

WHO Indoor Air Quality Guidelines: Household Fuel Combustion

Review 10: Burns and Poisoning

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Disclaimers

World Health Organization:

The work presented in this technical paper for the WHO indoor air quality guidelines: household fuel combustion has been carried out by the listed authors, in accordance with the procedures for evidence review meeting the requirements of the Guidelines Review Committee of the World Health Organization.

Full details of these procedures are described in the Guidelines, available at: <http://www.who.int/indoorair/guidelines/hhfc>; these include declarations by the authors that they have no actual or potential competing financial interests. The review was conducted in order to inform the development of recommendations by the Guidelines Development Group. Some of

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Personal Burn Story

Sunita is a 28 year old woman who was burned on 20 January, 2012, while igniting a pressure stove to start cooking. She filled the reservoir to the brim with kerosene while it was still burning. The flame was not strong, so she pumped air vigorously into the reservoir. The flame still did not improve, so she stuck a pin in the center of the nozzle in the midst of the flame. Kerosene sprayed out and ignited. The stove was on the floor, so she stood up quickly to get away, but was engulfed by the ball of fire. The flames were two feet higher than her head, and her clothing ignited. Her husband poured water over her immediately and removed her sari. She arrived in the burn center hospital 15 minutes later. The burn covered 22% of her body surface. Of those, 15% were full-thickness in depth and required surgical excision and grafting. She was discharged in 18 days to a step-down unit on the hospital grounds. Once her wounds were healed, she began wearing pressure garments to minimize the scarring. Now one year later she no longer needs the pressure garments, and range of motion has returned to normal. She lives happily with her husband and is back to work.

Sunita was fortunate. Not only was there another adult nearby, but her husband had the sense of mind to pour water on her and remove the burning clothing. In addition, she had the good luck to live in a city with a hospital with a burn center. Because of prompt and appropriate first aid and acute care, she had an uneventful recovery. Not everyone who suffers from a stove explosion is so lucky, however.

Summary

Background

The use of household fuels for cooking, heating and lighting is associated with a myriad of environmental and health problems, including significant injuries and illnesses caused by burns and unintentional poisoning. Although less common than acute and chronic respiratory illnesses associated with smoke production, burns and flammable fuel poisoning cause a substantial number of deaths each year. For those that survive burn injuries, chronic disability and handicap frequently follow recovery. Low and middle-income countries (LMICs) are disproportionately affected by burn injuries.

Objectives and key questions

The aim of this review was to synthesize and present the current evidence base for burns associated with the combustion of household fuels used for cooking, heating, and lighting in low and middle-income countries. A second objective was to summarize the evidence concerning poisoning related to the unintentional ingestion of liquid household fuel. The main questions addressed by this evidence review were:

1. What is the epidemiology (incidence, morbidity, mortality, sequelae) of burns and poisoning in low- and middle-income countries attributable to household fuel combustion and use?
2. What are the important risk factors, including the role of household fuel use, for burns and poisoning in LMIC homes?
3. What are the impacts of technology and behavioural interventions on the risks of burns and poisoning in LMIC homes?

Methods

A systematic literature review was carried out to identify epidemiologic and intervention studies related to the epidemiology of burns and poisoning in LMICs. The epidemiologic studies were described in terms of burden and risk factors. Prevention efforts were also summarized. The quality of intervention studies were assessed using standardized methodological quality appraisal forms (LQATs).

Findings

The published literature is sparse when examining the burden, risk factors, and prevention efforts associated with these issues. Available data indicates that an estimated 195,000 deaths occur worldwide from fire-related burn injuries and result in approximately 10 million disability-adjusted life years lost annually; although it is generally accepted by both the international burn community and WHO that this figure is likely to be a gross underestimation. More than 90% of these deaths occur in LMICs. In 2004, an estimated 11 million people had acute burns severe enough to require medical attention. In LMICs, a substantial proportion of burns are sustained in the kitchen or cooking area and associated with the use of cookstoves and lamps. Women and children are typically at increased risk for these types of injuries. Most literature about cookstove-related burn injuries in LMICs is based on retrospective hospital studies and focuses on liquid fuels such as kerosene. Interventions that have been proposed to reduce exposure to fires and flames seem intuitively correct but have largely not yet been formally tested for effectiveness in reducing burn injuries. Specifically, there is low quantity and quality of evidence for associated prevention (intervention) efforts. For example, except for one unpublished randomized controlled trial (1) and one quasi-experimental study from Madagascar (2) there are no experimental studies focused on burn injuries. Kerosene poisoning remains an important public health problem, especially among children in developing countries where kerosene is used regularly for cooking, heating, and lighting. Most of the literature in this area includes descriptive studies that report local burden.

Conclusions:

While there is substantial evidence that household fuel use (and especially kerosene) is an important cause of burns and poisoning in LMICs, the role of solid fuels and other fuels (including liquid propane gas) in causing these injuries is poorly described, primarily due to a lack of population-based studies. Cookstoves may represent the single most important modifiable risk factor for burn injuries. Research on cookstove burn safety should focus on improving cookstove designs and implementation, and increasing quality data collection and reporting. In the meantime, there are four main practices that can increase the public health benefits in a growing movement to develop and disseminate cookstoves in LMICs: targeting high risk populations, increasing health education and promotion efforts (e.g., in tandem with the rollout of cookstove programs), informing policy efforts, and collaborating with international partners. To address the issue of household fuel-related poisonings, there is a need for better population-based and country-level estimates of incidence, as well as for research studies that further develop prevention strategies.

1. Introduction and Scope

1.1 A Neglected Aspect of the Home Environment

- **“Healthy housing” should include safety provisions that reduce or eliminate burns and prevent poisoning from household fuels.**

- **Improvements in stove design should ensure that improved stoves are safe as well as clean.**

The guiding principles for “healthy housing” suggest that homes should be dry, ventilated, contaminant-free, pest-free, clean and maintained (3). The achievement of a healthy home can be especially challenging in LMICs due to living conditions and limited access to healthy housing options. Homes are an important intersection for lifestyle and health issues because these environments pose risk for many types of health outcomes. There have been substantial scientific discussions about household fuel combustion and associated health impacts (4, 5). Largely absent from this discourse, however, is the necessary attention to burn and poisoning risks associated with these fuels. More than 3 billion people rely on solid fuels (biomass such as wood, animal dung, and coal) to cook at home in open fires or with crude stoves (6). The desire to transition households to the use of “cleaner” fuels higher on the energy ladder presents challenges to maintaining safety. In particular, the use of liquid fuels such as kerosene also has high risks for burn injuries and in addition may result in unintentional poisonings, particularly among children. Thus, although the transition from use of biomass in open fires to the use of kerosene in Primus stoves (a type of pressure-burner stove that uses kerosene) has led to meaningful reduction in air pollution, this has been accompanied by an unacceptable increase in the number and severity of burn injuries in the home from stoves and lamps.

This review presents evidence on the burden (that is, incidence, morbidity and mortality), risks, and prevention efforts related to burns, including scalds, with a focus on those arising from the combustion of fuels in the home for the defined purposes of cooking, heating, and lighting. We also summarize the literature on unintentional poisonings to children from ingestion of liquid fuels, in particular kerosene. Research gaps and needs are identified.

The combustion of household fuels used for cooking, heating, and lighting often results in burns, including scalds. Many of these fuels are also poisonous. For these reasons, the World Health Organization (WHO) is devoting a review to these topics. In addition, the Global Alliance for Clean Cookstoves, led by the United Nations Foundation, is targeting the universal adoption of clean cookstoves and fuels that would specifically benefit the health and well-being of many people in LMICs (7). From a public health perspective it is necessary to ensure that these cookstoves are not only “clean,” but also safe in terms of reducing the risk for burn injuries. Similarly, in May 2011 the National Institutes for Health (NIH) held a two-day conference to present the state of the science on the health impacts of global indoor air pollution, specifically related to the use of open fires or cookstoves utilizing solid fuels. The conference consisted of small work groups tasked with reporting on a variety of health outcomes (for example lung cancer, pneumonia, low birth weight, cardiovascular disease) related to indoor air pollution including a work group on burn injuries because of safety concerns surrounding cookstoves. This meeting helped raised visibility of the idea of making cookstoves safe as well as clean. The deliberations of the meeting will help inform policies set by the Global Alliance for Clean Cookstoves as it makes its push toward the universal adoption of clean cookstoves and fuels, particularly among LMICs¹.

¹ The World Bank Based classifies all the country economies according to their gross national income (GNI) per capita (<http://data.worldbank.org/about/country-classifications>). These classifications are low income, middle income (subdivided into lower middle and upper middle), or high income. LMIC encompasses the first two classifications.

1.2 Definitions for Burns and Poisonings

- **Most household burns are caused by flames or exposure to hot liquids and solids.**

A burn is an injury to the skin or other organic tissue primarily caused by thermal or other acute trauma, according to the International Society of Burn Injuries. It 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. In the combustion of fuels at home (for example cooking), most burn injuries are caused by a hot liquid (scalds), a hot solid (contact burns), or a flame (flame burns) (6). For the purpose of this review, the term “burn” will encompass scalds, contact burns and flame burns unless otherwise noted.

In addition to burn injuries, household fuels can also pose another unintentional injury risk, that of poisoning. Poisoning injuries result from exposure to an exogenous substance that causes cellular injury or death. A poison is any substance that is harmful to the body if too much is eaten, inhaled, injected, or absorbed through the skin. Any substance can be poisonous if too much is taken, but very little kerosene needs to be ingested to cause severe health problems. In this review, we will first focus on unintentional burn injuries arising from the combustion of fuels in the home for the defined purposes of cooking, heating, or lighting. Second, we will address unintentional household poisonings experienced by children ingesting liquid fuels, with a particular focus on kerosene. Kerosene is synonymous with paraffin and will be used throughout the document except in particular studies that use the term paraffin.

2. Evidence Review Methods

2.1 Objectives and key questions for the review

The objectives of this review were twofold. First, to synthesize and present the current evidence base for burns associated with the combustion of household fuels used for cooking, heating, and lighting in low and middle-income countries. A second objective was to summarize the evidence concerning poisoning related to the unintentional ingestion of liquid household fuel. The main questions addressed by this evidence review were:

1. What is the epidemiology (incidence, morbidity, mortality, sequelae) of burns and poisoning in low- and middle-income countries attributable to household fuel combustion and use?
2. What are the important risk factors, including the role of household fuel use, for burns and poisoning in LMIC homes?
3. What are the impacts of technology and behavioural interventions on the risks of burns and poisoning in LMIC homes?

In summarizing the impact of household fuel use interventions on burns and poisoning the following PICO was adopted:

Criteria (PICO)	Description
Population	Households from LMICs using traditional solid fuels and kerosene in traditional cooking stoves/ open fire.
Intervention(s)	Burns: Improved solid fuel stoves (charcoal and biomass)

	Clean fuel (ethanol) Health awareness raising/ education Home safety visit Poisoning: Awareness raising/ education materials Child resistant containers (kerosene) Home safety visits
Comparison	Continued use of traditional solid fuel stoves and kerosene (including storage and handling of fuel)
Outcome	Burns: Safety practice and knowledge Risk factor recognition Reported child and adult burns (frequency and severity) Poisoning: Inpatient cases of poisoning Safety knowledge Risk factor knowledge (poisoning score)

2.2 Systematic Review Methods

A systematic review was conducted to identify peer-reviewed literature relating to the two outcomes: (i) burns and (ii) unintentional poisoning from ingestion of fuel.

For burns, relevant articles included injury from the handling of hot fuel and liquids as well as through contact with hot stoves or cooking utensils. Only studies from low and middle income countries (LMICs) were selected.

The main electronic bibliographic databases were searched (Table 1) using the search terms shown in Table 2.

Table 1. Electronic Databases Searched for the Systematic Reviews^a

MEDLINE^b
 EMBASE^c
 Cochrane Controlled Trials Register^d
 Cumulative Index to Nursing and Allied Health Literature^e
 Latin American and Caribbean Health Sciences Information System^f

^a All databases were searched from 1966 to 2011.

^b National Library of Medicine, Bethesda, Maryland.

^c Elsevier B. V., Amsterdam, the Netherlands.

^d The Cochrane Collaboration Secretariat, Oxford, United Kingdom.

^e EBSCO Publishing, Glendale, California.

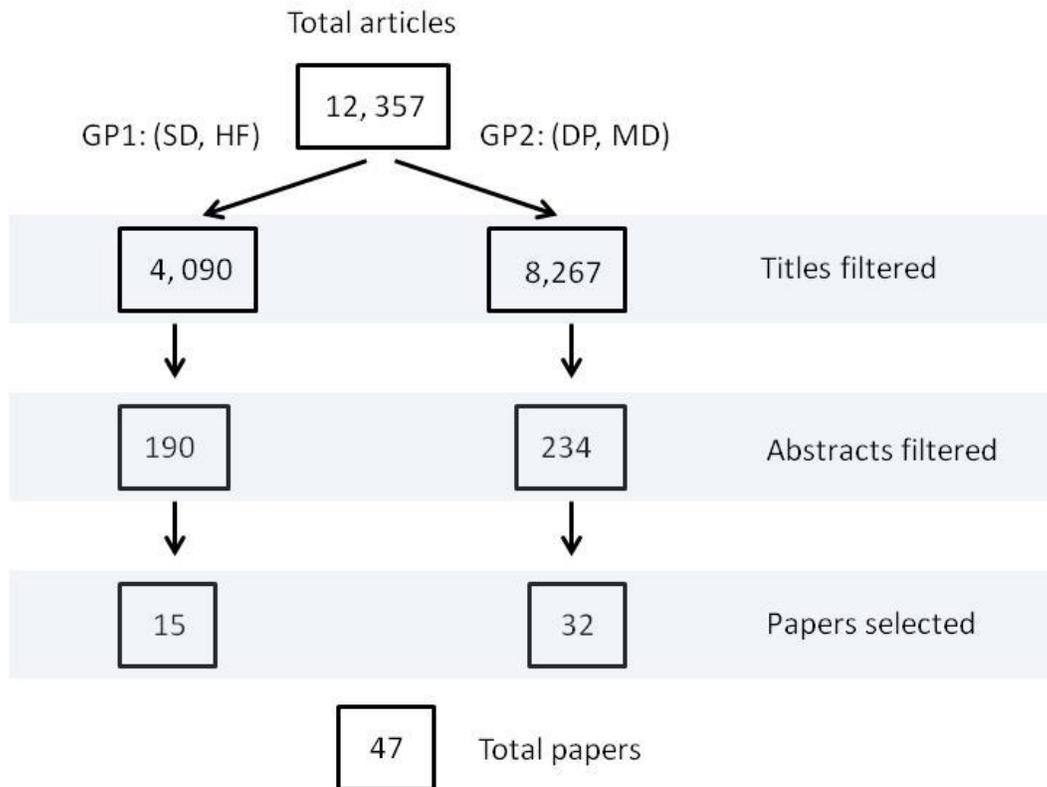
^f BIREME, Sao Paulo, Brazil.

