Research Article

Ability Versus Hazard: Risk-Taking and Falls in Older People

Annie A. Butler, Stephen R. Lord, Janet L. Taylor, and Richard C. Fitzpatrick

Neuroscience Research Australia and University of New South Wales, Sydney, Australia.

Address correspondence to Richard C. Fitzpatrick, BSc, MBBS, PhD, MD, Neuroscience Research Australia, Barker St, Randwick, NSW 2031, Sydney, Australia. Email: r.fitzpatrick@unsw.edu.au

Abstract

Background. Among older people, undue risk taking could lead to falls, irrespective of physical ability. We investigated the interaction between risk-taking behavior and physical ability and its contribution to falls.

Methods. Participants (N = 294, age ≥ 70) were asked to walk as quickly as possible to a visible destination by choosing one of six paths. Each contained a raised plank that had to be walked along without falling. The shortest path had the narrowest and tallest plank and the longest had the widest and lowest. Behavioral risk was defined as the probability of falling off the chosen plank. This was estimated from a ground path walking task because, for safety, participants were stopped before crossing the plank. Self-reported everyday risk-taking behavior, fear of falling, physical functioning, and 1-year prospective fall rates were measured.

Results. Older participants and those with poor physical ability chose easier planks to cross. Participants with good physical ability consistently took a slight behavioral risk, whereas those with poor physical ability took either very-high behavioral risks or chose the overly safe path with no risk. Unexpectedly, participants reporting cautious behavior on the everyday risk-taking behavior scale took greater behavioral risks. Independent of physical performance, behavioral risk was significantly associated with falls during the subsequent year.

Conclusions. Assessing behavioral choice in relation to physical ability can identify risk-taking but neither the difficulty of a chosen action nor self-reports of risk-taking behavior are sufficient. Risk-taking behavior is an independent risk factor for falls and management of undue risk-taking might complement existing fall prevention strategies.

Key Words: Risk-taking behavior—Balance—Physiological function—Falls.

Decision Editor: Stephen Kritchevsky, PhD

Risk-taking personality traits are prevalent in people of all ages (1). In older people, a propensity to act despite the likelihood of significant adverse outcomes relative to benefit might develop from a failure to adapt behavior in accord with age-related declines in sensorimotor performance (2–4). Cognitive impairment, which is often coupled with physical functional decline, could also diminish the ability to make decisions that are appropriate for ability (5).

Among older people, falls are the most common cause of injury death and nonfatal injuries requiring hospital admission (6). Fall risk assessments have been primarily directed toward identifying physical, medical, and environmental risk factors (7,8) and more recently, reduced executive function and concern about falling have been identified as behavioral risk factors (9–13).

How psychological traits such as impulsivity and risk-taking predispose older people to falls is uncertain? Factors possibly related
such as hurrying, carelessness, and inattention have been identified as apparent causes of falls by questionnaire (14–16). However, risk estimates could be inaccurate (17) if they do not examine the risk taken in relationship to physical ability and task difficulty.

In this study, we presented older people with the task of walking as quickly as possible to a visible destination by choosing one of six paths that contained a raised plank (a plank crossing choice task). Choosing a shorter, more direct path meant taking a greater risk of falling from a more difficult plank, while choosing a longer, less direct path meant taking a lower risk of falling from a less difficult plank. The individual behavioral risk taken was determined by comparing the path choice with balance ability assessed with a ground path walking task. In this way we could calculate the likelihood of success in crossing the chosen plank as an objective measure of behavioral-risk taking, and in a prospective study design, determine whether it is a significant risk factor for falls.

The first hypothesis was that behavioral risk is a significant predictor of falls after adjusting for predisposing physiological factors in older people. The second hypothesis was that behavioral risk is significantly associated with self-reported risk taking in everyday life and concern about falling.

