Losing Balance Upon Standing

Do Construction Workers Perceive the Problem?

By Angela T. DiDomenico, Raymond W. McGorry, Michael F. Blair and Yueng-Hsiang Huang

The construction industry is one of the largest sectors of the U.S. economy, employing 7,439,000 people in 2009 (BLS, 2009). Although worksite safety has improved, incidents continue to occur, causing numerous fatalities and injuries to workers.

IN BRIEF

- **Falls are a serious concern within the construction industry. This study explored factors affecting perceptions of balance upon standing from different working postures.**
- **Data were collected on perceptions of balance upon standing, fall protection measures employed and factors affecting balance. Ratings of perceived balance were significantly affected by working posture, construction trade and age of worker.**
- **Construction workers identified measures they use to maintain balance, including those that do not require additional equipment, such as transitioning to an intermediate posture prior to standing.**
- **Findings may lead to recommendations for redesign of tasks or tools to reduce the use of certain working postures, and mitigate fall risks through a proactive approach of maintaining balance and reducing the occurrence of falls.**

Falls account for the most fatalities and are the second most common cause of nonfatal workplace injuries in the construction industry (CPWR, 2007). Loss of balance often is a contributing factor in falls (Hsiao & Simeonov, 2001), although it is not always clear what factors cause the imbalance. One possible factor is the transitory nature of construction work activities that requires workers to perform tasks in awkward postures and frequently transition to a standing posture before proceeding to the next task and/or location.

OSHA has requirements regarding fall protection ranging from training to personal fall protection devices. Fall protection devices may be active [e.g., personal fall arrest systems (PFAS) such as horizontal and vertical lifelines] or passive systems (e.g., guardrails and safety nets).

In general, fall protection is used to react to a loss of balance and eliminate or minimize injury. A proactive approach is for workers to perceive situations that place them at risk so they can employ techniques to maintain balance. At this time, it is unclear to what extent workers can perceive fall risks, particularly those associated with standing up after working in a nonerect posture.

What Factors Affect Balance?

Maintaining balance is a critical factor for successful task performance; it requires information from the visual, vestibular (detects motion of the head-in-space) and proprioceptive (senses relative position of body parts) systems (Danis, Krebs, Gill-Body, et al., 1998). Sensory input is integrated to provide the individual with information that influences balance control and allows for compensatory movements necessary to maintain postural control (Cobb, 1999). These movements depend on the integrity of the musculature and the effectiveness of processing within the central nervous system (Horak, Shupert & Mirka, 1989). In general, stable con-

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trol of posture and balance is automatic for healthy individuals, although alterations to sensory inputs may make maintaining balance more challenging.

Transitions between postures can affect all three sensory systems involved in maintaining balance. Altering the orientation of the head influences visual input and has been shown to challenge balance control in healthy working-age adults (age 22 to 50) due to a decreased ability to discern the orientation of the head and body with respect to gravitational vertical (Paloski, Wood, Feiveson, et al., 2006).

Changing proprioceptive feedback also can affect balance as shown in studies that examined the after-effects of standing on an inclined surface (Kluzik, Horak & Peterka, 2007; Mezzarane & Kohn, 2007); walking on an inclined surface (Leroux, Fung & Barbeau, 2002; Wade & Davis, 2005); and standing on compliant surfaces (Simeonov, Hsiao & Hendricks, 2009). The interaction of all these factors at an elevation make maintaining balance control more difficult, yet critical in the prevention of falls.

Survey Development

The research team developed a written pencil and paper survey with assistance from subject-matter experts. Information from semistructured interviews was obtained from current construction workers (i.e., painter, mason, plumber) and loss prevention construction specialists (i.e., technical consultants) of an insurance company.

Cognitive interviews were conducted to examine the meaning of survey items (for clarification purposes) and the extent to which these items reflect the domain being investigated. This process was implemented to maximize content and face validity.

Participants were recruited for their expertise in and familiarity with the construction industry. Questionnaire items were revised based on subject-matter experts' comments and suggestions. The revised survey was completed by 10 current construction workers who represented the target participant population to ensure sufficient understanding of the questions and determine an expected range of responses. This feedback was used to finalize the survey questions and format.

