OSC|12
Ohio Safety Congress & Expo

WELL AT HOME. SAFE AT WORK.

251 New Methods for Reducing Injury Risk

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Ohio | Bureau of Workers' Compensation

Session Overview

- Introduce the rotate carrier technology
- Demonstrate how physical exposure was quantified during assembly processes
- Illustrate which rotation angles had the least physical demand on the workers

Traditional Horizontal, New Rotating Auto Body Carrier

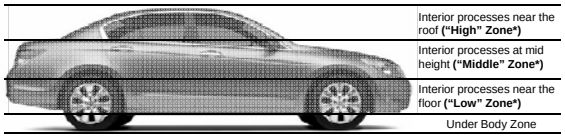
Center for Occupational Health in Automotive Manufacturing (COHAM)

Background

- Musculoskeletal disorders (MSDs) continue to be a common and costly problem industry
- One potential intervention may be the rotate carrier however with all the infinite rotation angles one may question how to adjust the rotate carrier in order to prevent MSDs.
- Honda of America sponsored a project to quantify how much physical demand on the workers changed as a function of rotation angle
  - Back, shoulder, neck, wrist

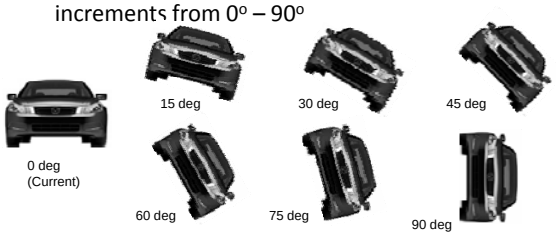
Objective

- Gain an understanding of how vehicle rotation will impact the physical demands on the worker
- One assembly task was evaluated in each region
- Vehicle was divided into vertical region



Initial Rotate Carrier Evaluation

- The rotate carrier has infinite adjustability form - 90º to +90º
- Pilot study evaluated 7 angles in 15 degree increments from 0º – 90º

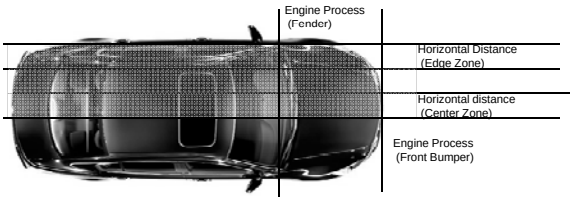


Initial Rotate Carrier Results

- The initial study results determined feasible angles for our full evaluation
  - 3 Interior regions were examined
    - no more than 60 degrees rotation
  - 1 Underbody – region 45 and 90 degrees rotation
- More regions

Additional Regions

- Horizontal work regions and engine room zone
  - Center and edge for underbody and interior



* Regions areas are dictated by vehicle type

Vehicle Body Regions

Interior Processes

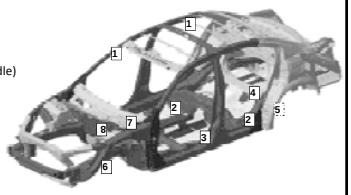
1. Side Curtain Air Bag (SCAB)
   - High, edge
2. SRS
   - Low, center
   - Middle, edge
3. Seat Belt (Low, edge)
4. Rear Seat Gusset (middle, middle)

Under Body Processes

5. Fuel Canister (center)
6. Front Inner Cowl (edge)

Engine Room Processes

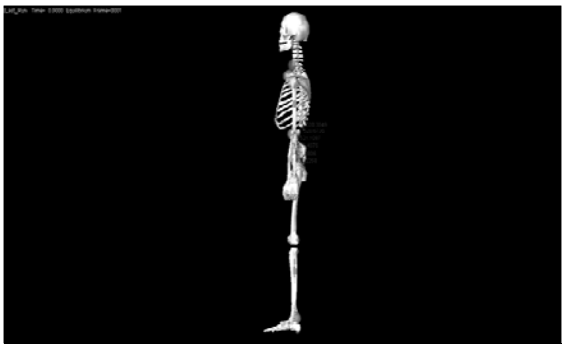
7. Wiper Motor Mount (from fender)
8. UV/ Breakline Connect (from front bumper)



