



Factors associated with residential fires: Insights from Dutch national incident data

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ABSTRACT

Residential fires pose a threat to public safety, yet limited research has examined the factors associated with their occurrence. This study analyzes household, dwelling, and neighborhood characteristics linked to residential fire incidents in the Netherlands. Using 2022 national fire incident data from the Integrated Dispatch Center System (GMS), linked with Statistics Netherlands microdata, over 7 million households were included, of which 5622 experienced a reported fire.

Multivariable logistic regression showed that fires were more common in older dwellings and detached or semi-detached houses. Households with children were more likely to report a fire. An interaction between age and care dependency indicated that care dependency increased fire occurrence among younger households (<65 years), but not among older households (≥ 65 years). Lower-income households (1st–50th percentile) had higher odds of fire compared to the highest income group. Migration background showed only a weak association with fire risk, suggesting that behavioral or cultural factors may offer better explanatory value.

The findings underscore the importance of targeted fire prevention strategies, particularly for vulnerable groups and high-risk dwelling types. Limitations include the absence of behavioral data and potential non-reported (minor) fires. Future research should incorporate behavioral and home renovation data to better understand fire risk mechanisms.

1. Introduction

Residential fires pose a serious threat to public safety, with consequences that extend beyond immediate physical damage. Such incidents can result in fatalities, injuries, and substantial material losses, while also having long-lasting psychological effects on those involved [1–3]. Previous research has extensively examined the factors associated with injuries and fatalities resulting from residential fires (e.g. [4–6]), and less attention has been paid to factors that contribute to the occurrence of residential fires themselves.

In 2024, more than 6800 residential fires were reported to the fire service in the Netherlands. Nearly 300 individuals were rescued and there were 30 confirmed fatalities [7]. The number of reported residential fires highlights the urgent need to better understand the factors associated with their occurrence at the household level. Gaining insight into these factors is essential for developing effective, targeted prevention strategies and reducing the human and societal costs of residential fires.

Studies at both the household level and the neighborhood level indicate that the likelihood of residential fires is higher for families with children. Turner et al. [8], in a systematic review, found that

households with a higher number of children were more frequently involved in fire incidents. Nilson et al. [9] identified that the presence of children aged 6 to 12 years increased the likelihood of fire, while the presence of children in other age group did not show a significant association with residential fires. Chhetri et al. [10] found that areas with a higher proportion of families with children under 15 years of age were more vulnerable to residential fires. In addition, residential fires were associated with single-parent households [8,10].

Turner et al. [8] reported a higher likelihood of fire with an increase in the number of household members and there was no evidence of an increased risk of residential fires for single-person households. However, neighborhood level studies showed that more fires occurred in neighborhoods with more single-person households [11,12]. Households with older members (65+) experienced fewer fires, yet this age group has a high risk of injuries and fatalities [8]. Additionally, “vulnerable” residents, residents with reduced mobility, dementia, mental illness, or impaired by alcohol or drugs, have a higher risk of fire-related injuries or fatalities [4,5,13–15]. Although these factors are researched in relation to injury risk and fatalities, their role in fire occurrence is not well understood.

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There is a positive association between fire and unemployment, which was found on household level [8] and neighborhood level [10, 11, 16]. On household level, the role of educational attainment was ambiguous [8], but on neighborhood level the fire rate was highest in neighborhoods with higher educational attainment [16]. Turner et al. [8] also reported that several studies have found that low household income is significantly associated with an increased risk of fire incidents, however the most methodologically robust study included in this review did not observe a statistically significant relationship between income and the risk of fire incidents.

While some studies have identified associations between ethnic background and fire incidence, findings remain inconsistent. For example, a Swedish study reported a positive association between being born outside the Nordic countries and the likelihood of residential fire [9]. Other research has suggested that the ethnic composition of a neighborhood, or the proportion of the native population, may be relevant predictors of fire incidence [10, 11]. A Dutch report found that, in univariable analyses, residential fires in the city of Amsterdam occurred more frequently in households with non-Dutch surnames [17]. In contrast, Greene [18] found no significant relationship between ethnicity and fire occurrence. Although Smith et al. [19] initially observed a positive correlation between the proportion of Caribbean/African residents and house fire rates, this association disappeared after adjusting for socioeconomic factors. Ethnicity may not be direct risk factor, but rather a proxy for other underlying variables. Factors such as language barriers and cultural differences in fire safety practices may contribute to elevated fire risk among certain ethnic groups. Nilson and Bonander [20] found that country of birth influenced both the possession of fire prevention equipment and knowledge of fire safety. Supporting this, Australian research showed that individuals who speak a language other than English at home were significantly less likely to have a working smoke alarm installed [21].

