Assessment of Ergonomic Risk and Compressive Force on Lumbar Spine for Farmers in the Complete Rice Cultivation Cycle

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Low back pain is considered the most prevalent musculoskeletal condition in the process of rice cultivation in Thailand. Each step of rice cultivation process involves different tool use and requires different work postures, force exertions and movement patterns. Therefore, different cultivation steps might lead to different levels of risk of low back injury. This study focused on job assessment of risks due to force, motion and posture in an attempt to pinpoint factors of risk conditions and identify the cultivation step posing the highest risk of low back injury. Biomechanical analysis was also conducted to quantitatively identify levels of risk of low back injury in terms of compressive force on lumbar spine. Results indicated planting task performance to pose the highest compressive load on lumbar spine, as well as induce the highest risk level of low back injury, primarily due to force and posture factors. Other tasks with high risk of back injury included harvesting and plowing. While expert analysts rated harvesting task to pose higher risk of back injury, as compared with plowing task; the biomechanical analysis showed greater load on lumbar spine during plowing performance. This was due to the biomechanical load computation was based on loading and postural conditions. Besides force and posture factors, back injury risk assessment was also considered motion repetition. Moreover, risk assessment was rated based on “worst case” scenario, which was represented by the tallest farmer who required additional trunk forward bending during harvesting task performance.

Practitioner Summary: The findings suggested a need for developing interventions and guidelines for farmers to minimize risk factors of low back injury with focus on reducing forceful exertion and awkward posture during planting process. For harvesting task, the interventions and guidelines should focus on reducing repetitive motion and posture correction, especially for tall farmers.

Keywords: Low back injury, risk assessment, biomechanical loads, rice cultivation process

1. Introduction

Low back pain is considered the most common musculoskeletal condition in the process of rice cultivation in Thailand. Previous studies found that 56-73% of Thai farmers experience low back pain (Taechasubamorn et al., 2011; Puntumetakul et al., 2011). Rice cultivation process consists of field plowing, seeding, planting, nursing and fertilization, and harvesting (Mokkamul, 2006). Each step of rice cultivation involves different tool use and requires different work postures, force exertions and movement patterns. The rice field plowing is performed with bare feet in slippery tilted walking surface and involves a use of heavy vibrating machinery. The seeding and fertilization processes involve lifting and carrying the heavy loads and prolonged walking on muddy surface filled with water. The planting task requires high repetitive trunk forward bending and laterally twisting while standing on muddy surface filled with water. The harvesting process involves prolonged stoop, trunk twisting and walking on dry and rough soil. Therefore, different cultivation steps might lead to different levels of risk of low back injury. Maras (2000) explained the mechanism of back structure injury to be due to varying types of force on lumbar spine, for example, torque, shear and compression force resulted from internal and external loads. Beyond this, the risk of lumbar spine injury was also related to frequency of force as well as work postures (Maras, 2000). Rice cultivation tasks involve carrying and lifting heavy loads,
combining with prolonged and repetitive movements of walking, stooping and trunk twisting. Such work conditions were found to be risk factors of low back injury (e.g., da Costa and Vieira, 2010; Miranda et al., 2008; Pope et al., 2002). This study focused on job assessment of risks due to force, motion and posture in an attempt to pinpoint factors of risk conditions and identify the cultivation step posing the highest risk of low back injury. Biomechanical analysis was also conducted to quantitatively identify levels of risk of low back injury in terms of compressive force on lumbar spine. The results of biomechanical computation were expected to supplement the risk assessment of cultivation activities. The cultivation step, along with associated risk factors, posing the highest risk of back injury should be emphasized in order to develop interventions and guideline to prevent low back pain and injury in rice farmers.

2. Method

Video analysis of 30 experienced farmers was used to capture farmer motions in each step of the rice cultivation process. Low back risk assessment was rated by 3 expert analysts (ergonomists and physiotherapists) using the “worst case” of major tasks in the complete cultivation cycle. The systematic job screening tool was developed based on Rapid Upper Limb Assessment (RULA; McAtamney and Corlett, 1993) to identify farmer exposure to repetitive motion, force exertion and awkward posture. The aggregate risk level across risk factors was range from 0 to 30 with score exceeding 17 points representing high risk priority.

Compressive force on lumbar spine was determined using 3D Static Strength Prediction Program (3DSSPP Version 6.0; Center of Ergonomics, University of Michigan). The force was calculated based on a static posture (captured from videos) of each farmer performing each step of cultivation process. Figures 1a-1e showed a human figure model overlaying a farmer picture for each rice cultivation stage. The hand load inputs of each stage were estimated based on the maximum weight that farmers had to carry. Specifically, for the plowing process, the 10 kilograms weight was distributed equally to both farmer hands. This weight was measured at the handles of a real plow machine by force sensors. During seeding and nursing process, the farmers typically carried a full bucket of wet seed (6 kg) and fertilizer (5 kg) in the left hand and grasped a handful of seed and fertilizer (0.15 kg and 0.1 kg, respectively) with the right hand. For planting task, farmers carried a full bundle of rice sprouts (3 kg) in the left hand and approximately one tenth of bundle weight (0.3 kg) on the right hand. For the last stage of cultivation, farmers held a sickle (0.5 kg) with the right hand to harvest the ripe rice and carried the harvested rice with the left hand (until approximately a full 3-kg bundle) before put them down on the field.
3. Results

Descriptive statistics were used to identify average risk ratings of low back injury for each cultivation step (Table 1). The aggregate rating score across risk factors indicated rice cultivation steps, including planting (24.8 points), harvesting (21.3 points), and plowing (18.8 points), to pose high risk of low back injury.

