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Self-reported risk taking predicts handrail use on a stepladder in older adults

Michelle Tsizhovkin [a], Jami X. Stuckey [a], Erika M. Pliner [b,1,2,*], Daina L. Sturnieks [b,c], Kurt E. Beschorner [a]

[a] Department of Bioengineering, University of Pittsburgh, 301 Schenley Place, 4420 Bayard Street, Pittsburgh, PA 15213, USA
[b] Falls, Balance, and Injury Research Centre, Neuroscience Research Australia, Randwick, NSW 2031, Australia
[c] Faculty of Medicine and Health, University of New South Wales, Sydney, NSW 1466, Australia

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ABSTRACT

Objective: Identify individual factors that predict handrail use and quantify the impact of handrail use on balance while using a stepladder. *Background:* Ladders are among the riskiest consumer products especially for older adults. Individual factors such as physiological capacity or risk-taking propensity have been found to influence safety behaviors and fall risk. When available, the use of a handrail is a common safety strategy for stabilizing balance. Thus, there is potential for individual factors to influence handrail use, and for their combined effect to influence balance while using a ladder. *Method:* Participants ($n = 104$) over 65 years completed physiological, cognitive, risk-taking, and stability assessments and were subsequently asked to undertake a lightbulb changing task using a stepladder. A force plate measured the center of pressure under the ladder and videos were analyzed to characterize participant handrail use during the task. Univariate and multivariate logistic regression analyses were performed to determine the individual factors associated with handrail use. The effect of handrail use (controlling for individual factors) on stability while completing the ladder task was analyzed. *Results:* Self-reported risk-taking was a predictor of handrail use, where a lower risk-taking score correlated with a higher probability of using the handrail. Individuals with poor balance were more likely to use the handrail, but self-reported risk-taking was a stronger mediator of handrail use. Neither the use of the handrail nor the individual factors were found to influence stability during the ladder task, suggesting a more complex relationship between individual behavior and physical ability on stability in hazardous working conditions. *Conclusion:* This study suggests that self-reported rating of risk-taking is associated with observable behaviors during ladder use. *Practical Application:* Such ratings may be useful in screening safety behaviors of older ladder users.

1. Introduction

Ladder falls commonly occur in households at a rate of approximately 1 per 1,000 people each year (Faergemann & Larsen, 2000). Compared with other consumer products, ladders are associated with a comparatively higher injury risk (Hayward, 1996). Ladder falls result in more severe injuries and adverse outcomes than other fall types (e.g., same-level fall due to a slip or trip) (Socias, Chaumont, Collins, & Simeonov, 2014) with fractures being a common injury associated with ladder falls (Shigemura et al., 2021). Older adults are more likely to experience a fatal injury involving a ladder (Dong, Wang, & Daw, 2012). Despite these risks, domestic ladder use is common among older adults (Hicks, Pliner, Lord, & Sturnieks, 2021).

Performing a work task is a major contributor to the loss of stability and falls from ladders (Cohen & Lin, 1991; Tichon, Baker, & Ojalvo, 2011; van Roden, George, Milan, & Bove, 2021). Stability is maintained by keeping the center of mass within the base of support (Pai & Patton, 1997). When standing on the ground, a loss of stability (i.e., the center of mass moving beyond the base of support) can be corrected by taking a compensatory step (Jensen, Brown, & Woollacott, 2001; Mansfield, Peters, Liu, & Maki, 2010) or applying force to an external object (Komisar, Nirmalanathan, King, Maki, & Novak, 2019; Komisar,

* Corresponding author at: 1495 E 100 S, Salt Lake City, UT 84112, USA.
E-mail address: erika.pliner@utah.edu (E.M. Pliner).
[1] Present address: Department of Mechanical Engineering, University of Utah, Salt Lake City, UT, 84112, USA.
[2] Rocky Mountain Center for Occupational and Environmental Health, University of Utah, Salt Lake City, UT, 84111, USA.

