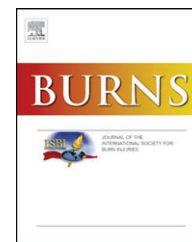


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Review

Epidemiology of burns throughout the world. Part I: Distribution and risk factors

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ABSTRACT

Globally in 2004, the incidence of burns severe enough to require medical attention was nearly 11 million people and ranked fourth in all injuries, higher than the combined incidence of tuberculosis and HIV infections. Fortunately, although burns and fires account for over 300,000 deaths each year throughout the world, the vast majority of burns are not fatal. Nonetheless, fire-related burns are also among the leading causes of disability-adjusted life years (DALYs) lost in low- and middle-income countries (LMIC).

Morbidity and mortality due to fire and flames has declined worldwide in the past decades. However, 90% of burn deaths occur in LMIC, where prevention programs are uncommon and the quality of acute care is inconsistent. Even in high-income countries, burns occur disproportionately to racial and ethnic minorities such that socioeconomic status—more than cultural or educational factors—account for most of the increased burn susceptibility.

Risk factors for burns include those related to socioeconomic status, race and ethnicity, age, and gender, as well as those factors pertaining to region of residence, intent of injury, and comorbidity. Both the epidemiology and risk factors of burns injuries worldwide are reviewed in this paper.

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Contents

1. Introduction	1088
2. Epidemiology	1088
2.1. Incidence	1089
2.2. Burn sequelae: impact in communities	1089
2.3. Burn admissions	1089
2.4. Burn mortality	1089
2.5. Inequitable distribution of burns among groups	1089
2.6. Burn morbidity and emotional impact: additional inequity	1090
2.7. Limitations of data	1091

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3.	Risk factors for fires and burns	1092
3.1.	Socioeconomic factors	1092
3.2.	Race and ethnicity	1092
3.3.	Age-related factors: children	1093
3.4.	Vulnerability associated with developmental stage	1093
3.5.	Environment: home and other circumstances	1094
3.6.	Age-related factors: the elderly	1094
3.7.	Gender-related factors	1095
3.8.	Regional factors	1096
3.9.	Intent of injury	1096
3.10.	Comorbidity	1097
4.	Conclusions and recommendations	1097
	Acknowledgements	1098
	References	1098

1. Introduction

Injury is the physical damage that results when a human body is suddenly subjected to energy in amounts that exceed the threshold of physiologic tolerance [1]. As a significant cause of disability and death, injury is a public health problem; one out of every ten deaths worldwide results from injury [2]. In high-income countries (HIC), the incidence of injuries is decreasing at a slower rate than the incidence of illness. In low- and middle-income countries (LMIC), both death and disability from injuries is increasing very rapidly. In the LMIC of the Americas, Europe, and the Eastern Mediterranean, among men aged 15–44 years, more than 30% of disability-adjusted life years (DALYs, the loss of the equivalent of one year of good health) due either to death or disability was from injury [2].¹

Fire-related burns are among the leading causes of DALYs lost in LMIC [2]. For example, approximately 6% of all unintentional injuries in children less than 15 years of age come from burns of under 20% total body surface area (TBSA) [2]. Worldwide injuries are thus the most common cause of loss; in 2004 these injuries accounted for 17% of DALYs lost in adults aged 15–59 [2].

As defined by the International Society of Burn Injuries, a burn is an injury to the skin or other organic tissue primarily caused by thermal or other acute trauma. A burn occurs when some or all of the cells in the skin or other tissues are destroyed by hot liquids (scalds), hot solids (contact burns), or flames (flame burns). Injuries to the skin or other organic tissues due to radiation, radioactivity, electricity, friction or contact with chemicals are also identified as burns.

Globally in 2004, the incidence of burns severe enough to require medical attention was nearly 11 million people [2] and fourth in all injuries, behind road traffic accidents, falls, and interpersonal violence—this is higher than the combined incidence of tuberculosis and HIV infections, and just slightly less than the incidence of all malignant neoplasms. Burns under 20% TBSA occur to 153 per 100,000 population of children aged 0–15 years, making them the fifth most common cause of non-fatal childhood injuries after intracranial injury, open wounds,

poisoning, and forearm fractures [2]. In Nepal, 5% of disabilities occurring at all ages are from burns and scalds [3].

Risk factors for burns are multivariate and interrelated, and much of the impact of burns is emotional, psychological and spiritual. Both retrospective and prospective studies done at US burn centers regarding recovery from burn clearly show that the ability to adjust following injury is less dependent on the physical characteristics of the burn (such as burn size, burn depth or location), and more dependent on the status of the burn victim's pre-injury level of adjustment. Coping skills, family and community support, and general psychological health have more impact on recovery from burns than the characteristics of the burn itself [4].

In HIC, this means that burn survivors from struggling family backgrounds are likely to have problems re-assimilating into school and community. In LMIC, the consequences are direr, with isolation from or even abandonment by the family, social segregation, unemployment, and extreme poverty. Although burn victims from affluent families in LIC have a chance of recuperation, the vast majority of burn survivors will start from living situations that deny them the opportunity to recover from even a small burn.

Additionally, the sequelae of non-fatal burns are often severe enough to cause permanent disability. In the Global Childhood Unintentional Injury Surveillance pilot study conducted among children (0–12 years of age) in Bangladesh, Colombia, Egypt and Pakistan, 17% of survivors had long term (greater than six weeks) temporary disability, and 8% had permanent disability [5]. The incidence of long-term temporary disability was highest in children surviving burns and traffic injuries. Only near-drowning victims had a higher rate of permanent disability. Permanent disability was eight times more common in burn survivors than in those children recovering from falls.

Thus comes the wisdom of one of the founding fathers of burn care in India, Dr. M.H. Keswani: “The challenge of burns lies not in the successful treatment of a 100% burn, but in the 100% prevention of all burn injuries” [6].

2. Epidemiology

Knowledge of the epidemiology of burns comes from studies including national and regional public health registries, hospital and/or burn center registries, and community

¹ Income categories for 2004 as defined by the World Bank by 2004 gross national income per capita. Low is US\$285 or less; lower middle, US\$285–3255; upper middle, US\$3256–10,065; high, US\$10,066 or more.

surveys (self report). This knowledge is affected by the sources of data and the differences in methodologies used. Here is discussed the incidence of burns and fires and their sequelae in communities.

