HYPOTHERMIA AS AN URBAN PUBLIC-HEALTH RISK: A CASE STUDY OF LUBLIN, POLAND

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Abstract: Hypothermia remains an important yet under-recognised public health hazard in temperate climate cities. This study analyses the incidence and meteorological background of hypothermia in Lublin, the largest city in eastern Poland, and evaluates the usefulness of the Universal Thermal Climate Index (UTCI) in identifying periods of increased cold-related risk. We examined 372 Emergency Medical Service call-outs classified as hypothermia during 2022–2023. Meteorological data were obtained from the Hydrology and Climatology Observatory of Maria Curie-Skłodowska University in Lublin. Lublin's Municipal Crisis Management Plan (MPZK 2023) was reviewed to interpret results in relation to operational thresholds. A total of 185 (2022) and 187 (2023) incidents were recorded, with men accounting for 72% of all cases. Call-outs peaked between November and January and during morning hours (06:00–12:00). The frequency of interventions increased with lower air temperature, higher relative humidity and moderate wind speed (2–4 m · s^{-1}). Most cases occurred under UTCI categories indicating moderate or strong cold stress (SCS), confirming the index's potential as an early warning tool. Despite ongoing climate warming, hypothermia continues to threaten vulnerable groups – particularly homeless individuals, older adults and persons with substance use disorders. Integrating UTCI-based alerts into municipal emergency management procedures and targeted support programs could help reduce cold-related morbidity in urban environments.

Keywords: hypothermia, urban climate, cold temperature, Universal Thermal Climate Index, emergency medical services, meteorology

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Introduction

Accidental hypothermia remains a relevant public health concern in temperate-climate cities, where meteorological and social factors jointly determine the risk of body cooling. This study examines these interactions in Lublin (Poland), integrating medical and biometeorological data with the Universal Thermal Climate Index (UTCI). According to the widely accepted clinical definition, accidental hypothermia is an unintentional decrease in core body temperature to ≤35.0°C due to environmental cold exposure (Danzl, Pozos 1994, Brown et al. 2012). It is associated with significant disturbances in cardiovascular, respiratory and nervous functions, and may result in death if untreated. Depending on the decrease in core temperature, hypothermia is divided into three clinical stages. Mild hypothermia (35.0–32.0°C) is characterised by shivering, tachycardia, vasoconstriction and mild impairment of coordination. Moderate hypothermia

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(32.0–28.0°C) causes a marked reduction in shivering, bradycardia, hypoventilation and loss of fine motor control. Severe hypothermia (<28.0°C) is associated with progressive loss of consciousness, ventricular arrhythmias and, if untreated, eventual cardiac arrest (Danzl, Pozos 1994, Brown et al. 2012, Kosiński et al. 2015). This classification reflects the physiological mechanisms of progressive cooling and provides a framework for interpreting the medical data used in this study.

Hypothermia constitutes a serious hazard in the temperate climate zone, where recurrent winter cold waves and transitional-season variability lead to repeated human exposure to sub-optimal thermal conditions. In cities such as Lublin, the risk is additionally shaped by social vulnerability, including poverty, homelessness, alcohol dependence, and advanced age. Data obtained from the Emergency Notification Centre (pol. *Centrum Powiadamiania Ratunkowego* CPR) and the Medical Dispatch Centre (MDC) in Lublin show that paramedics intervene in about 200 hypothermia-related incidents per year. The problem thus remains clinically and socially relevant despite overall climate-warming trends. The true incidence of hypothermia, however, is difficult to determine. Hospital and emergency databases register only the most severe and life-threatening cases, whereas mild or moderate episodes and deaths occurring outside hospital settings are frequently omitted. Importantly, the latest climate projections for Europe indicate that, despite the general warming trend, excess mortality attributable to cold exposure will persist for the coming decades due to population ageing and widening social inequalities (Masselot et al. 2025). The biometeorological effects of cold stress in urban areas remain a major yet frequently underestimated public health concern. In this context, the term urban public health risk refers to health threats that arise from the interaction between environmental stressors and socio-economic conditions typical of urban settings. Such risks are particularly significant in cities, where high population density, social inequalities, poor housing quality and limited access to healthcare amplify vulnerability to weather extremes (Ebi, Semenza 2008). Cold-related conditions such as hypothermia exemplify this pattern: while exposure to low temperature is universal, its health consequences are unevenly distributed, affecting socially marginalised groups most severely. Consequently, hypothermia represents not only a biomedical phenomenon but also a multidimensional urban health risk shaped by both climatic and social determinants. An analysis of hypothermia deaths in Tokyo found that half of 157 fatalities occurred at moderate outdoor temperatures (0–5°C), underlining the dominant role of social factors such as homelessness and alcohol consumption (Tanaka, Tokudome 1991). Similar results were obtained in New York City, where between 2005 and 2014 nearly 75% of hypothermia victims were found outdoors, half of whom were homeless (Lane et al. 2018). Recent modelling for 854 European cities further shows that cold-related excess mortality will decline only partially, even under ambitious adaptation scenarios, underscoring the persistence of cold-stress risk despite climatic warming (Masselot et al. 2025). Polish urban centres follow this pattern. A long-term analysis of the eight largest cities confirmed an increase in mortality by 9%–19% on days with extreme cold stress (ECS) (UTCI ≤ −13°C) and clear differentiation between the colder east and the warmer west of the country (Kuchcik 2021). Although projections for Warsaw indicate a decline in the frequency of strong cold stress (SCS), population ageing and social inequalities may offset potential benefits (Błażejczyk et al. 2013). Hospital data highlight the importance of behavioural determinants: in 68% of hypothermia-related hospitalisations, alcohol consumption was recorded, and in one-third of cases, core temperature was not measured (Kosiński et al. 2015).

In Poland, UTCI has been increasingly used in studies evaluating thermal stress and its influence on health outcomes. For instance, Kuchcik (2017) demonstrated its applicability in assessing temperature-related mortality. Masselot et al. (2025) further confirmed the validity of UTCI as a comprehensive indicator linking meteorological conditions with human health risks.