Housing type also relates to the likelihood of experiencing a residential fire. Compared to detached, single family dwellings, it was found that residential fires are more likely to occur in duplexes, apartments, and other types of housing [8]. In a univariable analyses on data from the region of Amsterdam, the Netherlands, it was found that more fires occurred in detached dwellings, both in the city of Amsterdam and in the surrounding municipalities [17]. Furthermore, low property value and living in social housing were related to residential fires [8, 22]. Only one study has examined building age and dwelling fires, finding no significant association [18]. A Dutch report provided insight into the association of levels of urbanization and residential fires. Incidence of cooking-related fires declined with decreasing levels of urbanization, where heating-related fires showed the opposite urbanization pattern with higher incidence in households less urbanized areas [23].

The current study aims to examine the associations between various household, building and neighborhood characteristics and the occurrence of fire in the Netherlands. The findings of this study are intended to contribute to the development of scientifically informed prevention and policy measures aimed at improving fire safety in the Netherlands.

2. Methodology

2.1. Data preparation

In the present study, we used data from the Integrated Dispatch Center System (Geïntegreerd Meldkamer Systeem, GMS) in the Netherlands. GMS is the nation-wide system in which all incoming emergency calls are registered. It contains information like location, time and classification of the incident and the notified emergency vehicles. Incident reports classified as “Fire” and “Building” that took place from January 1, 2022 to December 31, 2022 were selected. Only those incidents where a fire brigade unit was confirmed to have been on scene – based on the unit status codes – were included in the analysis.

Incident reports were enriched with nonpublic microdata, defined here as datasets containing records corresponding to individual statistical units, i.e., persons and households, from Statistics Netherlands (SN) [24]. These microdata are compiled and made available by SN and are primarily based on administrative register data [25]. When necessary, these registers are supplemented with other data sources. By utilizing administrative data, these registers constitute the most comprehensive source for the entire target population. All datasets contain unique, pseudonymized identifiers at the level of persons, households, or dwellings, enabling linkage across datasets.

The incident report data were transferred to the secure remote access environment of SN and pseudonymized by SN to secure privacy and allow for linkage with microdata. Several preprocessing steps were undertaken to construct the final dataset. All data preparation and analyses were conducted within the secure remote access environment of Statistics Netherlands.

First of all, incident records with missing or inconsistent location identifiers were excluded prior to linkage ($n = 400$). Next, based on microdata on the dwelling stock, a dataset of all residential objects existing on January 1, 2022, was constructed. This dataset was subsequently merged with the selected GMS incident reports based on the pseudonymized dwelling identifiers. Incident records linked to non-residential objects were excluded from the analysis.

Next, the microdata allow the identification of individuals residing at each address at a given point in time. Individual residents were first linked to the main income earner of their household. Through this linkage, household membership could be established, and household-level characteristics could subsequently be assigned to all residents and linked to the residential object. This made it possible to attach both individual and household characteristics to each dwelling. Household and resident characteristics were based on individuals registered at the address on January 1, 2022. For dwellings with a reported fire incident, only residents who were registered at the address both on January 1, 2022, and on the date of the reported fire were retained.

During linkage with microdata, cases that could not be matched due to missing or invalid linkage variables were sequentially removed (see Table 1). Additionally, households with missing values on any of the variables included in the regression analysis were excluded, resulting in a complete-case dataset.

2.2. Variables

From the available microdata, we extracted the following variables, selected based on their relevance identified in the existing literature. Building characteristics included property ownership (categorized as rentals managed by housing associations, private sector rentals, and owner-occupied), housing type (categorized as apartment, semi-detached house, terraced house, corner house, and detached house), and year of construction. Year of construction was categorized into four groups. The included neighborhood characteristic was population density, defined as number of people per square kilometer of land, categorized into four groups based on distribution and content-driven cut-off points. Household characteristics included the presence of children aged 0–11 years old, the presence of children aged 12–18 years old, and the disposable income of the household, which refers to the total gross income of a household, reduced by mandatory financial obligations. Households were grouped into percentile categories based on their disposable income, resulting in 100 equally sized groups. For the analysis, these percentiles were further aggregated into quartiles. Individual characteristics, aggregated to the household level, included migration background (classified as Dutch if the majority of adult persons in the household were born in the Netherlands, migrant if the majority were born outside of the Netherlands, or mixed if the distribution was similar), whether at least one person was care-dependent (defined as receiving special care from the social support act, long-term care scheme, care for a sensory disability, and/or community nursing),

Table 1
Linkage and selection households.

