Tropical Journal of the Built Environment (TJOBE)
Vol. 4 No. 2 December 2023

Evaluation of Physical Design Features That Impact on Fall Accidents in Universities' Halls of Residence

***Akinfolarin Jobi[1], Bolawole Ogunbodede[2] and Ayoola Solaja[3]**
[1,2&3] Department of Architecture, University of Lagos, Lagos, 101017, Nigeria
***Corresponding Author's** email: ajobi@unilag.edu.ng

Abstract
Building-induced fall accidents are avoidable hazards that occur partly due to building design inadequacies. This study therefore examined the physical design elements in universities' halls of residence that act as latent conditions in providing opportunities for fall accidents. The study adopted a multi-stage sampling technique. This resulted in the selection of a total of 617 respondents from 17 halls of residence in 4 federal universities in Southwest Nigeria. The findings revealed that there was a low prevalence of building-induced fall accidents in universities' halls of residence, but that fall accident was found to correlate significantly with the dwelling floor level as more fall accidents were experienced by respondents living on upper floor levels in the halls of residence. This higher prevalence was largely attributed to the practice of most residents not holding on to the handrail when using the stairways. The paper therefore recommends a vigorous promotion of safety awareness among students on proper stair usage practices.

Keywords: Building-induced accidents, Falls, Halls of residence, Physical design features, safety.

Introduction
Building-related fall accidents in residential environments and workplaces have been attributed mainly to the occurrence of slip, trip or stumble incidences (Burnfield & Powers, 2006). Globally, falls have been identified as a major public health issue and are said to account for the second leading cause of unintentional injury and death after road traffic accidents (WHO, 2012; Kim, 2015).

Fall accidents have become a complex problem, requiring multi-disciplinary, multi-faceted approaches. Studies carried out on fall accidents show that it involves the interplay of various risk factors which are biological, environmental, behavioural and socio-economic, thus making it difficult to determine the exact causal factor (Baxtera, et al, 2023).

According to Perry (1982), many of these fall-related accidents are related to structural or design features of the home or workplaces, a position collaborated by Ozanne-Smith et al (2008) contending that building design has the potential to mitigate many of these falls. These building-induced falls are mainly due to inadequacies in the building design elements thereby impacting directly or indirectly on the safety of occupants. Most fall fatalities have occurred among the elderly, the sick and children, hence many studies have largely focussed on these vulnerable groups who experience such building-induced falls (Van Hoof et al, 2010).

However little attention is been paid to fall accidents among students living on campus who are not immune to such building-induced falls, hence this study, therefore, examines the physical design features in students' halls of residence that impact fall accidents using some selected Federal Government-owned residential-based universities situated in Southwest, Nigeria.

Literature Review

Fall is a term coined for slip, trip, and fall (STF) incidences and used to describe a person's loss of equilibrium and control, where the body movement shifts the body too far off the center of balance, thereby bringing the person inadvertently on the ground. Slips occur due to a lack of friction between a human's feet and the walking surface, while trips result from interruption of movement that occur from either hitting low obstacles that are not easily noticed, uneven edges in flooring as well or overstepping low heights such as steps, stairs and curbs (Larue et al., 2021).

Slip, trip and fall (STF) incidents are nonetheless multifactorial and most times difficult to pinpoint their exact causes (Chang et al., 2016). Three risk factors identified by Chang et al. (2016) as to why people fall are listed as environmental, behavioral, and host-related factors. There are however arguments by Ulria and Sven (1995) that falls are consequences of users' poor health state and inappropriate behavior rather than the inadequacies in the construction and design of the environment, but studies done by Templer (1992); Jackson & Cohen (1995); Haslam et al. (2001) and Ozanne-Smith et al., (2008) asserted that environmental factors are the primary cause of fall-related accidents, advocating that modification of design features and stricter adherence to construction regulations would be the most effective preventive measure that would most likely to lead to a reduction in fall incidence.