An analysis of winter UTCI variability shows that Polish cities still experience a large number of days with at least moderate cold stress (MCS) – ranging from 46% in Łeba to 66% in Zielona Góra – which confirms the population's systemic exposure to cold (Wereski et al. 2020). Existing research demonstrates that effective mitigation of cold-related health impacts requires combining operational biometeorological forecasts, such as

UTCI, with targeted interventions that prioritise older adults, persons experiencing homelessness and people with alcohol use disorders (Lane et al. 2018, Masselot et al. 2025). In addition, UTCI-based systems are already being applied in local forecasting services in Poland and neighbouring countries. For example, the Institute of Meteorology and Water Management (IMGW-PIB) regularly publishes national UTCI maps, while similar services in the Czech Republic and Slovakia provide daily biometeorological bulletins used for public-health warnings (Novák 2013). Services providing UTCI forecasts implemented, for example, in Poland and the Czech Republic, deliver, alongside thermal-stress maps, preventive recommendations for the public. Analyses of Emergency Medical Services (EMS) interventions in Lublin Voivodeship show that the level of cold stress correlates well with the number of hypothermia call-outs, indicating the utility of forecasts in planning emergency-service activities (Krzyżewska et al. 2017, Di Napoli et al. 2021). As Lublin is located in eastern Poland – a region characterised by more frequent and severe cold-stress conditions compared to the country's western part – it represents a particularly suitable case for studying the biometeorological and social determinants of hypothermia. From the perspective of urban adaptation in Central and Eastern Europe, integrating biometeorological forecasts with programmes aimed at people experiencing homelessness, older adults and those with alcohol problems is already recommended in local strategies (e.g. Warsaw 2030) and constitutes a key element in reducing winter excess mortality (Błażejczyk et al. 2013, Romaszko et al. 2017, Kuchcik 2021).

This study aims to analyse the biometeorological and social determinants of accidental hypothermia, to identify meteorological factors contributing to body cooling, and to assess preventive and response measures implemented in Lublin (Poland).

Study area

Lublin is the largest city in eastern Poland and serves as the capital of Lublin Voivodeship (Fig. 1). The municipal area covers 147.45 km², and the population in 2024 was approximately 330,000 inhabitants (Statistics Poland 2024). The study area is an important academic hub. It also attracts tourists thanks to its rich history, numerous monuments and several international festivals.

According to the Köppen climate classification (Peel et al. 2007), Lublin belongs to the Cfb zone, i.e. a temperate climate with evenly distributed precipitation and warm summers. In the bioclimatic regionalisation of Poland proposed by Kozłowska-Szczęsna et al. (1997) and modified by Błażejczyk and Kunert (2011), Lublin is located in Region V (South-Eastern). Compared with other regions, it is characterised, among other features, by a higher number of days with burdensome cold stress, which makes Lublin a valuable area for investigating hypothermia in cities of this part of Europe (Wereski et al. 2020).

The mean annual air temperature in Lublin during 2012–2023 was 9.8°C. The highest monthly mean occurred in July (20.7°C), while the lowest was observed in January (−1.4°C). The warmest year was 2019, with a mean of 11.0°C, whereas the coldest was 2012 at 9.0°C. January most frequently records the lowest daily temperatures. The minimum temperature for the period 2012–2023 was −20.2°C, registered on 7 January 2017 at 05:00 UTC.

The city's topography, with elevations ranging from 165 m a.s.l. to 238 m a.s.l., influences local airflow and cold-air drainage, especially during calm winter nights. Low-lying areas and river valleys (notably along the Bystrzyca River) tend to accumulate cold air masses, intensifying cold stress under stable atmospheric conditions. From the perspective of urban climate research, Lublin represents a medium-sized Polish city with a transitional spatial structure: a compact historic centre surrounded by residential and industrial districts and extensive open areas on the outskirts.

Materials and methods

To investigate the mechanisms and variables that trigger hypothermia, we analysed the influence of meteorological factors on the human body. The medical data used in this study were obtained from the Emergency Notification Centre (ENC) and the MDC in Lublin and include all requests for medical intervention in

