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The Effect of Heat and Cold Waves on the Mortality of Persons with Dementia in Germany

Thomas Fritze

German Center for Neurodegenerative Diseases (DZNE), Venusberg-Campus 1, Building 99, 53127 Bonn, Germany; thomas.fritze@dzne.de

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Abstract: We investigated whether persons with dementia (PwD) are at particular risk of mortality when exposed to extreme temperatures and whether the temperature effect depends on long-term care (LTC) need and residency. German health claims data provide information on inpatient and outpatient sectors. Data from the German Meteorological Service were merged, and measures of immediate and delayed heat, cold, and normal temperature (Heat Index, Wind Chill Temperature Index) were calculated. Cox models were applied to explore the interaction of temperature, dementia, and LTC, as well as residency. Immediate and delayed effects of heat and cold were tested as compared to normal temperatures. Models were adjusted for age, sex, comorbidities, urban/rural living, and summer/winter climate zones. The 182,384 persons aged ≥65 contributed 1,084,111 person-years and 49,040 deaths between 2004 and 2010. At normal temperatures, PwD had a 37% (p-value < 0.001) increased mortality risk compared to persons without dementia (PwoD). Immediate heat effects further increased this effect by 11% ($p = 0.031$); no immediate heat effect existed for PwoD. The immediate heat effect was even greater for PwD suffering from severe or extreme physical impairment and for those living in private households and nursing homes. Immediate and delayed cold effects increased mortality independent of dementia. Care level and type of residency did not modify this effect among PwD. PwD revealed an increased vulnerability to immediate heat effects. Cold waves were risk factors for both groups. LTC need appeared to be an important intervening factor.

Keywords: extreme temperatures; mortality with dementia; interaction effects; residency; long-term care; health claims data

1. Introduction

Extreme weather conditions affect health and mortality. The association of ambient temperature and mortality follows a V-, J-, or U-shaped distribution, with lowest death rates during periods of 20 to 25 °C and higher death rates below or above these temperatures [1]. Heatwaves significantly affect death tolls [2,3] and admission rates related to specific causes, such as fluid and electrolyte disorders, renal failure, septicemia, heat stroke [2], and unintentional injuries [4]. Ambient heat exposures are positively associated with mortality [1]. Likewise, cold temperatures are associated with an increase in hospital admissions [5] and the number of total and cause-specific deaths, such as cardiovascular, respiratory, and cerebrovascular deaths [6]. The elderly, infants, persons of low socioeconomic status, as well as persons with impaired health or limited mobility, suffer from increased risk of morbidity and death induced by extreme weather [7]. Therefore, people with cognitive constraints and dementia may be at particular risk. Among the elderly, dementia is one of the most common syndromes and is associated with increased mortality and decreased life expectancy [8]. An estimated 44.35 million people worldwide, 11 million in Europe [9], and 1.4 million people in Germany currently suffer from dementia [10]. The literature on the association between weather conditions and morbidity and mortality of persons with dementia (PwD) is scarce. Studies have found increased risks of hospital admissions and death among persons with mental illness and dementia during hot weather [11,12]. A higher number of deaths was found in the winter than in the non-winter months among those with dementia and Alzheimer's disease as the cause of death in England and Wales [13]. Following causal chain models, the increased mortality of PwD is the effect of biomedical reactions to extreme outdoor temperatures. The effects are likely moderated by socioeconomic and behavioral aspects, such as the type of housing, exposure to outdoor temperatures, the ability to dress appropriately, air pollution, and others [14,15]. The human ability and efficacy to tolerate extreme heat and cold stress are affected by impaired cognition, inadequate shelter and clothing, immobility, body weight, illness, medication, age, and sex [14–16]. Elderly and PwD often suffer from diseases such as cardiovascular and cerebrovascular diseases [17] which are aggravated during periods of extreme ambient temperatures.

The purpose of this study was to explore how exposure to apparent temperatures affects the mortality of PwD in Germany. In addition, the question of whether living in private households or nursing homes and receiving long-term care are potential intervening factors was examined.

Positive findings in terms of increased mortality during extreme temperatures and a potential impact of the intervening factors would have large health, social, and political implications. To our knowledge, this is the first study to investigate the effects of extreme cold and heat on mortality in a population-based sample of PwD that includes those in nursing homes and with information on long-term care needs.

2. Materials and Methods

About one-third of the German population is insured through the "Allgemeine Ortskrankenkasse" (AOK), and this proportion increases with age [10]. A random sample of 250,000 insured persons born in or prior to 1954, who had at least one day of insurance coverage by the AOK in the first quarter of 2004, was drawn by the scientific institute of the AOK (WIdO). A unique person-identifier code enabled us to follow persons quarterly between 2004 and 2010. The data included complete records of the inpatient and outpatient treatments. Persons with inconsistent or missing information on sex or on dates of birth and death were excluded, giving us a study sample of 182,384 persons aged 65 and above.

Meteorological data stemmed from the "Deutscher Wetterdienst" (DWD, http://www.dwd.de/) and contained information on daily mean air temperature, relative humidity, and wind velocity from 80 weather stations across Germany. The location of the stations was assigned according to the two-digit postal code region. We computed mean values within each postal code region with more than one weather station. Missing values on a specific date in a specific region occurred if no station existed or if a station existed but no values could be recorded on that day in that region. Missing values were then replaced by computing mean values of the indicator in the surrounding regions.

Health claims data were expanded from a quarterly to a daily format and were then linked to the meteorological data via date and postal code.

The outcome of interest in this study was the transition to death, which was measured according to the date of death in the claims data.

Dementia was defined according to the International Classification of Diseases, 10th Revision, (ICD-10) codes: G30, G31.0, G31.82, G23.1, F00, F01, F02, F03, and F05.1. To avoid a potential overestimation of the true number of cases, we applied a validation procedure. Firstly, we considered only those diagnoses from the outpatient sector flagged as "verified" and from the inpatient sector those flagged as "discharge" or "secondary" diagnoses. Secondly, diagnoses were considered valid if they occurred simultaneously in the inpatient and outpatient sectors, or if at least two physicians (general practitioners, neurologists/psychiatrists, or other specialists) made a diagnosis of dementia in the same quarter. Dementia diagnoses were also confirmed by co-occurrence over time. If the patient died in the quarter with the first dementia diagnosis, the diagnosis was considered valid even though the initial diagnosis could not be confirmed by a second diagnosis (see [18] for details).

