Biomechanical Posture Assessment of Salted Fish Industry Workers in West Aceh

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Abstract. Salted fish is dried fish that is preserved by adding salt as the preservative medium. The process of production starts with cleaning, salting, boiling, drying, sorting, and packing. The length and complexity of the process lead to an increase in the risk of MSDs and posture complaints among the workers. This study aimed to find out the factors that caused the complaints with the biomechanical posture method. Six subjects were measured for the tension at erector spinae and the moment at (lumbar 5 sacrum 1) L5-S1 vertebral joint created by body segments and load, the calculation of the workers’ body segment weight, the distance of the body’s center point to the lumbar 5 sacrum 1 (L5-S1), and biomechanics at L5-S1. The largest body segment weight was found at the cleaning station, which dealt with the process of manually lifting the fish, with a bodyweight value of 70 kg, W_trunk: 350 N, W_head: 58.8 N, W_arm: 35.7 N and W_load: 300 N. The farthest distance from the body’s center point to L5-S1 was found at the drying station, which deals with the process of drying the fish, with values of the distance of head (d_head): 54.78 cm, distance of trunk (d_trunk): 59.26 cm, distance of arm (d_arm): 67.39 cm and distance of box (d_box): 86.11 cm. The largest moment in force on L5-S1 was found at the packing station, which deals with the fish transferring and packaging process, with the value of the moment of force at 5351.86 N and 4215.28 N. Therefore, it is suggested that the salt fish industry finds solutions, redesigning the work station, decreasing the lifting load, and producing proper equipment to assist workers during labor to improve their safety and health.

1. Introduction
Salted fish is one of the commodities in Aceh province, Indonesia, with high production in the district of West Aceh, an area on the coastline. Most of the residents in the area work as fishermen. Big catches cause the fishermen to find solutions so that the excessive fish do not rot. Hence, the alternative is to make salted fish.

Salted fish is dried fish preserved by adding salt as the preservative medium. It is processed from marine fish, which is then preserved traditionally. The traditional method of preservation aims to reduce the water content in the body of the fish, so as not to provide an opportunity for bacteria to grow. Besides, salted fish has been found to contain a rich source of proteins, approximately 80-85% of protein, which would be a good solution for consumers [1].

The work process carried out at the place of business of making salted fish, starting from cleaning, salting, boiling, drying, sorting, and packing of the fish. This can increase the risk of
musculoskeletal complaints. The boiling work process is the most exhausting work among the routines of making salted fish. This is due to the static standing posture in the boiling work, the work facilities that are not in accordance with anthropometry, direct contact with the stove and the hot steam, and the strong, pungent smell of the fish.

According to Tarwaka and Sudiajeng [2], subjective complaints of skeletal muscle disorders with static standing posture are commonly reported at 54.2% in the lower neck, 33.3% in the right shoulder, 50% in the back, 45.8% in the right and left thighs, 58.3% in the right and left knees, and 33.3% in the right and left calves. Meanwhile, subjective complaints of skeletal muscle disorders with dynamic standing posture are commonly reported at 37.5% in the lower neck, 62.5% in the right shoulder, 50% in the back, 87.5% in the waist, 41.7% in the right and left thighs, 16.7% in the right and left knees, and 54.2% in the right and left calves. These skeletal muscle disorders affect the capacity of workers to carry out their work.

In 1994, 705,800 cases (32%) of all cases in the United States which occurred due to overexertion or repetitive motions, including 367,424 cases of back pain, were caused by overexertion in lifting and 65% of the cases affected the back of workers. From 93,325 cases which were due to overexertion in pushing or pulling objects, about 52% of them affected the back. As is usually the case in the industry, the position and procedures of work are often not well designed so that the operational performance is not optimal. Besides, the ineffective working conditions accelerate fatigue and cause many complaints, pain, and injury to the limbs in the short and the long term to the workers [3][4]. A similar case is experienced by workers in the salted fish industry. Improper work positions can cause interference with the body parts of the workers. This is very likely to cause injury if done inappropriately.

