# SACRUM LOAD-DISPLACEMENT BEHAVIOUR AND SI LOCKING MECHANISM IN WEIGHT LIFTERS

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**INTRODUCTION:** Weight lifting produces tremendous loads on the sacroiliac (SI) joints, and tt has been shown that SI dysfunction could decrease performance in weight lifting (Charbonneau, 1989). The plane shape of the SI renders it vulnerable to shearing forces and consequently to dysfunction (Snijders, 1993a; Vleeming 1995). In the presence of considerable loads and especially in extreme positions, the elastic ligamentous deformation could decrease the ability of the SI joints to transfer loads to the inferior limbs. This could predispose the individual to pelvic biomechanical dysfunction (Snijders, 1995). Vleeming (1990) explains that SI locking is achieved via 2 mechanisms: "Form Closure" and "Force Closure". Form closure refers to a stable situation in which closely fitting joint surfaces remain in opposition with no extra forces needed to stabilise the joint. With Force closure, active compressive forces and friction forces are needed to withstand vertical load and therefore resist shear. Shear in the SI joint is prevented by the combination of the specific anatomical features, articular surface roughness, ligamentous tension, and muscle contraction (Vleeming 1990a; Vleeming 1990b). Lee (1995) refers to the terms "osteoarticularligamentous" and "myofascial" to describe the model which seems to efficiently resist shear forces.

The erector spinae, gluteus muscles and latissimus dorsi muscles are said to produce moments necessary to lock the SI through increased tension in the thoraco-lumbar fascia (Vleeming, 1990a). To our knowledge, experimental demonstration *in vivo* that the pelvic musculature and thoraco-lumbar fascia are involved in limiting sacrum movement has not been made. This study aims to determine if the increased tension of the thoraco-lumbar fascia and hip extensors during maximum voluntary contraction (MVC) contribute efficiently to the SI locking mechanism.

**METHODS:** Ten experienced male weight lifters aged between 18 and 25 years took part in the study. A sacrum load-displacement apparatus that had been developed in our laboratory (Gosselin, 1993; Gosselin, 1995) was used to apply external loads and to measure displacement. This was essentially a metal cubic structure on which an adjustable lever arm was attached, permitting the application of perpendicular loads on the $1^{st}$ and $5^{th}$ sacral segments. Measurement was recorded with an electronic goniometer placed on the lever arm (precision to $0.1^{o}$). Subjects were first placed prone on a flat surface and again on a triangular support structure producing $30^{o}$ hip flexion in order to produce tension in the thoraco-lumbar fascia. Dental plaster casts were moulded to the posterior part of the sacrum in order to apply loads without patient discomfort. Plaster support blocs were also moulded to the antero-superior iliac spines and to the pubis. The subjects were therefore supported in the prone position on these three anterior plaster blocks without having other pelvic structures touching the table. The

experimental plan contained 5 series of load applications in 2 experimental positions at each of the 2 sacral segments measured.
Loads of 250 N in 50 N increments were applied randomly to $S_1$ and $S_5$ while the patient was in a relaxed position, and again with a minimum of 80% of MVC hip extensors for every experimental situation. The hip extensor force was measured at the ankles with a strain gauge and was fed back to the subject during the procedure in order to maintain a constant effort. The displacement measurement was taken in the mid-respiratory cycle after the load had been applied for 10 seconds. A multivariate ANOVA was used to measure the association between the existence or not of thoraco-lumbar fascia tension and of hip extensors MVC on the sacrum mobility.

**RESULTS:**

**SI joint mobility:** Generally, the range of motion increased significantly ($p<0.001$) as the load applied increased. There was a significant difference in the results between movement in nutation and contra-nutation ($p<0.05$), and in this experimentation, there was a larger range of motion in nutation.

Table 1: Sacrum load-displacement behaviour in nutation and contra-nutation.

| LOAD | NUTATION (± SD) | CONTRA-NUTATION (± SD) | TOTAL MOTION (± SD) |
|---|---|---|---|
| 100 N | 0.27°± 0.08 / 2.2 ± 0,6mm | 0.23° ± 0.5 / 1.8 ± 0.4 | 0.5 ± 1.3 / 4.0 ± 1.0 mm |
| 150 N | 0.47° ± 0.1 / 3.8 ± 0.8mm | 0.40° ± 0.2 / 3.2 ± 1.6 mm | 0.87 ± 0.3 / 7.0 ± 2.4 mm |
| 200 N | 0.66° ± 0.09 / 5.3 ± 0.7mm | 0.53° ± 0.6 / 4.2 ± 0.5 mm | 1.2 ± 1.5 / 9.5 ± 1.2 mm |
| 250 N | 0.88° ± 0.1 / 7.1 ± 0.8 mm | 0.69° ± 0.2 / 5.5 ± 0.2 | 1.6 ± 0.3 / 12.6 ± 1.0 mm |

**Hip extensor MVC and sacrum mobility:** MVC of hip extensors reduced the sacrum mobility significantly ($p<0.001$) in both positions. Furthermore, the locking efficiency was still significant at loads of 250 N. On average, the MVC reduced the movement by 41%, and there was no difference in the efficiency in relation to position.

