Development of a Biomechanical Model to Study the Effects of Lifting Load on Sciatic Pain

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Abstract. Sciatica is a frequently encountered leg pain that originates in the human lower back and travels down the buttocks through the large sciatic nerve present in the back of the leg. Due to lifting heavy loads at different angles, the humans could acquire sciatica at different levels. Thus, the reason of using biomechanical model was to mimic the human spine in such a way that the increased force while lifting the load could easily be measured. This could help to beware the humans to not lifting load at these angles. This paper presents the findings of an experiment conducted to measure the increased forces at 6 different angles i.e. 95º, 105º, 115º, 125º, 135º and 145º. Experiments were carried out by connecting the model and a load cell with PASCO CAPSTONE. Results were concluded using both statistical and graphical analysis. The resultant force increased as the angle of bending was increased due to increased load on the back model. Stair climbing is one of the unique exercises which is frequently used and helps in maintaining the leg muscles active and healthy.

1. Introduction
Sciatica is a cause of extreme leg pain and lack of adequate power, strength or physical or mental ability. The pain originates in the lower region of the back and goes through the entire sciatic nerve in the leg as shown in figure 1. Some primary sciatic patients are treated with normal medication, but others require surgery. About 90% cases are caused by a herniated disc in which nerve root is compressed [1]. The relationship between the body mass index and low back pain was evaluated with the lumbar and thoracic curves for patients with low back pain which was evaluated with the lumbar and thoracic curves for patients with low back pain which is caused by several factors including increased body mass index and changes in lumbar kyphosis and lordosis [2]. Sciatica treated with surgery is comparatively more convenient and effective than prolonged medication [3]. The medicines discovered for sciatic disease so far is not really efficient [4]. Sciatica could be treated easily with surgery in the beginning but after one year, the body loses its immunity and a person starts facing the same problem again [5]. Usually disc herniation and low back pain result from excess physical work, lifting load, acquiring bad posture and height, factors like obesity, body stress, smoking and poor health [6]. Low back pain in initial stage is usually treated within weeks but extreme pain or other disabilities can take long time for recovery [7]. It has been observed that bio psychosocial rehabilitation with functional restoration can help reduce the pain and chronic low back pain [8]. Lumbar disc herniation usually occurs at L4/L5 and L5/S1 levels in more than 90% cases [9]. The normal lumbosacral angle in upright
position of about 319 males was observed to be 41.1° with 7.7° of standard deviation [10]. Sciatic pain is usually observed during the summer or autumn due to increased physical activities and drying up of joint fluid [11]. The electrical stimulation significantly treated the lumbar disc herniation-induced sciatica, reduced pain, lessened the clinical symptoms and signs of patients, regulated the peripheral ROS level, and prevented the oxidative damage of myocardial tissues [12]. Study of effects of acupuncture therapy in the patients suffering with Postpartum sciatica was carried out for 111 women patients. The acupuncture therapy had relatively effective results as compared to bed rest [13]. In recent years, transplantation of stem cells into transacted sciatic nerve in animal models demonstrates clinical improvement, inducing vigorous nerve regeneration accompanied by myelin synthesis [14]. Sciatica can also be well treated with the help of epidural steroid injection via transformational route [15].

2. Methodology

2.1. Designing the Model
The human back model was designed manually from human structure model PASCO ME-7001 as shown in figure 2. For locating lumbar 4 vertebra, the total length of human skeleton was measured in inches. Similarly, the total length of human back model designed was also measured in inches. The average result of the two was assumed to be lumbar 4 region of the model where basically, the sciatic nerve initiates. The human back model was connected to PASCO Capstone software. The muscles of back model were mimicked using tension cords. The resultant forces on different muscle positions using different loads at different angles were calculated with the help of load cell attached to model. The angles were set using goniometer. The length of skeleton measured was 13 inches and 2 cm and that of human back model was measured 26 inches. The average of the two calculated was 19.5 inches which was assumed to be lumbar 4 of the human back models as shown in table 1.