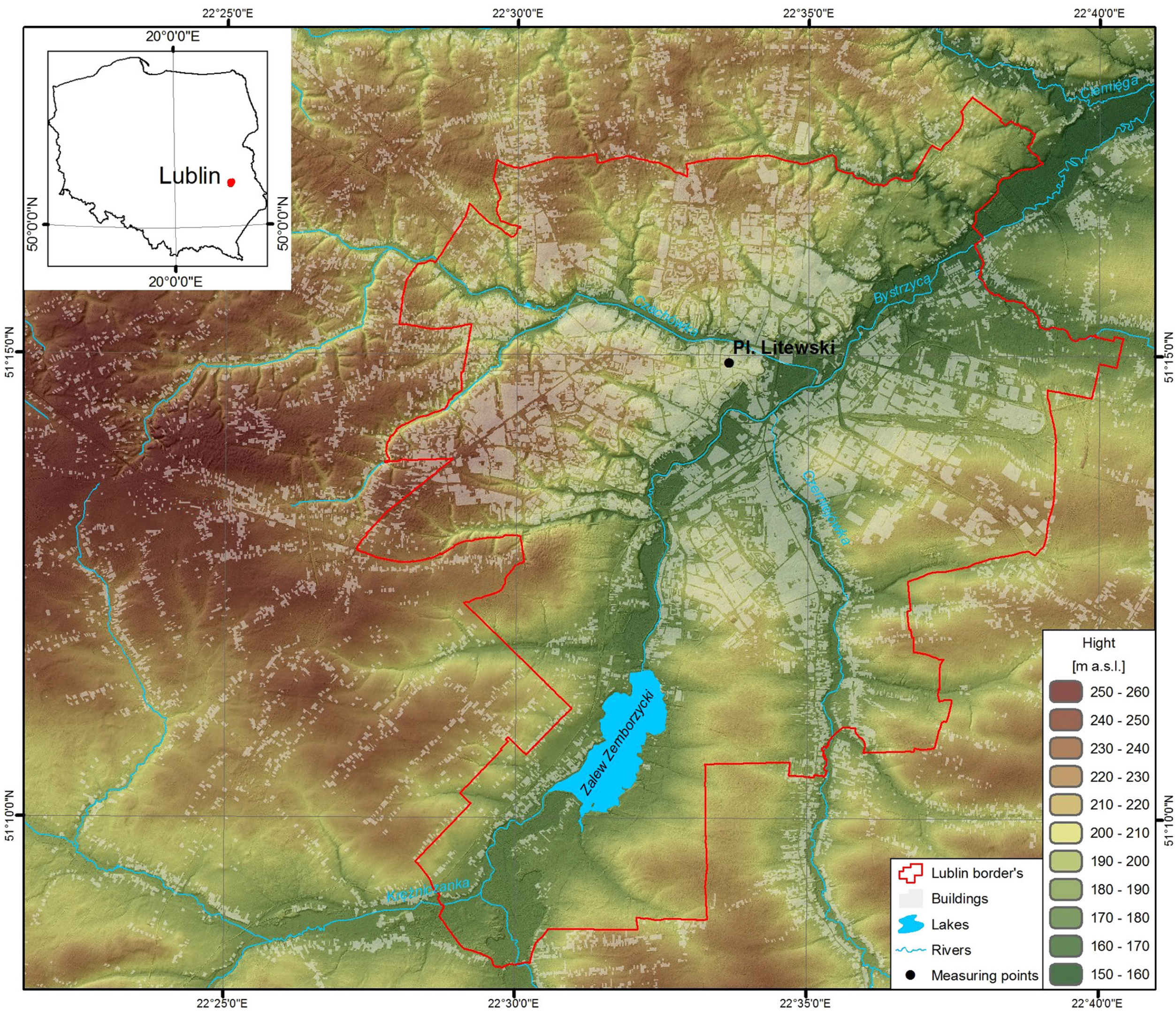

Fig. 1. Location of the study area and meteorological measurement station (UMCS).

2022/2023 that paramedics classified as hypothermia. The meteorological data were collected from the measurement station of the Department of Hydrology and Climatology at Maria Curie-Skłodowska University (UMCS), located in the city centre at Plac Litewski (51°14′N, 22°33′E; elevation 197 m a.s.l.). This site represents the urban thermal environment of Lublin, influenced by the urban heat island (UHI) effect and local anthropogenic factors. These data cover the period 1991–2023. The UTCI was calculated using BioKlima 2.6 software . A consultation was also conducted with an official from the Voivodeship Crisis Management Centre in Lublin, who outlined the procedure for notification and warning of hypothermia within the Lublin Voivodeship.

In this study, accidental hypothermia was identified using International Classification of Diseases (ICD-10) codes X31, T68, and T73, which correspond respectively to exposure to excessive natural cold, hypothermia, and other effects of low environmental temperature. It should be emphasised that emergency medical teams may only suspect hypothermia in the field, as the final diagnosis requires direct measurement of core temperature – typically rectal or oesophageal – which is not always possible under pre-hospital conditions.

In addition to medical and meteorological data, the study included a qualitative review of the functioning of the public warning and crisis management system in Lublin. This review was based on information provided by the Voivodeship Crisis Management Centre and official municipal documents such as the Municipal Crisis Management Plan (MPZK 2023). The purpose of this material was to provide contextual background for interpreting emergency intervention data and to identify preventive mechanisms relevant to hypothermia risk mitigation. Hypothermia is defined as a state in which core body temperature falls below 35.0°C. It is caused by a negative heat balance – i.e., when heat loss from the body exceeds heat production and storage. Typical manifestations of this state include pronounced body cooling, shivering, and weakness. When exposed to cold discomfort, the body seeks to warm itself to maintain an optimal temperature; this is a natural defence mechanism. A person's initial preventive actions are behavioural reflexes such as increased physical activity or putting on additional layers of clothing. These reflexive responses help to warm the body (Krzeszowiak, Pawlas 2015). Higher clothing insulation retains heat near the body and thus reduces the sensation of cold. Physical activity, in turn, generates heat through muscle work and metabolic processes and helps maintain

Table 1. Scale of assessment of thermal stress of the organism according to UTCI, and ways of counteracting unfavourable biothermal conditions from a given class (Błażejczyk et al. 2013).

Universal Thermal Climate Index [°C]	Stress category	Physiological responses
>46	Extreme heat stress	– Increase in rectal temperature (Tre) time gradient – Steep decrease in total net heat loss – Averaged sweat rate >650 g · h^{-1}, steep increase
38.1–46.0	Very strong heat stress	– Core to skin temperature gradient <1 K (at 30 min) Increase in Tre at 30 min
32.1–38.0	Strong heat stress	– Dynamic thermal sensation at 120 min >+2 – Averaged sweat rate >200 g · h^{-1} – Increase in Tre at 120 min – Latent heat loss >40 W at 30 min – Instantaneous change in skin temperature >0 K · min^{-1}
26.1–32.0	Moderate heat stress	– Change of slopes in sweat rate, Tre and skin temperature: mean (Tskm), face (Tskfc), hand (Tskhn) – Occurrence of sweating at 30 min – Steep increase in skin wetness
9.1–26.0	No thermal stress	– Averaged sweat rate >100 g · h^{-1} – Dynamic thermal sensation TS at 120 min <1 – Dynamic thermal sensation between −0.5 and +0.5 (averaged value) – Latent heat loss >40 W, averaged over time – Plateau in Tre time gradient
0.1–9.0	Slight cold stress	– Dynamic thermal sensation at 120 min $<^{-1}$ – Local minimum of Tskhn (use gloves)
−12.9 to 0.0	Moderate cold stress	– Dynamic thermal sensation at 120 min <−2 – Skin blood flow at 120 min lower than at 30 min (vasoconstriction) – Averaged Tskfc <15°C (pain) – Decrease in Tskhn – Tre time gradient <0 K · h^{-1} – 30 min face skin temperature <15°C (pain) – Tmsk time gradient $<^{-1}$ K · h^{-1} (for reference)
−26.9 to −13.0	Strong cold stress	– Averaged Tskfc <7°C (numbness) – Tre time gradient <−0.1 K · h^{-1} – Tre decreases from 30 min to 120 min – Increase in core to skin temperature gradient
−39.9 to −27.0	Very strong cold stress	– 120 min Tskfc <0°C (frostbite) – Steeper decrease in Tre – 30 min Tskfc <7°C (numbness) – Occurrence of shivering – Tre time gradient <−0.2 K · h^{-1} – Averaged Tskfc <0°C (frostbite). – 120 min Tskfc <−5°C (high risk of frostbite)
<−40.0	Extreme cold stress	– Tre time gradient <−0.3 K · h^{-1} – 30 min Tskfc <0°C (frostbite)