We used the Heat Index for temperatures >20 °C [19] and the Wind Chill Temperature Index for temperatures <10 °C [20] to indicate particularly high (≥27 °C), low (≤0 °C), or normal apparent temperatures. We explored the potential immediate and delayed effects of extreme temperatures. Immediate effects referred to the current and past three days (0–3) and whether there was at least one extreme hot or cold day. Delayed effects referred to the period of 4–7 days before the current day and whether there was at least one extreme hot or cold day.

We controlled for residency, that is, living in a private household versus a nursing home, and for long-term care quantified by the level of care as defined by the German Law (§ 15 SGB XI). Individuals are entitled to the benefits or services covered by the German statutory long-term care insurance if they pass an assessment mainly based on impairments in activities of daily living (ADL). They are assigned to one of three care levels (considerable need for care = level 1, severe need for care = 2, and extreme need for care = 3).

We included a series of comorbidities: diabetes mellitus (ICD-10 codes E10–E14); hypertension (I10–I13, I15); hypercholesterolemia (E78.0); cerebrovascular disease (I60–I69, G45–G46, H34.0); cancer (all C codes); diseases of the heart (I43, I50, I099, I110, I130, I132, I255, I420, I425–I429, P290); chronic lung diseases (J4, J60–J61, I278, I279, J684, J701, J703); rheumatism (M05–M06, M315, M351, M353, M360); paralysis (G81, G82, G041, G114, G801, G082, G830–G839); injuries to the lower extremities (S7–S9, T003, T006, T013, T016, T023, T025-T026, T033-T034, T043–T044, T053–T056, T12–T13, T24–T25, T336–T338, T346–T348, T355, T871); and blindness (H54). All medical diagnoses indicated whether a certain disease was observed at least once starting in 2004 and if remained from that point onwards until the end of observation. Thus, these comorbidities could be interpreted as the effect of having ever experienced the respective condition since the beginning of 2004. A variable in the model indicated the number of diagnoses a person received during the observation period. To identify those living in urban areas we referred to postal codes related to cities with ≥100,000 inhabitants. We adjusted for regional climatic differences within Germany by introducing two variables. The first variable defined regions according to the lowest two-day mean air-temperature values reached 10 times over the last 20 years (regions 1–4 with −10, −12, −14, and −16 °C, respectively). Another variable indicated summer climate zones according to monthly mean temperatures (summer cool: ≤16.5 °C, temperate: 16.5–18 °C, summer hot ≥ 18 °C). Demographic information contained sex and age.

Methods of survival analysis were conducted to analyze the risk of mortality. The observation period started on January 1, 2004, and the calendar time of the period 2004–2010 was used as the underlying process time. We presented mortality rates and applied Cox models to explore the effect of apparent temperature on mortality. Immediate and delayed effects of heat and cold were tested to immediate and delayed effects of normal temperatures, respectively. We then explored the interaction between dementia, the potentially intervening factors, and the temperature variables. All models were adjusted for sex and time-dependent information on age, urban living, summer and winter climate zones, and comorbidities as potential confounders. Individuals were followed up until death, withdrawal from the insurance, loss to follow-up, or through December 31, 2010.

3. Results

The 182,384 persons contributed 1,084,111 person-years and 49,040 cases of death during the period from 2004 to 2010 (Table 1). The overall mortality rate (MR), displayed as death cases per 1000 person-years, was 45.24 (95% confidence interval CI = 44.84–45.64). With regard to immediate temperature effects, mortality rate was highest on extremely cold days (MR = 48.48, CI = 47.77–49.20), compared to days with normal (MR = 43.52, CI = 43.01–44.04) and high temperatures (MR = 43.93, CI = 42.47–45.45). Rates related to delayed temperature effects revealed similar results. The rate for PwD (MR = 192.12, CI = 189.52–194.76) exceeded the rate for persons without dementia (PwoD; MR = 29.04, CI = 28.70–29.38). Those living in nursing homes had higher rates than those in private households (MR = 280.78 vs. MR = 34.82). Mortality rates increased with higher care levels and were highest in care level 3 with MR = 488.12 (CI = 478.07–498.61).

Table 1. Mortality rates by immediate and delayed temperature effects, dementia, residency, and care level.

Variable	Category	Exposures #	Deaths	Mortality Rate *	LCI	UCI
Immediate temperature effects	Normal	639,788.64	27,845	43.52	43.01	44.04
	Cold	368,254.12	17,853	48.48	47.77	49.20
	Heat	76,068.30	3342	43.93	42.47	45.45
Delayed temperature effects	Normal	641,531.76	27,913	43.51	43.00	44.02
	Cold	366,687.05	17,943	48.93	48.22	49.65
	Heat	75,892.26	3184	41.95	40.52	43.44
Dementia	Without dementia	976,448.74	28,356	29.04	28.70	29.38
	With dementia	107,662.32	20,684	192.12	189.52	194.76
Residency	Private household	1,038,202.70	36,150	34.82	34.46	35.18
	Nursing home	45,908.40	12,890	280.78	275.97	285.67
Care level	No care level	941,155.50	16,761	17.81	17.54	18.08
	Care level 1	73,505.43	8546	116.26	113.82	118.75
	Care level 2	51,667.52	15,051	291.30	286.69	296.00
	Care level 3	17,782.61	8682	488.23	478.07	498.61
Total		1,084,111.10	49,040	45.24	44.84	45.64

Data source: Claims data "Allgemeine Ortskrankenkasse" (AOK) 2004–2010, "Deutscher Wetterdienst" (DWD) data 2004–2010; N = 182,384; # in person-years; * mortality rate per 1000 person-years; LCI: 95% lower confidence interval, UCI: 95% upper confidence interval.

According to the hazard ratios (HR) from Cox regression models, at normal temperatures, PwD faced a 37% (p-value < 0.001) increased mortality risk compared with PwoD after controlling for all the covariates included in the model. Immediate heat effects further increased this effect by 11% (HR = 1.37 × 1.11 = 1.52). The immediate (HR = 1.05, p = 0.011) and delayed (HR = 1.08, p < 0.001) increase in mortality associated with cold temperatures seemed to be independent of dementia. Regarding residency, persons living in nursing homes revealed a mortality risk increased by 10% (HR = 1.10, p < 0.001) compared to persons in private households. The mortality risk was increased among persons with care levels compared to persons without (HR = 3.25, p < 0.001; HR = 7.31, p < 0.001; HR = 12.72, p < 0.001, for care levels 1–3, respectively) (Table 2).

