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Article

Electrical Home Fire Injuries Analysis

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Abstract: Domestic electrical fires can occur for a variety of reasons, including faulty wiring and plugs, overloaded circuits, and malfunctioning electrical appliances. In this article, the circumstances of domestic electrical fire injuries between 2011 and 2022 in the county of Merseyside in Northwestern England were examined in order to inform fire prevention activities. Householder carelessness appeared to be less of a factor in electrical fire injury compared to other types of fire injury such as cooking or smoking fire injury. Faulty electricity supplies were the main cause of electrical fire injuries. Male residents were slightly more likely to sustain injury in an electrical fire in comparison to females (1.25 to 1). Those aged 75+ appeared to be more at risk of electrical fire injuries compared to other age groups.

Keywords: electrical; fire; injury; analysis

1. Introduction

Common causes of fires in the home can include faulty wiring and plugs, overloaded circuits, and malfunctioning electrical appliances [1–7]. Once ignited, electric cable fires can potentially spread to other floors and rooms in a building along the cables [8]. Domestic electrical fires can be due simply to poor contact of electrical connectors [9]. Domestic electrical fires may occur due to the age of electrical appliances, or poor management of such appliances, or even simple carelessness [10,11]. Even low-power consumption domestic electrical appliances, such as light bulbs, can cause fires simply from the loosening of the fixture, which can be difficult for residents to detect [12]. In addition, newer types of domestic electrical fires are emerging such as lithium-ion battery fires [13–15] in particular, e-bike and e-scooter lithium-ion battery fires [16], and photovoltaic electrical fires [17]. In 2023, the London Fire Brigade attended 143 e-bike electrical fires along with 36 e-scooter electrical fires [16]. Lithium-ion energy storage systems (https://www.enelgreenpower.com/learning-hub/renewable-energies/storage/lithium-battery, accessed on 4 December 2024), which are electrochemical devices, have very different fire characteristics compared to existing electrical devices [10] due to the potential for thermal runaway, which can lead to explosive fires.

Keeping domestic electrical appliances clean and properly maintained can improve electrical safety and can also keep them energy efficient and prolong their lifespan [18]. In the UK, domestic electrical safety is covered by the Electrical Equipment (Safety) Regulations 2016 [19], which applies to all domestic electrical equipment. Manufacturers of domestic electrical equipment are required to provide clear and legible instructions in easily to understand English. Importers of domestic electrical equipment into the UK have legal obligations, such as checking that manufacturers have carried out the right conformity assessment procedures. The electrical safety of dwellings in the UK is covered by the UK Building Regulations 2010 [20]. Understanding the nature of electrical hazards and adopting appropriate safety measures is important in order to protect lives and property [21].

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The research reported in this article examined domestic fire injuries associated with the different types of domestic electrical fires including:

- Electricity supply (including faulty electricity supplies, wiring, cables, plugs, and electrical apparatus, including batteries and generators)
- Electrical domestic appliances (including kettles, tumble dryers, TVs, central heating/hot water systems, dishwashers, computers, electric blankets, and electric cookers)
- Electric lighting (including fairy lights, incandescent lights, and spotlights).

The aim of the research was to examine the circumstances associated with domestic electrical fires in order to inform fire prevention strategies. The research covered the time period from 2011 to 2022 in the county of Merseyside in England. Merseyside covers 645 km^2 and in 2021 had a population of 1,423,100, based on the UK Census [22]. The Merseyside area includes a mixture of urban, suburban, and semi-rural areas [23]. The authors chose Merseyside as the area of study, as there was a memorandum of understanding between Merseyside Fire and Rescue Service and the university for which one of the authors worked that covered research into fire prevention.

2. Materials and Methods

2.1. Electrical Fires

In England in 2023/24, there were 11,089 domestic electrical fires which constituted 17.9% of the total number of domestic fires. UK Fire and Rescue Services advise not to run electrical appliances or to charge electrical devices overnight, as there will be less time for residents to react should a fire start [18]. In particular, charging devices should not be left charging for long periods of time, and the correct chargers should always be used. When using laptop computers, these should not be put on soft materials, as this increases the likelihood of them overheating and catching fire [24]. Householders should turn off electrical appliances overnight if they are not designed to be left on, such as washing machines, dishwashers, tumble driers, and electric blankets [25] [18]. Electrical products may contain many different types of materials, which when they burn can produce a variety of toxic fumes and gases [5], including hydrogen chloride [26], hydrogen cyanide [27], and carbon monoxide [28]. Electrical appliances should be kept clean and in good working order. In particular, householders should be aware of fuses that blow, circuit-breakers that trip for no obvious reason and flickering electric lights which can be signs of electrical faults that could trigger a domestic fire [24]. When purchasing an electrical appliance UK householders should check for a British or European safety mark [24]. Faulty residential circuit breakers can pose an increased likelihood of fire for the occupants of dwellings with such faulty circuit breakers installed [29].

