The objective recording of the biomechanical profile of reflexes by means of a kinesiometer

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Clinical observation of reflex activity is a subjective process and, in practice, the magnitude and briskness of response are not recorded in quantitative repeatable fashion by automatic process. In some instances, photographic devices are used but the evaluation of their printouts is still subjective. This paper describes a simple apparatus which has been developed for the direct measurement of reflexes, including the patellar reflex, suitable for use in office procedures. The device traces simultaneously three biomechanical parameters of single joint movement involved in a reflex: displacement, velocity and acceleration of a suitable reference point on the body surface. Reaction time is obtained as well.

ACCELERATION is an especially important component of reflex movement as it is entirely independent of displacement. Even minimal displacement may be performed under conditions of high acceleration. For example, high acceleration is produced by tremors, however small. Since the reflex response of the muscle is a contraction against a constant mass, acceleration is a measure of the degree of muscular involvement. Its magnitude is related to the number of motor units firing at a given time. Similar information can be obtained from an integrated electromyogram, but electrode placement may affect the recording. Acceleration measurement is not subject to this source of variation. Furthermore, the bioelectrical phenomena which give rise to the electromyogram precede the actual contraction of the muscle, and therefore are a less direct measure of contraction.

When activity is voluntary, then acceleration is an excellent measure of co-ordination and biomechanical control. In conditions involving loss of co-ordination, acceleration, and in many cases deceleration, may be indicative of pathology or conditions such as drug effects, which disrupt normal movement patterns. The usefulness of acceleration in the evaluation of voluntary movement suggests that it might

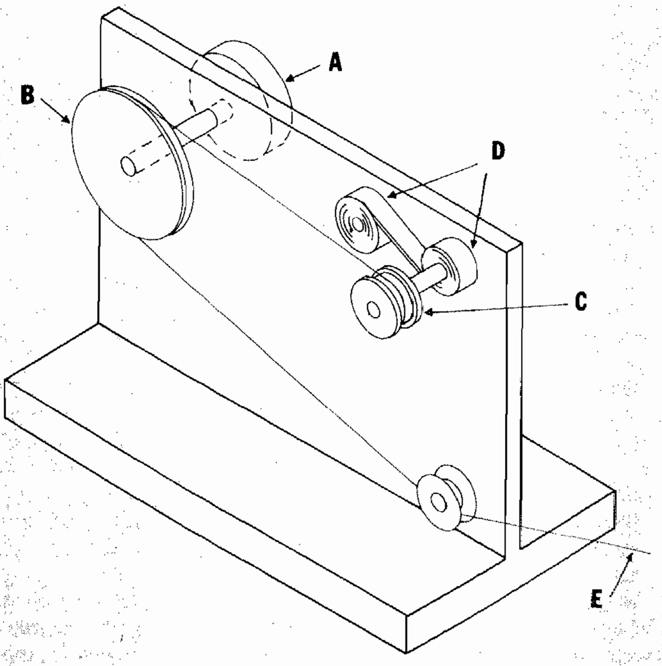

Fig. 1. Schematic of kinesiometer. (For explanation see text.)

