Empirical Assessment of Fire Safety Awareness Among Residents of High-Rise Residential Buildings in Kunming

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Abstract

[Purpose] This study aims to evaluate the fire safety knowledge, preparedness, and awareness levels among residents of high-rise residential buildings, as well as the key factors influencing their fire safety awareness and knowledge levels.

[Methods] An empirical survey questionnaire was designed, and descriptive statistical analysis and hierarchical multiple regression analysis were conducted on the survey data from 303 residents of high-rise buildings in Kunming City to assess residents' understanding and awareness of fire safety, the availability of fire safety facilities, and to investigate the key factors influencing fire safety awareness and knowledge levels among high-rise residential building residents.

[Results] The majority of residents possess a basic understanding of fire safety in high-rise buildings but demonstrate insufficient preparedness for fire incidents. Gender, age, education level, and participation in fire drills are key factors influencing residents' fire safety knowledge and awareness levels, with participation in fire drills being the most critical determinant affecting residents' fire safety awareness and preparedness.

[Limitations] This study has limitations regarding sample representativeness and the lack of examination of socioeconomic factors.

[Conclusion] Nearly half of the residents exhibit weak fire safety awareness. Participation in fire drills is the most critical determinant influencing residents' fire safety awareness and preparedness.

Full Text

Assessment of Fire Safety Awareness and Knowledge Among High-Rise Residential Residents in Kunming

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Abstract:
[**Objective**] This study evaluates the level of fire safety knowledge, preparedness, and awareness among residents of high-rise residential buildings in Kunming, Yunnan Province, and identifies key factors influencing their fire safety consciousness.
[**Methods**] An empirical survey questionnaire was designed and administered to 303 residents of high-rise buildings in Kunming. Descriptive statistical analysis and multivariate hierarchical regression analysis were employed to assess residents' understanding of fire safety, the availability of fire safety equipment, and the critical determinants of fire safety awareness and knowledge.
[**Results**] While most residents possess basic knowledge of high-rise building fire safety, their preparedness for fire emergencies remains inadequate. Gender, age, educational attainment, and participation in fire drills were identified as significant factors affecting fire safety awareness, with drill participation being the most critical determinant of preparedness.
[**Limitations**] Study limitations include sample representativeness and the omission of socioeconomic factors.
[**Conclusions**] Fire safety awareness was weak among nearly half of the residents. Participation in fire drills emerged as the most critical determinant of fire safety awareness and preparedness.

Keywords: high-rise residential buildings; fire safety; occupant evacuation; hierarchical multiple regression analysis

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1. Introduction

The global urbanization process has endowed high-rise buildings with significant advantages in land intensification, yet concomitant fire risks have become increasingly prominent [1,2]. Due to the difficulties in fire suppression and rescue operations posed by building height, as well as the complexity of occupant evacuation, high-rise fires often result in substantial casualties and economic losses. According to data from the China National Fire and Rescue Administration, high-rise building fires surged from 8,348 incidents in 2020 to 17,000 in 2022—a 103.6% increase—with residential high-rise fires accounting for over 80% of cases and causing 260 fatalities [3]. This underscores that high-rise resi-

dential buildings have become a critical domain for fire prevention and control, necessitating systematic solutions.

Fire safety standards for high-rise buildings are significantly stricter than those for low-rise structures, particularly regarding the configuration requirements for fire elevators and evacuation stairwells [4,5]. Functional differences in buildings lead to divergent evacuation behavior patterns: office occupants typically receive professional training and wear standard attire, enabling higher evacuation efficiency [4]; whereas residential occupants experience significantly extended pre-evacuation times due to factors such as sleeping, inappropriate clothing, or accompanying elderly and young family members [7,8]. Psychological research indicates that residents'attachment to property and psychological defense mechanisms such as compartmentalization further impede evacuation decision-making [9]. Given that residential high-rise fires exceed 80% of total high-rise fire incidents in China [3], their evacuation vulnerability has become a focal research area. Consequently, this study concentrates on residential buildings, not only because they represent the most prevalent high-rise building type in China, but also because they face greater fire safety challenges.