Regarding the interactions between temperature, dementia, and care level, we found significantly increased mortality at normal temperatures among PwoD with a care level and among PwD without and with a care level compared to PwoD without a care level (results not shown). Immediate heat effects further increased the effects by 14% among PwD with care level 2 (HR = 1.14, p = 0.037) and by 19% among PwD with care level 3 (HR = 1.19, p = 0.012). This underlines the importance of physical disability in the association between apparent temperature and mortality with dementia. Among PwoD, we found a similar effect for those with care level 3 (HR = 1.18, p = 0.084) (Figure 1). Delayed cold effects increased the mortality for PwoD who had no care level (HR = 1.16, p < 0.001). In association with delayed cold effects, being assigned to a care level had protective effects for PwoD (HR = 0.87, p = 0.011, and HR = 0.90, p = 0.098, for care levels 1 and 3, respectively), but not for PwD (Figure 2). No significant interaction occurred for immediate cold and delayed heat effects.

Regarding the interaction between temperature, dementia, and residency, at normal temperatures, PwoD in nursing homes, as well as those with dementia in private households and nursing homes, revealed increased mortality risks compared to PwoD in private households (results not shown). Immediate heat effects further increased the risks of PwD in private households (HR = 1.13, p = 0.025) and nursing homes (HR = 1.11, p = 0.073). PwoD in nursing homes tended to have increased mortality risks associated with immediate heat effects, although this was not statistically significant (HR = 1.14, p = 0.139) (Figure 3). Among PwoD in private households, we found an increase in mortality by 12% associated with delayed cold effects (HR = 1.12, p < 0.001). At the same time, delayed cold effects decreased the effect among PwoD in nursing homes by 12% (HR = 0.88, p = 0.054). No significant delayed cold effects appeared among PwD, neither in private households nor in nursing homes (Figure 4). No significant interaction occurred for immediate cold and delayed heat effects.

Table 2. Hazard ratios of mortality: the interaction between immediate and delayed temperature effects and dementia.

	Variable	Category	Hazard Ratio	*p*
	Dementia	Without dementia	1	
		With dementia	1.37	<0.001
	Temperature: main effects			
	Immediate temperature	Normal	1	
		Cold	1.05	0.011
PwoD		Heat	0.98	0.521
	Delayed temperature	Normal	1	
		Cold	1.08	<0.001
		Heat	0.95	0.052
	Temperature: Interaction effects			
	Immediate temperature effects, Dementia	Normal, Without dementia	1	
		Cold, With dementia	0.98	0.497
		Heat, With dementia	1.11	0.011
PwD	Delayed temperature effects, Dementia	Normal, Without dementia	1	
		Cold, With dementia	1.05	0.115
		Heat, With dementia	0.98	0.595
	Age		1.06	<0.001
	Age × Age		1.00	<0.001
	Sex	Male	1	
		Female	0.56	<0.001
	Residency	Private household	1	
		Nursing home	1.10	<0.001
	Care level	No care level	1	
		Care level 1	3.25	<0.001
		Care level 2	7.31	<0.001
		Care level 3	12.72	<0.001
	Comorbidities	0	1	
		1	1.16	<0.001
		2	1.47	<0.001
		3	1.91	<0.001
		4	2.46	<0.001
		5	3.02	<0.001
		6	3.34	<0.001
		≥7	6.75	<0.001
	Urban living	No	1	
		Yes	1.03	0.002
	Climate zone, winter	1 (−10 °C)	1	
		2 (−12 °C)	0.94	<0.001
		3 (−14 °C)	0.89	<0.001
		4 (−16 °C)	0.84	<0.001
	Climate zone, summer	1 (≤16.5 °C)	1	
		2 (16.5–18 °C)	1.00	0.926
		3 (≥18 °C)	0.99	0.543

Data source: Claims data AOK 2004–2010, DWD data 2004–2010; N = 182,384; PwD = Persons with dementia, PwoD = Persons without dementia.

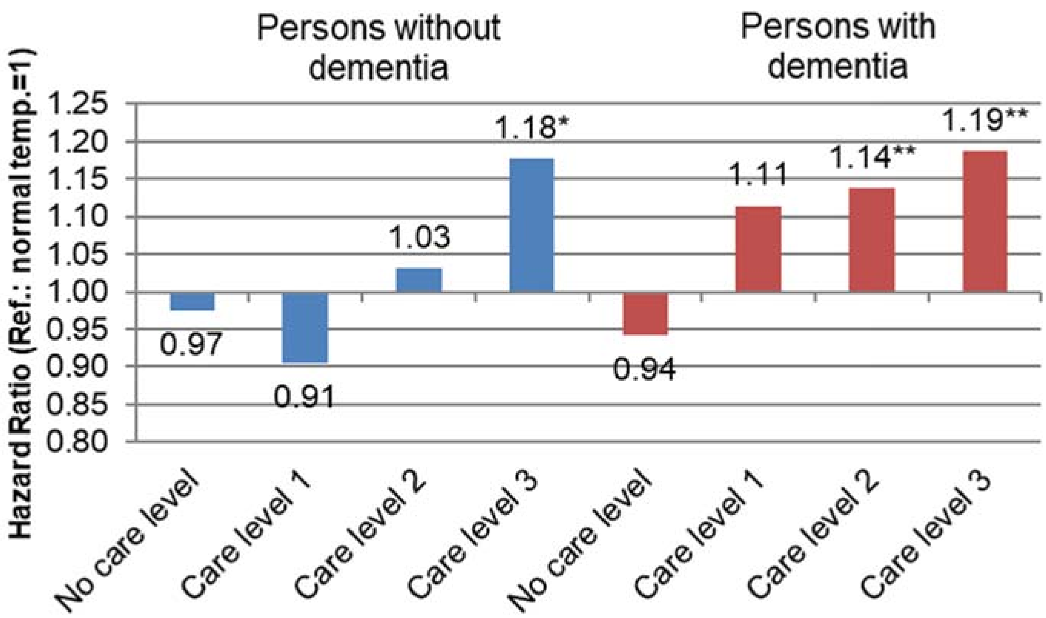

Figure 1. Immediate heat effect on mortality (hazard ratio) in comparison to immediate normal temperatures among persons with and without dementia by care level. Data source: Claims data AOK 2004–2010, DWD data 2004–2010; N = 182,384; adjusted for age, sex, residency, comorbidities, urban living, winter and summer climate zones, and interaction between dementia, care level, and delayed temperature effects; immediate cold effect not shown; *** $p \leq 0.01$, ** $p \leq 0.05$, * $p \leq 0.1$.