Measures to Examine Physical Demands on the Worker

- 12 Subject (6 workers, 6 student)
- Measurement Equipment
  - Lumbar motion monitor (LMM)
  - Xsens (9)
  - Goniometers (4)
  - Electromyography (16)
- Data Analysis
  - LIMS
  - Matlab
  - Adams
- Output
  - Spine (posture, loads)
  - Shoulder (posture, muscle activity)
  - Neck (posture, muscle activity)
  - Wrist (posture)

U/V Breakline Connect Current Condition



U/V Breakline Connect 90 ^{0} Rotation

Results

Interior Regions

Interior Region: High, Edge

Spine — Vehicle Rotation

Load (N)	0 deg	45 deg	60 deg
Compression (L_4/S_1)	1919.7 ↓	1255.6 ↓	1155.1
Lateral Shear (L_4/L_5)	306.6	347.7	313.6
A/P Shear (L_4/L_5)	1063.3 ↓	850.2 ↓	790.9
Posture (deg)			
Max. Flexion	39.0 ↓	14.0 ↓	15.1
Max. Lateral Bend	19.7	18.4	13.8
Max. Twist	14.4	13.2	17.8

Neck — Vehicle Rotation

Muscle Activity (%MVC)	0 deg	45 deg	60 deg
R. Superior Trapezius	[illegible]	0.37	0.38
L. Superior Trapezius	0.36	0.31	0.35
Posture (deg)			
Max. Flexion	38.1	28.6	33.3
Max. Extension	30.1	33.5	29.4
Max. Right Side Bend	25.7	24.3	24.8
Max. Left Side Bend	33.7	18.8	17.5

Wrist — Vehicle Rotation

Posture (deg)	0 deg	45 deg	60 deg
Max. R. Radial	17.5	17.1	19.8
Max. R. Ulnar	29.6	33.7	30.1
Max. L. Radial	20.5 ↓	11.7	15.8
Max. L. Ulnar	25.5 ↑	33.3 ↑	32.0
Max. R. Flexion	19.6	25.4	32.8
Max. R. Extension	54.8	54.4	57.4
Max. L. Flexion	9.4 ↑	24.8 ↑	23.6
Max. L. Extension	50.0 ↓	48.5 ↓	50.3

Shoulder — Vehicle Rotation

Muscle Activity (%MVC)	0 deg	45 deg	60 deg
R. Lateral Deltoid	0.39 ↓	0.30 ↓	0.31
L. Lateral Deltoid	0.24 ↓	0.22 ↓	0.20
R. Anterior Deltoid	0.35 ↓	0.31 ↓	0.34
L. Anterior Deltoid	0.24 ↓	0.20 ↓	0.20
Posture (deg)			
Max. R. Shoulder Flexion	94.5	88.1	78.9
Max. L. Shoulder Flexion	115.5 ↓	90.7 ↓	90.3
Max. R. Shoulder Abduction	60.9	60.6	73.8
Max. L. Shoulder Abduction	35.4	40.5	43.2

↓ Indicates statistical significant difference from zero

Interior Region: Low, Center

Spine — Vehicle Rotation

Load (N)	0 deg	15 deg	45 deg
Compression (L_4/S_1)	1778.4	1706.9 ↓	1325.2
Lateral Shear (L_4/L_5)	267.3	295.5	267.3
A/P Shear (L_4/L_5)	706.3 ↑	941.6	843.4
Posture (deg)			
Max. Flexion	[illegible] ↓	25.6 ↓	14.8
Max. Lateral Bend	10.3	9.8	10.3
Max. Twist	8.4	9.1	9.9

