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Oblique abdominal muscle activity in standing and in sitting on hard and soft seats

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Summary

The activity of the oblique abdominal muscles was investigated with the trunk in unconstrained, symmetrical and static postures. Electromyographic recordings in six healthy subjects revealed that in all subjects the activity of both the internal and the external obliques is significantly higher in unconstrained standing than in supine posture. Activity of the internal oblique was higher than that of the external oblique abdominal. The sacrospinal, gluteus maximus and biceps femoris muscles showed practically no activity in unconstrained erect posture. During unconstrained sitting both oblique abdominals are active. In most subjects the activity of the oblique abdominals was significantly smaller when sitting on a soft car seat than when sitting on an office chair with a hard seat. The possibility is discussed that contraction of the oblique abdominals in unconstrained standing and sitting may help in stabilizing the basis of the spine and particularly the sacroiliac joints. During standing and sitting the oblique abdominal muscles apparently have a significant role in sustaining gravity loads.

Relevance

Back pain and pelvic pain are often experienced in prolonged standing and sitting postures. In these postures the oblique abdominals are shown to be active. The present study gains clinical significance by the studies showing relatively small oblique abdominal muscle strength in patients with low back pain. A soft seat may be helpful in treatment and prevention, because it substitutes oblique abdominal muscle activity.

Key words: Abdominal muscle, posture, sitting, car seat

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Introduction

In general, abdominal muscles are considered to be important for the increase of intra-abdominal pressure (IAP) in heavy performance[1]. Prelifting coactivation of diaphragm and abdominal muscles reduced erector spinae activity at lift-off and/or during trunk erecting movement[2]. Measurement of the activities of individual muscles of the ventrolateral abdominal wall with wire electrodes[3] showed that the transverse abdominal muscle activity is consistently related to changes in IAP. However, Hemborg et al.[4] showed that training of oblique abdominal muscles improves strength but generally does not affect IAP at lifting. Furthermore, IAP during lifting was the same in low back pain patients and in healthy controls[4] whereas low back pain patients had reduced oblique abdominal muscle strength (−25%). Obviously, the oblique abdominal muscles are of no decisive importance to the IAP. In a study on respiratory muscles Estenne et al.[5] concluded that the external oblique muscles were active in sitting. But the activation pattern could not be related to inspiratory function.

The foregoing suggests additional functions of the oblique abdominal muscles. This expectation is supported by a study in which EMG recordings of trunk muscles were compared with predictions from a biomechanical model[6]. It was concluded that oblique abdominal muscles in general appear to be more active in flexion–extension exercises than predicted.

With respect to loads in other planes, torsional stability of the trunk is ascribed primarily to the activity

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of the internal and external oblique abdominals[7]. The importance of this active stability role of the oblique abdominals as well as that of the transversus abdominis is well recognized by several researchers and clinicians[6,8,9].

Clinical significance of oblique abdominal muscle strength can be taken from the earlier mentioned study of Hemborg et al.[4]. Furthermore, Helewa et al.[10] showed that subjects with low back pain had lower oblique abdominal muscle strength than subjects without low back pain. With regard to pregnancy an attempt was made[11] to determine its effect on abdominal muscle strength and to correlate this strength with low back pain. It was concluded that abdominal muscles responsible for the performance of a sit-up become insufficient during pregnancy. There was no statistically significant correlation between the sit-up performance and backache. Oblique abdominal muscles were not separately measured in this study.

The foregoing literature suggests a possible role of oblique abdominal muscle weakness in the origin of low back pain. However, their stability function in strenuous situations remains obscure except in torsional load of the trunk. As to the biomechanical function, in the studies known to us no special role is ascribed to the oblique abdominal muscles in unconstrained, symmetrical static postures. Therefore we performed EMG-recordings on healthy subjects to answer the question as to whether the oblique abdominals have a function in such postures. Because small activities can be expected, recordings were taken in supine posture for comparison.