Step	Fire cases	Non-fire cases	Total
Residential units	7369	8,597,343	8,604,712
Link table 'persons' to table 'residential units'	6970	7,718,698	7,725,668
Link table 'main earner'	6970	7,718,567	7,725,537
Link table 'household information'	6970	7,715,999	7,722,969
Select households during fire incident ^a	5999	7,715,999	7,721,998
Link table 'neighborhood characteristics'	5999	7,715,987	7,721,986
Select houses with only one household	5735	7,505,725	7,511,460
Exclude institutional households ^b	5673	7,419,425	7,425,098
Exclude households with missing values	5622	7,340,392	7,346,014

^a Only for fire cases.

^b Institutional household: household consisting of one or more people living in one accommodation whose housing and daily needs are provided professionally.

and the age composition of the adults in the households, categorized as households where all adult members were below 40 years old, households where at least one member was 40 years old or above, and all members were <65 years old, households where at least one member was 65 years old or above, and all members were <80 years old, and households where at least one member was 80 years or older.

2.3. Statistical analysis

All variables were compared between households that reported a fire and those who did not using Pearson's χ^2 test. Next, logistic regression analyses were conducted to examine the association between all variables and the occurrence of residential fire. Univariable and multivariable logistic regression analyses were performed. To get a better understanding of the association between age of the household members and fire occurrence, the model included an interaction with age and care dependency. While older household members appear to experience fewer fires, their higher injury and fatality risk suggests that care dependency might moderate this association. Results are reported as odds ratios with their 95% confidence intervals. $P < 0.05$ was considered statistically significant. Data management was done using Python (3.11.9), and analyses were performed using R (4.4.3).

3. Results

As of January 1 2022, the Netherlands had 8,604,712 residential objects. The GMS dataset contained 10,260 reported fire incidents, of which 400 (3.9%) could not be linked to SN objects due to missing or incorrect location data. The remaining 9860 incidents occurred in 9627 unique objects, of which 7326 (76.1%) were residential. All other residential objects were treated as non-fire cases. To construct the final dataset, multiple microdata tables were linked. At each step, linkage limitations led to a reduction in usable cases. This is shown in Table 1.

The final dataset included 5622 fire cases (0.08%) and 7,340,392 non-fire cases (99.92%), totaling 7,346,014 households. The majority of dwellings were owner-occupied (59.52%) and built in 1960–1979 (28.90%). Detached dwellings comprised 13.13% of the data. In total, 16.84% of the households had children under age 12 and 12.08% had children in the age category 12–18 years old. In 5,962,053 (81.16%) households, the adult household members were born in the Netherlands. The minority of households had at least one household member in the age ≥ 80 (8.51%) years old. In 15.06% of the households at least one person was care-dependent. All variables significantly differed between households with and without reported fires, as indicated by the χ^2 -tests (Table 2).

In the univariable analysis (Table 3), several building characteristics were associated with the occurrence of residential fires. Rental dwellings managed by housing associations showed higher odds of fire (OR 1.22, 95% CI 1.11–1.34), as did owner-occupied dwellings (OR 1.10, 95% CI 1.00–1.20), compared to private sector rentals. Year of construction was a significant factor: dwellings built before 1960

had the highest odds (OR = 2.40, 95% CI 2.19–2.63), followed by those built between 1960–1979 (OR = 1.79, 95% CI 1.63–1.96), and 1980–1999 (OR 1.32, 95% CI 1.19–1.45), compared to dwellings built in or after 2000. Housing type was also significantly associated with the occurrence of fires. Compared to apartments, detached dwellings had the highest odds (OR 1.80, 95% CI 1.68–1.94), followed by semi-detached dwellings (OR 1.19, 95% CI 1.08–1.30). Terraced dwellings had lower odds of fire (OR 0.80, 95% CI 0.75–0.86), while corner dwellings did not show a significant difference (OR 0.93, 95% CI 0.85–1.02), compared to apartments.

Population density was inversely associated with the outcome. Households in areas with ≥ 7000 people per km^2 had lower odds of fire (OR 0.75, 95% CI 0.70–0.80), as did those in areas with 4600–6999 people per km^2 (OR 0.66, 95% CI 0.61–0.71) and 2500–4599 people per km^2 (OR 0.67, 95% CI 0.62–0.72), compared to areas with <2500 people per km^2 .