2.1. Incidence

The incidence of burns and deaths from fires are integrally interwoven with a number of factors. These factors include age, gender, intent of injury, comparison of % TBSA, analysis of trends, availability of (hospital/burn center) burn beds vs. burden of disease, and inequitable distribution among populations. Some of these factors are discussed in the section on risk factors.

Fortunately, although burns and fires account for over 300,000 deaths each year throughout the world, the vast majority of burns are not fatal [2]. In 2008 there were 410,149 non-fatal burns in the US, resulting in an age-adjusted rate of 136 per 100,000 each year [7]. A higher estimate comes from data collected in the US by the National Hospital Ambulatory Medical Care Survey during the period of 1993–2004, in which the average annual emergency department visit rate for treatment of burns was 220 per 100,000 population [8]. Patients with the vast majority of these burns were treated and released from the emergency department; only 5% were hospitalized or transferred. In comparison, only 45% of patients with non-fatal firearm injuries and near-drowning sequelae were treated and released, suggesting that the severity of most burns requiring medical treatment is low compared to other types of injury [7].

2.2. Burn sequelae: impact in communities

Epidemiologic studies from LIC lend insight into the true impact burns have in communities. A cross sectional survey of nearly 1400 households in Tigray, Ethiopia, showed that 1.2% of the population is burned each year. Over 80% of these burns occurred at home, and 90% healed without any complications. Only 1% of the burn victims died [9]. A population-based survey of over 170,000 households representing nearly 350,000 children and 470,000 adults during 2003 in Bangladesh revealed that the overall incidence of non-fatal burns was 166 per 100,000, and that about 173,000 Bangladeshi children suffer moderate to severe burns each year, which is an annual rate of 288 burns per 100,000 children. As was the case in the Ethiopian study, 90% of the burns occurred at home. In Bangladesh, the rate of permanent disability due to burns in childhood was 5.7 per 100,000, and the mortality rate was 0.6 per 100,000 [10–12].

2.3. Burn admissions

Other studies confirm the relative infrequency with which burn patients require hospitalization. In a recent study of patients treated for burns at emergency departments in North Carolina, 4% were admitted and only 4% were transferred to burn centers [13]. Based on the incidence of burns treated at emergency departments and the proportion of those patients requiring admission, it appears that anywhere from 5 to 16 burn patients per 100,000 population require admission for treatment of their injuries. In Pennsylvania in 1994, the rate of

hospitalizations for treatment of burns was 26.3 per 100,000, based on hospital discharge records [14]. Similarly, burn admissions to the National Health Service in England and Wales between 2005 and 2009 averaged 20.6 per 100,000 annually [15]. Global data are even more elusive, but an estimate of the frequency with which children are hospitalized throughout the world for treatment of burns is a rate of 8 per 100,000 [16]. In a rural community survey in Ethiopia, burns were the second most common injury to children under 15 years of age. The annual incidence of burns severe enough to restrict activity for one or more days was 80 per 1000 children [17]. Burns were therefore the leading cause of admission for injury to pediatric hospitals in Ethiopia, and ranked third as a source of outpatient visits [18,19].

In both the United Kingdom and the US, a decrease in emergency department visits for burn occurred between 1993 and 2004 [7,15]. The absolute number of burns in these HIC may be declining, or the severity of those injuries may be decreasing, or both [20]. Fortunately a similar trend is being observed elsewhere. For example, the number of burn patients admitted annually to the Burn Unit of Lok Nayak Hospital and Maulana Azad Medical College in New Delhi, India, between 1993 and 2007 has declined from 1276 to 724 patients [21].

2.4. Burn mortality

In parallel with the decline in emergency department visits and hospitalizations for burns, there has been a decline across the world in mortality due to fire and flames. In the two decades from 1982 to 2002 we have witnessed a reduction in fire and burn mortality in many countries [22]. During this time period, for instance, fire and burn mortality in Australian men declined from 1.5 to 0.7 per 100,000. Similarly the fire death rate in Brazilian women went from 1.1 to 0.5 per 100,000. From 1982 to 2002, other countries that observed reductions in fire and burn mortality included Canada, France, Mexico, Panama, Thailand, the UK, and Venezuela [22]. In the US, the age-adjusted death rate from fire and burns has dropped from 2.99 per 100,000 in 1981 to 1.2 per 100,000 in 2006 [7]. Even in just the brief period between 2000 and 2004, the Global Burden of Disease Project noted a 6% decline worldwide in fire and burn deaths, from 5.1 to 4.8 per 100,000 [2].

Yet not all countries have experienced a simple linear decline in the incidence of burn deaths during the last three decades. Significant political and economic upheaval in the nations which used to belong to the Union of Soviet Socialist Republics (USSR) has left its mark on trends in fire and burn deaths. Following a gentle decline through the early 1980s, fire and burn deaths began to rise before and just after the dissolution of the USSR in 1991. By the late 1990s, as capitalism and democracy began to replace communism, death rates again began to decline [23]. National variations in injury-related mortality may be related to individual factors, such as alcohol consumption and risk-taking behavior, as well as alterations in social, political and environmental factors [24].

2.5. Inequitable distribution of burns among groups

As noted by Mock and associates in a recent editorial in the *Bulletin of the World Health Organization*, each year injuries and

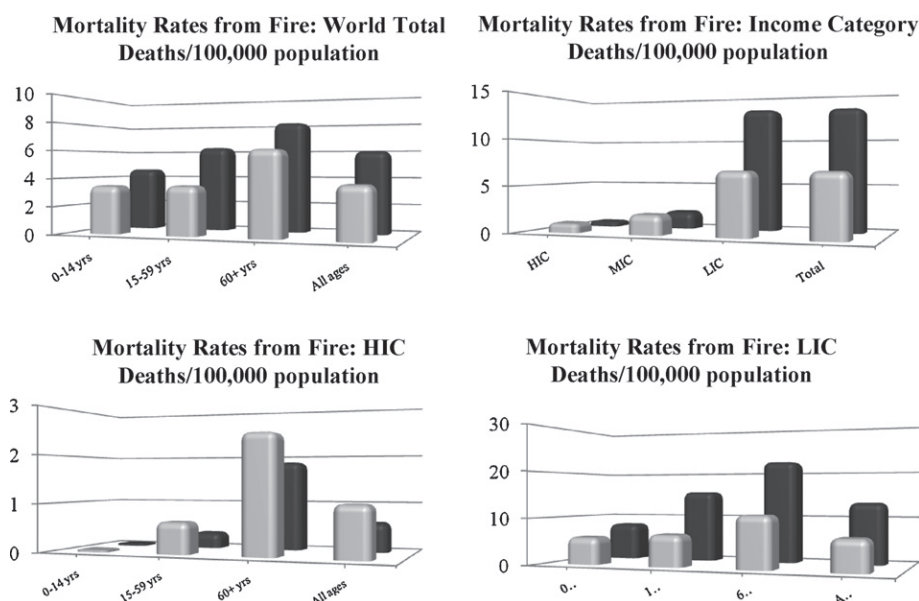


Fig. 1 – Low-income countries (LIC) disproportionately suffer the impact of fire deaths and burns throughout the world, according to statistics from the Global Burden of Disease project [2]. In this figure, grey represents males and black represents females.

violence cause disability and death to tens of millions of people across the globe. This burden is unfairly borne primarily by those in LMIC where prevention programs are uncommon and the quality of acute care is inconsistent [25]. Burns are dramatic examples of the inequity of injury.