2.2. Electrical Fire Injury Prevention

E-bikes and e-scooters are becoming increasingly popular in the UK. E-bikes and e-scooters are typically powered by lithium-ion batteries, which can be charged in the home. If e-bikes and e-scooters are not charged in a safe and correct manner, the lithium-ion batteries they contain can ignite and potentially explode or result a fire that can give off toxic gases with very limited prior warning [30,31]. In order to safely store and charge e-bikes and e-scooters in the home, UK fire and rescues services recommend following the relevant manufactures instructions, storing the e-bike or e-scooters and their batteries in a cool place, always using a manufacturer approved charger for the product, not overcharging and always unplugging the charger when finished charging, and not charging such products whilst asleep or away from the home [32]. The UK National Fire Chiefs Council had recently provided warnings concerning poorly manufactured or converted e-bikes and e-scooter batteries [33,34] and the fire risks that they pose and have advised the UK Government regarding regulatory and legislative changes in order to reduce fire risks. The UK National Fire Chiefs Council recommended that e-bikes, e-scooters, and associated batteries should have a third-party safety certification by an approved body. E-bikes and e-scooters should be safe for the purchaser from the point of purchase [33].

However, currently in England, lithium-ion battery fires are not categorised distinctly in the English Fire Incidence Recording System.

UK fire and rescue service guidance concerning domestic electrical fires is to never use water on such fires and to avoid personal safety risks. Pulling the plug out to the appliance concerned or switching off the power should only be performed if it is safe to do so [24]. Electrical appliances, old or poorly wired electric plugs, and cables can pose fire risks. Plugs or sockets that give off heat, fuses that blow frequently, or flickering lights may indicate loose wiring or other electrical faults. Overloading sockets by connecting too many appliances can result in overheating. Cabling that is damaged or frayed can also pose a danger, and householders should ensure that outer coverings of power leads are in good condition [35].

Previous research had considered domestic fire injuries in general; however, there has been only limited research specifically examining electric fire injuries in the home [36]. Although sufficient information may be available regarding electrical installation safety, many countries do not collect data concerning electrical accidents, which impacts the development of effective public policies to reduce the risk of electrical accidents and injuries [37].

2.3. Research Method

Domestic accidental electrical fire injury data that was recorded by the Merseyside Fire and Rescue Service in the UK Fire Incident Recording System [38] between 2011 and 2022 was analysed with regard to the following research questions:

- What are the circumstances of domestic electrical fire injuries?
- At what time of day do domestic electrical fire injuries occur?
- Who is injured in domestic electrical fires?
- What types of injury result from domestic electrical fires?

These are important questions since domestic fire injuries have costs for the individual, for society, and for healthcare providers [39], and it is therefore important to understand the nature, patterns, and circumstances of domestic electrical fire injuries in order to inform future fire prevention initiatives. The electrical fire injury circumstances examined included instances of householder carelessness with regard to such injuries, the ignition sources involved, the room of origin of the electrical fire leading to injury, the type of property where the fire injury occurred, and the time of day when the electrical fire injury occurred. The inclusion criteria for the Fire Incidence Recording system records that were used in the analysis were that the incident occurred in the Merseyside area between 1 April 2011 and 31 March 2022 (financial years) and that the ignition source was electrical in nature, including: Electricity supply (including faulty electricity supplies, wiring, cables, plugs, and electrical apparatus including batteries and generators), Electrical domestic appliances (including kettles, tumble dryers, TVs, central heating/hot water systems, dishwashers, computers, electric blankets, and electric cookers), and Electric lighting (including fairy lights, incandescent lights, and spotlights). The focus of the research was the Merseyside area because there was a memorandum of understanding between the Merseyside Fire and Rescue Service and the university for which one of the authors worked that covered research into fire prevention, and also because the Merseyside Fire and Rescue service provided more detailed data regarding electrical fires than is available through UK Government websites for fire statistics.