Table 2. Search terms used to identify relevant peer-reviewed literature for the reviews

Exposure	Outcome
1. "domestic fuel"	31. "burn"
2. "traditional fuel"	32. "burns"
3. "solid fuel"	33. "scald"
4. "coal"	34. "scalds"
5. "charcoal"	35. "thermal injury"
6. "wood"	36. "thermal injuries"
7. "dung"	37. "thermic injuries"
8. "biomass"	38. "thermic injury"
9. "kerosene"	39. "fire injuries"
10. "oil"	40. "fire injury"
11. "paraffin"	41. "poisoning"
12. "ethanol"	42. "ingest*"
13. "stove"	43. "31 OR 32 OR 33 OR 34 OR 35 OR 36 OR 37 OR 38 OR 39 OR 40 OR 41 OR 42"
14. "chula*"	
15. "chulla*"	
16. "fire"	
17. "heating"	
18. "cooking"	
19. "lighting"	
20. "lamp"	FINAL SEARCH: Combined terms "30 AND 43"
21. "house*"	
22. "home"	
23. "risk*"	
24. "incidence"	
25. "prevalence"	
26. "epidemiology"	
27. "prevent*"	
28. "treat*"	
29. "care"	
30. "1 OR 2 OR 3 OR 4 OR 5 OR 6 OR 7 OR 8 OR 9 OR 10 OR 11 OR 12 OR 13 OR 14 OR 15 OR 16 OR 17 OR 18 OR 19 OR 20 OR 21 OR 22 OR 23 OR 24 OR 25 OR 26 OR 27 OR 28 OR 29"	

The process of selecting studies for data extraction is shown in Figure 1. Two researchers (DP, MD) independently conducted the initial electronic searches creating an Endnote file of identified articles after deleting duplicates. The articles were then randomly assigned into two groups and allocated to four researchers (DP, MD) and (SD, HF) who filtered relevant articles based on titles and then abstracts. Disagreements were reconciled through discussion.

In addition to the database searches, reference was also made to the extensive collections of papers and reports held by the authors, contacting other experts, and reviewing the reference lists of publications. These approaches were carried out after the systematic review of databases for published references and therefore some relevant studies are included in the review that postdate the database search period (up to December 2011).

Figure 1: Flowchart of the process of selecting studies for data extraction

Methodological quality was assessed for studies looking at interventions to reduce (i) burns and/or (ii) poisoning through ingestion of fuel. Design specific quality assessment tools (Liverpool Quality Assessment Tools) (LQATs) (8) were used awarding a star rating for each study (this approach has effectively been employed in other systematic reviews by the authors (9, 10). Quality criteria focused on any major bias/error and adequacy of adjustment for confounding (if randomisation was found to be imbalanced). Quality was assessed independently by two researchers (DP, NB).

2.3 Assessment of the Strength and Quality of Evidence

The assessment of quality of evidence review is presented in the relevant sections; that is, burns in Section 3, and poisoning in Section 4.

The evidence available for burns does not lend itself to straightforward application of GEPHI assessment. However, because of the importance of this issue for practice and policy recommendations, a provisional assessment was made and the quality of intervention studies were assessed using standardized methodological quality appraisal forms (LQATs). It is recognized that, because of the limitations of the available evidence in terms of randomized and other intervention studies, other sources of evidence and practice need to be drawn on to determine the nature and strength of recommendations.

For poisoning, the evidence is also limited although more studies relating to the impacts of interventions are available. As with burns however, it is important to draw on evidence and practice from developed countries in formulating recommendations.

3. Burns

3.1 Global Burden of Burn Injuries

Burns continue to be an important global public health problem (11-14) and are the fourth most common type of injury worldwide, following traffic accidents, falls, and interpersonal violence. The occurrence of burns worldwide has increased over the last decade by more than a third. Burn injuries in HICs and LMICs are on two very different trajectories. In general, HICs have quality surveillance and epidemiologic data, clearly defined and successful prevention and protection strategies to address key risk factors (for example smoke alarms), and excellent treatment facilities. Consequently, many HICs have seen progress in reducing household burn injury fatalities during the past 30-40 years (15). This is not evident in LMICs where data is sparse and appropriate and effective prevention strategies have not been widely applied to key risk factors such as risks from cookstoves. Similarly, many of the burn treatment and care advances, which have led to higher survival rates and improved functional recovery of burn victims in most HICs, have yet to make a substantial impact in most LMICs. As a result, the burn injury burden remains extremely high in many LMICs, especially in the Indian Subcontinent and Sub-Saharan Africa (13, 16) as well as among the poorer members of higher income countries. Because the situations are so divergent and because the guidelines are addressing the cookstove issue - which is predominantly an LMIC issue - we have focused this systematic review on LMICs. We occasionally introduce information from HICs to illustrate certain points or to highlight the contrast with LMICs, but we do not provide systematic data on HICs.

3.1.1 Mortality

- **Fire and flames account for nearly 200,000 deaths each year across the globe, although the true figure is likely to be substantially greater, and the vast majority of these occur in LMICs.**

The primary source for worldwide fire-related burn injury estimates is the WHO Global Burden of Disease (GBD) report (16). As part of an ongoing project, this report provides comprehensive, consistent, and regularly updated estimates of mortality and morbidity for more than 135 causes of disease and injury (16). The estimates derived in the report are subject to several limitations related to the data collection and reporting issues, which suggest that the burn injury estimates may grossly underestimate the true scope of the problem (17). These limitations include substantial data gaps and deficiencies, particularly for regions with limited death registration data (18, 19); and the lack of representativeness of available data (18); measurement error, and systematic biases. In addition, the estimates are subject to limitations inherent in the modeling and extrapolation processes used to compensate for incomplete data (17).

The WHO estimates that there are approximately 195,000 deaths worldwide from fire-related burn injuries (18). More than 90% of these deaths occur in LMICs (11, 20, 21), which have rates nearly thirteen times higher than in high-income countries (HICs). Table 1 presents selected mortality rate estimates for 2011, by cause and by World Bank Income Group.

There are many more burn deaths (in addition to fire-related deaths) from scalds, electricity, chemical burns and other forms of burns (21).

The Geneva Association (an international association for the study of insurance economics), through its World Fire Statistics Centre (WFSC), produces an annual bulletin comparing international statistics on fire deaths and fire death rates. These statistics are based on the

WHO GBD. The most recently reported data, ranging from 2000 to 2008, indicate that the fire death rates per million population among 26 industrialized nations ranges from 1.1 (Singapore) to 20.8 (Finland), with an average of 9.8 across all reporting nations (22). According to a United States Fire Administration report, international fire death rates have decreased over the last 30 years (from 1979-2007) in 21 of the 24 industrialized nations with available data (15). However, even these rates are subject to reporting problems (15). While fire death rates appear to be decreasing in most HICs, there is lack of data among LMICs to examine similar trends.

Although the WHO reports burn injury estimates for LMICs, there is little population-based or country-specific information related to morbidity and mortality. Most LMICs do not have a national burn surveillance system and reported burn injury rates and estimates (for example incidence, morbidity and mortality) are inevitably inaccurate (23, 24). As reported by Atiyeh and associates (2009), national vital registration data are only available in approximately 20% of the countries in the African Region (20). This lack of data precludes international comparisons, which is often compounded by that fact that many nations do not share very much, or very specific, data with other countries (15).

Table 1: Mortality Rates (per 100,000 population) by Cause and by World Bank Income Group, 2011*

Causes of Death	Mortality Rates by World Bank Income Group				
	HIC	Upper MIC	Lower MIC	LIC	LIC to HIC Ratio
All causes	842.2	701.8	796.3	944.4	1.1
Communicable diseases, maternal and neonatal conditions, and nutritional	55.6	71.8	269.5	512.5	9.2
Non-communicable conditions	735.6	565.8	444.2	343.5	0.5
All injuries	51.1	64.2	82.6	88.5	1.7
All unintentional injuries	34.5	46.1	60.8	65.3	1.9
Falls	8.7	6.4	12.9	8.0	0.9
Fire, heat and hot substances	0.8	1.7	5.1	10.2	12.8
Drowning	1.7	4.3	6.4	8.8	5.2
Poisoning	2.1	2.5	3.0	3.9	1.9
Road traffic accidents	9.0	21.4	190.0	17.9	2.0

HIC= High Income Countries, Upper MIC=Upper Middle Income Countries, Lower MIC: Lower Middle Income Countries, LIC= Lower Income Countries

Source: The Global Burden of Disease (2010), and World Health Organization (2008) available from: http://www.who.int/healthinfo/global_burden_disease/estimates_regional/en/index.html

* Note: Due to changes in data and some methods, the 2010 estimates are not comparable to previous WHO estimates for 2008 or 2004 for countries without good death registration data.

There are widespread variations in the reporting of fire-related burn injuries, with HICs being more likely to have enough quality data for generating fairly accurate nationwide estimates. The data collection and reporting issues in LMICs creates uncertainties about estimates used to generate worldwide statistics. As a result, it is suspected that the estimate of 195,000 deaths worldwide from fire-related burn injuries is uncertain and could be a very substantial underestimate.

3.1.2 Morbidity

The primary source for worldwide non-fatal fire-related burn injury estimates is also the WHO Global Burden of Disease (GBD) report. Therefore, the morbidity estimates are subject to similar data collection and reporting limitations as mortality estimates. Non-fatal burn-related injuries are a leading cause of morbidity. In 2004, there were estimated to be 11 million people globally who had new burns severe enough to require medical attention (12, 25). More severe burn injuries can lead to a wide spectrum of physical impairments, disabilities and disfigurements (for example contractures of limbs, facial deformities). Many of these burn injuries result in a long recovery time, repeated hospitalizations and surgeries, devastating emotional and mental functioning effects, and financial hardships due to treatment costs, loss of livelihood, etc. (26).

Despite limitations with determining a global estimate, it is clear that non-fatal burn injuries are a substantial public health problem and leading cause of global morbidity.

3.1.3 Total burden: Disability-Adjusted Life Years Lost (DALYs)

- **In LMICs, disabilities from burn injuries result in the loss of an estimated 10,500,000 years of full health throughout the world each year.**
- **Burn survivors suffer from a wide range of physical and psychological impairments that can lead to severe social and economic costs.**

Disability-adjusted life years lost (DALYs) is a summary measure of the burden of disease that combines the sum of years of life lost (YLL) due to premature death in the population and the years lived with a disability (YLDs) for incident cases of the health condition (17). One DALY represents a loss equivalent to one year of full health. The WHO provides global DALY estimates for diseases, injuries, and health conditions, including fire-related burn injuries, in their Global Burden Disease reports (18). The DALY for burn injuries includes individuals with burn wound contractures and other physical impairments, which limit their functional abilities and thus may negatively impact their economic and social productivity. It also does not account for the impacts of disfigurements, which often result in social stigma and societal restrictions (for example isolation or segregation) and are difficult to quantify.

In 2004, fire-related burn injuries resulted in approximately 11.27 million disability-adjusted life years lost annually worldwide, of which approximately 10.5 million were in LMICs (16, 21). This is comparable to the 11 million DALYs each year in Africa due to tuberculosis, in the Americas due to unipolar depression, and in South East Asia due to road traffic accidents. On the other hand, burns DALYs are much less than those from chronic obstructive pulmonary disease (COPD), which contributed to 30 million DALYs worldwide, and lower respiratory infection (the leading cause of disability in LMICs) with 77 million DALYs (9% of total DALYs) (16). The quality and accuracy of DALY estimates differ based on the data used to generate them. There are many weaknesses with the global burn mortality and morbidity estimates, which suggests that burn-related DALYs may be more inaccurate than DALY estimates for other health conditions.

Furthermore, severe burn injuries can lead to substantial morbidity (as detailed in section 3.1.2). Because many of these consequences are not fully captured or incorporated into current disability weights, for example, the derived DALYs are likely an underestimate.

3.2 Costs of Burn Injuries

There are no global estimates for burn-related costs. There are some cost data for HICs. For example, based on the sum of medical expenditures and lost productivity due to morbidity and mortality, the total US lifetime costs of injuries that occurred in 2000 from fire and burns was \$7.5 billion (27). One article indicates that it costs approximately \$1,000 a day per patient to provide satisfactory burn care in the Western world (20). The paucity of burn injury cost data suggests that this is an area of opportunity for research. Cost data can provide more evidence about the burden of burn-related injuries and inform public policy makers about the issue. Unfortunately, it would be extremely difficult to generate national cost estimates associated with burn injuries in LMICs that do not have surveillance systems in place that are capable of capturing burn related outcomes (for example deaths, hospital admissions).

3.3 General Risk Factors for Burn Injuries

Risk and protective factors for home-related burn injuries and death are often inter-related and vary across regions (and even within countries). These factors influence each other at the personal, environmental, and home levels. The main source of burn injury risk factors in the United States is the National Fire Protection Association, which provides annual reports on residential fires including risk factors, injuries, and deaths. Diekman and associates synthesized various NFPA reports on U.S. residential fires and associated injuries and identified the following risk factors: age (< 5 years of age and \geq 65 years of age), gender (male), individuals with disabilities, alcohol or other drug use (for example tobacco), living in rural communities, and poverty (28). A review of the literature concerning risk factors for fires and burns throughout the world identified risk factors specific to LMICs (25). Table 2 lists the main burn injury risk factors reported in the literature for in HICs and LMICs at the personal and environmental levels. These risk factors are described more fully in the sections that follow.

Table 2: Personal and Environmental Factors Associated with Burn Injuries and Deaths in High Income Countries (HICs) and Low- and Middle-Income Countries (LMICs).

