ELSEVIER

Journal of Biomechanics 34 (2001) 491–496

JOURNAL OF BIOMECHANICS

www.elsevier.com/locate/jbiomech
www.JBiomech.com

Analyses of myo-electrical silence of erectors spinae

Ajay Gupta*

Department of Orthopaedic Surgery, Maulana Azad Medical College & Associated L. N. Hospital, New Delhi, India

Accepted 25 October 2000

Abstract

Electromyographic activity of the erector spinae was studied in 25 healthy, young individuals during forward bending and then coming back to erect posture. Sudden onset of electrical silence called the flexion – relaxation phenomenon was seen to occur in all at 57% of the maximum hip flexion and at 84% of the maximum vertebral flexion. Abrupt re-commencement of the activity was seen at almost similar flexion angle while coming back to erect position. The experiment was repeated with the buttocks held against the wall so as to prevent the posterior migration of the pelvis and also the hip flexion to some extent. The effect was to produce inhibition of the electrical activity earlier at 75% of maximum vertebral flexion ($p < 0.001$) while reactivation of erector spinae occurred soon after the extension started from the maximum trunk flexion. Eleven male subjects repeated the experimental task holding 22 lb weight in front and then on their back tied around the iliac crest. In both the instances the myo-electrical silence was found to occur at greater vertebral flexion. It is concluded that the passive equilibrium between gravity induced tensile torque and the extension torque of stretched posterior vertebral ligaments is responsible for the flexion–relaxation phenomenon than the stretch receptors.

Keywords: Erector spinae; Trunk muscles; Electromyography; Electrical silence; Flexion–relaxation phenomenon

1. Introduction

Trunk flexion from the erect position is the combined movement of the vertebral and the pelvic flexion and is produced by moment of the upper body weight. The vertebral flexion is controlled by the eccentric contraction of the erector spinae while the eccentric contraction of the hip extensors and hamstring muscles control the pelvic part of the trunk flexion. The electrical activity in the erector spinae suddenly stops after a certain amount of trunk flexion, and there is sudden re-commencement of the electrical activity during extension from the fully flexed position at almost similar position of trunk flexion. The cessation of erector spinae activity has been observed to occur at maximum trunk flexion (Morris et al., 1962; Pauly, 1966) though contrary claims, that erector spinae inactivity occurs before full trunk flexion have also been reported (Portnoy and Morin, 1956; Okada, 1970; Farfan, 1975; Wolf et al., 1979). This phenomenon called the flexion–relaxation phenomenon (Floyd and Silver, 1955) though described by Allen as back as 1948, continues to be controversial about its etiology.

Most authors have described this phenomenon mainly in terms of trunk flexion. Patients with chronic low backache have been reported not to show this flexion–relaxation phenomenon due to the abnormal neuromuscular coordination between the trunk and hip movements (Shirado et al., 1995). We thought it could be interesting to perform trunk flexion in various abnormal combinations of the vertebral and hip movements and observe their effect on the flexion–relaxation phenomenon. In view of the specific design of the study, we proposed to measure all the three flexion angles including the trunk, hip and the vertebral angle than merely the trunk flexion. The present study aimed to produce the myo-electrical variance and an altered flexion–relaxation phenomenon by (1) experimentally producing abnormal combination of the trunk and hip movements by making the subjects bend forward with the pelvis held against the wall which prevents posterior migration of the pelvis and also limits the pelvic component of the trunk flexion considerably, (2) making the subjects bend forward with weights tied posteriorly

*Correspondence address: Armed Forces Hospital, P.O. Box 454, Safat 13005, Kuwait.

E-mail address: drajaygupta@hotmail.com (A. Gupta).

0021-9290/01/$ - see front matter
PII: S0021-9290(00)00213-X

around the iliac crest, thereby restricting the pelvic movement and (3) making the subjects bend forward holding weights in their hands. The last part of the experiment was incorporated in the study with a view to test or reaffirm the findings of Kippers and Parker (1984) who reported the flexion–relaxation phenomenon with subjects holding weight in their hands to show inhibition of the activity at greater vertebral flexion. It also provided comparative assessment of the effect of the weights placed anterior or posterior to the axis of the hip on the flexion–relaxation phenomenon. The study was also aimed to work out a plausible etiology for the flexion–relaxation phenomenon based on the observations.