Methods
Participants
Three hundred people (mean age = 77.4 years [SD = 4.6], 157 female) participated in this study. They were recruited from 1,037 cognitively intact, community-dwelling men and women living in Eastern Sydney who participated in the Sydney Memory and Ageing Study (MAS, Wave 1) that began in January 2006 and was completed by October 2007 (18). The MAS exclusion criteria were: diagnosed dementia as determined by DSM-IV or a Mini-Mental State Examination score <24 after adjustment for age and educational level, and inability to speak and understand English. For this sub-study, participants with neurological or cardiovascular conditions or major musculoskeletal impairment that precluded walking 20 m without a walking aid were also excluded. The sample size was chosen conservatively so as to provide at least 20 outcome cases (fallers) for up to five variables entered as covariates in multivariate models.

Approval for the study was obtained from the University of New South Wales Human Research Ethics Committee and all participants gave written informed consent prior to participation.

Measures
Plank crossing choice task
Within a gait laboratory, participants were asked to choose between six footpaths that included a plank (labeled 0–5) that had to be walked along to reach a common goal as quickly as possible (plank crossing choice task; Figure 1A). The target and full length of each path was visible from the start point. The paths ranged from short but difficult to long but easy. The shortest path required crossing via a narrow, tall plank (#5), whereas the longest path required walking 4.5 times as far but crossing a wide, low plank (#0). The length, height, and width of each plank were selected to give a range of difficulties using a simple proportional model: difficulty = length x height/width and normalized such that the most difficult plank (#5: 21 cm high, 5 cm wide, 2.4 m long) had a difficulty score of unity. Successive planks were each approximately half as difficult giving plank #1 (7 cm high, 23 cm wide, 3.7 m long) a relative difficulty of 0.11 (see Supplementary Material for the dimensions of all planks and the calculation of risk vs. benefit for each plank choice). The benefit of choosing a more difficult plank was travelling a shorter distance. With the shortest path (#5, most difficult) assigned a benefit of unity, paths 1–4 were rated: benefit = 1 minus the extra distance. The lengths of paths 1–5 were set to keep the difficulty/benefit ratio constant. The easiest path (#0) was the exception to this scaling. It was a “default” choice, made excessively easy relative to distance so that even the most cautious and unsteady would participate.

Participants were informed that the task was a walking balance study and were instructed to “choose a path to reach the end target as quickly as possible.” However for safety reasons, they started the walk but were stopped as they were about to step onto their plank, and their choice was recorded.

Ground path walking task
As participants did not actually cross the plank they chose, a separate test of walking balance (ground path walking task) was used to calculate behavioral risk; the likelihood that they would have fallen from their chosen plank. Participants walked along a narrow ground path (10 m long, 18 cm wide; Figure 1B) and were instructed to keep within the edges of the path. The experimenter recorded by direct observation of the distribution of lateral foot placement as steps within the lines, on the lines (one error point), or outside the lines (three error points). Physical ability to perform the ground path walking task was scored as errors per step.

Calculation of behavioral-risk taken
To determine the probability of a participant falling from a plank (behavioral risk) the proportion of steps outside, on, and within the lines during the ground path walking task were fitted with a Lorentzian distribution (Figure 1C). This distribution was chosen because it is non-asymptotic, bounded, and theoretically consistent with the physical limits of lateral foot placement (set 50 cm). It fitted the data closely (median individual cumulative sum $r^2 = .98$, group $r^2 = 1.00$). Using this distribution, the width of the chosen plank, the predicted number of steps to cross it, and an average foot width (10 cm), the probability of each person falling ($P_{fall}$) from their chosen plank was calculated as $P_{fall} = 1 - P_{survive}^{jump}$. $P_{survive}$ is the probability of surviving each step and steps is the predicted number of steps to cross the plank based on individual mean step length in the ground path walking task and the length of the chosen plank (Figure 1D).

This probability ($P_{fall}$) was the measure of behavioral risk. Thus, a person with good physical function who chose to cross a more difficult plank could have the same behavioral risk as a person with poor physical function who chose an easier plank. Alternatively, a person with good physical function who chose the same plank as a person with poor physical function would have a lower behavioral risk of falling from that same plank. Please see Supplementary Material for further details of the behavioral risk calculation.