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Nirmalanathan, & Novak, 2018; Mansfield et al., 2010). A difference when standing on a ladder is that the fixed location of the rungs limits the user's ability to take a step to correct for a loss of stability. Furthermore, the compliance of the ladder destabilizes balance especially for older adults (Yang & Ashton-Miller, 2006). Fortunately, ladders are typically designed to allow the user to grasp a section of the ladder. Grasping provides multiple means of improving stability. Grasping provides sensory feedback that can enhance postural responses to correct sway, which has been demonstrated through the use of a cane (Jeka, 1997) or during light touch (Baldan, Alouche, Araujo, & Freitas, 2014; Clapp & Wing, 1999). Handrail use or ladder rungs also provides the opportunity to apply stabilizing forces that improve the postural response to external perturbations (Beschorner, Slota, Pliner, Spaho, & Seo, 2018; Komisar et al., 2019; Maki, Perry, & McIlroy, 1998). Applying force to an external object, such as a handrail on a stepladder, may be essential to support balance control (Komisar et al., 2019; Komisar et al., 2018) and can effectively extend the base of support (Borrelli, Komisar, Novak, Maki, & King, 2020). Furthermore, the orientation of a handrail (horizontal) on a stepladder enables the user to generate a high pulling force to stabilize their balance in the anterior direction (Seo, Armstrong, & Young, 2010). Thus, understanding the factors that influence grasping is relevant to understanding user risk during ladder use.

Given the role of physiological function, cognition, and risk-taking behavior (collectively referred to as individual factors hereafter) on fall risk (Butler, Lord, Taylor, & Fitzpatrick, 2015; Gleason, Gangnon, Fischer, & Mahoney, 2009; Lord, Menz, & Tiedemann, 2003; Ramirez, Wood, Becho, Owings, & Espino, 2010; Taylor, Lord, Delbaere, Mikolaizak, & Close, 2012) and ladder use (Hicks et al., 2021; Pliner, Sturnieks, Beschorner, Redfern, & Lord, 2021; Pliner, Sturnieks, & Lord, 2020) among older adults, these factors may also influence safety while undertaking tasks on a ladder. Ideally, poorer physiological function or cognitive abilities would coincide with a reduction in risk-taking, resulting in a caution level that is appropriate for a person's risk. When risk-taking behavior is not reduced in response to physiological or cognitive decline, the person may be incapable of safely completing balance challenging activities (Bégin et al., 2023; Butler et al., 2015), especially relevant in the context of ladder use, for which previous work has found older people frequently report unsafe ladder behaviors (Hicks et al., 2021). Participants who reported taking part in unsafe behaviors generally used the ladder more frequently, had better physical strength, fewer health problems, a reduced fear of falling, and engage in more risk-taking behaviors in daily activities (Hicks et al., 2021). Thus, there is a clear rationale for assessing the effect of risk-taking propensity on ladder use behavior in the context of a person's physiological and cognitive ability.

Older adults often hold on to handrails and apply an external force to sustain their balance during bathroom use, entering/exiting the bath or shower, and climbing stairs (Levine, Montgomery, & Novak, 2021; Novak, Komisar, Maki, & Fernie, 2016; Reeves, Spanjaard, Mohagheghi, Baltzopoulos, & Maganaris, 2008). While previous studies have focused on the role of handrail position (e.g., height and position) (Komisar et al., 2019; Komisar et al., 2018) on standing balance, fewer studies have examined the factors that contribute to whether a person makes the choice to use a handrail especially in tasks where the handrail is not necessary. Thus, identifying factors associated with handrail use could assist in identifying those at risk of falling from ladders.

This paper aims to examine how individual factors of cognitive function, physiological function, and risk-taking propensity influence handrail use. Another goal is to determine the impact of handrail use on standing stability while using a ladder when controlling for these individual factors.

2. Materials and methods

This research is a secondary analysis of a previously published study that reported on the individual factors that influenced the task performance, while using a ladder (Pliner et al., 2021). This research complies with the Declaration of Helsinki and was approved by the Human Research Ethics Committee at the University of New South Wales (HC17864). Informed consent was obtained from each participant.

2.1. Participants

Participants were recruited via advertisements, presentations, research registries, and word-of-mouth approaches. Eligibility was contingent on living independently at home or in a retirement community and participants' willingness to complete different ladder use tasks. Participants were excluded for the following reasons: mobility aid use inside the home, neurological disorders, weight exceeding 120 kg, and experiencing pain while changing a lightbulb.

