Assessment of Proprioception in Mechanical Low Back Pain

Dina M. Ali Al Hamaky[1*], Alaa E. Abdelhakim Balbaa[2] , Lilian A. Zaki Shehata[3]

[1] Assistant lecturer of Physical Therapy, Faculty of physical therapy, Cairo University, Egypt
[2] Professor of Physical Therapy Faculty of Physical Therapy, Cairo University, Egypt
[3]Assistant Professor of Physical Therapy, Faculty of Physical Therapy, Cairo University, Egypt

ABSTRACT

Background: Mechanical low back pain (MLBP) is a common musculoskeletal pain condition. The relationship between proprioception deficit and mechanical pain in glueatal region still the etiology unknown well. Objective: The target from the present work was to explore the role of proprioception deficit in occurring low bach pain where some investigators not paid great attention and considered it as a subgroup of low back pain via determining the mistakes in active repositioning through Biodex Isokinetic Dynamometer. In case of presence of corralation a new physiotherapy program must be applied for training of paitients on low back pain. Methods: In this study, 110 persons (55 patients with mechanical low back pain and 55 normal persons) were assigned randomly into two groups. Group A: fifty- five patients (17 females and 38 males) with mechanical low back pain were involved in this group. The averages of age, weight, height, and body mass index (BMI) were 22.04 ± 2.19 years,73.14± 12.05 kg, 173.84 ± 8.08 cm, and 24.14 ± 3.18 kg/m^2 respectively. Group B: fifty-five normal individuals (11 females and 44 males) were joined this group. The averages of age, weight, height, and BMI were 21.65 ± 1.78 years, 73.09 ± 12.58 kg, 175.48 ± 7.91 cm, and 23.77 ± 4.22 kg/m^2 respectively. Result: The results revealed that there is a correlation between proprioception deficit and mechanical low back pain. The mean ± SD active repositioning error of group A was 34.35 ± 6.32 and that for group B was 31.48 ± 3.1. The average difference between groups was 2.87. The reults found a significant increase in active repositioning error of group A compared with that of group B (p = 0.001). It is concluded that a correlation was found between mechanical low back pain and proprioception deficit; therefore, great attention must be paid for carrying training courses for patient elevation proprioception in physical therapy rehabilitation program concerning paitients suffering from mechanical low back pain with respect to the age.

Key Words: *Mechanical low back pain, proprioception, repositioning error*

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INTRODUCTION

Globally, Low back pain (LBP) is considered a common phenomina which reached to a high level ((12% - 33%), where the incidence rate averaged 22-65% at 1- year and lifetime incidence rate (11- 84%) [1].While LBP is usually self-limiting, it can continue creating in a strong individual, c
ommunal and financial burden[2] In the patients, an exact diagnosis for low back pains does not depend on the phaysiological or anatomical malformation, inspite of the progressing in examination tools available nowadays such as scanning tactics which can be used to show the actual sever etiology of LBP disorders (e.g. tumours and infections), structural anomalies, like that linkage with advanced ages, are usually noticed in contrarily healthy subjects without signs of illness[3].Although, the improvement of infinite highly advanced diagnostic technologies, it is frequently hard to diagnose the source of LBP because it is frequently confused by public, psychological, and monetary circumstances. The hypophysis which reported that the fundamental problematic is arises from the disks

Corresponding author: Dina M. Ali Al Hamaky
Address: Assistant lecturer of Physical Therapy, Faculty of Physical therapy, Cairo University, Egypt
e-mail dinaali2008@hotmail.com
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in the lumbar vertebrae is an unconfirmed hypothesis yet [4]

The signs of CMLBP are frequently deteriorated during movement and amended somewhat during rest. Physical movement, specially flexing, spreading, turning and thrilling, generally worsens the signs, while limitation of pain-producing motions leads to an enhancement at least momentarily. Characteristic physical outcomes are not defined, comprising limited scale of movement of the spine, fitted constraining muscles, para vertebral muscle seizures, muscular stimulating points, painfulness and worsening of signs on extension or flexion and traditional leg levitation checks [4]

Proprioceptions are described as the coupled neural response to the CNS from precise nerve terminations called mechanoreceptors, which are found in the ligaments, muscles, capsules, skin, joint, and tendons Proprioception denotes to the sensation of body/joint[5] movement, tension/vigor, and limb corresponding situation[6]