Physiological fall risk
Seven measures of physiological function related to balance were recorded: (i) lower-limb proprioceptive sense, (ii) quadriceps muscle strength, (iii) simple reaction time, (iv) visual contrast sensitivity, (v) postural sway during standing, (vi) visual acuity, and (vii) lateral balance in tandem stance (19). A combined weighted score of the first five of these measures can provide an estimate of physiological fall risk (20). From these data, participants were classified as having a low or high falls risk using a cut point that best discriminated fallers from nonfallers determined by the Youden Index.
Everyday risk-taking and Falls Efficacy

A 10-item self-report Everyday risk-taking scale was also administered (see Supplementary Material and modified version in Kwan and coworkers [21]). Answers were scaled from 1–4 (cautious-risky behavior) and tallied to create an Everyday risk-taking score across activities. Principal component analysis of responses with oblique rotation discriminated three factors. Factor 1 (accounting for 21.3% of variance) reflected daringness as a pedestrian and using public transport (crossing against lights to catch a bus, running to catch a bus, crossing on don’t walk, standing on a bus). Factor 2 (20.7%) reflected balance tasks around the home (using stairs without handrail, standing to put on shoes). Factor 3 (12.8%) included using escalators, climbing on chairs, moving around home without a light at night. Reliability analysis showed the combined questions to have good internal consistency (Cronbach’s $\alpha = .7$) and test–retest reliability as assessed in a subgroup of 40 participants was excellent (Intraclass Correlation Coefficient $[ICC]_{3,1} = 0.85; 95\%$ CI 0.71–0.92). The Falls Efficacy Scale-International (FES-I) was used to measure concern about falling (22).

Falls

Falls were defined according to the consensus definition of “an unexpected event in which the participant comes to rest on the ground, floor, or lower level” (23) and monitored for 12 months after testing with monthly return-mail calendars and follow-up telephone calls as necessary. For analysis, participants were classified as fallers (one or more falls during the follow-up period) or nonfallers.

Statistical Analysis

Stepwise multiple regression was used to determine predictors of plank choice. As behavioral risk scores and ground path walking task performance were not normally distributed, participants were divided into behavioral risk and ground path walking task performance quartiles for analysis. To test our primary hypothesis, modified Poisson regression was performed to determine whether behavioral risk (as a continuous variable) was an independent risk factor for falls status (ie, fallers vs. nonfallers) when adjusting for physiological fall risk (20). This regression procedure is analogous to logistic regression, but provides relative-risk statistics instead of odds ratios.

Results

Demographic, medical, and test outcome measures for the particpants categorized as fallers and nonfallers are presented in Table 1.

Plank Crossing Choice Task

Plank choice was centrally distributed with men choosing more difficult planks to cross (2.2 [2.0–2.4] than women (1.6 [1.4–1.8]; $p < .001$, univariate ANOVA). Plank choice difficulty was inversely associated with age ($r = -0.25, p < .001$) and concern about falling as assessed with the FES-I ($r = -0.29, p < .001$).

Ground Path Walking Task

Participants took a mean of 19.6 steps ($SD = 4.1$) to walk the 10-m ground path walking task. They stepped on the path edge 4.3 (5.8)
### Table 1. Prevalence of Major Medical Conditions, Medication Use, and Outcome Measures in the Study Population for the Nonfallers and Fallers