Finally, several household characteristics were associated with fire occurrence. The presence of children in the household increased the odds of fire. Households with children aged 0–11 years old had higher odds (OR 1.34, 95% CI 1.25–1.42), as did those with children aged 12–18 years old (OR 1.46, 95% CI 1.36–1.57), compared to households without children in these age groups. The analysis showed that households with adults with a non-Dutch migration background had higher odds of fire (OR 1.20, 95% CI 1.11–1.29) compared to households with a Dutch migration background. Households with both Dutch and non-Dutch migration backgrounds did not differ significantly from households with a Dutch migration background (OR = 1.00, 95% CI 0.90–1.12). The age composition of a household was also associated with the odds of fire. Compared to households where all adults were under 40, those with at least one adult aged ≥ 40 had slightly higher odds (OR 1.12, 95% CI 1.05–1.20), whereas households with at least one adult aged ≥ 65 or ≥ 80 had lower odds (OR 0.82, 95% CI 0.76–0.89 and OR 0.87, 95% CI 0.78–0.98, respectively). Households with care dependency had significantly higher odds of fire compared to those without (OR = 1.29, 95% CI 1.20–1.38). Finally, households with the lowest incomes (1–25th percentile) had significantly higher odds (OR = 1.38, 95% CI 1.29–1.49), while those in the 26–50th percentile and 51–75th percentile did not differ significantly from the households with the highest income (76–100th percentile) (OR = 1.04, 95% CI 0.96–1.12 and OR 0.94, 95% CI 0.87–1.01, respectively).

In the multivariable analysis (Table 4), several building characteristics remained significantly associated with fire occurrence. Compared to households living in private sector rentals, those in dwellings managed by housing associations had higher odds of reporting a fire (aOR 1.31, 95% CI 1.18–1.44), as did owner-occupied dwellings (aOR 1.14, CI 1.03–1.26). Relative to dwellings built in or after 2000, fires were more often reported in older dwellings. Highest odds were found for dwellings built before 1960 (aOR 2.26, 95% CI 2.06–2.48), followed by dwellings built between 1960–1979 (aOR 1.81, 95% CI 1.65–1.99) and dwellings built between 1980–1999 (aOR 1.37, 95% CI 1.24–1.51). Housing type also showed differences. Compared to apartments, detached and semi-detached dwellings had significantly higher odds of

Table 2
Descriptive statistics.

Variable	No Fire, n (%)	Fire, n (%)	χ^2	df	p
Property ownership			21.35	2	<.001
- rental, private sector	847,742 (11.55)	577 (10.26)			
- rental, housing association	2,123,604 (28.93)	1766 (31.41)			
- owner-occupied	4,369,046 (59.52)	3279 (58.32)			
Year of construction			515.13	3	<.001
- ≥ 2000	1,327,181 (18.08)	605 (10.76)			
- 1980–1999	1,963,899 (26.75)	1179 (20.97)			
- 1960–1979	2,120,948 (28.89)	1727 (30.72)			
- <1960	1,928,364 (26.27)	2111 (37.55)			
Housing type			495.52	4	<.001
- Apartment	2,490,934 (33.93)	1812 (32.23)			
- Detached	963,153 (13.12)	1264 (22.48)			
- Semi-detached	669,466 (9.12)	578 (10.28)			
- Corner	972,236 (13.25)	658 (11.70)			
- Terraced	2,244,603 (30.58)	1310 (23.30)			
Population density			181.22	3	<.001
- <2500 people per km ²	1,791,099 (24.40)	1791 (31.86)			
- 2500–4599 people per km ²	1,843,919 (25.12)	1229 (21.86)			
- 4600–6999 people per km ²	1,843,774 (25.12)	1211 (21.54)			
- ≥ 7000 people per km ²	1,861,600 (25.36)	1391 (24.74)			
Children aged 0–12			79.11	1	<.001
- 0	6,104,193 (83.16)	4425 (78.71)			
- 1	1,236,199 (16.84)	1197 (21.29)			
Children aged 12–18			114.29	1	<.001
- 0	6,453,682 (87.92)	4681 (83.26)			
- 1	886,710 (12.08)	941 (16.74)			
Migration background adults in household			23.01	2	<.001
- Dutch	5,957,603 (81.16)	4450 (79.15)			
- Non-Dutch	936,131 (12.75)	837 (14.89)			
- Mixed	446,658 (6.08)	335 (5.96)			
Age composition			87.62	3	<.001
- all adults <40	1,664,746 (22.68)	1274 (22.66)			
- at least one member ≥ 40 , all <65	3,317,679 (45.20)	2844 (50.59)			
- at least one member ≥ 65 , all <80	1,732,986 (23.61)	1086 (19.32)			
- at least one member ≥ 80	624,981 (8.51)	418 (7.44)			
Care dependency			54.02	2	<.001
- 0	6,235,357 (84.95)	4578 (81.43)			
- 1	1,105,035 (15.05)	1044 (18.57)			
Disposable income			137.26	3	<.001
- 76–100th percentile	1,921,712 (26.18)	1363 (24.24)			
- 51–75th percentile	1,903,666 (25.93)	1265 (22.50)			
- 26–50th percentile	1,852,191 (25.24)	1361 (24.21)			
- 1–25th percentile	1,662,823 (22.65)	1633 (29.05)			