All three forms can be predictable consciously and loss of consciousness, donating to involuntary control of joint firmness, motion equilibrium, and and accordingly being necessary to convey walking, sports activities and the daily living jobs[6] Patients with low back pain are identified to have decayed motor control (dysfunction) in the lumbopelvic region[7], and as different methods of measuring proprioception in the region are planned, the evidence is emerging that proprioception is also affected [8],The damage in proprioception would lead to to dysfunction in the neuromuscular synapsis and potential reduced segmental constancy in paitions complaining from LBP, which may be exaggerated and result in increasing the danger of injury or multiple injuries [9],Hence, for efficient treatment of paitients suffering from low back pain symptims it is required to apply a training program on proprioception as vital constituent of the restoration exercise platform [9].

The collected data revealed that no sufficient researches covering all aspects of patients with LBP etiology or their subgrouping. Therefore, the present study was concerned with the assessment of patients' subgroups and the study involved also large scale of ages particularly the young one, where physical therapy normally involved stretching, strengthening and soft tissue management without paying ann attention to proprioception training.

SUBJECTS, INSTRUMENTATİON, AND METHODS

This study was conducted at the Isokinetic Laboratory at the Faculty of Physical Therapy, Cairo University.

Subjects:

The study was conducted on 110 individuals into 2 groups:

Group A 55 individuals with mechanical low back pain.

Group B 55 normal individuals

Inclusion criteria:

Patients were selected to meet the following criteria in order to participate in the study:

- Patients with mechanical low back pain with duration 8 weeks and visual analogue scale beteen 3 and 10 most days of the week
- Their age ranges from 18-25 years and considering socioeconomic level

Exclusion criteria:

Patients were excluded according to the following conditions:

- Patients with systemic disease
- Patients with neurologic impairment
- Patients with vestibular impairment
- Patients with psychological impairment
- Patients with previous spine surgery
- Patients with pathological conditions related to the back (lumbar disc prolapse, lumbar spondylosis, spondylolisthesis, spondylolysis etc)
- Patients with spine kyphosis or scoliosis
- Patients with lower limb injury
- Patients with lower limb disorders
- Patients with thyroid gland problems or malnutrition
- Patients who are pregnant or breast feeding

Instrumentations:

1-Biodex Isokinetic Dynamometer

The Biodex System 3 Multijoint Testing and Rehabilitation System (Biodex Medical System, Shirley, NY, USA) was used for collecting the isokinetic parameters[10]

The system is being widely used in research, clinical testing and rehabilitation to objectively assess factors of muscle performance that would otherwise be difficult to obtain using manual testing techniques in addition to proprioception assessment capability[10].

The participant was seated on the chair of the Biodex system, knee block positions were individually adjusted by two curved anterior leg pads, the feet were held in a position with no contact with the floor, both thighs were stabilized by two straps, the pelvic brace was then applied and positioned as far down as possible to press firmly, but comfortably, against the superior aspect of the proximal thighs. In addition, the lumbar pad was located against the lower lumbar spine. The seat was adjusted so that the axis of the actuator arm was aligned with L5/S1 disc space. This was clinically identified by palpation of the posterior superior iliac spine (PSIS),

which is at the level of S2 and then moving one inch superiorly. The upper part of the trunk was strapped to the back attachment with a belt. With the subject sitting erect, the force application straps were adjusted vertically with the second intercostal cartilage on the anterior chest wall. The head was stabilized neutrally on adjustable head rest [10].

2- Height and weight scale

A universal height and weight scale were used to determine height and weight of the participant's.