<table>
<thead>
<tr>
<th>Variable</th>
<th>Nonfaller (N = 153)</th>
<th>Faller (N = 141)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Demographic factors</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gender—female [n (%)]</td>
<td>84 (54.9)</td>
<td>73 (51.8)</td>
</tr>
<tr>
<td>Age—mean (95% CI)</td>
<td>77.4 (76.6–78.1)</td>
<td>77.3 (76.6–78.1)</td>
</tr>
<tr>
<td><strong>Health and medical conditions [n (%)]</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Previous stroke</td>
<td>3 (2.0)</td>
<td>6 (4.3)</td>
</tr>
<tr>
<td>Arthritis</td>
<td>79 (51.6)</td>
<td>83 (59.0)</td>
</tr>
<tr>
<td>Diabetes</td>
<td>15 (9.8)</td>
<td>15 (9.8)</td>
</tr>
<tr>
<td>Psychoactive medications</td>
<td>15 (9.8)</td>
<td>17 (12.1)</td>
</tr>
<tr>
<td>Four plus medications</td>
<td>101 (66.0)</td>
<td>83 (59.0)</td>
</tr>
<tr>
<td>Previous falls</td>
<td>27 (17.6)</td>
<td>21.4 (19.4–22.1)</td>
</tr>
<tr>
<td>Used a walking aid outside</td>
<td>8 (5.2)</td>
<td>18 (12.8) †</td>
</tr>
<tr>
<td><strong>Outcome measures</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Plank choice—mean (95% CI)</td>
<td>1.98 (1.78–2.18)</td>
<td>1.74 (1.54–1.94)</td>
</tr>
<tr>
<td>Ground path walking task—median interquartile range (IQR)</td>
<td>0.15 (0.22–0.38)</td>
<td>0.25 (0.08–0.51)*</td>
</tr>
<tr>
<td>Everyday risk-taking scale—mean (95% CI)</td>
<td>21.4 (20.6–22.1)</td>
<td>20.2 (19.4–21.0) †</td>
</tr>
<tr>
<td>Physiological fall risk—high [n (%)]</td>
<td>82 (53.6)</td>
<td>95 (67.4) †</td>
</tr>
<tr>
<td>FES-I scores—median (IQR)</td>
<td>20 (18–23)</td>
<td>21 (19–27.3)*</td>
</tr>
</tbody>
</table>

**Notes:** Differences among groups assessed using ANOVA and chi-square tests for cross-tabulation tables and Mann–Whitney U tests for nonparametric data. *p < .001, †p < .01, *p < .05.

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Times and completely outside the path 0.7 (1.4) times (median errors per step 0.2, interquartile range [IQR] 0.1–0.5). Poorer performance in the ground path walking task was significantly associated with age (r = .26, p < .001) but did not differ between men and women (p = .43, Mann–Whitney U test). Poorer ground path walking performance was associated with other physiological indicators of poor balance function including increased postural sway standing on a foam surface (r = .16, p = .006), increased lateral sway in tandem stance (r = .35, p < .001), decreased knee extension strength (r = .19, p = .001), reduced visual contrast sensitivity (r = .21, p < .001), and poor visual acuity (r = .14, p = .02).

Participants who performed poorly in the ground path walking task chose easier planks and this measure was the strongest predictor of plank choice in a stepwise regression analysis (β = −.34, p < .001), which also included gender (β = −.25, p < .001) and age (β = −.17, p = .001).

**Behavioral Risk**

Demographic and outcome measures for the total sample categorized into five behavioral risk groups are presented in Table 2. Behavioral risk could not be calculated for the 42 (14.3%) participants who chose to walk to the default plank because it had been designed with effectively zero risk and therefore was not on the same continuum as the other planks. These participants were older, reported a high concern about falls, performed poorly in several physical tests (ground path walking, quadriceps strength, postural sway, reaction time) and suffered a high rate of falls (57%) in the follow-up year. The remaining 252 participants were divided into behavioral risk quartiles (low, medium, high, very high).

Behavioral risk for the remaining 252 participants ranged from almost 0 for those who chose an easy plank relative to their ability in the ground path walking task, to 0.92 (median 0.16, IQR 0.04–0.38). Of those who did not choose the default plank, ~20% took a behavioral risk of <0.03, whereas 33% took a behavioral risk of >0.3 (Figure 2A).

The spread of behavioral risk taken was similar across the different planks in the plank crossing choice task (p = .77, Kruskal–Wallis) and men tended to take greater risks than women (median 0.21 vs 0.15; p = .058, Mann–Whitney U test). The best performers in the ground path walking task took lower behavioral risks (range 0.01–0.12), whereas the poorest performers took high behavioral risks (0.23–0.92, p < .001, Kruskal–Wallis test).