Table 2(a) Personal factors

Factors studied	HICs	LMICs	Reference(s)
Main Factors			
Age			
• < 5 years	X	X	(28-45)
• \geq 65 years	X	-	(25, 28, 46-48)
Sex			
Female	-	X	(11, 25, 49-53)
Male	X	-	(25)
Gender Roles (e.g., roles related to cooking)		X	(25, 42, 54-58)

Factors studied	HICs	LMICs	Reference(s)
Comorbidities			
Epilepsy & Seizures	-	X	(25, 59-66)
Physical or cognitive disabilities	X	X	(25, 28, 63)
Additional Factors			
Race & Ethnicity			
African American	X		(67-69)
Native American	X		(67-69)
Aboriginal		X	(70, 71)
Substance Use			
Alcohol Use	X	-	(72-74)
Tobacco Use	X	-	(72-74)
Family Patterns			
Single parents		X	(20)
Large families		X	(20)
Recent pregnancies		X	(20)
Mothers being away from home		X	(20)
Maternal education		X	(12, 75-77)
Knowledge of burn risk		X	(76)
Access to first aid services		X	(76, 78)
Alertness to burns among parents		X	(54)
Clothing of manmade fabrics		X	(54)
Lapse in child supervision		X	(54)
Parental illiteracy		X	(54)
Prior history of sibling burn		X	(54)

Table 2(b) Environmental factors

Factors studied	HICs	LMICs	Reference(s)
Main Factors			
Socioeconomic			(11, 21, 77, 79-81)
Poverty	X	X	(11, 20, 28, 50, 62, 77)
Low family income	X	X	
Overcrowding		X	
Lack of water supply		X	(11, 82)
High population density	-	X	(20, 50)
Regional factors			
Climate	X	X	(12, 25, 83-86)
Living in rural communities	X	X	(12, 21, 25, 28, 83-87)
Additional Factors			
Cultural beliefs and Practices			(49, 59, 60, 65, 82, 88)

3.3.1 Personal Risk Factors for Burns

Age

- **Although scald burns are very common in young children, fire deaths also occur disproportionately more often in this vulnerable age group.**
- **Physical and mental disabilities leave older adults more susceptible to flame burns and fire deaths. In addition, recovery from burns in older adults is often attended by a loss of functional independence.**

Children are a high risk group for burn injuries and deaths because of a combination of limited awareness of fire dangers, impulsiveness, curiosity, and imitation of adult behaviors (20, 28); and, in the case of a home fire, the inability to safely exit a house during a fire without the assistance of an adult. In the United States, children younger than 5 years of age--and infants in particular--are at increased risk for home fire deaths (28, 48). Israel and Korea have shown that greater than 50% of burns occur in children under the age of 15 (29, 30). In LMICs (for example Afghanistan (38), China (39), Egypt (32, 41), Iran (44, 45), Lithuania (31), Mozambique (43), Pakistan (42), Turkey (40)), most burn data are from hospitals and indicate that children are the most vulnerable population. Data from Brazil, Cote d'Ivoire, and India indicate that a substantial proportion of all childhood burns occur among children 0-4 (33-35, 89). In China, 2008 survey data indicated that burns were the 3rd leading cause of non-fatal injuries among children under the age of 5 years old (90). Kai-Yang and associates conducted a systematic review of Chinese journals (2000-2005) and identified 19 studies reporting data on the proportion of pediatric patients (under 15 years of age) with burn injuries: the range was from 23% to 55% (91). A Chinese study examined the incidence and related risk factors of injuries in pre-school children aged 0-6 years in the Shenzhen region during 2011 (92). Burns were the second leading cause of injury (18%) after falls (61%). A 2004 systematic review (36) of African studies revealed that 56% of pediatric burn injuries occurred in the 0-4 year age group, and burns represented up to 18% of total hospital admissions among children 0-4 years. Hyder and associates (37), also examined the frequency and nature of childhood burn injuries using emergency department data from cities in Bangladesh, Colombia, Egypt and Pakistan. The multi-country child injury surveillance system captured 1,559 injured children (65% male; 40% aged < 5 years). Most (56%) injuries occurred in and around the home. Burns represented 13% of all injuries and most were from hot liquids (scalds). Studies suggest that children tend to experience scald injuries most frequently, whereas adults are most likely to experience flame burn injuries (for example (41, 93)).

Older adults are more vulnerable in a fire than the general population because of a combination of factors, including limited mobility and a greater probability of mental and physical disabilities; as well as a greater use of medications in countries like the United States (46-48). Older adults have a much more pronounced burn injury risk in HICs, particularly in the United States (28). In the United States, older adults aged 65 years and older have death rates from residential fire that are 2.8 times higher than the overall population and those 85 years and older have rates that are 4.3 times higher (69). The leading cause of fire deaths in older adults is smoking and the leading cause of fire injuries in older adults is cooking. There are limited published studies indicating this is a high risk age group in LMICs (83, 94), but this may be due to under-reporting (11).

Sex

- **Throughout most LMICs, women are at higher risk of burn injuries. This increased risk is likely due to multiple factors, including:**
 - **Responsibility for cooking duties**

- **Use of flowing, loose-fitting clothing while cooking**
- **Suicides and assaults (intentional injuries)**

Males and females exhibit different burn patterns when comparing HICs with LMICs. In general, males are more likely to experience burn injuries in HICs, whereas there is a female predominance in most LMICs (11). Burn injury is the only form of trauma that is more common in females in many areas of the world. In the 15-59 age group, males tend to have higher fire death rates than females in HICs, but in LMICs the rate for females is twice that of males (25). In India, an estimated 65% of burn death victims are women (49). The greatest number of fire related deaths in India is seen in women aged 15 to 34 years old, and 25% of female deaths within this age group in the urban Indian population were fire-related (49, 50). A study in Ghana found that males experienced more burns from birth until four years of age, whereas females had a higher incidence thereafter (51). In an Iran burn center, 54% of the female burn patients admitted between 2000 and 2001 were 16-25 years old (53). One explanation for the higher proportion of burn injuries and fatalities among females compared to males in LMICs is the increased exposure to risk due to routine activities performed by women. For example, one study looking at rural areas of Iran found that teenage girls were 3 times as likely to be burned in the kitchen compared to teenage boys (52). Kitchen duties in this at-risk female age group could be contributing to the burn injuries. A 2008-2009 survey of 2100 households in Aligarh City, India revealed that 58% of female respondents spent more than four hours a day cooking in the kitchen (86). The breakdown according to "income group" was as follows: 84.4% for very low income; 76.4% for low income; 33.4% for medium income; and 24.9% for high income group.

Gender roles influence burn injuries through risk exposure. This is evident in the proportion of work-related industrial accidents, which affect more men, versus the proportion of home accidents, which affect women and children more. While cooking, women in LMICs may be involved in multiple tasks while preparing meals, including caring for younger children, and lapse in supervision is associated with an increased burn injury risk (25, 54, 57, 84). The practice of wearing loose-fitting clothing, such as *saris* (*sarees*), while cooking has also been associated with increased burn injury risk (42, 56). In India, an examination of fatal burn cases from September 1985-October 1986 revealed that 74% of the burn victims caught fire while cooking and all of these cases were female (55). The authors suggested that "loose, voluminous, highly inflammable, synthetic garments, sarees of the victims, catch fire suddenly while cooking" and are contributory factors in a majority of the accidental burn cases.

Although the focus of this review is on unintentional burn injuries, it is important to note that intentional burn injuries are a problem in certain regions, particularly among young women (for example (58, 85, 93, 95-97)). Intentional burn injuries may be either self-inflicted or inflicted by others (homicidal). For example, a study examining Iran burn center data revealed that 46% of the 170 female burn patients admitted during a one year period (2000-2001) had self-inflicted burns(53). Another India study characterizing fatal burn cases (between October 1985 and September 1986) brought to a district mortuary revealed that 62% (n=111) of the cases were accidental, 24% (n=43) were suicides, and 14% (n=26) were homicides; 68 out of the 69 suicide and homicide cases were female (55). Sri Lanka most likely has the highest incidence of self-immolation (setting oneself on fire), with this type of self-inflicted injury accounting for approximately 25% of all burn admissions (42). Another study examined news reports of burns among women in Pakistan between January 2004 and December 2005 (97). Results indicated that 33% (63/189) of the burn victims were set on fire. A study of 278 burn patients admitted to a Mumbai, India hospital during 2007 indicated that among female cases, 26% were suicidal and 31% were homicidal (98). In addition, dowry deaths (i.e., the murder or suicide of a married

woman caused by a dispute over her dowry) accounted for 34% of homicidal deaths. A review of deliberate self-burning (DSB) in various parts of the world suggests that these types of burn victims generally fall into three categories: “psychiatric patients (Western and Middle-Eastern countries); those committing DSB for personal reasons (India, Sri Lanka, Papua-New Guinea, Zimbabwe); and those who are politically motivated (India, South Korea) (95).” It should also be noted that some of these victims may be killed by other means, such as strangling or poisoning, and then burned to death to cover up the crimes (55).

Comorbidities

Comorbidity is a risk factor (25). In LMICs the main comorbidities associated with higher risk for burns include epilepsy, peripheral neuropathy and other physical and cognitive disabilities (25). Others reports of burns caused by seizure activity have been noted in Bangladesh, Papua New Guinea, and Liberia (61, 62, 66). In a case-control study of Ghanaian children, the presence of a pre-existing impairment (that is, hearing loss, difficulty in seeing, lameness, or a history of epilepsy or a convulsion) in a child was associated with the highest risk of a childhood burns (OR: 6.7) (63). Sensory disabilities can make it difficult for an individual to perceive risks during fire situations whereas physical disabilities can make it difficult or impossible to escape independently. For example, people with impaired tactile sensation may be at increased risk for fire and burn injuries because of their diminished ability to perceive heat. People with mental disabilities may not recognize danger or be able to learn new procedures and follow safety directions. In the United States, people with physical disabilities are at increased risk for home fire deaths and cognitive disabilities are a contributing factor in many deaths including among older adults (28). Elderly dementia is not an established risk factor for burns in LMICs, but the general sentiment among burn centers is that it is an important risk factor (25).

Additional risk factors

Race and ethnicity are well-documented risk factors in the United States, where African Americans and Native Americans experience a disproportionate burden of burn injuries (67-69). There is limited empirical evidence documenting racial and ethnic differences in LMICs, although a Western Australian study using data from 1983-2008 reported consistently higher age-standardized rates of burn-related hospital admissions and mortality for Aboriginal populations compared to their non-Aboriginal counterparts (71). Although substance use (primarily alcohol and tobacco use) is a strong risk factor in U.S. residential fire deaths (70, 73, 74), there is little published literature citing of its role in burn fatalities among LMICs. A Cape Town, South Africa study looked at burn mortality by blood alcohol content and found that intoxication levels were highest amongst males in the 25-38 age range; which also was the age group most affected by burn mortality (incidence of 19 per 100,000) (99). The authors stated that binge drinking has become more common in South Africa as the availability and accessibility to alcohol has increased. The review of risk factors for burn injuries by Atiyeh and associates found that family pattern factors associated with higher burn risk in most studies included “single parents, large families, recent pregnancies, and mothers’ being away from home...” (20). Maternal education appears to be consistently protective (12, 75-77) along with knowledge about burn risks and ready access to first aid services (76, 78). In a case-control study of urban children in Bangladesh, there was a significant association between burns and the following factors: lack of alertness to burns among parents, clothing of manmade fabrics, lapse in child supervision, parental illiteracy, and prior history of sibling burn (54).

3.3.2 Environmental Level Factors

Socioeconomic Factors

There is ample and consistent evidence linking social and economic factors with burn injuries (62). Many of the identified burn injury risk factors are related to poverty – such as overcrowding, lack of water supply, and inadequate child supervision (11). In a Peruvian study of shanty town homes, those lacking a home water supply had 5 times the odds of experiencing a burn (77); the stated reasons for this observation are that shantytown houses without running water represent the poorest families and the need to heat water on pots for cooking and bathing presents a particular burn injury risk. Fire injuries in England and Wales showed fire mortality is 16 times higher in the lowest socioeconomic class compared to the highest (80). A study in India found that an increase in per-capita income resulted in a decrease in admissions to the burn center (79).

Regional Factors

Geographically, the burn injury burden is unevenly distributed. For example, more than 90% of fire-related burn deaths occur in LMICs, which have rates nearly six times higher than in high-income countries (5.5 versus 0.9 deaths per 100,000 people, per year) (21). Burn fatalities are more likely to occur in certain regions of the world, even when controlling for other confounders (for example gender, national income status) (20). Climate can affect the type of fuel used to heat homes and consequently affect burn injury risk. In the United States, people in rural communities are at increased risk of experiencing burn injuries and their consequences. The smallest communities in the United States have the highest population-based rates of overall fires and fire deaths. In 2004-2008, rural communities had an overall fire death rate twice as high as the nation as a whole (87). While most burns occur in urban environments, the consequences may be more severe in rural areas where inadequate pre-hospital care leads to more severe morbidities and disabilities, and increases the risk of death.

Additional risk factors

Cultural beliefs and practices can be risk factors for burn related injuries. For example, Islamic countries often see a spike in burns in epileptic patients during the holy month of Ramadan. One prospective study in Saudi Arabia noted that 40% of burns in epilepsy patients were sustained during the month of Ramadan because patients did not take their medications during ritual fasting (59, 60). In Ethiopia, there is a traditional belief that epilepsy is contagious, so potential rescuers of burn victims may fear aiding the patient (65). A Malawi study of burn unit data (1,825 burn patients from 1994-1999) found that 83% (122/145) of epileptic burn patients suffered burns from open fires, whereas the most common cause of burns in the remaining study population was hot water (40%) followed by open fire (23%) (64). Seasonal trends in the frequency of burn injuries are documented in some countries, often with higher frequencies in winter months (for example (100-102)); these findings have been associated with weather patterns (for example West Africa's "Harmattan", which is a dry and dusty trade wind associated with lower temperatures (103, 104)) that increase the likelihood that fuel sources are also used for heating. A retrospective analysis of fire-related deaths in India found reports of a disturbing form of cultural violence of dowry deaths and bride burnings in which a young woman is doused with kerosene and then set on fire by members of her conjugal family (49). One study looking childhood burns in Zaria, Nigeria found numerous cultural factors contributing to burns, such as bush burning as a farming method, cooking with firewood at ground level, and a traditional ritual of hot baths and mud beds heated by firewood (82). In Nigeria, the tradition of a hot water baths for a mother right after childbirth is suggested as being associated with high risk for burn injuries (88). In Turkey, a common custom in the countryside involves heating milk in a cauldron to produce cheese. Large cauldrons are big enough to fit a preschool child. In addition, these cauldrons, full of milk and without a lid, are typically heated on the ground by a wood fire. Unfortunately, this exposes children to potential scald burns due to hot milk that is produced as

a part of this cooking practice. A study examining this phenomenon determined that child scald victims fell directly into the cauldron or collided with it and were scalded by the splashed hot milk (105).

3.4 Risks from Cooking

Most burn injuries, particularly among women and children, occur in the domestic environment (11, 13, 23, 37, 41, 42, 58, 84, 96, 106-112). A substantial proportion of burns are sustained in the kitchen or cooking area and relate to the design and use of domestic appliances for cooking (that is, stoves; ovens dug into the ground) (41, 42, 58, 76, 100, 108-110, 113-118). In some regions, such as South Eastern Nigeria (119), the cooking area may be located in the backyard of homes and on the ground level.