proper blood circulation, which supplies warmth to all parts of the body. When human-dependent measures fail to bring the expected effect, the body initiates physiological responses such as peripheral vasoconstriction, increased heart rat,e and faster breathing, as well as uncoordinated trembling of muscle fibres. Each of these reactions aims to generate heat and retain it in the body, thereby preserving the victim's vital functions (Krzeszowiak, Pawlas 2015). Infants and older adults are particularly susceptible to severe cooling. Factors that lower the body's resistance to cold stress also include alcohol, intoxicants, malnutrition, fatigue, and cranio-cerebral injuries (Sosnowski et al. 2015).

Hypothermia is divided, according to its triggering mechanism, into accidental and induced forms. Accidental hypothermia is caused by exposure to external environmental factors such as severe frost, cold water, snow avalanches or strong winds. It is worth noting that high wind combined with temperatures only slightly below 0°C can have effects on humans similar to those of still air at temperatures below −30.0°C. Induced hypothermia is a drop in body temperature resulting from ingested substances. These include anaesthetic agents, vasodilatory and antihypertensive drugs, antipyretics, neuroleptics, and narcotics. Hypothermia is also observed as an accompanying factor in many diseases, e.g. hypothyroidism, Parkinson's disease, diabetic coma, multiple sclerosis or severe burns (Kożuch 2019).

The UTCI was used as a biometeorological indicator to describe the level of thermal stress acting on the human body (Table 1). It quantifies human thermal load based on a heat balance model that integrates air temperature, wind speed, humidity and radiation (Bröde et al. 2012). The biometeorological background for Lublin was determined for 12:00 UTC, which is considered the time of highest daily activity (Kozłowska-Szczęsna et al. 1997). The selection of the UTCI index for this analysis was motivated by its holistic nature: it integrates multiple meteorological elements (temperature, humidity, wind, radiation) into one composite measure of human thermal stress. This makes it superior to traditional indices such as wind chill or apparent temperature, which consider only partial effects (Di Napoli et al. 2021). Furthermore, UTCI has been validated for European climatic conditions and is widely used by public health authorities and meteorological services in Poland and across the European Union. For each day in the period 2012–2023, UTCI values were computed using hourly meteorological data (air temperature, relative humidity, wind speed and cloud cover) from the measurement station. The results were then aggregated to describe seasonal and interannual variability. These data were cross-compared with medical intervention records for 2022–2023 to identify potential relationships between cold-stress intensity and the number of hypothermia cases. To assess the temporal pattern of hypothermia events, daily UTCI values corresponding to the dates and approximate times of emergency calls were extracted. For each case, the UTCI class (according to Błażejczyk et al. 2013) was assigned to describe the level of cold stress perceived by the human body at the time of exposure. Descriptive statistics and frequency distribution analyses were applied to explore relationships between hypothermia incidents and meteorological parameters (temperature, humidity, wind speed, UTCI). Where possible, relationships were expressed graphically (monthly, diurnal and meteorological dependencies).

Results

For the urban station located at Litewski Square in Lublin, the mean annual air temperature during the 1991–2020 reference period was 11.7°C, with monthly averages of −0.7°C in January and 23.3°C in July. The mean annual relative humidity was 64.9%. The mean monthly UTCI at 12:00 UTC reached 9.2°C, indicating predominantly thermally comfortable conditions, with seasonal cold stress in winter and heat stress in summer.

In 2022, the mean annual temperature was 12.8°C, relative humidity 64.5% and UTCI 10.6°C, while in 2023 the respective values reached 10.8°C, 76.5% and 13.9°C. These characteristics illustrate the typical bioclimatic conditions in Lublin, with cold-stress episodes primarily in winter and the transitional seasons, and occasional thermal discomfort during summer months. All data were derived from the Litewski Square station; UTCI values refer to 12:00 UTC observations.

In Lublin, 185 hypothermia cases were recorded in 2022 and 187 in 2023. An analysis of monthly reports showed that in 2022, the maximum of 47 incidents occurred in December (Fig. 2). Up to mid-year, the number of hypothermia cases decreased month by month until August, when the trend reversed. July was an exception: despite high air temperatures, as many as five hypothermia incidents were registered. Each call in that month, however, was accompanied by additional factors – alcohol intoxication in two cases and, respectively, hyperglycaemia, an open cranial injury, and alcohol combined with essential hypertension.

In 2023, the highest number of hypothermia notifications (34) was received in November, followed by January and December (Fig. 2). In subsequent months, a pattern similar to that of 2022 was observed: as air temperature increased during the year, the number of hypothermia interventions decreased. An exception was April, when the number of calls was comparable to January and December. Reports were filed between 1 and 27 April, with the highest counts on 3 and 26 April. The six incidents recorded from 2 to 6 April were probably related to several days of lower air temperature. During the summer months, three out of six incidents had accompanying factors such as hypoglycaemia and malnutrition, alcohol intoxication and head injury.