Falls are mainly triggered by slip, trip, or stumble incidences that occur either on the same level or from an elevated height (Chang *et al*., 2016). The number of steps defining a level differential has been found to substantially determine the likelihood of an accident occurring, as the placement of just one or two steps in a hallway or at a doorway can be hazardous, especially when the users fail to notice this few numbers of steps on their pathway. It has therefore been suggested that to better enhance the visibility of changes in levels, a group of at least three steps should always be used in buildings. Also, there must be prominent markings using strong color contrast or flooring material texture to make such few steps obvious to users (Templer, 1992; Pierce, 2000; Pauls, 2012; Foster et al., 2014; Kim & Lockhart, 2020)

Falls from elevated heights, especially those that happen on stairways, result in more severe injuries than falls that occur on the same floor level, which are much more common (Foster et al., 2014). There is general agreement in the literature that injuries sustained when descending stairs are generally more severe than when ascending (Jackson & Cohen 1995; Templer, 1992). The primary causes identified for such fall accidents when descending the stairs include catching the heel on the stair nosing, the foot slipping off the stair nosing, overstepping by missing the step completely, under stepping by locking the heel against the risers as well as being unaware of the presence of steps. Studies have also demonstrated that a disproportionate amount of stairway accidents occur mostly at the bottom first three stairs in a flight or the last three stairs at the top (Templer, 1992; Pierce, 2000; Pauls, 2012; Foster et al., 2014), the reason being that, at these locations, the users are often confronted with changes in level and distraction due to the varying visual cues of next route to be taken.

In relating stair design features to residents' safety, Pauls (2012) identified step geometry, handrails, and stairway visibility as basic criteria essential for a safe and usable stairway. The dimensions of stairways are very important for preventing stairway incidents as dimensional inconsistency in stairway treads has been found to play a major contribution to the incidences of falls in stairways (Roys, 2011). The steepness or pitch of a stair increases the likelihood of a fall. Risers that are too high may cause stair users to fatigue quickly, therefore making them prone to tripping; while if they are too low may cause misstep (Chang et al., 2016).

Lack of proper lighting in stairways has long been an issue of concern for safety on stairs (Jacobs, 2016). Proper lighting in stairways whether artificial or natural should enable the user to see the treads and risers easily. Pena-Garcia et al., (2015) also pointed out the need for uniform illumination across the stairwell to prevent shadows on the stair edges, especially at night.

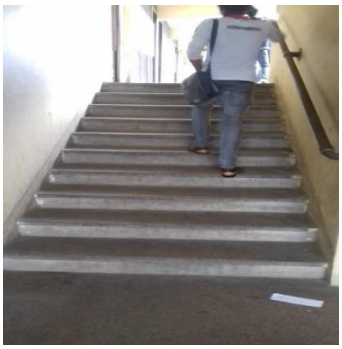
Falls on stairways have been attributed to the personal characteristics, attitude, and behavior of the stair users. Several studies have demonstrated females to be more prone to stairway falls than males, which has largely been attributed to the high-heeled footwear being worn by young females (Hemenway et al, 1994).

Research Methods

The study adopted a survey research design which utilized a cross-sectional survey that was carried out within the second semester to ensure that respondents have at least a semester living experience in their present halls of residence. The data collection was done using a multi-level sampling technique. In the first stage, which is the university level, a purposive sampling based on proximity was employed to select four out of the six federal universities situated in the southwest region of Nigeria. The selected federal-owned tertiary Institutions are those conceived as residential-based educational institutions where student housing forms an integral part of the educational system. The universities are namely the University of Ibadan, University of Lagos, Obafemi Awolowo University, Ile-Ife, and Federal University of Technology, Akure.

At the hall level, the four selected universities have thirty-five (35) undergraduate halls of residence which constitute the sample frame for the study. The halls of residence were grouped into clusters based on gender, size of the hall, and their typologies, which were derived graphically from the architectural drawings taking into consideration the morphological characteristics common to the different halls of residence. A stratified random sampling was used to select 17 halls of residence from the identified clusters such that the number of halls selected from each cluster is in a ratio proportional to the number of halls in such cluster. The selected halls of residence were limited to those that were purposely built by the respective institutions for student accommodation within the university campus, thus excluding those either on or off campus built by private individuals or organizations.

At the third stage which is the respondent level, the systematic sampling technique was used to select a sample size of 617 rooms, in which an occupant residing in the selected room is taken as a respondent. The two survey instruments used in gathering data for this study were the closed structured questionnaires administered to occupants of universities' halls of residence and the other was the checklist of observations undertaken by the researcher.