Cookstoves may represent the single most important modifiable risk factor for burn injuries because they are amenable to multiple technological and behavioral modifications. As a result, cookstoves (and associated fuels) are central to all public health efforts to decrease burn injuries in LMICs. For these reasons, and because there are sufficient data and studies, we have singled out cookstoves for a more intense discussion in this review.

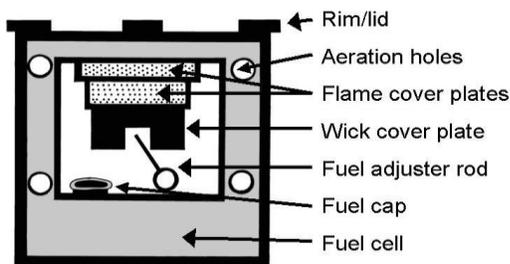
3.4.1 Burden of Burns from Cooking

In the United States, data from 2003-2007 indicated that cooking equipment was involved with more than 1 in 3 reported home-fire injuries and nearly 1 in 5 home fire deaths (120). The vast majority of cooking equipment in the US is fueled by electricity or liquid propane gas (LPG). Safety standards regulating production and installation of these devices keeps low the number of injuries sustained as a direct result of equipment malfunction. The majority of kitchen fires occur as a result of clothing or food ignition. Additionally, in a 2009 report, Ahrens indicated that more than half (57%) of the civilians injured in reported cooking fires were trying to fight the fire themselves. Although fire departments are rarely called to incidents because someone's clothing has caught fire, 13% of the cooking fire deaths resulted from this scenario.

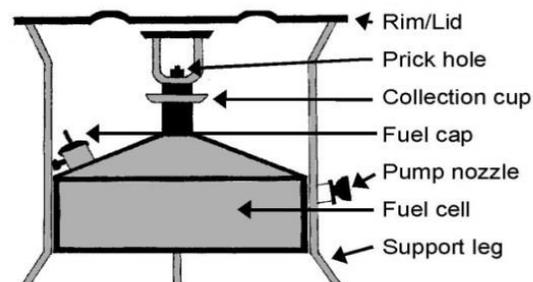
In many LMIC households, particularly in rural areas, cooking involves burning fuel in a rudimentary stove or in a traditional open fire, where proximity to open flames and hot liquids leads to an increased risk of burn injuries. Two common types of cooking devices are the flame and primus stoves, shown in Figure 2.

Figure 2: Flame and Primus stoves:

Flame stove



Primus stove



There is a paucity of population-level data in LMICs about cooking-related burn injuries. Most cooking-related burn injury data in LMICs come from hospital-based studies that provide information about the proportion of burns among hospital admissions that were caused by cookstoves. Unfortunately, hospital-based studies rarely provide insight into the true burden of injury within a community because so few burn patients in LMICs are treated at specialty hospitals. In Cape Town, South Africa an analysis of burn unit data from January 1990 through June 1992 revealed that 17% of all burn injuries (33/194) were sustained from a Primus stove, which is a type of pressure-burner stove that uses kerosene (12). Flame (non-pressure) stove injuries accounted for 13% of all adult burns admitted to burn units at two hospitals in Cape Town (121). In a prospective study from 1998 to 1999, at Cape Town's Tygerberg Hospital, 25% of adult patients admitted with burns were injured in stove-related incidents (40/160) (122). Similarly, a retrospective study of surgery unit data (1995-2004) in South Africa's Kalafong Hospital indicated that paraffin stoves were the second leading mechanism of burn injuries (26%), following open flames (30%), among adult patients aged 12 years or older (123). In most cases, the aforementioned studies demonstrated that the severity, length of hospital stay, mortality rates, and cost for treatment were often worse for cookstove-related burns than for other types of burns.

3.4.2 Risk Factors for Cooking-Related Burns

Risk factors for burns resulting from the use of kerosene stoves for cooking include:

- Fuel leaks onto surrounding materials or clothing during refueling
- Malfunctioning stoves explode
- Stoves are unstable, and tip over easily
- Kerosene is contaminated with gasoline
- Children play near stoves, endangering themselves and others
- Living conditions are crowded, materials for stopping the spread of fires are not at hand, and plans for fire management are non-existent

Cooking-related risk factors for burns and scalds can be categorized into those related to the individual (personal), the equipment used for cooking, and the physical environment in which cooking occurs.

In the United States, most residential cooking-related burn injury risk factors relate to the use of gas or electric fuel sources. In the United States, ranges (with or without ovens) account for the majority of civilian injuries (77%) and deaths (84%) related to the use of cooking equipment in homes (72). More than half (57%) of the civilians injured in reported cooking fires were trying to fight the fire themselves (70). Ignition of clothing leads to 13% of cooking fire deaths (70). Children under five years of age and adults 65 or older are at increased risk of death due to a home fire involving cooking equipment. In addition, children under age 5 are at increased risk for experiencing contact burns and scald burns associated with ranges or ovens, scald burns associated with microwave ovens, and burns and scalds from cookware (for example pots and pans) (72).

Despite the paucity of population-level data on cookstove-related burn injuries, studies have identified specific risk factors associated with cooking environments in LMICs. A review of the literature investigating the relationship between burn injuries and non-electric domestic appliances, including cookstoves, found that in the published literature the incidence of burn injuries is largely associated with the use of stoves and lamps that use liquid fuels such as

kerosene [7]. The contributing factors for these injuries included the types of cookstove design and construction, fuel combustion and instability, and insufficient knowledge about the safe use of cookstoves. In addition, industry and government regulations and standards were generally non-existent or poorly enforced.

The WHO Plan for Burn Prevention and Care² identified many of the cooking-related risk factors identified previously as well as the wearing of long, loose-fitting clothing while cooking and the use of ground level stoves for cooking (21). In many regions the culture is to cook at ground level which poses unique risks (e.g., children running into cooking apparatus) and has resulted in numerous documented burns particularly among women and children, for example in Liberia and Nigeria (66, 124).

Wood and other biomass are frequently used as a fuel sources for cooking in many rural areas and countries (for example Kenya, (125)), but they are rarely cited in the scientific literature in relation to burn injuries. Most literature on cookstove-related burns involves liquid fuels such as kerosene (also known as paraffin). The flammability of fuel types used in cookstoves varies greatly and influences the incidence and severity of burn injuries. Although kerosene is often less expensive than other liquid fuels, it is highly flammable (126) and has the potential to explode if it leaks into the air and makes contact with an ignition source, such as when cooking or using heating equipment.

According to Schwebel and associates, kerosene-related burns are associated with several risk factors (126). First, these stoves frequently leak fuel, which often occurs when stove reservoirs are being filled. Kerosene can leak onto clothing or vapors can ignite when heat and flames are present. Second, these small, portable stoves are unstable, and easily tipped over when being moved or even when resting in place. Moreover, these devices may be placed on an unstable surface. Third, children often play near (kerosene) stoves and can accidentally catch on fire. Fourth, all of these factors may interact with a home environment full of other risk factors such as homes constructed of flammable materials and a high number of people living in a small space.

Stoves that use liquid fuels are a major cause of serious burns in LMICs, such as has been documented in Egypt, Ethiopia, India, Nigeria, and Pakistan (126-128). Over an 18-month period during 1995-1996, 40% of all outpatient burns treated in a Cairo hospital were caused by kerosene stoves (131). Approximately 1/3 of children hospitalized to the burn unit during that time period sustained flame burns from kerosene stove explosions. Between 1982-1987, 58% of patients admitted with burns to the Postgraduate Institute of Medical Education and Research in Chandigarh, India had burns from kerosene stoves(114). Another study in India revealed that 29% of burn patients over a 9-year period were due to malfunctioning kerosene stoves, which represents 35% of all flame burns (116).

A Pakistani study of burn patients (12 years of age and older) admitted to the Pakistan Institute of Medical Sciences between January 2002 to December 2003 revealed that “stove burst” was the leading mechanism of burns (22%) among females; whereas stove burst accounted for less than 4% of the male cases (100). Stove burst has been documented as causing more severe

² http://www.who.int/violence_injury_prevention/media/news/13_03_2008/en/index.html This document outlines a 10 year strategic plan for WHO and partner organizations to work together towards the goal of decreasing the rates of burn and burn-related death, disability and disfigurement globally. The steps in this plan aim to address challenges in burn prevention and care in the following seven areas: 1) advocacy, 2) policy, 3) data and measurement, 4) research, 5) prevention, 6) services, and 7) capacity building.

burns, as measured by the percent of Total Body Surface Area (% TBSA), than other types of burn injuries (for example (56)).

Contamination of kerosene with gasoline leads to disastrous results. Despite the hazards associated with kerosene use, it is not nearly as dangerous as gasoline. Although kerosene fumes at room temperature are unlikely to ignite, gasoline fumes ignite readily and burn at 1500-1800° F. In Nigeria, it was discovered that “adulterated kerosene” was responsible for an epidemic of severe burn injuries (88). A study of 55 burn cases admitted to a Lagos (Nigeria) teaching hospital in the month of March 1984 revealed that 53 (96%) of those cases were due to flame burns resulting from explosions that occurred while using kerosene appliances for cooking and lighting, an incidence well higher than the normal number of burns admitted from this cause (128). The authors suggested that the explosions were mostly likely due to petrol contamination of the kerosene. Another Nigerian study examined teaching hospital data on children (ages 0 to 15) seen and treated for burns between December 1995 and January 1986. Results indicated that explosions resulting from the mixture of gasoline with kerosene accounted for 16% of the child cases (119).

Cookstoves that use liquefied petroleum gas (LPG) appear to a safer alternative than those fueled by kerosene, but still pose serious burn injury risk if not properly used, maintained, or replaced. In one study, a majority of LPG-related domestic cooking burns (75%) were caused by leaks from the rubber connecting tube. An additional 26% of LPG burns occurred because the valve on the stove was not properly positioned or closed (129). Similar to other highly flammable liquids, LPG has the potential to cause devastating explosions if there is a leak and an ignition source is present.

Burn injuries have also been associated with “Tandir” ovens, which are dug into the ground and generally use embers surrounded by an iron sheath for cooking. Tandir burn injuries tend to occur predominantly among women and small children who fall into the openings. One study in Turkey examined Burn Center data from September 1996 to January 2006 (107). Tandir burns accounted for 9% of all burned patients. Over half of the Tandir burn victims were under 5 years of age. A majority of patients (62%) were female. Another Turkish study analyzed major burn follow up cases admitted to burn units over a three year period (130). Among the 68 major burn cases, 47% (n=32) were caused by falling into a Tandir. A majority of these burn injuries affected the head/neck and hands.

Type of residence is inter-related with socioeconomic status and includes substandard housing and poor living conditions. Erratic electrical power supply, which is common in LMICs, protracts the use of kerosene stoves and lamps beyond the time at which the householders would prefer to make the switch to electrified appliances. Technological progress in terms of electricity, gas, and chemical substances were also a potential source of burn injury risk, but the impact of introducing new technology and fuels to naïve populations remains largely unexplored.

The WHO Plan for Burn Prevention and Care identified home level burn and scald risk factors including the use of open fires for space heating, high set temperature in hot water heaters, and sub-standard electrical wiring (21). Table 3 lists the main cooking-related burn injury risk factors in LMICs.

Table 3. Cooking-Related Risk Factors Associated with Burn Injuries and Deaths in Low- and Middle-Income Countries.

Factors	Reference(s)
<i>Personal</i>	
Attempting to put out a fire	(70)
The wearing of long, loose-fitting clothing while cooking	(21, 62)
Flammable clothing worn by appliance users	(62, 131)
Children playing near cookstoves	(115, 131)
Insufficient knowledge about the safe use of cookstoves	(103, 115, 131)
<i>Cooking Equipment</i>	
Cookstove design and construction	(12, 50, 103)
Use of ground level stoves	(21, 103)
Fuel source: combustibility and instability	(12, 100, 114, 131)
Instability of the pots and stoves	(131)
Lack of enclosure of open fires	(21, 103, 132)
<i>Environment</i>	
Nearby storage of flammable substances and fuels	(12, 131)
Confined space/crowding	(131)
Cooking equipment within reach of children	(115, 131)
Non-existent or poorly enforced industry and government regulations and standards	(119)

3.4.3 A case example of Household energy-related Injuries in South Africa

Household energy-related injuries, including poisonings and burns, are a serious problem in Southern Africa. The Paraffin Safety Association of Southern Africa (PASASA) developed an injury surveillance system based on Geographic Information System (GIS) technology, in which household burns and poisonings have been recorded (133). Data collected testify to the widespread impact of the devastating emotional, financial and physical damage inflicted.

According to these injury surveillance data, 24% of surveyed households suffered from fires, burns, or poisonings (134). Kerosene (paraffin) and electricity were responsible for 73% of the burns reported. The most common burns were scalds (38%), and flame burns accounted for 18% of the injuries (see Figure 3). Of the flame burns, 53% occurred because the kerosene stove exploded or was knocked over (see Figure 4).