Survey Topics

The survey was divided into three main sections. The first section was used to evaluate the workers' perceived sense of balance after standing from a working posture. Photos of 10 different, nonerect working postures were presented (Figure 1). Standing was included as the 11th posture following the nonerect postures and used as a point of comparison. General pictorial representations were intentionally used without specific tasks, tools, PPE, etc., to allow for generalizability across trades and tasks.

For each posture, the workers estimated how much time each posture was used during a typical month. If participants indicated that they used a given posture, they were asked to rate their perceptions of balance upon standing after working in that posture. Details regarding the five-point Likert-type rating scale (1 = unstable, 2 = somewhat unstable, 3 = neither unstable nor stable, 4 = somewhat stable, 5 = stable) used to obtain perceptions of balance can be found in DiDomenico, McGorry, Huang, et al. (2010).

The second set of questions examined the methods that construction workers used to maintain balance when a threat to balance is perceived. The final set of questions explored contextual factors that

Figure 1

Nonerect Working Postures

Pictorial representations of the 10 nonerect working postures included in the survey: a) reclined kneeling; b) lying on back; c) lying on stomach; d) sitting on level surface; e) upright kneeling—knee(s) on ground; f) lying on either side; g) sitting on elevated surface; h) bent over at waist; i) forward kneeling—hand(s) on ground; j) squatting.

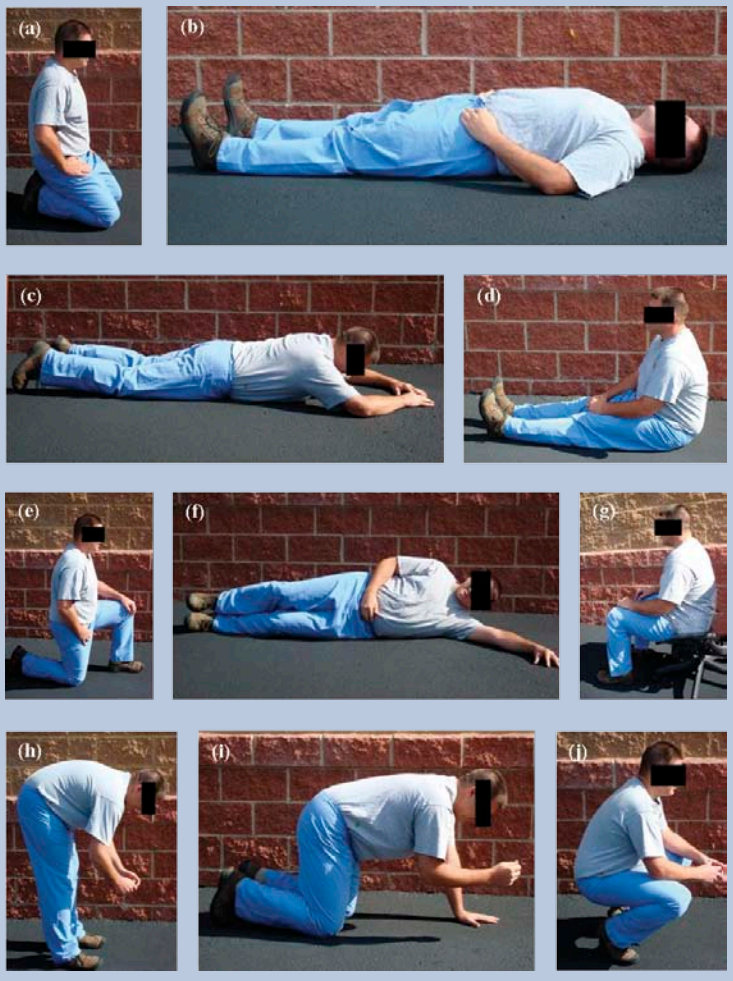


Table 1
Participant Demographics

Variable	Frequency	Percentage
Trade		
Masons	16	8.5
Carpenter	28	14.8
Floor installer	13	6.9
Drywaller	17	9.0
Electrician	18	9.5
Laborer	16	8.5
Plumber	19	10.1
Sheet metal worker	28	14.8
Ironworker	15	7.9
Roofer	19	10.1
Gender		
Female	6	3.2
Male	183	96.8
Age[a]		
18-32 (younger)	63	33.5
33-47 (middle)	94	50.0
48-63 (older)	31	16.5

Note. n = 189. [a]One value missing for age.

may increase risk of falling, including environmental, task and personal factors. Participants were asked to indicate in the affirmative or negative for each factor. Data were also collected regarding each construction worker's trade, age, gender and years of experience.