	
Non-holding to the handrail when using the staircase. **Mariere Hall (Unilag)**	Few steps defining the same floor level differential. - Adeniyi Hall (FUTA)

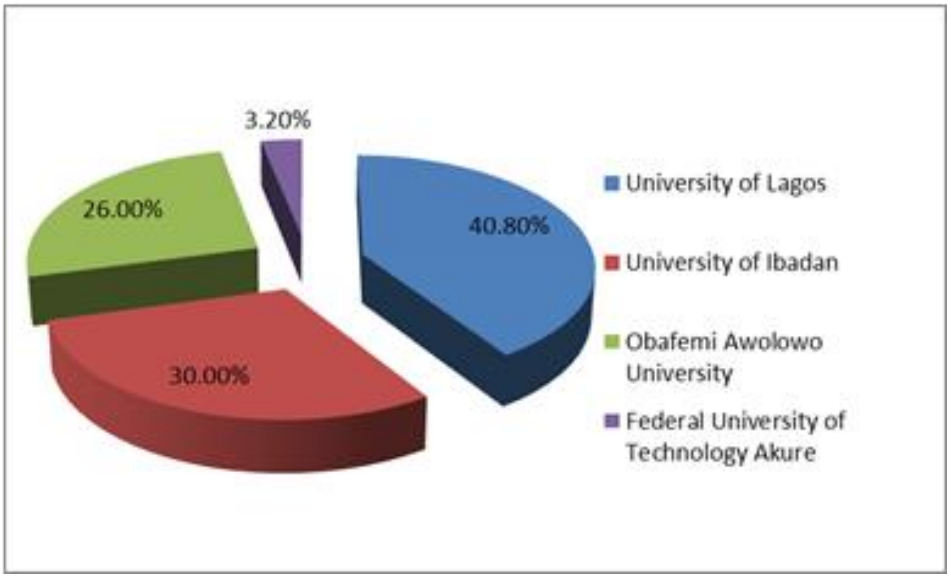


Fig 1: Distribution of respondents according to selected universities

Analysis and Discussion

In this study, fall accidents were measured by the slips, trips, and falls experienced by students residing in the halls of residence. The duration of stay of most students in the universities' halls of residence in Nigeria is for one academic session, which is made up of two semesters. Hence the survey was conducted during the second semester with the prevalence of falls in their halls of residence operationalized by how often respondents experienced falls, slips, or trips in the previous first semester. The responses were measured on a 5-point Likert scale. Factors such as demographic characteristics, physical design features, and stair safety practices were examined if they had any relationship with the prevalence of fall accidents experienced in the halls of residence.

Prevalence of Slip, Trip, or Fall (STF) incidences.

The prevalence of fall accidents was measured by how often respondents witnessed slips, trips, and falls in the halls of residence in the previous semester. The results of the study as presented in Table 4.1

indicated that among the 617 respondents, 11.7% of them have never experienced any fall accident, 44.2% responded that it does not happen often, while only 26.8% attested that they often experience falls, slips or trips in their halls of residence. A result shows that there is a low prevalence of falls among students within the previous semester in the halls of residence.

Demographic Characteristics and Prevalence of Fall-accidents

The analysis of the respondent's demographic characteristics reveals that 56.3% of the respondents were male and 43.7% female. Almost all the respondents (96.4%) are single, with more than half of them (56.2%) within the age bracket of 19 to 21 years. The distribution however shows that the majority of the respondents are presently in their second and third year of study, and an overwhelming 99.4% of the respondents do not require any form of assistance to walk around in the halls of residence, however, only 19.8% of them do wear glasses.

When the prevalence of falls was examined in relation to respondents' demographic characteristics, the result with respect to gender revealed that more female students (36.7%) than males (17.4%) experience fall incidents in the halls of residence with a significant statistical relationship established (λ^2=31.781, df = 4, p= 0.000). The result reinforces earlier findings by Hemenway et al., (1994) contending that females are more prone to fall accidents.