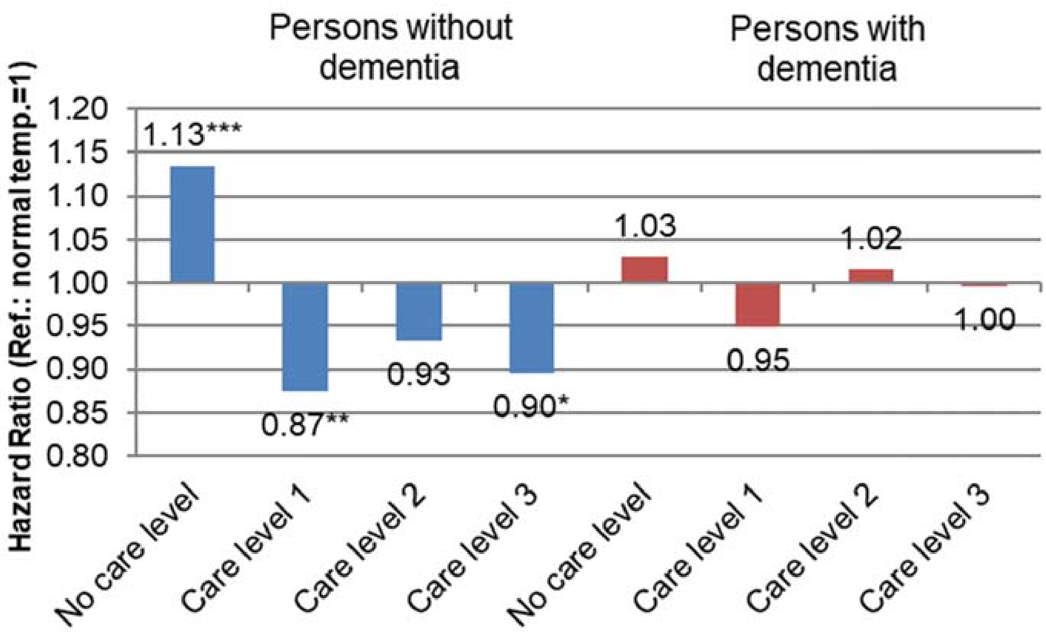

Figure 2. Delayed cold effect on mortality (hazard ratio) in comparison to delayed normal temperature effects among persons with and without dementia by care level. Data source: Claims data AOK 2004–2010, DWD data 2004–2010; N = 182,384; adjusted for age, sex, residency, comorbidities, urban living, winter and summer climate zones, and interaction between dementia, care level, and immediate temperature effects; delayed heat effect not shown; *** $p \leq 0.01$, ** $p \leq 0.05$, * $p \leq 0.1$.

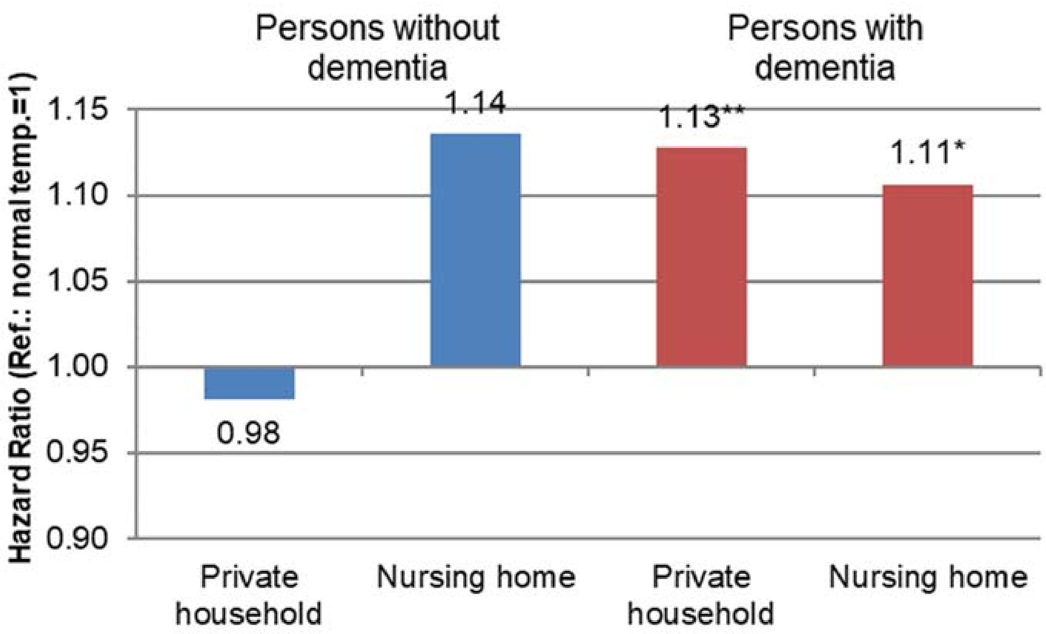

Figure 3. Immediate heat effect on mortality (hazard ratio) in comparison to immediate normal temperatures among persons with and without dementia by residency. Data source: Claims data AOK 2004–2010, DWD data 2004–2010; N = 182,384; adjusted for age, sex, care level, comorbidities, urban living, winter and summer climate zones, and interaction between dementia, residency, and delayed temperature effects; immediate cold effect not shown; *** $p \leq 0.01$, ** $p \leq 0.05$, * $p \leq 0.1$.