In addition, domestic electrical fire injury demographics were examined in terms of gender and domestic electrical fire injuries per 100,000 of population age groups within Merseyside, as well as the types of injury sustained in domestic electrical fires. Microsoft Excel 365 was used to undertake the statistical analyses reported in this article, which included histograms and line charts for frequency analysis, percentages, ratios, odds, and correlation coefficients.

3. Results

3.1. Domestic Electrical Fire Injury Occurrence

Figure 1 shows the numbers of domestic and electrical domestic fire injuries in Merseyside per year between 2011 and 2022. Overall, a 47.9% decrease was observed in the number of overall domestic fire injuries per year over the study period; however, this was not reflected in the numbers of domestic electrical fire injuries per year, which did not show an overall decrease over the study period. In total, there were 1041 domestic fire injuries and 90 domestic electrical fire injuries over the period studied. Domestic electrical fire injuries constituted a relatively small proportion of overall domestic fire injuries (8.7%) in Merseyside over the study period. In terms of the correlation between the overall domestic and electrical domestic fire injuries per year over the period studied, the Pearson product moment correlation coefficient was 0.10 with a significance level of 0.76, indicating a very weak non-significant correlation. This means that there was very little correlation between the overall number of domestic fires and number of electrical fires per year, and even this very small correlation could be due to chance.

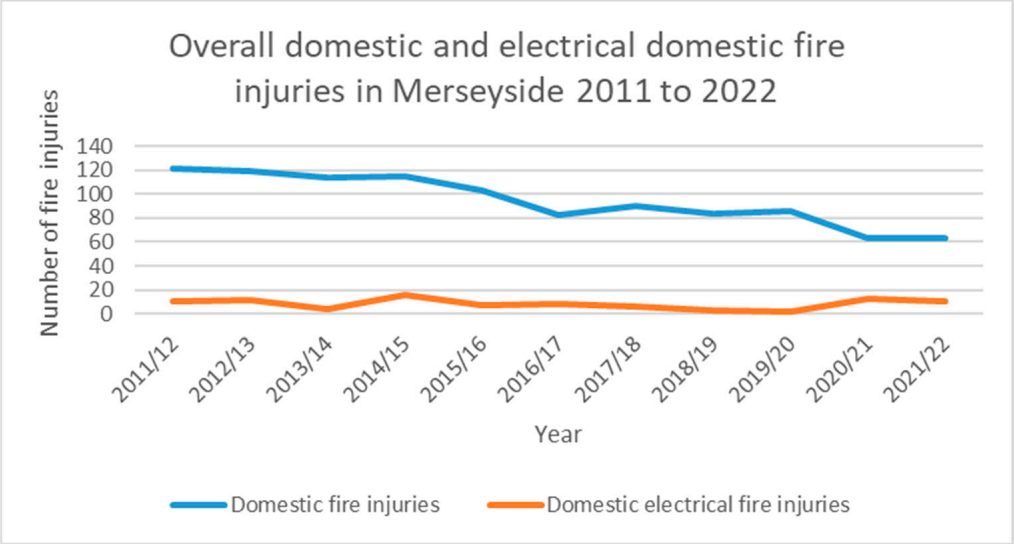

Figure 1. Overall domestic and electrical domestic fire injuries in Merseyside 2011 to 2022.

Of the 90 domestic electrical fire injuries over the period studied, 4 were due to negligent use of electrical equipment, five were due to careless handling of electrical equipment (knocking lights over), and 5 were due to leaving combustible materials too close to an electrical heat source. The 90 domestic electrical fire injuries resulted from 66 electrical fire incidences in total.

Overall, 15.6% (14) of the ninety domestic electrical fire injuries were due to householder carelessness. This equated to odds of 0.18 to 1 that a domestic electrical fire injury was due to householder carelessness. The slight increase in the number of electrical fire injuries per year from 2020 onwards related to electricity supply in terms of wiring, cabling, and plugs, since all the fire injuries from 2020 onwards were in this category.

Figure 2 and Table 1 depict domestic electrical fire injuries by ignition source over the study period. 57.8% (52) of the ninety domestic electrical fire injuries resulting from 38 domestic electrical were due to faulty electricity supply concerning wiring, cabling, and plugs.

