 21 -4R & L).

The visco-elastic nature of the muscle protein and fibro-elastic connective tissue components supporting the mandible from the skull confer a characteristic resistance to jaw displacement during menton tap. This may explain the apparent absence of jaw movement at low levels of force application (Fig. 14a and 9c) as suggested by extrapolating the force-displacement line to the force axis. Light loads therefore appear insufficient to overcome mandibular inertia and the visco-elastic connective tissue supporting components to bring about jaw displacement. With sequential increase in the size

of the impulse delivered a progressively greater magnitude and velocity of jaw displacement would be expected and this is consistent with the observed results.

Oscillations in the tracings of jaw displacement with the mandible rigidly supported reflect vibration of the short metal bar securing the miniature lamp to the lower teeth. However, stimulus delivery at postural jaw position may also cause oscillations of the lower jaw due to elastic interaction of neck and facial connective tissues. Difficulties also exist in ensuring stability of head-frame attachments and although this factor was closely monitored, slight head movement relative to frame, although unlikely, may have occurred during perturbations and may have contributed to the recorded oscillations.

5. CONCLUSIONS

5. CONCLUSIONS

1. A device may be constructed that will deliver short duration mechanical impulses to the chin of a human subject. This device may be triggered remotely by an electronically controlled switch so that consecutive activations will be brought about by current flows of constant duration.

2. The tapping system that was developed is capable of delivering mechanical stimuli that are reproducible. This reproducibility relates to the construction of the system, which consists of a solenoid-driven plunger that is activated for a fixed time period and which is determined electronically. Friction is reduced in the moving parts of the system by employing nylon bearings. The perturbations delivered by the system were shown to be reproducible by monitoring jaw displacement during the delivery of menton taps employing an opto-electronic tracking system. The close superimposition of successive jaw movement traces reflects the ability of the system to impart consecutive impulses of reproducible magnitude.

3. The chin-tapping apparatus could be adjusted by altering the distance travelled by the plunger prior to contact with the chin plate. Impulses generated at these individual settings of the plunger system were shown to differ in

absolute magnitude by monitoring jaw displacement during impulse delivery. A quantification of the range of forces imparted in one subject (1.5 to 2.5N) allowed evaluation of pressures generated through the chin-plate and these were calculated to lie between 1.07 and 1.79 Ncm^{-2}. As this was assessed in one subject only, then impulse magnitudes may be different for other subjects, however, it is considered that the levels quoted would approximate the general magnitudes of force imparted.

4. Employing this reproducible instrumentation, impulses were delivered to the chin of each subject in a sample population consisting of twenty-seven tertiary education students and five referral patients. Each impulse delivered was of constant magnitude as far as the plunger system was concerned. A clearly discernible and measurable response could be demonstrated in 78% of the sample population whilst in the remainder, either a response was not evoked or, if evoked, could not be clearly distinguished above background noise levels.

5. With the same tap forces applied in different subjects, jaw-closing reflexes were evoked with a wide range of recorded values. The range of mean values in the three groups for latency, duration and amplitude were: 6.95 msec to 11.16 msec; 3.23 msec to 6.86 msec; and 0.07 mV to 1.56 mV, respectively. Thus, impulses imparted at the same setting of the plunger system in different subjects will

not produce jaw-closing reflex responses exhibiting identical values for each of latency, duration and amplitude. However, when responses were evoked at constant tap force in the same individual, jaw-closing reflexes exhibited latency, duration and amplitude measurement parameters that were more reproducible than have been achieved in the past. However, the degree of reproducibility of evoked reflexes was not necessarily of the same order between sides within a subject or between subjects.

6. The need for a standardised system for imparting mechanical perturbations to the menton region is highlighted by the changes in reflex response parameters with alterations in tap force. With stronger tap force, duration and amplitude values tended to increase whilst latency tended to decrease.

7. Mean jaw-closing reflex parameter values were not necessarily the same between sides within a subject. For latency and amplitude these differences appeared to correlate with the presence or absence of dysfunction. It is concluded that the jaw-closing reflex might be of assistance in the grouping of individuals into dysfunction and non-dysfunction categories. However, further research is indicated to assess whether these differences are gross indicators of masticatory functional state or whether they relate to more subtle manifestations such as asymmetrical patterns of motor coordination between sides reflecting

characteristic dental interrelationships. Thus in three of the group A (non-dysfunction) subjects, significant differences were observed between sides, yet these subjects lacked signs and symptoms of muscle-joint pain and dysfunction as defined previously.

Although differences were apparent between sides within a subject, when mean values were averaged for an entire group, the differences observed became submerged by the variability in response parameters between subjects.

8. In order to correct latency values to account for variations in soft tissue displaceability prior to the moment of commencement of jaw movement, a mean adjustment factor (1.63 msec) was calculated. The corrected jaw-closing reflex latency values for the three groups together were - mean: 7.20±0.91 msec (right masseter); 6.73±0.79 msec (left masseter); range: 4.77 msec to 10.10 msec (right and left masseter). Latency values recorded in this study and corrected by this factor more closely approximate the delays dependent on neural pathways and independent of the mechanical factors of overcoming jaw displacement prior to spindle stretch.

9. Transmission of vibration through bone and soft tissue to the muscle spindles without spindle stretch would not appear to be the major factor in the initiation of the jaw-closing reflex. Enhanced descending projections, during clench, during the Jendrassik manoeuvre and in

anxious subjects, may increase alpha motoneurone excitability by potentiating activity in fusimotor efferents or enhancing central excitability or both. Under such conditions the vibratory stimuli generated during menton tap, and without spindle stretch, may be sufficient to evoke a response either by increasing spindle afferent firing or by bringing alpha motoneurones closer to threshold.

10. Employing the chin-tapping system described, movement artefact did not appear to be a significant contribution to the evoked reflex in most subjects. However, it is conceivable that artefact may be a complication in some subjects depending on variations in electrode stability between individuals.

11. Further research indicated by this investigation include:

11.1 What are other factors likely to influence the dimensional parameters of the jaw-closing reflex, for example, the effect of side preference during chewing; the frequency and duration of parafunctional habits; the age and sex of the subject?

11.2 Does the presence of differences in jaw-closing reflex parameters between sides truly mirror the presence or absence of overt dysfunction or do they measure more subtle characteristics of jaw function such as side preference in chewing, the stability of median occlusal position

contacts, the presence and distribution of mediotrusive interferences?

11.3 In comparisons of reflex parameter values between sides, is the numerical difference between sides more important than the level of significance of the difference (t-Test significance)?

11.4 What is the significance of the variation in reproducibility of evoked reflexes between sides within a subject and between subjects? Does the presence or not of this inherent variability, despite the standardised conditions, signify certain clinical or subclinical characteristics of the masticatory system?

11.5 If asymmetries of reflex parameters between sides do correlate with dysfunction, can a numerical cut-off value be ascribed indicating the transition to disease?

11.6 What is the effect of routine forms of treatment on the various reflex parameters and do they mediate a return to "normality" as defined by parameters from the non-dysfunction subjects?

11.7 What is the effect of selective block of peripheral receptor feedback on the evoked reflex? Does this modify the reflex manifestations as would be predicted from the discussion above?

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