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ELECTROMYOGRAPHIC STUDIES ON THE VERTEBRAL PORTION OF THE PSOAS MUSCLE

With Special Reference to its Stabilizing Function of the Lumbar Spine

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With the introduction of a method for *in vivo* disc pressure measurements, information can be obtained of the load on the lumbar intervertebral discs in different positions of the body (20). In these measurements it was found that in the upright sitting position 140 kg is carried by the third lumbar disc in a 70 kg man while in the upright standing position this load is 100 kg.

The spinal column, which serves as a sustaining rod for the maintenance of the upright position of the body, was considered by *Lucas & Bresler* (1961) (14) to have both an intrinsic and an extrinsic stability. Intrinsic stability is provided by the alternating vertebral bodies and discs of the spine which are bound together by ligaments, while extrinsic stability is provided by the paraspinal and trunk muscles. The trunk muscles, especially those of the abdomen, form a contractile muscular wall about the body compartments which is capable of compressing the viscera. With the contraction of these muscles, the intracavitary pressures are increased, aiding in many bodily functions such as childbirth, respiration, return of venous blood, and, as has been shown, stabilization or support of the spine (2, 7, 9, 18). No mention of the psoas muscle was made in these studies.

The isolated ligamentous spine behaves like a modified elastic rod (14). When it is fixed at the base, its critical load—*i.e.*, the greatest vertical load it can sustain on top of the first thoracic vertebrae without buckling—is only 2 kg. The stability of the spine in the living human being is therefore dependent largely on the extrinsic support provided

by the trunk musculature. The lack of inherent or intrinsic stability of the vertebral column and the importance of the trunk muscles are clearly demonstrated if one tries to hold an unconscious person upright.

Sypher (1960) (23) thought, for theoretical reasons, that the psoas muscle was called upon to compensate for imbalance between anterior abdominal muscles and posterior spine muscles in stabilization of the lumbar portion of the spine and to be active if full power is to be derived from more distal muscles in the extremities.

In vivo discometry demonstrated that a relationship exists between the load on the middle lumbar discs on the one hand and the position of the subject and weight of the body above the level measured on the other hand (19, 20). In the unsupported sitting position this can be written:

Eq. (1) $$P(kg) = 30 + 2{,}8\,W + 3{,}6\,W \sin \alpha$$

where P is load on the lumbar disc, W the bodyweight above the level measured and α the angle of forward leaning, if any.

In the standing position the relation is:

Eq. (2) $$P(kg) = 20 + 2{,}1\,W + 3{,}6\,W \sin \alpha$$

The results from these measurements can be summarized as in Figure 7.

According to the findings of *Braune & Fischer* (1889) (4), *Dempster* (1955) (8) and *Asmussen & Klausen* (1962) (1) gravitational forces alone cannot explain the loads in the upright standing and sitting positions found from these measurements and with the knowledge that the electromyographic activity of the sacro-spinalis and anterior abdominal musclegroups are relatively small in these positions (3, 5, 10, 11, 12, 17, 21, 22) other muscular forces than those mentioned should be considered. *Lucas & Bresler* (14) found it improbable that the intrinsic stability of the spine itself offered by the ligaments and intervertebral discs is enough to stabilize the body in the positions outlined above.

The psoas muscle arises at the transverse processes of the 12th dorsal and all the lumbar vertebrae and at the lateral bodies and intervertebral discs at the same levels. It is attached together with the iliacus portion of the muscle to the femur somewhate above and to the lesser trochanter.

Previous investigations on the function of the ileopsoas muscle has mostly centered around the hip joint. It has been demonstrated that

the ileopsoas is a flexor of the hip joint (3, 6). From their electromyographic studies these authors also concluded that the muscle is neither an inward nor an outward rotator of the hip as was previously said (13).

