Tractor Driving and the Low Back

The effect of an air cushion and a swivel seat on spinal movement during rotation

A report for the Rural Industries Research and Development Corporation

by S Scutter, I Fulton & V Cheng
University of South Australia

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Foreword

Back pain is common in farmers and has been shown in previous research to be related to the exposure to vibration which farmers experience while driving tractors. Various methods of reducing the effects of vibration and the rotated posture are used by farmers, but more information is needed about their effectiveness and mechanisms of operation.

Through farmer questionnaires and field and laboratory trials, this project looked at the effectiveness of simple devices such as an air-filled cushion and a swivel seat and the resulting changes in the movement patterns in the low back.

Funding for this project was provided by the Joint Farm Health and Safety Research Venture, is managed by RIRDC, with contributions by RIRDC, GRDC, CRDC, the Woolmark Company and MRC.

This report, a new addition to RIRDC's diverse range of almost 400 research publications, forms part of our Human Capital, Communications and Information Systems sub-program, which aims to enhance human capital and facilitate innovation in rural industries and communities.

Most of our publications are available for viewing, downloading or purchasing online through our website:
- downloads at www.rirdc.gov.au/reports/Index.htm

Peter Core
Managing Director
Rural Industries Research and Development Corporation
Acknowledgments

This study was supported by the Rural Industries Research and Development Corporation. The cushions used were supplied by THE C’AIRECUSH COMPANY, NSW, Australia. Chris Adey, physiotherapy student of University of South Australia, acted as a model for the photographic illustrations.
Contents

Foreword ...........................................................................................................................................iii
Acknowledgments................................................................................................................ .............iv
Executive Summary ......................................................................................................................... vi
  Background ................................................................................................................................. vi
  Research Design .......................................................................................................................... vi
  Summary of Results ...................................................................................................................... vi
      1. Incidence of back pain in farmers ..................................................................................... vi
      2. Laboratory trial ................................................................................................................... vi
      3. Field trial ............................................................................................................................. vi
Background to the Project ..........................................................................................................1
Objectives of the Project ...........................................................................................................3
Technical Information ............................................................................................................4
  1. 3-SPACE TRACKER .................................................................................................................... 4
  2. THE SWIVEL SEAT ...................................................................................................................... 4
  3. C’AIRECUSH .............................................................................................................................. 5
Methodology ................................................................................................................................. 6
  Introduction ........................................................................................................................................ 6
  Methodology of Individual Areas ................................................................................................. 6
      Questionnaire on Incidence of Back Pain in Farmers .............................................................. 6
      Laboratory Trial of Effect of Cushion and Swivel Seat on Spinal Movement During Rotation... 6
      1. Fixed swivel seat with cushion .............................................................................................. 7
      2. Swivel seat with cushion ....................................................................................................... 8
      3. Fixed swivel with no cushion ............................................................................................... 8
      4. Swivel seat with no cushion ................................................................................................ 8
      Field Trial of the Effect of Cushion on Back Pain ..................................................................... 9
Results ......................................................................................................................................... 10
  Questionnaire on Incidence of Back Pain in Farmers ............................................................. 10
  Laboratory Trial of Effect of an Inflatable Cushion and Swivel Seat on Spinal Movement During Rotation ........................................................................................................ 13
      Field Trial ................................................................................................................................ 17
Discussion .................................................................................................................................... 18
  Questionnaire on Incidence of Back Pain in Farmers ............................................................. 18
  Laboratory Trial of Effect of Cushion and Swivel Seat on Spinal Movement During Rotation.... 19
      Field Trial of the Effect of Cushion on Back pain ................................................................... 20
Conclusion .................................................................................................................................... 21
References ..................................................................................................................................... 22
Executive Summary

Background

This project investigated the effects of an inflatable cushion and a swivel seat on farmers’ back pain and movement patterns. Initially, a questionnaire was used to determine the incidence of back problems in farmers. The results of the questionnaire showed that 102 of 138 farmers had back pain in the last year and 80 out of 116 farmers found that tractor driving caused back pain. Laboratory trials then followed to investigate the effect of an air filled cushion and a swivel seat on spinal movement during rotation. Field trials were used to investigate the effects of an inflatable cushion on back pain symptoms.