fire (*aOR* 1.93, 95%*CI* 1.74–2.14 and *aOR* 1.21, 95%*CI* 1.09–1.36, respectively). Terraced dwellings had significantly lower odds (*aOR* 0.84, 95%*CI* 0.77–0.91), while corner dwellings showed no significant difference (*aOR* 0.97, 95%*CI* 0.88–1.07). Households in more densely populated areas had lower odds of reporting a fire compared to those in the least populated areas (<2500 people per km²). This pattern held for areas with ≥ 7000 people per km² (*aOR* 0.88, 95%*CI* 0.81–0.99), for 4600–6999 people per km² (*aOR* 0.86, 95%*CI* 0.79–0.93) and for areas with 2500–4599 people per km² (*aOR* 0.83, 95%*CI* 0.77–0.90).

Several household characteristics also remained significant. Households with children were more likely to report a fire. Compared to households without children aged 0–11, households with one or more children in this age group had higher odds (*aOR* 1.26, 95%*CI* 1.17–1.35). Similarly, households with children aged 12–18 had higher odds compared to those without children in that age group (*aOR* 1.32, 95%*CI* 1.22–1.42). Migration background showed a modest effect: compared to households in which all members were born in the Netherlands, the odds for households in which all adults were born outside the Netherlands was slightly increased (*aOR* 1.14, 95%*CI* 1.05–1.23), while mixed-background household did not differ significantly (*aOR* 1.04, 95%*CI* 0.93–1.17). Income was associated with fire occurrence. Households in the lowest income quartile (1–25th percentile) had the highest odds (*aOR* 1.50, 95%*CI* 1.36–1.64), followed by those in the second quartile (26–50th percentile) (*aOR* 1.18, 95%*CI* 1.09–1.28), compared to the highest quartile. Households in the third quartile

(51–75th percentile) did not differ significantly (*aOR* 1.02, 95%*CI* 0.94–1.10).

Finally, an interaction between age and care dependency was observed, and a combined variable was included in the final model ($\chi^2(2) = 157.11$, $p < .001$). In general, care-dependent households were more likely to report a fire, but this association decreased with increasing age. Compared to households without care dependency where all adults were under 40 years old, care-dependent households in the same age group had the highest odds (*aOR* 2.00, 95%*CI* 1.70–2.36). Care-dependent households with members aged 40–65 also had elevated odds (*aOR* 1.50, 95%*CI* 1.33–1.70), whereas no significant differences were found for care-dependent households with members aged 65–80 or 80+ years (*aOR* 0.98, 95%*CI* 0.85–1.13 and *aOR* 0.95, 95%*CI* 0.82–1.09, respectively). Among households without care dependency, those with members aged 65–80 or 80+ years had lower odds of fire (*aOR* 0.81, 95%*CI* 0.74–0.90 and *aOR* 0.79, 95%*CI* 0.66–0.94, respectively), while households with members aged 40–65 did not differ significantly (*aOR* 1.05, 95%*CI* 0.97–1.14).

4. Conclusion and discussion

In the Netherlands, residential fires were most common in older dwellings, detached or semi-detached dwellings, rented dwellings managed by housing associations or owner-occupied dwellings, and dwellings in sparsely populated areas. Households with children and households with younger care-dependent people were more likely to report

Table 3
Univariable logistic regression results.

Variable	B	OR	95% CI	p
Property ownership				
- rental, housing association	0.20	1.22	[1.11, 1.34]	<.001
- owner-occupied	0.09	1.10	[1.00, 1.20]	.030
- rental, private sector (ref)				
Year of construction				
- <1960	0.88	2.40	[2.19, 2.63]	<.001
- 1960–1979	0.58	1.79	[1.63, 1.96]	<.001
- 1980–1999	0.28	1.32	[1.19, 1.45]	<.001
- ≥ 2000 (ref)				
Housing type				
- Detached	0.59	1.80	[1.68, 1.94]	<.001
- Semi-detached	0.17	1.19	[1.08, 1.30]	<.001
- Corner	−0.07	0.93	[0.85, 1.02]	.113
- Terraced	−0.22	0.80	[0.75, 0.86]	<.001
- Apartment (ref)				
Population density				
- ≥ 7000 people per km ²	−0.29	0.75	[0.70, 0.80]	<.001
- 4600–6999 people per km ²	−0.42	0.66	[0.61, 0.71]	<.001
- 2500–4599 people per km ²	−0.41	0.67	[0.62, 0.72]	<.001
- <2500 people per km ² (ref)				
Children aged 0–11				
- 1	0.29	1.34	[1.25, 1.42]	<.001
- 0 (ref)				
Children aged 12–18				
- 1	0.38	1.46	[1.36, 1.57]	<.001
- 0 (ref)				
Migration background adults in household				
- Non-Dutch	0.18	1.20	[1.11, 1.29]	<.001
- Mixed	0.00	1.00	[0.90, 1.12]	.942
- Dutch (ref)				
Age adults in household				
- at least one member ≥ 40, all <65	0.11	1.12	[1.05, 1.20]	<.001
- at least one member ≥ 65, all <80	−0.20	0.82	[0.76, 0.89]	<.001
- at least one member ≥ 80	−0.13	0.87	[0.78, 0.98]	0.017
- all adults <40 (ref)				
Care dependency				
- 1	0.25	1.29	[1.20, 1.38]	<.001
- 0 (ref)				
Disposable income				
- 1–25th percentile	0.33	1.38	[1.29, 1.49]	<.001
- 26–50th percentile	0.04	1.04	[0.96, 1.12]	.356
- 51–75th percentile	−0.07	0.94	[0.87, 1.01]	.095
- 76–100th percentile (ref)				