Survey Administration

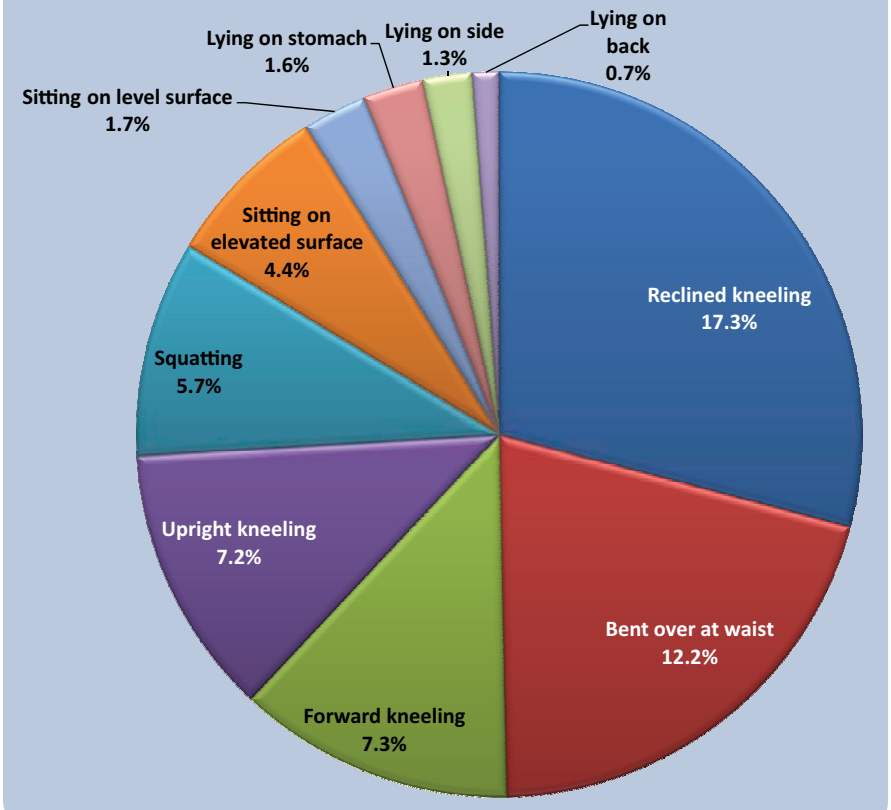
Workers were recruited from 10 construction trades with an emphasis on trades directly involved in building construction. All currently employed construction workers who comprehended English were eligible. Participation was completely voluntary and recruitment occurred at five jobsites and through local advertisements. Prior to taking the survey, all participants completed an informed consent procedure approved by the Liberty Mutual Research Institute for Safety's Institutional Review Board.

One hundred and ninety-six workers in the northeastern U.S. participated in the study. An effort was made to have a similar number of participants from each construction trade complete the survey with a minimum of 10 workers from each trade taking part. Of participants, 97% were men, a proportion representative of the construction industry as a whole. Workers surveyed averaged 15.9 (*SD* = 11.5) years' experience within the construction industry and 13.5 (*SD* = 11.1) years' experience within their current trade.

Table 1 summarizes participant demographics, including the distribution within the three age categories used during analysis. Participants completed the survey in approximately 15 to 20 minutes. Responses from seven participants were removed due to insufficient data, resulting in 189 usable surveys and a completion rate of 96.4%.

Figure 2
Working Postures Use

Percentage of time each working posture was reported to be used during a typical month.



