Reaching on Ladders

Do Motivation & Acclimation Affect Risk Taking?

By Angela T. DiDomenico and Mary F. Lesch

Ladders are widely used by workers on many jobsites, and falls from ladders occur at a high frequency. Falls from ladders account for a large portion of workplace injuries related to falls from heights. In fact, in 2010, 129 workers died after falling from a ladder (BLS, 2010a) and 14,710 suffered an injury that required at least 1 day out of work, with the median number of days away from work being 25 (BLS, 2010b). The frequency of falls from ladders and the severity of the injuries involved create a critical safety issue.

IN BRIEF

- **Falls from ladders are a serious concern in many industries. This study explored the effects of acclimation and motivation on lateral reach distances by novice ladder users while standing on 6- and 12-ft stepladders.**
- **Initial maximum lateral reach distances were compared to those that occurred after limited practice. Although not statistically significant, novice users did reach 35 mm (~1.38 in.) after only ~15 minutes on the stepladder.**
- **Motivated maximum lateral reach distances were determined using a push-button task and encouragement to complete the task as quickly as possible. Such motivation led to a greater reach distance of 66 mm (2.50 in.).**
- **Findings indicate that workers can reach farther than is recommended for safe ladder use. Proper training and continuous reinforcement that safety supersedes task completion speed are key.**

A recent study of workers who were injured while using a ladder found that 51.3% reported standing and working on the ladder when the incident occurred (Lombardi, Smith, Courtney, et al., 2011). Furthermore, 51.0% of falls occurred while the individual was using a stepladder.

Stepladders have a large base of support and are traditionally formed in an "A" shape, with upper treads narrower than lower treads. Although guidelines recommend that the body remain within the rails of the ladder (the "belly button" or "belt buckle" rule), many falls occur because of lateral movement and extended reaching while performing a task. Injuries can occur because the individual loses balance and falls off the ladder, or because the ladder tips over, causing the individual to fall with it.

Numerous factors may interact to influence reaching behavior while working on a stepladder. For example, research indicates that the more familiar users are with a product, the less likely they are to look for or read warning information (Dorris & Purswell, 1977; Godfrey & Laughery, 1993). That is, users with greater familiarity of a product tend to perceive less of a hazard associated with its use, which, in turn, decreases the likelihood of their complying with associated safety precautions. Therefore, novice ladder users might be expected to take fewer risks than more experienced users and to increase their level of risk-taking as experience increases.

The proper working height required to safely complete a task will influence the height of the ladder selected. Research has shown that physical manifestations of anxiety are present for many individuals while at higher working levels. This anxiety detrimentally affects postural control (Davis, Campbell, Adkin, et al., 2009; Huffman, Horslen, Carpenter, et al., 2009) and will likely influence lateral reach distances. Many people use 4- and 6-ft stepladders to perform household chores. Low working heights such as these have a minimal effect on postural control and increased familiarity over time also may re-

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duce anxiety. Since the use of taller ladders is less common away from jobsites, it is supposed that the novice user would initially be more careful on taller ladders and, therefore, would not reach as far.

Training is another important factor. In their study, Lombardi, et al. (2011), indicated that 50% of the injured workers had less than 3 years' job experience and 62% had no on-site safety training. Without proper safety training, workers may not be aware of the repercussions associated with overreaching while working on a ladder. Direct experience or observations of others using a ladder may provide on-the-job training, but such learning can take time and the information gathered may be erroneous (e.g., watching a coworker overreach without falling). Ladder users must understand that having successfully overreached in the past (i.e., without falling) or having observed others doing so is no guarantee that they will not fall in the future; it may simply mean they were lucky.

Even with proper training, workers may have other motivations to overreach (e.g., "The faster I finish this job, the earlier I'll go home"). Workers may determine that it is worth not taking the time to climb down the ladder, reposition it and climb back up, especially if additional tools or equipment must be carried or moved. The company's attitude and priority placed on safety as dictated by coworkers and management as compared to productivity and rapid task completion also play an important role during this decision-making process.