### Associations Between Behavioral Risk and Self-Reported Everyday Risk Taking

High scores on the Everyday risk-taking scale were associated with more difficult plank choices (r = .45, p < .001), better performances in the ground path walking task (r = .38, p < .001), younger age (r = −.20, p = .001), male gender (p = .008), and lower FES-I scores (r = −.54, p < .001). In contrast to hypothesis, participants who took higher behavioral risks in the plank crossing choice task reported significantly more cautious behavior on the Everyday risk-taking scale (p < .05, ANOVA, post hoc Fisher’s least significant difference; across the behavioral risk groups). There was also a tendency for those with an increased concern about falling (high FES-I score) to have higher behavioral risks (p = .17, Kruskal–Wallis test).

### Falls

Of the 294 participants available for follow-up, 141 (48%) fell one or more times in the 12-month follow-up period. The proportion of fallers increased significantly across the four ground path walking task performance groups (p = .042, χ² across groups). Similarly, more fallers than nonfallers had high physiological fall risk scores (54% vs 39% respectively; p = .016, χ²).

Falls were also associated with behavioral risk (p = .016, χ²) and higher behavioral risk remained a significant predictor of falls after adjusting for physiological fall risk, (RR = 2.38, 95% CI 1.05–5.41, p = .005, modified Poisson regression, Figure 2B).

Despite the higher fall rate during follow-up for participants who took high behavioral risks in the plank crossing choice task, those who fell had significantly lower scores on the Everyday risk-taking scale (p = .030), indicating a subjective view that they were cautious and took low risks.
In this study, behavioral risk was significantly associated with prospective fall incidence independent of physiological fall risk. That is, fall rates were lower among participants who made behavioral choices that matched their physical ability and higher in those who overestimated their physical abilities and undertook undue risks.

Self-reports of ability and behavior often disagree with objective testing and observation (17,24). It is clear in this study that self-reporting everyday risk-taking activity did not reflect the everyday risk-taking level of behavior. The greatest objective risk-takers (those with the highest behavioral risk) reported the lowest subjective levels of everyday risk-taking activity, suggesting these people inappropriately overestimated their ability when assessing behavioral risk.

Table 2. Demographic and Outcome Measures for the Total Sample Categorized into Five Behavioral Risk Groups

<table>
<thead>
<tr>
<th>Variable</th>
<th>No Risk/Default (n = 42)</th>
<th>Low (n = 63)</th>
<th>Some (n = 63)</th>
<th>High (n = 63)</th>
<th>Very High (n = 63)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gender—female [n (%)]</td>
<td>29 (69.0)</td>
<td>35 (55.6)</td>
<td>33 (52.4)</td>
<td>36 (57.1)</td>
<td>24 (38.1)</td>
</tr>
<tr>
<td>Age—mean (95% CI)**</td>
<td>79.1 (77.7–80.5)</td>
<td>75.5 (74.3–76.6)</td>
<td>77.3 (76.2–78.4)*</td>
<td>77.4 (76.3–78.5)*</td>
<td>78.1 (77.0–79.2)*</td>
</tr>
<tr>
<td>Plank choice—mean (95% CI)</td>
<td>0</td>
<td>2.51 (2.27–2.74)</td>
<td>1.83 (1.59–2.06)</td>
<td>2.14 (1.91–2.38)</td>
<td>2.22 (1.99–2.46)</td>
</tr>
<tr>
<td>Ground path walking task—median (IQR)**</td>
<td>0.30 (0.18–0.88)</td>
<td>0.00 (0.00–0.00)</td>
<td>0.13 (0.07–0.19)*</td>
<td>0.27 (0.15–0.39)*</td>
<td>0.50 (0.38–0.75)*</td>
</tr>
<tr>
<td>Physiological fall risk—high [n (%)]</td>
<td>32 (53.6)</td>
<td>32 (50.8)</td>
<td>31 (49.2)</td>
<td>41 (65.1)</td>
<td>41 (65.1)</td>
</tr>
<tr>
<td>Everyday risk-taking score—mean (95% CI)*</td>
<td>17.51 (16.2–18.9)</td>
<td>23.0 (21.9–24.2)</td>
<td>21.4 (20.3–22.5)*</td>
<td>20.6 (19.4–21.7)*</td>
<td>20.5 (19.3–21.6)*</td>
</tr>
<tr>
<td>FES-I scores—median (IQR)</td>
<td>2.53 (2.0–3.1)</td>
<td>19 (18–22)</td>
<td>20 (20–23)</td>
<td>20 (18–24)</td>
<td>21 (18–28)</td>
</tr>
<tr>
<td>Prospective fallers [n (%)]†</td>
<td>24 (57.1)</td>
<td>22 (34.9)</td>
<td>25 (39.7)</td>
<td>31 (49.2)</td>
<td>39 (61.9)</td>
</tr>
</tbody>
</table>