2.2. The Experiment
The experiment was conducted by connecting human back model to PASCO Capstone, where different forces were calculated. Four different muscle positions with reference to lumbar 4 of the models were taken and two loads i.e. 100 and 150 grams were attached to each muscle position at different angles i.e. 95°, 105°, 115°, 125°, 135° and 145°. The cords mimicked as muscle positioned are given in table 2. Initially, a 100 grams load was attached to position 1 at an angle of 95° as revealed in figure 3 (a). The forces acting on position 1 could be observed through load cell on PASCO. The average of these forces was then calculated for this angle. Similarly, the forces on the same position for the other angles i.e. 105°, 115°, 125°, 135° and 145° were calculated as shown in figure 3 (b), (c), (d), (e) and (f) respectively. The same load i.e. 100 grams was attached to the other positions and corresponding average resultant forces at desired angles were observed. Then, the average resultant forces were measured by attaching 150 grams load to each muscle position at each angle.
### Table 1. Location of L4 on human back model.

| Length of human skeleton | Length of human back model | Average |
|--------------------------|-----------------------------|---------|
| 13-inch 2 cm             | 26 inches                   | 19.5 inch |

### Table 2. Muscles and their locations.

| Positions | Mimicked muscles of model | Location in inches |
|-----------|---------------------------|--------------------|
| 1         | Iliocostalis Lumborum     | 26                 |
| 2         | Latissimus dorsi          | 15.4               |
| 3         | Iliocostalis              | 12                 |
| 4         | Semispinalis              | 10.2               |

3. **Results and Discussion**

The resultant forces for each muscle position at different angles measured by using the two loads are discussed below:

3.1. 100 grams load

Initially, a 100 grams load was hanged to back model at the four different muscle positions by changing different angles.

3.1.1. At Position 1

The position 1 refers to the muscle Iliocostalis Lumborum. Figure 4 shows the average resultant forces at different angles for position 1 that were recorded with 100 grams load hanged. From the graph, it is observed that with increasing angles, the force at position 1 increases. There are maximum chances of rise of sciatic pain with the maximum angle i.e. 145°. This is because the distance between load and lower back increases.

3.1.2. At Position 2

Figure 5 also shows that with increasing angles, the force at position 2 increases. Here also, there are maximum chances of rise of sciatic pain with the maximum angle i.e. 145° because of the distance that increased between load and lower back.

3.1.3. At Position 3

Figure 6 shows that with increasing angles, the force at position 3 increases. There are maximum chances of rise of sciatic pain with the maximum angle i.e. 145°. This is because of the increase in distance between load and lower back.

3.1.4. At Position 4

Applying the same protocol, a 100 grams load was attached to position 4 of the model. The average of the resultant force readings at different angles are given in the figure 7 where the average resultant force increases for the lower angles i.e. 95°, 105° and 115°. However, the trend is different for the next two angles i.e. 125° and 135° where the resultant forces decrease respectively perhaps due to acting of less resultant forces on these angles while for angle 145°, the value of resultant force again increases to 11.60 N.
3.2. 150 grams load
Similarly, 150 grams load was hanged to the 4 positions and average resultant forces were observed on PASCO at different angles.

3.2.1. At Position 1
From figure 8, it is observed that with increasing angles, the force at position 1 increases. There are maximum chances of rise of sciatic pain with the maximum angle i.e. 145° due to increase of distance between load and back.

3.2.2. At Position 2
Figure 9 shows that as the angle increases, the average resultant force increases correspondingly with 150 grams load. There are more chances of rise of sciatic pain with the maximum angle i.e. 145° which shows that as the lifted load is away from the lumbar region, the stress increases at the back.

3.2.3. At Position 3
Figure 9 also shows that as the angle increases, the average resultant force increases correspondingly with 150 grams load. There are more chances of rise of sciatic pain with the maximum angle i.e. 145° which shows that as the lifted load is away from the lumbar region, the stress increases at the back.

3.2.4. At Position 4
The same protocol for position 4 was followed using 150 grams load. The average resultant force can be observed in figure 11. It shows that the average resultant forces increase with increasing angle from 95 degrees to 145 degrees due to increased distance from load.

