



A survey of leaning and bracing behaviours in an automotive assembly plant



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ABSTRACT

It is common for workers to use objects within the task environment to externally support themselves, when performing a task. We refer to this as 'leaning', when using the contralateral hand for support, or 'bracing', when using the trunk, hips or thighs for support. However, currently, ergonomists are unable to predict when these behaviours will occur when performing proactive ergonomic assessments, leading to incorrect estimates of how the jobs will be performed. The purpose of this survey was to quantify the types of external support used by workers during automotive assembly tasks. 250 automotive assembly jobs were observed, and the external support behaviours were documented using a 13-item survey adapted from Jones et al. (2008). We observed that 103 jobs (41.2%) were performed with the use of leaning and/or bracing. Of those, workers leaned, braced, or used both behaviours simultaneously 54.5%, 22.0%, and 23.5% of the time, respectively. Leaning was most prevalent at a height of 150 cm, while bracing was most prevalent at a height of 50 cm. This survey catalogues the leaning and bracing behaviours from a large array of assembly jobs. The trends we have identified can be used by ergonomists to predict whether or not external support is likely to be used by a worker during a certain task.

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1. Introduction

In various industrial tasks, workers may be faced with physical barriers that can obstruct task performance, by limiting the postures that they are able to adopt and/or constraining how close they can place their body near the objects they are manipulating. While often constraining, these can also provide a surface that the worker can use for external support. We will define 'leaning' as the use of the non-working hand or forearm for external support, and 'bracing' as the use of any other body part for support. These behaviours are common in automotive assembly, as workers often need to complete their jobs in and around the existing framework of the vehicle.

Jones et al. (2008) provided some of the only published documentation of external support behaviours, based on workers in 20 automotive assembly jobs. They identified the engine compartment and the vertical pillars of the vehicle as the most commonly used contact surfaces for external support. If a worker is performing a task within the engine compartment, for example, they may brace

by placing their pelvis on the side fender panel for support while completing this task. Although that survey provided much-needed insight into the prevalence of leaning and bracing in the automotive industry, its limitations include the relatively small number of jobs surveyed relative to the total number of jobs found in an assembly plant, and the selection of only jobs that had a contact surface which would afford the use of external support behaviours. In addition, it was not documented at what absolute height the leaning or bracing behaviours occurred.

Recently, automotive manufacturers have used modeling technology to perform ergonomic assessments early in the manufacturing design process (Chaffin, 2005; Dukic et al., 2007; Savin, 2011). Work simulation, in which a digital human is immersed within the proposed task environment, is conducted to assess injury risks before workers enter the task environment. Although it is known that these support behaviours are used, currently, ergonomists are unable to accurately predict leaning and bracing in these types of proactive analyses. There is a need for a larger database cataloging the occurrence of these behaviours, and identifying the conditions that may result in the use of supported behaviours, so that accurate predictions can be made as to when a worker will lean and/or brace. The goal, in developing this database, is to aid automotive manufacturers in improving the validity

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of the work simulation process by facilitating more accurate predictions of how most workers will perform a task. This will ensure that external support behaviours are accurately accounted for when assembly jobs are initially designed. Thus, the purpose of this survey was to expand upon the excellent work of Jones et al. (2008) by collecting leaning and bracing data from a wider range of assembly tasks. Our goal is to identify common task parameters that may indicate when these behaviours are most likely to be employed.

2. Methods

A survey was conducted at a Ford Motor Company automotive assembly plant in North America, where mid-sized vehicles were assembled. The goal of this survey was to identify jobs that required workers to adopt postures where leaning and/or bracing behaviours were needed. In total, 250 jobs designated to the assembly of the trim and chassis components of a mid-size crossover sport utility vehicle were surveyed. Of the 250 jobs observed, 103 (41.2%) demonstrated leaning and/or bracing behaviours.

2.1. Subjects

Participants in the survey included assembly line workers with an average of 4.4 ± 2.8 years of experience. There were 96 male (height: 179.7 ± 7.7 cm, weight: 88.9 ± 14.4 kg) and 7 female (height: 166.7 ± 3.0 cm, weight: 59.0 ± 7.8 kg) employees surveyed. The university's Research Ethics Board approved all portions of this study.