Across the world, the majority of burn deaths (90%) occur in lower middle or low income countries. Slightly more than 7% occur in high middle-income countries. Only 3% of burn deaths occur in HIC (Fig. 1) [2]. The rate of child injury death from fire and flames is nearly 11 times higher in LIC than in HIC (Table 1) [2]. In HIC, although the death rate in children from fire and flames is only 3% of the overall rate of death from unintentional injuries of all kinds, in LIC this rate is over 10% [2]. In absolute numbers, the proportion of childhood deaths due to fire and flames in LIC is twice that in HIC (Table 2).

Even in HICs, burns disproportionately occur to racial and ethnic minorities in which socioeconomic status—more than cultural or educational factors—account for most of the increased susceptibility to burns. In the Republic of Korea (South Korea), for instance, the severity of burn is highest in the lowest socioeconomic groups [26]. As another example, the proportion of African-American infants requiring hospitalization for treatment at US burn centers is double the proportion of all African-Americans in the general population [27]. Similarly, in Manitoba, the standardized mortality ratio

for fire deaths in 1981–1982 among Aboriginals was 4.3 times that of the population of the entire province [28]. Indeed, in many Aboriginal communities in North America and Greenland, the third most common cause of unintentional fatal injury is house fires [29,30].

2.6. Burn morbidity and emotional impact: additional inequity

At the time of burn, all patients, whether young or old, experience shock, horror, pain and anxiety. The events that follow the injury may confuse the victims, and lead them to believe (sometimes correctly) that their death is imminent. Because few burn victims in LMIC receive appropriate first aid or immediate acute care, the medical mismanagement of the burn is likely to lead the survivor to the hopeless conclusion that little or nothing can be done to soothe the pain and relieve their suffering. As a result, burn survivors become emotionally overwhelmed and typically withdraw. They lose interest in food and activity, and retreat to dark corners where they may lay motionless for hours. Unfortunately, this lack of activity exacerbates the speed at which the healing burn wound causes wound contractures to occur, and heightens the survivor's disability. For these reasons, the distribution of burn morbidity is also imbalanced. The prevalence of

Table 1 – Unintentional injury death rates per 100,000 children (0–20 years of age) by cause and country income level [2] (HIC = high-income countries, LMIC = low- and middle-income countries).

	Road traffic	Drowning	Fire and burns	Falls	Poisoning	Other	Total
HIC	7.0	1.2	0.4	0.4	0.5	2.6	12.2
LMIC	11.1	7.8	4.3	2.1	2.0	14.4	41.7
World	10.7	7.2	3.9	1.9	1.8	13.3	38.8

Table 2 – Unintentional injury deaths (in millions) in children (0–14 years of age) by cause and country income level [2] (HIC = high-income countries, MIC = middle-income countries, LIC = low-income countries).

	Road traffic	Drowning	Fire and burns	Falls	Poisoning	Other	Total
HIC	6	2	1	1	0	5	14
MIC	53	71	10	11	9	137	292
LIC	108	62	62	23	23	120	399

moderate and severe disability due to unintentional injuries in people less than 60 years of age is 35.4 million in LMIC, 12.5 times higher than in HIC [2].

2.7. Limitations of data

This article summarizes the available data from both lower- and higher-income countries. There are, however, significant gaps between these two sets of nations for a number of reasons. First, as mentioned, the methodologies of reports from the two cohorts vary. Second, data from HICs are, in general, more often accurately recorded and easily available, whereas data from LMICs are either not collected or only sparsely published.

Uncertainty is a factor in many incidence reports of burns and this must be considered when analyzing data. The majority of uncertainty in estimates of death in the Global Burden of Disease (GBD) reports is associated with the assessment of systematic errors in primary data. That is, information about prevalence, incidence and mortality from injuries is generally fragmented, partial, incomparable and diagnostically uncertain [31]. In the GBD reports a simulation approach was used to estimate uncertainty for regional mortality. Ranges of uncertainty were created, accounting for imprecision of estimates of the expected number of total deaths, the diagnosis of underlying cause of injury, and the miscoding of cause, among others. Based on these estimates of uncertainty, the range of uncertainty for fire deaths is 3000–5000 deaths lower or higher than the estimates for fire deaths in East Asia, the Pacific, Europe and Central Asia. Even more uncertain are the estimates in South Asia and Sub-Saharan Africa, where the range of uncertainty surrounding the stated estimates is 10,000–14,000 deaths lower or higher. Thus the real number of fire deaths each year in this region may be almost 30,000 higher than the estimate of 310,000. Sources of uncertainty for estimating burden of injury in the Global Burden of Disease reports include [31]:

- Incomplete information
- Biases in information
- Disagreement among heterogeneous information sources
- Model uncertainty
- The data generation process itself.

To determine the extent of disability related to burns, varying weights were applied to a list of disabilities. The reasoning for assigning a weight to a specific disability rests on an agreed-upon definition and on an accepted method for measuring disability. First, there needs to be delineation of the health states among those living with the particular sequelae (such as burn scars), where a health state is defined by the levels on the various dimensions that constitute health.

Second, there needs to be a valuation function that provides a systematic way to aggregate across multiple dimensions of health in order to arrive at a single index value that captures the overall level of health associated with a given health state [32]. Clearly the challenge is to find universal definitions for disability and tools for disability assessment. Accordingly, as many as one half million more DALYs may be lost to fires each year than is currently estimated [31].

Routine reporting of fatal burns may be poor in LMIC. Special surveys or demographic surveillance by verbal autopsy and lay reporting may be needed to obtain trustworthy information. Community surveys, such as performed by Mashreky and associates in Bangladesh [10], will determine the incidence, circumstances, agent and mechanism, severity and consequences of burns, both fatal and non-fatal. The prevalence of disability and disfigurement, as well as the economic impact on the household, probably cannot be obtained except from comprehensive and thorough community surveys [33].

