Industrial Ergonomics and Workstation Design: Two Case Studies

Arijit Sengupta, Associate Professor
Department of Engineering Technology
New Jersey Inst. Of Technology
Sengupta@njit.edu

Case Study # 1
Assessing lower back pain risk in a beef de-skinning workstation

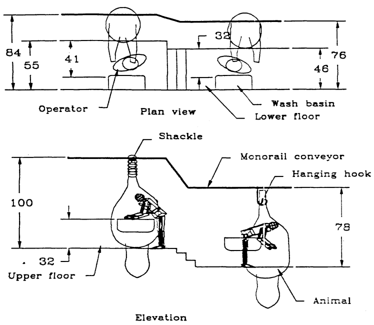
Background

- In a meat processing plant, a worker experienced a disabling lower back pain (LBP) while performing his regular work. Subsequently, his illness was confirmed by a physician's diagnosis. However, the worker was denied worker compensation because management believed that the LBP was not job related.
- The worker and his union claimed that a recent modification of the workstation caused the back injury. We were retained by the workers' union to examine the task and workstation, and to provide expert opinion in an arbitration trial against the management.

Overview of the beef de-skinning operation

- In the beef de-skinning line, an overhead monorail conveyor carried dead steers through a series of workstations. In each workstation, a specific set of de-skinning tasks were performed in a sequential manner.
- The average processing rate was 500 steers per 8 hour shift. The average cycle time in each station was about 60 seconds.
- A specific portion of a steer was skinned at each workstation, and the tasks performed were repetitive in each cycle.

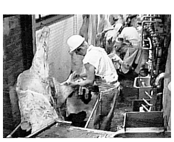
Sketch of the workstation

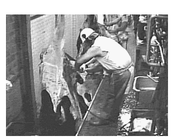


Relevant task features of the workstation under review

- The tasks in the workstation **did not** require use of large physical force.
- The tasks involved skinning the thigh of the animal with a straight knife in normal standing position and then bent over to skin the middle and lower portion with a pneumatic circular knife (weighing about 1.5 Kg, including rubber hose).
- The most demanding task perceived by the workers was skinning the lower portion of the animal where they had to bend beyond waist level for the skinning operation.

Typical work postures at the workstation under review





Assessment approach

- The objective of this investigation was to assess whether or not the tasks involved in the beef skinning operation would pose a significant risk related to back pain or injury.
- To establish the risk (preferably on a quantitative basis) we needed to:
  - Identify the established guidelines form existing literature regarding the limits of work related stresses.
  - And, measure the specific work related stresses and compare them with these limits.

The two factors seemed to be most relevant were

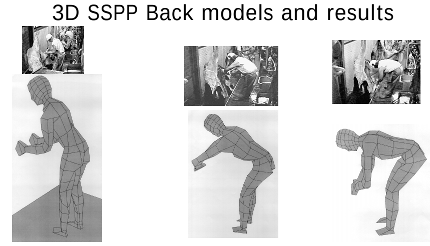
(1) biomechanical stress on the lower back and

(2) postural effects of bent torso.

Evolution of Biomechanical Models of Lower Back

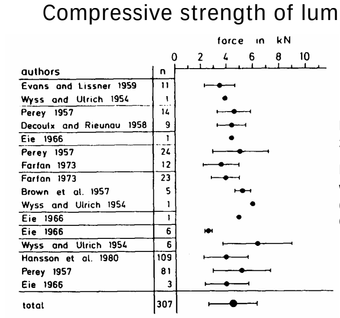
- Static 2D models for symmetric loading: Requires information about mass and CG locations of the body segments, and position of the line of action of the erector spinae muscle w.r.t. the axis of lower spine – considers a single pair of back muscles support the torso.
- Static 3D models for asymmetric loading: Requires all of the above and considers multiple back muscles that support the torso. It is a statically indeterminate problem solved by mathematical optimiza tion.
- Dynamic models can take into account inertial loading: Requires all of the above plus mass moment of inertia, radius of gyration, and acceleration/deceleration of each body segment throughout the movement.
- EMG assisted models can handle asymmetric loading: More accurate but difficult to apply in shop floor environment. Strength of the EMG signals from different back muscles are used to determine the load sharing by different back muscles during asymmetric loading.

3D SSPP Back models and results



	Comp. Force (N)	%Increase
Normal slump posture	1574	
Bent posture	2164	37%
Extreme bent posture	2253	43%

Compressive strength of lumber vertebrae



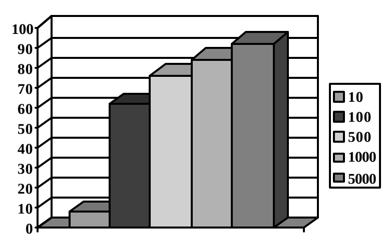
From Jager and Luttman 1989

μ = 4.36KN
σ = 1.88 KN

NOISH Action limit = 3400 N or 770 lbs

Max. compressive force was 2253 N which was 66% of NIOSH Back Compression Design Limit

Fatigue fracture probabilities of human lumber vertebrae at a cyclic load level 60-70% of the static limit (Brinckmann et al. 1987).