2. Methodology

At this stage, it is necessary to know what factors cause a problem, which is necessary for the research so that the right solution can be offered to solve the problem. The problems found in this industry were: mapping of salted fish craftsmen, MSDs and posture factors, and identification of complaints from the workers using the Nordic Body Map questionnaire. Data were collected for a month at UKM (Usaha Kecil dan Menengah or Small Medium Industry) Stefen Aluy, Meulaboh, West Aceh, from six subjects (i.e. workers) who worked eight hours a day in a week. They were done through interviews and surveys. The interviews were conducted directly during their work, using a video camera. Calculations were also conducted on the workers' body segment weight, the distance of the body’s center point to the lumbar 5 sacrum 1 (L5-S1), which is the distance of head (d_head), the distance of the trunk (d_trunk), the distance of the arm (d_arm) and distance of the box (d_box), and the torque and moment of the arm at L5-S1 in the static position. Figure 1 shows the erector spinae with a moment of the arm of 6 cm from the L5-S1 joint center [5]. The moments of force on the activities experienced extreme muscle stress on the L5-S1 and are classified as dangerous based on NIOSH’s standard of 3400 N for maximum load lifting [6].

\[
\sum T_{L5-S1} = 0
\]

\[
0 = (F_m) \times (6cm) - \left[ (W_{head}) \times (d_{head}) + (W_{trunk}) \times (d_{trunk}) + (W_{arms}) \times (d_{arms}) + (W_{box}) \times (d_{box}) \right]
\]
3. Results and discussion
Based on surveys conducted with workers, using the Nordic Body Map questionnaire [7] the initial data was obtained in the form of a questionnaire distributed to six workers. Table 1 shows the description of workers’ complaint percentages obtained through the questionnaire. Approximately 45.24%, or about half, of the informants, felt “painful” during work. They informed that the most pain was felt in the neck, waist, back pain, and others (see Table 2).

| No. | Type of complaint | Level of complaint |
|-----|-------------------|--------------------|
|     | Parameter of Complaint | Percentage |
| 1   | Not painful               | 21.43              |
| 2   | Slightly painful         | 33.33              |
| 3   | Painful                  | 45.24              |

From Table 2, for instance, four out of six workers stated “painful” in the neck and waist while working, while two workers stated “very painful”. This indicates that the work carried out by the worker was forceful and required improvement of the work system to minimize the risk of injury to the body, especially in the neck and waist.

| No. | Type of complaint       | Not painful  | Slightly painful | Painful  | Very painful |
|-----|-------------------------|--------------|------------------|----------|--------------|
| 1   | Upper neck pain/stiffness| 16.7         | 50.0             | 33.3     | -            |
| 2   | Lower neck pain/stiffness| -           | 50.0             | 50.0     | -            |
| 3   | Left shoulder pain      | 33.3         | -                | 66.7     | -            |
| 4   | Right shoulder pain     | -            | 33.3             | 66.7     | -            |
| 5   | Left upper arm pain     | 16.7         | 50.0             | 33.3     | -            |
| No. | Body Part                  | Left % | Right % | Total % |
|-----|---------------------------|--------|---------|---------|
| 6   | Back pain                 | -      | 50,0    | 50,0    |
| 7   | Right upper arm pain      | 33,3   | -       | 66,7    |
| 8   | Waist pain                | 33,3   | -       | 66,7    |
| 9   | Buttock pain              | -      | 33,3    | 66,7    |
| 10  | Hip pain                  | 16,7   | 50,0    | 33,3    |
| 11  | Left elbow pain           | 16,7   | 50,0    | 33,3    |
| 12  | Right elbow pain          | -      | 50,0    | 50,0    |
| 13  | Left lower arm pain       | 33,3   | -       | 66,7    |
| 14  | Right lower arm pain      | -      | 33,3    | 66,7    |
| 15  | Left wrist pain           | 16,7   | 50,0    | 33,3    |
| 16  | Right wrist pain          | 16,7   | 50,0    | 33,3    |
| 17  | Left hand pain            | -      | 50,0    | 50,0    |
| 18  | Right hand pain           | 83,3   | 16,7    | -       |
| 19  | Left thigh pain           | 83,3   | 16,7    | -       |
| 20  | Right thigh pain          | 83,3   | 16,7    | -       |
| 21  | Left knee pain            | 16,7   | 50,0    | 33,3    |
| 22  | Right knee pain           | 16,7   | 50,0    | 33,3    |
| 23  | Left calf pain            | -      | 50,0    | 50,0    |
| 24  | Right calf pain           | 33,3   | -       | 66,7    |
| 25  | Left ankle pain           | -      | 33,3    | 66,7    |
| 26  | Right ankle pain          | 16,7   | 50,0    | 33,3    |
| 27  | Left foot pain            | -      | 50,0    | 50,0    |
| 28  | Right foot pain           | 33,3   | -       | 66,7    |

Meanwhile, Figure 2 shows that the most felt pain by the workers was “painful”. This indicates that the workers’ working condition was not safe and could result in danger to their health. In some cases, when this situation occurred, the industry could fabricate equipment to assist and ease the pain of workers while working [8].