An analysis of the dependence of hypothermia incidents on time of day showed that in 2022–2023 (Fig. 3), most notifications occurred between 06:00 and 11:59, whereas the fewest were recorded at night between 00:00 and 05:59. This pattern does not correspond to the typical diurnal course of air temperature. Although the Earth's surface is coldest at night and the absence of solar radiation cools the atmosphere, fewer calls are

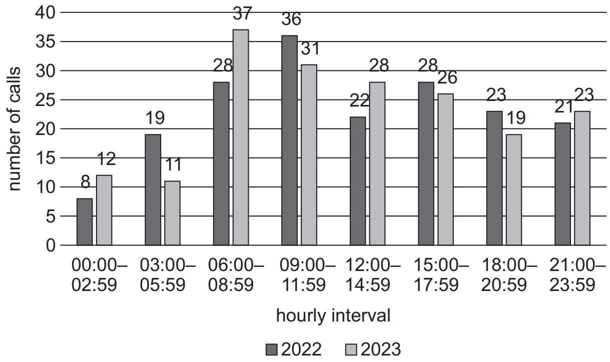

Fig. 3. Relationship between the number of reported hypothermia cases in Lublin and the time of day (2022–2023).

registered than in the subsequent morning hours. The relatively small number of night-time interventions and the peak in the forenoon may reflect the fact that a body exposed to adverse thermal conditions during the night cools gradually until a critical state is reached in the morning hours. In addition, human daily activity should be considered: help is often summoned only in the morning, for example, after household members wake up and discover a person in need of assistance.

The main external factors influencing the body-cooling process are air temperature, relative humidity, and wind speed (Krzeszowiak, Pawlas 2015). Most diagnosed hypothermia cases were recorded when air temperature ranged from −5.1°C to 0.0°C (Figures 4 and 5). A relatively high risk of hypothermia was also observed when air temperature fluctuated between 0.1°C and 5.0°C. As temperatures increased beyond this range, the number of reported incidents declined.

It should be noted that the relationship between hypothermia and temperature alone does not fully capture the physiological cold stress

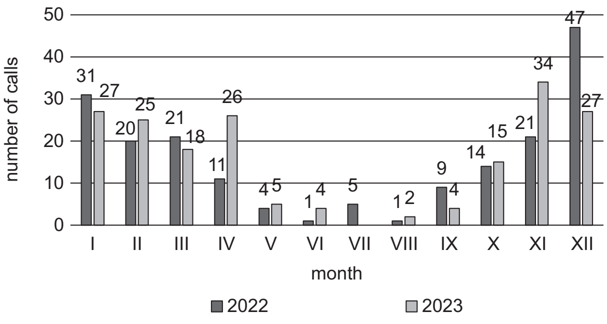

Fig. 2. Monthly distribution of reported hypothermia cases in Lublin (2022–2023).

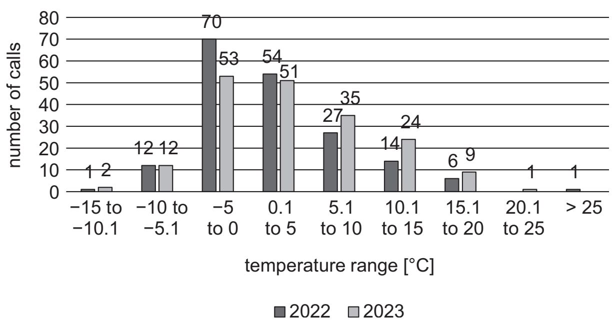

Fig. 4. Relationship between temperature and the number of reported hypothermia cases in Lublin (2022–2023).

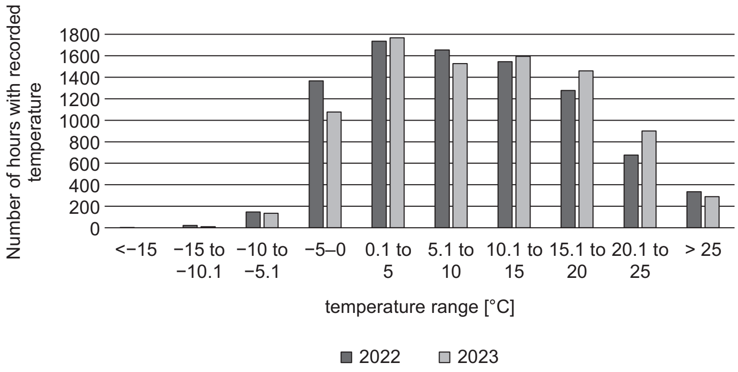

Fig. 5. Ranges of air temperature values in Lublin (2022–2023).

experienced by the human body. Therefore, additional meteorological parameters – humidity and wind speed – were analysed using the UTCI framework.

Another factor that affects human thermal perception is relative humidity, which, combined with low air temperature, can lead to excessive body cooling.

As the relative humidity values increased, the number of reported hypothermia cases in Lublin also rose (Fig. 6). This confirms the premise that relative humidity is an important contributor to hypothermia, especially when it occurs together with low air temperature.

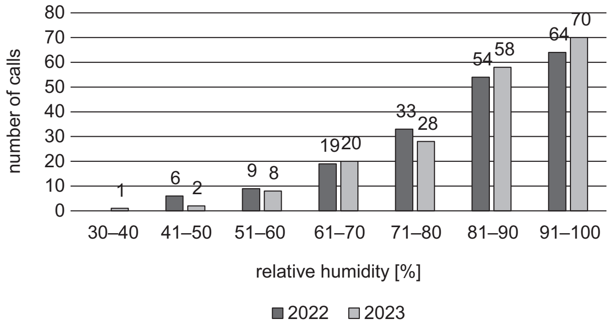

Fig. 6. Relationship between relative humidity and the number of reported hypothermia cases in Lublin (2022–2023).

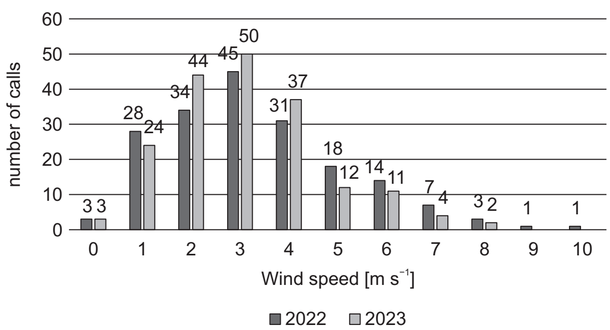

Fig. 7. Relationship between wind speed and the number of reported hypothermia cases in Lublin (2022–2023).