Very few reports have been given on the function of the psoas muscle on the vertebral column, although some authors like *Michele* (16) and *Sypher* (23) believed for theoretical and anatomical reasons that the psoas played an important rôle in different patterns and forms of posture. *Basmaijan* (3) investigated four subjects with a needle electrode inserted in the psoas major muscle and revealed activity in the upright standing position. He called it an active postural muscle.

The reasons for the scanty reports found in the literature can be summarized as was done by *Close* (6), who found the recording of psoas EMG:s "hazardous and dangerous". In this study a roentgen-image intensifier was used. In three of the nine cases the test had to be interrupted because of discomfort. One of these subjects had a vaso-vagal syncope. The other subjects took part in the experiment after a few minutes rest.

Since it is obvious that gravitational forces alone are insufficient to explain the size of the load in both upright standing and sitting positions found at discometry and with the previous knowledge that the electromyographic activity of the sacro-spinalis and anterior abdominal muscle groups are relatively small in the sitting and in the standing positions studied (3, 10, 11, 12, 17, 21), this investigation on the vertebral portion of the psoas muscle was carried out. The anatomical relation of the psoas muscle to the lumbar spine is such that activity in the vertebral portion of this muscle will exert a compressive force on the spine.

MATERIAL AND METHODS

Single coaxial electrodes were used and inserted into the psoas muscle via the posterior lumbar sympathetic block approach (Figure 1). The position of the needle was checked by anterior-posterior and lateral roentgenograms (Figure 2). *The eventual risks were reduced and the insertion helped by the use of a roentgen image intensifier.* The needle was always inserted from the right side at the level of the third intervertebral disc (Figure 1). One electrode was also inserted into the right-sided sacro-spinalis group of muscles at the same level. Recordings of the activity were made using a Disa electromyograph.

The material consists of eight normal volunteers, four men (age 21, 30, 30, 47 y.) and four women (age 23, 24, 25, 34 y.). The following positions were studied.

1. Upright sitting without support.
2. Upright sitting without support, 10 kg in each hand.
3. Sitting and forward leaning by flexion in the hip joints by 20 degrees.

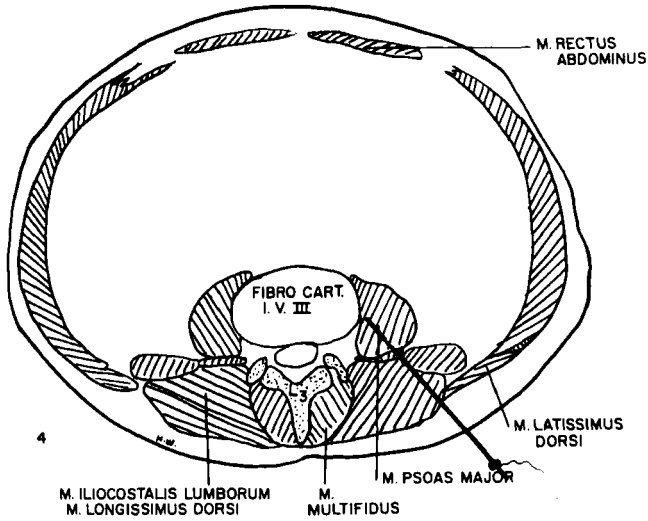
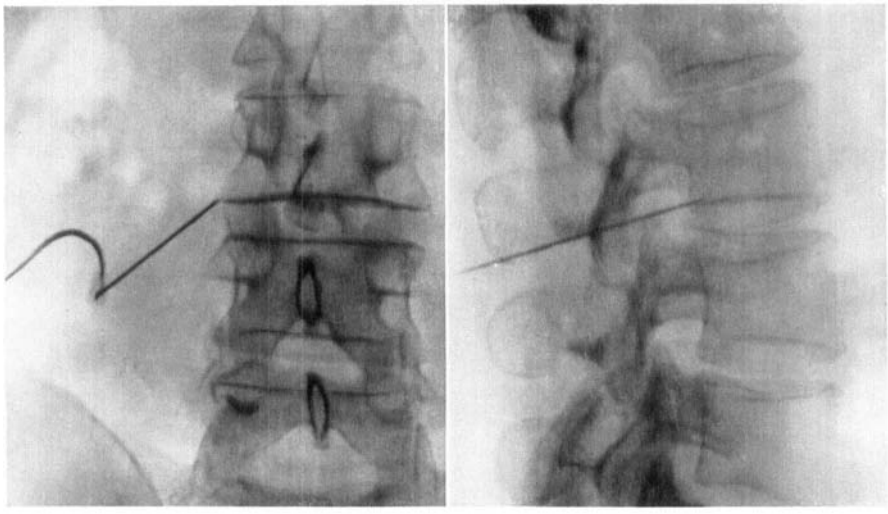


