Research Article

Impact of load carriage on lumbar spine mobility among Indian workers

Abstract

This study was taken up to investigate the effects of different modes of load carriage on lumbar kinematics and the risk of Low Back (LB) pain among Indian construction workers. Ten young construction workers (26.3±1.95 years) volunteered in the study. Lumbar kinematics was measured by using Industrial Lumbar Motion Monitor (iLMM). The volunteers were asked to walk for a distance of 75 meters in three different load conditions i.e. head load, hand load and shoulder load of 20% of body weight. The Lumbar kinematic parameters studied were- Average Twisting Velocity (ATV), Maximum Sagittal Flexion (MSF) and Maximum Lateral Velocity (MLV). It was observed that all the above-mentioned lumbar kinematics - ATV, MSF and MLV increased with the change of modes of load carriage. It had increased the risk of LB problem.

Keywords: lumbar kinematics, lateral velocity, material handling

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Abbreviations: LB, lower back; iLMM, industrial lumber motion monitor; ATV, average twisting velocity; MSF, maximum sagittal flexion; MLV, maximum lateral velocity; MSDs, musculoskeletal disorders; MMH, manual material handling; Q angle, quadriceps angle

Introduction

Musculoskeletal disorders (MSDs) account for large pecuniary onus on industry. Limitations in spinal mobility could impede our important functional skills and activities of daily living. Diminution in spinal mobility was usually the earliest and reliable indicator of back problems. The prevalence of low back problem due to manual handling of loads was very common among industrial workers. A prevalent musculoskeletal injury symptom due to manual load handling was low back (LB) pain. A great many biomechanical and epidemiological studies had reported LB pain to be highly correlated with manual material handling.[1–3] Many findings had quantified low back injury as the most recurrent form of Manual Material Handling (MMH) musculoskeletal injury and thus foregrounded the importance of minimizing the prevalence of LB pain within the working population of industrial sectors. LB pain was caused by repeated lifting and carrying of building materials, twisting of the back at the same time, bending over for long periods of time. Back problems, which seemed to take shape overnight, might, had been edifice up slowly over a period of time. Younger workers even were often more susceptible to LB pain due to endurance and tolerance factors, inept work strategies, and postural effects. Workers, who developed LB pain often, had indigent movement approach that made them vulnerable to injury.[4] There was a need to study in detail the prevalence rate of musculoskeletal problems, especially LB pain among manual labors, handling loads in construction industrial sites in India.

While the lifetime prevalence of LB pain was reported at 80% of the general population, it was reported as 90% in construction industries in America.[5] It had been found that LB pain was elementary and proper anatomical distortion cannot be distinguished.[6] However, the recurrent diagnosis of idiopathic LB pain had made it difficult to link a specific job factor to a specific anatomical or biomechanical failure.[7] Various physical job characteristics had been found to increase the incidence of LB pain symptoms. After reviewing previous studies, the five main biomechanical factors were listed which were believed to led to LB pain symptoms. The five factors were i) high force, ii) static loaded posture, iii) dynamic bending and twisting, iv) specific manual material handling activities like lifting, carrying, pushing, and pulling and v) high repetition.[8] Later, it was further analyzed and was also found that those five factors were significant predictors of lower back pain.[9,10] The five common manual material handling activities that were related to LB pain did not directly cause pain symptoms or low back injury but rather, it is the biomechanical parameters responsible for spinal mobility caused by different manual material handling actions that imparted the damage and thus caused symptoms of LB pain.[11] Load carriage had been allied with lumber spinal pain in both non manual workers and manual workers. When reviewing current scientific literature; it became evident that the manual labors of construction industries had not been investigated for their back health issues with properly analyzing the biomechanical parameters of LB changes occurring during load carriage. There has been a very little biomechanical research investigating impact of different modes of load carriage on spinal mobility which raised the need of doing this study taking into considerations of Indian manual workers back health.

Objectives

The purpose of this study was to investigate the effects of three different modes of load carriage i.e. Head load, shoulder load, hand load carriages on lumbar kinematics and the risk of Low Back (LB) pain among Indian construction workers.

Methodology

Target participants of this study

The study was conducted on ten young Indian construction workers within the age range of 21-30 years with a mean age of 26.3±1.95 years. All subjects included were healthy; there was no incidence of serious neurological or musculoskeletal illness or injury at the time of the study. None of the subjects was using any prescribed medication at the time of study. The subjects were interviewed before inclusion in the study to categorize their activity levels. It was found that all the volunteers were physically active and efficiently performing their task of load carriage.