Procedure:

Initially, the participants were informed about the objectives of the study and invited to sign a consent form. Each subject was positioned into an upright neutral starting position. This position will be adjusted by ensuring that the anterior superior iliac spine and the PSIS will be aligned in the horizontal plane. The predetermined spinal range of motion, which was chosen to be the "target position" for participants during the testing protocol, was from neutral spinal posture to
30° lumbar flexions. This angle will be chosen so that it can be achieved by all subjects. Each subject was asked to move into flexion as much as he/she can to determine the maximum available lumbar ROM and to determine whether he would be able to perform the experimental task. The dynamometer was locked in the 0° position to ensure the same starting position in the three testing trials for each participant [10]

The testing procedure started by a practice trial, where each participant would be allowed to perform three repetitions of the test. Once each participant would complete the practice trial, the standard test session would start. Each participant was passively moved by the dynamometer and positioned in 30° of lumbar flexion for 10 seconds and they instructed to remember the position because they will be asked to reproduce this position with closed eye at velocity 30 degrees per second

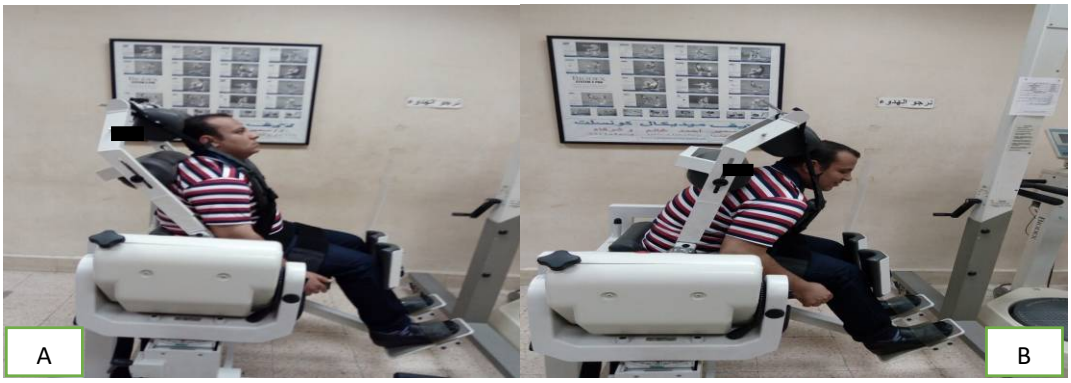

Figure 1.The active repositioning test; (A)starting position (0° lumbar flexions), and (B) End position (30° lumbar flexion

Statistical analysis:

The absolute error (AE) values about the 30° target position were recorded for the three trials done by each participant and the mean deviation was calculated. A sample t-test allows us to test whether a sample mean of a normally distributed interval variable significantly differs from a hypothesized value.

RESULTS

This study aimed to investigate the impact of mechanical low back pain on proprioception. A total of (55) patients with mechanical low back pain (group A) were compared with (55) normal subjects (group B).

Data obtained from both groups regarding back proprioception was subjected for statistical analysis.

- General characteristics of the participants :

The number of participating subjects were 130 persons comprises 65 normal subjects and the equall number (65) of subjects suffereing from mechanical LBP . After thorough examamination there was an exclusion of a total of 20 subjects 10 subjects from each group due to insuffient data either in control group(10 not completely normal) and LBP group (10, previous spine surgery, lower limb injury etc **).**

Group A:

A total of fifty five patients (17 females and 38 males) with mechanical low back pain were involved in LBP group. The mean ± SD of (age, weight, height and BMI) were 22.04 ± 2.19 years, 73.14 ± 12.05 kg, 173.84 ± 8.08 cm, and 24.14 ± 3.18 kg/m^2 respectively as shown in table (1).

Group B:

A total of fifty-five normal subjects (11 females and 44 males) were involved in control group. The mean ± SD of (age, weight, height and BMI) were 21.65 ± 1.78 years, 73.09 ± 12.58 kg, 175.48 ± 7.91 cm, and 23.77 ± 4.22 kg/m^2 respectively as shown in table (1).

With respect to the general features of subjects charing in the study , the results showed that no significant variations was recorded between the two groups in the following parameters: mean weight, age, BMI or height ($p > 0.05$).

Table 1. Descriptive statistics and t-test for the mean age, weight, height and BMI of both groups (A and B).