Figure 1. Schematic drawing of the approach to the psoas muscle.



a b

Figure 2. Roentgenograms of the electrode inposition.

4. Forward leaning 20 degrees and holding 10 kg in each hand.
5. Standing upright at ease.
6. Standing upright, 10 kg in each hand.
7. Standing and forward leaning 20 degrees.
8. Standing and forward leaning 20 degrees, 10 kg in each hand.
9. Standing on left leg with right leg in abduction.

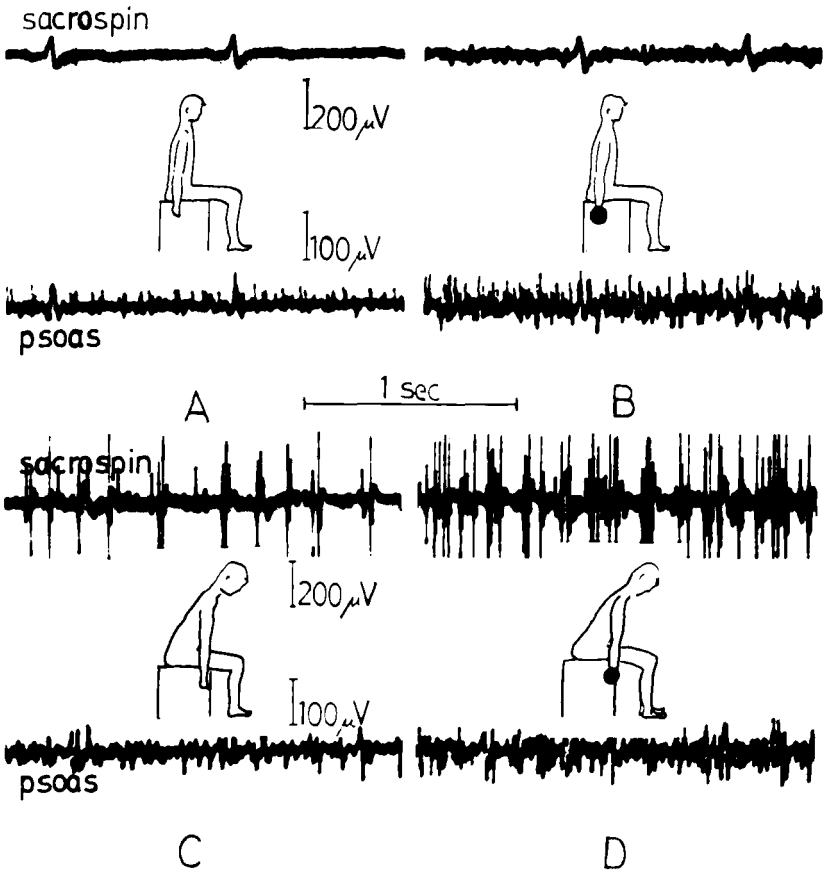


Figure 3. The electromyographic activity of the vertebral portion of the psoas major muscle, right side, in a male age 24 y.

A. Upright unsupported sitting.
B. Upright unsupported sitting, 10 kg in each hand.
C. Sitting and forward leaning twenty degrees by flexion in the hip joints.
D. Sitting and forward leaning twenty degrees by flexion in the hip joints and holding 10 kg in each hand.