2. Material and methods

This study included 25 healthy subjects, 15 males and 10 females, who had never had any symptoms relating to their back. The age ranged from 20 to 35 years with an average of 27.4 years (Table 1). Each subject was made to bend forward to maximum trunk flexion from the erect posture trying to touch their toes, keeping the knee joints straight. The full flexion was maintained for a while followed by gradual extension to the initial erect position. The whole task was repeated twice and the time permitted for it was maintained to be 10 s each with the help of a timer watch. The electromyographic activity of different group of muscles including the erector spinae, abdominals, hamstrings and the hip extensors were recorded using Neuromatic 2000 (Dantec, Denmark) and the surface electrodes. The electrodes were placed bilaterally at the level of the spinous process of third lumbar vertebra, approximately 5 cm from the mid-line for the erector spinae, on the anterior abdominal wall in mid-line approximately 10 cm on either side of umblicus for abdominal muscles, over the medial and lateral hamstrings approximately 3 cm above the beginning of their tendons for hamstrings and at the middle of the buttocks for the hip extensors (Portnoy and Morin, 1956). Two markers were applied to the skin surface, one connecting the anterior superior iliac spine to the posterior superior iliac spine and another connecting spinous process of first dorsal vertebra to right acromion process so as to determine the flexion angle of the vertebrae and the pelvis, accurately. A 35 mm camera placed at 3-m distance to the right side of the subjects was activated manually by the experimenter as the amplitude of the signal on the oscilloscope suddenly decreased to zero. The maximum amplitude of the signal of the oscilloscope screen was about 3 cm with the channel sensitivity set at 500 μv/div. At about $\frac{2}{3}$ of the trunk flexion from the erect position, the activity in erector spinae abruptly stopped (silent position one–SP1). This electrical silence of erector spinae persisted during further trunk flexion and also during initial extension of the trunk from the fully flexed position. The trunk position corresponding to the reappearance of the activity in erector spinae was termed silent position two (SP2). The various trunk positions photographed were the erect position (E), the SP1, SP2 and the position of maximum forward flexion (MFF).

All the subjects repeated the experimental task with their pelvis closely held against the wall (Fig. 1a). This did not permit the pelvis to move posteriorly during the trunk flexion and, therefore, prevented the pelvic component of the trunk flexion considerably. All the four positions were recorded again during this modified forward bending. Photographs were taken to record the two silent positions and the maximum forward flexion. Eleven male subjects (Table 2) performed the experiment holding 22 lb weight in their hands in front and then holding weight on their back tied around the iliac crest (Fig. 1b–c). The two silent positions and position of maximum forward flexion were recorded again.

The trunk angle (TA) was measured as the angle between the long axis of the thigh and the plane of the trunk represented by the line joining spinous process of the first dorsal vertebra with the centre of the hip joint. The angle between the plane of the pelvis represented as a line connecting the two superior iliac spine and the long axis of the thigh formed the hip angle (HA). Vertebral angle (VA) was between the plane of the pelvis and the long axis of the vertebral column drawn as a line connecting the posterior superior iliac spine with the spinous process of the first dorsal vertebra (Fig. 2).

3. Results

The flexion–relaxation phenomenon was seen in all 25 subjects. Forward bending from the erect posture demonstrated abrupt silence of the electrical activity in

Table 1
Characteristics of 25 healthy subjects performing the task of normal and the modified bending forward (15 males, 10 females)

	Mean	Range
Age (year)	27.4	20–35
Weight (kg)	52.0	43–75
Height (m)	1.58	1.54–1.76

Table 2
Characteristics of 11 healthy subjects performing the task with weights

	Mean	Range
Age (year)	22.8	22–28
Weight (kg)	59.0	54–75
Height (m)	1.65	1.60–1.76