2.2. Individual assessments

Individuals completed a series of physiological and cognitive assessments. The Physiological Profile Assessment (PPA) was used to characterize physiological factors associated with fall risk, including vision, peripheral sensation, muscle force, reaction time, and postural sway (Lord et al., 2003). A higher score indicates reduced physiological function and is associated with increased fall risk (Lord et al., 2003; Taylor et al., 2012). Cognitive function was measured by the Mini-mental State Examination (MMSE), wherein a lower score indicates poorer global cognition (Tombaugh & McIntyre, 1992), which is associated with increased fall risk (Gleason et al., 2009; Ramirez et al., 2010) and poorer task performance on stepladders (Pliner et al., 2021). Psychological factors were measured by the Risk Taking Behavioral Scale (RTBS), in which a higher score indicates a higher likelihood of taking risks (Butler et al., 2015). This risk assessment focused on everyday risk-taking situations, such as jaywalking or entering a dark room without turning on a light. The Coordinated Stability Test, CST, was used to assess balance (Lord, Ward, & Williams, 1996). In this test, participants moved a pen attached via a rod to a belt worn around the pelvis. The pen was maneuvered through a track that required that they move near the limits of their base of support. A score was assigned based on the number times that they failed to stay within the track or failed to reach a corner of the track. Higher CST score indicated worse balance control of the individual.

2.3. Experimental setup

A household stepladder with three steps was used for this study (Fig. 1). The stepladder had a handrail and a tray, where the replacement light bulb (Edison, screw-base) was set. The fixture holding the lightbulb, which was to be changed during the task, was adjustable for each participant to reduce the effect of height as a confounding factor. The height of the lightbulb socket was varied to ensure all participants could reach it using the same posture (i.e. the participant standing on the second step of the stepladder with 90° shoulder and elbow flexion). Videos of participants completing the task were recorded from posterior and lateral views.

Center of pressure (CoP) data were collected at 200 Hz using force plates beneath the front and back feet of the ladder. The 95% elliptical area was calculated from the CoP excursion. A larger elliptical area was interpreted as lower stability of the participant.

2.4. Procedure

Participants were instructed to change a lightbulb as quickly and safely as possible after climbing to the second step of the stepladder. Participants received no instruction on whether to use the handrail. Participants practiced unscrewing and screwing in a new light bulb on ground level prior to doing this task on the stepladder. This task was

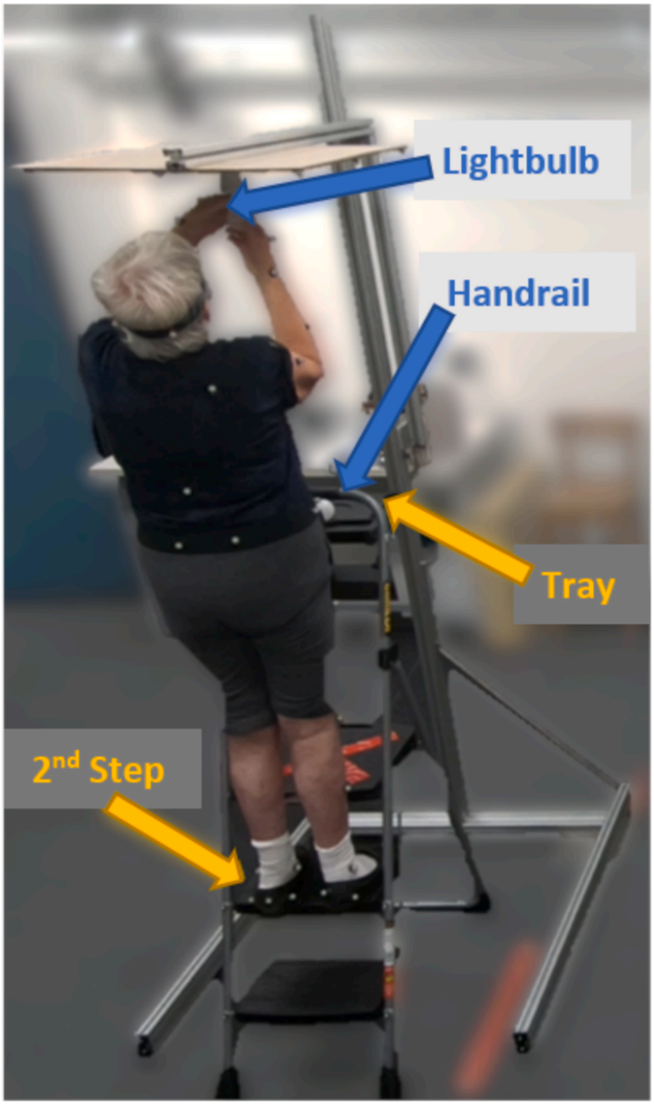

Fig. 1. Experimental Ladder Setup. Participants climbed to the second step and replaced a lightbulb. The replacement lightbulb was on a tray in front of the participant and a handrail was available as needed ahead of the participant.

performed twice: once without a cognitive distraction (single task) and once while naming animals (dual task). The order of these two tasks was randomized.