Figure 3: Most common types of burns and poisoning in South Africa

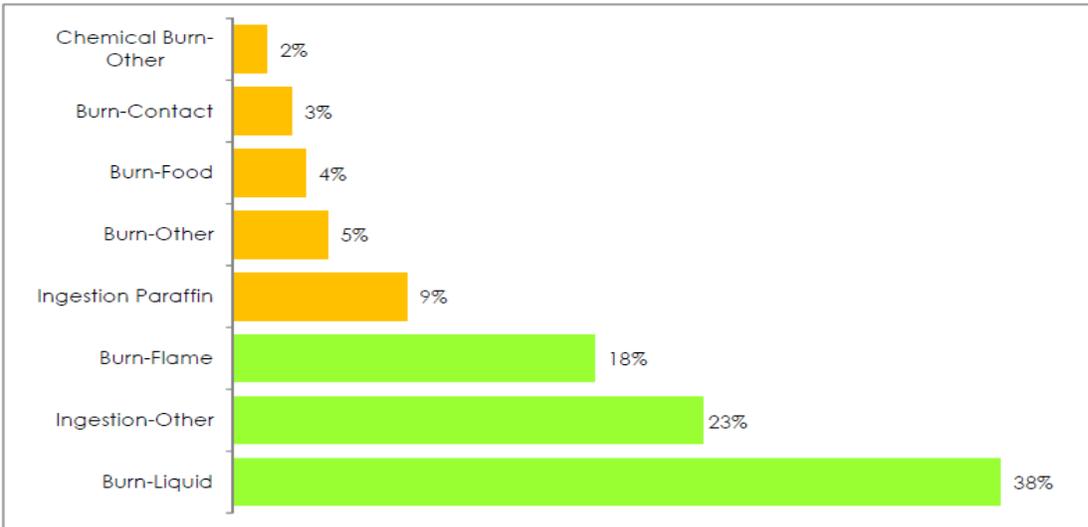
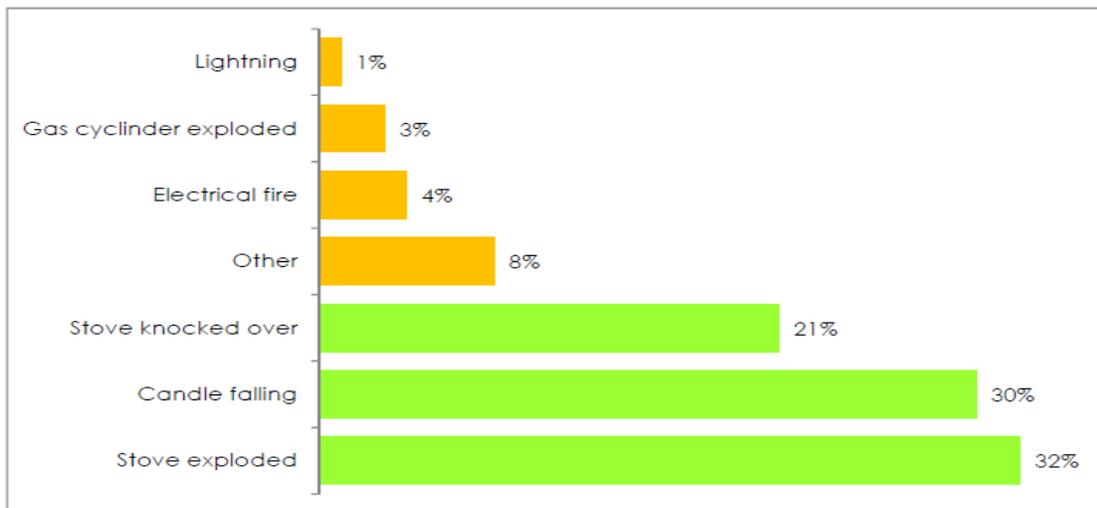


Figure 4: Main causes of burns in South Africa



3.4.4 Prevention of Burns from Household Fuel Use

Health education and promotion efforts aimed at changing behavior include:

- Lectures and demonstrations
- Age-appropriate activities
- Information posters
- Providing greater supervision for children
- Consultation, training and practice in proper fuel storage

Policy strategies include:

- Clothing flammability standards
- Restrictions on sales and use of fireworks
- Safety standards for residential electrical wiring
- Regulation of hot tap water temperatures

Environmental strategies include:

- Elevation of cooking stoves from floor level
- Installation of cooking guards in kitchens
- Protection from open fires
- Proper design and maintenance of kerosene stoves and lamps
- Provision of stable stands for lamps that use flammable fuels
- Reducing storage of flammable fuels near ignition sources

Major prevention approaches in LMICs can be categorized as educational, policy (that is, legislation, regulation), or environmental and are summarized in two review articles. The first review, by Atiyeh and associates (20), summarized different burn prevention approaches and stressed the importance of educating children about burn injury prevention—particularly in LMICs where they are an extremely vulnerable sub-population. In the review, the authors discussed educational programs involving lectures, demonstrations, age-appropriate activities, and informative posters. The authors stressed the importance of ongoing educational efforts and cited literature suggesting that prevention programs need to be repeated multiple times to increase the likelihood of cognitive and behavioral change (78, 87). Policy and environmental prevention recommendations included regulation of clothing fabrics to decrease flammability, legislative restrictions of fireworks, and safety regulations for homes in regards to electrical wiring, smoke alarms, and hot water temperature limitations.

The second review, by Parbhoo and associates (115), focused on burn injury prevention efforts targeting pediatric patients and identified many common, successful prevention strategies among both high income countries (HICs) and low and middle income countries (LMICs). Several studies identified in their review discussed specific changes that can be made in the kitchen or cooking area. For example, one study looked at the burn incidence in children in a region of Nigeria and recommended that the raising of the cooking surface could decrease childhood burn injury (103). Another study evaluating prevention strategies in Norway showed success with the installation of cooking guards in the kitchen (132). Other home safety prevention measures included protection from open fires (103), better home ventilation (119), safe storage of flammable liquids (135), lowering tap water thermostats (132, 136), and proper design of kerosene lamps and stoves (11). Education efforts were also discussed as essential to a prevention strategy. An intervention in Jamshedpur, India focused on domestic burns prevention and first aid awareness, with a focus on reaching high risk sub-populations in a two settings: women and teenage girls in the communities and children in the city schools. Results estimated that up to 10,000 people may have been reached by the program. However, as is unfortunately typical of the majority of studies which describe prevention programs, there was no documentation of the program's impact on the domestic burn incidence and the number of people using inappropriate first aid among those reached (137).

An article by Nordberg (13) presented public health strategies to prevent and control injuries, including burns, in Sub-Saharan Africa. "Proven" burn injury prevention strategies for low-income populations included improvement of housing quality/safety, replacement of high-pressure home cooking stoves, promotion and manufacture of clothes with less flammable fabrics, promotion of inexpensive stands to stabilize bottle lamps, promotion of enclosed

ceramic stoves to replace open fires, and restricted use of fireworks and explosives.

In general there is little published information in LMICs about the incidence and impact on burn injuries in LMICs resulting from the use of prevention strategies to reduce such injuries as they relate to cookstoves (20). Interventions that have been proposed to reduce exposure to fires and flames seem intuitively correct but have largely not yet been formally tested for effectiveness. Indeed, anecdotal observations over the last decade suggest that transition from open fires and kerosene-fueled stoves to LPG and electrical cooking appliances may not reduce the incidence of burns so much as substitute one type of injury for another.

Nonetheless, there are several practical and inexpensive changes that have taken place in behavior and in the physical environment of kitchens, which likely have made the daily act of cooking a safer activity. These include separating cooking areas from living areas (including efforts to reduce the use of indoor fires for cooking), ensuring cooking surfaces are at elevated heights, reducing the storage of flammable substances in households, improving educational awareness among childcare providers (for example nursery schools, day care centers), and greater supervision of young children (20, 25, 54, 64, 82, 105, 108).

3.4.3.1 Studies of interventions to prevent burns from household fuel use

The systematic review identified four studies of interventions to prevent burns from household fuel use, one of which measured the impacts on the incidence of burns in children (1), one on children and women (2), one on changes in a burns risk index (138) and one on knowledge of safety in relation to kerosene usage (126). Summaries of these studies are provided in Table 44, and discussed below. As described above, the quality of each study was assessed using standardized methodological quality appraisal forms (LQATs) (8).

RESPIRE trial (Guatemala)

Between 1992-1994, a household randomized trial called RESPIRE³ was implemented in rural, highland Guatemala. The primary aim of this study was to determine the impact of reduced household air pollution by using an enclosed chimney wood stove (the *plancha*) in comparison with the traditional 3-stone open fire on child pneumonia, and the opportunity was taken to study the impact on burns among the study children and their older siblings (1, 21). The *plancha* stove presents a very different cooking environment compared to the open fire. It is built on a stone/brick plinth, so the cooking surface is at waist height. The combustion chamber is closed, and smoke is vented by a chimney often made of metal. The stove elevation and closed combustion chamber are intuitively important safety factors; although the *plancha's* metal cooking surface and chimney are both very hot, which compared to open flames is not visible to a young child, and unfamiliar (at least initially) to the parents. Two groups of children were studied: (i) the sample of children up to 18 months used for the main trial outcome of pneumonia 'index children', and (ii) their older siblings up to age 15 years, if they had siblings.

For the 514 young study children aged up to 18 months, there was no significant difference in the overall rate of burns (RR = 1.08, 95% CI: 0.62, 1.89, p=0.80), Table 4, but a highly statistically (p<0.001) significant change in how the burns occurred, Table 5. Specifically, although the serious occurrence of falling into the fire was almost completely avoided in the *plancha* homes (the 2 cases resulted from continued use of open fires in those homes, in addition to the *plancha*), a substantial number of burns occurred through the child touching, or being placed in contact with, the hot griddle (*plancha*). Given the height above the floor and age

³ RESPIRE: Randomized exposure study of pollution indoors and respiratory effects

of these very young children, this could only happen when the child was on the mother's back, or placed on the tiled surround, implying that greater efforts were needed to raise mothers' awareness of this potential hazard. For example, the Plancha installations could have coincided with stronger education about the operation and maintenance of cookstoves, as well as protective supervision of children while cooking.

Among 1039 siblings, prior to the intervention, the baseline burn incidence rate was 83 per 1,000 child years (95% CI: 55.5, 125.7); All burn injuries occurred to children under the age of 5 years and the great majority were in children in the age group 2-4 years, and most (74%) caused by the child falling into the open fire. Over the follow-up period, there was a total of 31 burns; around one-third fewer burns occurred to children in the intervention group, although the difference was not statistically significant (RR = 0.65, 95% CI: 0.32, 1.35, $p=0.25$). As with the index children, there was some evidence of a difference in the cause of the burns with many fewer resulting from falls into open fires, but this was not significant ($p=0.17$). Although numbers are small, compared to the index children the older siblings seems less likely to be burned on the hot stove (equal numbers as for control group), but more likely to be scalded by hot liquid in a falling receptacle. This problem of children reaching up and pulling down pots on surfaces at waist height is common in developed countries, and it would be important to emphasize this in awareness-raising when such interventions are introduced in developing countries— especially among users more familiar with cooking at floor level.

Table 4. Summary of cooking-related experimental studies of impacts of interventions on burn injuries

First author, Year; Design	Location	Population/ Setting	Intervention	Measurement of burns	Results (expressed as rates)	Quality assessment [§]																																																												
Practical Action Consulting 2011 Quasi-experimental (Before and after study with control group)	Ambositra Madagascar (Highland region)	Total sample size of 180 (control and 4 intervention groups). Eligible households selected by local community groups (rapid appraisal)	Health awareness raising (n=36) Improved charcoal stove ICS (n=36) Ethanol stove (n=36)	Adult burns since baseline at interview (questionnaire). Child burns since baseline in adult interview. Frequency, severity and cause recorded. At baseline, no difference was observed for the 12 month occurrence of burns by intervention group for adults (p=0.821) or children (p=0.864).	<p>Adults (rate per 100 person months)*</p> <table border="1"> <thead> <tr> <th>Intervention</th> <th>No.</th> <th>%</th> <th>Rate*</th> <th>p-value[@]</th> </tr> </thead> <tbody> <tr> <td>Control</td> <td>8</td> <td>23.5</td> <td>4.7</td> <td></td> </tr> <tr> <td>Awareness</td> <td>8</td> <td>24.2</td> <td>4.84</td> <td>1.000</td> </tr> <tr> <td>ICS - charcoal</td> <td>3</td> <td>9.7</td> <td>1.94</td> <td>0.189</td> </tr> <tr> <td>Ethanol</td> <td>0</td> <td>0.0</td> <td>0.00</td> <td>0.005</td> </tr> </tbody> </table> <p>Children: rate per 100 person months)*</p> <table border="1"> <thead> <tr> <th>Intervention</th> <th>No.</th> <th>%</th> <th>Rate*</th> <th>p-value[@]</th> </tr> </thead> <tbody> <tr> <td>Control</td> <td>7</td> <td>20.6</td> <td>4.7</td> <td></td> </tr> <tr> <td>Awareness</td> <td>7</td> <td>21.2</td> <td>4.84</td> <td>1.000</td> </tr> <tr> <td>ICS - charcoal</td> <td>3</td> <td>9.7</td> <td>1.94</td> <td>0.307</td> </tr> <tr> <td>Ethanol</td> <td>0</td> <td>0.0</td> <td>0.00</td> <td>0.011</td> </tr> </tbody> </table> <p>[@] Fishers Exact p-value (control vs interventions)</p>	Intervention	No.	%	Rate*	p-value [@]	Control	8	23.5	4.7		Awareness	8	24.2	4.84	1.000	ICS - charcoal	3	9.7	1.94	0.189	Ethanol	0	0.0	0.00	0.005	Intervention	No.	%	Rate*	p-value [@]	Control	7	20.6	4.7		Awareness	7	21.2	4.84	1.000	ICS - charcoal	3	9.7	1.94	0.307	Ethanol	0	0.0	0.00	0.011	9/11										
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	Vatomandry Madagascar (Coastal region)	Total sample size of 144 (control and 3 intervention groups). Eligible households selected by local community groups (rapid appraisal)	Health awareness raising (n=36) Improved charcoal stove ICS (n=36) Improved biomass (n=36) Ethanol stove (n=36)	Adult burns in last 12 months at interview (questionnaire) at baseline and follow-up. Child burns last 12 months reported in adult interview. Frequency, severity and cause recorded. At baseline, no difference observed for 12 month occurrence of burns by	<p>Adults: rate per 100 person months)*</p> <table border="1"> <thead> <tr> <th>Intervention</th> <th>No.</th> <th>%</th> <th>Rate*</th> <th>p-value[@]</th> </tr> </thead> <tbody> <tr> <td>Control</td> <td>13</td> <td>43.3</td> <td>8.66</td> <td></td> </tr> <tr> <td>Awareness</td> <td>8</td> <td>27.6</td> <td>5.52</td> <td>0.299</td> </tr> <tr> <td>ICS - charcoal</td> <td>4</td> <td>13.3</td> <td>2.66</td> <td>0.025</td> </tr> <tr> <td>ICS-wood</td> <td>5</td> <td>15.2</td> <td>3.04</td> <td>0.055</td> </tr> <tr> <td>Ethanol</td> <td>1</td> <td>3.2</td> <td>0.64</td> <td>0.001</td> </tr> </tbody> </table> <p>Children: rate per 100 person months)*</p> <table border="1"> <thead> <tr> <th>Intervention</th> <th>No.</th> <th>%</th> <th>Rate*</th> <th>p-value[@]</th> </tr> </thead> <tbody> <tr> <td>Control</td> <td></td> <td></td> <td></td> <td></td> </tr> <tr> <td>Awareness</td> <td></td> <td></td> <td></td> <td></td> </tr> <tr> <td>ICS - charcoal</td> <td></td> <td></td> <td></td> <td></td> </tr> <tr> <td>ICS-wood</td> <td></td> <td></td> <td></td> <td></td> </tr> <tr> <td>Ethanol</td> <td></td> <td></td> <td></td> <td></td> </tr> </tbody> </table>	Intervention	No.	%	Rate*	p-value [@]	Control	13	43.3	8.66		Awareness	8	27.6	5.52	0.299	ICS - charcoal	4	13.3	2.66	0.025	ICS-wood	5	15.2	3.04	0.055	Ethanol	1	3.2	0.64	0.001	Intervention	No.	%	Rate*	p-value [@]	Control					Awareness					ICS - charcoal					ICS-wood					Ethanol					9/11
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Dherani, 2013 RESPIRE randomised control trial	San Lorenzo, Guatemala (Highland region)	Total sample size of 534 households, followed up with weekly home visits till children 18 months old. Older siblings in same homes assessed every six months.	Improved chimney wood stove (the 'plancha') randomly allocated to 265 homes while control homes (253) continued using 3-stone open fire.	<p>Index children: followed-up at home visits every week and parent interviewed for incidence of any burns in the past week.</p> <p>Siblings: followed up every six months and asked questions (same wording as for index children) regarding any burns episode in the past 6 months. The follow-up was at baseline, 6, 12 and 18 months.</p>	<p>Index children (<=18months)</p> <table border="1"> <thead> <tr> <th>Intervention</th> <th>No.</th> <th>Rate</th> <th>95%CI</th> <th>p value</th> </tr> </thead> <tbody> <tr> <td>Control</td> <td>23</td> <td>7.81</td> <td>5.59,11.75</td> <td>RR:1.08 95%CI:0.62,1.89</td> </tr> <tr> <td>Plancha</td> <td>26</td> <td>8.41</td> <td>5.73,12.36</td> <td>p = 0.80</td> </tr> </tbody> </table> <p>Sibling (1 year to 12 years)</p> <table border="1"> <thead> <tr> <th>Intervention</th> <th>No.</th> <th>Rate</th> <th>95%CI</th> <th>p value</th> </tr> </thead> <tbody> <tr> <td>Control</td> <td>22</td> <td>4.03</td> <td>2.6,6.1</td> <td>RR:0.81 95%CI:0.42,1.52</td> </tr> <tr> <td>Plancha</td> <td>17</td> <td>3.25</td> <td>2.0,5.2</td> <td>p = 0.5</td> </tr> </tbody> </table>	Intervention	No.	Rate	95%CI	p value	Control	23	7.81	5.59,11.75	RR:1.08 95%CI:0.62,1.89	Plancha	26	8.41	5.73,12.36	p = 0.80	Intervention	No.	Rate	95%CI	p value	Control	22	4.03	2.6,6.1	RR:0.81 95%CI:0.42,1.52	Plancha	17	3.25	2.0,5.2	p = 0.5	10/11
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Swart, 2008 Randomised control trial	South Africa	4 low-income communities near Johannesburg and Cape Town; random selection. Intervention n=189	Home visit program to improve home safety: included four visits, with safety information, completion of home hazard checklist,	Scores from a risk assessment tool. The key outcomes developed to measure the presence of household hazards were scores for burns (safety practices, paraffin, and electrical), poisoning, and falls.	<p>Burns electrical Score – Post Intervention: Control: 1.3, SE=0.14 Intervention: 1.1, SE=0.14 Intervention effect -0.19 (-0.54, 0.16) P-value=0.294</p> <p>Burns paraffin Score – Post Intervention: Control: 3.2, SE=0.21 Intervention: 3.2, SE=0.21 Intervention effect -0.03 (-0.64, 0.57) P-value=0.911</p>	10/11																														