Neck — Vehicle Rotation

Muscle Activity (%MVC)	0 deg	15 deg	45 deg
R. Superior Trapezius	0.28	0.32	0.29
L. Superior Trapezius	0.18	0.27	0.22
Posture (deg)			
Max. Flexion *	[illegible]	14.5 ↓	24.3
Max. Extension	[illegible]	[illegible] ↓	[illegible]
Max. Right Side Bend	11.3	13.0	16.9
Max. Left Side Bend	8.4	10.2	8.4

Wrist — Vehicle Rotation

Posture (deg)	0 deg	15 deg	45 deg
Max. R. Radial	[illegible]	[illegible]	[illegible]
Max. R. Ulnar	28.3	28.0	30.1
Max. L. Radial	12.8	11.6	12.1
Max. L. Ulnar	24.9	26.2	[illegible]
Max. R. Flexion	23.5	29.8 ↑	33.9
Max. R. Extension	[illegible]	45.1	[illegible]
Max. L. Flexion	22.7 ↑	45.6	26.8
Max. L. Extension	46.2	46.2	[illegible]

Shoulder — Vehicle Rotation

Muscle Activity (%MVC)	0 deg	15 deg	45 deg
R. Lateral Deltoid	[illegible]	[illegible]	[illegible]
L. Lateral Deltoid	[illegible]	[illegible] ↓	[illegible]
R. Anterior Deltoid	0.30	0.33 ↓	0.22
L. Anterior Deltoid	0.38	0.40	0.33
Posture (deg)	0.29	0.32	0.29
Max. R. Shoulder Flexion	121.3	110.7 ↓	102.3
Max. L. Shoulder Flexion	99.1	97.2 ↓	85.4
Max. R. Shoulder Abduction	49.8	48.3	50.7
Max. L. Shoulder Abduction	39.9 ↑	42.6 ↑	44.0

↓ Indicates statistical significant difference from zero

Interior Region: Middle, Edge

Spine — Vehicle Rotation

Load (N)	0 deg	15 deg	45 deg
Compression (L_4/S_1)	2009.6 ↓	1161.0 ↓	1022.0
Lateral Shear (L_4/L_5)	518.3 ↓	281.5 ↓	178.2
A/P Shear (L_4/L_5)	[illegible]	755.6 ↓	661.9
Posture (deg)			
Max. Flexion	11.4 ↓	31.4 ↓	14.2
Max. Lateral Bend	19.5 ↓	12.9 ↓↓	8.6
Max. Twist	11.5	13.8	17.8

Neck — Vehicle Rotation

Muscle Activity (%MVC)	0 deg	15 deg	45 deg
R. Superior Trapezius	0.26	0.24 ↓	0.18
L. Superior Trapezius	0.21	0.23	0.20
Posture (deg)			
Max. Flexion	5.0 ↑	29.1 ↑	30.4
Max. Extension	40.7 ↓	41.3 ↓	0.0
Max. Right Side Bend	32.4 ↓	19.2 ↓	21.3
Max. Left Side Bend	4.5	3.3	1.5

Wrist — Vehicle Rotation

Posture (deg)	0 deg	15 deg	45 deg
Max. R. Radial	[illegible]	[illegible]	8.9
Max. R. Ulnar	23.0	24.1 ↑	29.7
Max. L. Radial	11.2	11.1	6.9
Max. L. Ulnar	27.7	25.3	29.8
Max. R. Flexion	9.0	10.6	6.5
Max. R. Extension	[illegible]	[illegible]	[illegible]
Max. L. Flexion	35.2	39.0	33.2
Max. L. Extension	33.9	31.5	31.5

Shoulder — Vehicle Rotation

Muscle Activity (%MVC)	0 deg	15 deg	45 deg
R. Lateral Deltoid	0.25	0.29 ↓	0.15
L. Lateral Deltoid	0.20	0.22	0.16
R. Anterior Deltoid	[illegible]	0.39 ↓	0.27
L. Anterior Deltoid	0.12 ↑	0.19 ↑	0.17
Posture (deg)			
Max. R. Shoulder Flexion	107.5	101.8 ↓	84.4
Max. L. Shoulder Flexion	77.7 ↑	91.2 ↓	81.1
Max. R. Shoulder Abduction	19.7	18.1	30.6
Max. L. Shoulder Abduction	41.7	35.5	32.8