Much of the published burn epidemiology literature, which characterizes burn etiology, severity and outcomes, arises from studies of populations of patients treated at burn centers. Because of their design, these studies cannot enumerate the incidence and prevalence of important factors and variables that typify the burns that are commonly treated either at home or in primary care settings. Community surveys and examination of data from emergency rooms or clinics are preferable methods for establishing the magnitude of the burden of burns throughout a district or region.

Other limitations arise in the interpretation of some data variables from the US, specifically those related to race/ethnicity and length of stay (LOS). Although race as a variable is often studied, the limitations of commonly used racial and ethnic designations are subject to misinterpretation [34]. There are also pitfalls associated with use of LOS as an outcome variable [35]. In one retrospective study of LOS in burn patients, the variance unexplained by the studied variables was very high, with a coefficient of variance of nearly 100% [36]. Patients admitted on Fridays may have longer LOS for the same severity of injury as those admitted early in the week because of limited resources for discharge planning over weekends. Excision and grafting of even small burns will lead to longer LOS for pain control, immobilization, rehabilitation therapy, and assistance with activities of daily living than will treatment of burns with topical antimicrobials only. Administration of intravenous medications, especially antibiotics and narcotics, will increase LOS. Smoke inhalation injury and high-voltage electrical injury will also increase LOS beyond the range noted for any given burn size. Lack of social support systems leads to longer hospital stays in the absence of medical factors necessitating continued inpatient care.

3. Risk factors for fires and burns

Risk factors include those related to socioeconomic status, race and ethnicity, age, and gender, as well as those factors pertaining to region of residence, intent of injury, and comorbidity. All risk factors combine and overlap, exponentially exacerbating the problem.

3.1. Socioeconomic factors

Household income and home value are correlated with fire deaths and burns. In metropolitan Oklahoma City in 1987–1990 the fire-related hospitalization and death rate was 3.6/100,000 [37]. However, when the examination of data was focused on an area of Oklahoma City characterized by lower median household income, lower property values, and poorer quality of housing, the fire injury rate was much higher, 15.3/100,000 [38]. In Dallas, Texas, census tracts with low median incomes had the highest rates of injury related to house fires, over 8 times that in tracts with high incomes [39]. Although there are a multitude of risk behaviors in low-income neighborhoods, such as alcohol and drug abuse, which put those communities at risk for residential fires, clearly one important factor is the frequent absence of functioning smoke detectors. From 1991 through 1997 in Dallas, as shown by population-based surveillance, the prevalence of operational smoke detectors was lowest in those households in the census tracts having the lowest median incomes [39].

In England and Wales, fire injuries show the steepest social class gradient among all childhood injuries; death from fire and flames is 16 times higher in the lowest socioeconomic class compared to the highest [40]. In an impoverished, multiethnic area of inner-city London in 1996–1997, non-fatal smoke inhalation injuries occurred at an incidence of 25/100,000 persons per year, over 30 times higher than the deaths from smoke inhalation in this series based on computerised databases from hospitals and emergency community services [41]. In this same quarter of London, as revealed from a systematic review of 13 randomized controlled trials, the hospitalization rate for unintentional fire and flame injuries (8.2 per 100,000) was 1.75 times that in the southeastern United Kingdom, which includes urban, suburban and rural neighborhoods [42].

Longitudinal observations of patients admitted to a single burn center in New Delhi suggest that overall socioeconomic improvements lead to a reduction in the frequency of injuries severe enough to require admission to a burn center. In 1993, the per-capita income in Delhi was US\$450/year and 1276 patients were admitted that year; by 2005 the per-capita income in Delhi had risen to US\$1542 and the number of admissions declined to 695 [21]. Unproven but compelling is the hypothesis that the gradual decline in fire and burn deaths across the world is following improvements in income and living conditions.

3.2. Race and ethnicity

In the US there are striking differences in susceptibility to burn by race. In population-based survey reports from 1991 through

1997, African-Americans in Dallas were 2.8 times more likely to be injured in house fires than whites [39]. In 2008 in the US the rate of non-fatal burns was 161 per 100,000 African-Americans, much higher than the observed rate of 109 per 100,000 in white non-Hispanics. In fact, in black Americans aged 35–39 years, the rate was 221 per 100,000 blacks, remarkably higher than the rate in whites in the same age group (135 per 100,000 whites) [7]. The emergency department visit rate for burns from 1993 to 2004 in the US was 62% greater among black than white subjects (340 vs. 210 per 100,000, respectively) [8].

The age-adjusted death rate from burns of all causes in the US in 2006 was highest in blacks (2.43 per 100,000) and lowest in Asians (0.44 per 100,000). Intermediate rates were noted among Native Americans (1.45), white non-Hispanics (1.11), and Hispanics (0.77 per 100,000) [7]. Among children there is a striking disparity in fire death rates between black and white children under the age of 15 years, with African-American children dying in residential fires at a rate nearly three times that of white children. This difference between the races disappears by age 15–19 [7], but reappears at older ages; elderly African-Americans had 4.6 times the death rates of white seniors [43]. The fire fatality rate was highest among older African-Americans in Alabama from 1992 to 1997 [44]. As household income increases, differences in fire death rates between blacks and whites diminish [45], due largely to inequities in resources, education, etc.

Racial differences in burn admissions occur by age group in data collected by the American Burn Association for the National Burn Registry [27].² In children under age five, rates of admissions to burn centers were 22% for black children and 44% for white children. In seniors aged 60 or older, only 15% were black and nearly 75% were white (Table 3). In parallel with the decline of prevalence of blacks in the hospitalized burn population as age increases, Hispanic representation at burn centers was only 4% of the elderly, compared to nearly 20% of children under five (Table 3). Hospital discharge rates for treatment of burns in Pennsylvania in 1994 showed that blacks were hospitalized for burns more than twice as frequently as whites (46.6 vs. 20.6 per 100,000, respectively) [14].

However, racial differences observed in the US can in themselves shed no light on the relative weight of cultural, ethnic, and socioeconomic factors. Similarly, observations elsewhere within the world of differences in burn admissions do little to elucidate the cause of racial and ethnic differences. For example, the age standardized rates of burn-related hospital admissions and mortality in Western Australia from 1983 to 2008 were higher for Aboriginal than non-Aboriginal people. In addition, although the rates of both hospital admissions and death declined in both groups, the rate of decline was markedly steeper in Aboriginals [46].