	Group A ±SD	Group B ±SD	MD	t- value	p-value	Sig
Age (years)	22.04 ± 2.19	21.65 ± 1.78	0.39	1.18	0.23	**NS**
Weight (kg)	73.14 ± 12.05	73.09 ± 12.58	0.05	0.02	0.97	**NS**
Height (cm)	173.84 ± 8.08	175.48 ± 7.91	-1.64	-1.25	0.21	**NS**
BMI (kg/m^2)	24.14 ± 3.18	23.77 ± 4.22	0.37	0.61	0.54	**NS**

X : Mean MD: Mean difference p value: Probability value SD : Standard deviation
T-value: Unpaired t value NS:Non significant

- Sex distribution:

The sex distribution of group A revealed that there were 26 females with reported percentage of 35% while the number of male patients was 49 with reported percentage of 65%. The sex distribution of group B revealed that there were 23 females with reported percentage of 31% and the number of males was 52 with reported percentage of 69% as illustrated in table (2) . No significant variations was recorded concerning sex distribution among the studied groups

Table 2. The frequency distribution and chi squared test for comparison of sex distribution of both groups (A and B):

	Group A	Group B	χ^2	p-value	Sig
Females	26 (35%)	23 (31%)	0.27	0.61	**NS**
Males	49 (65%)	52 (69%)			

χ2: Chi-squared value p value: Probability value NS: Non significant

- Comparison of active repositioning error between group A and B:

The mean ± SD active repositioning error of group A was 34.35 ± 6.32 and that for group B was 31.48 ± 3.1. The average variation among both groups was averaged 2.87. There was a significant increase in active repositioning error of group A compared with that of group B (p = 0.001). (Table 3).

Table 3. Comparison of the active repositioning error between group A and B.

	Group A ± SD	Group B ± SD	MD	t- value	p-value	Sig
Activerepositioning	34.35 ± 6.32	31.48 ± 3.1	2.87	3.52	0.001	**S**

M: Mean SD: Standard deviation MD: Mean difference
t value: Unpaired t value p value: Probability value S: Significant

DISCUSSION

The obtained data from this study revealed to a variation in the proprioceptive senses in the two studied groups (normal and CLBP groups). Moreover, the joint location intelligence and postural governor capability of CLBP patients were less than that in healthy subjects[11] Some investigators reported that the decays in proprioceptive senses are asscociated with diminish in the neuro muscular governor capability and induce unbalance in the body posture , and subsequently may cause repeated injury , follow-on with constant malicious ring[12].The results in the current research indicated that the proprioceptive senses were declined greatly in CLBP group as compared with control group [11].Only 4 studies dealt with subgroups of low back pain.

The present data were well-matched with the data of Astfalck et al. [15] who reported a variation in repositiong fault among ill subjects with undefined LBP and healthy subjects. The study was carried on 28 patients who were classified into flexion and extension patterns of NSLBP depending on O'Sullivan classification against normal individuals.

Moreover, O'Sullivan et al. [28] found in a study carried out on 15 patients suffering from NSLBP that there was a diminishing in proprioception as compared with normal individuals . Whereas, in another study carried by O'sullivan et al. [29]who established a decline in proprioception among patients with lumbar segmental insecurity. The present data were harmonious with the results of Sheeran et al. [30] that non defined LBP had a failing to reposition into neutral spinal position.

Several studies[14-30,31,33,34] applied active JRS to measure lumbar proprioception, 3 studies[23,32,34] used passive JRS, and 2 studies[23,34] used both. There was wide variation in test protocols between studies. Different measurement devices were used, including electronic sensors, electro goniometers, custom lumbar motion devices, and tape measures[35].Target positions range from neutral

lumbar spinal postures to targets in pelvic tilting and lumbar flexion, extension, lateral flexion, and rotation [35]Target positions were also presented with differing modalities and time limits to memorize positions[35]

There is a potential connection between sitting, especially prolonged, slumped postures, and worsening of LBP[37,39]This is likely a result of muscle inactivity causing transmission of forces to passive spinal structures,[40,41]leading to tension on the soft tissue.[39,42,43] their results suggest that impairment in lumbar proprioception could be interfering this by increasing adoption and preservation of poor postures. Impaired lumbar proprioception in sitting position may promote a loss of a neutral spine, leading to a position of poor muscular mechanical advantage.[36,44] Furthermore, impaired proprioception may reduce the sensitivity to postural abnormalities and preserve this poor positioning. Sitting may provide less sensory feedback compared with standing because of less sensitivity of muscle mechanoreceptors in sitting, unmasking proprioceptive deficits caused by less afferent input compensating for impaired proprioception. These differences in sensory input between standing and sitting might explain why active JRS is impaired in sitting but not in standing.[38]

