# Safety Strategies for Mitigating Slip-and-Fall Incidents in Restrooms: Infrastructure, Technology, and Behavioural Approaches

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More than 80% of home-related injuries take place in restrooms. Falls in restrooms rank as the second most common cause of unintentional injury deaths worldwide, resulting in substantial financial and medical costs. The majority of current fall prevention strategies focus on changing an individual's behaviour and using technology, with little consideration of environmental factors, especially in developing nations. Comprehensive intervention strategies that combine technology, infrastructure, and behavioural approaches in urban Nigerian settings are not well studied. 300 online questionnaires were administered to various age groups in Lagos, Kano, and Abuja cities using a mixed-methods approach that included correlation analysis and the Relative Importance Index (RII) in four validated domains: behavioural practices, intervention effectiveness, causal factors, and infrastructure quality. Infrastructure installations are generally effective, yet wet flooring poses safety hazards, particularly slip-and-fall risks. The Risk Index Indicator (RII) of 0.415 suggests moderate effectiveness in mitigating accident risks. Notably, water accumulation (RII = 0.518) and loose bathroom mats (RII = 0.306) are identified as moderately dangerous factors. Effective safety measures include proper drainage (RII = 0.822), improved lighting (RII = 0.808), and physical supports such as grab bars (RII = 0.772). Moreover, risk awareness (RII = 0.850) and knowledge of safety equipment (RII = 0.820) are essential for enhancing safety behaviours. This gives infrastructure upgrades and environmental moisture management more importance than technology-based fixes. In place of focusing on individual behavioural interventions, building codes and healthcare policies should be revised to prioritise comprehensive environmental modifications.

**Keywords:** Injury prevention; Public health; Restroom design; Safety interventions; Slip-and-fall prevention; Toilet safety

## Introduction

Falls that occur in restrooms are a serious public health issue that affects social costs, healthcare systems, and individual health (Hernandez, 2025). According to the World Health Organisation's Global Report on Falls Prevention, falls are the second leading cause of unintentional injury-related deaths worldwide. Approximately two-thirds of home-related injuries happen while bathing or showering, and more than 80% of these incidents occur in restrooms (Liu, 2025). Given the significant financial burden of billions of dollars in emergency treatment, surgery, rehabilitation, and long-term care costs each year, this poses a serious safety concern that needs to be addressed right away (Mikos *et al*., 2021). Demographic shifts toward ageing populations make the issue worse, as older people are more likely to have accidents in the restroom, particularly if they are medication-dependent or have limited mobility (Anttila, 2025). Geographic disparities reflect differences in infrastructure quality and safety protocols, with developing nations exhibiting higher incident rates (Ihnacik *et al*., 2025). The fall rate is 30% higher for women due to factors such as osteoporosis and polypharmacy (Yu *et al*., 2021).

According to earlier studies, environmental improvements, specifically the installation of grab bars and improved lighting, can reduce the incidence of falls by 60–70% (Clemson & Pighills, 2021). These studies, however, mostly focus on institutional settings, with little exploration of private residential contexts, where installation and maintenance quality vary widely. Rasmussen (2021) found that slip-resistant materials reduce the risk of falls by only 25–40%, and their efficacy largely depends on maintenance procedures and installation quality. The assumption that technological solutions alone are adequate without addressing implementation and maintenance challenges is a serious flaw in current approaches that this research exposes. Educational initiatives can increase safety practices and risk awareness; when paired with environmental changes, integrated approaches have been shown to reduce incidents by 20–35% (Righi *et al*., 2021). Smith *et al*. (2023) point out that programmed efficacy differs greatly across demographic groups, indicating the need for customised strategies.

Most recent research focuses on individual interventions rather than comprehensive strategies, thereby omitting the intricate relationships among behavioural, technological, and environmental elements (Dyreborg *et al*., 2022).

There are significant gaps in our knowledge of prevention techniques for resource-constrained environments because most research focuses on developed nations with well-established safety infrastructure (Alabi *et al.,* 2025). Particularly in Sub-Saharan African contexts, prior research has not sufficiently addressed how intervention effectiveness differs across age groups, socio-economic backgrounds, and cultural contexts (Appiah, 2022). According to Goekcimen (2023), the ability to identify prevention opportunities before accidents occur is limited because many studies rely on retrospective incident reporting rather than prospective risk assessment.