(2) Posture analysis of bent torso

- The total cycle was broken down into 3 logical task elements: slitting skin, skinning left hind leg, and skinning thigh and belly.
- Torso posture was classified into 6 groups: (1) straight back ($\alpha<25^0$), (2) mild flexion ($25^0<\alpha<45^0$), (3) severe flexion ($45^0<\alpha<70^0$), (4) very severe flexion ($\alpha>70^0$), (5) twist ($\beta>25^0$), and (6) flexion and twist ($\alpha,\beta>25^0$).
- Two workers were analyzed based on video recording. The VCR was paused every second and the posture was recorded.

Posture analysis of bent torso

Cycle: 1 :VCR Counter -07:50 to -06:57

	Work element	Straight a<25	Bent 25>a>45	45>a>70	a>70	Total bent a>25	Bent a>45	Twist	Twist & bent	Element time (sec)
1	Slitting buttock	15				0	0	2		17
2	Skinning left hind leg	3	8	1		9	1	1	2	15
3	*Skinning thigh & belly*	*2*	*1*	*6*	*10*	*17*	*16*	*2*	*1*	*22*
		20	9	7	10	26	17	5	3	54

Cycle: 2 : VCR Counter -06:56 to -06:06

	Work element	Straight a<25	Bent 25>a>45	45>a>70	a>70	Total bent a>25	Bent a>45	Twist	Twist & bent	Element time (sec)
1	Slitting buttock	12				0	0	1	2	15
2	Skinning left hind leg	4	4	4		8	4	1	3	16
3	Skinning thigh & belly		1	4	13	18	17	2		20
		16	5	8	13	26	21	4	5	51

Posture analysis results

Average time spent in different postures

	Work elements		***Straight back*** $a<25^o$	***Flexed*** $a<45^o$	***Severe flexed*** $a<70^0$	***Very severe flexed*** $a>70^0$	***Twisted*** $b>25^o$	***Bent & twisted*** $a,b>25^0$	***time seconds***
1	Slitting skin	Second	12.0	1.1	-	-	1.0	1.2	15.3
		% time	78.3%	7.2%	-	-	6.5%	8.0%	100%
2	Skinning left leg	Second	4.6	5.0	2.6	1.1	1.4	2.6	17.2
		% time	26.5%	29.0%	14.9%	6.4%	8.4%	14.8%	100%
3	Skinning thigh and belley	Second	1.0	1.7	3.3	10.4	1.4	1.7	19.6
		% time	5.1%	8.5%	17.0%	53.4%	7.4%	8.5%	100%
Average time per cycle			17.6	7.8	5.9	11.6	3.9	5.4	52.1
Percent time in a shift			33.7%	14.9%	11.3%	22.2%	7.4%	10.4%	100%

OWAS: Postural Stress Analysis

- OWAS (Ovaco Working posture Analysis System) is one of the most widely used postural stress analysis system.

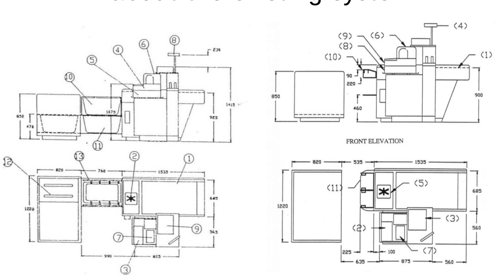
Back posture	OWAS action Classification 1 Normal	2 Strain	3 Clear strain	4 Hard strain	Observed values
Bent	<30%	30-80%	>80%	-	48.4%
Twisted	<20%	20-50%	>50%	-	7.4%
Bent and twisted	<5%	5-30%	30-70%	>70%	10.4%

Conclusions

- Spine compressive stress of 2253 N with repetition of over 5000 in two weeks constituted high risk of structural failure (90% probability).
- Bent trunk posture was 48% of the cycle time which exceeded the acceptable limit of 30%.
- Twisted back posture was 7.5% of the cycle time which was within the acceptable limit which is 25%
- Twisted posture with back bent was 10.4% which also exceeded the acceptable limit of 5%.
- Actions were needed in near future to alleviate the situation through redesign of the workstation, work method and tools.