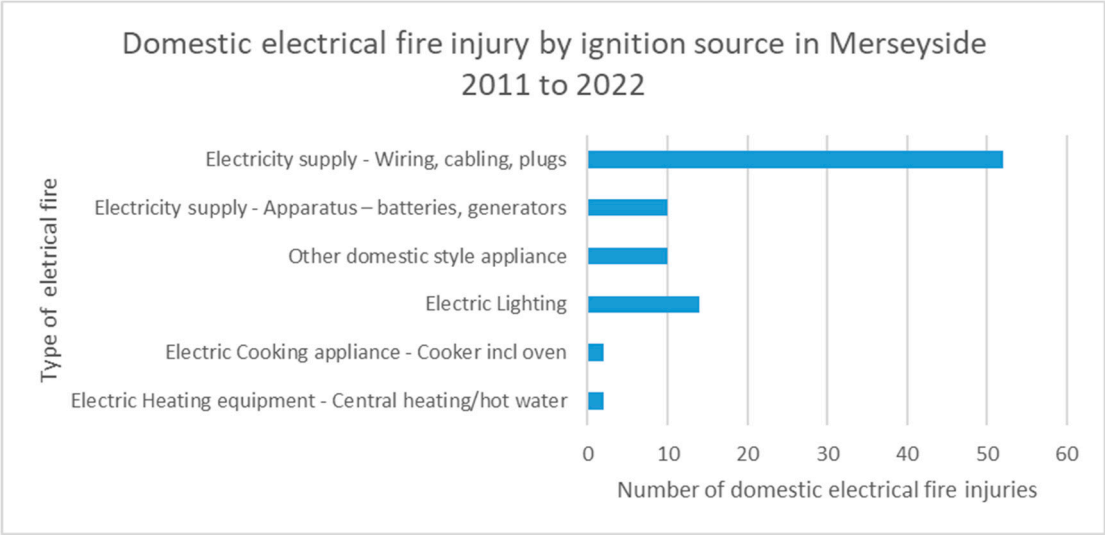

Figure 2. Domestic electrical fire injury by ignition source in Merseyside between 2011 and 2022.

Table 1. Domestic electrical fire injury by ignition source in Merseyside 2011 to 2022.

Ignition Source	Number of Domestic Electrical Fire Injuries
Electricity supply—Wiring, cabling, plugs	52
Electricity supply—Apparatus—batteries, generators	10
Other domestic style appliance	10
Electric Lighting	14
Electric Heating equipment—Central heating/hot water	2
Electric Cooking appliance—Cooker incl. oven	2

Figure 3 and Table 2 depict the distribution of domestic electrical fire injuries by room of origin of the fire in Merseyside over the period studied. 31.1% (28) of the 90 domestic electrical fire injuries resulted from an electrical fire starting in the bedroom, with 20.0% (18) starting in the living room, 5.6% (5) starting in the kitchen, and 15.6% (14) starting in a corridor or hall. Bedroom electrical fires in which injuries occurred were mainly due to wiring, cabling, and plugs (17 out of 28), with smaller numbers of injuries relating to lighting (3) and electric blankets (3). In comparison, living room electrical fires in which injuries occurred were due roughly equally to lighting (8 out of 18) and wiring, cabling, and plugs (6 out of 18). Corridor or hall electrical fires in which injuries occurred were nearly always due to wiring, cabling and plugs (13 out of 14). Kitchen electrical fire injuries were mainly due to wiring, cabling, and plugs (7 out of 14), along with tumble driers (3) and electric cookers (2).

Figure 4 and Table 3 depict the distribution of domestic electrical fire injuries in Merseyside by property type over the period studied. Electrical fire injuries occurred mainly in single occupancy houses (including bungalows) 65 out of 90 (72.2%). Then, 17.8% (16) of the 90 electrical fire injuries occurred in multiple occupancy dwellings of three or more storeys, and 6.7% (6) of the 90 electrical fire injuries occurred in multiple occupancy dwellings of up to three storeys. Of the 14 electrical fire injuries where the fire started in the kitchen, 7 were due to the electricity supply (wiring, cabling, plugs), 5 were due to domestic appliances, and 2 were due to electric cookers. Of the 14 electric fires where the fire started in a corridor/hall, 1 was due to electricity supply (batteries, generators), and 13 were due to the electricity supply (wiring, cabling, plugs). Of the 28 electrical fire injuries where the fire started in a bedroom, 3 were due to lights, 5 were due to electrical appliances, 3 were

due to electricity supply (batteries, generators), and 17 were due to the electricity supply (wiring, cabling, plugs). Of the 18 electrical fire injuries where the fire started in a living room, 8 were due to lights, 4 were due to the electricity supply (batteries, generators), and 6 were due to the electricity supply (wiring, cabling, plugs).