↓ Indicates statistical significant difference from zero

↓↓ Indicates statistical significant difference between zero and 45, as well as 15 and 45

Interior Region: Low, Edge

Spine — Vehicle Rotation

Load (N)	0 deg	15 deg	45 deg
Compression (L_4/S_1)	1911.9 ↓	1532.1 ↓	1422.4
Lateral Shear (L_4/L_5)	524.5 ↓	447.6 ↓	271.6
A/P Shear (L_4/L_5)	768.8	866.2	818.2
Posture (deg)			
Max. Flexion	[illegible] ↓	20.9 ↓	28.5
Max. Lateral Bend	18.8	18.6 ↓	13.3
Max. Twist	5.7	6.4	5.7

Neck — Vehicle Rotation

Muscle Activity (%MVC)	0 deg	15 deg	45 deg
R. Superior Trapezius	0.30	[illegible]	0.29
L. Superior Trapezius	0.34	0.36	0.33
Posture (deg)			
Max. Flexion	21.6	41.8 ↑	42.3
Max. Extension	8.9 ↑	25.8 ↑	23.0
Max. Right Side Bend	3.1	4.0	4.8
Max. Left Side Bend	9.7	8.2	7.5

Wrist — Vehicle Rotation

Posture (deg)	0 deg	15 deg	45 deg
Max. R. Radial	8.6	4.0	1.1
Max. R. Ulnar	29.7	27.8	28.1
Max. L. Radial	5.4	7.8	6.3
Max. L. Ulnar	[illegible]	[illegible] ↑	[illegible]
Max. R. Flexion	36.0	39.1	30.2
Max. R. Extension	13.1	12.3	15.7
Max. L. Flexion	45.0	45.8 ↓	33.5
Max. L. Extension	1.8 ↑	10.0 ↑	22.2

Shoulder — Vehicle Rotation

Muscle Activity (%MVC)	0 deg	15 deg	45 deg
R. Lateral Deltoid	0.28	0.21 ↓	0.16
L. Lateral Deltoid	0.27	[illegible]	0.26
R. Anterior Deltoid	[illegible]	0.31 ↓	0.21
L. Anterior Deltoid	0.18	0.25	0.22
Posture (deg)			
Max. R. Shoulder Flexion	99.1	92.3	66.0
Max. L. Shoulder Flexion	43.4	34.3	37.0
Max. R. Shoulder Abduction	16.8	26.9	32.7
Max. L. Shoulder Abduction	55.4	[illegible]	47.6

↓ Indicates statistical significant difference from zero

Interior Region: Middle, Middle

Spine — Vehicle Rotation

Load (N)	0 deg	15 deg	45 deg
Compression (L_4/S_1)	2000.5 ↓	1739.5 ↓	1343.4
Lateral Shear (L_4/L_5)	477.2 ↓	356.8 ↓	331.1
A/P Shear (L_4/L_5)	[illegible]	352.3 ↓	841.9
Posture (deg)			
Max. Flexion	31.3	26.7 ↓	19.3
Max. Lateral Bend	14.2	11.0	12.2
Max. Twist	15.7	11.9 ↓	9.7

Neck — Vehicle Rotation

Muscle Activity (%MVC)	0 deg	15 deg	45 deg
R. Superior Trapezius	0.30	0.23	0.24
L. Superior Trapezius	0.19	0.40	0.40
Posture (deg)			
Max. Flexion	15.6	22.5	21.6
Max. Extension	28.7	8.2	7.0
Max. Right Side Bend	1.8	16.0	15.7
Max. Left Side Bend	27.3 ↓	11.9 ↓	9.7

