Changes in Neck and Back Pain, Cervical Range of Motion and Cervical and Lumbar Flexion-relaxation Ratios after Below-knee Assembly Work

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Abstract: Changes in Neck and Back Pain, Cervical Range of Motion and Cervical and Lumbar Flexion-relaxation Ratios after Below-knee Assembly Work: Seung-je SHIN, et al. Department of Physical Therapy, The Graduate School, Inje University, Republic of Korea—Objectives: This study examined the changes in neck and back pain visual analog scale (VAS) scores, cervical range of motion (CROM), cervical flexion-relaxation ratio (FRR) and lumbar FRR after below-knee assembly work. Methods: Fifteen young male workers were recruited. Neck and back pain VAS scores, active CROM and cervical and lumbar FRRs were measured in all subjects once before and once after 10 minutes of below-knee assembly work. Results: The VAS scores for both neck and back pain increased significantly with below-knee assembly work. The CROM for all measures decreased significantly with below-knee assembly work. Both the cervical and lumbar FRRs on the left and right sides decreased significantly with below-knee assembly work. Conclusions: We postulate that 10 minutes of below-knee assembly work can increase neck and back pain and cause changes in the active CROM and cervical and lumbar FRRs. (J Occup Health 2014; 56: 150–156)

Key words: Below knee assembly work, Cervical flexion-relaxation ratio (FRR), Cervical range of motion (CROM), Lumbar flexion-relaxation ratio (FRR)

Most construction workers are prone to awkward, prolonged, stooped and kneeling working positions. Stooped working positions are required for tasks involving frequent and/or sustained trunk flexion. Such work is common in many industries, especially agriculture, construction and mining. Many studies have reported that these positions can be risk factors for work-related musculoskeletal disorders. Postures like stooping and kneeling, which are used when working at floor level, occur more in construction sites than in other areas. Stopped and kneeling postures in working situations have quite often been related to neck/shoulder pain and low back pain. Today, a major issue in many workplaces is upper-extremity musculoskeletal disorders such as shoulder disorders resulting from assembly work. Shoulder and neck pain are evaluated by cervical range of motion (CROM), and posture, and pain questionnaires are used to assess subjective neck pain, including the visual analogue scale (VAS). Representative causes of neck and shoulder pain include reduced range of motion and abnormal activation patterns of the cervical paraspinal muscles.

The flexion-relaxation phenomenon is used as a quantitative measure of neck and back pain. Healthy individuals display the lumbar flexion-relaxation phenomenon, and its absence is one myoelectric measure used to characterize patients who suffer from chronic low back pain. Due to its power to distinguish between individuals with and without back pain, the flexion-relaxation response is favored as a quantitative method with which to evaluate certain changes in neuromuscular function. Changes in the flexion-relaxation ratio (FRR) accounted for 38% of the improvement in self-reported disability by the Oswestry Disability Index after an exercise program for patients with low back pain. This suggests that the FRR is likely to be a significant indicator of neuromuscular impairment and its reversal with proper intervention.

The cervical FRR is much lower in patients with neck pain than in those without. It can also be a reliable indicator of altered neuromuscular control in patients with neck pain. The cervical FRR evaluates...
the effects of treatment by quantifying neck disability/damage and neck disorders\(^\text{11}\).

The FRR is calculated by dividing the maximal activation during re-extension by the activation during relaxation\(^\text{11,16}\). Use of this ratio allows normalization of the degree of activation in each individual and thus facilitates comparison between symptomatic and asymptomatic populations.

Few studies have objectively quantified the changes in neck and shoulder pain or back pain during below-knee assembly work. Therefore, this study examined the changes in neck pain, back pain, CROM, and cervical and lumbar FRRs after 10 minutes of below-knee assembly work.