Results & Interpretation

Ratings of Perceived Balance by Working Posture

Postures were ranked across all construction trades according to the frequency of use during a typical working month (Figure 2), although the rate of use for many postures was not the same across trades. Ratings of perceived balance (RPBs) averaged 4.1 [1.1] or "somewhat stable" when examining all postures and trades. RPBs provided were statistically different among the various postures, indicating that the working posture maintained prior to standing has a perceived influence on balance and the vulnerability to fall risk immediately following the transition in posture.

Figure 3 illustrates the RPBs for each posture. Post-hoc testing indicated that bent over at waist, squatting and forward kneeling resulted in the lowest RPBs, whereas working while sitting on level surfaces and standing were associated with the highest RPBs.

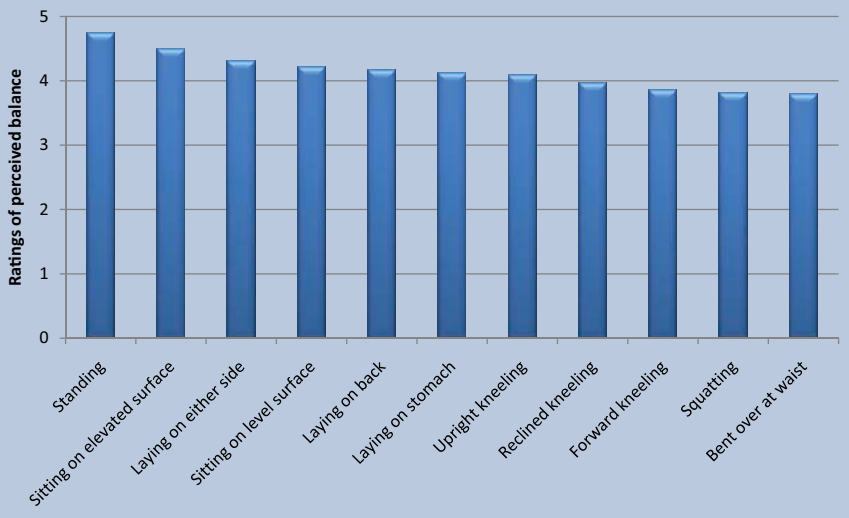
Transitioning from one posture to another requires adjustment within multiple sensory systems during or immediately following the transition to return the body to balance equilibrium. Bending at waist, squatting and forward kneeling may create a heavier burden on multiple sensory systems, decreasing balance and resulting in lower RPBs.

Input to the vestibular system is affected by movement of the head, and deviations of the head from a neutral position

affect neck proprioception (Norre, 1995). When maintaining and transitioning between postures, the sensory organs within muscles, ligaments and joints of the lower extremities respond to static and dynamic stimuli associated with loading and stretching of the musculoskeletal system. In addition, the cardiovascular and peripheral vascular systems may be affected after maintaining certain working postures for prolonged periods .

Figure 3
Mean Balance Ratings

Mean balance ratings (1 = unstable; 5 = stable) for each working posture are averaged across all construction workers.



Ratings of Perceived Balance by Construction Trade

RPBs provided by the various trades were significantly different when averaged across all postures. Floor installers and sheet metal workers reported significantly lower RPBs as compared to carpenters and drywall installers, who reported the highest RPBs overall.

Further investigation identified specific postures which differed for each trade that were perceived to be more problematic. Sheet metal workers perceived lower levels of balance associated with forward kneeling (RPB = 3.3) and lying on back (RPB = 3.0), whereas floor installers provided significantly lower RPBs for bent over at waist (RPB = 2.7). Furthermore, plumbers recognized lying on stomach (RPB = 2.7) and sitting on level surface (RPB = 3.0) as precursors to potential imbalance, and iron workers provided lowest RPBs for squatting (RPB = 3.2).

Even though the utilization of postures is not identical among trades due to the diversity of the work performed, results suggest that no inherent difference exists between construction trades in self-reported RPBs upon standing. Differences in RPBs averaged across postures seem to stem from the differences in the tasks performed and the postures required to complete those tasks.

Ratings of Perceived Balance by Age Groups

RPBs among the three age categories were significantly different, with older workers reporting higher RPBs. Construction workers age 48 and older reported higher levels of balance upon standing (mean RPB = 4.4) as compared to younger colleagues (mean RPB = 4.0).