Research Design

The project was divided into 3 parts.
1. A questionnaire was used to determine the incidence of back pain in farmers, and work practices related to the back pain. Questionnaires were sent to subjects recruited from across South Australia.
2. A Laboratory trial of the effect of the air cushion and a swivel seat on spinal movement during rotation, as measured by the 3-Space Tracker. Subjects attended on one occasion and were tested during four experimental conditions.
3. A Field trial of the effect of the air cushion on back and neck pain, as monitored by a logbook. Subjects were given a logbook, which was to collect data during normal tractor driving activities.

All subjects were farmers who were participating in farming work.

Summary of Results

1. Incidence of back pain in farmers
The postal questionnaire was sent to 250 farmers of whom 138 responded. From the returned questionnaires, 102 farmers had experienced back pain in the last year. The major activities causing back pain were sheep work, general tractor work and general heavy work.

2. Laboratory trial
With the use of the air cushion, or swivel seat, or cushion and swivel seat together, there was an increase in the range of movement of lumbar right lateral flexion and right rotation.

3. Field trial
With the use of the air cushion, farmers experienced less low back pain and neck pain while driving the tractor and less back pain after tractor driving.
Background to the Project

Back pain is one of the most frequently occurring and most costly problems in occupational health (Troup 1984). It has been found to be more common in occupations such as truck and tractor driving, where there is an exposure to vibration (Burdorf et al 1990, Kesely et al 1989) (Pope et al 1998). Whole-body vibration while driving tractors has been found to be a cause of low back pain in freight-container tractor drivers (Nishiyama et al, 1998) and agricultural tractors (Bovenzi and Betta, 1994). Forty three percent of sprain/strain injuries in farmers have been found to be back strain injuries (Low and Griffith 1993).

Modifications to tractor seats, including changes to the suspension, may change the vibration to which farmers are exposed (Nishiyama et al, 1998). Seat adjustments have been found to significantly reduce the symptoms of back pain in forest tractor workers, although interestingly the presence of a lumbar support or changes in backrest inclination did not change the incidence of symptoms (Perkiomakela and Riihimaki, 1997). Pope et al (1998a) found that the type of seating used affected the response to vibration, and that the movements of the pelvis were a large component of this effect. Seats which reduce vibration and appropriate ergonomics in tractor cabs were suggested as means of decreasing back pain with vibration exposure (Pope et al 1998b)

Farmers while driving tractors often assume a rotated posture as they are watching the implement attached to the rear of the tractor. Activities such as raking, grading and ploughing will require such a rotated posture. Farmers involved in these activities may spend many hours, often up to 12 to 14 hours a day, in this rotated posture. Boshuizen et al (1992) hypothesized that the cause of back pain in fork-lift truck and freight-container tractor drivers was the posterior intervertebral joints of the spine being damaged when they twisted the spine while looking backward. The rotation angle needed for damaging the posterior intervertebral joint is only slightly larger than the rotation angle that can be produced by voluntary muscle activity (Adam and Hutton 1981). Thus the rotation to which farmers are exposed may also result in the development of symptoms.
In order to reduce the rotatory load on the spine, many farmers in Australia install swivel seats. Tractor seats with sophisticated suspension systems are available to reduce vibration, although these are expensive. The effectiveness of these seats has not been fully tested, although Ozkaya et al (1996) found that simple seating designs transmitted less vibration than more complex designs. A simple modification which can be made to a tractor seat is the addition of an inflatable cushion. The C’AIRECUSH Pressure Distributing Seat Cushion (THE C’AIRECUSH COMPANY, Turramurra, New South Wales, Australia) is used effectively for the reduction of symptoms in wheelchair users, and anecdotal evidence from farmers has suggested that it may be of use in alleviating back pain symptoms in tractor drivers.