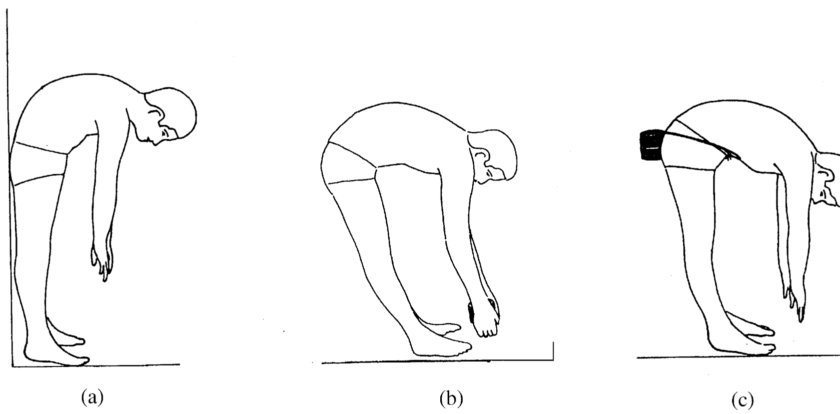

Fig. 1. Various experimental posutres of the trunk flexion (a) with buttocks held against the wall so as not to allow it to move posteriorly, (b) with weight held in front and (c) with weight held posteriorly tied around the iliac crest. Note the decreased posterior displacement of the pelvis as compared to 'b'.

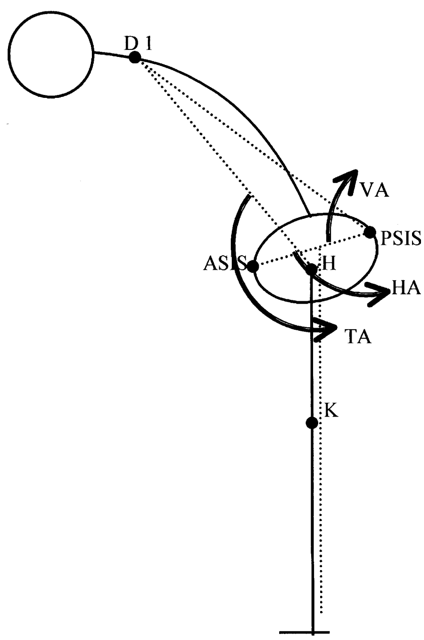

Fig. 2. Measurements of various angles. D1 — spinous process of the first dorsal vertebra; ASIS — anterior superior iliac spine; PSIS — posterior superior iliac spine; H — centre of hip joint; K — centre of knee joint; TA — trunk angle; VA — vertebral angle.

erector spinae at 57 and 84% of the maximum hip and vertebral flexion, respectively (SP1). The electrical activity during extension from fully flexed position, reappeared at average 64 and 88% of maximum hip and vertebral flexion, respectively (SP2). Average maximum flexion was 68.8° (S.D. 11) for the hip and 57.1° (S.D. 8) for the vertebrae. All the flexion values at maximum forward flexion were greater than those at the silent positions ($p<0.001$). All flexion values at the recommencement of the myo-electrical activity (SP2) though appeared greater than the first silent position (SP1), but were found not to be significant.

The silent position one (SP1) was seen to come much earlier ($p<0.001$) at an average hip and vertebral flexion of 28 and 75% of the maximum flexion value when the forward bending was performed with the buttocks held against the wall. Though the first silent position appeared to come earlier than the maximum forward flexion, but the difference was not found to be significant. Extension of the trunk from the fully flexed position, with the buttocks held against the wall, however, failed to demonstrate SP2 as the erector spinae showed activity from the very beginning of the extension (Table 3).

The electromyographic study of the abdominal muscles demonstrated absolute electrical silence during trunk flexion from the erect position and also during the extension from the fully flexed position. This occurred in all but four subjects whose abdominal muscles showed mild activity during the terminal range of the trunk flexion appearing some time after the commencement of myo-electrical silence in erector spinae (SP1). The appearance of activity in the abdominal muscles during the terminal flexion however was consistently seen when the trunk flexion was performed with the buttocks held against the wall and appeared almost coinciding with the commencement of myo-electrical silence in erector spinae (SP1). A good electrical activity was seen in the hamstrings during the whole act of flexion and also during extension from the fully flexed position. The hip extensors also showed mild activity throughout the act in 18 of the 25 subjects. Four subjects showed activity in hip extensors during extension only from the fully flexed position while 3 subjects showed no activity at all.