**Methods**

**Subjects**

Fifteen young male workers aged 20 to 23 years with a mean height of 174.1 ± 6.0 cm and weight of 65.7 ± 9.6 kg participated in this study (Table 1). All participants gave informed written consent according to the protocol approved by the Inje University Faculty of Health Sciences Human Ethics Committee. Subjects with current back or neck pain or with past lower back pain, cervical or thoracic pain, spinal trauma or surgery were excluded from the experiment. Severe subjects have mild neck pain and back pain during activities of daily living. All subjects were right-hand dominant. The subjects were not accustomed to below-knee assembly work.

**Instrumentation**

1) The 100-mm VAS

The VAS used in this study was a 100-mm horizontal line anchored by word descriptors at each end. The subject marked the point on the line that represented their perception of their current pain. The VAS score was determined by measuring in millimeters from the left-hand end of the line to the point marked by the subject. No pain was defined as a score of 0 mm, mild pain was defined as a score of 10–30 mm, moderate pain was defined as a score of 40–70 mm, and severe pain was defined as a score of 80–100 mm\(^\text{17,18}\).

2) CROM instrument

The CROM instrument (Performance Attainment Associates, St. Paul, MN, USA) measures CROM in the coronal, sagittal and transverse planes using separate orthogonally positioned inclinometers. The sagittal and coronal inclinometers measure flexion-extension and lateral flexion, respectively, and are gravity dependent. The transverse inclinometer is a compass goniometer that requires participants to wear a magnetic yoke around the neck and measures axial rotation. CROM was measured before and after below-knee assembly work. Each participant was seated in a standard folding chair and fitted with the CROM instrument. Before the measurements, the participants were asked to self-correct their posture by demonstrating the most erect posture they could achieve. They were then asked to place the CROM goniometer on their head like a pair of glasses, and measurements of cervical flexion and extension, right and left lateral flexion and right and left rotation were recorded in a randomized order.

3) EMG

Muscle activity was measured using an MP150 system (BIOPAC Systems, Santa Barbara, CA, USA) with a pair of Ag/AgCl electrodes measuring 2 cm in diameter. The electrodes were applied over both ES muscles at the C4 level approximately 2 cm from the spinous process and at the L3–L4 level laterally 2 cm from the spinous process\(^\text{11,19}\). The reference electrode was attached to the lateral epicondyle of the humerus. The electromyography (EMG) signals were preamplified by a preamplifier placed close to the electrodes, and the signals were sent to the data acquisition unit of the MP150 system (BIOPAC Systems, Santa Barbara, CA, USA), which amplified and sampled the EMG inputs at 1,000 Hz. The EMG signals were band-pass filtered between 20 and 450 Hz, and the root mean square values were calculated. The EMG data were analyzed using a program created with AcqKnowledge (ver. 3.9.1) and are expressed as the mean percentage of the reference voluntary contraction.

**Procedures**

Neck pain and back pain VAS scores, active CROM, cervical FRR and lumbar FRR were measured in all subjects once before and once after below-knee assembly work.

Neck pain and back pain VAS scores were measured before and after below-knee assembly work. The participants marked on the line the point that represented their perception of their current pain. CROM was measured in a natural sitting posture before and after below-knee assembly work. The subjects were told to slowly lower their heads until their chin was near their upper chest. They maintained this posture until they were told to return to

<table>
<thead>
<tr>
<th>Variable</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gender</td>
<td>15 males</td>
</tr>
<tr>
<td>Age</td>
<td>21.2 (± 1.3) yr</td>
</tr>
<tr>
<td>Height</td>
<td>174.1 (± 6.0) cm</td>
</tr>
<tr>
<td>Mass</td>
<td>65.7 (± 9.6) kg</td>
</tr>
</tbody>
</table>
the neutral position. The therapist made sure that the trunk was fixed in the initial posture during the procedure. The subjects lowered their head until they felt muscle tightness or pain. The neck flexion and re-extension task comprised flexion, relaxation and re-extension periods (Fig. 1). Each movement period lasted 3 seconds. The trunk flexion and re-extension task comprised relaxed standing, forward flexion, full flexion and re-extension periods (Fig. 2). Each movement period lasted 3 seconds. The EMG signal was collected for 3 seconds. The speed and duration of all movement phases were standardized with a metronome. Sufficient practice was allowed before data collection to familiarize each subject with the movement periods and speeds. One trial was performed in each testing session. The cervical FRR was calculated by dividing the maximal muscle activation during the 3-s re-extension period by the average activation during the 3-s relaxation period. The lumbar FRR was calculated by dividing the maximal muscle activation during the 3-s re-extension period by the average activation during the 3-s full flexion period. All subjects performed below-knee assembly work (bolt and nut assembly) for 10 minutes using the same workstation. The participants were barefoot, with their feet positioned 50 cm apart. The below-knee assembly work was performed at a height of 32 cm above the floor.