10. Standing on left leg with right leg in adduction.
11. Standing on right leg only.
12. Standing on left leg with maximal flexion and adduction of the right hip.

The four last mentioned tests were also performed to investigate whether the vertebral portion of the psoas takes any active part in abduction or adduction of the hip, a matter of discussion in the literature (6, 13, 16).

One subject was measured twice with one weeks interval. The result from the two tests were identical.

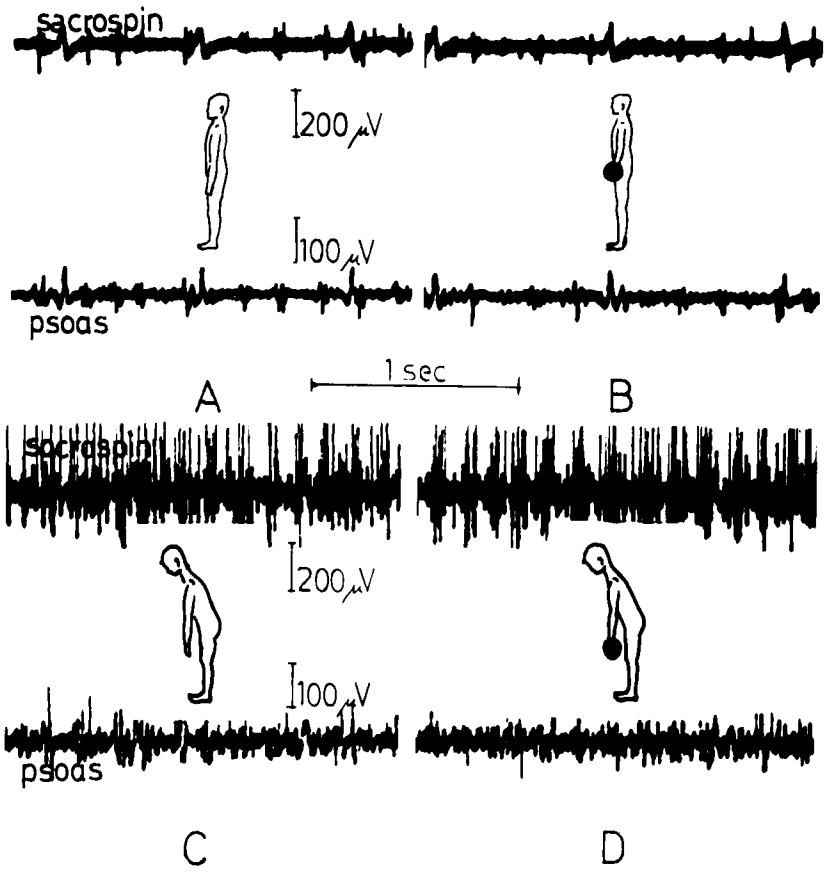


Figure 4. The electromyographic activity of the vertebral portion of the psoas major muscle, right side, in a male age 24 y.

A. Upright standing at ease.
B. Upright standing, 10 kg in each hand.
C. Standing and forward leaning twenty degrees by flexion in the hip joints.
D. Standing and forward leaning twenty degrees, by flexion in the hip joints and holding 10 kg in each hand.

RESULTS

Postiton 1. Upright sitting without support. In all eight subjects a somewhat varying amount of muscle action potentials could be recorded, while from the sacro-spinalis no activity could be read off from seven and slight activity in one. The psoas activity was always greater. The same holds for