Case Study # 2 Redesigning a Supermarket Check-stand Workstation: A Systematic Ergonomic Approach

1. Obtain relevant information about about the existing system.



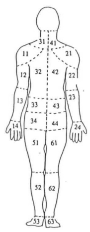
2. Questionnaire Survey to document worker perception about job difficulty

- Cashiers, all female, n = 24, subjective rating in a scale of 1 to 7
- Environmental factors – noise, temperature, lighting and workspace
- General fatigue – physical, mental and visual.
- Physical demand of the tasks – scanning and bagging, bin handling, keyboard and cash box operations, and posture.
- Postural discomfort during the course of a regular work day.

Postural Discomfort Chart

LEFT

#	Body Region	No Discomfort → Extreme Discomfort
11	Shoulder	0 1 2 3 4 5 6 7
12	Arm	0 1 2 3 4 5 6 7
13	Elbow & forearm	0 1 2 3 4 5 6 7
14	Wrist & hand	0 1 2 3 4 5 6 7
31	Neck	0 1 2 3 4 5 6 7
32	Back	0 1 2 3 4 5 6 7
33	Lower back	0 1 2 3 4 5 6 7
34	Buttocks	0 1 2 3 4 5 6 7
51	Hip & thigh	0 1 2 3 4 5 6 7
52	Knee & leg	0 1 2 3 4 5 6 7
53	Ankle & foot	0 1 2 3 4 5 6 7



RIGHT

#	Body Region	No Discomfort → Extreme Discomfort
21	Shoulder	0 1 2 3 4 5 6 7
22	Arm	0 1 2 3 4 5 6 7
23	Forearm & elbow	0 1 2 3 4 5 6 7
24	Wrist & hand	0 1 2 3 4 5 6 7
41	Neck	0 1 2 3 4 5 6 7
42	Back	0 1 2 3 4 5 6 7
43	Lower back	0 1 2 3 4 5 6 7
44	Buttocks	0 1 2 3 4 5 6 7
61	Hip & thigh	0 1 2 3 4 5 6 7
62	Knee & leg	0 1 2 3 4 5 6 7
63	Ankle & foot	0 1 2 3 4 5 6 7

The results of the survey

- One store rated temperature was unacceptable
- The bin handling task and prolonged standing posture perceived to be most strenuous.
- The mean postural discomfort rating was found to be increasing as work shift time elapsed.
- Significantly high postural ratings were found in the lower back, back, neck, ankle and foot, knee and leg regions.
- The mean discomfort level was highest in the lower back (2.4) and next highest in neck (1.5).

Main shortcomings

- Work height too high for average female operators
- Excessive reach requirements on the conveyor belt
- Bent over or stooped posture
- Continuous turning and twisting to reach keyboard
- Excessive reach requirement to weigh scale
- Frequent turning to read display terminal

Major problems were reach, work height, frequent turning, tote box lifting and placement of price display.

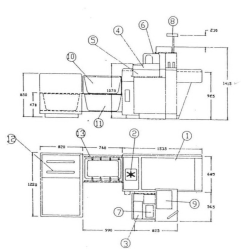


Table 2 Standing work surface height for female operators in cm

Type of work	Population percentile 5th	50th	95th
Delicate work with close visual requirement	99–104	110–115	116–121
Manual work	84–89	90–95	96–101
Forceful work aided by upper body weight	59–84	65–90	71–96

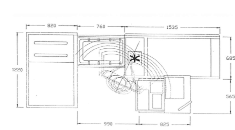
Table 3 Anthropometric measures for females and maximum reach in cm

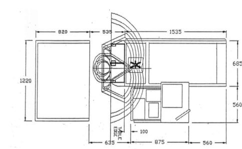
Population percentile	Arm length (K)	Shoulder height (F)	Elbow height (L)	Maximum reach (R)
5th	60	128	99	53
50th	66	138	105	58
95th	72	147	111	63

Engineering anthropometry and dimensional matching

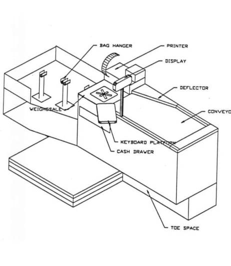
- Work surface height was lowered from existing 92.5 cm (+ 15 cm average product height) to 85 cm for 5th percentile female.
- Normal and maximum reach areas for female operators were used to optimally locate the frequently used components of the workstation in forward facing manner.
- Lateral clearances for 95th percentile female was used for placement of keyboard
- Eye height and comfortable angle of vision was used to locate the product price display.

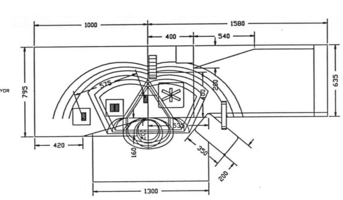
5th, 50th and 95th percentile reach envelopes superimposed on the work surface





Final Design Recommendation





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- Das, B. and Sengupta, A. K. 1996, Industrial workstation design: A systematic ergonomics approach, *Applied Ergonomics, Vol 27, No. 3, 157-163*