Table 1. Low back risk assessment scores and priority levels of major tasks in rice cultivation process.

<table>
<thead>
<tr>
<th>Rice farming process</th>
<th>Motion rating (level)</th>
<th>Force rating (level)</th>
<th>Posture rating (level)</th>
<th>Total rating</th>
<th>Priority level</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plowing</td>
<td>4.0 (M)</td>
<td>7.3 (H)</td>
<td>7.5 (H)</td>
<td>18.8</td>
<td>H</td>
</tr>
<tr>
<td>Seeding</td>
<td>3.5 (M)</td>
<td>4.8 (M)</td>
<td>4.0 (M)</td>
<td>12.3</td>
<td>M</td>
</tr>
<tr>
<td>Planting</td>
<td>6.0 (M)</td>
<td>8.8 (H)</td>
<td>10.0 (H)</td>
<td>24.8</td>
<td>H</td>
</tr>
<tr>
<td>Nursing</td>
<td>1.5 (L)</td>
<td>3.0 (L)</td>
<td>2.5 (L)</td>
<td>7.0</td>
<td>L</td>
</tr>
<tr>
<td>Harvesting</td>
<td>7.0 (H)</td>
<td>6.5 (H)</td>
<td>7.8 (H)</td>
<td>21.3</td>
<td>H</td>
</tr>
</tbody>
</table>

Note: L = low priority level; M = moderate priority level; H = high priority level.

Repeated measures ANOVA was conducted to compare compressive loads on farmer lumbar spine among cultivation steps. The significant different compressive force was found due to varying cultivation steps ($F=53.1, p<0.0001$). Post-hoc results revealed planting task posing the highest force on farmer lumbar spine.
spine. However, the results indicated loads on lumbar spine during plowing step to be significant higher than loads resulted from harvesting task.

Figure 2. Post-hoc results of the compressive force on farmer lumbar spine for each cultivation step (means with different letter labels are significantly different with p<0.05).

4. Discussion

Results of this study indicated planting task performance to pose the highest compressive load on lumbar spine, as well as induce the highest risk level of low back injury, primarily due to force and postural factors. The findings suggested a need for developing interventions and guidelines for farmers to minimize risk factors of low back injury with focus on reducing forceful exertion and awkward posture during planting process.

Other tasks with high risk of back injury included harvesting and plowing. While expert analysts rated harvesting task to pose higher risk of back injury, as compared with plowing task; the biomechanical analysis showed greater load on lumbar spine during plowing performance. This was due to the biomechanical load computation was based on static postures. Therefore the calculation only considered lumbar disk stress due to loading and postural conditions. Since harvesting task required high frequency of trunk movement, motion repetition of harvesting step was considered to be high risk. However, during field plowing step, rice farmer’s back and torso moved in relatively steady motion with infrequent pauses. Such movement was rated as moderate risk of back injury. Another explanation is that back injury risk assessment was rated based on “worst case” scenario. In harvesting task, such case was represented by the tallest farmer who required additional trunk forward bending to reach down to below-waist-height rice crops. Figure 3 showed examples of trunk posture differences performed by smaller and taller farmers during harvesting process. Therefore, the postural factor resulted from analyst ratings was more critical than mixed postures of tall and small farmer groups used in lumbar disk force calculation. The intervention and guideline for harvesting task should focus on reducing repetitive motion and posture correction, especially for tall farmers.
5. Conclusion

Results of this study indicated rice cultivation tasks including, planting, harvesting and plowing, to be at risk of low back injury. The level of risk can be quantitatively identified in terms of compressive force on lumbar spine. Individual characteristics, for example height and weight, were critical factors to specify force and postures when the work conditions cannot be altered. Besides force and posture factors considered in biomechanical computation, motion repetition was also an important factor for risk assessment. The findings in this study suggested a need for developing interventions and guidelines for rice farmers with focus on reducing forceful exertion and awkward posture during planting process in order to minimize risk factors of low back injury. For harvesting task, the interventions and guidelines should focus on reducing repetitive motion and posture correction, especially for tall farmers.

This present study assessed low back injury risk based on working postures, force exertion and motion required for rice cultivation task performance. In addition to these factors, rice cultivation activities in Thailand are typically performed with bare feet on muddy terrain. Such environment condition would increase force acting on back and lower extremity joints due to mud viscous force (Schramm, 2006). Our future study will include examination of effects of muddy work terrain on body joint loading during cultivation tasks in order to use as a supplementary guideline for design of the intervention for real work environment usage.

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