Position 2., when 10 kg were added to each hand. In this position,

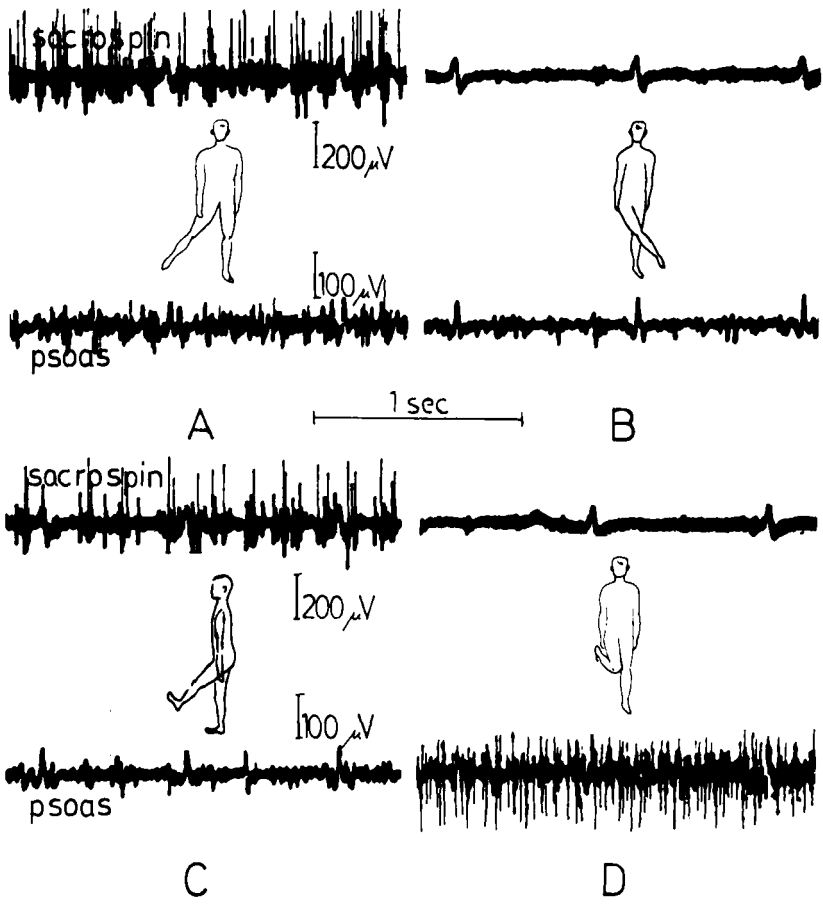


Figure 5. The electromyographic activity of the vertebral portion of the psoas major muscle right side in a male age 24 y.

A. Standing on left leg with right leg abducted.
B. Standing on left leg with right leg adducted.
C. Standing on right leg alone.
D. Standing on left leg with right hip flexed and adducted.

however, four individuals out of eight showed increased activity in the sacro-spinalis group of the muscles (Figure 3 A and B).

Position 3. Sitting and forward leaning 20 degrees. The psoas activity decreased from positions 1 and 2 in all eight subjects. The sacro-spinalis activity increased markedly in all subjects as compared to the previous position. With loads added, *Position 4.*, there was increase in both the psoas and the sacro-spinalis activity. Still the psoas

activity in Position 1 was greater than in Position 4 in six out of the eight subjects (Figure 3 C and D, Figure 6 A–D).

Position 5. Standing upright at ease. In this position seven of the eight individuals showed activity in the psoas major muscle. In the sacro-spinalis group of muscles activity was found in five and no activity in three.

Position 6. With weights of 10 kg in each hand some activity in the psoas muscle was found in all cases and in the sacro-spinalis in six out of the eight subjects. (Figure 4 A and B).

Position 7. Standing and forward leaning 20 degrees. The activity in the psoas muscle increased compared to upright standing in five out of eight. It was of about the same magnitude as in upright sitting, (Position 1). The activity increased somewhat in four with increasing load but remained the same in four. The back muscles were very active and increased to an observed maximum in *Position 8* when weights were added (Figure 4 C and D).

Position 9 and 10. Standing on left leg, right leg in abduction and adduction, respectively. Activity was found in the psoas muscle in all the cases. It was of about the same magnitude as in the upright sitting position. When the right leg was abducted three individuals showed less activity in the psoas muscle than when the leg was adducted, four showed greater activity and in one individual the activity was the same. In the sacro-spinalis group of muscles two patients showed no activity when the leg was out and two patients showed no activity when the leg was in. Otherwise the activity was about the same and moderate in all patients (Figure 5 A and B).

