An insight into the fatigue and injury mechanism of tractor operators body due to influence of impinged vibration

V.K Tewari¹, K.P.Vidhu² and Satya Prakash Kumar³

¹ Professor and Head, Agricultural & Food Engineering department IIT Kharagpur, India
² Assistant Professor and Head, Dept. of Mechanical Engineering, Vignan University Guntur, India.
³ Research Scholar, Agricultural & Food Engineering department IIT Kharagpur, India

Abstract
The vibration level of tractors chronically enhances the chances of number of health issues like low back problem, sciatic pain and stomach disorders. The vibration energy transmitted to and absorbed by the hand arm and whole body system results in relative compression and extension of muscle tissues (Reynolds, 1977). Therefore, an insight into the muscle fatigue of the operator can be gained through study of electrical activity of the concerned muscles. A study was planned with 78 tractor drivers. They were asked to operate tractor under varying field conditions and with different implements hitch to the tractor. Necessary instrumentation was employed to record and assess the effect of work included vibration on the human operator with regard to health issues such as body pain, muscle stress, spinal injury etc. A medical practitioner was consulted for the study. It is researched that low back pain could be an effect of Abdominal Aortic Aneurysms (AAA) or Chronic Pancreatitis (CP) among others. Though the hearing loss in tractor drivers could not be directly connected to the exposure to vibration, correlating the result with the previously explained reports, it could be generally termed that exposure to vibration has an effect on reduction of hearing ability among the tractor drivers.

Key words: Work stress, Muscle fatigue, Posture analysis, Vibration transmissibility, Vibration isolator

1. Introduction

Human body is more strained during driving of tractor than any other off-road vehicles, next to trucks. The operator work place in Indian tractor is open to numerous unpleasant factors unlike the industrial worker such as absence of closed cabin, prevailing tropical climate and agro-socio economical conditions, to name a few. The vibration level of tractors chronically enhances the chances of number of health issues like low back problem, sciatic pain and stomach disorders. To assess the situation, a survey was carried out among the tractor drivers of West Midnapore district of West Bengal, India. The vibration energy transmitted to and absorbed by the hand arm and whole body system results in relative compression and extension of muscle tissues (Reynolds, 1977). Therefore, an insight into the muscle fatigue of the operator can be gained through study of electrical activity of the concerned muscles. When muscle fibers contract, they conduct electrical activity that can be measured by electrodes affixed to the surface of the skin above the muscles. Studies on construction workers, office workers and heavy duty vehicle operators have claimed that the latter group showed significant
low back pain (LBP) over the years (Luoma et al., 2000). Kumar et al. (1999) had used MRI technique to assess the LBP issues of tractor drivers. Physical and psychophysical differences between working in the stooped and prone postures were compared while performing a simulated agricultural harvesting task by Mayer and Radwin (2007). The measures used to compare the two postures included perceived discomfort, electromyography (EMG) and heart rate (HR). Average hamstrings localized discomfort (0–10 scale) was 6.17 for the stoop posture and 0.67 for the prone posture. Erector spinae and hamstring EMG rms increased 68% and 18%, respectively, while mean power frequency for the hamstrings decreased 13% for the stoop task. Average heart rate during the last work cycle was 35% greater than the resting heart rate for the stoop posture while average heart rate was 17% greater for the prone posture. Fathallah et al. (2008) evaluated the role of stooped work in the problem of low back disorder (LBDs) among agricultural workers by examining the epidemiological literature, evaluating the scope of stooped work in agriculture, and examining current and potential intervention approaches. To determine the inter- and intra-rater reliability of assessing upper limb postures of workers performing manufacturing tasks, Angela et al. (2009) used Multimedia Video Task Analysis (MVTA) for assessment of neck, shoulder, and wrist postures of 20 manufacturing employees with two raters. They proposed that posture assessment of manufacturing workers using MVTA is a reliable method. Jin et.al. (2009) conducted a study to explore the changes in the low back biomechanical responses during a harvesting task as a function of different harvesting techniques/postures and to explore the effects of an ergonomic intervention designed to reduce the low back stress during work activity. The results showed that three postures—knee support, squatting, and stooping—required high flexion of low back and squatting and stooping postures showed significantly higher passive tissue moment compared with two kneeling postures. Sandhya et al. (2008) has demonstrated that early vibration injury of nerves occurs at both low and high frequencies. The vibration characteristics of muscles can help to quantify the influence of impinged vibrations, and provide a better insight into the fatigue and injury mechanism of the operator’s body. Therefore, it is essential to measure the hand and body muscle activities involved in various actions performed during the different field operations of tractor-implement system, in terms of reference voluntary electrical (RVE) activity with respect to maximum voluntary contraction (MVC) to systematically understand and quantify the muscle fatigue level leading to operator’s work stress.