There were no differences in the prevalence of falls among respondents with health conditions, as more than half of the respondents (53.3%) who wear glasses and 75% who require some form of assistance to walk claim they do not often experience fall incidences in the halls of residence. No relationship was established as indicated in the Pearson Chi-square value of p= 0.506 and p= 0.814 respectively. This shows that unlike gender, the respondents' disability does not account for the prevalence of falls in the halls of residence hence other non-human factors such as physical design features can be explored to proffer an explanation for fall accidents in halls of residence.

Floor-Level Characteristics and Fall-related Accidents

Dwelling floor level:

The relationship with the prevalence of fall accidents as presented in Table 4.2 shows that the percentages of respondents who often experienced fall incidences the previous semester in the halls of residence were found to be highest among those living on the second floor (30.6%) followed by third floor (29.7%) and first floor (29.3%). A statistically significant relationship with a Pearson Chi-square value of p= 0.008 was established with the dwelling floor levels where the students live.

Table 4.1 How often do you experience falls, trips, or slips in your hall of residence the previous semester

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	never	72	11.7	11.7	11.7
	not often	273	44.2	44.2	55.9
	do not know	107	17.3	17.3	73.3
	often	133	21.6	21.6	94.8
	very often	32	5.2	5.2	100.0
	Total	617	100.0	100.0	

Corridor Length:

The corridor length in the halls of residence was classified into two, either short or long-type corridors based on the number of rooms between service cores on a floor. The short type corridors were those that had ten rooms or less between the service cores while the long corridors had more than ten rooms. A look at Table 4.2 showing the relationship between the prevalence of falls experienced the previous semester and the corridor length indicates that 25.0% of them on the short corridor type often experienced falls the previous semester in the halls of residence as against 28.5% on the long corridor type. Hence no relationship was found to exist with corridor length, as the differences in prevalence of falls on short and long corridor types were found not to be significant as shown by the Pearson Chi-square value of 0.692.

Corridor Loading:

The design of the corridors in the halls of residence in the study area was categorized into three types namely single-loaded, double-loaded, and partial double-loaded corridors. A cross-tabulation of fall incidences experienced with corridor loading as presented in Table 4.2 shows that 27.3% of the respondents living on single-loaded corridors experienced falls, trips, or slips the previous semester in the halls of residence while 27.8% and 23.6% were on double loaded and partial double loaded corridors respectively. However, there was no statistically significant relationship between the corridor loading and the prevalence of injuries due to falls, trips, or slips in the halls of residence as reflected in the Pearson Chi-square value (p= 0.076).

Table 4.2: Floor-level Characteristics and Prevalence of Falls in Halls of Residence

Floor level Characteristics	**Did you experience any falls, trips, or slips the previous semester in the hall**					
	Never	**Not Often**	**Undecided**	**Often**	**Very Often**	**Total**
Dwelling floor level						
Basement	5(12.2%)	15(36.6%)	14(34.1%)	5(12.2%)	2(4.9%)	41(6.6%)
Ground floor	17(10.8%)	70(44.3%)	38(24.1%)	30(19.0%)	3(1.9%)	158(25.6%)
1st floor	16(9.0%)	88(49.7%)	21(11.9%)	42(23.7%)	10(5.6%)	177(28.7%)
2nd floor	23(14.4%)	60(37.5%)	28(17.5%)	37(23.1%)	12(7.5%)	160(25.9%)
3rd floor	11(13.6%)	40(49.4%)	6(7.4%)	19(23.5%)	5(6.2%)	81(13.1%)
Total	72(11.7%)	273(44.2%)	107(17.3%)	133(21.6%)	32(5.2%)	617(100.0%)
Pearson Chi-square	λ^2=32.783, df = 16, p= 0.008					
Corridor Length						
Short 37(11.6%)		141(44.2%)	61(19.1%)	63(19.7%)	17(5.3%)	319(51.7%)
Long 35(11.7%)		132(44.3%)	46(15.4%)	70(23.5%)	15(5.0%)	298(48.3%)
Total	72(11.7%)	273(44.2%)	107(17.3%)	133(21.6%)	32(5.2%)	617(100.0%)
Pearson Chi-square	$\boldsymbol{\lambda^2}$=2.236, df = 4, p= 0.692					
Corridor Loading						
Single loaded	57(13.0%)	177(40.3%)	85(19.4%)	97(22.1%)	23(5.2%)	439(71.1%)
Double loaded	3(4.2%)	39(54.2%)	10(13.9%)	17(23.6%)	3(4.2%)	72(11.7%)
Partial double-loaded	12(11.3%)	57(53.8%)	12(11.3%)	19(17.9%)	6(5.7%)	106(17.2%)
Total	72(11.7%)	273(44.2%)	107(17.3%)	133(21.6%)	32(5.2%)	617(100.0%)
Pearson Chi-square	$\boldsymbol{\lambda^2}$=14.226, df = 8, p= 0.076					