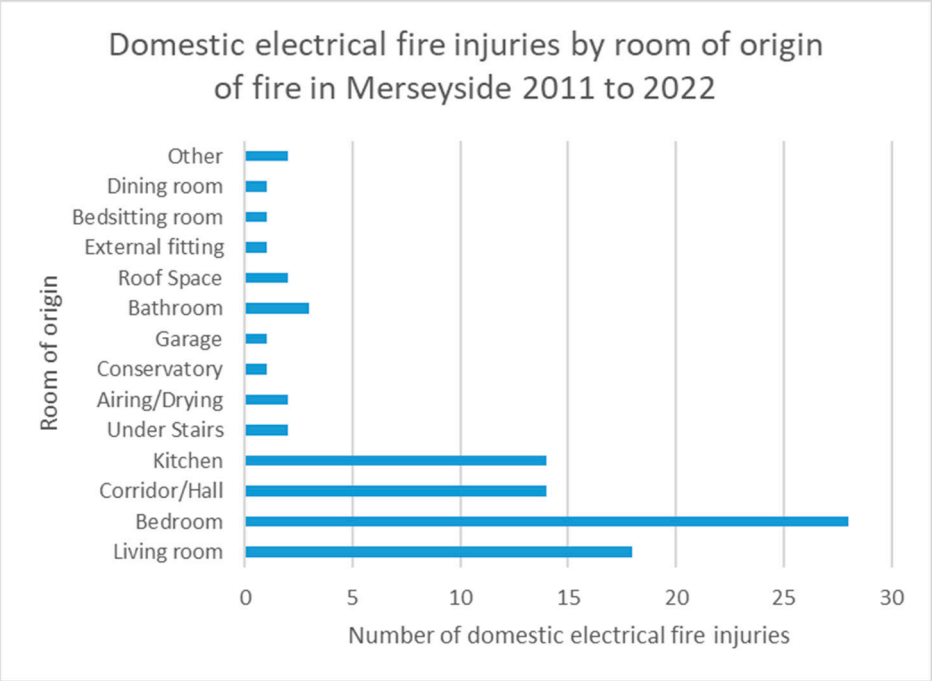

Figure 3. Domestic electrical fire injuries by room of origin of fire in Merseyside between 2011 and 2022.

Table 2. Domestic electrical fire injuries by room of origin of fire in Merseyside 2011 to 2022.

Room of Origin	Number of Domestic Electrical Fire Injuries
Other	2
Dining room	1
Bedsitting room	1
External fitting	1
Roof Space	2
Bathroom	3
Garage	1
Conservatory	1
Airing/Drying	2
Under Stairs	2
Kitchen	14
Corridor/Hall	14
Bedroom	28
Living room	18

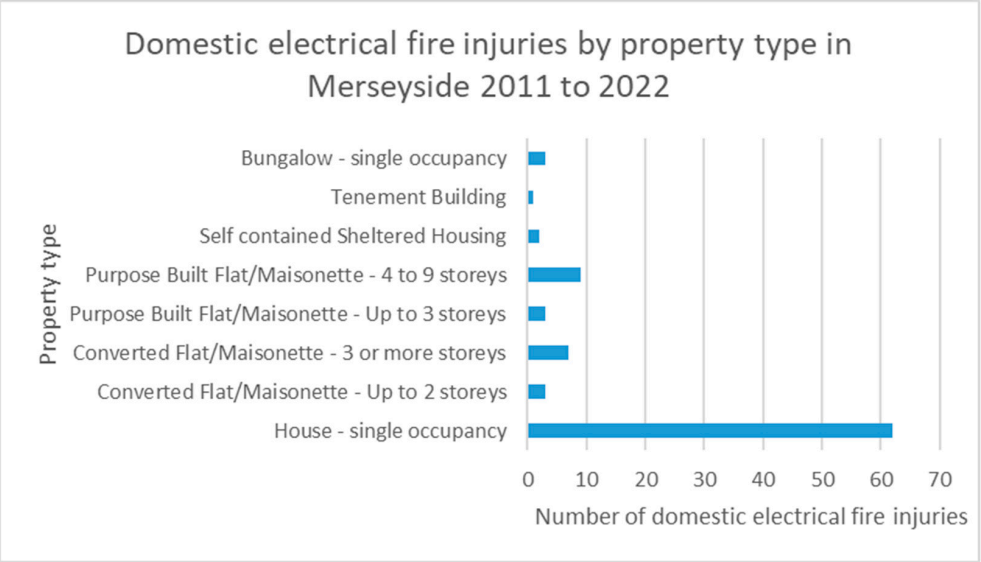

Figure 4. Domestic electrical fire injuries by property type in Merseyside between 2011 and 2022.