![Figure 3. Six bending angles of human back model.](image)

**Figure 3.** Six bending angles of human back model.

![Figure 4. Resultant forces at position 1 for 100g](image)

**Figure 4.** Resultant forces at position 1 for 100g

![Figure 5. Resultant forces at position 2 for 100g](image)

**Figure 5.** Resultant forces at position 2 for 100g
4. Conclusion
In cases where full restoration is not possible or in degenerative conditions, the maintenance approach is used within the biomechanical approach to enable preservation of the client’s physical performance capabilities and slow declines in impairments and task abilities. Therefore, development of sciatic biomechanical model would help in understanding the effects of lifting different loads in order to decrease the pain among patients. The force acting along the back muscles of sciatic patient increases with increasing angle of bending and by adding more load forces. By increasing the load force from 100 to 150 grams in accordance with six different angles and four positions, the resultant force increased accordingly. However, for position 4 of 100 grams load, the trend became slightly different. The values of resultant force decreased for angle 125º and 135º which might be because of mechanical or human error. This shows that as sciatica itself is painful, the added weight of the lifting an object causes increased stress on the back muscles and lifting heavy loads or bending over too much strains the back muscles causing pain in the lower back region.
Acknowledgments

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5. References

[1] Koes BW, Van Tulder MW and Peul WC 2007 Diagnosis and treatment of sciatica BMJ. 334 1313–1317
[2] Mohammad H, Fateme G and Asghar A 2007 The Relationship between Lumbar and Thoracic Curves with Body Mass Index and Low Back Pain in Students of Zahedan University of Medical Sciences J Med Sci. 7 984-990
[3] Van D H W, Peul WC, Koes BW, Brand R, Keivit J, Thomeer RT and Leiden The HagueSpine Intervention Prognostic Study Group 2008 Prolonged conservative care versus early surgery in patients with sciatica from lumbar disc herniation: cost utility analysis alongside a randomised controlled trial. BMJ. 336 1351-4
[4] Rafael ZP, Chris GM, Manuela LF, Paulo HF, Mark H, Vinicius CO, Andrew JM, Bart K2012 Drugs for relief of pain in patients with sciatica: systematic review and meta-analysis BMJl. 344
[5] Wilco CP, Wilbert BH, health economist, Ronald B, statistician, Ralph T W M T and BartW 2008 Prolonged conservative care versus early surgery in patients with sciatic caused by lumbar disc herniation: two year results of a randomised controlled trial BMJ. 1355-8
[6] Marku H 1989 Risk factors for low back pain and sciatica Ann Med. 21 257-264
[7] Pengel LH, Herbert RD, Maher CG and Refshauge KM 2003 Acute low back pain: systematic review of its prognosis BMJ. 327 323
[8] Guzmán J, Esmail, Karjalainen K, Malmivaara A, Irvin E, Bombardier C 2001 Multidisciplinary rehabilitation for chronic low back pain: systematic review BMJ. 322 1511-6
[9] Chou R, Qaseem A, Snow V, Casey D, Cross JT Jr, Shekelle P and Owens DK 2007 Diagnosis and treatment of low back pain: a joint clinical practice guideline from the American College of Physicians and the American Pain Society Ann Intern Med. 147 47891
[10] Theodore EK and H.Keith H 1971 Measurement of the normal lumbosacral angle AJR.113 642-645
[11] Robert WB 2018 What Causes Sciatica? Sciatica and Chronic Pain 2018 SpringerLink. 19-32
[12] Lulu W, Weiqiang F, Caihong Y, Minglei L and Guisen Sun 2018 Clinical effects of electrical stimulation therapy on lumbar disc herniation-induced sciatica and its influence on peripheral ROS level JMNI. 18 393-398
[13] Bing SH, Yang L and Tong G 2018 Preliminary Clinical Evaluation of Acupuncture Therapy in Patients With Postpartum Sciatica JMWH.
[14] Dadon-Nachum M, Melamed E and Offen D Stem cells treatment for sciatic nerve injury Expert Opin Biol Ther. 11 1591-7
[15] Ritesh P 2016 Efficacy of Epidural Steroid Injection in Management of Lumbar Prolapsed Intervertebral Disc: A Comparison of Caudal, Transforaminal and Interlaminar Routes J Clin Diagn Res. 10
[16] Sciatica Ravenswood Chiropractic & Wellness Center