![Figure 2](image1.jpg)  
**Figure 2.** The process of moving fish with a moment force of 5351.80 N.

![Figure 3](image2.jpg)  
**Figure 3.** The fish packaging process with a moment force of 4215.28 N.

Calculating the distance of the body’s center point to the lumbar 5 sacra 1 (L5-S1), and biomechanics at L5-S1. Before the analyses, the data must be normal, uniform, and sufficient. Therefore, it is necessary to conduct a data normality test, data uniformity test, and data adequacy test.
3.1. Body segment weight

Body Segment Weight (BSW) for each worker in this study is shown in Tables 3-7. Meanwhile, the BSW for workers in the salted fish industry was calculated using the equation below [9].

| Table 3. Sorting workstation. |
|-------------------------------|
| No  | Subject | Work Posture | Body Weight (Kg) | W Trunk (N) | W Head (N) | W Arm (N) | W Load (N) |
|-----|---------|--------------|------------------|-------------|------------|-----------|------------|
| 1   | Subject 1 | Sorting | 55 | 269.77 | 46.2 | 28.05 | 5 |
| 2   | Subject 1 | Lifting the Box | 55 | 275 | 46.2 | 28.05 | 250 |

| Table 4. Cleaning workstation |
|-------------------------------|
| No  | Subject | Work Posture | Body Weight (Kg) | W Trunk (N) | W Head (N) | W Arm (N) | W Load (N) |
|-----|---------|--------------|------------------|-------------|------------|-----------|------------|
| 1   | Subject 2 | Lifting the box | 45 | 225 | 37.80 | 22.95 | 250 |
| 2   | Subject 2 | Cleaning | 45 | 225 | 37.80 | 22.95 | 5 |

| Table 5. Boiling workstation |
|-------------------------------|
| No  | Subject | Work Posture | Body Weight (Kg) | W Trunk (N) | W Head (N) | W Arm (N) | W Load (N) |
|-----|---------|--------------|------------------|-------------|------------|-----------|------------|
| 1   | Subject 6 | Lifting the box fish | 66 | 330 | 55.44 | 33.66 | 125 |
| 2   | Subject 3 | Boiling | 70 | 350 | 58.8 | 35.7 | 5 |

| Table 6. Drying workstation |
|-------------------------------|
| No  | Subject | Work Posture | Body Weight (Kg) | W Trunk (N) | W Head (N) | W Arm (N) | W Load (N) |
|-----|---------|--------------|------------------|-------------|------------|-----------|------------|
| 1   | Subject 4 | Lifting the Box | 45 | 225 | 37.8 | 22.95 | 125 |
| 2   | Subject 5 | Sorting fish | 56 | 280 | 47.04 | 28.56 | 5 |

| Table 7. Packing workstation |
|-------------------------------|
| No  | Subject | Work Posture | Body Weight (Kg) | W Trunk (N) | W Head (N) | W Arm (N) | W Load (N) |
|-----|---------|--------------|------------------|-------------|------------|-----------|------------|
| 1   | Subject 3 | Lifting the Box | 70 | 350 | 58.8 | 35.7 | 300 |
| 2   | Subject 6 | Packing | 66 | 330 | 55.44 | 33.66 | 5 |

3.2. Calculation of distance from body segment weight to L5-S1

The distance from body segment weight to L5-S1 for workers in the salted fish industry was performed using the following calculation using the still picture to measure the distance in pixel and convert the distance to cm.

3.2.1. Subject 1 (Sorting workstation in Figure 4)
Calculation of $dt$ (distance from L5-S1 to trunk segment weight)

$$dt = (3085 - 2873) \times 0.059$$

$$= 212 \times 0.059$$

$$= 12.51cm$$

Calculation of $dh$ (distance from L5-S1 to head segment weight)

$$dh = (3085 - 1178) \times 0.059$$

$$= 324 \times 0.059$$

$$= 19.12cm$$

Calculation of $da$ (distance from L5-S1 to arm segment weight)

$$da = (3085 - 2851) \times 0.059$$

$$= 234 \times 0.059$$

$$= 13.81cm$$

Calculation of $db$ (distance from L5-S1 to load segment weight)

$$db = (3085 - 2585) \times 0.059$$

$$= 500 \times 0.059$$

$$= 29.5cm$$

Figure 4 shows the results of the calculation of the distance from body segment weight to L5-S1 from Subject 1 at the sorting work station. The details of the calculation of the distance from body segment weight to L5-S1 for workers at each work station are shown in Table 8.
Table 8. Recapitulation of calculation of the distance from body segment weight to L5-S1.