This study addresses identified research gaps by investigating the relative effectiveness of integrated safety strategies — such as infrastructure improvements, technological interventions, and behavioural education — in preventing slip-and-fall incidents in private restrooms across Nigerian urban centres. The research is justified by the fact that Nigeria's rapid urbanisation and varying infrastructure quality create unique safety challenges that require context-specific solutions (Ezeudu & Fadeyi, 2024). With an ageing population and increasing prevalence of chronic diseases, preventive interventions are essential for healthcare sustainability (Mbata *et al*., 2024). Understanding cost-effective prevention strategies is crucial for resource allocation in developing healthcare systems (Pamulaparti, 2023). Limited research exists on integrated intervention approaches in West African contexts, despite high fall incident rates (Renz *et al*., 2025).

This study employs an integrated theoretical approach combining three complementary frameworks: Socio-Technical Systems Theory, which provides the foundational understanding that safety interventions must account for complex interactions between technology, environment, and human behaviour rather than treating these elements independently (Zarei, 2023). While, Environmental Justice Framework recognises built environment quality as a social determinant of health, emphasising how infrastructure deficiencies create differential health risks independent of individual characteristics (Murray *et al*., 2022), and Theory of Planned Behaviour explains the knowledge-implementation gap by demonstrating that attitude and perceived behavioural control does not automatically translate to comprehensive behavioural implementation across all safety domains (Kempen *et al*., 2024).

## Research Methodology

This cross-sectional quantitative study was conducted across three Nigerian cities (Lagos, Kano, and Abuja), selected as the foremost cities in 3 of the 6 geopolitical zones. Lagos is the largest metropolitan area in Nigeria, with diverse housing types —from high-rise apartments to informal settlements —providing insights into safety challenges across socio-economic strata. Kano represents Northern Nigeria's urban centres, with distinct cultural practices, traditional architecture, and varying climate conditions that affect restroom design and usage patterns. Abuja is a capital urban city representing emerging cities with mixed formal and informal housing development, offering insights into intermediate infrastructure contexts. This geographic distribution ensures findings are applicable across Nigeria's diverse urban landscape while providing sufficient variation to identify context-specific factors influencing intervention effectiveness.

A purposive sampling was used to ensure representation across age groups (18-35, 36-55, 56-85 years), socio-economic backgrounds (low, middle, high income), gender balance (50% male, 50% female) and housing types (formal/informal settlements) Based on expected fall prevalence of 26.5% (AbdulRaheem, 2023), with 95% confidence interval and 3% margin of error, the required sample size was calculated as 292 participants. To account for potential non-response and ensure adequate representation, the study recruited 300 participants (100 per city).

A comprehensive 60-item survey instrument with (4) validated domains of (15 items) each: *Domain* 1: Infrastructure Quality Assessment, Domain 2: Accident Causal Factor, Domain 3: Intervention effectiveness and Domain 4: Behavioural Practice. The five-point Likert scale, ranging from 1 (Not Effective) to 5 (Very Highly Effective), was used to represent the Infrastructure Quality Assessment Domain, Intervention Effectiveness Domain, and Behavioural Practice Domain. In contrast, the Accident Causal Factor Domain used a risk analysis scale ranging from 1 (Not Risky) to 5 (Very Highly Risky) for interpretation. Online-administered questionnaires distributed through community networks, ensuring informed consent and privacy protection. Data collection occurred between August 2024 and April 2025. Relative Importance Index (RII): Used to rank factors within each domain using the formula: $RII = \Sigma(W \times S) / (A \times N)$, where W = weight assigned to responses, S = frequency of responses, A = highest weight, and N = total responses. Descriptive Analysis was used for the interpretation.