² The 2009 report of the National Burn Repository reviews the combined data set of acute burn admissions for the period 1999–2008. Seventy-nine hospitals (including 51 verified by the ABA as centers of excellence) from 33 states plus the District of Columbia contributed to this report, totaling 127,016 records. Sixty-two hospitals contributed more than 500 cases. Data were not dominated by any single center and appeared to represent a reasonable cross section of US hospitals.

Table 3 – Summary of data from the national burn repository of the American Burn Association 1999–2008 [27].

Age in years	White	Hispanic	Black	Scald	Flame	Contact	Electrical	Chemical	Burns <10% TBSA	Mortality
0–0.9 N = 3675	42%	17%	24%	55%	6%	22%	<1%	<1%	67%	<1%
1–1.9 N = 9387	42%	21%	22%	57%	4%	20%	<1%	<1%	67%	<1%
2–4.9 N = 7987	47%	20%	20%	46%	16%	13%	2%	<1%	60%	1%
5–15.9 N = 13,457	57%	14%	18%	23%	38%	6%	2%	<1%	54%	<1%
16–19.9 N = 7230	66%	12%	13%	17%	40%	4%	2%	2%	50%	2%
20–29.9 N = 19,033	60%	13%	16%	18%	35%	4%	4%	3%	47%	2%
30–39.9 N = 17,657	61%	13%	15%	18%	36%	4%	5%	4%	45%	3%
40–49.9 N = 18,421	64%	9%	17%	17%	38%	4%	5%	4%	46%	4%
50–59.9 N = 12,523	66%	8%	17%	16%	39%	5%	4%	3%	44%	6%
60–69.9 N = 6987	69%	6%	16%	16%	40%	4%	2%	2%	43%	9%
70–79.9 N = 4825	72%	4%	14%	15%	42%	4%	<1%	<1%	40%	16%
80+ N = 3594	77%	3%	13%	16%	38%	6%	<1%	<1%	36%	25%
(Census 2000)	(70%)	(6%)	(12%)							

3.3. Age-related factors: children

Despite their remarkable resilience, children across the world are commonly seriously injured, with pain and suffering, disability and occasionally death as the outcome. Globally, the highest fire-related death rates in children occur in infants and children under four years of age. Death rates begin to climb again after age 15, presumably because of greater exposure to hazards, experimentation and risk-taking, as well as employment [2]. In the US in 2006, fires and burns were the third leading cause of unintentional injury and death for children one to nine years of age [7].

Non-fatal burns in children are extremely common as well. In 2008 in the US, the crude rate of non-fatal burns was 156 per 100,000 in children under the age of 18 [7]. Strikingly, the rate for children up to three years of age was a staggering 358 per 100,000, and in infants, burns are the fifth leading cause of unintentional non-fatal injury [7]. The fact that 93% of these young children were treated and released from emergency departments suggests that the burns were probably minor scald and contact burns. In fact, 67% of the children hospitalized in the US for burns sustained burns of less than 10% TBSA [47].

In LMIC children under age five have a disproportionately higher rate of burns [48] as compared to those in HIC. For example, in Brazil, Côte d'Ivoire and India, nearly half of all childhood burns occur in infants [49–51]. Even in HIC, children who live in poor districts are at high risk of residential fire related injuries [52].

Various issues impact the likelihood that a child will be burned. These include characteristics of mothers (including literacy, education, and age), knowledge of the risk of burns and of the means to secure health care, ownership of the

house, kitchens separated from other living areas, use of fire-retardant chemicals in fabrics and upholstery, installation of smoke alarms and residential water sprinklers, appropriate first-aid and emergency response systems, and the existence of quality health care services [48]. Education of mothers is a factor in children's vulnerability. Historical cohort data of maternal demographic characteristics, collected in Tennessee from 1980 to 1995, reveal that children whose mothers had less than a high school education had nearly 20 times greater risk of dying in a fire [53] than those children whose mothers had a college education. Similarly, children whose mothers had three or more other children had over six times greater risk of dying in a fire when compared with children whose mothers had no other children. Likewise, when contrasted with children whose mothers were 30 years or older, children whose mothers were younger than age 20 had almost four times the increased risk of dying in a fire. Fortunately, children thus characterized comprise only 1.5% of the population. Nonetheless, the fatal fire rate for this high-risk group was 28.6 per 100,000, far exceeding the national norms for fire fatalities [53].

3.4. Vulnerability associated with developmental stage

The greater susceptibility to burns of children as compared with adults is associated with their stage of development. Children's curiosity and desire to experiment is matched neither by their capacity to understand the potential of danger nor by their ability to respond to it [54]. Beginning at six months of age, children start reaching for objects and crawling, and are fully mobile by 18 months. This escalation in motor skills and activity increases the chance that children will encounter hot liquids and solids, electrical cords, candles,

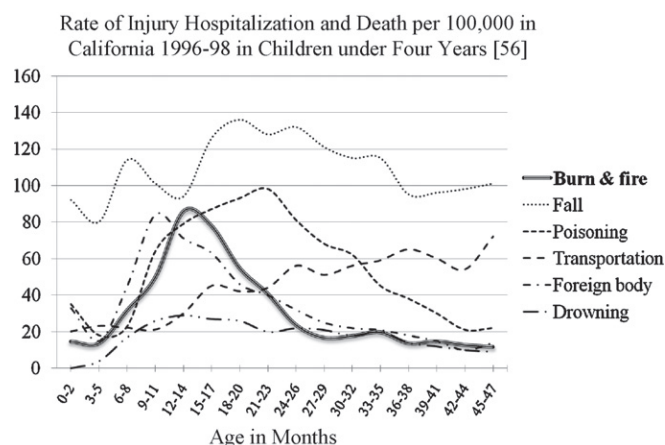


Fig. 2 – Rates of injury hospitalization and death per 100,000 for children under four years of age in California between 1996 and 1998 [59]. Rates are illustrated by three-month intervals for the major categories of injury. The rate of burn and fire injuries peak between 12 and 18 months age, similar to the pattern seen with foreign bodies in the airway and gastrointestinal tract. Rates of poisoning begin to rise at the same period of childhood as burns, but do not decrease until after 27 months of age, nearly three-quarters of a year later than the onset of the decrease in burns.

fireplaces, microwaves, treadmills, hair curlers and curling irons, ovens and stoves, chemicals, and other harmful agents. For instance, the majority of scald burns in US children between the ages of six and 36 months are from hot foods and liquids spilled in the kitchen or dining room [55].