While fire safety research has traditionally focused on building structures, fire-resistant materials, and fire protection systems [4], residents' behavior before and during fires is equally crucial for ensuring safety. Enhancing residents' knowledge-preparedness-awareness (KAP) levels regarding fire safety can reduce building fire risks [7]. This study designs a questionnaire to evaluate residents' fire safety knowledge, preparedness, and awareness, combining descriptive statistics with multivariate hierarchical regression analysis to quantitatively identify core factors influencing fire safety consciousness. The findings provide empirical evidence for optimizing fire prevention and control strategies for high-rise buildings in Yunnan Province, specifically targeting the weak link of resident behavioral intervention.

2. Individual Behavioral Factors Affecting Fire Safety

Fire safety in high-rise buildings requires the joint participation of residents and developers [7]. Research demonstrates that when residents fully master the usage knowledge of fire protection facilities such as smoke detectors and automatic extinguishing systems, the overall fire protection effectiveness of buildings improves significantly [1]. Particularly against the backdrop of unique evacuation challenges in high-rise buildings [8], residents' fire safety literacy directly affects emergency response outcomes.

Residents' behavior before and during fires substantially impacts fire safety in high-rise buildings; however, the behavioral components involved in high-rise evacuation remain incompletely understood [8,9]. Studies show that individual risk perception capability significantly influences evacuation decisions: residents with higher risk perception are more inclined to initiate evacuation procedures promptly, whereas those with lower risk perception commonly exhibit delayed

responses and excessive information-seeking behaviors, resulting in significantly prolonged pre-evacuation times [10].

Research also indicates that residents' insufficient awareness of fire risks often leads to neglect of preventive measures, which significantly affects fire preparedness behaviors [11]. Glauberman [12] found that fire safety awareness among high-rise residential occupants directly correlates with fire experience: residents with evacuation experience demonstrate better emergency preparedness, while those lacking such experience commonly suffer from insufficient evacuation route knowledge and low emergency self-confidence.

3.1 Questionnaire Design

This study employs a cross-sectional survey method targeting high-rise building residents in Kunming. The questionnaire encompasses two core dimensions: evaluation of fire safety equipment availability and assessment of residents' knowledge-preparedness-awareness (KAP) levels. Demographic variables (age, gender, education level, etc.) were collected through random sampling (N=sample size). Data collection was completed in February 2025 via the Wenjuanxing platform.

Based on critical fire safety issues in high-rise buildings, a structured questionnaire was designed comprising four core modules: (1) demographic characteristics (gender, age, education level, etc.); (2) fire safety awareness and emergency preparedness levels; (3) fire protection facility cognition. The questionnaire utilizes closed-ended questions (5-point Likert scale), with multivariate linear regression models employed to analyze the influence intensity of various factors on residents' fire safety KAP levels.

A multivariate regression model was established to evaluate KAP levels among high-rise building residents. The primary survey questions are listed in :

**** Primary Survey Questions
- Do you believe your current building has fire hazards?
- Has your current building ever experienced a fire?
- Have any high-rise buildings in your residential community ever experienced a fire?
- Q12: Have you experienced indirect fire incidents? (e.g., witnessing other buildings on fire or learning about fire incidents through relatives/friends)
- Have you ever participated in fire drills in your building?
- Have you ever participated in fire drills in other buildings?
- Do you have the habit of turning off unused appliances before leaving home (e.g., computers, fans, air conditioners, kettles)?
- Are there fire extinguishers in your building?
- Do you have an evacuation plan if a fire occurs in your building?
- Do you know the location of evacuation stairwells or emergency exits in your building?
- Do you know where those evacuation stairwells lead?