In the current study, a preliminary questionnaire was used initially to determine whether back pain was present in a sample of farmers in a variety of farming pursuits in South Australia. After establishing that back pain was present in a large proportion of working farmers, a field trial was used to determine whether an inflatable cushion (C’AIRECUSH) would alleviate any symptoms. Laboratory trials were then undertaken to determine whether the C’AIRECUSH changed the movement patterns which farmers used during rotation. These effects were compared with the changes in movement patterns resulting from using a swivel seat.
Objectives of the Project

1. To study the incidence of back pain in farmers
2. To investigate the effect of an inflatable cushion (the C’AIRECUSH Pressure Distributing Seat, THE C’AIRCUSH COMPANY, Turramurra, New South Wales, Australia) and swivel seat on spinal movement during rotation
3. To investigate the effect of an air inflated cushion (the C’AIRECUSH Pressure Distributing Seat) on back pain in the field.
Technical Information

1. 3-SPACE TRACKER

The 3-Space Tracker (Polhemus, Vermont, USA) was used to measure the relative movement between the sacrum and the chair, and between the lumbar spine and the sacrum. The 3-Space tracker, with one electromagnetic source and two sensors, is shown in Figure 1.

Figure 1 The 3-Space Tracker, with one source and two sensors.

By utilizing a low frequency magnetic field, the 3 Space Tracker continuously monitors the position and the orientation of the first sensor in relation to the source and the second sensor in relation to the first sensor, with six degrees of freedom. The information system was interfaced with a personal computer for data storage and conversion into degrees of movement. The computer also provides a graphical representation of the angular change over the time measured. Figure 2 is a sample graph showing the movement changes.

Figure 2. A sample graph from 3 Space Tracker. Three ranges of movement over time are recorded: flexion/extension, left and right bend (lateral flexion) and left and right twist (rotation).

2. THE SWIVEL SEAT

The swivel seat was a modified tractor seat mounted on a rigid frame. It could be unlocked and swiveled 135 degrees to the right side (Figure 3).

Figure 3. Swivel seat on the whole body vibration simulator in neutral position (left) and rotated to the right.
3. C’AIRECUSH

The C’AIRECUSH Pressure Distributing Seat Cushion (THE C’AIRECUSH COMPANY, Turramurra, NSW, Australia) (Figure 4) is an inflatable cushion which consists of four layers of fire resistant plastic, sealed to form two separate chambers, each with 12 baffles and its own inflator. The cushion uses air to distribute pressure evenly. When the cushion is inflated, air moves through clearly defined channels - north to south in one chamber and east to west in the other. After any body movement, the contained air immediately redistributes pressure away from the bony prominences.

Figure 4. THE C’AIRECUSH PRESSURE DISTRIBUTING SEAT
Methodology

Introduction

The three areas of the project will be detailed individually in Section 3 under the following headings.

1. Questionnaire on Incidence of Back Pain in Farmers
2. Laboratory Trial of Effect of Cushion and Swivel Seat on Spinal Movement During Rotation
3. Field Trial of The Effect of Cushion on Back pain

Methodology of Individual Areas

Questionnaire on Incidence of Back Pain in Farmers

A trial questionnaire was conducted at the early stage of this project. After a preliminary analysis of this trial questionnaire, a more complete and detailed questionnaire (see Appendix A) was developed to determine the incidence of back pain in farmers, and the factors related to it.

The questionnaire was distributed to all farmers participating in Part 1 and 2 of the study and was also distributed to farmers from a wide range of farming areas across South Australia.

Laboratory Trial of Effect of Cushion and Swivel Seat on Spinal Movement During Rotation

Ethical approval was received from University of South Australia Human Research Ethics Committee. Weight, height and age of subjects were collected before testing.