Wrist — Vehicle Rotation

Posture (deg)	0 deg	15 deg	45 deg
Max. R. Radial	[illegible]	[illegible]	6.1
Max. R. Ulnar	22.6	21.0	23.1
Max. L. Radial	3.9	4.7	6.9
Max. L. Ulnar	35.9	27.6	[illegible]
Max. R. Flexion	6.0	5.1	11.7
Max. R. Extension	57.0 ↓	55.2 ↓	43.0
Max. L. Flexion	39.5	42.2	41.5
Max. L. Extension	19.7	13.2	15.0

Shoulder — Vehicle Rotation

Muscle Activity (%MVC)	0 deg	15 deg	45 deg
R. Lateral Deltoid	0.37 ↓	0.19 ↓	0.08
L. Lateral Deltoid	0.31 ↓	0.23 ↓	0.23
R. Anterior Deltoid	0.33 ↓	0.17 ↓	0.12
L. Anterior Deltoid	[illegible] ↓	[illegible] ↓	0.12
Posture (deg)			
Max. R. Shoulder Flexion	47.8	60.3 ↓	44.8
Max. L. Shoulder Flexion	112.7	98.8 ↓	96.1
Max. R. Shoulder Abduction	28.9	19.2 ↓	19.6
Max. L. Shoulder Abduction	25.5	23.7	28.3

↓ Indicates statistical significant difference from zero

Results

Under Body Regions

Under Body: Center

Spine — Vehicle Rotation

Load (N)	0 deg	45 deg	90 deg
Compression (L_4/S_1)	1619.9	1299.3	1140.6
Lateral Shear (L_4/L_5)	200.6	178.1	194.0
A/P Shear (L_4/L_5)	1075.1	952.7	872.6
Posture (deg)			
Max. Flexion	22.4	16.4	13.1
Max. Lateral Bend	12.1	9.9	9.2
Max. Twist	7.9	7.5	7.3

Neck — Vehicle Rotation

Muscle Activity (%MVC)	0 deg	45 deg	90 deg
R. Superior Trapezius	0.23	0.19	0.15
L. Superior Trapezius	0.20	0.17	0.17
Posture (deg)			
Max. Flexion *	14.9	5.6	5.4
Max. Extension	11.0	25.2	14.8
Max. Right Side Bend	12.0	13.9	16.1
Max. Left Side Bend	11.9	17.8	18.3

Wrist — Vehicle Rotation

Posture (deg)	0 deg	45 deg	90 deg
Max. R. Radial	[illegible]	[illegible]	18.0
Max. R. Ulnar	12.8	11.7	13.3
Max. L. Radial	[illegible]	[illegible]	[illegible]
Max. L. Ulnar	10.0	16.7	24.3
Max. R. Flexion	21.7	19.6	15.3
Max. R. Extension	[illegible]	[illegible]	[illegible]
Max. L. Flexion	14.9	6.6	3.3
Max. L. Extension	[illegible]	[illegible]	[illegible]

Shoulder — Vehicle Rotation

Muscle Activity (%MVC)	0 deg	45 deg	90 deg
R. Lateral Deltoid	0.25	0.15	0.11
L. Lateral Deltoid	0.17	0.08	0.07
R. Anterior Deltoid	0.46	0.34	0.26
L. Anterior Deltoid	0.48	0.37	0.31
Posture (deg)			
Max. R. Shoulder Flexion	[illegible]	[illegible]	54.3
Max. L. Shoulder Flexion	65.3	53.3	45.9
Max. R. Shoulder Abduction	19.6	7.1	9.6
Max. L. Shoulder Abduction	1.8	3.8	6.1

↓ Indicates statistical significant difference from zero ↓↓

Under Body: Edge

Spine — Vehicle Rotation

Load (N)	0 deg	45 deg	90 deg
Compression (L_4/S_1)	975.0	948.7	869.4
Lateral Shear (L_4/L_5)	202.2	127.0	116.7
A/P Shear (L_4/L_5)	717.1	652.0	612.7
Posture (deg)			
Max. Flexion	15.2	14.0	9.1
Max. Lateral Bend	10.0	7.6	6.2
Max. Twist	10.7	9.1	7.6