a fire, while fires were less often reported in households with older members. Although present, the association between reporting a fire and non-Dutch migration background was minor.

4.1. Dwelling characteristics

Detached dwellings were associated with a higher likelihood of fires in this study, consistent with earlier Dutch research conducted in the Amsterdam region [17]. Although these findings differ from the findings reported by Turner et al. [8], which summarize research conducted in the UK and US, a possible explanation may lie in cross-national differences in housing classifications or construction practices, which may affect both dwelling categorization and susceptibility to fire.

The strong association between the construction age and likelihood of fire, particularly for dwellings built before 1960, is a noteworthy finding, given the limited attention this factor has received in prior research. Whereas Greene [18] reported no significant relationship, the present results suggest that building materials or historical safety regulations may contribute to an elevated fire risk in older dwellings. A limitation of this study is that the year of construction does not necessarily reflect the current condition of a dwelling, as renovations may have taken place over time. Unfortunately, data on such modifications were not available in this study. Renovations that include upgrading

electrical installations and ensuring proper grounding may reduce the likelihood of fires. However, additions such as heat pumps and solar panels, may introduce new fire risks [26].

This study found elevated odds of dwelling fire for both owner-occupied and rental dwellings managed by housing associations, compared with rental properties in the private sector. Previous research has predominantly reported higher susceptibility to fire for public or social housing [8,22]. As the analyses controlled for construction year, dwelling type, and household income, these differences are unlikely to be attributable solely to building characteristics or demographic composition of the residents. One possible explanation relates to differences in the available time, resources or knowledge regarding preventive measures, safety improvements or maintenance. Housing associations often manage large dwelling portfolios, which may complicate timely inspections, constant enforcements of safety standards, or prompt repairs. Owner-occupiers may lack sufficient knowledge, financial resources, or awareness of fire prevention measures. Private-sector landlords, by comparison, may face legal requirements and market pressures, which may create stronger incentives to maintain properties and address safety risks. These suggestions are speculative and highlight the need for further research to understand the underlying drivers of these differences.

Table 4
Multivariable logistic regression results.

Variable	B	OR	95% CI	p	χ^2	df	p
Property ownership					13.81	2	.001
- rental, housing association	0.19	1.20	[1.09, 1.33]	<.001			
- owner-occupied	0.13	1.14	[1.03, 1.26]	.015			
- rental, private sector (ref)							
Year of construction					406.79	3	<.001
- <1960	0.82	2.26	[2.06, 2.48]	<.001			
- 1960–1979	0.59	1.81	[1.65, 1.99]	<.001			
- 1980–1999	0.32	1.37	[1.24, 1.51]	<.001			
- ≥ 2000 (ref)							
Housing type					325.70	4	<.001
- Detached	0.66	1.93	[1.74, 2.14]	<.001			
- Semi-detached	0.19	1.21	[1.09, 1.36]	<.001			
- Corner	−0.03	0.97	[0.88, 1.07]	.522			
- Terraced	−0.18	0.84	[0.77, 0.91]	<.001			
- Apartment (ref)							
Population density					23.64	3	<.001
- ≥ 7000 people per km ²	−0.13	0.88	[0.81, 0.96]	.006			
- 4600–6999 people per km ²	−0.15	0.86	[0.79, 0.93]	<.001			
- 2500–4599 people per km ²	−0.18	0.83	[0.77, 0.90]	<.001			
- <2500 people per km ² (ref)							
Children aged 0–11					38.64	1	<.001
- 1	0.23	1.26	[1.17, 1.35]	<.001			
- 0 (ref)							
Children aged 12–18					47.94	1	<.001
- 1	0.28	1.32	[1.22, 1.42]	<.001			
- 0 (ref)							
Migration background adults in household					9.47	2	.009
- Non-Dutch	0.13	1.14	[1.05, 1.23]	.002			
- Mixed	0.04	1.04	[0.93, 1.17]	.477			
- Dutch (ref)							
Age * care dependency					157.11	7	<.001
- <40, CD	0.70	2.00	[1.70, 2.36]	.001			
- 40–65, CD	0.41	1.50	[1.33, 1.70]	.001			
- 40–65, no CD	0.05	1.05	[0.97, 1.14]	.189			
- 65–80, CD	−0.02	0.98	[0.85, 1.13]	.808			
- 65–80, no CD	−0.21	0.81	[0.74, 0.90]	<.001			
- 80+, CD	−0.05	0.95	[0.82, 1.09]	.454			
- 80+, no CD	−0.24	0.79	[0.66, 0.94]	.007			
- <40, no CD (ref)							
Disposable income					87.92	3	<.001
- 1–25th percentile	0.40	1.50	[1.36, 1.64]	<.001			
- 26–50th percentile	0.17	1.18	[1.09, 1.28]	<.001			
- 51–75th percentile	0.02	1.02	[0.94, 1.10]	.694			
- 76–100th percentile (ref)							