Methods

Subjects

A series of six healthy young subjects (three male, three female) was tested. Anthropometric data of subjects are listed in Table 1. They had to meet the following requirements: (1) no history of significant low back pain, (2) no history of severe trauma, (3) no previous surgery through the abdominal wall, (4) good physical condition, (5) no previous pregnancies. All subjects were students and involved in sports activities at least twice a week.

Electromyographic recordings

Surface electromyographic (EMG) recordings were taken unilaterally (right side) with disposable bipolar Ag–AgCl electrodes (Medicotest A/S Ølstykke, Denmark), E-50-VS; active surface area: 0.2 cm^2 placed at the following positions: sacrospinal (erector spinae muscle, ES) at about 3 cm from the midline at the level of the L_3–L_4 vertebrae[12]; gluteus maximus (GM) midway between the posterior superior iliac spine and the ischial tuberosity[13]; biceps femoris caput longum (BF) midway between the ischial tuberosity and the caput fibulae; external oblique (OE) above the anterior half of the iliac crest[14]; internal oblique (OI) in a triangle formed by the inguinal ligament, a line from anterior superior iliac spine to umbilicus, and the midline[14]. According to Floyd and Silver[14] crosstalk from psoas major and cremaster muscles is insignificant at this location. They state that activity from the underlying transverse abdominal fibres might be picked up. Since at this place these fibres appear to have a function similar to the internal oblique they did not try to differentiate between them. To reduce hum, electrodes were placed after skin preparation[15] and an electrode paste (Teca Corp. (Pleasantville, USA), cat. no. 822-201210) was used. Electrode pairs were placed at an interelectrode distance of 15 mm (centre to centre) parallel to the underlying muscle fibres and were secured with elastic Band aid. A reference electrode soaked in saline solution was placed around the right wrist. The EMG signals were preamplified 15 times (Medelec (Woking, UK), PA 63 preamplifier), bandpass filtered (20–10 kHz) and further amplified 1000 times (Medelec, AA6T amplifier) before being recorded on magnetic tape (Racal Thermionic, Store 14) for later analysis.

Table 1. Anthropometric characteristics of the test subjects

	Mean	*SD*	*Range*
Age (years)	24	2.1	20–26
Height (m)	1.75	0.06	1.65–1.84
Weight (kg)	64.3	7.4	54–71

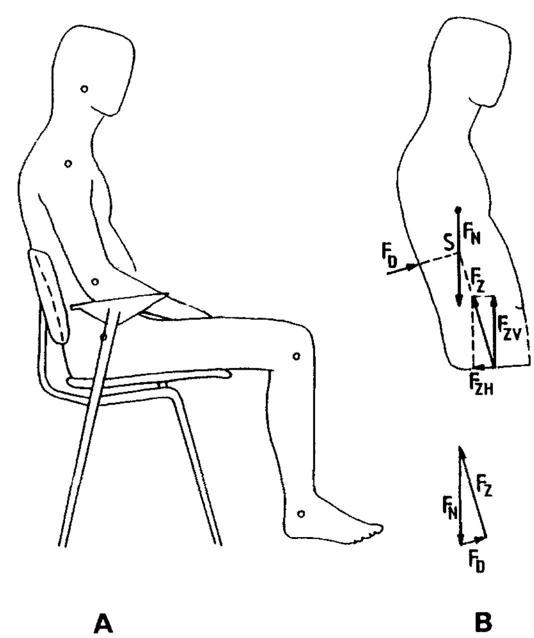

Figure 1. Passive sitting of a subject during EMG recordings. The free body diagram of the trunk shows a stable position by means of back rest force (FD), weight force (FN) and resultant force from the seat (FZ), which intersect in one point (S) and form a closed triangle of forces.