Instrumentation

The study was conducted by using Industrial Lumbar Motion Monitor (iLMM), made Bio-Dynamic Solutions, Inc. c/o NexGen Ergonomics, Inc. USA and Ballet 2.0 software, BIOMEC Inc. USA.[7] The iLMM is a tri-axial electro- goniometer that acts as a lightweight exoskeleton of the lumbar spine. It was positioned on the back of a subject directly in line with the spine and attached by harness at the pelvis and thorax. Four potentiometers at the base of the iLMM measured the instantaneous position of the spine in there-dimensional space relative to the pelvis, as the subject performs tasks. Position data from the potentiometers were recorded at 60Hz, transmitted to an analog-to-digital (A/D) converter, and then recorded on a microcomputer. The data were then processed to calculate the position, velocity and acceleration of the spine in each of the three planes of motion as a function of time. Measurements were taken where accomplished through wireless telemetry from the iLMM to a laptop computer. The assessment of spine loading focused on the forces imposed on the lumbosacral junction (L5/S1) during the materials handling task. This low back location is where most back injuries occur.

The iLMM exoskeleton was adjusted for the small, medium and large sized employees at neutral position (Zeroing) by keeping it on a flat surface of each subject before the test. After adjusting the equipment, it was placed on the back of the volunteers to track the motion of the low back in three-dimensional space (Figure 1).

Figure 1 iLMM fixed on the back of a subject.

The use of postural adjustments as a proximate part comprehend the axiom that larger postural deracination from the unloaded position increases the probability of developing spinal pain. By experimentally manipulating loads and the way they are carried, and measuring the induced biomechanical changes on lumbar spine can reduce the lower back pain caused due to exterior load on spine.[12] The effect of load weight and method, position and time of load carriage on young people has been investigated in the following manner (Figure 2–4).

Figure 2 Head load.

Figure 3 Shoulder load.

Figure 4 Hand load.

There had been plenty of evidence in the past decade that revealed that the asymmetric arrangement as well as the changing dynamic action of the trunk during work greatly affected the ability of a worker to perform a task. It was found to be due to decreased trunk strength as the trunk moved fast and more asymmetrically and thus loading of the spine was also believed to increase under these conditions. Therefore, it is necessary to document the asymmetry and dynamic motion characteristics of the trunk when workers are exposed to various load carriage tasks. The LMM is an exoskeleton of the spine

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that is orchestrated, so that transitory changes in trunk position, velocity and acceleration can be obtained in three-dimensional space. Researchers had shown that the LMM was about twice as accurate as a video-based motion evaluation system in estimation of lumbar spine mobility.[13] There were a lot of advantages and connotations of using LMM for work assessment and clinical purposes (Figure 5 & 6).

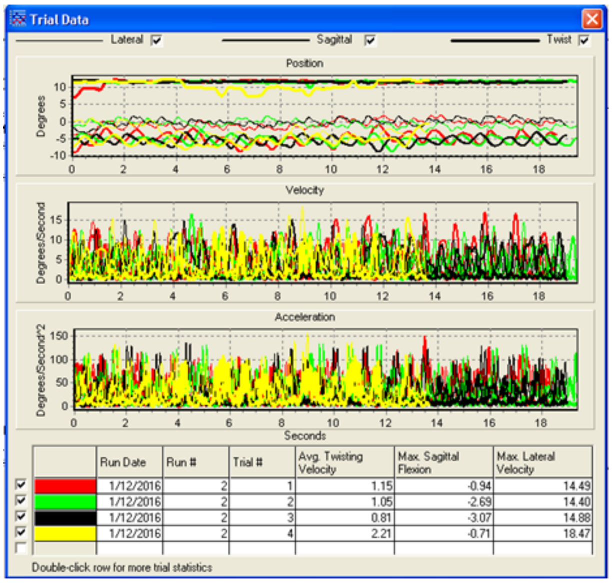

Figure 5 Recording of lumbar kinematics by iLMM.

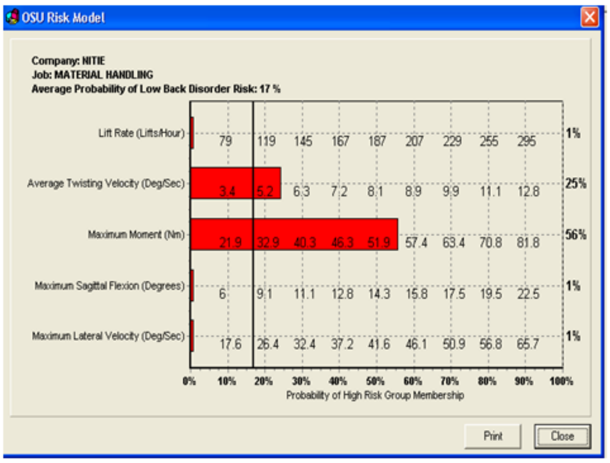

Figure 6 Graphical representation of average probability of LBD risks.