Hot liquid and vapor were cited as the leading specific causes for injuries in children 12–17 months, according to a review of injuries in Californian children under the age of four years (Fig. 2) [56]. This age coincides with developmental achievements such as independent mobility, exploratory behavior, and hand-to-mouth activity. Although the child is able to gain access to hazards, he or she has not yet developed cognitive hazard awareness and avoidance skills [56]. Just as poisoning is linked to the grasping and drinking behavior of children one to three years of age, scald burns are more common in children between one and five years of age than in any other age group [27].

Once risks are encountered, children may lack the ability to escape danger. And because their cognitive development is not as advanced as their motor development, they are not aware of the potentially damaging consequences of their behavior. For example, fires resulting from children's play are the leading cause of residential fire deaths in children under 10 years [55]. Therefore developmental stage becomes a risk factor for burns [47].

3.5. Environment: home and other circumstances

Although the home is full of hazards, the young child views his or her dwelling as the centerpiece of their physical existence, in which they must eat, sleep, play, and resolve conflicts. Most home environments were not configured by architects to minimize the risk of injury to children. The space set aside for preparing and consuming food is such an example. Most women (mothers, grandmothers, aunts, nieces and older female children) find themselves involved in multiple tasks

while preparing meals, including caring for the younger children. It is not surprising that low-income families are functioning in overcrowded conditions with only basic utilities and utensils, and are continually stressed by hunger, fatigue, frustration and fear. The prevention of scald or flame burns may be the last item on the agenda of the teenage sister charged with making dinner and caring for her younger siblings while her parents are away at work. In this regard, there is little difference between impoverished families in LMIC and HIC, thus explaining why scald burns in young children are universally common.

However, the presence of adults does not eliminate risk to children. In Greece, children are often passengers on the rear of the motorcycles driven by adults. The annual overall incidence of burns sustained from contact with hot exhaust pipes while riding motorcycles is 17 per 100,000 [57]. Similarly, review of childhood injuries treated at a large urban hospital in the US from 1972 through 1993 showed that adults were present 54% of the time in which children were injured by fireworks; for whatever reason, the presence of adults did not protect the children from harm [58]. Nonetheless, parents are aware of their responsibility to protect children from the risk of burns, and consider lack of supervision around the home to be negligence, as noted in a survey of parents, students and teachers in rural Bangladesh [59].

3.6. Age-related factors: the elderly

The elderly are at higher risk of injury than the younger age groups because they are more prone to injury. Their susceptibility arises from age-related deterioration of judgment and coordination, alterations in cognition and balance secondary to medication use, and the pathophysiologic consequences of the physical insults of injury. Deaths from fires were the fourth leading cause of unintentional injury death (behind falls, motor vehicle incidents, and suffocation)

among people aged 65 years or older in 2006 [7]. The elderly are at higher risk of dying in a residential fire than any other age group except for the very young [60]. Mortality data from 1984 collected by the US National Center for Health Statistics showed that 29% of the residential fire deaths were victims older than 65 years, although older people only represented 12% of the US population at that time [43].

Even small, shallow burns are poorly tolerated by seniors. Elderly burn patients treated for scald burns had relatively small burns (mean 7% TBSA) but high mortality (22%) [61]. In addition, two-thirds of those who had been living independently before the burn were forced into skilled nursing facilities following hospitalization for burn care.

Behavior patterns exacerbate the risk to the elderly. Older individuals who smoke are more likely to die in residential fires than younger people who smoke [62]. Smoke detectors were absent in 75% of the fatal fires involving the urban African-American elderly in Alabama from 1992 to 1997, and were completely absent in all of the fires leading to the death of rural African-American seniors [44]. The cause of fire ignition was most often heating devices, which are used more commonly by the elderly and often with inadequate attention to the safe functioning of the device. Interestingly, alcohol was a factor in only 29% of deaths of the elderly, compared with 74% of the middle-aged [44].

Not only are the elderly more likely to die in residential fires, they are also more likely to succumb to complications following thermal injury. In US burn centers during the decade 1999–2008, in-hospital mortality was 9% for the seventh decade of life, 16% for the eighth, and 25% for those over 80 years [27]. These rates are even more striking when compared to the mortality rates for adults from 20 to 50 years (3%) and especially to those for children under 16 years (<1%) (Table 3).

In addition to their increased susceptibility to infectious and metabolic complications, the elderly are at higher risk for death after sustaining burns because the burns for which they are admitted are larger in dimension. For example, although two-thirds of children under age two are hospitalized for treatment of burns over less than 10% of their body surface area, nearly 60% of the elderly over 60 years of age are hospitalized for burns greater than 10% BSA (Table 3) [27]. One study in Pennsylvania noted that patients 75 years and older had significantly more severe fire and burns than younger patients (using the MedisGroups™ morbidity score assigned during hospital stay) [14].

Indeed, age (along with burn size and presence of smoke inhalation injury) is one of the three most powerful predictors of outcome following thermal injury. Whereas the percentage of body surface area burned at which 50% of cases will be fatal (LA_{50}) is over 90% in children under two years of age, the LA_{50} for patients in their 70s is under 40% TBSA, and for those 80 years and older the LA_{50} is under only 20% TBSA [27].

3.7. Gender-related factors

For many injuries, gender-related rate differences begin to appear within the first year of life. Sex differences in behavior appear about the same time as differences in injury rate and correlate with injury type. Boys are 70% more likely to die by

injury than girls in OECD³ countries [63]. For children under 15 years of age, there are 24% more injury deaths among boys than among girls [2].

Gender related burn mortality patterns follow a slightly different pattern. In the US in 2006 the mortality rates for burn deaths for children less than 20 years of age was nearly identical (0.7 per 100,000 for boys and 0.65 per 100,000 for girls). However, in the youngest age group (infancy through four years) the fire death rate for boys was 1.24 that of girls [7].

There are several theories about why boys are more likely to be injured than girls. Boys are socialized differently: parents are more likely to allow boys to roam further with fewer limits and to play alone [64–66]. Boys are also engaged in more risk taking and higher activity levels and behave more impulsively than girls [67,68]. However, in a study done in 1978 of injuries in children reported to the US Consumer Product Safety Commission, the gender differences were not explained by exposure to risk [69].