Another factor analysed in relation to body cooling is wind speed, which accelerates heat loss by convection and promotes the evaporation of sweat, thereby intensifying the sensation of cold. The greatest number of hypothermia cases occurred when wind speed was between $2\ m \cdot s^{-1}$ and $4\ m \cdot s^{-1}$ (Fig. 7). This may be because at higher wind speeds, people reduce outdoor activity, leading to fewer diagnosed hypothermia incidents, and also to the relatively small number of days per year with wind speeds exceeding $5\ m \cdot s^{-1}$.

Relationships between sex and the number of reported hypothermia cases in Lublin in 2022–2023 show that men accounted for 72% of incidents (Figs 8 and 9). This pattern may stem from the fact that hypothermia is often linked to homelessness and poverty (Krzeszowiak, Pawlas 2015). Nationwide surveys of the homeless population indicate that men experiencing homelessness outnumber women by more than five to one.

Hypothermia is often accompanied by co-occurring conditions. In the analysed years in Lublin, more than 20% of patients diagnosed with hypothermia were under the influence of alcohol. Alcohol disturbs thermal perception through its action on the central nervous system and has sedative as well as soporific properties. These features impair consciousness and reduce self-control, which further promotes body cooling (Kuchcik 2017). This factor may also explain why the disparity between female and male hypothermia cases is so large, as men are more likely to struggle with alcohol problems (Skoczek et al. 2020). According to 2022 and 2023 data for

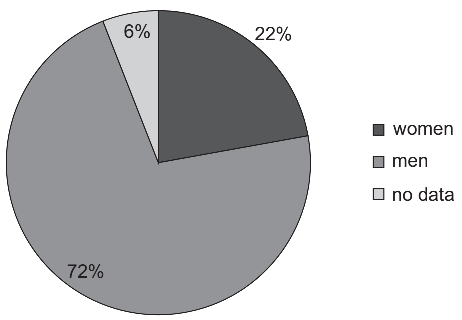

Fig. 8. Relationship between gender and the number of reported hypothermia cases in Lublin in 2022.

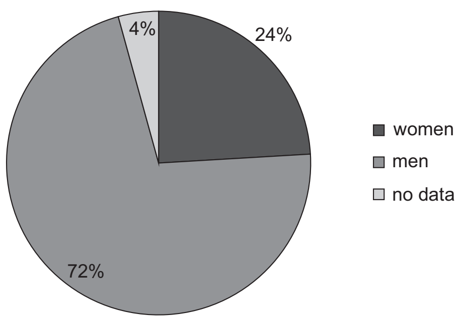

Fig. 9. Relationship between gender and the number of reported hypothermia cases in Lublin in 2023.

Lublin, hypoglycaemia accompanied 17 hypothermia cases. It should be noted, however, that the information obtained from the MDC might be incomplete, as it is based only on paramedics' initial assessment rather than detailed medical examinations.

Moreover, paramedics often work under time pressure, so the amount of information recorded in the report depends on external factors. Syncope, collapse and blood pressure abnormalities were also frequently observed in conjunction with hypothermia. One of the most common co-occurring phenomena was trauma, especially head injuries, which accounted for 5% of all notifications.

The combined analysis of meteorological and medical data indicates that approximately 70% of all hypothermia incidents occurred under UTCI conditions classified as 'moderate' or 'strong cold stress' (Figs 10 and 11). This suggests that even relatively mild cold environments can pose substantial health risks for socially vulnerable populations, particularly under the influence of alcohol or disease. The highest daily number of hypothermia reports (n = 6) was recorded on 11 December 2022, coinciding with the onset of a short cold spell. On that day, the air temperature ranged from −1.0°C at midnight to −4.3°C at 23:00, with relative humidity remaining above 95% throughout the entire 24-hr period. Calm wind conditions and persistent atmospheric moisture increased the perception of cold stress despite the absence of extremely low air temperatures. It is noteworthy that this was not the coldest day of the analysed period, suggesting that social and behavioural factors – such as homelessness,

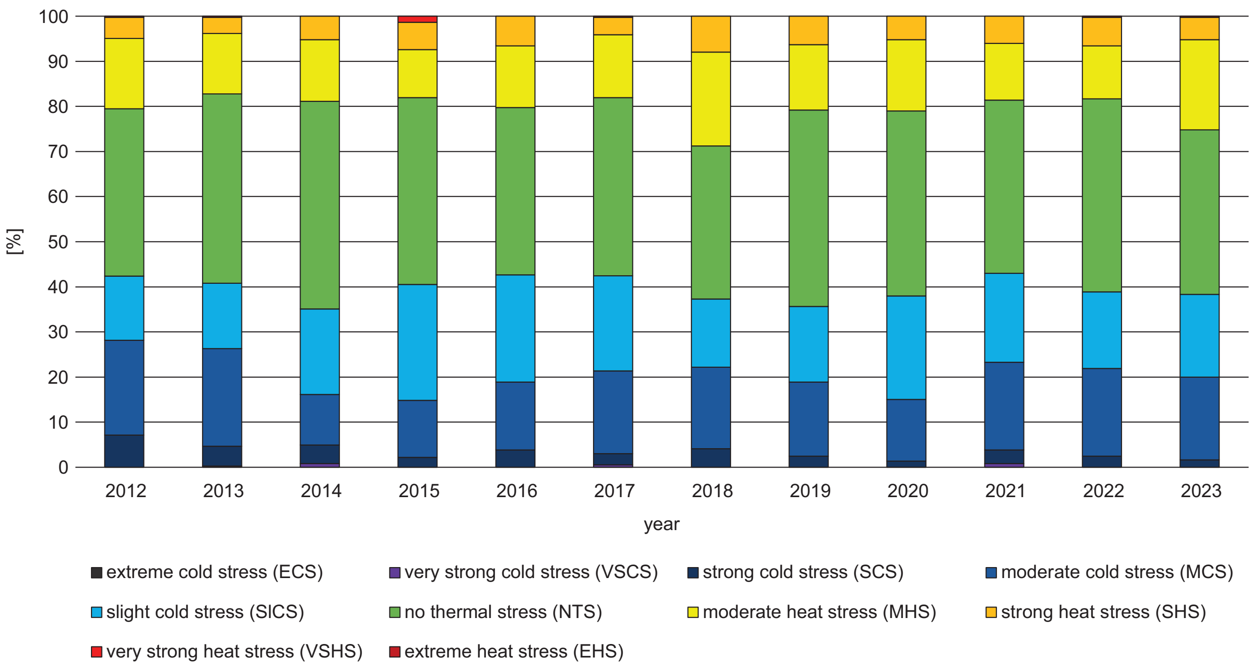

Fig. 10. Annual frequency of days with specific thermal sensations in Lublin (2012–2023).