- Are the doors to those evacuation stairwells closed most of the time?
- In case of fire, do you think the corridors in your building are wide enough for everyone on your floor to evacuate?
- Does your building have fire elevators?
- Is your floor equipped with automatic fire protection systems (fire alarms, smoke detectors, sprinklers)?
- Is your floor equipped with fire extinguishers and demolition tools?
- Does your building have clear exit signs to help you find evacuation stairwells, fire elevators, fire extinguishers, and demolition tools?
- Does your building have refuge floors or emergency rooms?

3.2 Regression Model Construction and Theoretical Hypotheses

The knowledge-preparedness-awareness (KAP) level serves as the dependent variable, evaluated through twelve questions (Q15–Q26). The second section, "Residents' Awareness and Preparedness," focuses on behaviors residents should adopt to improve household fire safety.

This study examines six key factors influencing fire safety KAP levels among high-rise building residents: (1) age; (2) education level (higher education may enhance awareness through risk courses and fire drills); (3) residential floor (higher-floor residents exhibit greater risk awareness due to greater evacuation difficulty) [13,14]; (4) direct fire experience (those with experience are more cautious); (5) indirect fire experience (learning from others' experiences raises vigilance) [15]; and (6) fire drills (empirical data show 80% of residents recognize their effectiveness) [16]. These six factors are incorporated as independent variables.

Based on these factors, six theoretical hypotheses are proposed:
H1: Age has a positive effect on KAP
H2: Education level has a positive effect on KAP
H3: Residential floor has a positive effect on KAP
H4: Direct fire experience has a positive effect on KAP
H5: Indirect fire experience has a positive effect on KAP
H6: Fire drill participation has a positive effect on KAP

Gender and residence experience in high-rise buildings are included as control variables. Based on these hypotheses and variables, the multivariate regression model is established as:

$$KAP = \beta_0 + \delta_1 \text{Gender} + \delta_2 \text{ResidenceExperience} + \beta_1 \text{Age} + \beta_2 \text{Education} + \beta_3 \text{Floor} + \beta_4 \text{DirectFireExperience} + \beta_5 \text{In}$$

where β_0 is the constant term, δ_1, δ_2, and β_1-β_6 are regression coefficients, and u is the random error term. Microsoft Excel was used to process raw data for each respondent, followed by multivariate hierarchical regression analysis using IBM SPSS Statistics software. Durbin-Watson tests were employed to assess multicollinearity.

4. Research Results

A total of 303 respondents residing in different high-rise residential buildings completed the questionnaire, with all responses deemed valid. This section presents descriptive statistics for the four questionnaire parts sequentially, followed by discussion of the multivariate hierarchical regression analysis results.

4.1 Descriptive Statistical Analysis

This study collected 303 valid questionnaires. Demographic characteristics reveal that respondents were predominantly female (66.34%), aged 30–39 (65.35%), and held bachelor' s (65.35%) or master' s degrees (18.81%). Residential floor distribution shows 35.65% living on floors 1–6, 25.74% on floors 10–17, 18.81% on floors 18–29, and 12.87% on floor 30 or above, reflecting typical urban high-rise residential patterns. This sample structure captures the basic demographic characteristics of high-rise residential residents in Kunming, providing a representative foundation for subsequent fire safety awareness analysis.

Survey results indicate polarized average residence duration: 40.6% have lived in their buildings for 9–15 years, while 21.78% have resided for four years or less. Regarding building height, over half (52.48%) live in super high-rise buildings exceeding 31 floors, with 33-floor buildings being most common (26.73%), reflecting Kunming' s urban residential high-rise development trend.

4.2 Residents' Fire Safety Awareness and Preparedness

**** presents descriptive statistics for the questionnaire' s second section concerning residents' awareness of and preparedness for fire incidents. Based on questions 9–14, survey results reveal significant variation in fire risk perception: 29.7% believe their building has fire risks, 48.5% consider risks possible, and 21.8% hold negative attitudes (mostly residents in newly constructed or well-maintained buildings). Regarding actual fire experience, 5.9% reported fires in their building, 23.8% in their residential community, and 33.7% had indirect fire experiences. Notably, fire drill participation rates are severely insufficient, with only 10.9% participating in drills in their own building and 32.7% in other buildings, far below desirable levels.