**Data analysis**

The SPSS statistical package (SPSS, ver. 20.0; IBM, Armonk, NY, USA) was used to compare the VAS scores for neck and back pain, active CROM, cervical FRR and lumbar FRR recorded before with those recorded after below-knee assembly work using the paired t-test; statistical significance was defined as \( p < 0.05 \).

**Result**

The VAS scores for neck pain and those for back pain increased significantly with below-knee assembly work (both \( p < 0.05 \)) (Table 2). Additionally, all CROM values decreased significantly with below-knee assembly work (\( p < 0.05 \)) (Table 3). Furthermore, the cervical FRR on the left and right sides and the lumbar FRR on the left and right sides decreased significantly with below-knee assembly work (both \( p < 0.05 \)) (Tables 4 and 5, respectively).

**Discussion**

This study examined changes in the neck and back pain VAS scores, CROM and lumbar FRRs after below-knee assembly work. The results revealed a significant increase in pain as measured by the VAS score with below-knee assembly work. Murphy et al. reported that, in their study, the mean VAS score for the neck pain group was 37 ± 18, and that for the

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**X axis labels ->** Flexion phase, Relaxation phase, Re-extension phase.

**Y axis labels ->** Electromyography signal of the left cervical erector spinae muscle, Electromyography signal of the right cervical erector spinae muscle.

**Fig. 1.** Three phases of movement were measured: flexion, relaxation and re-extension.
Fig. 2. Three phases of movement were measured: forward flexion, full flexion and re-extension.

Table 2. The visual analog scale score of the neck pain and back pain

<table>
<thead>
<tr>
<th>VAS Score</th>
<th>Mean ± SD (mm)</th>
<th>Before below-knee assembly work</th>
<th>After below-knee assembly work</th>
<th>t-value</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Neck pain</td>
<td>15.0 ± 17.3</td>
<td>40.1 ± 16.6</td>
<td>−6.97</td>
<td>0.000</td>
<td></td>
</tr>
<tr>
<td>Back pain</td>
<td>16.5 ± 19.6</td>
<td>45.3 ± 18.4</td>
<td>−4.72</td>
<td>0.000</td>
<td></td>
</tr>
</tbody>
</table>

VAS: visual analogue scale.

Table 3. The mean values of the cervical range of motion

<table>
<thead>
<tr>
<th>Cervical range of motion</th>
<th>Mean ± SD (°)</th>
<th>Before below-knee assembly work</th>
<th>After below-knee assembly work</th>
<th>t-value</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flexion</td>
<td>69.3 ± 9.5</td>
<td>64.3 ± 10.2</td>
<td>2.33</td>
<td>0.035</td>
<td></td>
</tr>
<tr>
<td>Extension</td>
<td>82.5 ± 13.9</td>
<td>76.1 ± 11.7</td>
<td>3.03</td>
<td>0.009</td>
<td></td>
</tr>
<tr>
<td>Right lateral flexion</td>
<td>48.3 ± 7.8</td>
<td>43.5 ± 8.6</td>
<td>2.86</td>
<td>0.013</td>
<td></td>
</tr>
<tr>
<td>Left lateral flexion</td>
<td>49.9 ± 7.2</td>
<td>44.0 ± 6.7</td>
<td>9.29</td>
<td>0.000</td>
<td></td>
</tr>
<tr>
<td>Right rotation</td>
<td>72.5 ± 7.6</td>
<td>67.1 ± 7.7</td>
<td>3.46</td>
<td>0.004</td>
<td></td>
</tr>
<tr>
<td>Left rotation</td>
<td>72.1 ± 4.9</td>
<td>66.8 ± 6.9</td>
<td>3.508</td>
<td>0.003</td>
<td></td>
</tr>
</tbody>
</table>
control group was 0\(^{11}\). During their rehabilitation program, the mean VAS score for lumbar pain was
\(47.39 \pm 23.72\) at 0 weeks, \(32.11 \pm 24.78\) at 4 weeks, 
\(22.61 \pm 17.53\) at 8 weeks, \(23.94 \pm 19.71\) at 12 weeks 
and \(20 \pm 15.82\) at 3 months\(^{16}\). In that study, the VAS score decreased during rehabilitation. Our study showed that during short-term below-knee assembly work, subjects experience increases in neck and back pain. It is possible that sustained activity of the neck and back muscles causes muscle stiffness and occasionally muscle pain.