Experiment

A laboratory study was conducted to explore the effects of acclimation (practice) and motivation (task completion) on lateral reach distances while working on a stepladder. The scope of the data presented here is limited to findings based on novice ladder users; these results should not be extrapolated to more experienced ladder users. The research team hypothesized that 1) reaches would be shorter on a higher ladder than on a lower ladder; 2) as novice users' experience (i.e., acclimation) working on a stepladder increased, their reaching would increase (reflecting decreased risk perception); and 3) novice ladder users would reach farther when motivated to do so.

Twenty-four male novice ladder users age 18 to 67, free of musculoskeletal injury and disease, were recruited. A participant was considered to be a novice if he had never used a ladder as part of employment or received training on proper ladder use and setup. Mean (*SD*) age, height and weight of the participants were 39.7 (*6.3*) years, 170.9 (*6.3*) cm and 85.5 (*26.5*) kg, respectively.

Uniform below-ankle hiking shoes (Nike Bandolier II) were provided to all participants. Before the experimental protocol was initiated, all participants completed an informed consent procedure approved by the Institutional Review Board. A full body harness attached to a belay system (a fall arrest system that used a rope and carabineer combination attached to an upright post bolted to the ground to create friction and prevent an individual from falling) was used to maintain participant safety throughout the experiment.

New Type 1A fiberglass 6- and 12-ft stepladders were used during the experiment (Photo 1). Extra-heavy-duty industrial ladders rated for up to 300 lb (Type 1A) were chosen since they are most commonly used in commercial settings such as construction sites. Motion capture markers were placed on the participant's body to identify the location of body segments. Additional markers were placed on the ladders to identify the location of rails and rungs relative to the body (e.g., reaching arm). Motion capture data were collected at 100 Hz using Motion Analysis System Eagle cameras and Cortex software (Santa Rosa, CA).

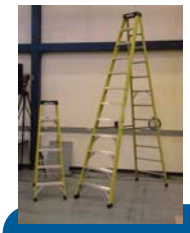


Photo 1: This experiment used 6-ft and 12-ft Type 1A fiberglass ladders.

Lateral reaches toward the right side of the ladder were performed while participants stood on the third rung from the top. For each ladder height, the order of which was randomly presented, a participant initially performed a lateral reach with the instructions to "reach as far as you feel comfortable." For the second trial, the participant was asked to "reach as far as you can." This trial established the initial maximum reach distance and was used to establish the lateral target locations used in the subsequent trials. *Reach distance* was defined as the distance from the ladder rail to the right wrist. The distance to the end of the hand was not used to determine reach distance so as not to influence the technique used to push the target by dictating which finger should be used.

A target (key from a computer keyboard) was placed at a vertical height midway between the right shoulder and elbow heights. A motivated maximum reach distance was determined using the target and a modified method of constant stimuli procedure. Participants were required to reach and press the target, which required a low level of force but some level of motor control (Photo 2). Participants were not allowed to lean on or brace against the target to maintain balance.

The target was placed closer to and farther from the ladder rail until a maximum motivated lateral reach distance was established. If the participant was able to reach the target, the subsequent reach distance was presented without substantial delay. If the participant felt he could not reach the target at the current location, the participant had to climb down from the ladder and perform a short card-sorting task. In this manner, the participant was motivated to reach for the target since the instructions implied that successful reaches would result in decreased time to complete the experiment. Each participant was paid a flat rate for completing the experiment so taking longer did not deliver a financial benefit.

Photo 2: A participant reaches toward the target from a 6-ft stepladder.

After the motivated maximum reach distance was determined, the target was removed and another unmotivated trial was performed. This reach distance, called the accli-

Photo 3 depicts the influence of acclimation (46 mm; 1.81 in.) and motivation (66 mm; 2.60 in.) on lateral reach distance.

mated maximum, was used to determine the effect of practice. Additionally, the distance from the participant's belly button to the ladder rail was measured.

Experimental Results

Data analysis indicated that the average maximum lateral reach distance was 66 mm (2.60 in.) shorter on the 12-ft stepladder than on the 6-ft ladder, whereas the distance of the belly button from the rail was only 46 mm (1.81 in.) shorter on the 12-ft ladder. An analysis of variance, controlling for any effect of age or participant, indicated that ladder height significantly affected both the lateral reach distance and the distance of the belly button from the rail ($p < 0.001$).