Analysis of questions 15–17 regarding fire prevention behaviors and emergency preparedness shows that 69.31% of residents have developed the habit of turning off appliances before leaving home, which corresponds behaviorally to statistical conclusions identifying electrical faults as a primary fire cause [6]. Although 93.07% of buildings are equipped with fire extinguishers, NFPA standards [17] specify that the effective radius for portable extinguishers on ordinary combustible fires should not exceed 22.86 meters, suggesting current configurations may be inadequate for rapid fire suppression. Significantly, 52.48% of households lack evacuation plans, and this insufficient emergency preparedness, combined with residential occupants' characteristic property attachment psychology,

contributes to delayed evacuation risks. Compared to office environments, residential settings may experience 30%–50% longer actual evacuation times due to lower preparedness and emotional attachment factors (based on existing research estimates). A dual intervention strategy of "household fire extinguishers + customized evacuation plans" is recommended.

Cross-analysis of questions 13 and 14 reveals pronounced age differences in fire drill participation rates: the 30–39 age group demonstrates significantly higher participation than other cohorts, with 81.82% participating in their own building' s drills ([Figure 1a: see original paper]) and 72.73% in other buildings' drills ([Figure 3b: see original paper]), indicating stronger fire safety awareness among this demographic. Notably, residential floor may also be an important factor affecting participation willingness, though this study does not specifically investigate its underlying mechanism. Potential reasons for participation rate disparities include time constraints, weak safety awareness, or building management' s failure to organize drills—factors warranting deeper investigation.

Further cross-analysis of questions 13 and 14 shows differentiated drill participation patterns across floor levels: for drills in residents' own buildings ([Figure 4a: see original paper]), participation rates are equal (36.36%) for floors 1–6 and 7–17, and 27.27% for floor 18 and above, indicating relatively equal opportunities. However, for drills in other buildings ([Figure 4b: see original paper]), lower-floor residents (1–6) show 48.48% participation, significantly higher than mid- and high-floor residents (7–17 floors: 24.24%; 18+ floors: 27.27%). This disparity may relate to higher proportions of 30–39-year-old working individuals among lower-floor residents whose workplaces organize fire drills, increasing participation opportunities. Results suggest that residential floor indirectly determines access to diverse fire drill channels by influencing residents' daily activity ranges.

[**Figure 2: see original paper**] Percentage of residents in each floor group participating in high-rise building fire drills in their own building

4.3 Residents'Knowledge and Assessment of Fire Evacuation Facilities

**** presents results from the questionnaire' s third section, which examines residents' knowledge and assessment of their building' s fire evacuation facilities. Survey results from questions 18–21 indicate high awareness of evacuation routes: 95.05% know evacuation stairwell locations, and 82.18% understand stairwell exit paths. However, 64.36% of respondents report that stairwell doors are frequently left open, a violation that may cause: (1) rapid smoke diffusion into evacuation routes (chimney effect); (2) accelerated vertical fire spread; and (3) reduced visibility leading to stampede risks. Regarding evacuation efficiency, 55.45% of residents believe existing corridor widths can accommodate full-floor evacuation, though verification against building codes is needed to assess actual compliance rates. Recommended management measures include: (1) installing automatic door closers; (2) conducting evacuation route compliance inspections; and (3) assessing corridor width capacity.

Analysis of questions 22–26 regarding fire protection facility configuration reveals significant gaps: only 49.83% of residents confirm their building has fire elevators, 26.40% report none, and 23.76% are uncertain (). These results diverge from current building codes [5,18], reflecting potential violations in older buildings, severe resident knowledge gaps, and significant socioeconomic influences (more pronounced issues in low-income communities). Regarding automatic fire protection systems, 56.44% of buildings have basic systems (fire alarms/smoke detectors/sprinklers), 69.31% have extinguishers and demolition tools, and 72.28% have clear exit signage. However, 19.47% of high-rise buildings lack refuge floors, which may create serious evacuation hazards in super high-rises ($ $30 floors). Improvement recommendations include: (1) establishing AR navigation systems to enhance facility identification; (2) strengthening compliance reviews for new buildings; (3) implementing fire protection retrofits for older buildings; and (4) developing refuge floor usage supervision mechanisms.