2.5. Data analysis

The video recordings of each participant undertaking the light bulb changing task were analyzed by two individual observers to assess the handrail use. Handrail use was categorized into heavy, light, or none. Heavy handrail use was defined as a power grip forming around the handrail to assist in load bearing. This was coded when the fingers and palm engaged with the handrail. Flexing of the forearm was often observed when this grip was observed. Light handrail use was coded when the hand(s) were observed on the handrail but without oppositional engaging of the fingers and palm. Additionally, light handrail use typically was accompanied by noticeably relaxed forearms. Handrail use was only measured during the light bulb changing task, not during ascent or descent. In the case that the two observers disagreed on handrail use, a third observer resolved the discrepancy (consensus was achieved across the observers in all cases so the third observer was never needed).

2.6. Statistical analysis

Following the characterization of handrail use across all participants, trials were dichotomized into a heavy handrail use category and no handrail use category. This was justified because light handrail use was considered to be ambiguous for stability and occurred less frequently than the other two use outcomes. It is ambiguous how light touch influences balance since some studies indicated that light touch can improve balance (Jeka, 1997), while other studies have indicated that touching a nearby surface without grasping did not improve recovery compared to cases where participants did not use any external support (Levine, Montgomery, & Novak, 2023). Only the dual task condition (changing the lightbulb while naming animals) was considered in this study because dual tasking is more challenging and may divert cognitive resources used for balance control (Hofheinz & Schusterschitz, 2010; Menant, Schoene, Sarofim, & Lord, 2014; Muir-Hunter & Wittwer, 2016).

All analyses were performed using statistical software JMP Pro 14, SAS Institute, Cary, NC. A significance level of 0.05 was used. CST was square root normalized in all analyses to correct for positive skew in the data.

To investigate the effect of individual factors on handrail use, univariate logistical regressions were performed with each of the four individual factors as a predictor (PPA, RTBS, MMSE, CST) and handrail use as the dependent variable (using the χ^2 test statistic). For significant factors in the logistic regression analysis, odds ratios were calculated to estimate the effect size. The change in the regressor variable used to calculate the odds ratio was the interquartile range (i.e., the odds of handrail use for a person in the 75th percentile relative to a person in the 25th percentile). This enabled us to characterize the effect size of the regression line across the middle half of our participants. A multivariate analysis that included all four individual factors as the regressors and handrail use as the dependent variable was also performed to investigate the combined influence of individual factors on handrail use. To determine the effects of handrail use on stability while controlling for the individual factors, the four individual factors and the first-order interactions between handrail use and these individual factors were included as control variables in the multivariate model. Prior to this analysis, bivariate correlation analyses between handrail use and each individual factor (point biserial correlation) were performed. If the correlation was high ($|r|>0.5$), that individual factor and the interaction in the multiple regression model would be excluded.

Table 1
Mean (standard deviation) values for participant demographics and individual factors.

	All	Grasped Handrail	Did not grasp handrail
Demographic Factors			
Age (years)	72.9 (5.3)	74.5 (5.7)	71.4 (4.6)
Height (m)	1.7 (0.1)	1.7 (0.1)	1.7 (0.1)
Body mass (kg)	73.4 (14.2)	73.8 (13.9)	73.0 (14.6)
Individual Factors			
CoP Elliptical Area (mm^2)	1400 (950)	1230 (910)	1560 (970)
PPA[a] (score)	0.522 (0.821)	0.703 (0.866)	0.346 (0.745)
RTBS[b] (score)	23.9 (4.7)	21.6 (4.1)	26.3 (4.1)
MMSE[c] (score)	28.4 (1.4)	28.2 (1.5)	28.6 (1.3)
CST[d] (score)	5.3 (6.7)	6.9 (7.4)	3.7 (5.7)

[a] PPA: Physiological Profile Assessment.
[b] RTBS: Risk Taking Behavioral Scale.
[c] MMSE: Mini-mental State Examination
[d] CST: Coordinated Stability Test.