Table 2. Chronological order of measurements. From every posture five EMG recordings of 4 s each were made, except in static trunk flexion with two EMG recordings for every posture

Postures	*Intervals*
Supine	10 s between recordings
Standing, static trunk flexion	10 s between recordings and 2 min between two series
Sitting, office chair	1 min between recordings
Sitting, car seat	1 min between recordings

Measurement procedure

EMG recordings were made in three basic postures: supine, standing, and sitting (Figure 1), with several recordings per posture with set duration and set intervals (see Table 2). In all standing postures the arms were either relaxed beside the trunk or moving freely, and the knees were extended. In the sitting postures the arms were relaxed aside of the trunk with the hands folded in the lap and the head was held upright. All test sessions started with recordings in supine position with the subject lying on a firm mattress, a pillow under the head and knees, arms next to the trunk and legs extended. Next the subject was asked to stand unconstrained on both legs with hands folded in front of the body, the left thumb enclosed by the right hand[17] and the eyes looking downwards at an angle of 15° from the horizontal. This is called the erect posture (see Figure 2). Between recordings the subject moved arms and legs for a short while.

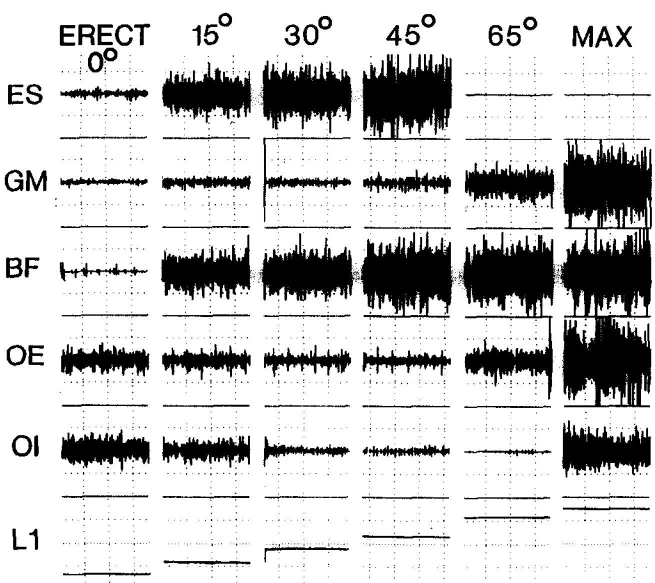

Figure 2. Typical example of unprocessed EMG recordings from five consecutive trunk positions from one subject. Erector spinae muscle drops at halfway forward bent posture which suggests transition of large forces to other structures. L_1: trunk angle measured at L_1; 0° (erect), 15°, 30°, 45°, 65° and maximal stooping. ES, erector spinae; GM, gluteus maximus; BF, biceps femoris caput longum; OE, obliquus externus; OI, obliquus internus.

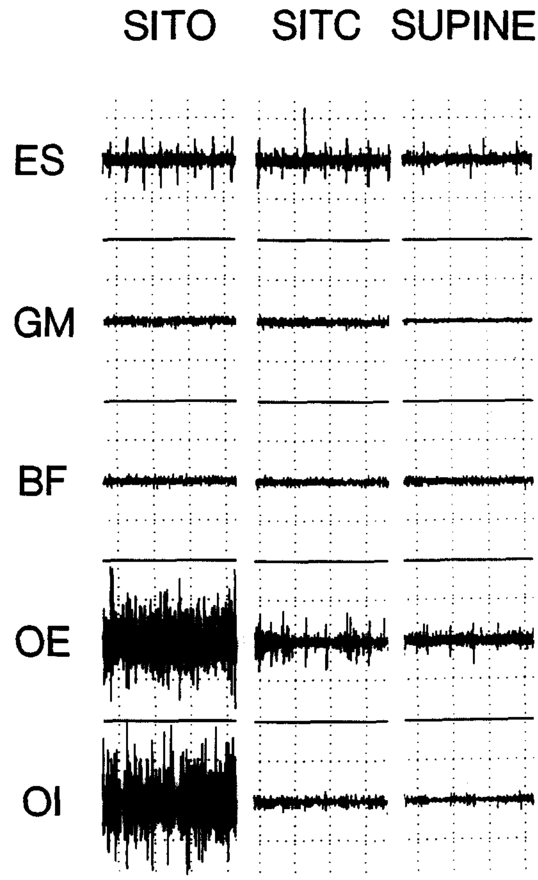

Figure 3. Unprocessed EMG signals from one subject recorded supine (right), during sitting on the hard seat of an office chair (left) and sitting on a soft car seat (middle). ES, erector spinae; GM, gluteus maximus; BF, biceps femoris caput longum; OE, external oblique; OI, internal oblique.