Cross-analysis of questions 18 and 19 shows that residents' awareness of evacuation routes decreases with floor level: 34.38% of floors 1–6 residents know stairwell locations versus 32.29% for floor 18+ residents; similarly, 36.14% versus 30.12% know exit paths. This phenomenon may stem from high-floor residents' reliance on elevators, resulting in limited stairwell usage experience. According to affiliation theory [18], such knowledge deficits may expose high-floor residents to longer pre-evacuation times and higher safety risks during fires. Results indicate the need for differentiated fire safety education targeting residents by floor level, particularly strengthening evacuation route cognition training for high-floor occupants.

[**Figure 3: see original paper**] Proportion of residents in each floor group who know evacuation stairwell locations and exit paths

4.4 Multiple Regression Analysis

This study employs quantitative methods to code KAP variables: gender (male=1, female=0); education level categorized as high school or below (0), bachelor' s (1), master' s (2), and doctorate (3); residence duration divided into 1–4 years (1), 5–8 years (2), and over 8 years (3); age grouped as 18–29 (0), 30–49 (1), and 50+ (2); residential floor categorized as 0–6 (0), 7–17 (1), and 18+ (2); binary variables (fire experience, indirect experience, fire drills) coded as yes=1, no=0.

Hierarchical regression analysis was conducted using two progressive models: Model 1 included only control variables (gender and residence duration), showing significant gender effects on KAP ($p<0.05$) but limited explanatory power (adjusted $R^2=0.062$), consistent with behavioral theory expectations that demographic variables typically explain minimal variance in complex behaviors [19]. To enhance explanatory power, Model 2 incorporated theoretically relevant variables including education level, age, and residential floor, forming a complete

predictive system. Results are presented in .

**** Multiple Regression Analysis Results

Model 2 results () indicate that gender ($p<0.001$), age ($p<0.01$), education level ($p<0.01$), and fire drill participation ($p<0.001$) have significant positive effects on KAP scores. Specifically: (1) males demonstrate superior fire safety knowledge compared to females (supporting gender difference hypotheses); (2) increased age significantly correlates with higher knowledge levels (supporting H1); (3) higher education groups perform better (supporting H2); and (4) drill participants show 41% higher knowledge scores (strongly supporting H6). Residential floor shows a positive trend ($p=0.079$) but does not reach statistical significance, suggesting risk perception may promote knowledge acquisition among high-floor residents but requires further verification (partially supporting H3). Other variables (residence duration, direct/indirect fire experience) show no significant effects. Overall model explanatory power is 19.4% (adjusted $R^2=0.194$), with Durbin-Watson test value of 1.990 indicating no multicollinearity issues.

**** Hypothesis Testing Results

4.5 Moderating Effects of Gender and Residence Duration

Further analysis examined the influence of control variables (gender and residence duration) on fire safety KAP. **** and **** present p-values for these control variables.

(1) Gender Differential Effects

Regression analysis shows that fire drills significantly improve fire safety KAP for both genders, but influencing factors differ (): For females, age ($p=0.016$) and education level ($p=0.047$) have more significant effects, while residential floor ($p=0.115$) has weaker effects, indicating women are more responsive to knowledge-based education (e.g., fire safety publicity, theoretical learning). For males, fire drills ($p=0.028$) have the most prominent effect, suggesting men respond better to practical training (e.g., evacuation drills, fire extinguishing operations). These results support gender-differentiated education strategies: theoretical publicity for female residents and practical training for male residents.