## Results and Discussion

Out of the 300 participants, 298 completed questionnaires (response rate: 99.3%). Sample characteristics: mean age 42.3±15.7 years, 51% female, 32% low income, 45% middle income, 23% high income. Distribution across cities was Lagos (n=100), Kano (n=99), and Abuja (n=99). Sixty (60) online questionnaires were administered into 4 domains of 15 questions each, the result of the questionnaire was obtained and a Relative Importance Index (RII) was categorised into (5) equal places and interpreted according to their respective relevance, (Very Highly Effective) 0.99 – 0.76, (Highly Effective) 0.75 – 0.53, Moderately Effective 0.52 – 0.38, Slightly Effective 0.37 – 0.23, and Not Effective 0.22 - 0.10, it was used to represent the result for an efficient descriptive analysis.

Infrastructure quality analysis is presented in Table 1. Although infrastructure installations seem to be "highly effective" overall, wet flooring traction —the criterion with the lowest performance — is the most important for safety, posing a significant risk of slips and falls even in the presence of otherwise excellent infrastructure.

Toilet seat stability (RII = 0.832). *Very Extremely Effective*: With an RII of 0.832, it is crucial for user comfort and safety, especially for those with disabilities or mobility issues, and should be prioritised through regular maintenance and inspections. The toilet bowl's height, with an RII of 0.726, is highly effective in improving user comfort and accessibility, thereby enhancing inclusivity and satisfaction. The RII of 0.596 indicates that flooring traction is moderately effective in preventing slips and falls when wet, suggesting that regular maintenance and use of slip-resistant materials can enhance safety.

**Table 1: Infrastructure Quality Assessment**

| Criteria | RII | Interpretation |
|---|---|---|
| Toilet seat stability | 0.832 | Very Highly Effective |
| Toilet flush mechanism: ease of operation | 0.796 | Highly Effective |
| Electrical safety (proper wiring) | 0.796 | Highly Effective |
| Floor drainage slope | 0.794 | Highly Effective |
| Lighting sufficiency | 0.770 | Highly Effective |
| Door opening safety | 0.762 | Highly Effective |
| Floor transitions smoothness | 0.734 | Highly Effective |
| Toilet bowl height appropriateness | 0.726 | Highly Effective |
| Material condition (tile, grout) | 0.760 | Highly Effective |
| Fixture security (towel racks) | 0.706 | Highly Effective |
| Space for safe movement | 0.706 | Highly Effective |
| Mobility aid space adequacy | 0.644 | Highly Effective |
| Ventilation adequacy | 0.636 | Highly Effective |
| Power outlet positioning | 0.632 | Highly Effective |
| Flooring traction when wet | 0.596 | Moderately Effective |
| **O**verall Domain: Relative Importance Index RII: 0.719 **(**Highly Effective) | | |

Causal Factors of Accidents Analysis (Table 2). The evaluated factors are moderately effective at increasing the risk of accidents, with an overall RII of 0.415. Water Accumulation Following Bathing (RII = 0.518). Slipping during shower transitions is moderately dangerous (RII = 0.382). Loose bathroom mats (RII = 0.306) are somewhat dangerous.

After Bathing, Water Accumulation (RII = 0.518) is the highest-ranked risk factor. It suggests that bathrooms with stagnant water present a serious risk of slips and falls. Regular maintenance and appropriate drainage systems can help reduce this risk. Slipping When Changing Showers. Slightly Risky: With an RII of 0.382, it ranks ninth. This implies that switching between surfaces can be dangerous. This risk can be decreased by installing grab bars and utilising non-slip mats and footwear. Loose bathroom Mats (RII = 0.306). Slightly Risky: It is ranked fifteenth. This implies that loose mats may pose a tripping hazard. This risk can be reduced by making sure mats are non-slip and firmly fastened.