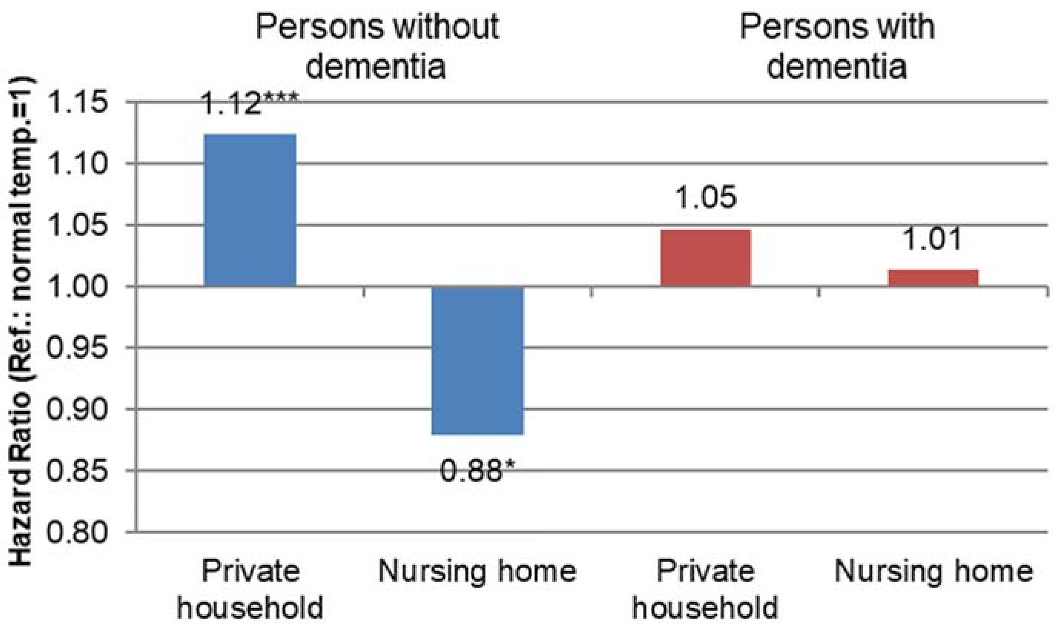

Figure 4. Delayed cold effect on mortality (hazard ratio) in comparison to delayed normal temperature effects among persons with and without dementia by residency. Data source: Claims data AOK 2004–2010, DWD data 2004–2010; N = 182,384; adjusted for age, sex, care level, comorbidities, urban living, winter and summer climate zones, and interaction between dementia, nursing home, and immediate temperature effects; delayed heat effect not shown; *** $p \leq 0.01$, ** $p \leq 0.05$, * $p \leq 0.1$.

4. Discussion

Based on large, longitudinal health claims data, we found that apparent temperature significantly increased the mortality of PwD. Their mortality rose as an immediate response to hot temperatures, which is not the case for PwoD. Increased mortality associated with immediate and delayed effects of cold temperatures was independent of dementia.

Other studies found acute effects of heat waves and hot temperatures on morbidity and mortality among people with mental disorders. Page et al. [11] explored temperature-related deaths in people with dementia and other mental illnesses in primary care patients living in the UK. They found an elevated risk of dying of 4.9% (95% CI = 2.0–7.8) per 1 °C-increase in temperature above the 93rd percentile of the annual temperature distribution. Among other studies that used dementia as the cause of death based on death certificates, Conti et al. [12] studied the effect of the extraordinary European heat wave of 2003 on cause-specific mortality in Genoa, Italy. They found an excess in mortality with dementia among persons aged 75 + as compared to the summer of 2002. A study analyzing the change in mortality rates among nursing home residents during the 2003 heat wave in France found that less frail patients contributed most to excess mortality. The authors concluded that medical care in terms of maintaining hydration and refreshment was primarily directed to more dependent persons, including those with dementia, to avoid complications [21]. Thus, it seems reasonable not to lose focus on less frail persons, while still taking care of physiologically and mentally more vulnerable persons.

The current results revealed a delayed mortality increase associated with cold temperature that was somewhat larger than the immediate increase. This finding was consistent with the results of a Dutch study [22] in which the cold temperature at the lag-periods 3–6 and 7–14 days had larger effects on mortality compared to cold temperatures at the lag-period 1–2 days. Additional findings in this study suggested that a portion of cold-related mortality resulted from the indirect effect of an increased incidence of influenza or influenza-like conditions. However, more recent research revealed that while influenza is most prevalent during winter seasons, its influence on cold-related mortality seems to be overestimated in many studies [14,23]. By contrast, cardiovascular, cerebrovascular, and respiratory diseases are of particular importance when explaining mortality peaks in winter seasons (see [14] for an overview). Influenza and pneumonia [24], circulatory diseases [17], as well as respiratory diseases [25] are frequent diseases and causes of death among PwD. We were not able to disentangle the temporal link between the occurrence or aggravation of such diseases during extreme weather conditions and death in the claims data. Information about diseases are provided on a quarterly basis and claims data do not include information on the cause of death. In addition, influenza is known to be underreported in claims data [26].

The increased immediate heat-related mortality and the inverse association for delayed heat-related mortality among PwD were, again, consistent with the Dutch study. The significant immediate effect indicated stronger direct effects of exposure of the human body to hot temperatures rather than influenza-like conditions or season [22]. The results of our study also suggested an effect of "mortality displacement" (or "harvesting"). This phenomenon describes the fact that death rates are increased during periods of extreme temperatures and are lower than expected shortly after these periods [27]. Mortality displacement depends on the population at risk with its baseline health status and socio-demographic characteristics [28] and may occur among people whose health status is already compromised and who will die shortly thereafter, even in the absence of exposure to extreme temperatures [29]. The effect is pronounced in heat periods [27,29] but not during cold spells [6,27]. PwD in our study had higher vulnerability compared to PwoD, which may have led to an increased mortality associated with immediate heat effects and to decreased mortality rates thereafter.

In our study, the level of care was included to quantify the long-term care need of the elderly. The assessment to define this care level was based on impairments in activities of daily living which are known to increase the risk of mortality [30]. We found increased risks among PwD with a long-term care need associated with heat exposure, stressing the increased vulnerability of elderly suffering from both physical and cognitive disabilities. Dementia is a risk factor for dehydration, which itself is known to be associated with high mortality rates [31]. Elderly people, particularly PwD, appear to be unable to effectively implement adaptive behaviors, such as drinking more fluids during hot days, or they are not able to express discomfort to their care givers [12,32]. The pattern is less clear among PwoD; only those with the highest grade of ADL dependency face larger mortality risks associated with hot temperatures. Studies of the 2003 heat wave in Europe revealed that higher co-morbidity and disability were independently related to death [33] and that the relative risk of mortality increased with the level of dependency [34].