Effects of weight: The effect of the weight on vertebral flexion was to significantly increase these measurements at the first silent position irrespective of its position whether anterior or posterior to the hip axis ($p<0.05$). The mean hip flexion at the first silent position was found to be considerably less when the weight was kept

Table 3
Flexion measurements during normal forward bending and bending with the pelvis held against the wall

Flexion measurement angle (°) $X \pm SD$	Normal bending			Bending with pelvis held against the wall		
	SP1	MFF	SP2	SP1	MFF	SP2
Trunk	80.3 ± 8	116.2 ± 14	85.6 ± 10	56.1 ± 9	57.3 ± 10	—
Hip	39.4 ± 7	68.8 ± 11	44.3 ± 6	18.9 ± 4	19.3 ± 4	—
Vertebral	47.1 ± 5	57.1 ± 8	50.3 ± 4	42.9 ± 8	43.5 ± 10	—

Table 4
Flexion measurements at silent positions in normal and weighted conditions and their correlations

Flexion measurement angle (°) $X \pm SD$	SP1			SP2		
	Normal	Weight ant.	Weight post.	Normal	Weight ant.	Weight post.
Trunk	90.7 ± 10	91.9 ± 8	86.2 ± 13	101.2 ± 6	98.0 ± 7	101.6 ± 11
Hip	37.5 ± 8	37.2 ± 6	29.7 ± 7^{a}	35.2 ± 6	31.1 ± 5	29.9 ± 8
Vertebral	55.2 ± 9	56.7 ± 8^{b}	60.1 ± 11^{b}	54.3 ± 9	54.1 ± 9	57.4 ± 11

[a] $p<0.02$.
[b] $p<0.05$.

posterior to the hip ($p<0.02$) except in one subject who showed it at a much greater flexion and was not included in the study. The addition of weight was not found to affect the trunk measurements to the significant level though the myo-electrical silence appeared to come later in trunk flexion when the weight was held in front (91.9°) and earlier with weight held posteriorly (86.2°) as against the 90.7° in the un-weighted task. The re-commencement of the myo-electrical activity (SP2) also did not change significantly for any of the flexion measurements with the addition of weights (Table 4).

4. Discussion

A number of physiological mechanisms have been proposed to explain the flexion–relaxation phenomenon in the back muscles. Allen (1948) gave the concept of position of full flexion equivalent to the SP1 and any further flexion being forced flexion. Stretch receptors have been suggested in the ligamentum flavum and other ligaments, which get stimulated when these ligaments are stretched, sending afferent impulses to cause reflex inhibition of the erector spinae (Floyd and Silver, 1955; Kippers and Parker, 1984; and Schultz et al., 1985). The flexion–relaxation phenomenon has been reported to occur considerably before full trunk flexion but only after the intervertebral rotation has reached a stage of completion. The persistent activity in erector spinae in-patients with backache is suggested a means to provide stability to help protect the diseased passive spinal structure (Kaigle et al., 1998). Many other proposals regarding the etiology of this flexion–relaxation phenomenon have been muscle lengthening reaction (Portnoy and Morin, 1956) and the flexion-limiting role of the erector spinae (Taylor and Towmey, 1980).

Trunk, for a simple mechanical model, may be considered as a flexible rod fixed over a rotating ball. The forward rotation of the ball produces flexion at the hip while the vertebral flexion is the deformation of the flexible rod. In any static position of trunk flexion, the hip flexion is maintained by balance of the torque of the upper body weight resisted by a combination of the tension and mass of the structures posterior to its axis. Similarly, the vertebral flexion is maintained by the torque of the upper body weight resisted by combination of tension and compression of post- and pre-vertebral structures, respectively. The silent positions may be one of the passive equilibrium between the torques due to gravity and the extension torque provided by the stretched posterior vertebral ligaments. Any trunk position, after having reached equilibrium between the two torques, has to switch off the activity in the erector spinae, if the state of equilibrium is to be maintained. The activity in erector spinae plays the key role of balancing the two entirely passive forces and providing controlled movement to the vertebral flexion through its eccentric contraction.