Position 11. Standing on the right leg only. Only five patients were tested. The activity in the psoas muscle was about the same as in the upright sitting position while the activity in the sacro-spinalis muscles was about the same as in the sitting and forward leaning position (Position 3), (Figure 5 C).

Position 12. Left leg stance, right hip flexed and adducted. In all eight subjects there was no activity in the sacro-spinalis group of the muscles but definite and strong activity in the psoas major muscle (Figure 5 D).

DISCUSSION

As mentioned in the introduction *Basmaijan* (1958) (3) reported definite activity in the upright standing position and he called this part of the ileopsoas muscle "an active postural muscle". The last-

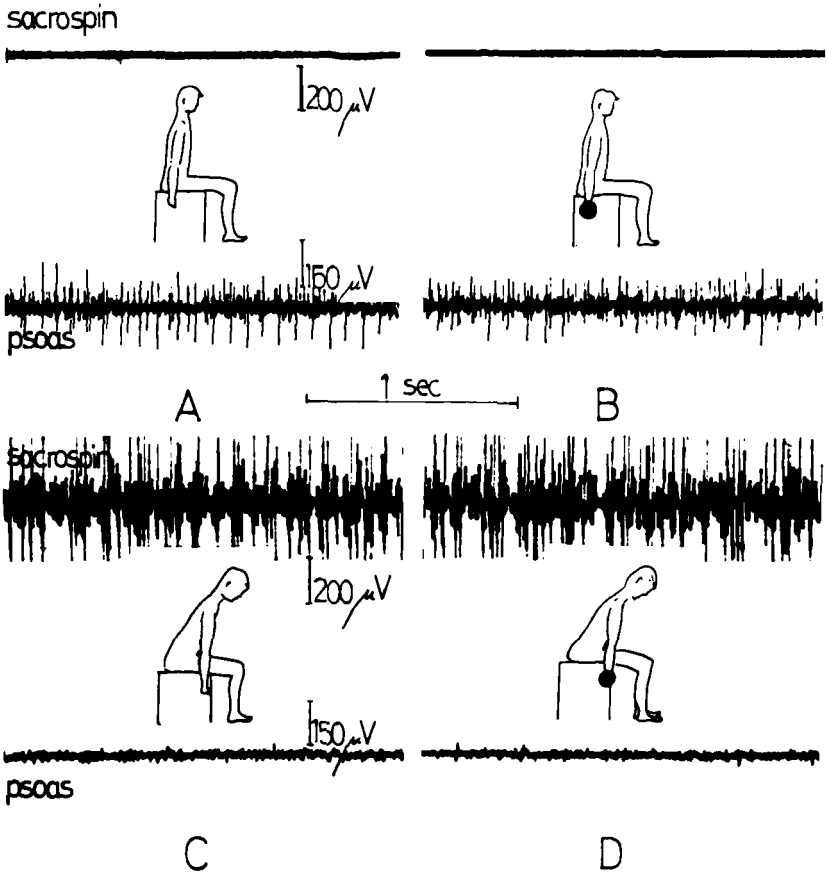


Figure 6. The electromyographic activity of the vertebral portion of the psoas major muscle, right side, in a male age 30 y.

A. Upright unsupported sitting.
B. Upright unsupported sitting, 10 kg in each hand.
C. Sitting and forward leaning twenty degrees by flexion in the hip joints.
D. Sitting and forward leaning twenty degrees by flexion in the hip joints and holding 10 kg in each hand.

This case clearly demonstrates how the activity in the psoas muscle decreases while the subject leans forward from the upright sitting position, which happened in the majority of the subjects.

mentioned author (3) and *Close* (1964) (6) who studied one subject via the same postero-lateral approach as used by *Basmaijan* (3), were mainly interested in the function of muscle upon the hip joint.