Note. CD = care dependency; <40 = all adults <40; 40–64 = at least one member ≥ 40, all <65; 65–80 = at least one member ≥ 65, all <80; 80+ = at least one member ≥ 80.

4.2. Neighborhood characteristics

Population density was associated with the occurrence of residential fires. The likelihood of reporting a fire was lower in densely populated areas than in more sparsely populated areas. Previous Dutch research has shown that this relationship varies by fire type: cooking-related fires were more common in urban areas, whereas heating-related fires occurred more frequently in less urbanized settings [23]. To better understand this association, future research should examine fire causes in greater detail, as the mechanisms behind this pattern are still not well understood.

4.3. Household characteristics

Consistent with earlier findings [8–10], this study found a significant association between household composition and the occurrence of dwelling fires. Households with children are more likely to report a fire, compared to households without children.

Fire risk is not evenly distributed across income levels. Lower-income households faced higher odds of experiencing a fire, with households in the first (1st–25th percentile) and second (26th–50th percentile) income quartiles showing elevated odds compared to those

in the highest income quartile. Greene [18] reported no association between income and fire incidents. Greene suggested, however, that this finding may reflect varying recall of fire events and willingness to participate in surveys across income groups, rather than the true absence of a socioeconomic gradient in fire risk. In contrast, our results are based on administrative records, thereby reducing susceptibility to reporting and recall biases. Altogether, our findings suggest that financial and material constraints faced by lower-income households may play a role in shaping their vulnerability to residential fires. Potential mechanisms could include differences in housing conditions and maintenance, or the capacity to invest in preventive measures, although these mechanisms cannot be directly verified with the available data.

This study further offers a more nuanced perspective of the relationship between household age structure, care dependency, and fire occurrence. Among the younger households (under 65 years of age), care-dependency increased the odds of fire. The effect of care-dependency disappeared in households with members aged 65 years and older. Unfortunately, older individuals are more likely to suffer severe consequences when fires do occur, potentially due to reduced self-reliance. Physical or cognitive impairments, such as reduced mobility, dementia, or mental illness, are known to increase the risk of fire-related injuries and fatalities among vulnerable populations [4,5,13–15].

Migration background was weakly associated with fire risk, with households of non-Dutch origin reporting more fires. This suggests that migration background alone is unlikely to be a sufficiently informative explanatory variable. More detailed factors, such as language barriers, cultural practices or behavioral patterns, are likely to play a role in fire risk. For example, differences in cooking habits, including the use of cooking oils and practices such as deep-frying, may contribute to the observed variation in fire occurrence [27]. Insights from a study covering twelve Dutch safety regions, which examined the fire incidence by cause, support this behavioral perspective [23]. Although this study only reported univariable analysis, precluding examination of interrelationships between variables, it nonetheless offers valuable complementary insights. Cooking was identified as the most frequent cause of fires, followed by heating. Determinants differed by fire type: cooking-related fires were more common in households with lower socioeconomic status and in households with children, and their prevalence generally declined with age, although this pattern varied across regions. By contrast, heating-related fires were more prevalent among households with higher socioeconomic status, those with children, and households with middle-aged adults. International research further supports these findings. In the United States, cooking is a major contributor to both reported and unreported dwelling fires [18,28]. In Australia, Xiong et al. [29] found that nearly half of non-injury dwelling fires could be attributed to human behavior, such as unsafe cooking or carelessness with electrical appliances. Additionally, smoking and the consumption of alcohol or drugs have been associated with dwelling fires, although these factors are primarily examined in studies focusing on fires resulting in injury or fatality [8].