This has been suggested to occur via modulation of afferent proprioceptive signals from muscle spindles and interactions between pain and proprioceptive inputs within the cortex, including changes in body perception [47,45] and gamma motor neuron activity.[52] Despite the mechanism, pain can significantly yield the ability to recognize changes in body position,

Impairing proprioception.Trunk muscle dysfunction may lead to modifications in afferent input from the affected muscles. Additionally, proprioceptive affection may lead to different stimulating forms and constitute new adaptive protective mechanisms. Whether being a cause or a result of CLBP, it is an anticipated consequence [53]

One study hypothesized that if proprioceptive impairments exist in the LBP group, they will more likely be exhibited on the more sensitive motion perception threshold test than on the repositioning tests (which rely on memory recall). One study noted that people with LBP have less acuity for identifying changes in trunk position during motion perception threshold testing. Repositioning tasks, on the other hand, showed no difference between LBP and control groups. This finding supports their assumption that motion perception threshold is more sensitive than the repositioning tests for detecting proprioceptive impairments (passive repositioning and active repositioning)[54]

The current work was restricted only to patients suffering from mechanical low back pain and their ages ranged between 18 to 25 years. There was a deficient in the investigations about chronic low back pain subgroups .We endorse with further investigations concerning with subgroups of chronic low back pain and proprioception deficit and its correlation with objective methods of assessment.

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REFERENCES:

[1] Bruce F. Walker .The Prevalence of Low Back Pain: A Systematic Review of the Literature from 1966 to 1998 .Journal of Spinal Disorders 2000; 13: 205-17.

[2] Walker BF, Muller R, Grant W. Low back in Australian adults: the economic burden. Asia Pac J Public Health 2003;15: 79-87.

[3] Deyo RA. Diagnostic evaluation of LBP; reaching a specific diagnosis is often impossible. Arch Intern Med 2002; 162:1444-7.

[4] - Alemo S and Sayadipour A J . Chronic Mechanical Lower Back Pain, Neurolog Orthop Med Surg 2008; 28 :(1): 5-11.

[5] Carpenter JE, Blasier RB and Pellizzon GG. The effects of muscle fatigue on shoulder joint position sense. Am J Sports Med 1998; 26(2):262-265.

[6] Riemann BL, Lephart SM (2002). The Sensorimotor System, Part I: The Physiologic Basis of Functional Joint Stability. J Athl Train 37(1):71-79.

[7] Pain and motor control of the lumbopelvic region: effect and possible mechanisms. Paul W. Hodges a, G. Lorimer Moseley a,b. Journal of Electromyography and Kinesiology 2003;13: 361–370.

[8] Brumagne S, Cordo P, Lysens R, Verschueren S and Swinnen S. The role of paraspinal muscle spindles in lumbosacral position sense in individuals with and without low back pain. Spine 2000; 25: 989–994.

[9] Brumagne S, Lysens R, Swinnen S and Vershueren S: Effect of paraspinal muscle vibration of position sense of the lumbosacral spine. Spine 1999b; 24: 1328–1331.

[10] Drouin JM, Valovich-Mcleod TC, Shultz SJ, Gansneder BM, Perrin DH: Reliability and validity of the Biodex system 3 pro isokinetic dynamometer velocity, torque and position measurements. European Journal of Applied Physiology.2004; 91: 1:22-29.

[11] Comparison of the Activity and Proprioception of Trunk Muscles According to Different Types of Bridge Exercises in Subjects with and without Chronic Low Back Pain. Vol.

[12] No. 6, December 2015. J Kor Phys Ther 2015:27(6):400-406, Yong-Soo Kong, Yoon-Tae Hwang 12- Prentice WE. Rehabilitation techniques in sports medicine. McGrw-Hil, 1999.

[13] Field E, Abdel-Moty E, Loudon J. The effect of back injury and load on ability to replicate a novel posture. Journal of Back and Musculoskeletal Rehabilitation. 1997;8: 199-207.

[14] A°sell M, Sjo¨lander P, Kerschbaumer H, Djupsjo¨backa M. Are lumbar repositioning errors larger among patients with chronic low back pain compared with asymptomatic subjects? Arch Phys Med Rehabil 2006; 87:1170-6.