Flexion–relaxation phenomenon is a definite characteristic in healthy subjects but lacks consistency in correlation between its various constituents and their absolute values. Kippers and Parker (1984) reported poor test and re-test correlation for trunk and hip flexion indicating that individuals vary the dynamic relationship during different trials. Floyd and Silver (1955) reported the two silent positions to have large range of trunk flexion (SP1 = 53–115; SP2 = 55–109). They further noted the two silent positions to be similar in terms of trunk and hip flexion. Kippers and Parker (1984) also made similar observations though reported variations for the vertebral flexion (SP2 > SP1). Shirado et al. (1955) reported trunk and hip flexion to be greater at the first silent position than the second silent position. Our findings were similar to the previous reports with no significant difference between the two silent positions.

The onset and cessation of the myo-electrical silence can be influenced by several factors which include lumbar lordosis, general laxity of the joints, strength and relative length of the muscles of the trunk and hip, co-ordination of trunk and hip movements and the velocity of the flexion extension movements, etc. The vast range of the normal variance of all these factors may be responsible for the variable behavior of the flexion–relaxation phenomenon. That is why it may not be possible to reproduce exactly similar observations, even if the experiments were matched for the parameters of age, sex and height, etc. The two experimental tasks in our study were not aimed to be compared to each other and so were not matched for the various characteristics.

Our results were similar to the previous results by Kippers and Parker (1984) who reported silent period to occur later in the vertebral flexion phase when additional weight was held in front. Addition of weights, whether anterior or posterior to the hip axis produce increased tensile torque. This requires the balancing act of the erector spinae to continue longer till the extension torque by the posterior vertebral ligaments is increased proportionally enough at greater vertebral flexion. Silent positions could be brought earlier in vertebral flexion ($p < 0.001$) if the pelvic movement was limited by making the patient stand against the wall while, addition of weight made it to come later ($p < 0.05$) in vertebral flexion. The flexion–relaxation phenomenon in the back muscles is a consistent finding in healthy subjects but the fact that it can be made to appear earlier or later in the vertebral flexion goes against the theory of stretch receptors in the ligaments causing reflex inhibition of the erector spinae.

The onset of electrical silence has mostly been described in terms of trunk flexion, which has been shown to occur between 45 and 90° in one study (Okada, 1970) and 80–90° in another (Taylor and Towmey, 1980). There have not been many studies measuring this phenomenon in terms of hip and vertebral flexion, which appear rather more appropriate than the trunk flexion particularly after such reports as an abnormal neuromuscular co-ordination between the trunk and hip leading to absence of flexion–relaxation phenomenon in chronic low backache patients (Shirado et al., 1995). The phenomenon has been reported to occur at 56% of maximum hip flexion and 89% of maximum vertebral flexion (Kippers and Parker, 1984) which our study also supports. They observed the vertebral flexion to be the most reliable measures at both silent positions, making them to suggest that receptors in the vertebral column or related structures to be involved in determination of erector spinae activity. The vertebral flexion may be the major determinant for both the silent positions, but the hip flexion also affects the silent position, though indirectly. The flexion torque of the upper body weight increases with increased hip flexion and decreases with decreased hip flexion for the identical vertebral position. That is why in the experimental task with the buttocks held against the wall, the associated decreased hip flexion produces lesser flexion torque and therefore, brings equilibrium at a lesser extension torque at a lesser vertebral flexion. Though there are several reports in the literature, describing various proposals to explain the etiology of the flexion–relaxation phenomenon of the back muscles, one very important aspect of this phenomenon as to what controls the vertebral flexion from SP1 to MFF has somehow not attracted much attention. We could not demonstrate any activity in the abdominals (except in four subjects) during this silent segment of trunk flexion. The continued hip flexion beyond SP1 causes increased flexion torque producing further increase in vertebral flexion. The vertebral flexion from SP1 to MFF is suggested to be occurring secondary to the hip flexion and controlled by the eccentric contraction of hip extensors and hamstrings. Similarly, extension from the fully flexed position is initiated by the contraction of the extensors of the hip and hamstrings. The continued hip extension produces decreased flexion torque causing rebound of the stretched vertebral ligament and the vertebral extension. This explains occurrence of the controlled extension from MFF to SP2 inspite of the myo-electrical silence in the erector spinae.