First author, Year; Design	Location	Population/ Setting	Intervention	Measurement of burns	Results (expressed as rates)	Quality assessment [§]																																				
		households; Control n=188 households. Children under 10 years.	distribution of safety devices (e.g. child proof locks and paraffin container safety caps)		<p>Burns safety practice score – Post Intervention: Control: 2.9, SE=0.12 Intervention: 2.5, SE=0.12 Intervention effect -0.41 (-0.76, -0.07) P-value=0.021</p> <p>[Note: lower mean score equates to lower risk]</p>																																					
Schwebel, 2009 Prospective Quasi-experimental, non-equivalent case vs. control groups	Phillipi and Du Noon districts (near Cape Town), South Africa	Low-income housing districts Controls n=106, Intervention n=100	Delivery of educational materials (theory-driven)	<p>Indirect measure of burns risk through assessment of knowledge and practices.</p> <p>Self-reported knowledge of kerosene safety; observed practice of safe kerosene use; self-reported recognition of risk for kerosene-related injury.</p>	<p>Survey scores:</p> <table border="1"> <thead> <tr> <th>Knowledge**</th> <th>baseline</th> <th>Post</th> <th>Mean change</th> </tr> </thead> <tbody> <tr> <td>Control</td> <td>11.83</td> <td>12.89</td> <td>1.07</td> </tr> <tr> <td>Intervention</td> <td>11.03</td> <td>14.39</td> <td>3.28</td> </tr> <tr> <td>Practice*</td> <td></td> <td></td> <td></td> </tr> <tr> <td>control</td> <td>0.41</td> <td>0.46</td> <td>0.05</td> </tr> <tr> <td>intervention</td> <td>0.38</td> <td>0.49</td> <td>0.10</td> </tr> <tr> <td>Risk Perception*</td> <td></td> <td></td> <td></td> </tr> <tr> <td>control</td> <td>3.76</td> <td>3.53</td> <td>-0.24</td> </tr> <tr> <td>intervention</td> <td>4.54</td> <td>3.65</td> <td>-0.87</td> </tr> </tbody> </table> <p>*Between group mean change p<0.05 unadjusted ** Between group mean change p<0.01</p>	Knowledge**	baseline	Post	Mean change	Control	11.83	12.89	1.07	Intervention	11.03	14.39	3.28	Practice*				control	0.41	0.46	0.05	intervention	0.38	0.49	0.10	Risk Perception*				control	3.76	3.53	-0.24	intervention	4.54	3.65	-0.87	9/11
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[§] Quality assessment represents total available “stars” for a specific study design (Section 2.2).

Table 5: Causes of burns among index children and their siblings, RESPIRE trial, rural Guatemala

Cause of burns	Index children (≤ 18 mo)*			Siblings (<16 years)**		
	Control	Plancha	All	Control	Plancha	All
Fell into fire	17	2	19	10	2	12
Burned on hot object	0	15	15	4	4	8
Receptacle with hot liquid fell down	1	0	1	3	5	8
Candle or lamp	4	6	10	-	-	-
Other	1	3	4	2	1	3
Total	23	26	49	19	12	31

* Fishers exact test for difference in cause of burns $p < 0.001$

**Fisher's exact test for difference in cause of burns $p = 0.17$

Although possessing limited power to detect differences in burn injury outcomes, this trial suggests two important conclusions. First, when a new stove (or fuel) is introduced, it should not be assumed that just because it has perhaps lower emissions into the home, or appears more advanced, that it is necessarily safer; the introduction of new stove technologies should therefore be accompanied by safety testing [See Section 5], user education, and in-field evaluation. Second, while the overall rates of burns were not reduced, there was some strong evidence that the causes of burns were very different, with far fewer being caused by children falling into the open flames. This is very likely to result in the most severe burns being avoided, and is an encouraging finding, although the possibility of scalding risk from pots being pulled down by older children is also noted.

Practical Action Consulting (PAC) Madagascar (2011)

Using a quasi-experimental design in two communities, one highland and the other coastal, the impact of ethanol stoves, improved wood and charcoal stoves, and an awareness only group, were compared with a no-intervention control group, Table 4 (2). There were no significant differences between the groups at baseline in terms of burns incidence among adults or children in the previous 12 months. After a period of 6-8 months follow-up since implementation of the interventions, there were significant reduction in burns incidence for the ethanol and wood stoves (the latter only used in Vatondry), but not for the charcoal or awareness only groups.

Swart et al (2008)

This RCT was carried out among four low-income communities near Johannesburg and Cape Town, South Africa, and tested the effect of a home visit program to improve safety, including in respect of burns from electricity and paraffin, Table 4 (138). Outcomes were assessed by scores from a risk assessment tool. There were small but non-significant improvement on the electricity and paraffin burns score, but a significant improvement in the burns safety practice score ($p = 0.021$).

Schwebel (2009)

In a quasi-experimental study in South Africa, Schwebel and colleagues (126) evaluated a train-the-trainer educational intervention delivered in low-income South African communities designed to reduce kerosene-related burns and poisonings (Table 4). The intervention resulted in significant changes in self-reported kerosene-related knowledge and safety practices, as well as recognition of kerosene injury risk, in the intervention communities compared to the comparison communities. While the intervention did appear to reduce risk related to kerosene-related safety and knowledge, the study did not formally assess burn injuries in the study

population. As is true in most attempts at behavior modification by education, there are few or no data available to clarify the link between improvements in knowledge and reduction of risk of burn injury. Nonetheless, improvement in knowledge is generally accepted as a reasonable surrogate for risk reduction for burn injuries.

3.4.5 Overall Assessment of Evidence for Cooking

This review found only two studies, one an RCT the other quasi-experimental that had assessed the impacts of 'improved' stoves and fuels on burns as an outcome, although the quality of both was high due to their inherent design features. Two others, also of high quality, studied the effects of awareness raising on safety risk scores and behaviors. This small and heterogeneous set of studies does not permit any more formal assessment of strength of evidence using GEPHI methodology.

Other available evidence describes risks mainly through description of the causes of burns seen in hospitals, and the proportion due to cooking, etc. These two groups of studies should probably be summarized separately.

Based on the number and design/type of studies, and some limitations, the strength/quality of studies assessing impacts of interventions is likely to be moderate at best, and the descriptive evidence of risk low at best. The overall conclusion however is that there is strong evidence that household fuel use, both solid and liquid fuels (as currently used), are a major risk for burns, including scalds. The evidence is relatively weak (or patchy), however on the specific design and behavioral requirements in LMIC settings needed to prevent burns in practice, and on the level of risk reduction that can be achieved by various preventive strategies.

3.4.6 Research Gaps/Future Research Needs for Cooking-Related Burns

Steps for improving cookstove design include:

- Defining burn risks and user acceptance of designs to mitigate those risks
- Establishing guidelines and standards
- Incorporating these standards into laboratory and field testing of newly designed stoves
- Following up populations throughout which large numbers of new stoves have been distributed to ensure that safety benchmarks are being met

In LMICs, the adoption of cleaner and more efficient cookstoves can have a tremendous impact on the health of many of these households. From a public health perspective, this impact could be even greater if cookstove efforts embraced the concept of safety, particularly burn prevention. To understand better the scope of the problem and efforts to address it, research should focus on improving cookstove designs and implementing change (e.g., enforcing standards for these designs) and increasing quality data collection and reporting.

Improving cookstove design and implementing change

In most LMICs, a substantial proportion of burn injuries are sustained in the kitchen or cooking area; these injuries, therefore, are related to the nature of domestic appliances used for cooking. Although as yet unproven, the generally accepted hypothesis is that cookstove design can be modified to improve the protection of cooking areas. However, the challenge is that there is no single engineering solution that simultaneously addresses reduction in air pollution and carbon dioxide production, preserves cost-efficiency in low-income settings, and reduces

hazards in the home. Therefore, any efforts in stove design research and development must include criteria for safety.

As a first step, burn safety features should be explicitly incorporated into cookstove design, which is a relatively new concept. The second step is to establish guidelines and standards for laboratory testing of cookstoves for burn safety that are commensurate with the actual burn injury risk. These guidelines should be fully vetted by experts in this field and pilot-tested under lab conditions. Pilot testing must also examine user acceptability and knowledge of how to use and maintain the new cookstove technology. Guideline development should build on previous work and take only one to two years. The third step is to incorporate these guidelines into the research, development, and testing of new cookstoves (with the built-in safety features). The development of newer, safer cookstoves, as well as their evaluation through research trials and studies is a multi-year effort. There is little information about rates of burn injuries associated with stoves currently undergoing randomized controlled trials or being widely disseminated in multiple countries; such information would clearly be valuable. The fourth and final step is to obtain follow-up data on the safety of stove usage once the new stoves have been distributed to large populations. The process for evaluating new stoves that are being distributed for use would thus involve (a) performing studies on burn injury rates and risk factors (e.g., randomized controlled trials, nested case control); (b) establishing surveillance to monitor burn injuries after dissemination of new stoves (this may use existing data and systems, for example linking population level data with hospital data); and (c) building local capacity for improved monitoring and evaluation of burn injuries.

Improving data collection and reporting

There are limited data available on cook-stove related burn injuries, and most of them come from retrospective, hospital-based studies. Data improvements should occur through enhanced surveillance efforts, well-designed epidemiologic studies, and the development of centralized burn registries. Ongoing, population-based surveillance systems are essential for planning and evaluation of prevention, acute care, rehabilitation, and service access and use among those with at risk for or suffering from burn injuries. Surveillance and epidemiologic studies describe the magnitude of the problem, and characterize how frequently burns occur, where and when they occur, who is affected, and what their care costs. Understanding the risk factors for cooking-related burns will guide prevention efforts and shape the design of safer cookstoves. For example, risk factors that cannot be modified, such as age, will identify the groups of individuals on which to focus prevention efforts. Modifiable risk factors, such as cooking behaviors or characteristics of home appliances and fuels, are potential target areas for behavior or environmental changes. Similarly, once protective factors (such as improved stove design) are identified, they can be much more widely distributed.

LMICs in particular have a need for better surveillance and population-based data (76). Most LMICs do not have a national burn surveillance system, and reported burn injury rates and estimates (for example incidence, morbidity and mortality) are often inaccurate (23, 24). As reported by Atiyeh and associates (2009), national vital registration data are only available in approximately 20% of the countries in the African Region (20). In addition to limiting the validity of burden of disease estimates, the lack of data limits the ability to assess trends and understand whether changes in stoves and cooking practices are having the desired impact. As the global market shifts from the use of biomass to refined hydrocarbons and electricity for cooking, more research is needed to understand better the effect of different cookstove designs and fuel types on the profile of risk and protective factors for burn injuries.

There are critical gaps in information from LMICs related to risk and protective factors for cookstove-related burn injuries. The paucity of such data on cooking-related burn injuries among LMICs limits the ability to match prevention strategies to the regional or local problem. The burn injury prevention field would also benefit from a minimum data set and modules (core and supplemental sets of validated questions) that could be used to collect data on incidence, cause, nature and severity of burn injury, treatment in acute and rehabilitation phases, and portrayal of impairment and disability, in hospital-based and population surveys, such as the Demographic and Health Survey (DHS) and Multiple Cluster Indicator Survey (MCIS). This would provide better data and allow for trend analysis and cross-country comparisons. It is also important that these data collection instruments are inexpensive, because cost is a major barrier in LMICs. Improvements can be made with better use of new and accessible technology (for example PCs, tablets, smart phones) as well as adequate training for individuals responsible for data analyses (139).