**Table 2: Causal Factors of Accidents**

| Criteria | RII | Interpretation |
|---|---|---|
| Water accumulation after bathing | 0.518 | Moderately Risky |
| Condensation on surfaces | 0.508 | Moderately Risky |
| Rushing to use the toilet at night | 0.498 | Moderately Risky |
| Cleaning product residue | 0.466 | Moderately Risky |
| Poor visibility/inadequate lighting | 0.460 | Moderately Risky |
| Inappropriate footwear | 0.436 | Moderately Risky |
| Lack of storage space | 0.420 | Moderately Risky |
| Fatigue or dizziness | 0.384 | Slightly Risky |
| Slipping during shower transitions | 0.382 | Slightly Risky |
| Wet floors from leaking pipes | 0.374 | Slightly Risky |
| Difficulty maintaining balance | 0.368 | Slightly Risky |
| Medication side effects | 0.346 | Slightly Risky |
| Vision impairments affecting hazard detection | 0.330 | Slightly Risky |
| Mobility aid transfers | 0.326 | Slightly Risky |
| Loose bathroom mats | 0.306 | Slightly Risky |
| **O**verall Domain: Relative Importance Index (RII): 0.415 **(**Moderately Effective) | | |

Safety Intervention Effectiveness Analysis (Table 3). This is a table that clearly prioritises safety interventions based on data, likely in settings such as healthcare, elder care, or home design. Strategies that prevent an incident from occurring in the first place (Proper Drainage 0.822), improve lighting (0.808), or offer basic, tangible support (Grab Bars/Handrails 0.772) are considered the most successful.

In general, safety interventions work well. Grab bars/handrails (RII = 0.772) and a proper drainage system (RII = 0.822) both indicate Very High effectiveness in reducing accidents; they are crucial safety interventions. Notably, enhanced lighting (RII = 0.706) and appropriate ventilation systems (RII = 0.706) are recognised as Highly Effective safety measures for improving user comfort and enhancing the efficiency of the lavatory. Furthermore, motion-activated safety features (RII = 0.0.550) and emergency call systems (RII = 0.582) are both Moderately Effective and crucial for improving the efficacy of safety interventions.

**Table 3: Safety Intervention Effectiveness**

| Criteria | RII | Interpretation |
|---|---|---|
| Proper drainage systems | 0.822 | Very Highly Effective |
| Improved lighting systems | 0.808 | Very Highly Effective |
| Grab bars/handrails | 0.772 | Very Highly Effective |
| Adequate space design | 0.756 | Very Highly Effective |
| Non-slip bath-towel mats | 0.730 | Highly Effective |
| Anti-slip floor treatments | 0.728 | Highly Effective |
| Automatic shut lights | 0.706 | Highly Effective |
| Proper ventilation systems | 0.706 | Highly Effective |
| Raised toilet seats | 0.674 | Moderately Effective |
| Lever-style faucet handles | 0.668 | Moderately Effective |
| Adequate storage solutions | 0.662 | Moderately Effective |
| Contrasting colours for visual perception | 0.632 | Moderately Effective |
| Emergency call systems | 0.582 | Moderately Effective |
| Heated floors | 0.562 | Moderately Effective |
| Motion-activated safety features | 0.550 | Moderately Effective |
| **O**verall Domain Relative Importance Index (RII): 0.684 (Moderate-High Effectiveness) | | |

Behavioural Practice Analysis (Table 4). The effectiveness of risk factor awareness (RII = 0.850) and knowledge of how to use safety equipment (RII = 0.820) is demonstrated by user behavioural practices. Family safety discussions (RII = 0.620) and fall response planning (RII = 0.586) are moderately effective, whereas regular safety reviews and updates (RII = 0.732) and cleaning product hazard consideration (RII = 0.712) are highly effective.

Risk factors awareness (RII = 0.850) and safety equipment usage knowledge (RII = 0.820) are Very Highly Effective and crucial for preventing accidents and mitigating risks. Educational programs and awareness campaigns can enhance safety. Regular safety reviews and updates (RII = 0.732) are highly effective in maintaining safety awareness and preparedness. Understanding the Hazard Consideration (RII = 0.712) associated with cleaning products is crucial for preventing accidents and enabling users to take appropriate precautions. Family safety discussions (RII = 0.620) and fall response planning (RII = 0.586) are moderately effective in raising awareness and promoting safe practices within households. Engaging in these discussions can enhance overall safety and minimise the impact of accidents, making users better prepared to handle falls and reduce their severity.