Eleven farmers formed the sample group and were recruited via newspaper advertisement and personal contact. Subjects were chosen if they experienced some degree back pain during normal work activities but they could continue to work. Subjects were informed as to the nature, purpose and procedure of the study. Informed consent was given by each subject (Appendix B).
Subjects were excluded from this study if:

- they had experienced back pain in the last six months which had prevented them from working or undertaking sport or leisure activities
- they had never experienced any back pain
- they suffered from any known medical condition which affected lumbar movement (e.g. ankylosing spondylitis, rheumatoid arthritis)
- they developed symptoms during the testing period
- there was any other reason that they were unable to carry out or complete the test procedure

Subjects were asked to lie prone on a plinth. The lumbosacral junction and the spinous process of the twelfth thoracic vertebra were palpated and the skin was marked for the position of the sensors of the 3 Space Tracker. The subject was then instructed to stand while the two sensors were attached to the subject’s back using adhesive tape (Figure 5). The source of the 3 space Tracker was held firmly in place with adhesive tape on the side of a wooden box placed on the ground behind the whole body vibration simulator (Figure 6). The subject was then seated in the swivel seat.

Figure 5. Two sensors were attached to the subject’s back using adhesive tape.

Figure 6. The source of the 3 Space Tracker was held with adhesive on the side of a wooden box placed at behind the whole body vibration simulator.

The testing consisted of four tests, which were carried out, in the following order.

1. **Fixed swivel seat with cushion**
   The swivel seat of the whole body vibration simulator was locked in a forward direction. The cushion was inflated and placed on the seat and the subject was asked to sit on the cushion. When the computer attached to the 3 Space Tracker was on, the subject was asked to turn to the right side from the neutral position (i.e. forward facing)
as far as possible and hold for five seconds. Then he returned back to the neutral position.

2. **Swivel seat with cushion**
The swivel seat was unlocked, with the inflated cushion still on the seat. The same procedure with the 3 Space Tracker was carried out as the first test, but the subject was instructed to turn to the right with the swivel seat.

3. **Fixed swivel with no cushion**
The swivel seat was then locked and the cushion on the seat was deflated. The same procedure with the 3 Space Tracker was performed as during the first test. This was used as a baseline movement of each subject.

4. **Swivel seat with no cushion**
The swivel seat was unlocked. The procedure with the 3 Space Tracker was same as the first test. (The cushion was still deflated.)

The four tests were performed immediately one after the other.

The data recorded was retrieved in graphical form. To determine the movement pattern of each testing occasion, the mid-point during the five second holding period was taken (Figure 7) and the directions and degrees of movement were recorded.

**Figure 7.** A sample graph showing the directions and degrees of movements recorded from the 3-Space Tracker graph. By moving the cursor to the mid-point of the holding period, the degrees of movements could be read directly from the figures shown. The top graph shows the flexion/extension direction, the middle graph shows lateral flexion direction and the bottom graph shows the rotation direction.
**Field Trial of the Effect of Cushion on Back Pain**

Fifteen farmers were recruited by advertisement or personal contact. The same inclusion/exclusion criteria applied as for the previous section. Some farmers took part in both parts 2 and 3 of the study.

A logbook was used to collect data from farmers during normal farming activities. The logbook collected details of the incidence and severity of neck and back pain, related to the farming activities undertaken. The data was collected over a sixteen day period, with farmers being instructed when to use the C’AIRECUSH Pressure Distributing Seat Cushion (the C’AIRECUSH) during this period. (see Appendix C).

After completion of the logbook, the farmers were offered $50 payment for participation in the study. Alternately, they could elect to keep the cushion.
Results

Questionnaire on Incidence of Back Pain in Farmers

From a total of 138 farmers responding to the 250 questionnaires sent, 102 had experienced some back pain in the last year, whereas 32 had experienced no back pain. Forty percent of farmers experienced pain on 2 or more days in the previous year. Seventeen percent experienced pain on at least 8 days (Figure 8).

Figure 8: Days with Back Pain

Figure 8 shows the number of days on which farmers experienced back pain in the last year. 40.6% of farmers experienced pain on 2 or more days in the previous year. 17% experienced pain on at least 8 days.