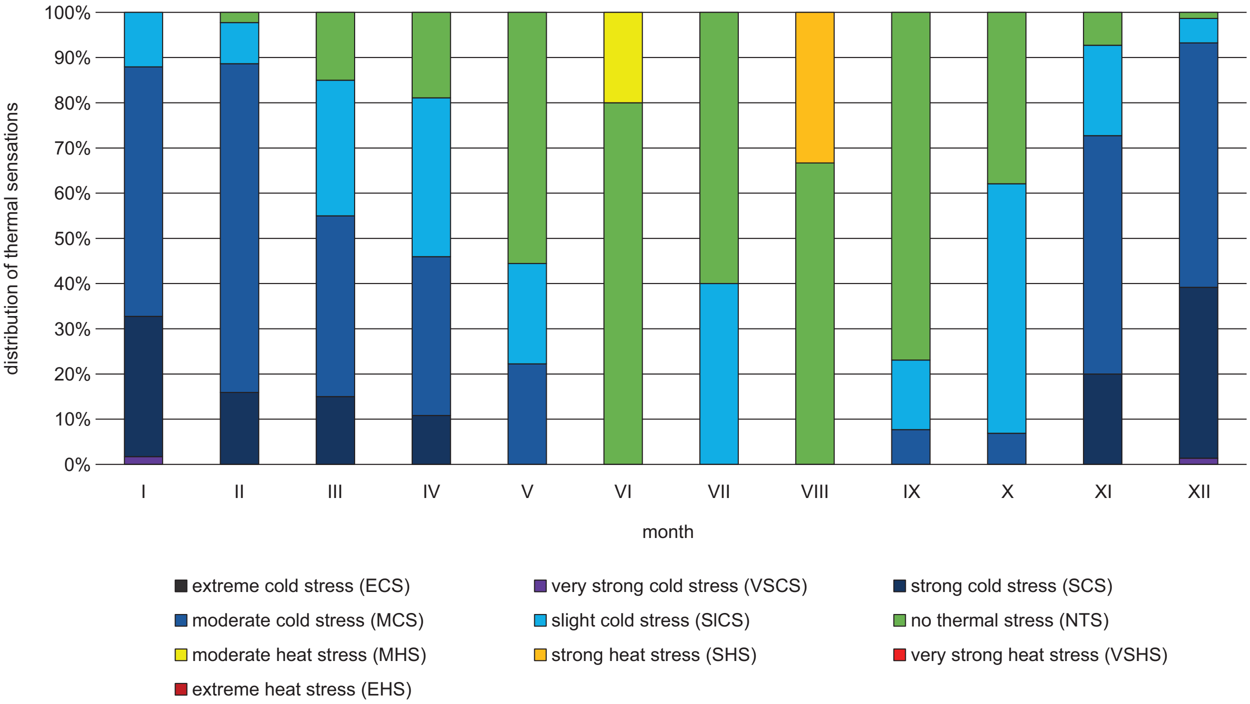

Fig. 11. Frequency of thermal load classes for the hours when hypothermia calls were received in Lublin (2022–2023).

alcohol consumption and prolonged outdoor exposure – likely played a decisive role in the occurrence of these incidents.

Discussion

The results demonstrate that hypothermia in Lublin is primarily driven by environmental cold exposure in combination with individual and social vulnerability factors. The seasonal and diurnal patterns observed correspond with findings from other Central European cities, where similar socio-meteorological interactions have been reported (Romaszko et al. 2017, Kuchcik 2021). Although low air temperature remains the dominant driver, the UTCI-based analysis confirmed that relative humidity and wind speed significantly amplify cold stress, especially when combined with temperatures slightly below freezing. These findings are consistent with the physiological mechanisms of heat loss – convection and evaporation – which are key determinants of accidental hypothermia. The observed morning peak of reported hypothermia cases may reflect the cumulative overnight cooling effect, when victims are exposed for several hours before being found and assisted. This mechanism was also reported in studies from Warsaw and Kraków, suggesting that delayed discovery is a crucial factor increasing mortality (Kuchcik 2017). The marked gender disparity, with men accounting for nearly three-quarters of all cases, can be explained by social and behavioural determinants such as a higher prevalence of homelessness and alcohol consumption among males (Skoczek et al. 2020). The latter factor is of particular importance: alcohol impairs thermoregulation, delays the perception of cold, and promotes risk-taking behaviour, which together contribute to fatal outcomes. It is also worth noting that hypothermia incidents occurred even at moderate or above-zero temperatures, which indicates that meteorological thresholds alone are insufficient for predicting health risk. Instead, human and social factors – alcohol use, chronic disease, or inadequate housing – must be integrated into early warning systems and public health interventions. The data also highlight the operational value of UTCI-based forecasts for use by emergency services. Because the number of hypothermia interventions correlates well with UTCI cold-stress levels, biometeorological indices could support short-term planning of patrols and targeted prevention. This approach is already partially implemented in Lublin Voivodeship, but could be expanded to integrate forecasts with social services. However, despite Lublin's structured emergency response system, the reach of official warnings remains limited among the most vulnerable groups – particularly people experiencing homelessness and extreme poverty. This finding aligns with evidence from other urban studies showing that standard communication channels (SMS alerts, online bulletins) do not effectively reach socially excluded populations. Long-term analyses in other Polish cities (Warsaw, Kraków, Wrocław) show similar relationships between cold-stress levels and emergency interventions, reinforcing the utility of UTCI in public health research (Kuchcik 2021). These parallels confirm that the observed dependencies in Lublin are not local anomalies but part of a broader climatic and social pattern in Central and Eastern Europe.