The findings on floor level characteristics imply that fall accidents in students' halls of residence are not differentiated based on the corridor length nor corridor loading but rather on the dwelling floor level where the students live, as most fall accidents witnessed in the halls of residence happen on the first, second and third floor levels with the least on the basement and ground floor, thus indicating that the major contributing factor to the falls, trip or slips witnessed on the upper floor levels was the use of stairways in the halls of residence.

Stair Design Features and Causes of Fall Accidents

The prevalence of falls, trips, or slips when considered with respect to the stair design features of the halls of residence, the result as presented in Table 4.3 showed that the highest percentage (38.8%) of the respondents attribute the cause of falls to the usage of staircase to transit to another floor level in the halls of residence while 30.7% of them attributes the cause of falls to the presence of a single step at the door to their rooms; whereas 22.7% of the respondents claims that falls results from the presence of a group of few steps defining floor level differential on most corridors and walkways in the halls of residence.

The low incidences of fall accidents on the same floor level can be attributed to the few number of single steps at the doorways as well as the groups of short stairs defining the same floor level differential on most corridors and walkways in the halls of residence. More importantly, where these design features are present, respondents can notice changes in floor levels mainly due to differences in floor finish texture, as out of the respondents that acknowledged there are same level floor differentials on corridors or walkways in their halls of residence, the most frequently cited features that enable them to notice changes in floor levels as shown in Figure 2 are the floor finish texture (28%), handrail (22%) and contrasting color (19%).

A further investigation into stair safety practices among residents in the halls of residence considering the findings that suggest that the prevalence of falls witnessed on the upper floor levels is likely due to the use of stairways in the halls of residence, hence the result of the stair safety practices in Table 4.4 revealed that most of the respondents (63.7%) claim they do see the edge of each step when using the staircase with 43.4% affirming that the staircases are well-lit to enable visibility. However, less than half of the respondents confirm that they do not feel the steepness of the steps (42.9%) and do not hold on to the handrail when using the staircase (27.1%). It therefore shows that the step geometry, stairway lighting, and visibility were the features found to facilitate this low prevalence of fall accidents in the halls of residence except for the practice of not holding on to the handrail when using the stairway.

Table 4.3: Stair Design Features and Causes of Falls

	Does this feature cause falls, trips, or slips in your hall of Residence.		
	No	**Do not know**	**Yes**
Floor level differential on the same floor level	101(58.7%)	32(18.6%)	39(22.7%)
Single step at the door	39(62.9%)	4(6.5%)	19 (30.7%)
Staircase to another floor level	118(47.2%)	35 (14.0%)	97(38.8%)