2.2. Survey components

Our survey was modeled after the classification system used by Jones et al. (2008) and documented the location and posture of the worker's hands, torso, and feet, in addition to characteristics specific to their leaning and bracing behaviours (Table 1). The term 'task hand' is used to indicate the hand(s) used to complete the

demands of the job. In addition, leaning refers to the hand, forearm, or elbow that was used for support but was not necessary for completion of the work-related task. Similarly, 'bracing' refers to external support with all body parts, other than those used for leaning. Bracing may include the shoulder, chest, abdomen, pelvis, thigh, or knees. In some cases, it was necessary for a worker to use a secondary point of support during task completion. Thus, it was possible for leaning and bracing to occur both independently, or simultaneously. The leaning and bracing postures, adopted by the workers that were surveyed, were not necessarily a requirement of the task itself; these behaviours were preferred by the worker.

After communicating with the employee, the researchers observed each job for a minimum of 10 cycles (approximately 10 min) to get an understanding of the typical workflow. Each job was then deconstructed into individual task elements. The items on the survey were documented for each task element completed by the worker. For example, if one worker's job was to retrieve a part from a bin and then fasten that part to the vehicle, and this was repeated once for each vehicle, the job was considered as having 2 task elements. For the purposes of this survey, only task elements involving leaning and/or bracing behaviours will be discussed.

3. Results

3.1. Prevalence of external support

Of the 250 jobs surveyed, 103 (41.2%) jobs contained at least one task element in which the worker used external support behaviours. Across all jobs, 31.2% contained at least one task element with leaning and 18.8% contained at least one task element with bracing (Fig. 1). The 103 jobs, with some leaning and/or bracing, required a total of 613 individual task elements (i.e. ~6 tasks/job). Of these, 363 task elements (59.2%) were identified as having leaning and/or bracing.

The following sections will only refer to the 363 task elements where leaning and bracing behaviours were employed.

Table 1
Description of the variables used on the leaning and bracing survey sheet.

Variable	Variable description	Range of values
Task Hand	The hand(s) that were used to complete the task component.	Right, Left, Both
Task Hand Posture	The hand posture/grip used to perform an exertion.	Power Grip, Pulp Grip, Hook Grip, Flat Press, Palm Press (Closed Fist), Enclosure, Lateral Pinch
Task Hand Wrist Posture	The wrist flexion/extension angle of the task hand(s).	Flexion, Extension, Neutral
Task Hand Force Direction	The direction of the effort exertion for the task hand(s).	Push Up, Push Down, Push Forward, Pull Backward, Exert Right, Exert Left
Stance Description	Denotes whether the worker was balanced evenly on both feet, or if they had the majority of their weight on one leg. Also indicated the presence of a moving sidewalk.	Single Stance, Double Stance Moving Sidewalk: Yes, No
Torso Angle	The rotation of the trunk forward with respect to vertical. Also indicated whether there was lateral bending to the side, or axial twisting.	0, 0–20, 20–60, >60° Lateral Bending: Yes, No Axial Twist: Yes, No
Leaning Side	The hand(s) or forearm(s) that were used for external support via leaning.	Right, Left, Both
Leaning Hand Posture	The hand posture/grip used to lean.	Power Grip, Pulp Grip, Hook Grip, Flat Press, Palm Press (Closed Fist), Enclosure, Lateral Pinch, Forearm/Elbow
Leaning Hand Wrist Posture	The wrist flexion/extension angle of the leaning hand.	Flexion, Extension, Neutral
Leaning Hand Force Direction	The direction of the effort used by the leaning hand(s) for support.	Push Up, Push Down, Push Forward, Pull Backward, Exert Right, Exert Left
Bracing Body Part	Body part(s) used for external support during bracing behaviours.	Thigh, Pelvis, Abdomen, Chest, Upper Arm & Shoulder
Contact Point	The location where the external support was applied to the vehicle. Was used to describe the leaning hand or the external bracing body part.	A, B, C, D Post; Rocker Panel, Floor Pan, Frame, Front Bumper, Fender Catwalk, Side Fender Panel, Other

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