3. Results

A total of 104 older adults (52 females) participated. Characteristics of these participants are described in Table 1. Of these participants, 15 were excluded due to missing or poor-quality video data during the ladder testing (typically due to the individual obstructing the view of their hands). Heavy handrail use was utilized by 35 participants, light handrail use was utilized by 18 participants (excluded from the statistical analyses), and the handrail was not used by 36 participants (71 participants were used in the logistic regression analyses). The bivariate correlation analyses (between PPA, RTBS, MMSE, and CST) and point biserial correlation (between each of the previously mentioned factors and handrail use) revealed no correlation coefficients with a magnitude above 0.5 (Table 2). Therefore, no factors were excluded from the multivariate analyses. Center of pressure data was missing for 3 participants leading to 68 participants being included for the analyses to assess the relationship between handrail use on stability.

In the univariate models, RTBS was associated with handrail use ($p < 0.001$) (Table 3). The odds ratio of increased handrail use for each point in RTBS was 0.755 (95% confidence interval: 0.654 to 0.877) and the odds ratio of handrail use from the first quartile to third quartile of RTBS score was 0.140, suggesting that increased risk-taking was strongly associated with less handrail use (Fig. 2). CST was also correlated with handrail use ($p = 0.034$). A higher CST score (indicating worse balance) was associated with more frequent handrail use, the odds ratio going from the first quartile of coordinate stability values to the third quartile was 1.43. Neither PPA ($p = 0.062$) or MMSE ($p = 0.153$) were associated with handrail use.

In the multivariate model assessing the impact of individual factors on handrail use, only RTBS significantly affected handrail use ($p < 0.001$) (Table 3). Interestingly, CST ($p = 0.818$) was not significantly associated with handrail use after controlling for the other individual factors. Similar to the univariate analyses, PPA ($p = 0.385$) and MMSE ($p = 0.228$) were not significant predictors of handrail use in this multivariate model.

The multiple regression model (i.e., effect of handrail use, individual factors, and selected interaction factors on elliptical area) revealed that handrail use when controlling for the individual factors did not predict the CoP elliptical area (Table 4). The entire multivariate model was also not predictive of CoP elliptical area ($F_{9,58} = 1.02$, $R^2 = 0.136$, $p = 0.438$).

4. Discussion

This study examined relationships between individual factors and handrail use while undertaking a task on a stepladder. The results suggest that increased self-reported risk-taking (RTBS) during daily life activities (e.g., jaywalking, or not turning on a light at night when walking from one room to another) is associated with reduced handrail use on a stepladder. Of the other individual factors (physiological factors measured by PPA, cognitive function measured by MMSE, and balance measured by the CST) only balance (CST) was related to handrail use in the univariate, yet not in the multivariate model. Neither handrail use nor individual factors were associated with stability (quantified by elliptical area), while completing the work task on the ladder.

The results of this study are consistent with some studies but inconsistent with other studies on risk-taking and protective behaviors, which may suggest that the way in which risk-taking generalizes to personal safety may be context dependent. Inconsistent with our findings, prior research observed that lower self-reported risk-taking (using the same questionnaire as the current study) was associated with selecting a more dangerous but faster walking path (i.e., took more behavioral risk) (Butler et al., 2015). This prior study suggested that certain participants simultaneously lose physical function and the ability to assess function. One potential reason that the current study did not observe the same trend as this previous study may be a difference in populations. The present study screened participants to ensure they were comfortable using ladders and may have excluded some older and lower functioning adults. Participants in the present study had a mean age of approximately 4 years younger than Butler et al. (2015). Several studies have found that increased risk-taking behaviors such as ignoring personal health (e.g., eating foods after their expiration date), gambling, and sensation/excitement seeking (desiring novel and intense stimuli) correlated with a higher likelihood of taking risks while driving and subsequently a higher risk of getting in a car crash or receiving an infringement ticket (Bhatti, Thiruchelvam, & Redelmeier, 2019; Schwebel et al., 2007; Wang, Rau, & Salvendy, 2011). One potential reason for the context-dependency of risk taking on behavior may be related to the novelty and complexity of the task. Driving and ladder use are both familiar and routine tasks that can be assessed based on prior experience. However, the task suggested in Butler et al. required participants to select a path across varying danger levels of paths, which requires evaluating risk in a novel and more complex scenario. Thus, the observed effects may generalize best for familiar and routine activities.