[15] Astfalck RG, O'Sullivan PB, Smith AJ, Straker LM, Burnett AF. Lumbar spine repositioning sense in adolescents with and without non-specific chronic low back pain: an analysis based on sub-classification and spinal regions. Man Ther 2013; 18: 410-7.

[16] Brumagne S, Cordo P, Lysens R, Verschueren S, Swinnen S. The role of paraspinal muscle spindles in lumbosacral position sense in individuals with and without low back pain. Spine (Phila Pa 1976) 2000; 2:989-94.

[17] Descarreaux M, Blouin JS, Teasdale N. Repositioning accuracy and movement parameters in low back pain subjects and healthy control subjects. Eur Spine J 2005; 14:185-91.

[18] Georgy EE. Lumbar repositioning accuracy as a measure of proprioception in patients with back dysfunction and healthy controls. Asian Spine J 2011; 5:201-7.

[19] Gill KP, Callaghan MJ. The measurement of lumbar proprioception in individuals with and without low back pain. Spine (Phila Pa 1976) 1998; 23:371-7.

[20] Hidalgo B, Gobert Fo, Bragard D, Detrembleur C. Effects of proprioceptive disruption on lumbar spine repositioning error in a trunk forward bending task. J Back Musculoskelet Rehabil 2013; 26:381-7.

[21] Kara B, Genc A, Yildirim Y, Ilcin N. Use of the tape measure in people with or without back pain in an assessment of reposition error. Turk Neurosurg 2011; 21:290-5.

[22] Koumantakis GA, Winstanley J, Oldham JA. Thoracolumbar proprioception in individuals with and without low back pain: intratester reliability, clinical applicability, and validity. J Orthop Sports Phys Ther 2002; 32:327-35.

[23] Lee AS, Cholewicki J, Reeves NP, Zazulak BT, Mysliwiec LW. Comparison of trunk proprioception between patients with low back pain and healthy controls. Arch Phys Med Rehabil 2010; 91: 1327-31.

[24] Lin YH, Sun MH. The effect of lifting and lowering an external load on repositioning error of trunk flexion-extension in subjects with and without low back pain. Clin Rehabil 2006; 20: 603-8.

[25] Mitchell T, O'Sullivan PB, Smith A, et al. Biopsychosocial factors are associated with low back pain in female nursing students: a cross-sectional study. Int J Nurs Stud 2009; 46:678-88.

[26] Newcomer K, Laskowski ER, Yu B, Larson DR, A KN. Repositioning error in low back pain. Comparing trunk repositioning error in subjects with chronic low back pain and control subjects. Spine (Phila Pa 1976) 2000; 25 :245-50.

[27] Newcomer KL, Laskowski ER, Yu B, Johnson JC, An K. Differences in repositioning error among patients with low back pain compared with control subjects. Spine (Phila Pa 1976) 2000; 25:2488-93.

[28] O'Sullivan K, Verschueren S, Van Hoof W, Ertanir F, Martens L, Dankaerts W. Lumbar repositioning error in sitting: healthy controls versus people with sitting-related non- specific chronic low back pain (flexion pattern). Man Ther 2013; 18:526-32.

[29] O'Sullivan PB, Burnett A, Floyd AN, et al. Lumbar repositioning deficit in a specific low back pain population. Spine (Phila Pa 1976) 2003; 28:1074-9.

[30] Sheeran L, Sparkes V, Caterson B, Busse-Morris M, van Deursen R. Spinal position sense and trunk muscle activity during sitting and standing in nonspecific chronic low back pain: classification analysis. Spine (Phila Pa 1976) 2012; 37:486-95.

[31] Tsai Y, Sell TC, Smoliga JM, Myers JB, Learman KE, Lephart SM. A comparison of physical characteristics and swing mechanics between golfers with and without a history of low back pain. J Orthop Sports Phys Ther 2010; 40:430-8.

[32] Yilmaz B, Yasar E, Taskaynatan MA, et al. Relationship between lumbar muscle strength and proprioception after fatigue in men with chronic low back pain. Turk J Rheumatol 2010; 25:68-71.

[33] Lam SS, Jull G, Treleaven J. Lumbar spine kinesthesia in patients with low back pain. J Orthop Sports Phys Ther 1999; 29:294-9.