Burn registries (i.e. collections of defined data sets from tertiary hospitals which specialize in burn care) can be invaluable parts of improved surveillance systems. They can track chronic morbidity, disability, cost, and utilization of resources, and they can be used to evaluate prevention strategies, programs, and policies. Currently, available data generally comes from hospitalized patients in burn centers typically located in large metropolitan areas, leading to gross underestimation of burns in LMICs because of the paucity of such specialty centers in developing nations (20, 23). Centralized burn registries, particularly in areas where cookstoves are widely used, would permit multiple burn epidemiology studies and provide a more comprehensive assessment of burn injury impact, particularly on the more severe injuries which are likely to threaten survival and result in permanent disability. If burn registry data were collected in standardized and validated formats, this would enable assembling national data into centralized burn registries and conceivably even enable cross-country comparisons.

3.4.7 Implications for Public Health Practice for Cooking-Related Burns

There are four main practices that can increase the public health benefits in a growing movement to develop and disseminate safer cookstoves in low and middle-income countries:

- Targeting high risk populations
- Increasing health education and promotion efforts
- Informing policy efforts
- Collaborating with international partners

Targeting high risk populations Since women and children are typically at greatest risk for cookstove burn injuries in LMICs, prevention efforts should target these two vulnerable populations. Effective interventions for these high-risk groups require broad, community-based interventions that also address underlying social conditions and inequities. Many fire prevention and protection strategies available to HICs, such as smoke alarms and residential fire sprinklers, may not be viable options in many LMICs.

Increasing health education and promotion efforts

The installation of clean and safe cookstoves alone will not ensure that health objectives will be achieved. Installations must coincide with education (for example operation and maintenance of cookstoves, protective supervision of children while cooking, appropriate first aid, and treatment of minor burns). Quantitative research (for example community surveys) and qualitative studies (for example ethnographic and case studies, focus groups, observational studies) will help to examine cookstove acceptability as well as ways to increase appropriate and safe use. These

findings will be necessary to provide accurate substance to promotion efforts that utilize the media and community organizations. It is expected that messages and materials will vary by type of cookstoves and by location, because of differences in cooking-related behaviors, social and cultural norms, and religious practices.

Informing policy efforts

The installation of improved cookstoves occurs at the individual home level. This type of public health approach is time-intensive, especially when accompanied by education on how to safely use the cookstoves. However, to achieve the maximum possible sustained public health impact, it is important to implement interventions at levels beyond the individual home. Policies, particularly those at the population level, can have a tremendous impact on community health. As seen in HICs, public policies in the form of legislation and standards (for example technologies and codes for smoke alarms and sprinklers) have reached broad segments of populations and contributed to reductions in residential fire fatalities during the past 30 years (15). Policy evaluation and translational research on policy development and implementation will be necessary to develop optimal prevention strategies in LMICs and increase the likelihood of lasting impacts.

Collaborating with international partners

Global partners, such as the International Society for Burn Injuries (ISBI), are important in supporting and sustaining these policy initiatives and dissemination efforts. The Global Alliance for Clean Cookstoves (GACC) is committed to ensuring that 100 million homes adopt clean and efficient stoves and fuels by 2020. While this initiative will have a tremendous impact on the health of many households, this impact could be even greater if cookstove efforts embraced the concept of safety--in particular, burn prevention. To this end, the ISBI and GACC are currently engaged in developing data collection and management programs for burn injuries. Interburns (International Network for Training Education and Research in Burns) is a leading global organization that addresses burn injuries in LMICs. Interburns has developed consensus standards for burn services, developed specific training courses explicitly designed for LMIC settings, and provided a platform for burn research and data collection efforts (www.interburns.org). Through its national and international alliances, the ISBI, GACC, Interburns other national and international programs, and non-governmental organizations should incorporate burn prevention into both cookstove development and widespread implementation.

3.5 Risks from Residential Heating

While heating in the home is a potential cause for burn injuries, there is limited evidence in the published literature on this topic in LMICs.

3.5.1 Burden of Burns caused by Residential Heating

The sole article on this topic in LMICs is from Turkey and involved an analysis of data from 1996-2000 of 314 adult burn patients treated in an emergency department in Central Anatolia (140). The study revealed that the most common cause of flame injury (54%) was liquefied petroleum gas (LPG), which is used as a fuel source for heating and transportation as well as cooking.

3.5.2 General Risk Factors for Residential Heating Burns

In the same study from Turkey, it was suggested that the kindling of stove fires was largely responsible for flame injuries during autumn and winter months (140).

3.5.3 Prevention of Residential Heating Burns

The article by Avşaroğulları and associates suggested that burns were associated with “carelessness, ignorance, hazardous traditions and improperly manufactured products.”(140) The authors indicated that public education may address several of these factors, some of which may be related to heating-related burns.

3.5.4 Overall Assessment of Evidence on Heating

The systematic review did not identify any experimental studies investigating the prevention of residential heating burns in LMICs. No conclusions can be drawn or recommendations provided due to the lack of quality intervention studies and empirical evidence regarding the burden of heating burns in LMICs.

3.5.5 Research Gaps/Future Research Needs on Residential Heating Burns

Future research on heating-related burn injuries should include starting or informing surveillance efforts and conducting epidemiologic studies to identify risk and protective factors.

3.6 Risks from Lighting

In LMICs, most studies regarding burns associated with household lighting report on homemade or commercial wick lamps.

3.6.1 Burden from Lighting-Related burns

There are a limited number of peer-reviewed journal articles related to the burden of burn injuries from bottle or wick lamps in LMICs.

In a review in 2008 by Peck and associates, there were only three studies cited on lamp-related burn injuries (141). Their review consisted of a retrospective review of the literature in the Pub Med database using the terms “burns”, “stoves”, and “lamps”, as well as the authors “reviewing institutional and regional experiences with injuries caused by non-electric domestic appliances.” The authors did not provide additional information on the range of years or the process of winnowing down the search results to the final set of articles for inclusion in their review.

Four studies from India documented burn injuries associated with lamps. A study in Northern India analyzed data on nearly 12,000 patients over a 8 year period (1993-2000) and found that approximately 2% of the patients treated for burns were caused by flame lamps (116). In Manipal, India, a study examined over 300 cases of children aged 10 years and younger who were treated for burn injuries at a hospital over a ten year period (1989-1998). In that study, oil spilled from kerosene lamps and caught fire accounted for 15% of child burn injuries (142). In Indore, India, researchers conducted a retrospective study on 110 burns of children under 15 years of age seen at the Choithram Hospital and Research Center Burn Unit over a period of 7 years (1993–1999) (143). Flames were the second most common cause of burn injuries (29%); several cases included burns from igniting *diya* (earthen oil lamps) and mishandling chimneys of

kerosene lamps. Between February and April 1994, hospitals within the four districts of the State of Rujnstan experienced an epidemic of lamp-related burn injuries (144). In total, 303 burn injuries were reported and most of these injuries occurred from a flame explosion when users poured a highly inflammable petrol-kerosene mixture into ignited lamps. The accidental mixture of petrol and kerosene occurred during the distribution process and not by the end users, similar to the epidemic of severe burns in 1984 in Lagos, cited above in the section on risk factors for cooking-related burns.

In Sri Lanka, 41% of patients admitted to the Batticaloa General Hospital for burns during 1999-2001 were burned by fires caused by falling kerosene bottle lamps (145). In Mozambique, most burn deaths in Maputo Central Hospital were caused by a homemade bottle lamp called a *xiphfo* (146).

A review of burn injury literature in Sri Lanka (from 1966-2005) revealed that as much as half of all domestic burns are the result of toppled kerosene lamps (42).

Ahmed and associates conducted interviews with the parents of 100 pediatric burn victims under the age of 16 years admitted to the Dhaka Medical College Hospital Burn Unit in Bangladesh from the middle of January to the end of June 2005 (147). Flames caused the majority of burn injuries (68%), one-quarter of which were produced by traditional kerosene oil lamps (*kupi bati*).

A nested case-control study conducted in rural Bangladesh examined burn injuries among children of less than 10 years old. The use of a *kupi bati* in the home tripled the risk of childhood burn injuries compared to homes not using a *kupi bati* (OR 3.16) (108).

There is limited available data on lamp-related burn injuries in LMICs. However, the evidence suggests that this issue should be examined more closely to include both lamps fueled by flammable gas or liquid, especially kerosene.

3.6.2 Risk Factors for Lighting-Related Burns

In 2008, Peck and associates highlighted design issues with lamps in LMIC settings (141). These design issues were derived primarily from the experiences of the authors, most of whom lived and worked in LMICs.

Lamps are a major source of lighting in parts of the world with limited or inadequate access to electricity. A potential risk factor in lamp-related burn injuries is the instability of their design. In Sri Lanka, for example, lamps traditionally are tall and narrow-based, and do not have secure lids. These factors likely contribute to burn injuries from toppled lamps (148). Homemade lamps (*xiphfo*) in regions of Mozambique are also noted to have instability problems similar to the lamps in Sri Lanka due to unstable bases (146). Furthermore, *xiphfo* are popular in suburban areas lacking electric power, where most of the population lives.

According to Ahmed and associates, Bangladeshi children wearing loose attire (*frock* and *lungi*) are at risk of burns while carrying a *kupi bati* (i.e., uncovered kerosene lamps) (147). This is a problem similar to that noted due to ignition of loose-fitting clothing (such as *saris*) worn by women and girls while working around open flames in the kitchen (See sections above on gender-related personal risk factors for all burns, as well as risk factors for cooking-related burns.)

3.6.3 Prevention of Lighting-Related Burns

Reviews of lighting-related burns highlight the Sri Lanka Safe Bottle Lamp Program, which successfully redesigned lamps and created a cottage industry for safe and affordable products to prevent kerosene spills (www.rolexawards.com). (11) The principles of this program should be used more widely in other LMICs. Nonetheless, electrification is by far the best overall policy option for lighting, because it will reduce household air pollution, as well as protect household occupants from burns. This can be by grid connection, mini-grid, or home-based systems including solar photovoltaic (PV) as well as compact fluorescent lamp (CFL) or a light emitting diode (LED) lanterns. The latter options have considerable feasibility and affordability in many LMIC settings, and have the additional benefit of minimizing CO₂ production at coal-powered electrical plants. Mashreky and associates suggest that the use of *kupi bati* should be avoided completely or at least restricted. The authors suggested that the *kupi bati* be replaced by a *hariken*, a type of kerosene lamp where the flame is protected by a glass chimney and there is minimal of oil spillage (108). Ahmed and associates indicated that technological improvements should aim to convert uncovered kerosene lamps, such as *kupi bati*, into more “affordable, safe, covered, and handy” lamps that will minimized the risk of catching fire (147).

3.6.4 Overall Assessment of Evidence on Lighting

The literature revealed that lighting-related burn injuries are most commonly caused by falling or toppled bottle or wick lamps. Design characteristics such as narrow, unstable bases and lack of secure lids appear to contribute to lamps being knocked over and causing flame burns. The limited evidence suggests that children may be at greatest risk for lighting-related burn injuries.

Only one intervention study was identified, which found that the use of a *kupi bati* in the home tripled the risk of childhood burn injuries compared to homes not using a *kupi bati*. Lighting with kerosene, candles, and other non-electric appliances, is an important risk, but evidence on specific preventive measures and the associated reduction in risk is weak. Recommendations will therefore take account of wider policy and practice, and the inherent safety of electric lighting that should be seen as the most important intervention strategy.

3.6.5 Research Gaps/Future Research Needs for Lighting-Related Burns

Among LMICs, there is a dearth of published literature on the combustion of fuel used in homes for lighting and its association with burn injuries. The existing literature focuses primarily on homemade or commercial wick lamps. Many lamps suffer from design issues that likely increase the risk of burns because these lamps are tipped over easily. To our knowledge, the sole intervention focuses on redesigning kerosene-fueled lamps to reduce spills, and, while promising, has not demonstrated effectiveness. Better surveillance data are needed with specific information related to burn admissions that involve lamps. This would help better understand the nature, severity, and long-term sequelae of these burn injuries. In addition, engineers should continue to (re-)design lamps and epidemiologists should evaluate the resultant impact on burn injuries.

4. Kerosene (Paraffin) Poisoning

Poisoning injuries result from exposure to an exogenous substance that causes cellular injury or death. A poison is any substance that is harmful to your body if too much is eaten, inhaled, injected, or absorbed through the skin. Any substance can be poisonous if too much is taken.

This section discusses poisoning from paraffin (or kerosene), which is a common fuel source for cookstoves and also a common cause of poisoning. There is little evidence that other fuel sources for cookstoves pose a substantial poisoning risk.

In low-income countries, paraffin continues to be used as an energy source for cooking, heating, and lighting. For example, in South Africa despite efforts to increase its population's access to electricity, 21.4% still use paraffin for cooking (149). This need results in individuals purchasing and storing paraffin in their homes. Homes in low-income countries often store paraffin in containers such as milk or soft-drink bottles.

4.1 Burden of Kerosene Poisonings

The high use of paraffin in the home not only increases burn risk, but it also increases the risk of poisoning through inadvertent ingestion. In 2004, an estimated 346,000 people died worldwide as a result of “accidental” poisoning from all substances (76). Circumstances and risks surrounding these depend on the substance, location of incident, community, and country.

Ingestion of kerosene can result in a range of clinical consequences (150-154). Gastro-intestinal symptoms, such as vomiting, diarrhea, and abdominal pains, are common, but often mild. Gasping, choking, and vomiting after kerosene ingestion predispose an individual for aspiration, which results in pulmonary injury. Most patients suffer from respiratory distress, including coughing, tachypnea, cyanosis, lung infiltrates, and pneumonia. Clinical features involving the central nervous system are less common, but may include symptoms such as restlessness, drowsiness, and convulsions. Severity and recovery depends on the amount of poison swallowed and how quickly treatment was received. Treatment can involve oxygen administration to avoid hypoxemia, and antibiotics can be prescribed to prevent secondary pulmonary infection; additionally, corticosteroids can be given for severe bronchospasms (155).

Reports of poisoning from home ingestions have come from numerous countries including Botswana (156), Kenya (157), India (33, 154, 158), Iraq (152), Israel (159), Jordan (160, 161), Nigeria (162), Pakistan (163, 164), South Africa (153, 165-167), Sri Lanka (168), and Zimbabwe (169, 170). In many instances, paraffin oil is a frequent substance ingested, and often the most common source for poisonings among children. The estimation of total burden is challenging since most of the studies are not really population based. Most are reports from individual hospitals, which may or may not be representative of that catchment area, and mostly likely not representative of the country as a whole.