The gender difference is observed in adults as well. The emergency department visit rate for burns from 1993 to 2004 in the US was 50% greater among men than women (270 vs. 180 per 100,000, respectively) [8]. In Pennsylvania in 1994, the overall hospital discharge rate for treatment of burns in men was over twice that in women (37 vs. 16.5 per 100,000, respectively) [14]. The age-adjusted rate of non-fatal burns in the US in 2008 was 143 per 100,000 in men, higher than the rate of 128 per 100,000 seen in women [7]. However, in the US from 2001 to 2006, non-fatal scald burns were more common among elderly women than elderly men (age 65 years or older) [70].

Nonetheless, fire death rates in the US are higher in elderly males than in elderly females [49]. However, the difference is most prominent in the 20–44 age group, in which the ratio of fire mortality in men is nearly twice that in women [7].

Additionally, males shoulder a higher proportion of the disability associated with injury. In Australia, men account for 78% of the DALYs lost from injuries to adults 15–44 years of age [71].

Occupational activities put people at risk for work-related injuries. During the time period 1993–2004, 23% of US emergency department visits for burn were work-related [8]. From 1999 to 2008, 11% of admissions to US burn centers were for occupational injuries [27]. US workers in the mining, transportation and public utilities industries had the highest rate of death from thermal injury in 1992–1999. Occupations with the highest risk of death by fire include truck drivers, firefighters, miners, airline pilots, and operators of ovens, furnaces and kilns [72]. Because the majority of these high-risk occupations are held by men, adult males will have higher rates of burns in countries that offer them these roles. For example, during 1993–2004 men were seen nearly twice as

³ The Organisation for Economic Cooperation and Development (OECD) is comprised of 29 countries which produce two-thirds of the world's goods and services. The OECD member countries, as of December 2000, are: Australia, Austria, Belgium, Canada, the Czech Republic, Denmark, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Japan, the Republic of Korea, Luxembourg, Mexico, the Netherlands, New Zealand, Norway, Poland, Portugal, Spain, Sweden, Switzerland, Turkey, the United Kingdom of Great Britain and Northern Ireland, and the United States of America [63].

often as women for work-related burns in US emergency departments [8].

Gender differences in burn incidence may vary by age, region and national income category. For instance, a 7-year retrospective review of 271 inpatient records in one rural Ethiopian hospital found that burns occur more often to boys than girls, but it is women who are more frequently burned than men [73].

Gender differences in HIC and LIC fire deaths are polar opposites. In HIC, rates of death by fire are twice as high in males as in females in the 15–59 year age group. However, in this same age group in LIC, female deaths from burns occur at a rate 2.3 times than in males. The discrepancy is greatest in World Health Organization Southeast Asia and Eastern Mediterranean Regions [2].

However, the gender distribution of non-fatal burns differs between countries. Although some countries such as Egypt and India have a greater proportion of burns among girls, a higher number of cases in boys have been reported in community surveys and hospital data from Angola, Bangladesh, China, Côte d'Ivoire, Kenya and Nigeria [11,50,74–80].

The gender discrepancy in LMIC fire death rates is present but less pronounced in young children. However, between the ages of 15 and 19 females begin to suffer a disproportionate share of fire deaths. Women between the ages of 15 and 59 in LIC have an astonishingly high fire death rate of 15.6 per 100,000 [2]. Nine percent of all deaths among Egyptian women of reproductive age were caused by burns [81]. In India, approximately 65% of burn deaths occur to women, most often caused by kitchen accidents, self-immolation and domestic violence [82].

The increasing proportion of burns among girls as they enter adolescence can be explained in some cases by the changing activities as they approach the responsibilities of adulthood. In the Ardabil province of Iran in 2006, teenage girls were three times as likely to be burned in the kitchen as teenage boys, as shown by prospective longitudinal data. In Ardabil, 21–37% of children are involved in kitchen jobs such as lighting the oven, preparing tea and carrying hot food; the mean age for beginning to help in the kitchen is approximately 8 years [83].

3.8. Regional factors

The burden of burns is also unevenly distributed throughout regions of the world. For instance, the incidence of burns severe enough to require medical care is nearly 20 times higher in the Western Pacific (including China) than in the Americas [2].⁴

Burn fatalities are more likely to occur in certain regions of the world, even when gender and national income status are considered. In these regions, infants and children are at

particular risk. Infants in Africa have an incidence of fire-related burns that is three times the world average for this age group [84]. Specifically, the 2004 fire mortality rate in infant girls in Africa was 35 per 100,000, considerably higher than that in LMIC in Europe (3.5/100,000), the Americas (2.2/100,000), or the Western Pacific (0.4/100,000) [48]. Similarly, fire death rates in boys 1–4 years old in the Eastern Mediterranean LMIC were nearly twice that reflecting boys 1–4 years old in European LMIC. Moreover, fire mortality in Southeast Asia was nearly six times that in the Western Pacific LMIC for boys under the age of four years [48].

Cold climates may be associated with a higher incidence of burn. Fatal residential fires in rural North Carolina that were not associated with smoking materials were caused primarily by heating appliances [85]. Lack of electricity mandates the use of hazardous flammable fuels, including open wood fires and kerosene heaters. Nepalese children spend a great deal of time huddled together around open fires to keep warm, and thus flame burns are common [3]. In a number of cold-climate regions, older children are often responsible for lighting and tending fires, stoves and lamps, thus increasing their vulnerability to burns [86,87].

On the other hand, the colder Northeastern region of the US had a lower fire and burn mortality rate in 2006 (0.97 per 100,000) than the more temperate South (1.49 per 100,000) [7]. In fact, the fire and burn mortality rates in some of the coldest states in the US were lower than the average national fire and burn mortality rate (1.23 per 100,000). For instance, the fire and burn mortality rate in New Hampshire and Vermont was 0.5 per 100,000, and in Minnesota it was 0.7 per 100,000. Nonetheless, Alaska had the highest fire and burn mortality rate in the US, 2.72 per 100,000. Although temperate climates are not protective, warmer climates in the US seem to have lower fire and burn death rates, as noted in Arizona with 0.87 and Florida with 0.84 per 100,000 [7]. Even though it is tempting to associate fire and death mortality rates with alcohol use, data from the Substance Abuse and Mental Health Services Administration (SAMHSA) do not suggest any correlation between the two variables at a state level [88]. More discerning inspection of data from districts, cities and neighborhoods will be necessary to establish the association between burns and environmental or behavioral variables.