This study adds to a growing body of evidence that psychological

Table 2
Correlation coefficients across regressors.

PPA[a]	RTBS[b]	MMSE[c]	CST[d]	
0.219	−0.498	−0.167	0.249	Handrail Use[e]
	−0.186	−0.157	0.480	PPA[a,f]
		0.111	−0.339	RTBS[b,f]
			−0.088	MMSE[c,f]

[a] PPA: Physiological Profile Assessment.
[b] RTBS: Risk Taking Behavioral Scale.
[c] MMSE: Mini-mental State Examination
[d] CST: Coordinated Stability Test.
[e] Point biserial correlation analyses is reported in this row.
[f] Pearson correlation coefficients are reported in these rows.

Table 3
Univariate and multivariate logistic regression analyses examining the impact of individual measures on handrail use.

Individual Measure	$\chi^2_{(1)}$	p-value	Unit change odds ratio (95% confidence interval)[a]	1st to 3rd quartile odds ratio (95% confidence interval)[b]
Univariate				
RTBS[c]	20.1	<0.001	0.755 (0.654 to 0.877)	0.140 (0.051 to 0.400)
CST[d]	4.5	0.034	N/A[e]	2.762 (1.044 to 7.316)
MMSE[f]	2.0	0.153	1.823 (0.549 to 1.106)	0.384 (0.100 to 1.472)
PPA[g]	3.5	0.062	1.749 (0.956 to 3.195)	1.749 (0.956 to 3.195)
Multivariate[h]				
RTBS	16.44	<0.001	0.753 (0.637 to 0.885)	0.137 (0.043 to 0.425)
CST	0.05	0.818	N/A[e]	2.763 (0.317 to 4.285)
MMSE	1.55	0.213	0.779 (0.490 to 1.185)	0.384 (0.065 to 1.915)
PPA	0.77	0.382	1.749 (0.654 to 3.03)	1.749 (0.654 to 3.03)

[a] Odds ratios per a unit change in the individual measure.
[b] Odds ratios across the interquartile range of the individual measure.
[c] RTBS: Risk Taking Behavioral Scale.
[d] CST: Coordinated Stability Test.
[e] Unit change odds ratio not conducted for CST because the applied transformation makes this unit change odds ratio vary across the range of values.
[f] MMSE: Mini-mental State Examination
[g] PPA: Physiological Profile Assessment.
[h] The multivariate model included all 4 individual measures and no other control variables.

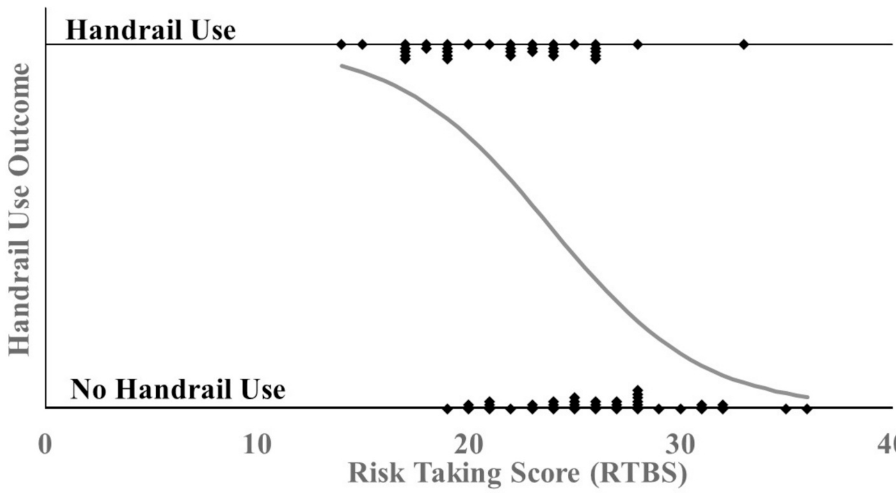

Fig. 2. Higher risk-taking score (RTBS) is associated with reduced handrail use. Each point represents an individual participant. The points are stacked so that the number of points at each score can be determined. The x-coordinate of each point represents that individuals Risk Taking Score (RTBS). Points stacked at the top of the graph indicate participants who used the handrail while those stacked at the bottom of the graph indicate those that did not use the handrail. The gray line represents the logistic regression fit line.