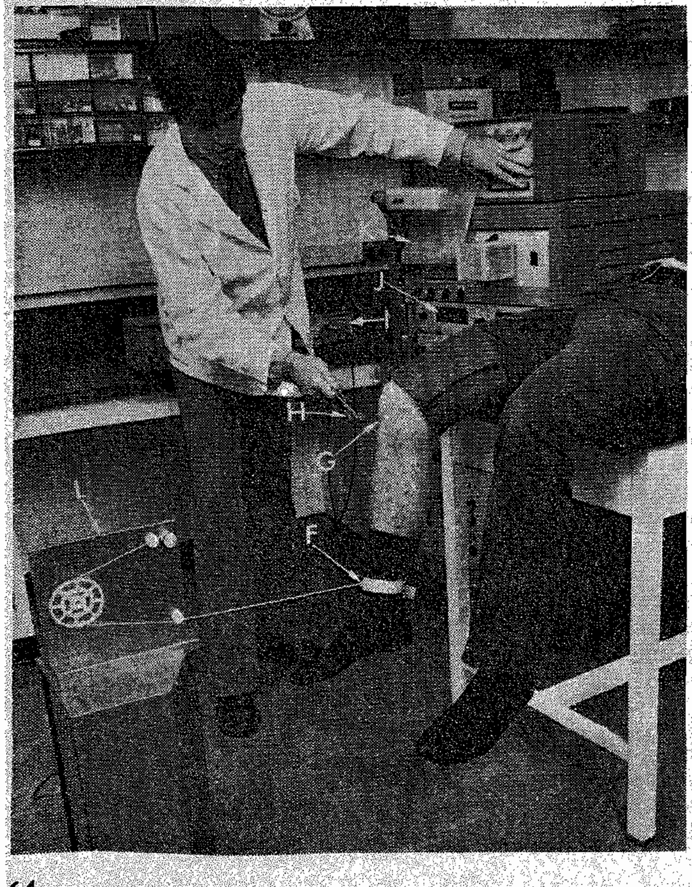

Fig. 2. (left). The kinesiometer in operation: L = kinesiometer; F = velcro strap; G = inkspot; H = hammer with built-in reaction time switch; I = analog computation module; J = digital readout of reaction time; and K = recording of biomechanical profile.

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also add information about neuromuscular control of involuntary motions.

Description of apparatus

The principle on which the apparatus (Figure 1) operates is the production of a voltage proportional to the position of the leg at any instant. A linear potentiometer (A in Figure 1) produces a voltage proportional to the degree of rotation of a shaft. A simple arrangement is used to rotate the shaft in proportion to the degree of flexion of the knee joint: a string (E) attached to the subject's ankle by a strap (F) is wrapped around a wheel (B) mounted on the shaft of the potentiometer, and then is wound onto a takeup spool (C) by a spring driven motor, exerting a constant torque (D). Rosin applied to the string prevents slippage.

The system is of low inertia and responds rapidly. As the string is pulled or released by the leg, it turns the wheel. The rotation produced per unit of linear motion at the point of attachment of the string is proportional to the circumference of the wheel. Depending on the size of the wheel used, a complete rotation of the potentiometer can be obtained from a linear motion of only a few centimetres up to about thirty centimetres on our apparatus. An excellent signal to noise ratio is obtained for responses of very small displacement.

The signal from the potentiometer is differentiated by an analog computation module (I) to yield velocity and acceleration respectively. The vector sum of velocity and acceleration is also computed. The voltages representing the three biomechanical parameters are recorded on a strip chart recorder (K).

The apparatus is placed forward of the leg, and in line with the path of motion of the ankle (L in Figure 2). The point of attachment of the string describes a flat arc as the leg moves through a small angle during the reflex. Its motion is very close to linear and uniplanar.

Reaction time is measured as the time from stimulus to the onset of a detectable velocity signal. The pulse from a microswitch embedded in the head of a percussion hammer (H) gates a 100 kHz square wave into a digital event counter (J), thus initiating elapsed time measurement when the knee is tapped. The input to the counter is terminated by the velocity signal as soon as the leg moves. Reaction time in milliseconds is then read out directly from the digital count.

Preliminary findings

Based on experimentation with 12 healthy subjects, during which a series of 30 knee jerks were obtained from each subject per session with five replications, we have found that recordings of the biomechanical profile of the patellar reflex by this technique, even when using only a tendon tap administered by hand, are quite repeatable. The point of application of the tap is apparently much more important than the force in determining the nature of the response (G in Figure 2).

Results of experimentation to be published soon in detail indicate that the shape of the acceleration trace of the patellar reflex may be attributed to differential contributions of force from slow red and fast white muscle fibres. The effects of exercise and drugs are clearly apparent from the recordings (Figure 3).

On the basis of other preliminary tests, it appears probable that recordings from this apparatus may assist in the early diagnosis of changes in reflex pattern resulting from the development of neuromuscular or other pathology.

This work was supported by Grant 8 T01 OH00103 of the National Institute of Occupational Safety and Health. Additional support was provided by the Social and Rehabilitation Service, U.S. Department of Health, Education and Welfare, under the designation of New York University as "Research and Training Center".