Figure 9 shows that 82 farmers had no pain on their best days. Three farmers experienced level 4 (level 0 was no pain whereas level 5 was the worst pain) pain even on their best days. The mean pain on best days was 0.67.

Figure 9: Pain on Best Days

Figure 9 shows the level of pain scored on the best days. No pain scored Level 0 whereas Level 5 pain was the worst imaginable pain. 82 farmers (59.4%) had no pain on their best days. 3 farmers experienced level 4 pain even on their best days. Mean pain on best days was 0.67.
Eleven farmers experienced level 5 pain (level 0 was no pain whereas level 5 was the worst pain) on their worst days and the mean pain on worst days was 2.5 (Figure 10).

Figure 10: Pain on Worst Days

Figure 10 shows that 11 farmers (7.9%) experienced Level 5 (worst imaginable) pain on their worst days. Mean pain on worst days was 2.5

One hundred and seven farmers had lost 0 or 1 day work in the last year due to back pain. 21 farmers had lost more than 2 days work in the past year (Figure 11).

Figure 11: Days lost from work

Figure 11. 107 subjects had lost 0 or 1 day work in the last year due to back pain. 21 subjects had lost 2 - 7 days. 23% of farmers had lost more than 2 days work in the past year.
Working on sheep, general tractor work and general heavy work were identified as the major activities causing back pain (Figure 12).

**Figure 12: Activities causing back pain**

Eighty farmers found that tractor driving was the driving activity that made back pain worse (Figure 13).

**Figure 13: Driving activities making back pain worse**

Among the 138 farmers that experienced back pain last year, 74 sought treatment. The most common treatment was chiropractor, although many farmers had used physiotherapy, home massage and exercises.
Laboratory Trial of Effect of an Inflatable Cushion and Swivel Seat on Spinal Movement During Rotation

From the graphs obtained from 3 Space Tracker, we could determine the change in angular movements in flexion/extension (Figure 14), rotation (Figure 15) and lateral flexion (Figure 16) for each individual in the four tests. The baseline movement of each subject, i.e. the movement in a fixed swivel seat with no cushion, was then taken away from the other three movements. The effect from the baseline movement influenced by different testing situations could then be determined.

Figure 14. Graphical representation of the change in lumbar flexion/extension from the baseline value for the three different conditions. (+ values = increased flexion, - values = decreased flexion)
The results of the laboratory trial are summarized in Table 1 (flexion/extension), Table 2 (rotation) and Table 3 (lateral flexion) below.
(+ values = increased flexion, - values = decreased flexion)

<table>
<thead>
<tr>
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<th>cushion</th>
<th>swivel</th>
<th>cushion &amp; Swivel</th>
</tr>
</thead>
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<td>1.53</td>
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<tr>
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<td>-18.68</td>
<td>-3.35</td>
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<td>-18.84</td>
<td></td>
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<td>-51.84</td>
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Table 1. Results of the laboratory trial of the change in lumbar flexion/extension from the baseline value for the three different experimental conditions.

(+ values = increased right rotation, - values = decreased right rotation)

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<td>131.2</td>
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<td>2.7</td>
<td>87.77</td>
<td>108.89</td>
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<td>8.98</td>
<td>81.72</td>
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Table 2. Results of the laboratory trial for the change in lumbar rotation from the baseline value for the three different experimental conditions.
(+ values = increased right lateral flexion, - values = decreased right lateral flexion)

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<td>29.96</td>
<td>-13.58</td>
<td></td>
<td>66.88</td>
</tr>
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</table>

Table 3. Results of the laboratory trial of the change in lumbar lateral flexion from the baseline value for the three different experimental conditions.

From Figure 14 and Table 1 it can be seen that there was no consistent pattern of change in flexion and extension: with some subjects using more flexion and some subjects using more extension with the cushion or the swivel seat. During the three experimental conditions there was generally an increase in the right rotation (compared to the baseline) in all experimental conditions. This can be seen in Figure 15 and Table 2. There was also a general increase in right lateral flexion for all of the experimental conditions. This can be seen in Figure 16 and Table 3. When the cushion was combined with the swivel seat, the same pattern occurred as when either the cushion or the swivel seat were used. Thus there was no advantage, in terms of increasing range of movement, in using both the cushion and the swivel seat combined.