A study was planned with 78 tractor drivers. They were asked to operate tractor under varying field conditions and with different implements hitch to the tractor. Necessary instrumentation was employed to record and assess the effect of work included vibration on the human operator with regard to the health issues such as body pain, muscle stress, spinal injury etc. A medical practitioner was consulted for the study.

2. Methodology

The respondents included professional drivers (38), farmers who drove their tractor themselves as full time (15) and farmers who drove tractors as part time (25).
2.1 Data analysis

The collected information was categorized, coded and statistically analyzed using Microsoft Excel tool box. The variations of parameters such as body pain in all identified areas, their levels, variations with age and experience, permanent and transient health issues etc were analyzed separately. Efforts were made to relate the body pain and health issues with the hours of exposure to vibration as it was assumed to be the main source of cause of health issues.

2.2 Medical examination of tractor drivers

A medical practitioner was consulted for this part of the study. The problem was discussed with him and the motive and criteria of the tests were clarified from ethical view point. It was made sure that the respondents at the time of data collection were in good health condition. The following medical tests were advocated in consultation with a medical expert: Lumbar Spinal MRI, Nerve Conduction Velocity Test, Ultrasonography of abdomen, Audiometry test.

An established diagnostic center at Midnapore, West Bengal, India, was contacted for conducting the tests. Pre-conditions required for all the specific tests were systematically followed for all the subjects. Digital images of tests were obtained along with the diagnostic details for all the subjects. To medically compare the results of possible health issues, the above selected tests were also conducted for 8 non-tractor drivers. The non-tractor drivers were the subjects who were free from any health issues and found fit for any physical activity including tractor driving for field operations. All the tests were accomplished for a total of 20 subjects in both tractor driver and non tractor driver category and the results obtained were compared.

2.3 Measurement of Work Stress

Work stress was evaluated based on the general body fatigue parameters namely; heart rate, oxygen consumption rate and work related body parts discomfort score along with muscular fatigue (EMG). These measurements were taken with standard instrumentations available with the experimenter. The experiment was conducted in all selected operations with 12 subjects. The subjects were taken as replications. The treatments were given in randomized order to minimize the effects of variation in environment conditions. There were 5 independent variables, the effect of which is to be studied in this set of experiments. Out of these, heart rate, oxygen consumption, work related body discomfort score (WRBD) and overall discomfort score (ODR) were studied during single set of experiments, but EMG was separately studied during another set of experiments. This was necessary because, the duration of both the sets were different. Care was taken to keep other pertinent factors that may affect the trials to be the same during both the experiment sets. This resulted in total of 96 experimental trials for work stress investigation study.
3. Results

The results of various experiments conducted during the course of the present investigation of tractor operators’ pain intensity and health issue along with the analysis and interpretation is presented in this section. The tractor drivers operated drove the tractor around 8 hours a day. With average annual use of 198.8 days, the total hours of operation works out to be 1590 hours per year. In terms of exposure to vibration, when calculated for an average 8 years of experience, the tractor driver is exposed to 12720 h of vibration. The maximum pain areas reported by the farmers were back, hip and bottom, forehead and chest. Fig.1 shows the pain intensity experienced by the tractor drivers.

![Graph showing pain intensity with hours of tractor driving]

Fig.1 Pain intensity with hours of tractor driving as experienced by surveyed operators.

Pain intensity was marked on a 10 point scale with 0 being least pain and 10 being the most. The maximum pain area was found to be upper and lower back with a pain intensity of 7.0, experienced by 71.8% respondents. Hip and bottom region was next higher contributing to 6.4 pain intensity.

During the survey, permanent ailments due to tractor driving were enquired. Fig.2 depicts the health issues reported by the respondents. Low back pain was one of the important problems reported by most of the operators. LBP was categorized in to three, viz., transient, chronic and acute. A person when recovered from the LBP within 24 hours either through medication or rest was considered to be suffering from transient LBP whereas a prolonged LBP for 6 months was considered to be chronic LBP. Acute LBP could be either transient or chronic depending upon the pain level experienced by the operator. Other major problems found were sciatic pain, stomach disorders, headache, chest pain and swelling in knee.
The age of operator also had a role on health issues as evident from Fig.3. All the health problems accelerated with age. Stomach disorders were seen to have almost constant effect on age, but sciatic pain reduced after the age of 40. As sciatic pain is the pain felt during the operation which is relieved after work, this was not prevalent among older age operators. However, the reason could not be explained. A majority of 71% respondents in the age group of 45-50 years felt chronic LBP.