Study protocol

The volunteers were asked to walk straight-line at self-selected speed on the level ground for a distance of 75 meters in three different given conditions- I) head load (20% of body weight) II) hand load (20% of body weight) and III) shoulder load (20% of body weight). The subjects were asked to wear their regular attire. Volunteers were instructed to pick the load boxes from the knuckle height, so that they could observe their picking and then carry the load and keep it at the same height. The square size of the box was held constant and the dimension of the box was 40cm×40cm×16cm. While the workers were performing the task, they were being continuously monitored so that trunk motion and loading characteristics could be assessed. Lumbar kinematic parameters like Average Twisting Velocity (ATV), Maximum Sagittal Flexion (MSF) and Maximum Lateral Velocity (MLV) were recorded by the iLMM and displayed online on the interfaced laptop through the Ballet 2.0 software during walking. Based on the Lumbar kinematics recorded, the software also predicted the risk of Low Back Disorder.

Data analysis

Following data collection, the data were viewed and analyzed using the Ballet 2.0 software. The data were time normalized with respect to the walking and movement of the lumbar. The Lumbar kinematic parameters for each trial with head load, hand load and shoulder load corresponding LBD risk were compared. Statistical analysis was performed using the IBM SPSS statistics (Version 21) software.

Results and discussion

The demographic variables of the subjects are independent variables which cannot be manipulated. It provides data regarding research participants and is necessary for the determination of whether the individuals in a particular study are a representative sample of the target population for generalization purposes. The demographic details are presented in Table 1.

The values of trunk length and circumference other than basic age height and weight were also considered for obtaining the lumbar kinematic parameters.

Kinematics is the study that concerns the motion of particles and rigid bodies without consideration of the forces involved.[14] Abnormal kinematics of the human lumbar vertebrae is widely considered to play an important role in Lower Back Pain.[15]

Table 2 showed different kinematic behaviors of lumbar spine under load carrying conditions in different modes like carrying load on head, across one shoulder and on hand in frontal plane.

Lumbar spine motions were recorded from ten healthy construction workers while performing tasks of lifting and carrying loads of 20% of their body weight. The influence of different modes of load carriage was distinguished from the changes in lumber motion characteristics of the workers while performing the task. Though there were relatively small changes among the young workers, but a correlation of age with lumber kinematic parameters implies that with advancing age, the parameters would be affected to a greater extent thereby demonstrating a greater sensitivity to load magnitude (Load carriage task. It was also found that biomechanical factors caused lower back problem through excessive load and repetitive loading on the spinal structures.[16] The biomechanical mechanism that explains how the external load leads to mechanical loadings which further result in mechanical strain, tissue damage and LBP. The mean and standard deviations of the lumber kinematic parameters average twisting velocity in degree per second, maximum sagittal flexion in degree, maximal lateral velocity in degree per second and lower back disorder in percentage while walking freely and while carrying load (20% of body weight) in different modes like on head, across one shoulder and on hand along the frontal plane have been represented in Table 2.

Box plots are used in this study to show overall patterns of response for the group. They provide a useful way to visualize the range and other characteristics of responses of change in lumbar spine kinematics at 20% of load with different modes of load carriage for each group. Not much significant changes were found in the parameters at different load conditions. Only the average twisting velocity was affected during load carriage across one shoulder

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compared to other modes of load carriage. In Figure 5, the changes in the maximum sagittal flexion in degree has been shown along the x axis in different load conditions and in Figure 6, the average twisting velocity and maximum lateral velocity in degree per second have been plotted along the x axis in different load conditions and has shown the changes in the lower back disorder risks in percentage along the x axis in different modes of load carriage.

In Table 3, the correlations between different anthropometric parameters of the subjects and the lumber kinematics have been presented. In Table 4, the correlations between lower back disorder (LBD) and lumber kinematics and quadriceps angles has been provided respectively.

A strong positive correlation has been found between age and average twisting velocity and maximum sagittal flexion. Stature also has shown a correlation with LBD. Trunk length also has an impact on the lower back disorder risk. It was showed that with the increase in trunk length which in turn coordinates with pelvis also while walking.[17] In Table 4, the correlation between the dependent variable LBD percentage and the lumber kinematics like ATV, MSF, MLV and the Q angle were presented. In Table 5, the correlation between the LBD and the Q angle at different modes of load carriage were compared. The sagittal movement, lateral movement and twisting of the spine decreases and thus can check excessive spine displacement.