[34] Silfies SP, Cholewicki J, Reeves NP, Greene HS. Lumbar position sense and the risk of low back injuries in college athletes: a prospective cohort study. BMC Musculoskelet Disord 2007;8: 129.

[35] Matthew Hoyan Tong, BAppSc, Seyed Javad Mousavi, Henri Kiers, b Paulo Ferreira, Kathryn Refshauge, Jaap van Diee¨n,: Is There a Relationship Between Lumbar Proprioception and Low Back Pain? A Systematic ReviewWith

Meta-Analysis Archives of Physical Medicine and Rehabilitation 2017; 98:120-36.
[36] Panjabi MM. The stabilizing system of the spine. Part II. Neutral zone and instability hypothesis. J Spinal Disord 1992; 5:390-7.
[37] Dankaerts W, O'Sullivan P, Burnett A, Straker L. Differences in sitting postures are associated with nonspecific chronic low back pain disorders when patients are subclassified. Spine (Phila Pa 1976) 2006; 31:698-704.
[38] Preuss R, Grenier S, McGill S. The effect of test position on lumbar spine position sense. J Orthop Sports Phys Ther 2003; 33:73.
[39] Womersley L, May S. Sitting posture of subjects with a postural backache. J Manipulative Physiol Ther 2006; 29:213-8.
[40] Mo¨ rl F, Bradl I. Lumbar posture and muscular activity while sitting during office work. J Electromyogr Kinesiol 2013; 2:362.
[41] Mork PJ, Westgaard RH. Back posture and low back muscle activity in female computer workers: a field study. Clin Biomech (Bristol, Avon) 2009; 24:169-75.
[42] Print J, Mackey MG, Higgs J. Kyphosed seated postures: extending concepts of postural health beyond the office. J Occup Rehabil 2008; 18:35-45.
[43] Callaghan JP, Dunk NM. Examination of the flexion relaxation phenomenon in erector spinae muscles during short duration slumped sitting. Clin Biomech (Bristol, Avon) 2002; 17:353-60.
[44] Willigenburg NW, Kingma I, van Dieen JH. Precision control of an upright trunk posture in low back pain patients. Clin Biomech (Bristol, Avon) 2012; 27:866-71.
[45] Eva-Maj M, Hans W, Per-Anders F, et al. Experimentally induced deep cervical muscle pain distorts head on trunk orientation. Eur J Appl Physiol 2013; 113: 2487-99.
[46] Ro JY, Capra NF. Modulation of jaw muscle spindle afferent activity following intramuscular injections with hypertonic saline. Pain 2001; 92:117-27.
[47] Weerakkody NS, Blouin JS, Taylor JL, Gandevia SC. Local subcutaneous and muscle pain impairs detection of passive movements at the human thumb. J Physiol 2008;586 :3183-93.
[48] Wand BM, Parkitny L, O'Connell NE, et al. Cortical changes in chronic low back pain: current state of the art and implications for clinical practice. Man Ther 2011; 16:15-20.
[49] Flor H, Braun C, Elbert T, Birbaumer N. Extensive reorganization of primary somatosensory cortex in chronic back pain patients. Neurosci Lett 1997; 224:5-8.
[50] 50- Moseley GL. I can't find it! Distorted body image and tactile dysfunction in patients with chronic back pain. Pain 2008; 140:239-43.
[51] Vartiainen N, Kirveskari E, Kallio-Laine K, Kalso E, Forss N. Cortical reorganization in primary somatosensory cortex in patients with unilateral chronic pain. J Pain 2009; 10:854-9.
[52] Thunberg J, Ljubisavljevic M, Djupsjo¨backa M, Johansson H. Effects on the fusimotor-muscle spindle system induced by intramuscular injections of hypertonic saline. Exp Brain Res 2002;142 :319-26.
[53] Relationship Between Lumbar Muscle Strength and Proprioception After Fatigue in Men with Chronic Low Back Pain. Turk J Rheumatol 2010; 25: 68-71.
[54] Angela S. Lee, BS, Jacek Cholewicki, Ph.D., N. Peter Reeves, Ph.D., Bohdanna T. Zazulak, DPT, Lawrence W. Mysliwiec Do.Comparison of Trunk Proprioception Between Patients With Low Back Pain and Healthy Controls . Arch Phys Med Rehabil 2010; 91:9:1327-31.