The 10% shift in RPBs may not reflect a greater ability to maintain balance. Differences in tasks performed, survivor effect and adaptation of tasks for the older workers may account for the variations in perceptions. Older workers may have had more opportunities to identify potentially risky situations and have learned how to adapt their behavior.

These adaptations to the performance of tasks may help explain why the two postures with the lowest balance ratings (bent over at waist and squatting) had the largest disparity in balance ratings between younger and older workers. Familiarity with the tasks and feelings of imbalance also may lessen the effect and perceptions over time as a worker's tenure increases.

These ideas are substantiated by the fact that no significant effect of age was found when each posture was evaluated separately. Over time and with experience, workers may reduce the use of certain postures that cause imbalance either by redesigning the task or altering the tools necessary to complete the task (e.g., using a drill extension that allows the employee to stand while working at ground level). Another adaptation to reduce imbalance after transitioning from a "risky" posture (e.g., bent over at waist or squatting) may be to reduce the speed of the movement or utilize visual cues.

Fall Prevention Measures

Fall prevention and protection measures available and used were dependent on the trade and the task being performed. Of the construction workers surveyed, only 21.7% reported using fall protection devices. As expected, the responses varied across trades, with electricians, masons and plumbers indicating almost no use of such devices. When available, 53.8% of workers indicated that they hold on to an object or work surface to help maintain balance. These results did not vary substantially across trades.

When workers must maintain balance without external assistance, 34.6% of respondents indicated that they pause in an intermediate posture before standing up completely from an awkward or uncomfortable posture, and 47.5% pause after standing up to regain balance before continuing to work or moving to the next location. Results indicate that many workers are aware of the potential imbalance created by transitioning to a standing position and alter behavior to mitigate the risk of falling.

Table 2
Difficulty Maintaining Balance

Percentage of participants who indicated the listed task or environmental factors made it more difficult to maintain balance while working.

	Overall	Carpenter	Drywaller	Electrician	Floor installer	Iron worker	Laborer	Mason	Plumber	Roofer	Sheet metal worker
Tired	57.4	39.3	41.2	52.9	76.9	57.1	28.6	62.5	68.4	72.2	74.1
Stand up fast	56.0	42.9	47.1	47.1	76.9	35.7	35.7	81.3	63.2	77.8	57.1
Carrying load/tool	36.9	32.1	29.4	25.0	58.3	28.6	50.0	43.8	31.6	29.4	46.2
Hot	34.8	32.1	17.6	23.5	46.2	21.4	33.3	31.3	31.6	66.7	40.7
End of shift	34.1	22.2	17.6	17.6	53.8	42.9	21.4	31.3	36.8	55.6	44.4
Glare	30.6	28.6	29.4	11.8	53.8	14.3	21.4	18.8	26.3	61.1	37.0
Working at elevation	27.9	32.1	11.8	11.8	46.2	21.4	42.9	31.3	21.1	27.8	33.3
Working overhead	25.0	17.9	17.6	23.5	7.7	21.4	33.3	12.5	42.1	33.3	33.3
Cold	18.1	14.3	17.6	17.6	15.4	14.3	21.4	18.8	0.0	11.1	42.3
Darker than normal	17.3	21.4	0.0	11.8	38.5	0.0	14.3	0.0	10.5	35.3	29.6
No visual reference	14.3	17.9	5.9	11.8	15.4	0.0	14.3	6.7	15.8	22.2	22.2
Noisy	7.7	3.6	11.8	5.9	0.0	0.0	14.3	0.0	10.5	11.1	14.8

Note. *n = 189.*

Factors Affecting Balance

Contextual factors can influence a worker's ability to maintain balance upon standing and in general. Table 2 lists several of these factors and indicates the percentage of construction workers who believe balance is more difficult to maintain under these conditions. Overall responses and those for each construction trade are presented.

More than half of the respondents (57.4%) indicated that maintaining balance was more difficult when they were tired. In addition, 56% indicated that it was more difficult to maintain balance after standing up quickly. Construction workers must perform tasks in a wide variety of environments under diverse conditions, and different factors may be more important to different workers depending on their trade.