The results presented suggest that the vertebral portion of the

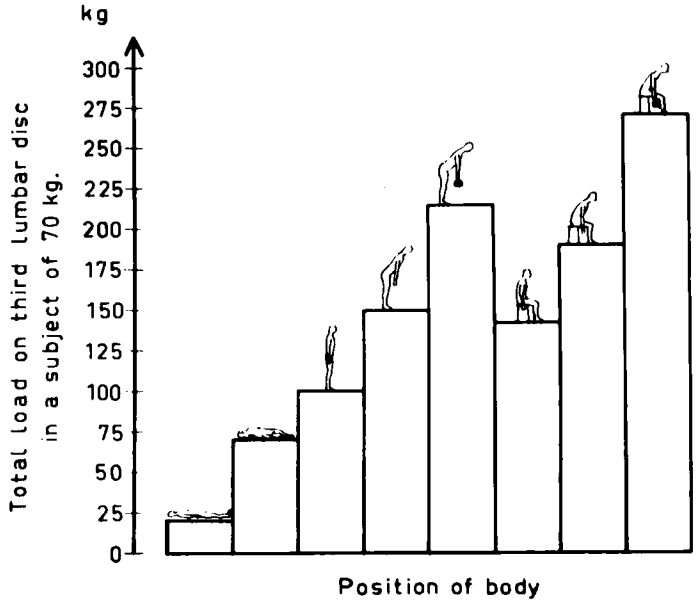


Figure 7. Approximate load on third lumbar disc in a subject of 70 kg in different positions of body. Positions shown are 1) reclining (relaxed, supine), 2) reclining (lateral decubitus) 3) standing upright, 4) standing + twenty degrees forward leaning without and 5) with 20 kg load in arms, 6) sitting upright, arms and back unsupported, 7) sitting + twenty degrees forward leaning without and 8) with 20 kg load in arms.

psoas muscle may aid in stabilizing the lumbar part of the spine, especially in the upright unsupported sitting and the upright standing positions. The present finding that there exists electromyographic activity in the psoas in these positions also means that it exerts some force on the lumbar part of the spine.

The results obtained from the sacro-spinalis group of muscles confirm those of earlier writers (11, 12, 17, 21, 22). In the upright sitting position less electromyographic activity at the lumbar level has been demonstrated by *Joseph* (12) and *Schoberth* (22) compared to other portions of the spine.

In recordings from the anterior abdominal wall muscles, *Floyd & Silver* (1950) (10) could demonstrate that in the standing at ease position there was slight activity in the internal oblique muscle only. In most cases no activity was found in the other abdominal muscles nor in the back muscles.

Åkerblom (1949) (24) has shown that in the upright sitting position the lumbar spine is flexed forward. In this study the activity in the

psoas muscle when standing and forward leaning 20 degrees was about the same as in the upright sitting position (Figures 3 and 4). On the other hand when the spine is bent forward in the sitting position the psoas becomes less active while the sacro-spinalis group seems to take over (Figure 3 C and D, Figure 6 A–D).

In the different positions of one leg stance a variable amount of activity was always found. The relation to the hip joint is uncertain. By virtue of the psoas activity in the static positions studied it can be concluded, however, that some compressive force is exerted on the lumbar spine.

Dempster (1958) (8) stated that whenever the body exerts forces on its environment, forming a closed chain system of forces, limb and trunk muscles do not directly exert pull forces; instead they maintain joint postures which permit body weight to exert an effective moment.

It seems that in the lumbar spine the posture in some positions is at least to some extent maintained by the psoas muscle.

SUMMARY

Lumbar disc measurements *in vivo* have in the unsupported upright sitting and upright standing positions revealed that heavier loads rest on the middle lumbar discs than can be explained by gravitational forces alone. In these positions the anterior abdominal and the sacro-spinalis muscles have been found relatively inactive in previous electromyographic studies. It has also previously been shown that the ligamentous lumbar spine essentially is an unstable rod which needs external force for stabilization.