Next, recordings were made of static stooped postures. A specially designed small inclinometer[16] attached to the skin with tape at the level of the L_1 vertebra was used to monitor the degree of stooping and to adjust the subject in positions with angles of 15, 30, 45 and 65 degrees with respect to the erect position (0 degrees). Maximum forced voluntary flexion was taken as the last recording of each series. Between the stooped postures subjects stood upright for 10 s. Recordings started immediately after a subject reached the appropriate flexion angle. Subsequently, sitting postures were recorded. Recordings were made 1 min after the subject adopted the sitting posture. In the first series the subject was sitting on an office chair with hard seat, backrest, and armrests (Figure 3). The chair could not be adjusted. Subjects were asked to sit relaxed upright against the backrest with knees and ankles at right-angles and with some space between the legs. The armrests were not used. One subject could not place her feet flat on the floor. In this case a wooden beam of appropriate size was used to support the feet so that ankles and knees stayed at right-angles. After each recording subjects lifted the body a little from the seat.

In the second series the office chair was replaced by a seat from an old French car. The chair used in our study had a soft seat, but at the same time provided for good support of the back. In general these seats had a good reputation. Inclination of the backrest was adjusted in such a way that the subjects assumed a trunk posture similar to the posture in the office chair. Seating height, leg, and foot position corresponded to car geometry.

Between the two sitting tests subjects stood upright for several minutes. With the exception of the supine tests the subjects watched an informative television programme to distract them. The television was placed in such a way that the line of vision was approximately 10–15° below horizontal. All tests occurred at room temperature while subjects were wearing sportswear.

Data analysis

The EMG signals replayed from tape were filtered (25–500 Hz, 4th-order Butterworth filter) and fed into a computer with sampling rate of 2000 Hz. A data acquisition program (AT CODAS) was used to acquire the signals. After data collection the signals were off-line full-wave rectified and the mean EMG amplitude over 6000 consecutive samples was calculated of all recordings of each muscle. The mean EMG amplitudes of the same posture were averaged and related to the maximum activity of the muscles and the activity in supine position. The averages related to supine were compared within the subjects. Statistical significance was tested with a Student t test, level of reliability, α, 0.05.

Results

In Figures 2 and 3 mV scales and time scales are omitted since these illustrations are only intended for qualitative analysis of activity patterns.

Trunk flexion

Figure 2 illustrates the muscle activities recorded during various trunk positions. During static stooped postures up to 40° the ES demonstrated a strong increase in activity in all subjects. Within the range of 40–70° activity fell to almost equal or lower levels than measured during unconstrained standing. With increasing stooping GM activity increased gradually in all subjects whereas BF activity increased abruptly, with a tendency to decrease during the last flexion positions. With increasing stooping the OE and OI demonstrated a gradual decrease in activity. However, during the last two bending positions a sudden increase in activity was often seen.

Unconstrained standing

In unconstrained standing practically no activity was seen in the sacrospinal, gluteus maximus, and biceps femoris muscles. All subjects showed significantly higher OE and OI activities than in the supine posture (Figure 2, Table 3a). The OE activity was on average 341% (range 144–666%) of the activity recorded in supine posture and 39% (11–74%) of the maximum

Table 3. Average activity (SD) of the oblique abdominals recorded in six subjects. Activities are displayed as percentages of the activities recorded during supine posture (sup) and as percentages of the maximum activities (max) recorded for each individual. OE, external oblique; OI, internal oblique. **a**, Standing; all subjects showed significantly higher activities in standing than in supine posture. **b1**, External oblique, when seated on the office chair (SITO) and on the car seat (SITC). All subjects except nos 2 and 6 showed significantly higher activities in sitting on the office chair compared to supine. All subjects except nos 1 and 6 showed significantly lower activities when seated on a soft car seat than when sitting on the hard seat of an office chair. **b2**, Internal oblique, when seated on the office chair (SITO) and on the car seat (SITC). Subjects nos 5–6 showed significantly higher activity in sitting on the office chair compared to supine. Subject no. 3 showed significantly lower activity. All subjects except no. 1 showed significantly lower activity when sitting on a soft car seat than when sitting on the hard seat of an office chair