Table 2: Hip extensors MVC influence on sacrum mobility (mean)

| Load | Position | Movement | Contraction | Rest | ANOVA |
|---|---|---|---|---|---|
| 100 N | Neutral | Nutation | 0.2° / 1.6 mm | 0.4° / 3.2 mm | P<0.005 |
| | | Contranutation | 0.2° / 1.6 mm | 0.3° / 2.4 mm | |
| | Flexion | Nutation | 0.1° / 0.8 mm | 0.4° / 3.2 mm | |
| | | Contranutation | 0.2° / 1.6 | 0.3° / 2.4 mm | |
| 150 N | Neutral | Nutation | 0.3° / 2.4 mm | 0.7° / 5.4 mm | P<0.001 |
| | | Contranutation | 0.4° / 3.2 mm | 0.4° / 3.2 mm | |
| | Flexion | Nutation | 0.2° / 1.6 mm | 0.7° / 5.4 mm | |
| | | Contranutation | 0.4° / 3.2 mm | 0.5° / 4.0 mm | |
| 200 N | Neutral | Nutation | 0.5° / 4.0 mm | 1.0° / 8.0 mm | P<0.001 |
| | | Contranutation | 0.4° / 3.2 mm | 0.6° / 4.8 mm | |
| | Flexion | Nutation | 0.4° / 3.2 mm | 1.0° / 8.0 mm | |
| | | Contranutation | 0.5° / 4.0 mm | 0.8° / 6.4 mm | |
| 250 N | Neutral | Nutation | 0.5° / 4.0 mm | 1.2° / 9.6 mm | P< 0.001 |
| | | Contranutation | 0.5° / 4.0 mm | 0.7° / 5.4 mm | |
| | Flexion | Nutation | 0.6° / 4.8 mm | 1.2° / 9.6 mm | |
| | | Contranutation | 0.7° / 5.6 mm | 0.9° / 7.2 mm | |

**Hip flexion and sacrum mobility:** There was no significant difference between the sacrum movement with the patient in a neutral or flexed position for either nutation or contra-nutation and this tendency was not influenced by the different loads applied.

**DISCUSSION:** Our results show less sacrum movement than suggested by Miller (1987), this might be explained by a different experimental method since some of the SI ligaments in his cadaver specimens were not intact. Our results are therefore similar to those obtained by Brunner (1990) (0.55 ° ± 0.26 °), and are slightly greater than Vleeming's (1990) results of total movement for loads of 250 N (1.2 ° ± 0.6 °). Furthermore, Frigerio (1974) noted increased mobility in live subjects when compared to one cadaver specimen. This could be attributed to a larger elasticity *in vivo*. Our results do not support his findings since our own results are comparable to cadaver specimens. Vleeming (1992b) noted only a slight change in movement from nutation and contra-nutation, but we have found a significant difference between the two. It is possible that in his experimentation, the fixation device of the L4 and L5 segments of the lumbar spine affected the results by partially limiting movement to take place at the lumbo-sacral junction.

Our results do not support the suggestion that an increased tension of the thoraco-lumbar fascia through a 30 ° of hip flexion positioning limits sacral movement. Specifically, hip flexion does not alter the SI locking during hip extensor MVC. It is possible that the 30 ° of hip flexion used in this experimentation was not sufficient to produce a high enough tension to contribute to a significant SI locking (i.e. such as a "squat" posture in weight lifting might produce). On the other hand, a squat position would necessitate the activation of other large muscle groups that would lock the SI efficiently.

In this study the potential participation of the latissimus dorsi in the tensing of the thoraco-lumbar fascia has been avoided. A further study specifically inducing thoraco-lumbar tension through latissimus dorsi contraction, and another evaluating the role of gravity in the sacrum load-displacement behaviour, are under way in our laboratory at the AECC.

By selecting weight lifters, we wanted to select subjects with a very strong pelvic girdle musculature in order to obtain an efficient force closure. It is interesting to note that in a preliminary study involving sedentary subjects, the SI locking was as efficient as in our weight lifters. On the other hand, these subjects could not hold a prolonged MVC, and they tired rapidly. This could indicate that during prolonged physical activity, or during intensive training, the SI locking mechanism may become less efficient in limiting shear forces, therefore possibly predisposing the athlete to injury. This would confirm Snijders (1995b) and Lee (1995) assumption that strengthening training of the pelvic girdle musculature might be an interesting approach to the treatment of SI hypermobility.

**CONCLUSIONS:** In our experiment, at 30 ° of hip flexion, the thoraco-lumbar fascia does not contribute to the SI locking mechanism. This study has demonstrated that MVC of the hip extensors in weight lifters significantly limits movements of the sacrum. Medical staff, trainers and coaches involved in weight lifting and other physical activities are encouraged to consider specific hip extensor exercises with the objective of increasing the SI locking and potentially preventing injuries. Finally, muscular synergy studies in symptomatic athletes may in some instances indicate an inefficient SI locking mechanism. These studies could provide interesting approaches to the treatment of individuals suffering from SI hypermobility.

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