Long-term care appeared to be protective for PwoD who experienced cold temperatures 4–7 days earlier. Long-term care implies regular supervision by professional caring staff. Adverse delayed effects of very low temperatures, such as respiratory diseases, can be recognized and treated. There was no protective effect among PwD and need of long-term care. This was most likely due to the higher vulnerability of PwD or to the lack of care and supervision.

The immediate heat effect was associated with increased mortality among PwD regardless of their residency. Although statistically not significant, PwoD in nursing homes tended to have higher mortality risks associated with immediate heat effects compared to PwoD in private households. This could be the result of the higher vulnerability of the institutionalized population or to poor air conditioning. Information on the equipment of private dwellings and nursing homes with air conditioning in Germany is scarce. As Germany is located in a temperate-climate zone, only 1–2% of German dwellings are air-conditioned [35]. While studies have shown that air conditioning appeared to be effective in reducing heat-related mortality [36,37], air conditioning is also associated with environmental, organizational, socioeconomical, biophysical, and behavioral challenges [38]. The latter study discussed alternative solutions to air conditioning, such as climate-sensitive urban planning and building design, alternative cooling technologies, and climate-sensitive attitudes and behaviors.

The protective effect of residency among the PwoD who experienced delayed cold effects could be interpreted either as the benefit of caring and supervision within institutions and appropriate heating, or as a selection effect because of the reduced exposure to outdoor temperatures. We did not find such a protective effect among PwD. This may be due to the higher vulnerability; on the other hand, there may be the scope of improving care and medical control of PwD during very cold periods. Contrary to this, Hajat et al. [39] found that extreme temperature effects in elderly deaths were stronger in nursing and care homes compared to deaths in private households. When restricting the analyses to persons aged 85 +, mortality differentials remained for heat exposure but disappeared for cold. This study did not take dementia into account.

We found similar overall patterns in separate models for men and women (results not shown). This is in line with several studies on cold-related mortality [6,14,39,40]. Research evidence for the influence of sex during heat is inconsistent. This is likely caused by the interaction of sex and social factors, including, among others, marital status, level of social isolation, or physical activeness (see review by Kovats and Hajat [15]). Such interaction effects would be an interesting field for further studies, however, social aspects are not included in claims data (see below).

We have to consider potential limitations associated with this data. AOK data display only a part of the German population, resulting in a lack of representativeness. However, the comparison of mortality patterns among the AOK and the German population indicates only marginal differences [41]. AOK insurees have a lower socioeconomic status compared to people insured in other public health insurance companies and privately insured persons, but this is largely among younger people [42,43]. Changes in the social status composition of the insured population were negligible in the time period studied here. Health claims data are a secondary data source; their main purposes being cost reimbursement and cost calculation, and this leads to three issues. Firstly, many important aspects which may have an intervening effect on the association between temperature and mortality are not relevant for cost reimbursement and are thus not collected. This includes information on air pollution, air quality, whether a person is living alone or not, leaving the home daily, social isolation, low socioeconomic status, poor housing conditions, and lack of air conditioning. Secondly, only those diagnoses leading to treatment are relevant for the purposes of cost calculation. Thus, a patient's cognitive impairment might not be documented if no further treatment is given. This could be particularly true for the mild cases of dementia and cognitive impairment. The incident dementia diagnosis will certainly be biased to higher ages when the symptoms of the syndrome become more obvious [44]. Further studies that allow assessing cognitive abilities should also explore the consequences of extreme temperature on persons with mild cognitive impairment in addition to PwD. Thirdly, we used a combined indicator for dementia using a series of specific dementia diagnoses. It could be useful to investigate specific diagnoses such as vascular dementia; however, different subtypes of dementia cannot be meaningfully distinguished. According to epidemiological studies, Alzheimer's disease is the most and vascular dementia is the second-most prevalent causes of dementia. In the AOK data, only 27% of dementia cases were diagnoses of Alzheimer's disease, but 45-50% of the dementia diagnoses were of unspecified dementia [10]. Dementia diagnoses in medical claims data are neither specific nor standardized. Nonetheless, dementia prevalence and incidence based on AOK claims data fit well to national and international studies [8,45].

The outstanding advantage of this study was that the information about dementia stemmed from medical records rather than death certificates. The majority of studies on seasonal mortality have investigated dementia reported on death certificates, which suffer from a general underestimation of dementia occurrence [46]. We avoided this disadvantage by using dementia as morbidity, with diagnoses from the inpatient (general practitioners and neurologists/psychiatrists) and outpatient sectors. To our knowledge, so far, only one study on heat-related mortality and dementia has used diagnoses instead of certificates. This study used information from primary care only and was not able to explore effects of residency [11]. We used regional temperature measures instead of national measures to minimize misclassification of exposure. Further strengths of the current study were the large longitudinal sample of more than 180,000 persons, including the institutionalized. There is no bias in the results due to self-selection, selection by the health care provider, or the study design. Using medical diagnoses also prevented recall bias by the patient.

In general, public health adaptation strategies should aim to develop and increase sensitivity and consciousness regarding consequences related to extreme weather conditions. This includes the reduction of exposure to extreme temperatures and the management of health risks particularly for vulnerable people suffering from cognitive and physical impairment. The implementation of emergency plans should organize behavioral rules, protective measures, and emergency services, and should advise us on how to cope with excessive outdoor temperatures. Appropriate warning systems should alert people with dementia and their formal and informal caregivers in a timely manner on upcoming extreme weather conditions and temperatures. A regular evaluation and further research should prove the effectiveness of such measures.

The focus of this study was on mortality with dementia and care need as an intervening factor. Instead of a-priori defined criteria that are assumed to be relevant regarding seasonal mortality, future studies may use data-driven approaches. Statistical learning methods, such as hierarchical cluster analyses, may consider the whole structure and characteristics of the available data, and may lead to more precise predictions regarding seasonal mortality. Such analyses may include all of the available information in claims data (diagnoses, medication, care need, and procedures) as well as other external data, such as data on air pollution, to get a better sense of the interaction between these factors.

5. Conclusions

This study found strong immediate effects of heat waves on the mortality of PwD. Cold waves were risk factors for both PwD and PwoD. In addition, long-term care proved to be an essential intervening factor. These results support the need for appropriate care and supervision for the vulnerable elderly with impairments in activities of daily living, and even more for PwD, in order to enable them to overcome the physical stresses affecting them during periods of extreme temperatures.