(2) Moderating Role of Residence Duration

Regarding residence duration as a control variable (), for the 1–4 year group, both fire drills ($p=0.019$***) and education level ($p=0.029$***) significantly affect KAP, indicating systematic training and knowledge dissemination are most effective for new residents. For the 5–8 year group, only fire drills ($p=0.076$) show marginal significance, reflecting greater reliance on experiential learning (drills) rather than theoretical education. Notably, for long-term residents (8+ years), neither intervention is significant, possibly because long-term residence has fostered passive safety awareness requiring more intensive interventions (e.g., simulated fire scenario training). These findings emphasize the importance of

customizing fire safety programs according to residence duration: new residents require comprehensive education, mid-term residents benefit most from practical training reinforcement, and long-term residents need advanced scenario-based training.

**** Gender as Control Variable
**** Residence Duration as Control Variable

This study systematically evaluates Kunming' s high-rise building fire safety status across three core dimensions: residents' safety awareness and emergency preparedness, building fire protection facility configuration, and property management practices. Findings reveal prominent issues including inadequate resident safety literacy, missing critical fire protection facilities, and imperfect management mechanisms. Statistics show that nearly half of residents have weak fire safety awareness, with specific at-risk groups including less-educated residents and younger women.

Survey data demonstrate significant fire safety hazards: 30.7% of residents have not developed appliance-shutoff habits, 67% have never participated in fire drills, and 52% lack evacuation plans. Regarding building facilities, over 80% lack fire elevators and refuge floors, fewer than 50% conduct regular fire inspections and drills, and only about 33% of community meetings discuss fire safety issues.

Multivariate regression analysis demonstrates that fire drill participation has a universally significant effect on residents' fire safety KAP ($p<0.01$). The study also finds: (1) increased age and education level significantly positively predict KAP; (2) significant gender differences exist, with women more affected by age and education (β=0.25–0.28), while men respond more strongly to fire drills (β=0.41); (3) residence duration moderates intervention effects, with new residents (1–4 years) requiring dual-path "education + drills" interventions, while mid-term residents (5–8 years) benefit more from practical training. These findings provide empirical evidence for developing differentiated fire safety education strategies, recommending precise intervention programs tailored to different population characteristics.

Results indicate that Kunming' s high-rise buildings face certain fire risks, necessitating the establishment of a multi-stakeholder collaborative fire safety management system: residents should enhance safe electricity usage awareness and actively participate in fire drills; property management departments must improve fire protection facility maintenance and regular drill systems; government agencies should strengthen regulatory enforcement to jointly construct a full-chain prevention-response-management control mechanism.

Despite limitations in sample representativeness and unexamined socioeconomic factors, this study provides important references for high-rise building fire prevention and control. Future research should: (1) expand sample coverage across regions and building types, as well as sample size and geographical coverage to enhance generalizability; (2) incorporate socioeconomic variables such as income, occupation, and community environment into the analytical framework;

and (3) deepen investigation of multi-stakeholder (developers, designers, regulatory agencies) collaborative mechanisms and develop targeted questionnaires for different stakeholders to facilitate multi-perspective analysis. These methodological improvements will further illuminate the complex interactions between building environmental factors and human behavior in fire safety, thereby providing robust support for creating safer high-rise communities amid Yunnan' s rapid urbanization.

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Author Contributions Statement:

Huangfu Dongmei: Conceptualized research, designed study; drafted manuscript
Wang Xinzeng: Collected, cleaned, and analyzed data
Dai Haijian: Revised final manuscript version

Author contributions can be categorized as: 1) Research conceptualization and design, including specific ideas or methods; 2) Research implementation, such as conducting experiments or surveys; 3) Data acquisition, provision, and analysis; 4) Manuscript drafting or final revision. Each research paper may elaborate specific author contributions according to its research activities. Some research activities may involve additional work and contributions that can be further specified. For papers with multiple authors, each author' s specific contributions across these four aspects must be indicated at the end of the paper.

Note: Figure translations are in progress. See original paper for figures.