Neck — Vehicle Rotation

Muscle Activity (%MVC)	0 deg	45 deg	90 deg
R. Superior Trapezius	0.26	0.17	0.17
L. Superior Trapezius	0.12	0.10	0.10
Posture (deg)			
Max. Flexion	27.0	18.9	28.6
Max. Extension	[illegible]	10.9	8.8
Max. Right Side Bend	19.4	15.1	14.1
Max. Left Side Bend	13.6	23.3	16.2

Wrist — Vehicle Rotation

Posture (deg)	0 deg	45 deg	90 deg
Max. R. Radial	12.3	13.8	8.8
Max. R. Ulnar	28.5	29.6	[illegible]
Max. L. Radial	11.2	14.1	10.2
Max. L. Ulnar	26.2	24.0	25.1
Max. R. Flexion	11.7	11.7	12.4
Max. R. Extension	67.8	68.3	61.7
Max. L. Flexion	12.7	11.3	10.2
Max. L. Extension	[illegible]	[illegible]	[illegible]

Shoulder — Vehicle Rotation

Muscle Activity (%MVC)	0 deg	45 deg	90 deg
R. Lateral Deltoid	0.32	0.15	0.18
L. Lateral Deltoid	0.08	0.06	0.05
R. Anterior Deltoid	[illegible]	0.39	0.36
L. Anterior Deltoid	0.26	0.24	0.18
Posture (deg)			
Max. R. Shoulder Flexion	[illegible]	[illegible]	[illegible]
Max. L. Shoulder Flexion	76.1	58.7	44.2
Max. R. Shoulder Abduction	39.2	20.6	24.4
Max. L. Shoulder Abduction	21.5	14.6	20.0

↓ Indicates statistical significant difference from zero

Results

Engine Room Region

Engine Room: Side Fender

Spine — Vehicle Rotation

Load (N)	0 deg	45 deg	60 deg
Compression (L_4/S_1)	1765.3	1159.1	1097.2
Lateral Shear (L_4/L_5)	329.9	148.6	144.2
A/P Shear (L_4/L_5)	[illegible]	729.7	680.3
Posture (deg)			
Max. Flexion	18.7	19.1	15.8
Max. Lateral Bend	11.7	8.1	7.2
Max. Twist	10.8	5.7	5.1

Neck — Vehicle Rotation

Muscle Activity (%MVC)	0 deg	45 deg	60 deg
R. Superior Trapezius	0.36	0.15	0.19
L. Superior Trapezius	[illegible]	0.15	0.16
Posture (deg)			
Max. Flexion	12.9	26.0	26.7
Max. Extension	[illegible]	0.7	1.8
Max. Right Side Bend	5.0	5.8	3.6
Max. Left Side Bend	[illegible]	8.3	9.8

Wrist — Vehicle Rotation

Posture (deg)	0 deg	45 deg	60 deg
Max. R. Radial	8.0	9.9	[illegible]
Max. R. Ulnar	[illegible]	26.9	[illegible]
Max. L. Radial	7.1	11.4	12.0
Max. L. Ulnar	[illegible]	28.6	[illegible]
Max. R. Flexion	26.7	9.4	11.0
Max. R. Extension	41.9	48.9	50.0
Max. L. Flexion	23.9	12.8	15.9
Max. L. Extension	40.4	40.0	43.0

Shoulder — Vehicle Rotation

Muscle Activity (%MVC)	0 deg	45 deg	60 deg
R. Lateral Deltoid	0.31	0.13	0.11
L. Lateral Deltoid	0.37	0.07	0.07
R. Anterior Deltoid	0.29	0.17	0.17
L. Anterior Deltoid	[illegible]	0.26	0.29
Posture (deg)			
Max. R. Shoulder Flexion	[illegible]	51.3	56.3
Max. L. Shoulder Flexion	[illegible]	56.0	54.5
Max. R. Shoulder Abduction	45.4	18.7	22.4
Max. L. Shoulder Abduction	51.0	14.5	14.0