Global climate change is expected to modify cold-related health risks in complex ways. While a general warming trend will likely reduce the number of extreme cold days, the persistence of social inequalities and population ageing may sustain or even increase the relative burden of hypothermia. UHIs may locally mitigate temperature extremes but do not eliminate the risk, particularly for socially exposed groups without access to shelter (Oke 2017, Masselot et al. 2025). Overall, the findings confirm that hypothermia should be treated as both a medical and social problem requiring intersectoral action that combines meteorological forecasting, crisis management, and social assistance.

Limitations

This study has several limitations. First, the dataset from the MDC and Emergency Notification Centre includes only those cases where paramedics explicitly recorded hypothermia as the main or contributing cause. This likely underestimates the true number of events, as mild or fatal cases without emergency intervention were not captured. Second, the classification of hypothermia in the field is often based on clinical observation rather than direct measurement of core temperature. Consequently, diagnostic uncertainty may exist, particularly in cases involving alcohol intoxication or trauma. Third, UTCI values were calculated for a single hour (12:00 UTC), which may not always correspond to the actual exposure time of victims. Future studies should incorporate hourly variability or reconstruct individual exposure histories. Finally, the study focused on one urban centre. While Lublin is representative of eastern Poland, regional differences in housing quality, healthcare access, and local policy mean that results may not be fully generalisable to other cities. Additionally, the available datasets do not include detailed demographic or socio-economic information about the victims (e.g., income, education level, housing conditions), which would allow for a more precise risk assessment. Future research should aim to integrate health, meteorological, and social data within a unified analytical framework. Despite these limitations, the study provides new evidence on the interaction between biometeorological conditions and hypothermia incidents in Central Europe and offers practical implications for public health and urban policy.

Conclusion

Hypothermia is a significant problem in Lublin and should not be underestimated. The most vulnerable social groups are the homeless, the extremely poor, those dependent on substances, the elderly, and people with chronic illnesses. The greatest risk occurs in the autumn–winter months because of low air temperatures, yet hypothermia can be equally dangerous during the remaining months of the year. Most reports of body cooling are recorded between 06:00 and 12:00, whereas the fewest occur between 00:00 and 06:00. The meteorological factors influencing the number of notifications are air temperature, relative humidity, and wind speed. Hypothermia affects men far more often than women. Based on UTCI, this study confirms that hypothermia is closely linked to perceived cold stress. The findings demonstrate that urban hypothermia results from a combination of meteorological and social factors. Therefore, effective prevention must combine biometeorological forecasting tools, such as UTCI, with targeted social interventions addressing homelessness, alcohol abuse and chronic disease.

The public warning system is built on four methods that may be insufficiently effective because hypothermia most often affects people who are homeless and extremely poor. Such individuals frequently lack access to mass media or regular information channels, which makes it difficult to reach them with warnings and advice on available assistance.

Additional solutions that are less dependent on personal telecommunication devices could be introduced so that residents who do not use such electronics still receive information about hazards in the city. One possibility is to post warnings in public spaces such as bus stops or inside public transport vehicles.

To meet the challenges posed by extremely low temperatures, Lublin undertakes actions in line with the Municipal Crisis Management Plan (MPZK 2023). These measures operate on three levels: detecting hazards via the city monitoring network, patrolling the city by police officers and providing immediate assistance to homeless people. Although the monitoring system is an effective tool, it has limitations. Cameras are installed only in the most frequented parts of the city, leaving several areas outside their range; persons located beyond the coverage zone therefore escape surveillance protection. In addition, the efficiency of monitoring depends on human factors such as vigilance and rapid response time. Police activities are crucial in combating hypothermia because they ensure that people in need receive support that can save their lives. Homeless assistance facilities are also invaluable, enabling people experiencing homelessness to survive the winter in relatively safe conditions. It would be worth considering the creation of additional premises that serve as warming centres (e.g. tents or containers). Such places would not offer as many benefits as shelters, yet they would be an effective means of combating hypothermia. Furthermore, the reintroduction of small-scale warming infrastructure (e.g. gas-powered outdoor heaters or temporary warming points) could provide immediate relief during episodes of extreme cold. Mobile aid points could also distribute blankets, warm clothing and hot drinks to those in need, while disseminating information about available shelters. In the long term, reducing the structural causes of hypothermia requires a combination of social, infrastructural and technological measures. The most effective strategies should focus on increasing the availability of permanent housing; supporting addiction treatment programmes and providing year-round access to low-threshold shelters that operate independently of weather conditions. It is also essential to expand social assistance networks to include outreach teams equipped with mobile communication devices and thermal imaging tools to locate individuals in need during cold spells. To address digital exclusion, local authorities could introduce hybrid information systems – combining SMS alerts, public displays and analogue information points at transport hubs and social service facilities – ensuring that even residents without smartphones or Internet access can receive critical weather warnings and information on available aid. These actions should be integrated into broader urban resilience policies and monitored systematically to evaluate their effectiveness over time.

Because hypothermia in urban settings is complex, long-term solutions are required in addition to periodic assistance. It is important that the city conduct information and education campaigns to familiarise residents with the problem of hypothermia, sensitise them to the plight of vulnerable individuals and teach them how they themselves can help.

The government CP (2024) may also prove helpful by supporting building insulation and heating upgrades, thus reducing exposure to cold in poorly heated dwellings.

Finally, the results obtained in this study could serve as a reference for other medium-sized cities in Central Europe with similar socio-climatic profiles. Integrating biometeorological data, health records and urban policy frameworks could enhance early warning systems and adaptation strategies for climate-related health risks.

Author Contributions

MD: conceptualization, methodology, formal analysis, visualization, writing – original draft, writing – review and editing, and preparation of responses to reviewers. AR: methodology, data preparation, data curation, formal analysis, visualization, writing – original draft, and writing – review and editing.

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