| No. | Work station | Subject | Work Posture | Distance from body segment weight to L5-S1 (cm) |
|-----|--------------|---------|--------------|-----------------------------------------------|
|     |              |         |              | $D_{\text{head}}$ | $D_{\text{trunk}}$ | $D_{\text{arms}}$ | $D_{\text{box}}$ |
| 1   | Sorting      | 1       | 1            | 36,24          | 31,27           | 31,16           | 35,91           |
|     |              | 1       | 2            | 19,12          | 12,51           | 13,81           | 29,50           |
|     |              | 2       | 1            | 27,55          | 18,96           | 22,81           | 33,77           |
|     |              | 2       | 2            | 37,29          | 24,82           | 27,79           | 54,17           |
| 2   | Cleaning     | 1       | 1            | 7,79           | 11,51           | 14,87           | 27,08           |
|     |              | 2       | 2            | 37,09          | 25,48           | 32,55           | 48,56           |
| 3   | Boiling      | 1       | 1            | 8,60           | 14,23           | 24,02           | 40,62           |
|     |              | 2       | 2            | 31,94          | 35,85           | 48,26           | 64,34           |
| 4   | Drying       | 1       | 1            | 46,82          | 42,97           | 39,98           | 42,97           |
|     |              | 2       | 2            | 54,78          | 59,26           | 67,39           | 86,11           |

3.3. Calculation of moment force on L5-S1

The moment of force calculation on L5-S1 was done to find out the muscle stress level that occurred at L5-S1 during salted fish processing work. Calculation using formula No.2 of moment of force for Subject 1 at the sorting work station is as follows.

$$
\sum T_{L5, S1} = 0
$$

$$(F_m \times E) - \sum (W \times d) = 0$$

$$(F_m \times 6) - [(275 \times 12.51) + (46.2 \times 19.12) + (28.05 \times 13.81) + (5 \times 29.5)] = 0$$

$$F_m = \frac{4858.46}{6} = 809.74$$

The details of the calculation of moment of force in workers in the salted fish industry at each work station can be seen in Tables 9-13.

Table 9. Moment of force at sorting workstation

| No. | Subject   | Work Posture | Bodyweight (kg) | Moment of force (N) |
|-----|-----------|--------------|-----------------|---------------------|
| 1   | Subject 1 | Sorting      | 55              | 809.74              |
| 2   | Subject 1 | Lifting the Box | 55            | 3354.18              |

Table 10. Moment of force at cleaning workstation

| No. | Subject   | Work Posture | Bodyweight (kg) | Moment of force (N) |
|-----|-----------|--------------|-----------------|---------------------|
| 1   | Subject 2 | Lifting the box | 45         | 2378.90              |
| 2   | Subject 2 | Cleaning     | 45              | 1317.12              |
### Table 11. Moment of force at boiling workstation

| No. | Subject | Work Posture     | Bodyweight (kg) | Moment of force (N) |
|-----|---------|------------------|-----------------|---------------------|
| 1   | Subject 6 | Lifting the box fish | 66              | 813.80             |
| 2   | Subject 3 | Boiling          | 70              | 2052.41            |

### Table 12. Moment of force at drying workstation

| No. | Subject | Work Posture | Bodyweight (kg) | Moment of force (N) |
|-----|---------|--------------|-----------------|---------------------|
| 1   | Subject 4 | Lifting the Box | 45              | 1525.93            |
| 2   | Subject 5 | Sorting fish  | 56              | 2206.74            |

### Table 13. Moment of force at packing workstation

| No. | Subject | Work Posture | Bodyweight (kg) | Moment of force (N) |
|-----|---------|--------------|-----------------|---------------------|
| 1   | Subject 3 | Lifting the Box | 70              | 5351.80            |
| 2   | Subject 6 | Packing      | 66              | 4215.28            |

### 4. Conclusion

Based on the calculation of the moment of force at each work station, excessive moments of force were found at the packing station, namely on the fish transferring and the packaging process, with the value of 5351.86 N and 4215.28 N respectively. The moments of force in the activities experienced extreme muscle stress in L5-S1 and are classified as dangerous based on NIOSH’s standard of 3400 N for maximum weight lifting. Therefore, it is suggested that the salt fish industry finds solutions such as work station be re-designed and the lifting load be decreased, and producing equipment to assist workers during labor and hence improve their safety and health.

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