**Table 4: User Behavioural Practices**

| Criteria | RII | Interpretation |
|---|---|---|
| Risk factor awareness | 0.850 | Very Highly Effective |
| Safety equipment usage knowledge | 0.820 | Very Highly Effective |
| Taking time to avoid rushing | 0.798 | Very Highly Effective |
| Behaviour modification for fall reduction | 0.798 | Very Highly Effective |
| Proper lighting usage at night | 0.796 | Very Highly Effective |
| Confidence in maintaining balance | 0.780 | Very Highly Effective |
| Regular hazard checking | 0.778 | Very Highly Effective |
| Immediate spill clean-up | 0.772 | Very Highly Effective |
| Safety measure awareness | 0.762 | Very Highly Effective |
| Regular safety review/updates | 0.732 | Highly Effective |
| Emergency procedure familiarity | 0.720 | Highly Effective |
| Cleaning product hazard consideration | 0.712 | Highly Effective |
| Medication effects understanding | 0.704 | Highly Effective |
| Family safety discussions | 0.620 | Moderately Effective |
| Fall response planning | 0.586 | Moderately Effective |
| **O**verall Domain Relative Importance Index (RII): 0.744 (Good) | | |

In engaging with the various theories earlier enunciated, looking at the socio-technical systems theory applications, by emphasising the interdependence of technology, the environment, and human behaviour in fall prevention, the study supported the socio-technical systems approach and argued that safety interventions are ineffective if they ignore this system (Zarei, 2023). Taking a look at environmental justice and health equity frameworks**,** the two most significant risk factors for health were medical and environmental, underscoring the built environment's role as a social determinant and bolstering environmental justice frameworks (Murray *et al*., 2022). Finally, in implementation science complexity, the study found that when environmental factors clash with behavioural interventions, individual behaviour modification techniques for fall prevention are ineffective (Hakvoort, 2021).

## Conclusion

This study examined how well integrated safety strategies, technological interventions, behavioural education, and infrastructure upgrades addressed slip-and-fall incidents in private restrooms in three Nigerian cities. Environmental factors and simple infrastructure improvements were crucial for reducing the risk of falls, and they often work better than complex technological solutions. Regarding environmental factors and infrastructure, fall risks were significantly influenced by environmental moisture factors, including condensation (RII=0.508) and water accumulation (RII=0.518). Fall incidents were significantly reduced by simple environmental interventions, such as adequate lighting (RII=0.808) and proper drainage (RII=0.822). The study emphasised that environmental moisture management and infrastructure improvements should take precedence over technological solutions. In terms of behavioural practices, users showed high levels of risk awareness (RII=0.850) and knowledge of safety equipment usage (RII=0.820), suggesting that safety practices could be significantly improved through educational initiatives. Fall response planning (RII=0.586) and family safety conversations (RII=0.620) were less successful, indicating a need for thorough social engagement and preparation.

In considering an integrated approach, the study emphasised that safety interventions must take into account the intricate relationships among technology, the environment, and human behaviour, and it supported the application of the Socio-Technical Systems Theory. The results supported the Environmental Justice Framework by emphasising that, regardless of personal traits, infrastructure deficiencies were important social determinants of health. Additionally, the Theory of Planned Behaviour was validated, showing that although attitude and perceived behavioural control were significant, they do not always lead to consistent behavioural implementation across all safety domains.

In understanding the complex nature of fall prevention in restrooms, this study highlighted the value of a comprehensive strategy that incorporates behavioural education, technology interventions, and infrastructure upgrades. Significant reductions in slip-and-fall incidents can be achieved by prioritising environmental factors and basic infrastructure upgrades, thereby improving public health outcomes and lowering healthcare costs. Comprehensive environmental changes should take precedence over individual behavioural interventions in building codes and healthcare policies. This entails ensuring that infrastructure is properly maintained and enhancing its quality. Cost-effective preventive measures should be identified and given priority in settings with limited resources to ensure sustainable healthcare systems. To be as effective as possible, educational programmes should be customised to target particular socio-economic backgrounds, cultural contexts, and demographic groups. Particularly in developing countries, context-specific solutions that address the specific

challenges of diverse urban environments should be the main focus of future research and policy development. In a related development, to identify prevention opportunities before accidents occur, future research should focus on prospective risk assessment rather than relying solely on retrospective incident reporting.

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