	Subjects	*1*	*2*	*3*	*4*	*5*	*6*	*Mean*
a, Standing	OE sup	342* (32)	354* (87)	274* (30)	263* (120)	666* (84)	144* (16)	341 (176)
	OE max	15 (1.4)	74 (18)	44 (4.8)	11 (5.4)	44 (5.6)	44 (4.8)	39 (23)
	OI sup	558* (76)	304* (66)	383* (31)	460* (57)	916* (84)	1010* (71)	605 (291)
	OI max	88 (12)	43 (9.2)	54 (4.3)	79 (9.8)	34 (3.1)	92 (6.5)	65 (25)
b1 Sitting	OE SITO sup	130* (32)	106 (19)	108 (5.0)	166* (11)	264* (98)	86 (6.7)	187 (47)[1]
	OE SITO max	5.8 (2.4)	22 (3.9)	17 (0.8)	7.3 (0.5)	18 (6.6)	26 (2.1)	16 (2.7)
	OE SITC sup	81 (5.5)	63** (2.4)	82** (4.1)	136** (4.7)	128** (42)	201 (36)	102 (35)[2]
	OE SITC max	3.7 (0.2)	13 (0.5)	13 (0.7)	6.0 (0.2)	8.5 (2.8)	61 (11)	10 (3.5)
b2 Sitting	OI SITO sup	118 (50)	111 (15)	80 (0.7)	258* (60)	393* (208)	356* (45)	336 (70)[1]
	OI SITO max	19 (7.8)	16 (2.1)	11 (0.1)	45 (10)	14 (7.6)	32 (4.1)	30 (16)
	OI SITC sup	84 (7.5)	77** (9.2)	64** (1.7)	125** (28)	102** (6.0)	73** (6.3)	88 (25)[2]
	OI SITC max	13 (1.2)	11 (1.3)	8.9 (0.2)	22 (4.9)	3.7 (0.2)	6.6 (0.6)	10 (7.0)

* significantly higher than supine (sup).
** significantly lower than sitting on an office chair (SITO).
[1] mean (SD) of *.
[2] mean (SD) of **.

activity. For the OI these numbers were 605% (304–1010%) and 65% (34–92%) respectively. Obviously interindividual differences are large.

Sitting postures

Figure 3 shows the unprocessed EMG recordings from a subject sitting on an office chair (left), in a soft car seat (middle), and lying supine (right). Table 3b shows the quantitative data for all subjects while seated on the office chair and in the soft car seat. When sitting on the office chair four subjects showed significantly higher OE activities than in the supine posture. In these subjects the OE activity was on average 167% of the activity recorded during supine and 12% of the maximum activity. In sitting significantly higher OI activities than in the supine posture were found in three subjects. These activities averaged to 336 and 30% respectively. Subject 3 showed a significantly lower activity. When the office chair was replaced by the soft car seat both OE and OI activities dropped. Subject 6, however, showed a significantly higher activity of the OE. The subjects with significant lower abdominal muscle activities in the soft car seat, as compared to the office chair, showed an average OE activity of 102% and OI activity of 88% of the activity recorded in the supine posture.

Discussion

The aim of this study was to depict oblique abdominal muscle activity in postures with moderate and small spinal loads and complete absence of torsion. Static postures were chosen, with the advantage of reproducibility but the disadvantage of very small muscle activity. This induced us to compare the unconstrained standing and sitting postures with supine. The activity of the sacrospinal, gluteus maximus, and biceps femoris muscles was recorded to verify relaxation. In strenuous situations like flexion–extension movements coactivation of sacrospinal, gluteus maximus, hamstrings, and abdominal muscles was demonstrated by Noe et al.[13] and Oddsson and Thorstensson[12,18]. By means of static stooped postures we introduced recordings with less spinal load. The measuring with surface electrodes does not give information about muscles that may be active in the respective postures, like the transverse abdominal and pelvic-floor muscles. The position of the internal oblique electrodes, however, may pick up activity of the underlying transverse abdominal fibres, but both muscles have a similar function at this level.