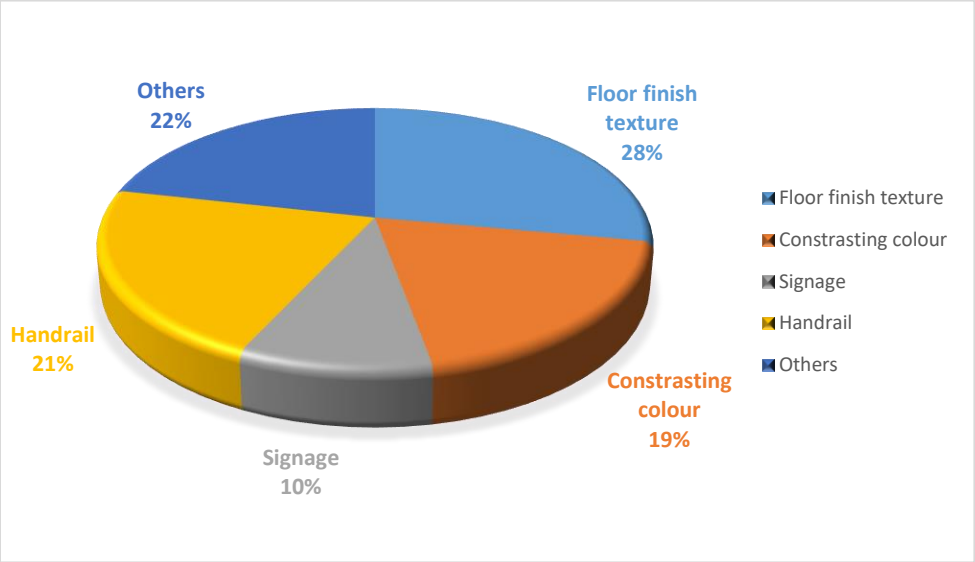


Fig 2: Features in Halls of Residence indicating change in Floor levels

Table 4.4: Stair Safety Perception in Halls of Residence

	Stair Safety Practice						
Stair Safety Indicators	**Strongly Disagree**	**Disagree**	**Neutral**	**Agree**	**Strongly Agree**	**Mean**	**SD**
I see the edge of each step	31 5.0%	57 9.2%	136 22.0%	301 48.8%	92 14.9%	3.59	1.01
I do not feel any steepness of the steps.	36 5.8%	116 18.8%	200 32.4%	205 33.2%	60 9.7%	3.22	1.05
I hold on to the handrail when using the stairs	53 8.6%	114 18.5%	189 30.6%	202 32.7%	59 9.6%	3.16	1.10
The staircase is well-lit for the steps/handrails to be seen	71 11.5%	101 16.4%	177 28.7%	190 30.8%	78 12.6%	3.17	1.19

Conclusions and Recommendations

This study evaluated the prevalence of fall accidents as it relates to physical design features in universities' halls of residence. The findings revealed that there is a low prevalence of fall accidents in students' halls of residence. The fall accidents are, however, not differentiated based on the corridor length or corridor loading, as only the dwelling floor level where the students live was the physical design feature found to impact significantly on fall accidents.

Most falls witnessed in the halls of residence were found to occur on the upper floor levels rather than on the ground floor which reinforces earlier findings by Tsai et al (2021) that there is a higher likelihood of falls among those living in story buildings. The higher prevalence of falls on the upper floor levels in the halls of residence found in this study was largely attributed to the usage

of stairways by residents accessing the upper floors. Findings from the study also showed that, though safety safeguards such as the dimension consistency of the step, handrails, and stairway visibility, were incorporated in the stairways to prevent fall incidents, however, the causal factor identified as being responsible for the fall accidents experienced by residents on these upper floor levels was found to be that majority of them do not hold on to the handrail when using the stairways.

Handrails are essential for guidance and balance but a substantial proportion of falls on stairs can be attributed to the inability of users to grab handrails to break the fall. The handrails not only serve as an anchor to steady users during falls but also provide visual clues indicating floor level changes (Pierce, 2000; Gunatilaka et al., 2005, Foster et al., 2014, Siddiqui et al., 2015).

The paper therefore recommends that when architects are assessing residents' safety from fall accidents in students' housing design; they should consider designing the handrails to be attractive for stair users to hold on to when using the stairway. It is also imperative for university administrators in charge of managing students' housing to vigorously promote safety awareness on proper stair usage practices among students, by integrating informative posters in strategic positions on the stairways to educate residents on the need to hold on to handrails to prevent fall accidents in the halls of residence.

References

Baxtera V, Boydellb V & McPherson S (2023). Multi-disciplinary support for families with complex needs and children on the edge of care in the UK: a mixed methods evaluation Journal of Social Welfare and Family Law 2023, VOL. 45, NO. 4, 307–325https://doi.org/10.1080/09649069.2023.2281840

Burnfield, J. M. & C. M. Powers (2006). Prediction of slips: an evaluation of utilized coefficient of friction and available slip resistance. *Ergonomics*, 49(10), 982 - 995.

Chang, W, Leclercq, S, Lockhart, T & Haslam, R (2016). State of Science: occupation slips, trips and falls on the same level, Ergonomics, 59(7), 861–883.