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References

1. Basu, R.; Samet, J.M. Relation between elevated ambient temperature and mortality: A review of the epidemiologic evidence. *Epidemiol. Rev.* **2002**, *24*, 190–202. [CrossRef] [PubMed]
2. Bobb, J.F.; Obermeyer, Z.; Wang, Y.; Dominici, F. Cause-specific risk of hospital admission related to extreme heat in older adults. *JAMA* **2014**, *312*, 2659–2667. [CrossRef] [PubMed]
3. Robine, J.M.; Cheung, S.L.; Le Roy, S.; Van Oyen, H.; Griffiths, C.; Michel, J.P.; Herrmann, F.R. Death toll exceeded 70,000 in Europe during the summer of 2003. *C R Bioltom* **2008**, *331*, 171–178. [CrossRef] [PubMed]
4. Otte Im Kampe, E.; Kovats, S.; Hajat, S. Impact of high ambient temperature on unintentional injuries in high-income countries: A narrative systematic literature review. *BMJ Open* **2016**, *6*, e010399. [CrossRef]
5. Myint, P.K.; Vowler, S.L.; Woodhouse, P.R.; Redmayne, O.; Fulcher, R.A. Winter excess in hospital admissions, in-patient mortality and length of acute hospital stay in stroke: A hospital database study over six seasonal years in Norfolk, UK. *Neuroepidemiology* **2007**, *28*, 79–85. [CrossRef]
6. Analitis, A.; Katsouyanni, K.; Biggeri, A.; Baccini, M.; Forsberg, B.; Bisanti, L.; Kirchmayer, U.; Ballester, F.; Cadum, E.; Goodman, P.G.; et al. Effects of cold weather on mortality: Results from 15 European cities within the PHEWE project. *Am. J. Epidemiol.* **2008**, *168*, 1397–1408. [CrossRef]
7. Balbus, J.M.; Malina, C. Identifying vulnerable subpopulations for climate change health effects in the United States. *J. Occup. Environ. Med.* **2009**, *51*, 33–37. [CrossRef]
8. Doblhammer, G.; Fink, A.; Zylla, S.; Willekens, F. Compression or expansion of dementia in Germany? An observational study of short-term trends in incidence and death rates of dementia between 2006/07 and 2009/10 based on German health insurance data. *Alzheimers Res. Ther.* **2015**, *7*, 66. [CrossRef]
9. Alzheimer's Disease International. *Policy Brief: The Global Impact of Dementia 2013–2050*; Alzheimer's Disease International (ADI): London, UK, 2013.
10. Schulz, A.; Doblhammer, G. Aktueller und zukünftiger Krankenbestand von Demenz in Deutschland auf Basis der Routinedaten der AOK—Current and future number of people suffering from dementia in Germany based on routine data from the AOK. In *Versorgungs-Report 2012: Schwerpunkt: Gesundheit im Alter*; Günster, C., Klose, J., Schmacke, N., Eds.; Schattauer: Stuttgart, Germany, 2012; pp. 161–175.
11. Page, L.A.; Hajat, S.; Kovats, R.S.; Howard, L.M. Temperature-related deaths in people with psychosis, dementia and substance misuse. *Br. J. Psychiatry* **2012**, *200*, 485–490. [CrossRef]
12. Conti, S.; Masocco, M.; Meli, P.; Minelli, G.; Palummeri, E.; Solimini, R.; Toccaceli, V.; Vichi, M. General and specific mortality among the elderly during the 2003 heat wave in Genoa (Italy). *Environ. Res.* **2007**, *103*, 267–274. [CrossRef]
13. Office for National Statistics. *Excess Winter Mortality in England and Wales, 2012/13 (Provisional) and 2011/12 (Final)*; Office for National Statistics: London, UK, 2013.
14. Rau, R. *Seasonality in Human Mortality. A Demographic Approach*; Springer: Heidelberg, Germany, 2007; pp. 39–81.
15. Kovats, R.S.; Hajat, S. Heat stress and public health: A critical review. *Annu. Rev. Public Health* **2008**, *29*, 41–55. [CrossRef] [PubMed]
16. Hanna, E.G.; Tait, P.W. Limitations to Thermoregulation and Acclimatization Challenge Human Adaptation to Global Warming. *Int. J. Environ. Res. Public Health* **2015**, *12*, 8034–8074. [CrossRef] [PubMed]
17. Winblad, B.; Amouyel, P.; Andrieu, S.; Ballard, C.; Brayne, C.; Brodaty, H.; Cedazo-Minguez, A.; Dubois, B.; Edvardsson, D.; Feldman, H.; et al. Defeating Alzheimer's disease and other dementias: A priority for European science and society. *Lancet Neurol.* **2016**, *15*, 455–532. [CrossRef]
18. Doblhammer, G.; Fink, A.; Fritze, T.; Günster, C. The demography and epidemiology of dementia. *Geriatr. Ment. Care* **2013**, *1*, 29–33. [CrossRef]