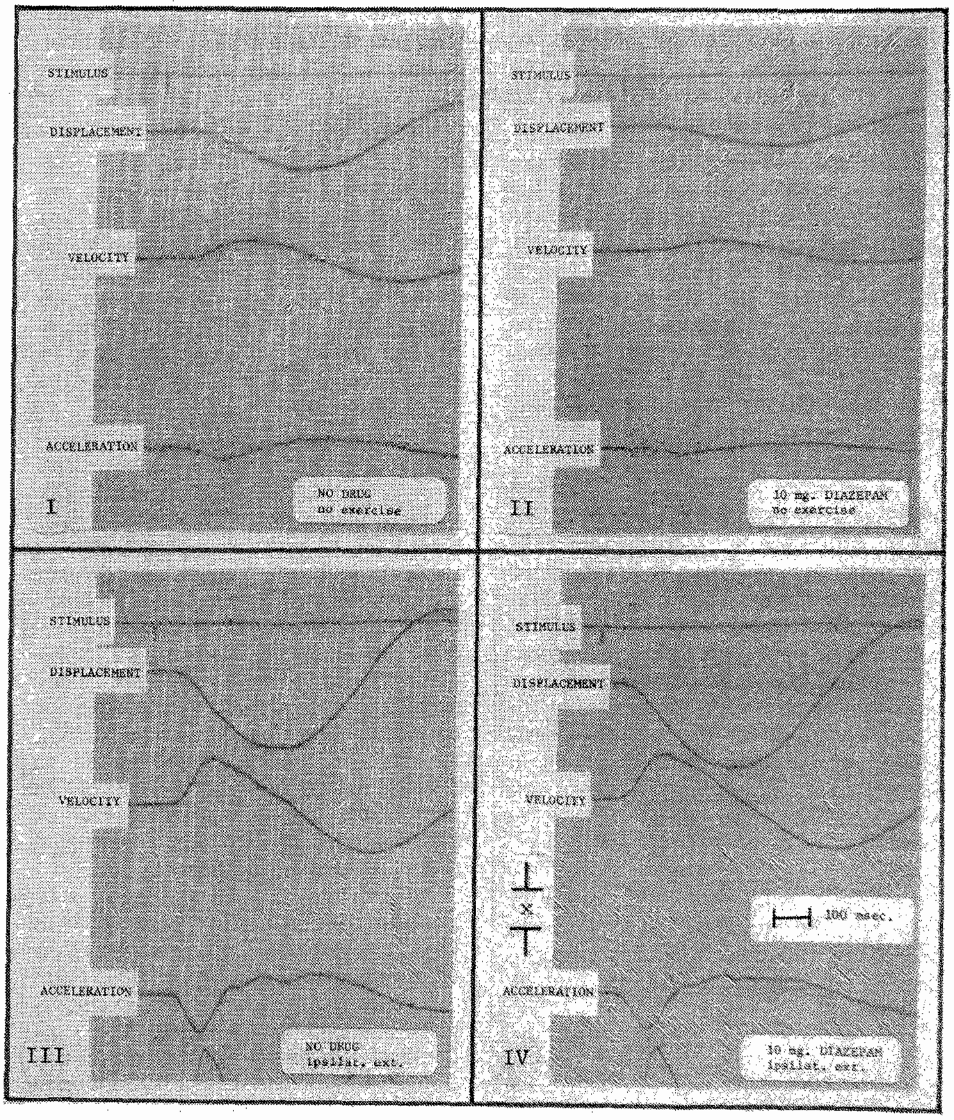

Fig. 3. Four representative sample recordings of the biomechanical profile of the patellar reflex of a healthy subject. The tracings include a time interval of approximately 7 to 800 milliseconds after the stimulus. Depression of the reflex caused by a centrally acting muscle relaxant, Diazepam, is seen by comparing traces I and II. Exercise facilitation resulting from twenty pound isometric ipsilateral elbow extension at the time of stimulus is shown between traces I and III. The depression caused by Diazepam is nullified by exercise facilitation as seen from traces II and IV. On the original recording paper, "x" = 1 cm. Calibration factors are: for displacement, 1 cm (x) = 5·0 cm for the point of attachment of the spring; for velocity, 1 cm (x) = 214·4 cm/sec for the point of attachment of the string; and for acceleration, 1 cm (x) = 4555·7 cm/sec^2 for the point of attachment of the string. Reaction time was obtained by direct digital readout.