Table 3. Domestic electrical fire injuries by property type in Merseyside 2011 to 2022.

Property Type	Number of Domestic Electrical Fire Injuries
Bungalow—single occupancy	3
Tenement Building	1
Self-contained Sheltered Housing	2
Purpose Built Flat/Maisonette—4 to 9 storeys	9
Purpose Built Flat/Maisonette—Up to 3 storeys	3
Converted Flat/Maisonette—3 or more storeys	7
Converted Flat/Maisonette—Up to 2 storeys	3
House—single occupancy	62

During the period studied, domestic electrical fire injuries occurred throughout the day, as indicated in Figure 5.

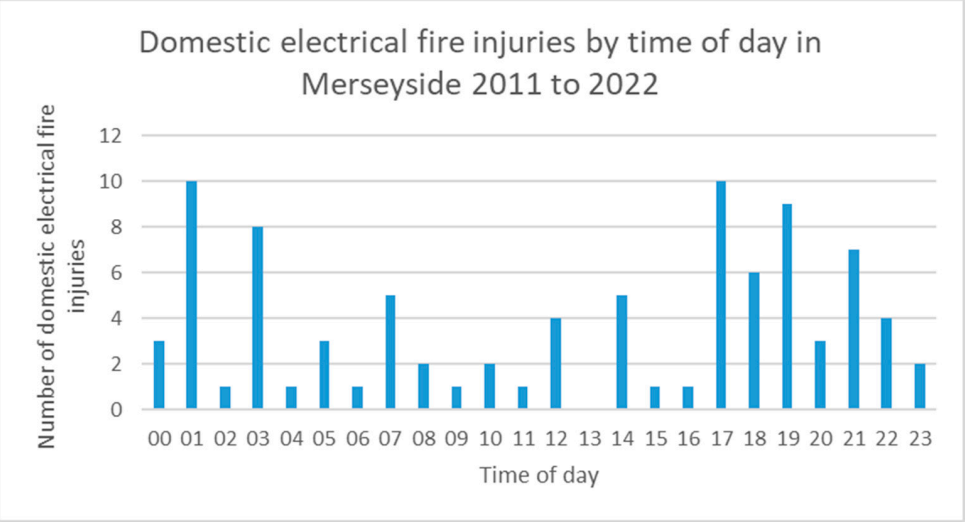

Figure 5. Domestic electrical fire injuries by time of day in Merseyside between 2011 and 2022.

Figure 5 shows domestic electrical fire injuries by hour of day in Merseyside between 2011 and 2022, and it shows that 36.7% (33) of the 90 domestic electrical fire injuries that resulted from 24 electrical fires occurred during the night time (between 22:00 and 06:00). This implies that householders would benefit from further advice and guidance regarding switching off electrical appliances before going to bed, and not charging electrical appliances overnight. In addition, 37.8% (34) that resulted from 26 electrical fires occurred during mid-day and evening mealtimes (between 12:00 and 14:00, and between 17:00 and 19:00) when more electricity usage may take place.

3.2. Domestic Electrical Fire Injury Demographics

Over the period studied, the ratio of male to female domestic electrical fire injuries was 1.25 to 1. Figure 6 and Table 4 show the distribution of domestic electrical fire injuries per 100,000 of population age groups over the study period. Although domestic electrical fire injuries occurred across all age bands, those aged 75+ appeared to be more at risk of electrical fire injuries compared to the other age groups. Electrical fire injuries for the 75+ age group originated in the kitchen (five injuries), bedroom (three injuries), living room (two injuries) and corridor/hall (two injuries), four injuries were due to the electricity supply (wiring, cabling, plugs), three injuries to lights, three injuries to domestic appliances, and two injuries to electric cookers.