19. Rothfusz, L.P. *The Heat Index Equation*; SR 90-23; National Oceanic and Atmospheric Administration, National Weather Service, Office of Meteorology: Fort Worth, TX, USA, 1990.
20. OFCM. *Report on Wind Chill Temperature and Extreme Heat Indices: Evaluation and Improvement Projects*; Office of the Federal Coordinator for Meteorological Services and Supporting Research: Washington, DC, USA, 2003.
21. Holstein, J.; Canoui-Poitrine, F.; Neumann, A.; Lepage, E.; Spira, A. Were less disabled patients the most affected by 2003 heat wave in nursing homes in Paris, France? *J. Publ. Health* **2005**, *27*, 359–365. [CrossRef]
22. Kunst, A.E.; Looman, C.W.; Mackenbach, J.P. Outdoor air temperature and mortality in The Netherlands: A time-series analysis. *Am. J. Epidemiol.* **1993**, *137*, 331–341. [CrossRef]
23. Donaldson, G.C.; Keatinge, W.R. Excess winter mortality: Influenza or cold stress? Observational study. *BMJ* **2002**, *324*, 89–90. [CrossRef]
24. Naumova, E.N.; Parisi, S.M.; Castronovo, D.; Pandita, M.; Wenger, J.; Minihan, P. Pneumonia and influenza hospitalizations in elderly people with dementia. *J. Am. Geriatr. Soc.* **2009**, *57*, 2192–2199. [CrossRef]
25. Brunnstrom, H.R.; Englund, E.M. Cause of death in patients with dementia disorders. *Eur. J. Neurol.* **2009**, *16*, 488–492. [CrossRef]
26. Scholz, S.; Damm, O.; Schneider, U.; Ultsch, B.; Wichmann, O.; Greiner, W. Epidemiology and cost of seasonal influenza in Germany—A claims data analysis. *BMC Public Health* **2019**, *19*, 1090. [CrossRef]
27. Revich, B.; Shaposhnikov, D. Excess mortality during heat waves and cold spells in Moscow, Russia. *Occup. Environ. Med.* **2008**, *65*, 691–696. [CrossRef] [PubMed]
28. Qiao, Z.; Guo, Y.; Yu, W.; Tong, S. Assessment of Short- and Long-Term Mortality Displacement in Heat-Related Deaths in Brisbane, Australia, 1996–2004. *Environ. Health Perspect.* **2015**, *123*, 766–772. [CrossRef] [PubMed]
29. Hajat, S.; Armstrong, B.G.; Gouveia, N.; Wilkinson, P. Mortality displacement of heat-related deaths: A comparison of Delhi, Sao Paulo, and London. *Epidemiology* **2005**, *16*, 613–620. [CrossRef] [PubMed]
30. Marengoni, A.; Von Strauss, E.; Rizzuto, D.; Winblad, B.; Fratiglioni, L. The impact of chronic multimorbidity and disability on functional decline and survival in elderly persons. A community-based, longitudinal study. *J. Intern. Med.* **2009**, *265*, 288–295. [CrossRef]
31. Schols, J.M.; De Groot, C.P.; van der Cammen, T.J.; Olde Rikkert, M.G. Preventing and treating dehydration in the elderly during periods of illness and warm weather. *J. Nutr. Health Aging* **2009**, *13*, 150–157. [CrossRef]
32. Williams, A.A.; Spengler, J.D.; Catalano, P.; Allen, J.G.; Cedeno-Laurent, J.G. Building Vulnerability in a Changing Climate: Indoor Temperature Exposures and Health Outcomes in Older Adults Living in Public Housing during an Extreme Heat Event in Cambridge, MA. *Int. J. Environ. Res. Public Health* **2019**, *16*, 2373. [CrossRef]
33. Foroni, M.; Salvioli, G.; Rielli, R.; Goldoni, C.A.; Orlandi, G.; Zauli Sajani, S.; Guerzoni, A.; Maccaferri, C.; Daya, G.; Mussi, C. A retrospective study on heat-related mortality in an elderly population during the 2003 heat wave in Modena, Italy: The Argento Project. *J. Gerontol. Biol. Sci. Med. Sci.* **2007**, *62*, 647–651. [CrossRef]
34. Belmin, J.; Auffray, J.C.; Berbezier, C.; Boirin, P.; Mercier, S.; de Reviers, B.; Golmard, J.L. Level of dependency: A simple marker associated with mortality during the 2003 heatwave among French dependent elderly people living in the community or in institutions. *Age Ageing* **2007**, *36*, 298–303. [CrossRef]
35. Bettgenhäuser, K.; Boermans, T.; Offermann, M.; Krechting, A.; Becker, D. *Klimaschutz durch Reduzierung des Energiebedarfs für Gebäudekühlung*; Umweltbundesamt: Dessau-Roßlau, Germany, 2011.
36. Semenza, J.C.; Rubin, C.H.; Falter, K.H.; Selanikio, J.D.; Flanders, W.D.; Howe, H.L.; Wilhelm, J.L. Heat-related deaths during the July 1995 heat wave in Chicago. *N. Engl. J. Med.* **1996**, *335*, 84–90. [CrossRef]
37. Marmor, M. Heat wave mortality in nursing homes. *Environ. Res.* **1978**, *17*, 102–115. [CrossRef]
38. Lundgren-Kownacki, K.; Hornyanszky, E.D.; Chu, T.A.; Olsson, J.A.; Becker, P. Challenges of using air conditioning in an increasingly hot climate. *Int. J. Biometeorol.* **2018**, *62*, 401–412. [CrossRef] [PubMed]
39. Hajat, S.; Kovats, R.S.; Lachowycz, K. Heat-related and cold-related deaths in England and Wales: Who is at risk? *Occup. Environ. Med.* **2007**, *64*, 93–100. [CrossRef] [PubMed]
40. Hales, S.; Blakely, T.; Foster, R.H.; Baker, M.G.; Howden-Chapman, P. Seasonal patterns of mortality in relation to social factors. *J. Epidemiol. Community Health* **2012**, *66*, 379–384. [CrossRef]
41. Nerius, M.; Fink, A.; Doblhammer, G. Parkinson's disease in Germany: Prevalence and incidence based on health claims data. *Acta Neurol. Scand.* **2017**, *136*, 386–392. [CrossRef] [PubMed]
42. Geyer, S.; Peter, R. Income, occupational position, qualification and health inequalities—competing risks? (Comparing indicators of social status). *J. Epidemiol. Community Health* **2000**, *54*, 299–305. [CrossRef] [PubMed]

43. Hoffmann, F.; Koller, D. Verschiedene Regionen, verschiedene Versichertenpopulationen? Soziodemografische und gesundheitsbezogene Unterschiede zwischen Krankenkassen. *Gesundheitswesen* **2017**, *79*, e1–e9. [CrossRef]
44. Doblhammer, G.; Schulz, A.; Steinberg, J.; Ziegler, U. *Demografie der Demenz*; Verlag Hans Huber, Hogrefe AG: Bern, Switzerland, 2012.
45. Doblhammer, G.; Fink, A.; Fritze, T. Short-term trends in dementia prevalence in Germany between the years 2007 and 2009. *Alzheimers Dement.* **2015**, *11*, 291–299. [CrossRef]
46. Romero, J.P.; Benito-Leon, J.; Louis, E.D.; Bermejo-Pareja, F. Under reporting of dementia deaths on death certificates: A systematic review of population-based cohort studies. *J. Alzheimers Dis.* **2014**, *41*, 213–221. [CrossRef]