Table 4
Statistical analyses for the effects influencing CoP elliptical area.

Individual measures	F-value	p-value
PPA	$F_{1,58} = 0.00$	0.985
RTBS	$F_{1,58} = 2.92$	0.093
MMSE	$F_{1,58} = 1.44$	0.235
CST	$F_{1,58} = 0.10$	0.758
Handrail Use	$F_{1,58} = 0.82$	0.368
Handrail Use * PPA	$F_{1,58} = 0.43$	0.517
Handrail Use * RTBS	$F_{1,58} = 0.13$	0.725
Handrail Use * MMSE	$F_{1,58} = 0.27$	0.604
Handrail Use * CST	$F_{1,58} = 1.21$	0.276

factors are relevant to ladder fall risk. Prior research has indicated that risk taking score (using the same scale and participants as the present study) predicts unsafe ladder use behaviors (Hicks et al., 2021). Furthermore, ladder reaching behavior has been shown to be influenced by available risk indicating that the situation may impact someone's propensity to accept higher risk (Williams, Beschorner, Sturnieks, Lord, & Pliner, 2022). The present study indicates a more subtle form of protective behavior by measuring whether the participant used the handrail to stabilize their balance, while completing a task. Participants with less risk tolerance may have prioritized safety over speed by grasping the handrail instead of having both hands available to assist with the task. Although this study did not find that grasping the rail altered CoP excursion, grasping the rail still likely offered important benefits for controlling balance (Kouzaki & Masani, 2008; Rogers, Wardman, Lord, & Fitzpatrick, 2001) and protection if a balance perturbation was experienced (Komisar et al., 2019; Komisar et al., 2018; Mansfield et al., 2010). This study, when considered in the context of this growing body of evidence, suggests a role for research that simultaneously considers psychological and biomechanical factors on ladder fall risk. Finally, this study provides additional justification to apply risk-taking assessments for older adults who still use ladders.

A noteworthy limitation of this study is excluding light handrail use from this analysis and only focusing on heavy handrail use and no handrail use. Light handrail use may give the user spatial awareness that contributes to their stability even if they did not apply substantial forces (Baldan et al., 2014; Clapp & Wing, 1999). Furthermore, a substantial portion of the data (n = 15) was excluded due to insufficient video to reliably categorize the handrail response. These limitations may inform future experimental designs when observing the hand behavior during ladder use tasks.

5. Conclusion

In conclusion, our findings demonstrate that self-reported risk-taking may predict the use of a handrail while changing a lightbulb on a stepladder. This study provides the first evidence of how psychological risk-taking influences grasping behaviors during ladder use. Improved identification using these profiles may enable screening of at-risk ladder users and eventually allow the targeting of interventions to higher risk individuals.

CRediT authorship contribution statement

Michelle Tsizhovkin: Validation, Formal analysis, Writing – original draft, Conceptualization. **Jami X. Stuckey:** Formal analysis, Conceptualization, Validation. **Erika M. Pliner:** Writing – review & editing, Methodology, Formal analysis, Supervision, Investigation, Data curation, Project administration, Funding acquisition, Conceptualization. **Daina L. Sturnieks:** Writing – review & editing, Methodology, Supervision, Data curation, Resources, Conceptualization. **Kurt E. Beschorner:** Supervision, Writing – review & editing, Formal analysis, Visualization, Conceptualization.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Michelle Tsizhovkin was an undergraduate researcher at the University of Pittsburgh during the completion of this work. She received a BS in Bioengineering from the University of Pittsburgh in 2022. She is currently a Program Manager at SK pharmteco.

Jami X. Stuckey was an undergraduate researcher at the University of Pittsburgh during the completion of this work. She received a BS in Bioengineering from the University of Pittsburgh in 2023. She is currently pursuing a nursing degree at Allegheny Health Network Schools of Nursing.

Erika M. Pliner is an Assistant Professor of Mechanical Engineering at the University of Utah. She received her PhD in Bioengineering at the University of Pittsburgh in 2020.

Daina L. Sturnieks is a Senior Lecturer in Anatomy at UNSW Medicine and Conjoint Senior Research Scientist at NeuRA. She received her PhD in Human Biomechanics at the University of Western Australia in 2004.

Kurt E. Beschorner is an Associate Professor of Bioengineering at the University of Pittsburgh. He received his PhD in Bioengineering at the University of Pittsburgh in 2008.