Foster, R. J., Hotchkiss, J., Buckley, J. G., & Elliott, D. B. (2014). Safety on Stairs: Influence of a tread edge highlighter and its position. *Experimental Gerontology*, 55, 152-158.

Gunatilaka, A., Clapperton, A., & Cassell, E., (2005). Preventing home fall injuries:Structural and design issues and solutions. *Hazard* 2005; 59:1-18.

Haslam, R.A. Sloane, J., Hill, L.D., Brooke-Wavell, K. & Howarth, P. (2001) "What do older people know about safety on stairs?" *Aging and Society*, 21, 759-776.

Hemenway, D., Solnick, S., Koeck, C., & Kytir, J. (1994). The incidence of stairway injuries in Austria. *Accident Analysis & Prevention*, 26(5), 675-679

Hoof J. V, Kort H.S. Duijnstee M.S.H, Rutten P.G.S & Hensen J.L.M (2010). The indoor environment and the integrated design of homes for older people with dementia Building and Environment Volume 45, Issue 5. May 2010, Pages 1244-1261. https://doi.org/10.1016/j.buildenv.2009.11.008

Jackson, P.L & Cohen H.H., (1995). An in-depth investigation of 40 stairway accidents and the safety stair literature. *Journal of Safety Research*, 26(3), 151-159

Jacobs J. V (2016). A review of stairway falls and stair negotiation: Lessons learned and future needs to reduce injury. Gait & Posture, Volume 49, Pages 159-167. https://www.sciencedirect.com/science/article/pii/S0966636216301096

Kim, I. J. (2015). Research Challenges on Slip-Resistance Measurements for Assessing Pedestrian Fall Incidents. *Journal of Ergonomics*, 5(3).

Kim, K., & Steinfeld, E. (2016). An Evaluation of Stairway Design

featured in Architectural Record between 2000 and 2012. *International Journal of Architectural Research*, 10(1).

Kim, H. N & Lockhart, T. E. (2020). Fall Risk in Older Adults Transitioning between Different Flooring Materials. *Sci 2 (25);* doi:10.3390/sci2020025

Larue, G. S., Popovic, V., Legge, M., Brophy, C., & Blackman, R. (2021). Safe trip: Factors contributing to slip, trip, and fall risk at train stations. Applied ergonomics, 92, 103316. https://doi.org/10.1016/j.apergo.2020.103316

Oyerinde, O. O. (1985). Home Accidents in Nigeria: Effects and Measures for Prevention *Journal for Home Economics* Vol. 1

Ozanne-Smith, J., Guy, J., Kelly, M. & Clapperton, A. (2008). The relationship between slips, trips, and falls and the design and construction of buildings. Monash University Accident Research Centre, Report No. 281

Pauls, J. (2012). Inclusive design of home stairways: Public health considerations and implementation challenges. Proceedings of 4th International Conference on Universal Design, Fukuoka, Japan.

Pena-Garcia, A., Hurtado, A & Aguilar-Luzon, M. (2015). Impact of public lighting on pedestrians'' perception of safety and well-being. *Safety Science*, 78 (2015), 142-148.

Pierce, M. (2000). Preventing Falls on Home Stairs. *House Facts Mail* published by Cooperative Extension Service of Kansas State University.

Roys, M. (2011). Consistency of step dimensions. Paper presented at the International Conference on Stairway Usability and Safety, Toronto, Canada.

Siddiqui, N. A., Yadav, B. P., & Nair, V. M. (2015). Study and Improvement of Safety on Staircases through Visual Reinforcement. *International Journal of Occupational Health & Safety, Fire & Environment- Allied Science,* 3(1).

Templer, J. A, (1992) *The Staircase: Studies of hazards, falls and safer designs*. Cambridge, MA: MIT Press.

Tsai, C., Lin, E., Li, Y., Tung, T., & Chen, W. (2021). The Relationship Between Storey of Buildings and Fall Risk. *Frontiers in Public Health*, Vol. 9

Ulria, T., & Sven, B. (1995). Unintentional injuries: attribution, perceived preventability, and social norms. *Journal of Safety Research*, 26(2), 63-73.

World Health Organisation, (2012). Falls. WHO Factsheet No 344. http://www.who.int/mediacentre/factsheets/fs344/en/