3.9. Intent of injury

The vast majority of burns occurring in the world are unintentional. In US burn centers from 1999 to 2008, 2% of admissions were for assault-by-burning (including child abuse), and less than 1% for self-harm or attempted suicide [27]. Similarly, in 1994 in Pennsylvania, 2% of burn admissions were for self-inflicted injuries and another 2% for assault-by-burning; 95% were unintentional [14]. Only 2.4% of admissions to burn centers in Taiwan, Republic of China, from 1997 to 2003 were for self-inflicted injuries [89].

Notably, India has the highest number in the world of cases of intentional self-harm by burning, where the majority of victims are young women. In contrast, victims of intentional self-harm in Europe are more often men in their 40s or 50s [90,91].

⁴ WHO Member States are grouped into six regions. Each region is further subdivided into low-income (LIC), middle-income (MIC), and high-income (HIC) countries. Both Africa and South-East Asia have no high-income countries. Listings of the countries in each region can be found at <http://www.who.int/about/regions/en/index.html>.

3.10. Comorbidity

Comorbidity is a risk factor for burn. Comorbidities that carry a higher risk for injury include epilepsy, peripheral neuropathy, and other physical and cognitive disabilities.

In LMIC, epilepsy can be considered a comorbid risk factor. Epilepsy is often untreated in these countries and thus is a frequent initiating factor in many severe burns [92]. During a seizure the epileptic may fall into an open fire or onto a stove. The severity of injury is sometimes and unfortunately exacerbated by traditional beliefs that epilepsy is contagious; victims in Ethiopia are often left to burn because potential rescuers fear they will contract the disease by touching the victim [93]. Burns precipitated by epileptic seizures occurred in 44% of adult burns in a community survey in rural Ethiopia, and 29% of hospital admissions in adult burn patients were precipitated by epileptic seizures [73]. Epilepsy was the most common personal risk factor, other than age, in remote subsistence village of the highlands of Papua, New Guinea during 1971–1986, where the mortality rates from fire and flames were nearly 15 per 100,000, many times higher than reported rates from other countries [94]. In rural Bangladesh, 0.7% of all deaths in women (15–44 years of age) were caused by falls into fires during seizure activity; this is an annual rate of approximately 2 per 100,000 [95].

Many Muslims with epilepsy are devoted to strict fasting during the holy month of Ramadan and hence miss their anti-epileptic medications. Therefore, burns in epileptics are commonly seen during Ramadan in Islamic populations. These burns are typically sustained during seizures while in the kitchen or falling on the hot ground (which can reach temperatures over 115 °F/46 °C). In a prospective study of burns in epileptics in Saudi Arabia, 40% of injured patients sustained the burn while fasting because they did not take their anti-epileptic medications [96,97].

Peripheral neuropathy is a disorder commonly caused by leprosy and diabetes mellitus, and results in sensory loss of the extremities. People with sensory peripheral neuropathy are vulnerable to burns, especially hot water scalds [98]. Handling hot cooking utensils or warming neuropathic feet too close to a fire can also cause deep burns.

Coexisting medical conditions is one of the reasons that the elderly are at higher risk of sustaining burn-related injuries. In one retrospective medical review of a single center's burn unit in Illinois, 77% of burn center patients aged 59 years or older had one or more preexisting medical condition at the time of injury, and in 57% of these individuals, the patient's judgment or mobility or both were impaired [99]. In another retrospective study from the UK, 50% of octogenarians admitted for burn treatment sustained injury because of a cerebrovascular accident [100].

Physical or cognitive disabilities are distinct risk factors for burns, especially for scald burns or for death from residential fires. Of the 37 injury-disabled patients admitted to a Toronto burn center between 1984 and 1992, the majority (84%) were admitted for scald burns sustained in the home [101]. Although some were elderly as well (median age was 58 years), the extent of disability was significant in all cases, including spinal cord disorders or injuries, epilepsy or other neurologic disorders. Given the relatively small size of burns

(mean was 10% TBSA), the mortality rate was 22%, which is high compared to 4% in the general burn population. The average length of stay for disabled burn patients was 2.8 days per percent body surface area burned, in comparison with the general population of burn patients in whom LOS is approximately one day per percent BSA burned [27,101]. Although the relative risk of burns in the elderly with dementia has not yet been established, the consensus opinion among burn centers is that dementia is a significant risk factor for burns. Indeed, elderly patients with dementia tend to have poorer outcomes from burns, and rehabilitation is very limited [102].

4. Conclusions and recommendations

Given the extent of burns worldwide, prevention is a first priority. Better research, including special surveys and registries will support preventive efforts, as will better models of effective preventive systems.

The approach to injury prevention includes four stages: surveillance, analysis, intervention and evaluation. Precise description of the problem(s) is the basis to planning effective interventions, yet in many LMIC, data on burns are scarce, inaccurate, or both. In some countries, a lack of reliable data on risk factors further hampers the development and enactment of effective burn prevention strategies, while in others, incomplete description of burn incidents leads to underassessment of the magnitude of the public health problem. There is a need for better surveillance with formal epidemiologic studies, which will more accurately assess the true incidence in vulnerable populations. A model for such a system can be found in Taiwan, Republic of China, where the support of the Childhood Burn Foundation provides resources to all 43 hospitals in the country to collect data on hospitalized burn patients. This comprehensive database, which utilizes the Internet for data entry, captured information on over 12,000 patients from 1997 to 2003 [89].

However, hospital-based surveillance systems will only capture a small portion of information about burns because the vast majority of burn patients are cared for outside specialty referral centers. For this reason, community surveys from districts, cities and neighborhoods are indispensable tools for assessing the true burden that burn places on a population. Excellent community surveys, clearly outlining not only the true incidence of burns within the community but also the extent of disability and death that accompany burns, have been done in Bangladesh, Ethiopia and Iran [9,10,103].

Community surveys are needed in the US to establish the degree to which Hispanics utilize the health care system for treatment of burns. The very low incidence of non-fatal burns in Hispanics treated at US hospital emergency departments suggests that many burns are being treated by families with home remedies. Only with an accurate appreciation of the burden of burns within a region can effective lobbying efforts move forward in funding agencies and government health departments.

Worldwide support for funding would provide backing for web-based data repositories and for community surveys.

Effective prevention of burns hinges on the collection, analysis and interpretation of reliable and comprehensive data.

Thus, the recommendations for the worldwide burn community are several:

- Identification of stakeholders, formation of a dynamic network for productive collaborations, and detection of funding sources.
- Creation of an international burn repository for epidemiologic and clinical data received from contributing centers throughout LIC, MIC, and HIC.
- Accomplishment of community surveys in both urban and rural areas, merging with hospital-based analyses and regional or national databases.

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