Analysis of the results could only be achieved by visual analysis. These results demonstrated that there was a definite alteration in the movement strategies that people adopted when exposed to the three different experimental conditions.
Field Trial

THE C’AIRECUSH was used on 79 days during the study period. It was not used on 69 days. The results of the field trial are summarised in Table 4. The number of hours spent on the tractor was similar on days when the cushion was used and not used. Thus it is valid to compare the symptoms experienced in the neck, mid back and low back when the cushion was and was not used. Before driving commenced for the day, there were similar levels of back, neck and midback pain, whether the cushion was to be used or not. During driving, there was significantly less pain in the neck and low back when the cushion was used. There was significantly less pain in the low back after driving on the days the cushion was used.

<table>
<thead>
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<th>Days when cushion used (n = 79)</th>
<th>Days when cushion was not used (n = 69)</th>
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<tbody>
<tr>
<td>Amount of tractor driving</td>
<td>7.8 hours</td>
<td>8.0 hours</td>
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<tr>
<td>Neck pain before driving</td>
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<td>24</td>
</tr>
<tr>
<td>Midback pain before driving</td>
<td>23</td>
<td>22</td>
</tr>
<tr>
<td>Low back pain before driving</td>
<td>35</td>
<td>30</td>
</tr>
<tr>
<td>Neck pain during driving</td>
<td>39</td>
<td>55*</td>
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<tr>
<td>Midback pain during driving</td>
<td>31</td>
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</tr>
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<td>Low back pain during driving</td>
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<td>62**</td>
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<td>Neck pain after driving</td>
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<tr>
<td>Midback pain after driving</td>
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<td>33</td>
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<tr>
<td>Low back pain after driving</td>
<td>35</td>
<td>52**</td>
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</table>

Table 4: Summary of data of Field trials of the C’AIRECUSH Pressure Distributing Seat Cushion

** p<0.01
* p<0.05
Discussion

Questionnaire on Incidence of Back Pain in Farmers

Boshuizen et al (1990) conducted a questionnaire survey to investigate the relationship between the occupational history of driving vibrating vehicles (mainly agricultural tractors) and back pain. The prevalence of back pain reported was approximately 10% higher in the tractor drivers than in workers not exposed to vibration.

In the current study, 80 of 138 farmers stated that tractor driving was the driving activity that made back pain worse when compared to truck and farm utility driving. Tractor driving always involves exposure to whole body vibration and frequent twisting of the spine when looking backward, which does not normally occur during truck and farm utility driving. We found that sheep work, heavy work and tractor work were the main activities that led to back pain. Following these findings, we conducted the next 2 parts of the project in order to further investigate a means to alleviate the back pain of farmers resulting from tractor driving.

From the results of the questionnaire, we found that although there were 35 farmers with back pain at level 3 (level 0 was no pain whereas level 5 was the worst pain) and 36 farmers at level 4 on their worst days, 107 out of 138 farmers only lost 0 or 1 day work due to back pain in the last year. Therefore many farmers have low back pain but do not have time off. In studies by Boshuizen et al (1990) and Manninen et al (1995), questionnaires used were mainly questioning about the health status, symptoms of back problem and exposure to whole body vibration. Therefore it is difficult to make any comparison between our study and others on this finding. Since most of the farmers still kept on with their work despite the back pain, it is very important to find out a way that can help reduce the back pain during work. Thus the effectiveness of the inflatable cushion (the C’AIRECUSH) and a swivel seat were investigated in the rest of this research.
Laboratory Trial of Effect of Cushion and Swivel Seat on Spinal Movement During Rotation

In previous research, studies of the effectiveness of various types of cushions have mainly examined posture effects and pressure distribution on wheelchair patients (Brienza et al, 1996, Koo et al, 1996 and Krouskop et al, 1996). No previous studies have investigated the effects of cushions on spinal movement.