The total time to complete all trials comprising each condition was approximately 15 minutes. The acclimation and increased familiarity that occurred during this time led to a 35 mm (1.38 in.) increase in unmotivated reach distances for the two ladder heights combined and a 19 mm (0.75 in.) increase in the distance of the belly button from the rail. However, these differences were not found to be statistically different from the initial maximum distances.

Motivation, which was introduced by the concrete targeting task, generated an additional increase of 66 mm (2.60 in.) in reach distance as compared to the acclimated maximum reach distance. Therefore, participants reached 101 mm (3.98 in.) farther when performing a concrete task after a short period of acclimation. Similarly, the distance of the belly button from the rail increased 56 mm (2.20 in.) when participants were motivated by a concrete task. Thus, the total increase in the distance of the belly button from the rail was 75 mm (2.95 in.). Changes in distances due to motivation were statistically different from the initial maximum and acclimated distances.

Photo 3 is a graphical illustration of the effect of acclimation and motivation on lateral reach distance as compared to the length of the hand. The photo depicts data combined from both ladder heights. Figure 1 illustrates the differences in lateral reach distance for each condition and ladder height. Data trends were similar for the distance of the belly button from the side rail. The interaction between ladder height and reach condition (or belly button distance) was not found to be significant for either measure ($p = 0.999$, $p = 0.963$).

Guidelines recommend that the belly button not move past a ladder's side rail during reaching or working on a ladder in order to prevent overreaching and tipping. Therefore, movement of the belly button due to acclimation and motivation is not necessarily detrimental unless it causes excessive movement. Although ladder movement was observed during this experiment, all participants maintained enough control to prevent the ladder from tipping over. Table 1 indicates the number of participants whose belly button moved past the side rail during each condition and ladder height.

Interpretation of Results

Ladders are common equipment on many jobsites that workers may be familiar with and use regularly. Although falls from ladders occur frequently, workers continue to disregard safety guidelines and increase fall risk by overreaching while on a ladder. Many factors influence workers' behaviors on the jobsite, including risk perception, peer pressure and time constraints imposed by management.

Individuals who associate a high level of fall risk with working on ladders may be less inclined to overreach. Since anxiety caused by working at heights may affect postural control (Huffman, et al., 2009; Davis, et al., 2009), it is not surprising that novice users would be less willing to reach farther on a taller ladder. Several participants were comfortable on a ladder, as shown by their willingness to reach far enough to place their belly button outside the side rails without practice or motivation.

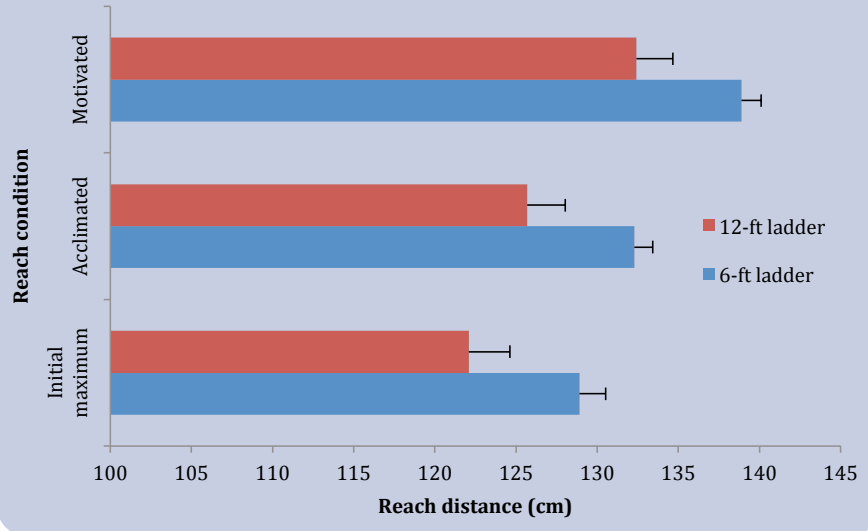
The effect of working at height, determined by ladder size in this experiment, becomes more apparent when individuals are asked to alter their initial behavior. More participants (9 for the 6-ft ladder, 3 for the 12-ft ladder) were willing to reach past the side rail after minimal practice while standing on the shorter ladder.