4.4. Strengths and limitations

A major strength of this study lies in the use of national-level data. The analyses were based on all residential fire incident reports submitted to emergency dispatch centers in the Netherlands in 2022. By linking these incident records to nationwide household registry data, we included the full population of households, minimizing selection bias as much as possible. Such population-level linkage is rare in fire risk research and provides a robust basis for identifying associations across a wide range of household and dwelling characteristics.

This study only included residential fires reported to the fire services. From Australian research it is known that a substantial part of the residential fires is never reported, particularly small-scale incidents that are extinguished without assistance [18,21]. Tannous and Agho [21] further showed that the likelihood of contacting the fire services is related to socioeconomic factors: being female, having a higher household income, possessing smoke alarms, and speaking a native language at home were all associated with a lower likelihood of reporting fires. The factors identified in this study in relation to the occurrence of residential fires are also associated with the likelihood that the fire services are contacted.

In the Netherlands, however, insight into the number of fires not reported to fire services and its socioeconomic distribution remains limited. The only source that offers an indication in non-reported fires is the Risk Monitor for Dwelling Fires, published by the Dutch Association of Insurers [30]. According to this source, the number of reported fire insurance claims is approximately seven to eight times higher (53,687 claims in 2022) than the number of dwelling fires reported to the emergency dispatch center (7326 dwelling fires in 2022). While this discrepancy provides a general indication of substantial difference in reported and non-reported fires, it remains unclear whether all insurance claims represent actual dwelling fires. Consequently, the extent to which selective reporting has biased the present findings, and the direction of any such bias, cannot be determined with certainty, particularly because not all residential fires necessarily require contact with the fire services.

A second important limitation concerns the absence of data on human behavior. Behaviors such as smoking, unsafe cooking practices, or careless use of electrical appliances are known to play a crucial role in the occurrence of residential fires [28,29,31], yet could not be included in the analyses. Without detailed information on behavioral factors, it is difficult to fully explain why certain household groups face elevated risks. Recent Dutch reports, documenting recurring patterns in fatal residential fires [32] and comparing fatal fires with non-fatal incidents involving rescue operations [33], highlight themes such as delayed detection, risk-enhancing behaviors, physical or cognitive limitations, and difficulties in self-rescue. These reports shed light on mechanisms influencing fire outcomes, but they do not explain differences in fire occurrence between households, as they focus only on incidents where a fire occurred.

A further limitation of this study is the use of data from a single year (2022). The occurrence of fire and associated risk factors may vary over time due to variations in weather conditions, policy interventions, and societal or behavioral changes. Consequently, the observed associations may be sensitive to year-specific circumstances and may not fully generalize to other time periods. Incorporating data from multiple years would allow future research to examine whether the findings hold over time.

In addition, no information was available on the presence, functionality, or maintenance of smoke alarms, nor on the level of fire safety knowledge among household members. Both elements are widely recognized as critical for early detection and effective response [20,34]. Although several dwelling characteristics were included in this study, these indicators may not adequately reflect the actual fire safety level within a home. Factors such as faulty or outdated electrical wiring [28] or poor housing conditions [35] are not captured in administrative housing data, but may substantially contribute to fire risk.

To better understand the interplay between human behavior, residential characteristics and fire safety measures, more detailed and in-depth quantitative research is required. At present, the Netherlands lacks a systematic data collection framework that integrates behavioral, organizational, and situational factors related to residential fires. Establishing a structured and integrated data collection system would therefore represent an important step toward improved fire risk analysis and evidence-based prevention policy.

Despite these limitations, this study shows that several household and housing characteristics are associated with residential fire risk. While further research is needed to clarify the underlying mechanisms, the findings are directly relevant for targeted prevention efforts. Fire prevention campaigns, based on the probability of occurrence alone, may be more effective when tailored to groups with specific risk profiles, such as households residing in older or detached dwellings or households with children. In addition, housing associations constitute a key target group, as they are well positioned to improve fire safety in rental properties through resident education, proactive communication, and the implementation of physical fire safety measures.

CRedit authorship contribution statement

Vera Oosterveen: Writing – original draft, Software, Project administration, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Hans Weda:** Writing – review & editing, Methodology, Investigation, Conceptualization. **Lieuwe de Witte:** Writing – review & editing, Conceptualization. **Amy Matser:** Writing – review & editing, Supervision, Methodology, Investigation, Conceptualization.

Declaration of competing interest

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

Data availability

The data that has been used is confidential.

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