Brienza et al (1996) suggested that support surfaces designed using tissue stiffness as a criteria could provide loading conditions intended to minimize relative deformation and, thus stress in load-bearing soft tissues. Koo et al (1996) concluded that sitting posture could significantly affect pelvic orientation and ischial pressure and the Roho cushion was significantly more efficient in compensating the adverse effects of sitting posture on pressure distribution.

In our study, we found that with the use of THE C'AIRECUSH, there was an increase in the right lumbar rotation and right lumbar lateral flexion when the subject rotated to the right as far as he could. The same result was also noted when the cushion and swivel seat were used together or when only the swivel seat was used. With the increase in the availability of the range, the strain in the restraining ligamentous structures may be less. When farmers need to rotate the trunk and look at the same target behind all the time during tractor driving, the increased available range may help them turn more easily without putting excess stress on their back. In turn, this can reduce their back and neck symptoms. Wikstrom (1993) suggested that to decrease back problems resulting from a twisted posture, a swivel seat or other device should be used to reduce the twisting in the spine. Another alternative is the use of wide mirrors, although many farmers find this inconvenient. The cushion in this study increased the rotation range available, potentially decreasing some of the stresses on spinal structures. The mechanism by which the cushion and the swivel seat increase range of movement was not investigated in this study. Although the effect of the swivel seat on increasing total range of movement could be expected, by increasing the range of movement of the sacrum with relation to the source sensor, it also had the effect of increasing the range of movement between the sacrum and the lower thoracic spine, ie within the lumbar spine.
As the cushion and swivel were found to have the same effect on increasing the availability of the right rotation and right lateral flexion ranges, the cushion can be used interchangeably with the swivel seat. The cushion has the advantage in that it could be expected to also reduce the effects of vibration, by absorbing some of the vibration transmitted from the terrain or the engine. Hence, the inflatable cushion used in this study may be a useful tool in reducing the incidence of back pain in farmers.

**Field Trial of the Effect of Cushion on Back pain**

In the questionnaire, questions about the neck and back pain before starting tractor driving, hours of tractor driving, and primary activity using tractor were asked and the results were very similar between cushion days and non cushion days. These factors could thus be eliminated as the variables from the rest of the results.

When using the cushion, there was less low back and neck pain while driving the tractor. There was also reduced low back pain after the period of tractor driving. The effectiveness of the cushion in reducing back pain symptoms supported the findings in the laboratory study. The effects of the cushion in reducing neck pain were not as prominent as that on back pain. Wilstrom (1993) studied the acute effects on drivers from different twisted positions and whole body vibration. He found that discomfort was exclusively localized to the lumbar spine and the neck-shoulder region in a rotated posture. The discomfort was even greater in the neck-shoulder region than in the lower back. The results of the current study suggested that THE C’AIRECUSH may be an effective way to decrease the neck and back pain of farmers due to tractor driving.

The current study was conducted on a small sample of volunteer farmers. Thus the results cannot be generalized to the wider population and these results must be interpreted with caution. However, the field results for the use of a cushion or swivel seat are encouraging and in line with the laboratory findings. Further investigation into the effects of the C’AIRECUSH and other cushions is warranted.
Conclusion

Farmers experienced considerable neck and back pain during normal working activities. As might be expected, heavy farm work like sheep handling increased back pain, but driving a tractor was a significant factor in precipitating back pain. Driving a tractor was much more of a problem than other forms of driving. Using an inflatable air cushion (the C’AIRECUSH) significantly reduced back pain during and after tractor driving, and reduced neck pain whilst driving. Although the laboratory findings suggest a mechanism for the positive effects of the cushion noted by farmers, no conclusions can be drawn regarding the efficacy of this cushion compared to other cushions. In laboratory trials, the inflatable cushion was shown to have a similar effect to a swivel seat, changing the movement patterns to allow increased rotation.
References


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