Body mass has been found to be associated with lumber kinematics. With the measurement of the trunk circumference and body mass, the subject's obesity can be taken into account and had shown a strong association has been found with lower back pain.[18]

Association of lumbar kinematics and lower back disorders as well as the relation between quadriceps angle (Q angle) and lower back disorder risk are shown.

Q angle, average twisting velocity and maximum sagittal flexion have a strong impact on lower back disorder risk. Maximum lateral velocity also has an impact on lower back disorder risk. Kuhn et al.[19] has found that deviation in quadriceps Angle (Q-Angle) of the lower extremity caused many conditions from low back pain to foot pain. Q-angle measurements were not different in various load condition and presented poor values of discrimination between the load conditions but have shown a strong association with the risk of lower back pain as small Q angle represents compressed pelvic structure which in turn can become a cause of low back pain.[20]

Table 1 Demographic details of the subjects

Independent variables →	Age	Height (cm)	Weight (kg)	Trunk length (cm)	Trunk circumference (cm)
Mean	26.3	166.55	64.66	63.3	148.3
SD (±)	1.95	5.05	6.49	1.89	7.27

Table 2 Lumbar kinematic parameters in different load carriage conditions

Dependent variables→	Average twisting velocity (Deg/ Sec)				Maximum saigittal flexion (Deg)				Maximum lateral velocity (Deg/Sec)				Lower back disorder (%)			
	Free walk	Head load	Hand load	Shoulder load	Free walk	Head load	Hand load	Shoulder load	Free walk	Head load	Hand load	Shoulder load	Free walk	Head load	Hand load	Shoulder load
Mean	2.106	2.642	3.332	4.297	1.541	1.234	1.177	0.307	32.704	32.741	33.792	30.662	16.5	18.9	20.1	20
SD	0.84	1.03	1.01	0.86	4.80	4.19	3.05	3.14	6.74	7.32	7.14	6.61	6.85	7.82	6.87	6.48

Table 3 Correlation between Lumber Kinematic Parameters and Anthropometric Parameters (r values)

Dependent variables→ Independent variables↓	Average twisting velocity (Deg/ Sec)	Maximum sagittal flexion (Deg)	Maximum lateral velocity (Deg/Sec)	Lower back disorder (%)
Age (Years)	0.692	0.598	-0.089	0.312
Height (cm)	0.33	0.14	0.30	-0.415
Weight (Kg)	0.385	0.133	0.80	-0.116
Trunk Length (cm)	-0.409	-0.333	-0.425	0.477
Trunk Circumference (cm)	-0.487	0.409	-0.486	0.401

Table 4 Correlation between risk of lower back disorders, lumber kinetics and quadriceps angle (r values)

Dependent Variables	Q angle (deg)	Average Twisting Velocity (Deg/ Sec)	Maximum Sagittal Flexion (Deg)	Maximum Lateral Velocity (Deg/Sec)
LBD (%)	-0.584*	-0.501*	0.498*	0.487

Table 5 Association of lower back disorders with the Q angle in different modes of load carriage

Dependent variables	Q angle of dominant leg (degree)			
	Free walk	Head	Hand	Shoulder
LBD%	0.584	0.497	0.5	0.512

It was observed that all the above-mentioned lumbar kinematics, namely average twisting velocity, maximum sagittal flexion and maximum lateral velocity were affected by different modes of load carriage, which in turn showed an impact on the risk of lower back disorder (LBD). Comparison of the risk of lower back disorder with various parameters in different load conditions showed that carrying load on head decreases the probability of LBD compared to load carriage across shoulder and on hand in the frontal plane and is dependent on the age, height, weight, trunk length and trunk circumference of an individual. It was found that the development of occupational lower back problem is affected by individual physical factors as well as psychosocial factors.[21]

Conclusion

Evidence suggests that workers are regularly carrying loads of 20% and more of their body weight. During load carriage there are alterations in posture, gait, trunk and spine activity, which could be linked to lower back problem. This study has identified the relationships between the anthropometric parameters and lumber kinematic parameters for average Indian manual material handlers in labor intensive sector like construction industries and provides information regarding the effect of different modes of load carriage on lumbar spine kinematics. This information could be used to provide both education and advice to the workers for reducing future risks of lower back problem. Study limitations, including a small sample of 10 subjects, limit the findings of this research. Further research is necessary to investigate the effect of increasing loads on lumbar spine mobility with advancing age among Indian worker populations.

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Conflicts of interest

The authors of the present study had participated sufficiently in the work to take the required responsibility for the whole content of the research paper, including participation in the idea, concept evaluation, analysis, writing, and revision of the research paper. Furthermore, each author of the research paper certifies the originality of the research work and also that this research material has not been and will not be submitted to or published in any other journal or any other publisher. So, the authors declare that there are no conflicts of interest.

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