The continuous activity in hamstrings and the hip extensors was seen to occur throughout the task in most subjects. This group of muscles evidently is the only muscles showing activity during the electrically silent phase of erector spinae. Abdominal muscles were seen to maintain complete silence during the whole task of normal bending. Activity seen during the terminal range of flexion of the modified bending probably resulted from the forced flexion. This is in complete conformity with Kippers and Parker (1984) who observed that the abdominal muscles activity is required to overcome the restraint of the ligaments beyond MFF to a position of forced flexion.

Since the initial myo-electrically silent segment of the vertebral extension (MFF to SP2) appears to be produced secondary to the hip extension, any modification in the act of extension from the fully flexed position which restricts the pelvic component of it is likely to reduce or eliminate the silent segment of the vertebral extension. That is probably the reason that the subjects standing with the buttocks held against the wall did not show SP2 and showed activity in erector spinae from the very beginning of the extension from the fully flexed position. SP2 probably denotes the end point of the elastic recoil of the stretched vertebral ligaments and thus remained constant showing no significant difference between the normal or the weighted task (Table 4). SP2 appeared to come earlier in vertebral flexion with weight held posteriorly though failed to stand the statistical significance. This could be caused by weights maintaining certain torque in vertebral ligaments making lesser elastic recoil available to rebound.

In conclusion, flexion–relaxation phenomenon appears to be occurring as a result of the passive equilibrium between the gravity-induced tensile torque and the extensor torque provided by the stretched posterior vertebral ligaments. The vertebral movement beyond a certain point (SP1) occurs secondary to the continued hip movement and the increased flexion torque thereof.

References

Allen, C.E.L., 1948. Muscle action potential used in the study of dynamic anatomy. British Journal of Physics and Medicine 11, 66–73.

Farfan, H.F., 1975. Muscular mechanism of the lumbar spine and the position of power and efficiency. Orthopedic Clinics of North America 6, 135–144.

Floyd, W.F., Silver, P.H.S., 1955. The function of the erectors spinae muscles in certain movements and postures in man. Journal of Physiology 129, 184–203.

Kaigle, A.M., Wessberg, P., Hansson, T.H., 1998. Muscular and kinematic behavior of lumbar spine during flexion — extension. Journal of Spinal Disorders 11, 163–174.

Kippers, V., Parker, A.W., 1984. Posture related to myoelectric silence of erector spinae during trunk flexion. Spine 9, 740–745.

Morris, J.M., Benner, F., Lucas, D.B., 1962. An electromyographic study of the intrinsic muscles of the back in man. Journal of Anatomy 96, 509–520.

Okada, M., 1970. Electromyographic assessment of muscular load in forward bending postures. Journal of the Faculty of Science of the University of Tokyo 8, 311–336.

Pauly, J.E., 1966. An electromyographic analysis of certain movements and exercises — some deep muscles of the back. Anatomy Records 155, 223–234.

Portnoy, H., Morin, F., 1956. Electromyographic study of postural muscles in various positions and movements. American Journal of Physiology 186, 122–126.

Shirado, O., Ito, T., Kaneda, K., Strax, T.E., 1995. Flexion–relaxation phenomenon in the back muscles. American Journal of Physical Medicine and Rehabilation 74, 139–144.

Schultz, A.B., Hadespeck-Grib, K., Sinkora, G., Warwick, D.N., 1985. Quantitative studies of flexion–relaxation phenomenon in the back muscles. Journal of Orthopedic Research 3, 189–197.

Taylor, J., Towmey, L., 1980. Sagittal and horizontal plane movement of the human lumbar vertebral column in cadavers and in living. Rheumatism and Rehabilitation 19, 223–232.

Wolf, S.L., Basmajian, J.V., Russe, C.T.C., Kutner, M., 1979. Normative data on low back mobility and activity levels. American Journal of Physics and Medicine 58, 217–229.