Notes: Differences among groups assessed using ANOVA, chi-square tests for cross-tabulation tables and Kruskal–Wallis tests for nonparametric data (n = 252 excluding Default group). **p < .001, *p < .01, †p < .05. Post hoc analyses with the low behavioral risk group as the reference group are marked with †p < .05.
In addition to possible life-long risk-taking traits (1), other factors might explain why some older people overestimate their balance abilities. Participants with poor physical ability were most likely to overestimate their ability, consistent with the idea that age-related loss of function can go unnoticed. However, it could be that inherent with a loss of function is an inability to assess function. The loss of cognitive function that results from sensory loss increases in old age (25–27) so that sensory loss might contribute indirectly to risk taking through reduced cognitive ability to assess options. Further, although participants in this study did not have significant cognitive loss, subtle age-related cognitive changes increase the risk of falls (12). Thus, misjudgment of task requirements and physical ability could contribute to the inappropriate decisions seen here. Finally, behavioral choices might be influenced by medications such as benzodiazepines and antidepressants that are commonly prescribed for older people as these can impair judgment and balance (28,29).

In contrast to the many participants who made risky plank decisions, 42 participants (14%) chose the safest, broadest plank (default) option. These participants reported a high concern about falls and risk avoidance on questionnaire, performed poorly in several physical tests, and suffered more falls in the follow-up year. Functional impairment can lead to fear and appropriately increased caution (30,31) that might protect against falls (21). However, it can also inappropriately restrict activity (17,32) and initiate an avoidable cycle of physical and cognitive decline (31). It is possible that a greater fear of falling and consequent avoidance of physical activity contributed to the higher fall rate among these “safe” participants.

For safety, participants did not actually walk across the plank in the plank crossing choice task. Thus, performance on the ground path walking task was used to estimate the probability of a successful crossing and measure the behavioral-risk taken. It is acknowledged that not being at height could have influenced walking performance (33,34). A few participants with good physical ability (assessed by the ground path walking task) walked quickly or ran toward the long, safe, default plank. This entailed a different type of risk; so, they have probably been misclassified as cautious avoiders of physical activity. The nature of this single-trial study design precluded determining the test–retest reliability for the plank crossing choice task. The study provides evidence for the concurrent validity of the new plank crossing choice task, the ground path walking task, the Everyday risk-taking scale and the Behavioral risk measure, as well as external validity for the Behavioral risk measure with respect to falls. These findings will require replication in external samples.

**Conclusion**

Our findings show that risk-taking behavior can be identified by assessing the behavioral choice to perform a task in relation to actual ability to perform it and that self-reports of risk-taking do not reveal actual risk-taking behavior in older people. Risk-taking behavior is identified as an independent predictor for falls. Thus, assessment and management of undue risk-taking could complement current fall prevention strategies.

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**References**


**Supplementary Material**

Supplementary material can be found at: http://biomedgerontology. oxfordjournals.org/