In static stooped postures the erector spinae activity dropped at approximately 40–70°, while the gluteus maximus and the biceps femoris remained active. The termination of erector spinae activity at the halfway forward bent posture suggests transition of large forces to other structures, which may influence a change of load on the sacrum. Here we refer to the biomechanical model from Snijders et al.[19] on the bifurcation in the lumbosacral load, which shows that the effect of forces acting directly on the sacrum (part of erector spinae muscle) is essentially different from forces acting directly on the hip bones (trunk muscles and thoracolumbar fascia). Limited control of this transition of force from one branch of the bifurcation to the other could play a role in the origin of acute low back injuries.

In static stooped postures the oblique abdominals showed small or no activity, whereas strong activity was present in extreme flexion. The absence of oblique abdominal activity in stooped postures does not meet the supposition of Floyd and Silver[14] that the internal oblique is in constant guard over the inguinal region.

In the erect posture we found limited or no activity in erector spinae, gluteus maximus, and biceps femoris muscles. In agreement with observations by Floyd and Silver[14] the activity of the internal oblique was considerable. The external oblique showed moderate activity. Recordings made in unconstrained standing and in sitting of oblique abdominal muscle activity could not be related to breathing.

In sitting the erector spinae, gluteus maximus, and biceps femoris muscles showed little or no activity, in agreement with the expectation. With reference to the sitting posture in Figure 1 it can be stated that the trunk is in a stable position. The backrest warrants sagittal and lateral stability and in this symmetrical posture no torsion is exerted on the spine. Therefore we do not expect that the oblique abdominal muscle activity recorded in sitting is necessary to maintain posture. This leads to the speculation that the oblique abdominals contribute to the stability of the sacroiliac joints. This speculation is based on a biomechanical model which explains sacroiliac joint stability in various loading situations[19–22]. Forces from muscles, especially in combination with the posterior lamina of the thoracolumbar fascia with lines of action crossing the sacroiliac joints, can provide joint compression, which can contribute to sacroiliac joint stability. Here an important role can be ascribed to the gluteus maximus muscles, which via the thoracolumbar fascia can produce a line of action together with the heterolateral latissimus dorsi. When the activity of the gluteus maximus is absent the biomechanical model suggests a role for the oblique abdominal muscles. In a reconstruction of the pelvis with macerated bones we could demonstrate compression in the sacroiliac joints by applying forces in the simulated direction of the oblique abdominals. In this way the sacroiliac joints were locked.

With respect to the effect of a soft seat, we think of forces on the pelvis in transverse direction, borne by the support of the left and right buttocks at the site of the greater trochanter. The forces in transverse direction can contribute to sacroiliac joint compression according to the biomechanical model of the pelvic arch[20]. This model is not applicable on a hard seat, in which situation the pelvis is supported by the ischial tuberosities without transverse force components.

Combination of EMG studies with measurement of sacroiliac joint stability could not be performed in the present study. No reliable instrumental method is known to us for the assessment of the stability of the *in-vivo* loaded sacroiliac joint.

Conclusions

From the study on the activity of trunk and leg muscles in relation to posture, the following can be concluded.

In static stooped postures the activity of both internal and external obliques is small or absent, whereas profound action occurs at extreme flexion. In unconstrained erect posture erector spinae, biceps femoris, and gluteus maximus are practically inactive, whereas the external oblique shows moderate and the internal oblique shows strong activity compared to supine. In passive sitting on an office chair with a hard seat and a back rest all muscles recorded showed little or no activity, except the internal and external obliques. Sitting on a soft car seat occurs with less activity of the oblique abdominals if compared to sitting on a hard seat of an office chair. The significant activity of the oblique abdominal muscles in standing and sitting points to a continuous task in sustaining gravity loads. A soft car seat may ease this task.

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