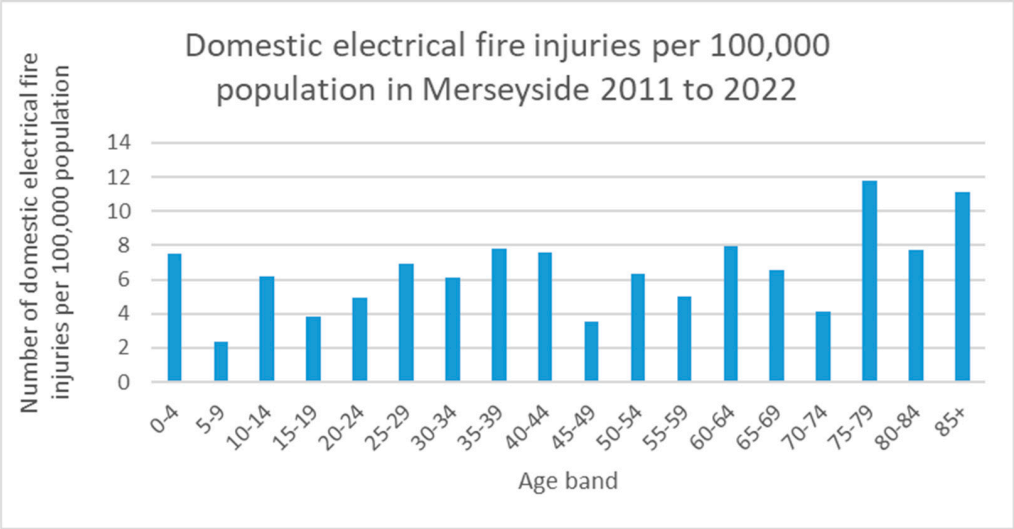

Figure 6. Domestic electrical fire injuries per 100,000 of population between 2011 and 2022 in Merseyside.

Table 4. Domestic electrical fire injuries per 100,00 of population 2011 to 2022 in Merseyside.

Age Band	Number of Domestic Electrical Fire Injuries per 100,000 of Population
0–4	7.52
5–9	2.35
10–14	6.21
15–19	3.82
20–24	4.97
25–29	6.92
30–34	6.09
35–39	7.80
40–44	7.60

Table 4. *Cont.*

Age Band	Number of Domestic Electrical Fire Injuries per 100,000 of Population
45–49	3.54
50–54	6.36
55–59	5.01
60–64	7.95
65–69	6.57
70–74	4.14
75–79	11.81
80–84	7.73
85+	11.08

3.3. Domestic Electrical Fire Injury Types

Figure 7 and Table 5 depict the distribution of domestic electrical fire injury types in Merseyside between 2011 and 2022. Being overcome by gas, smoke, or toxic fumes formed the majority of domestic electrical fire injuries, accounting for 54.4% (49) of such injuries over the study period.