We found that all CROM values decreased significantly with below-knee assembly work. Shin \textit{et al.} reported that active CROM decreased after overhead work\(^{20}\). Shin and Yoo reported that active CROM decreased after video display terminal work\(^{21}\). CROM scores were also found to be correlated with neck pain\(^{8}\). Clinically, CROM can be reliably measured with a cervical goniometer\(^{22}\). We found that CROM decreased rapidly with even a short period of below-knee assembly work. Below-knee assembly work may increase neck and shoulder muscle tension.

The cervical FRR on the left and right sides decreased significantly with below-knee assembly work. Shin \textit{et al.} reported that the cervical FRR on the left side was \(1.3 \pm 0.2\) before and \(1.1 \pm 0.2\) after overhead work; the respective values for the right side were \(1.4 \pm 0.5\) and \(1.2 \pm 0.3\), revealing a similar decrease with overhead work\(^{20}\). Lee \textit{et al.} suggested that the cervical FRR is a quantitative way to evaluate the potential for developing neck pain with heavy backpack loads. Heavy backpack loads decrease the cervical FRR\(^{23}\). The cervical FRR of patients with neck pain was significantly lower than that of the control group\(^{11}\). The cervical FRR reflects changes in neuromuscular function. With below-knee assembly work, workers experienced increased cervical muscle tension and muscle fatigue.

The lumbar FRR on the left and right sides decreased significantly with below-knee assembly work. The flexion-relaxation phenomenon has been extensively investigated in relation to the low back musculature\(^{15, 16}\). Watson \textit{et al.} tried to develop a credible and repeatable method to identify changes in the flexion-relaxation phenomenon of the lumbar paraspinal muscles during forward flexion based on the changes in the FRR in patients with chronic low back pain and healthy controls\(^{24}\). Studies on the lumbar FRR identified changes following exercise intervention\(^{19, 25}\). Marshall and Murphy found that the FRR of patients with low back pain changed after 12 weeks of exercise intervention\(^{25}\). Ultimately, the neuromyo-
logical changes in the neck and back reduced both the cervical and the lumbar FRR. Below-knee assembly work is a risk factor for neck and back musculoskeletal injury.

One limitation of this study was the small number of subjects. Further studies must include subjects who are accustomed to below-knee assembly work, some of whom should be female.

This study is important because it measured the change in neck pain and back pain caused by below-knee assembly work in terms of a VAS score, CROM, cervical FRR and lumbar FRR. We suggest that below-knee assembly work causes neck and back pain and discomfort.

Conclusions

We postulate that 10 minutes of below-knee assembly work can increase neck pain and back pain. It can also cause changes in the active CROM and cervical and lumbar FRRs. These results suggest that below-knee assembly work is a risk factor for musculoskeletal disorders.

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References


21) Shin SJ, Yoo WG. Changes in cervical range of motion, flexion-relaxation ratio and pain with visual display terminal work. Work 2013; Epub ahead of print.