↓ Indicates statistical significant difference from zero

Engine Room: Front Fender

Spine — Vehicle Rotation

Load (N)	0 deg	45 deg	90 deg
Compression (L_4/S_1)	1446.3	1101.0	959.7
Lateral Shear (L_4/L_5)	241.2	157.4	81.6
A/P Shear (L_4/L_5)	733.1	658.7	634.6
Posture (deg)			
Max. Flexion	26.1	15.1	8.7
Max. Lateral Bend	10.1	8.2	3.7
Max. Twist	14.8	5.8	5.4

Neck — Vehicle Rotation

Muscle Activity (%MVC)	0 deg	45 deg	90 deg
R. Superior Trapezius	0.16	0.17	0.06
L. Superior Trapezius	0.23	0.15	0.07
Posture (deg)			
Max. Flexion	14.0	11.5	20.4
Max. Extension	30.0	0.8	6.8
Max. Right Side Bend	6.0	0.5	8.1
Max. Left Side Bend	7.4	8.8	5.0

Wrist — Vehicle Rotation

Posture (deg)	0 deg	45 deg	90 deg
Max. R. Radial	7.1	6.0	2.2
Max. R. Ulnar	7.4	17.3	13.0
Max. L. Radial	[illegible]	[illegible]	[illegible]
Max. L. Ulnar	16.0	16.1	3.9
Max. R. Flexion	29.6	5.8	9.6
Max. R. Extension	53.7	24.8	21.2
Max. L. Flexion	5.4	17.9	5.0
Max. L. Extension	40.0	27.2	40.0

Shoulder — Vehicle Rotation

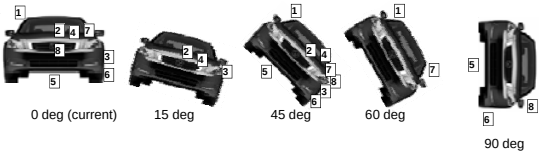
Muscle Activity (%MVC)	0 deg	45 deg	90 deg
R. Lateral Deltoid	0.25	0.11	0.06
L. Lateral Deltoid	0.19	0.07	0.07
R. Anterior Deltoid	0.22	0.13	0.09
L. Anterior Deltoid	0.37	0.19	0.16
Posture (deg)			
Max. R. Shoulder Flexion	[illegible]	49.3	38.3
Max. L. Shoulder Flexion	105.1	66.8	55.8
Max. R. Shoulder Abduction	18.8	8.4	3.9
Max. L. Shoulder Abduction	32.7	11.8	4.6

↓ Indicates statistical significant difference from zero

↓↓ Indicates statistical significant difference between zero and 90, as well as 45 and 90

Rotation Angle Summary

- **Green indicates the least musculoskeletal risk rotation angle for that zone**



Recap

- Rotate carrier is available
- While in this particular case we used a sedan car other vehicles or products may be rotated to reduce physical exposure to the workers and thereby reduce risk of MSD.
- 45º of rotation reduced physical demand most for interior regions and one engine room task
- 90º reduced physical demands most for under body and one engine room tasks.
- The rotate carrier did not solve all ergonomic issues additional changes may be needed to reduce risk of MSDs further.

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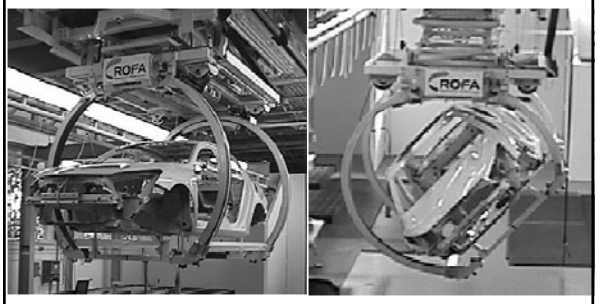
- Publication: Ferguson et al 2011, 42: 699-709, Applied Ergonomics "Musculoskeletal disorder risk as a function of vehicle rotation angle during assembly tasks.

THANK YOU



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OSC|12