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Development of a Risk Factor Analysis Model For Predicting Postural Instability at Workplace

Angshuman Bagchee, Amit Bhattacharya, Paul A. Succop, and Chwan-Fu Lai,
Dept of Environmental Health, University of Cincinnati, Cincinnati, OH 45267-0056.

Falls at the workplace are often preceded by a momentary loss of balance that may be attributed to several risk factors related to the workplace and the worker. Based on the multiple regression analysis performed on 52 industrial workers in a laboratory-based study, a risk factor analysis model was developed to evaluate the potential for postural instability. Based on the regression model, a windows-based application has been developed with simplified user-interface for entering the risk factors associated with any particular task. It shows the relative level of postural stability for a combination of risk factors and allows graphical display of what-if analyses. The model illustrates the possible use of laboratory-based statistical models to actual worksite analysis in determining the risk factors that would have a significant impact in reducing postural imbalance and preventing fall-related injuries.

Introduction

Falls have been found to be a significant contributor in causing fatal and non-fatal injury, especially in the construction industry, including lumbar spine injury, fracture of bones, and disability [1]. A number of fall risk factors exist at the workplace, and a combination of one or more of these risk factors may be responsible for momentary loss of balance leading to an accidents resulting from a fall or near-fall situation. Several extrinsic and intrinsic factors may influence a worker's ability to maintain postural upright stability during task performance. Extrinsic factors may include availability of peripheral vision, environmental lighting, surface condition and slipperiness. Intrinsic factors would involve the worker's physical ability, age, and other physiological factors such as neuromuscular coordination that influence postural balance maintenance [2]. Fatigue resulting from prolonged physical exertion and respiratory loading may suppress the ability of the nervous system to regulate the upright balance efficiently.

The relative role of each individual risk factors in influencing the workers' postural stability is poorly understood. A first step would be the identification of the risk factors influencing a worker's postural stability at the workplace and designing a laboratory-based study to quantify the role of these risk factors. The results from the laboratory-based study should then be able to provide us with the necessary tools for evaluating a task at the workplace based on the risk factors associated with that particular task. The present study aimed at identifying some of the risk factors associated with postural instability in industrial falls and evaluated the effect of these risk factors under laboratory conditions. Postural instability was quantified through sway area, sway length, and non-dimensional indices of postural stability representing the proximity and spread of the center of pressure (CP) to the functional stability boundary (FSB) of the subject, formed by the outline of his/her base of support. Based on the results, a mathematical model was developed to predict the postural stability outcome measures depending on the level of the individual risk factors associated with any given industrial task.

Methods

A total of 52 industrial workers (age = 37.4±8.9 years range 21.1 - 52.2 years; 50% male) participated in this study [3]. The study consisted of four experimental conditions 1. Surface slipperiness - Dry (coefficient of friction, COF = 0.6), and Slippery (COF = 0.3); 2. Environmental Lighting - Good (> 70 footcandles), and Poor (< 0.2 footcandles); 3. Peripheral Vision - Unblocked and Blocked; and 4. Standing Surface - Firm, and Compliant (aluminum plate over a 10.2 cm thick foam). The subjects performed four different tasks under each of these conditions. These tasks were: 1. Stationary: Subjects stood upright for 30 s; 2. Bending - Subjects stood still for 12 s, then bent down at the torso to touch the knees and maintained this posture for 5s, and regained their upright posture for remaining 13 s; 3. Sudden Loading - Subjects stood still for 30 s, while a weight of 2.3 kg was suddenly released from a height of 30.5 cm into a hand-held basket (weighing 170 g) at the elbow level at a randomly determined time; 4. Reach - Subjects stood still for 5s, then reached forward/upward to retrieve a 2.3 kg weight from functional upward/forward reach distance and deposit it to a shelf at maximal forward reach at elbow height, repeating the cycle four times.

The subjects performed these tasks under three different workloads - 0, 40, and 100 watts, administered on an ergometer. The ground reaction forces and moments were collected to calculate the movement of the CP under the feet. The subject's feet position were traced to obtain the FSB [2,4]. The dependent variables included the sway area and sway length from the projection of the subject's CP on the horizontal plane during the task. Three non-dimensional indices of IPSB, SAR, and WRTI, based on the proximity and the spread of the CP to the subject's FSB, were also used for outcome measures [4]. Further details of the study and the interpretation of the outcome variables can be found in Bhattacharya, et al. [3].

Results

The values of the estimated increase in the dependent measures of sway parameters were obtained from multivariate analysis of the results, and are indicated in table 1. Further details of the analysis may be found in Bhattacharya, et al. [3]. The values from table 1 were then utilized in constructing a Windows-based computer application software for use in estimating the magnitude of postural instability increase associated with a task where a worker is exposed to fall risk factors. The program is able to present a graphical interface with the following input - (i) measured baseline sway parameter of the worker for stationary standing (baseline sway parameter) and (ii) identification of the risk factors under which the worker has to perform the task at his/her workplace. The program then automatically evaluates the percent increase in the various sway parameters, and graphically represents the same for visual interpretation. The mathematical model, based on values from table 1, calculates the increase in the baseline sway parameters as follows:

For a task, with risk factors $r_1, r_2, \ldots, r_j, \ldots, r_n$,

(Sway parameter$_i$) = (baseline sway parameter$_i$)$(1+a_1/100)(1+a_2/100)..(1+a_j/100)..(1+a_n/100)$,

where a_j represents the percent increase corresponding to risk factor j for sway parameter$_i$ from table 1. The software also allows what-if analysis, whereby the risk factors can be manipulated to reduce the sway parameters as close to the baseline sway, thereby allowing the identification and prioritization of the risk factors contributing most to the postural instability associated with the task.

Discussion

The mathematical model and the computer software developed present an effective evaluation tool for identifying tasks which may cause undue postural instability at the workplace. The model considers both environmental and individual factors in predicting the increase in the postural instability. A higher value of sway area, sway length, SAR, WRTI, and a lower value of IPSB implies greater danger of postural instability. Although it is not clear at this stage, how much absolute values of these parameters will be associated with loss of momentary loss of balance leading to a fall, it allows the comparison of tasks and facilitates in prioritizing the risk factors responsible for postural instability. Larger number of subjects are required for establishing acceptable limits of the sway parameters.

Table 1. Estimated percent increase in the sway parameters due to environmental and inter-individual effects [3].

Main Effects		Sway Area	Sway Length	IPSB	SAR	WRTI
Task	Bending	425.91	140.92	-36.10	633.33	39.13
	Reach	671.55	244.81	-65.12	1300.00	321.74
	Loading	147.42	48.96	-44.55	333.33	26.09
Dim Light		16.29	12.58	-3.83	15.38	0.00
Compliant Surface		10.81	6.16	-31.69	7.14	100.00
Gender: Male		5.56	5.71	6.40	-13.33	-23.53
Peripheral vision: Obstructed		5.66	3.87	-0.69	7.14	0.00
Workload	40 W	3.88	2.15	-1.35	0.00	4.65
	100 W	2.73	5.00	-3.84	0.00	6.98
Age	29-37	-3.05	1.60	-2.18	-6.67	45.71
	37-45	-8.23	-1.89	-13.94	-6.67	57.14
	> 45	3.16	7.64	-5.01	-6.67	11.43
Surface: Oily		-3.39	-1.47	6.15	0.00	-12.50

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