Although all participants could be motivated to reach past the side rail of the 6-ft ladder, 5 participants were still not comfortable placing their belly button outside the side rail while standing on the 12-ft ladder. These results may indicate a differing level of risk perception depending

Figure 1

Lateral Reach Distances

Lateral reach distances, as defined by distance from side rail of ladder to right wrist of participant, for each condition separated by ladder height.



on working height, but all work at elevation is potentially dangerous; therefore, individuals must be aware of and abide by safety guidelines regardless of working height. Often, an individual's assessment of risk is not adequate and may lead to unsafe behaviors.

While this study did not find a significant effect of acclimation, it should be noted that the time on the ladder was relatively brief (~15 minutes); it may be that greater effects would be observed over longer durations. Further research is necessary to answer this question.

It also is of interest to assess the ramifications of the changes in lateral reach distances as indicated by changes in forces beneath the ladder feet and reaching techniques used to extend reach distances (e.g., lifting opposite leg and only maintaining two points of contact with the ladder). Since the change in belly button distance and lateral reach distance were not the same, it is clear that participants were implementing different reaching techniques (i.e., altered body segment locations and angles). Some reaching techniques do not follow safe guidelines for ladder use and, consequently, increase the risk of a fall even if the ladder itself does not tip over.

The introduction of a concrete task and a time component had a significant effect on reaching distance. People generally want to complete tasks and do so in an efficient and timely manner. This desire may alter an individual's assessment of risk, leading that person to perform tasks that s/he may deem unsafe in other circumstances. This desire may be intensified in newer employees trying to impress coworkers and managers. Therefore, management and peers must clearly articulate that safety is a priority on the jobsite.

The scenarios used in the current experiment were designed to simulate real-world influences on workers, but the laboratory environment could not replicate the high levels of pressure placed on workers or the physical challenges that may occur during a work task (e.g., uneven surface underneath ladder, handling of a heavy tool). Real-world situations would be expected to intensify the effects found during this experiment. This makes it even more critical that workers abide by guidelines for working safely on a ladder.

Recommendations for Practitioners

Several participants initially performed reaches that would be defined as *safe* according to the belly button rule, even though they may not have been aware of the guideline. However, after minimal practice many of those individuals were reaching far enough for the belly button to surpass the rail; when motivation was applied, all participants surpassed the rail on the 6-ft ladder and most of them did so on the 12-ft ladder as well. These data indicate that novice ladder users are capable of overreaching even though they might be expected to lack the confidence of more experienced ladder users. Further research is needed to determine whether proper training and prioritization by management can convince ladder users to reach at a safe level even though it may be less than their capabilities.

Ladder-specific safety training is essential as is continuous reinforcement that safety is more important than task completion speed. The criticality of ladder usage is an important message since falls from ladders often produce serious injuries, leading to multiple lost workdays. This message must be reiterated often since the proportion of falls to use may be low. Emphasizing the history of injuries due to ladders on the jobsite may be beneficial.

Stepladders are prevalent on jobsites due to their compact nature and the relative ease with which they can be moved during a task or between jobsites. Manufacturers have attempted to modify designs and create accessories to enhance stepladder stability, but it is unclear whether these changes affect worker behaviors; it also is possible that safer designs and accessories may decrease workers' risk perception, encouraging workers to reach even farther and possibly fall. To prevent falls from ladders, particularly when training and warnings seem to be ineffective, alternative equipment (e.g., rolling scaffold) must be considered and incorporated into a job plan to complete tasks at elevation. **PS**

Table 1
At-Risk Reaching

The number of participants whose belly button moved past the side rail during lateral reaches for each condition and ladder height.

	6-ft ladder	12-ft ladder
Initial maximum	11	9
Acclimated maximum	20	12
Motivated maximum	24	19

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