Electromyography of the right-sided psoas major muscle at the level of the third lumbar disc in eight normal subjects, four men and four women, has shown a varying amount of activity in the upright positions studied. In most instances this activity decreased when leaning forward while the activity of the sacro-spinalis group of muscle which were studied simultaneously increased.

In standing on left leg with right leg abducted or adducted, as well as in standing on right leg activity was also revealed in the psoas.

The present investigation seems to support the idea that the vertebral portion of the psoas muscle besides its function as a hip flexor also takes part in maintaining upright postures. By its activity it adds a compressive force to the lumbar spine, thus adding to the gravitational forces to which the lumbar discs are subjected.

RESUME

Des mensurations de la pression de la vertèbre lombaire *in vivo* ont révélé dans la position assise redessée et dans la position debout sans supports qu'une charge plus lourde repose sur les disques lombaires du milieu que celle que l'on peut expliquer uniquement par des forces gravitionnelles. Dans cette position, des études électromyographiques ont montré que les muscles abdominal antérieur et sacrospinal, étaient relativement inactifs. Il a aussi été démontré antérieurement que la colonne lombaire ligamenteuse est essentiellement un faisceau instable qui a besoin d'une force externe pour la stabiliser.

L'électromyographie du côté droit du muscle psoas au niveaus de la 3ème vertèbre lombaire chez huit sujets normaux, quatre hommes et quatre femmes, a montré des quantités variables d'activité dans les positions étudiées. Dans la plupart des cas, l'"activité diminue dans l'inclinaison an avant, alors que l'activité du groups sacro-spinal des muscles étudiés augmente simultanément.

Si l'on se tient debout sur la jambe gauche, la jambe droite en abduction ou en adduction, ou debout sur la jambe droite activité est aussi révélée dans le psoas.

La présente enquête semble soutenir l'idée que la portion vertébrale du muscle psoas, à côté de sa fonction comme fléchisseur de la hanche, participe aussi au maintien de la position verticale. Par son activité, il ajoute une force compressive dans la colonne lombaire que s'ajoute aux forces gravitionnelles auxquelles sont soumises les vertèbres lombaires.

ZUSAMMENFASSUNG

Druckmessungen an lumbalen disci intervertebrales *in vivo* bei nichtunterstützter aufrecht sitzender und aufrecht stehender Stellung haben gezeigt, dass eine grössere Belastung auf den mittleren Lendenscheiben ruht als dies durch Schwergewichtskräfte allein erklärt werden kann. In vorhergehenden elektromyographischen Untersuchungen verhielten sich die vorderen Abdominal- und die Sacro-spinalmuskeln relativ inaktiv. Es wurde auch früher gezeigt, dass die ligamentöse Lendenwirbelsäule im wesentlichen ein unstabiler Stab ist, der zur Stabilisierung äusserer Kräfte bedarf.

Elektromyographie des rechtseitigen m. psoas major in der Höhe des dritten lumbalen Diskus in acht normalen Personen, vier Männern und vier Frauen, hat einen verschiedenen Grad von Aktivitet in den

untersuchten aufrechten Positionen gezeigt. In den meisten Fällen nahm diese Aktivitet bei vorwärts Beugung ab, während die Aktivitet der sacro-spinalen Muskelgruppe, die gleichzeitig studiert wurde, zunahm.

Beim Stehen auf dem linken Bein mit dem rechten Bein in Ab-oder Adduktion oder umgekehrt auf dem rechten Bein, wurde ebenfalls Aktivitet in Psoas gefunden.

Die vorliegende Untersuchung scheint die Annahme zu unterstützen, dass der vertebrale Teil des m. psoas, abgesehen von der Funktion als Hüftbeuger, auch an der Erhaltung der aufrechten Stellung teilnimmt. Durch seine Aktivitet fügt er eine komprimierende Kraft auf die Lendenwirbelsäule hinzu und erhöht in dieser Weise die Schwergewichtskräfte, denen die Lendenzwischenwirbelsheiben ausgestzt sind.

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