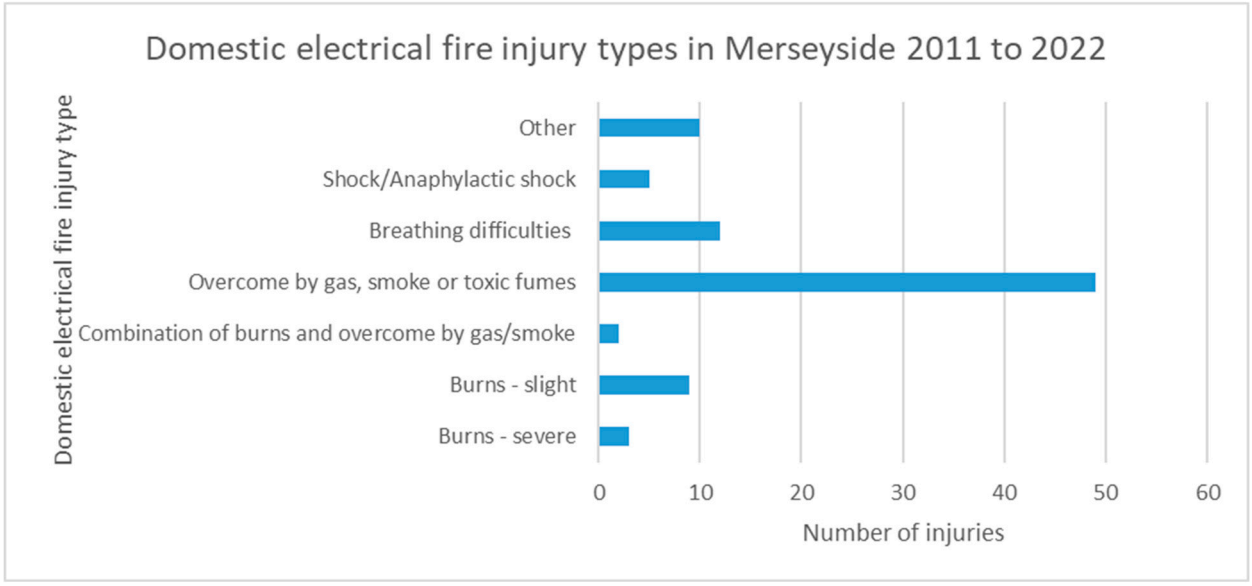

Figure 7. Domestic electrical fire injury types in Merseyside between 2011 and 2022.

Table 5. Domestic electrical fire injury types in Merseyside 2011 to 2022.

Domestic Electrical Fire Injury Type	Number of Injuries
Other	10
Shock/Anaphylactic shock	5
Breathing difficulties	12
Overcome by gas, smoke, or toxic fumes	49
Combination of burns and overcome by gas/smoke	2
Burns—slight	9
Burns—severe	3

4. Discussion

Previous research had indicated that other types of domestic fire injury, such as cooking, smoking, and candle use, are typically more likely to be due to householder carelessness than electrical fire [40]. A study in the Republic of Korea between 2017 and 2022 had also found that electrical wiring was the largest cause of domestic electrical fires, followed by electrical appliances [10].

A limitation of the research conducted concerned not all domestic fires being reported to fire and rescue services in the UK [41], and therefore the analyses conducted could only reflect those domestic electrical fire injuries that were attended by the fire and rescue service over the study period. In addition, the classification of a fire incident as actually being electrical in origin, and the classification of the type of fire injury would be carried out by firefighters attending the incident, and a householder could have sustained injuries that covered more than one of the twenty-five different fire injury categories that are used in the UK fire incident recording system. In addition, currently in England, lithium-ion battery fires are not categorised distinctly in the English Fire Incidence Recording System.

In terms of applying the results of the research to prevention strategies, currently the fire and rescue service concerned has concentrated home fire safety checks on the elderly. The further analysis provided by this research could inform the guidance for elderly householders in terms of the variety of electrical fire safety hazards in the home and how to avoid these.

5. Conclusions

Householder carelessness appeared to be less of a factor in domestic electrical fire injury (15.6% of domestic electrical fire injuries) compared to other types of domestic fire injury, such as cooking, smoking, or candle use. Domestic electrical fire injuries constituted a relatively small proportion of overall domestic fire injuries (8.7%) over the study period, and domestic electrical fire injuries per year did not correlate with the overall pattern of domestic fire injuries per year, and did not show a similar decrease.

Faulty electricity supplies were the main cause of domestic electrical fire injuries over the study period accounting for 57.8% of such injuries. The majority of domestic electrical fire injuries occurred during the nighttime (between the hours of 22:00 and 06:00) and mid-day and evening mealtimes (between 12:00 and 14:00, and between 17:00 and 19:00), implying that further electrical fire safety awareness is needed by householders before going to bed. Male residents were slightly more likely to sustain an injury in a domestic electrical fire compared to female residents in the ratio of 1.25 to 1. Although domestic electrical fire injuries occurred across all age bands, those aged 75+ appeared to be more at risk of electrical fire injuries compared to other age groups, possibly being related to reduced mobility in terms of avoiding fire injury. Being overcome by gas, smoke, or toxic fumes formed the majority of domestic electrical fire injuries (54.4% of such injuries) over the study period.

In practical terms for fire injury prevention relating to domestic electrical fires, since electrical fire injuries are not decreasing as per the decrease in overall domestic fire injuries, electrical fire injuries are an area of concern for fire and rescue services. Since wiring, sockets, and plugs are the major cause of electrical fire injuries, switching appliances off overnight and looking for signs of potential faults such as hot plugs or sockets, scorch marks, fuses that often blow, or flickering lights are important electrical fire safety messages to be conveyed to householders in fire prevention initiatives. In addition, the practice of overloading sockets by plugging too many electrical appliances into one socket should be avoided. The findings of the research may hopefully be useful for other fire and rescue services.

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