Considerations & Limitations

The measures within this study were derived from self-reports of current construction workers. Previous research has indicated limitations in obtaining valid self-report exposure estimates from individual workers, especially those involved in highly variable tasks (Hunting, Haile, Nessel, et al., 2010). Level of physical effort and manual material handling can be collected, but assessments are only accurate for detecting the absence or presence of an exposure with minimal accuracy regarding intensity, duration or frequency (Stock, Fernandes, Delisle, et al., 2005).

Therefore, it is not known whether RPBs correlated to direct quantitative measures of balance, such as postural sway, or whether participants were able to accurately recall feelings of imbalance associated with various working postures, especially those that are not used frequently (Unge, Hansson, Ohlsson, et al., 2005).

An attempt was made to adequately sample workers from a variety of construction trades to provide a general description of perceptions; however, no observational data of individual construction workers were collected to link to specific ratings. In addition, no considerations were made for differences in body mass index, footwear, loads, PPE or other job-specific factors that may influence balance.

Personality traits (e.g., machismo) and psychosocial factors associated with the largely male-dominated construction industry also may have influenced responses. Several construction workers expressed a

Potential Threats to Balance Upon Standing From a Working Posture

It may not be possible to improve balance perception through training, but it is possible to inform workers about safer postures that they can utilize and factors that may make it more difficult to maintain balance in the workplace. The postures investigated in this study are listed below in rank order with those creating the most perceived imbalance at the top.

Working Posture
- Bent over at waist
- Squatting
- Forward kneeling
- Reclined kneeling
- Upright kneeling
- Lying on stomach
- Lying on back
- Sitting on level surface
- Lying on either side
- Sitting on elevated surface
- Standing

Factors Affecting Balance
- Fatigue
- Standing up very fast
- Working on uneven or irregular surface
- Carrying a load
- Extreme temperatures
- Adverse weather conditions (e.g., fog)
- Glare
- Working at elevation
- Working with arms overhead
- Dim lighting

belief that providing lower balance ratings indicated a weakness or potential problem with their ability to successfully perform their job. Such beliefs could inflate RPBs; however, such a bias would likely be systematic across conditions and, thus, would not change the effects of the factors investigated.

Summary & Application

Contextual demands on a construction site make it beneficial, if not necessary, for workers to have good balance, especially those who are required to work on physically constrained surfaces or at heights (e.g., I-beams and roof tops) where a fall can result in serious injury or death. Maintaining balance on a level surface also is critical, especially when workers must contend with debris or construction materials nearby that may cause a slip or trip hazard. It is possible that individuals with good balance self-select into these trades and only those who can mitigate fall risks and perform tasks safely remain for long tenures.

Many factors can influence worker perceptions of balance upon standing from a working posture. One such factor is the working posture used to perform the task. This will depend on the trade, job within the trade, task being performed and the individual performing the task. Survey results suggest that perception of balance differs depending on the posture, with bent over at waist, squatting and forward kneeling causing the most imbalance upon standing.

Ongoing research will evaluate potential associations between workers' perceptions and force-plate-measured changes in postural sway, an indicator of balance. The effect of age also will be investigated experimentally to determine whether balance improves with age or whether other factors, such as a survivor effect or adaptation of task performance, contribute to the difference.

Recommendations for Practitioners

This survey revealed that postural transitions may present a risk of loss of balance. The results identify simple and common techniques used to minimize imbalance following transitions to standing.

When a threat to balance occurs, workers who are able to perceive the risk may be able to mitigate it by transitioning to more stable postures before standing or pausing for a few seconds after standing to regain balance. Understanding how task and environmental factors affect balance also is important to minimizing loss of balance. Maintaining balance was reported by more than half of the construction workers surveyed to be more difficult when tired or after standing up fast.

If workers can perceive a threat to balance prior to a fall, proactive maneuvers may be able to prevent falls and minimize risk of injury, including redesigning tasks or tools to reduce the use of working postures associated with higher self-reported levels of imbalance upon standing or minimize exposure to contextual factors that may increase imbalance. **PS**

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