The averaged EMG activity of all selected subjects in hand and body muscles during first till is depicted in Fig 4 and 5 respectively.
The trend in EMG activity during first till showed similar trend for all the hand muscles except a few places. The range for flexi carpi radialis (FCR) was highest at 16.6 to 36.5 µV, whereas extensor digitorum (ED), brachio radialis (BR) and Middle deltoid (MD) showed similar results. In body muscles, upper trapezius (UT) was much active ranging between 14.2 to 46.4 µV while latissimus dorsi (LD), middle trapezius (MT) and erector spinae (ES) were almost comparable. The ES had a lower range at the starting but gradually increased till approximately 10 min of trial and then declined.

4. Discussion

The percentage load of selected hand muscles was calculated against the MVC for each muscle to assess the muscle load in different selected operations. The load on hand muscles during different operations is given in Fig 6. The response of EMG during field operation of tractor indicated an average high load on FCR muscle, followed by ED, MD and BR muscles. The average muscle load for the FCR, ED, MD and BR muscles were 15.14, 12.42, 4.95 and 4.44% RVE respectively during transportation. Their corresponding values during first till were 22.05, 17.78, 7.57 and 5.47% RVE, while during second till; these were 20.75, 21.09, 7.8 and 7.04% RVE. Puddling recorded average muscle load on hand as 18.83, 14.99, 3.97 and 4.53 for FCR, ED, MD and BR muscles respectively.
The muscle loads on selected body muscles were also calculated against MVC. For the body muscles in selected operations, the load on UT was ranging between 10.02 to 14.54% RVE. First till and second till showed higher muscle load on MT while for the transportation and puddling it was minimal. Load on Erector spinae (ES) muscle was higher during first till (7.08%) followed by transportation (5.96%), puddling (5.72%) and second till (4.69%). Muscle load on LD muscle was higher in second till while for all other operations it was almost the same.

The shoulder abduction was minimal during transportation and puddling, which resulted in lesser load to the MD muscles. The lowest load of BR muscle during transportation was due to lesser frequency of use of control levers. Field operations require grasping the steering firmly along with the usage of levers which results in higher muscle load on Flexi carpi radialis (FCR), followed by Extensor digitorum (ED), MD and Brachio radialis (BR). Though the puddling operation is more strenuous which requires frequent usage of levers in lifting and lowering the implement, the load on BR and MD muscles was lowest among the selected operations. Since the unevenness of the ground coupled with the emanating vibration makes the operator to take support of the steering more in puddling which might be the cause of lower load on BR and MD muscles. The actuation of hydraulic lever intermittently for adjusting the depth as well as taking turn requires higher effort on FCR and ED muscles. Moreover, size of the field also affects the variation in muscle fatigue. Nag and Chatterjee (1981) have suggested that 20 to 30% MVC could be considered as an acceptable range of constant loading in agricultural work.

The abnormalities emerged in the MRI report are classified into different categories and presented in Table 1. The typical degenerative disc disease of L.S. spine with intervertebral disc bulge at L4-5 & L5-S1 was studied. This could be compared with a normal disc MRI where in the former; the bilateral facet joint hypertrophy is visible.
Table 1 Abnormalities reported in MRI of tractor and non-tractor drivers

<table>
<thead>
<tr>
<th>Sl No</th>
<th>Description</th>
<th>Tractor driver, No (%)</th>
<th>Non-tractor driver, No (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Minimal thecal indentation</td>
<td>4 (33)</td>
<td>2 (25)</td>
</tr>
<tr>
<td>2</td>
<td>Intervertebral disc bulge</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>- Indenting to thecal sac</td>
<td>9 (75)</td>
<td>1 (12)</td>
</tr>
<tr>
<td></td>
<td>- Exiting root nerve</td>
<td>5 (42)</td>
<td>1 (12)</td>
</tr>
<tr>
<td>3</td>
<td>Disc space reduction</td>
<td>-</td>
<td>1 (12)</td>
</tr>
<tr>
<td>4</td>
<td>Hypertrophied facet joint-bilateral</td>
<td>5 (42)</td>
<td>1 (12)</td>
</tr>
<tr>
<td>5</td>
<td>Lumbar spondylosis</td>
<td>2 (17)</td>
<td>-</td>
</tr>
</tbody>
</table>

It is researched that low back pain could be an after effect of Abdominal Aortic Aneurysms (AAA) or Chronic Pancreatitis (CP) among others. Though the hearing loss in tractor drivers could not be directly connected to the exposure to vibration, correlating the result with the previously explained reports, it could be generally termed that exposure to vibration has an effect on reduction of hearing ability among the tractor drivers.

References