4.2 Risk Factors for Kerosene Poisonings

Age

Numerous studies have documented that incidence of paraffin poisoning is most common among young children (153, 154, 160, 163, 165, 167). Toddlers, in particular, are curious, explore the world with their senses, and are not mature enough to identify and avoid hazardous materials like paraffin.

Poverty

Low socioeconomic communities and groups are at greater risk for paraffin poisoning (152, 161, 163, 164, 171). These households are more likely to use paraffin as an energy source, and thus have access and store paraffin in their homes.

Rural areas

Rural households are also more likely to be dependent of paraffin compared with urban areas that have more access to electricity. This and the fact that these households may have less exposure to media campaigns on television and radio result in added risk to these communities (153, 154). Transportation to the nearest health facility can be a problem for rural communities; therefore, poisoning incidents in these areas can be underreported.

Summer months

More children inadvertently drink paraffin in the summer months (159-161, 163, 165) when heat causes thirst and in extreme cases dehydration. Children can easily mistake paraffin for water as it is often stored in cold-drink or milk bottles (33, 161, 162, 164). Paraffin also has the appearance and viscosity of water, adding to the confusion. In the summer, the volume of poison that is swallowed may be larger with more dehydration and thirst.

Summary

The literature indicates that paraffin is the most common source of unintentional poisonings in LMICs. Children are most likely the highest risk group. Child poisonings appear to increase during summer months due to increased thirst and dehydration coupled with mistakenly confusing paraffin for other liquids such as water. Evidence suggests that low SES and rural communities experience disproportionate amounts of paraffin poisonings, most likely due to their higher dependence on and use of paraffin.

4.3 Prevention of Kerosene Poisonings

Child-resistant Containers and Child-resistant caps

There is evidence that the use of child-resistant containers (CRCs) is effective at preventing poisonings (172). The challenge with this strategy is cost. Programs that distribute CRCs can require substantial resources to implement, and selling paraffin in CRCs would notably increase the cost to both the seller and consumer. Another approach is the use of child-resistant bottle caps. These caps should be able to fit a variety of standard bottles that may be used to store paraffin. This is potentially more cost effective than CRCs.

Safe Storage

Paraffin exposure and access among children is related to how it is being stored in the home. Risk of paraffin poisoning to children may be reduced, if paraffin containers are stored in high spaces such as the top of cupboards and shelves, or are stored in locked cabinets.

Supervision

Children at risk are often not sufficiently supervised. In many cases, a child seen for paraffin poisoning was in the care of another child (153). In many high risk countries, it is common for older siblings to be responsible for the younger members of the household.

Education

Public health safety campaigns can be used to educate various audiences including children, parents, consumers, retailers, and health care workers. While public education is a common prevention strategy, there are only a few reports that assess the effectiveness of paraffin poisoning safety education. One safety campaign used radio ads and posters to describe the dangers of paraffin and the preventive measures that can be taken. They found that there was an increase in knowledge, but not improvement in safety behaviors (173). Another study conducted a survey in an area where general paraffin safety messages were delivered to the

public. These messages were being disseminated through various sources, such as radio, television, newspapers, etc. Among respondents that heard the safety messages, they found that there was no difference in reported paraffin ingestions or changes in safety behavior (171). A third study found that a paraffin hazard poster, which was developed by a petroleum company, was not well understood by children (174), indicating that such materials should be tested and evaluated prior to distribution.

Direct education through home visitation is another approach that has been shown to be effective for childhood thermal injury prevention in developed countries (175). One study examined this in low and middle income countries for poisoning. They used lay community workers to deliver a home intervention on burns, poisonings, and falls. The intervention included an injury hazard checklist, discussion on possible changes to reduce risk, and the provision of safety devices, such as paraffin safety caps. They found only modest reductions in injury risks, suggesting the need for further improvement and testing of home visitation programs (138). Another study used the home visitations, but they used a train-the-trainer approach and based their education on behavior change theories; specifically, they worked to alter the perception of vulnerability. They found improvements in knowledge, recognition of injury risk, and safety practices (126).

Color

Ingestion of paraffin by young children may be reduced if paraffin did not look so similar to water. This approach was used in Australia, where the color of paraffin was changed to blue as a warning of toxicity (176). While there is little evidence of this strategy being used in other countries, this could be a promising approach to address the issue in LMICs.

4.3.1 Summary of evidence for interventions to reduce poisoning through ingestion of fuel

In total, three intervention studies were identified from the conducted reviews relating to prevention of ingestion of fuel. These are shown in Table 7. All were conducted in South Africa with one randomized control study and two quasi-experimental designs. Schwebel et al (126) identified a significant improvement in self-reported knowledge of kerosene safety ($p < 0.01$) and observed practice of safe kerosene use ($p < 0.05$) following an educational intervention (theory-driven materials). However there was a significant decrease ($p < 0.05$) in the self-reported recognition of risk for kerosene-related injury within the intervention group. Krug et al (172) found a significant reduction in the incidence of clinical pediatric presentations to hospital for kerosene ingestion in an intervention area where 20,000 child-resistant storage containers were distributed (approximately 40% of households) compared to a control region in South Africa. Intervention and control regions had had similar incidence rates prior to the intervention. Swart et al (138) found a non-significant reduction in a poisoning score (from a risk assessment tool) following an intervention involving a home visit to improve home safety including the safe storage of liquid fuel. All three intervention studies were rated highly for methodological quality with a low risk of bias.

Table 7: Summary of experimental studies of the impact of interventions on kerosene poisoning

First author, Year; Design; Summary	Location	Population/ Setting	Intervention	Measurement of poisoning	Results	Quality assessment ^s																																				
Schwebel, 2009 Prospective Quasi-experimental, non-equivalent case vs control groups	Phillipi and Du Noon districts (near Cape Town), South Africa	Low-income housing districts Controls n=106, Intervention n=100	Delivery of educational materials (theory-driven)	Self-reported knowledge of kerosene safety; observed practice of safe kerosene use; self-reported recognition of risk for kerosene-related injury.	Survey scores: <table border="1"> <thead> <tr> <th>Knowledge*</th> <th>baseline</th> <th>Post</th> <th>Mean change</th> </tr> </thead> <tbody> <tr> <td>Control</td> <td>11.83</td> <td>12.89</td> <td>1.07</td> </tr> <tr> <td>Intervention</td> <td>11.03</td> <td>14.39</td> <td>3.28</td> </tr> <tr> <td>Practice*</td> <td></td> <td></td> <td></td> </tr> <tr> <td>Control</td> <td>0.41</td> <td>0.46</td> <td>0.05</td> </tr> <tr> <td>Intervention</td> <td>0.38</td> <td>0.49</td> <td>0.10</td> </tr> <tr> <td>Risk Perception*</td> <td></td> <td></td> <td></td> </tr> <tr> <td>Control</td> <td>3.76</td> <td>3.53</td> <td>-0.24</td> </tr> <tr> <td>Intervention</td> <td>4.54</td> <td>3.65</td> <td>-0.87</td> </tr> </tbody> </table> *Between group mean change p<0.05 unadjusted ** Between group mean change p<0.01	Knowledge*	baseline	Post	Mean change	Control	11.83	12.89	1.07	Intervention	11.03	14.39	3.28	Practice*				Control	0.41	0.46	0.05	Intervention	0.38	0.49	0.10	Risk Perception*				Control	3.76	3.53	-0.24	Intervention	4.54	3.65	-0.87	9/11
Knowledge*	baseline	Post	Mean change																																							
Control	11.83	12.89	1.07																																							
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Control	3.76	3.53	-0.24																																							
Intervention	4.54	3.65	-0.87																																							
Krug, 1994 Prospective study comparing control/intervention districts (after 14 months) Quasi-experimental	South Africa	Gelukspan and Lehurutshe districts	Distribution of 20,000 child-resistant containers in Gelukspan	Hospital and clinical records of pediatric paraffin ingestions	Post CRC distribution Incidence rates: Control area: 9.80/100,000 Intervention area: 4.54/100,000 P=0.015 RR=0.46 (unadjusted estimate but baseline poisoning incidence rates very similar intervention and control areas).	9/11																																				

First author, Year; Design; Summary	Location	Population/ Setting	Intervention	Measurement of poisoning	Results	Quality assessment [§]
Swart, 2008 RCT	South Africa	4 low-income communities near Johannesburg and Cape Town; random selection. Intervention n=189 households; Control n=188 households. Children under 10 years.	Home visitation program to improve home safety. Included 4 visits, distribution of safety information, completion of home hazard checklist, distribution of safety devices (e.g. child proof locks and paraffin container safety caps)	Scores from a risk assessment tool	Poisoning Score – Post Intervention: Control: 2.4, SE=0.20 Intervention: 1.9, SE=0.20 Intervention effect P-value=0.110 [Note: lower mean score equates to lower risk, but the intervention effect was not significant]	10/11

[§] Quality assessment represents total available “stars” for a specific study design (Section 2.2)

4.4 Research Gaps/Future Research Needs for Kerosene Poisoning

These few studies highlight the need for the development and evaluation of stronger educational efforts. Messages should address known risk factors and aim to improve safety behaviors, not just increasing awareness. Impact could be greater if education campaigns are part of a broader prevention plan that includes other strategies listed here.

5 Overall Assessment of the quality of evidence on burns and poisoning

A systematic review of burns and poisoning was carried out to assess risks associated with the use of various household fuels for cooking, heating and lighting. Prevention (intervention) efforts were also examined. Devices designed to be more energy efficient (including greater combustion efficiency) than prior alternatives may be considered as interventions that reduce pollutant emissions, but cannot be assumed to necessarily be as safe, or (ideally) safer than their predecessors. The review included two types of evidence relevant to assessing these issues:

- Descriptive studies of risk factors for burns and poisoning, including the devices and fuels used in the home, that might provide evidence having a bearing on the recommendations made to improve air quality
- Intervention studies of impacts of behavioural and technology interventions (although recommendations on improving safety were not a primary aim of these guidelines).

Risk factors

A substantial number of studies described risk factors for burns (including scalds) and poisoning, but an over-riding feature of the review was the lack of population-based studies; most were retrospective hospital studies and focused mainly on liquid fuels, in particular kerosene. This resulted in relatively little information being available on levels and characteristics of risk in the broader population, and concern that those cases reaching facilities are likely to be non-representative in terms of socio-economic and geographic factors, and possibly injury severity. The finding that household fuel use (especially for cooking), and in particular kerosene use, was among the most important causes of burn injuries in many studies, may provide a reliable indication of the importance of the household setting, and of the role of kerosene in particular. The lack of data on burns from solid fuel stoves, however, may be more a function of fewer community-based studies, as solid fuels are used more widely in rural areas. Kerosene was also found to be the main cause of household fuel poisoning injury, which is also judged to be a reliable finding as this is the most widely used liquid fuel.

Interventions

Meta-analysis was not carried out for the intervention studies due to the small number of studies and variable interventions and outcomes. The review for cooking-related burn interventions found two studies (one an RCT and the other a quasi-experimental design) that assessed the impacts of 'improved' stoves and fuels on burns as an outcome. The quality of both was high due to their inherent design features. Two other studies, also of high quality, examined the effects of awareness-raising on safety risk scores and behaviours. No intervention-based studies investigated the prevention of residential heating burns in LMICs. Only one intervention study was reported for lighting. Overall, it was therefore concluded that empirical evidence from LMICs on specific preventive measures and the associated reduction in risk is weak. For

kerosene poisoning, one RCT and two quasi-experimental studies investigated the prevention of a disparate range of interventions (educational materials, container proofing and home visits) and outcomes (knowledge and practice scores and incidence rates). No firm conclusions on poisoning prevention interventions can be drawn due to this heterogeneity.

Summary

This assessment found that, while there is substantial evidence that household fuel use (and especially kerosene) is an important cause of burns and poisoning in LMICs, the role of solid fuels and other fuels (including LPG) in injuries is poorly described, primarily due to a lack of population-based studies. Given the specificity of the linkage between fuel use and injury from burns and poisoning, however, the evidence that household fuels present an important safety risk (a key question for this systematic review) was assessed as being of **moderate** quality, with concern about kerosene noted. Although some high-quality experimental studies have been reported, these are still few in number and too variable in respect of interventions and outcomes to be pooled. Evidence on the level of risk reduction that can be achieved by various preventive strategies was assessed as being of **low** quality.

6. Stove Safety Testing

Cookstove design options that improve user safety can be overlooked in the absence of suitable protocols to test safety. And while there are several protocols used in controlled laboratory settings, laboratory methods and equipment are ill-suited for application in the field by small-scale stove producers throughout the world. Safety protocols that are developed to address the technical and financial limitations of manufacturers in this segment of the stove industry can benefit users and producers that are often underserved by product safety efforts.

6.1 Understanding the Challenge

Cookstove production volumes and manufacturing capabilities are varied throughout the developing world. In many areas artisans and household business produce hand-crafted cookstoves in small volumes that are distributed locally. In a few regions the recent introduction of mass-manufacturing techniques has produced machined stoves in high volumes for nationwide or international distribution. Yet, regardless of manufacturing origin, consumer safety should be a health priority. Due to the fragmented techniques and capabilities of the cookstove industry it is unlikely that the mechanism to improve consumer safety be universal, at least in the short term.

Available national and international stove standards are based on the premise that stoves are produced in high volumes at close tolerances using industrial equipment. Although these standards fit the industry in developed countries with regulatory bodies and advanced testing laboratories, the protocols and approval processes are poorly suited for application to small-scale stove production schemes in developing countries that face financial and logistical barriers for laboratory evaluation of stove safety. Even today many institutions and laboratories use in-house protocols to test cookstove safety and performance, suggesting that more work is needed to create a product standard appropriate for cooking stoves, whether they be machined or hand-crafted.

Many of the cookstoves available today have been produced in low volumes by artisans, household businesses, and local workshops. Improving the safety these cookstoves is a challenging issue that is unlikely to be addressed by national product standards with laboratory

equipment and procedures. Ideally, safety evaluation would be completed in the field to reach the distributed network of small-scale stove producers that lack money, have little equipment, and little laboratory training. In the interim, field-based protocols have been introduced to encourage these decentralized industries towards safer cookstove designs. The protocols focus on solid fuel cookstoves that form the majority of cooking technologies available in developing countries.

6.2 Field-based safety protocols for solid fuel cookstoves

A limited amount of statistical data is available on the specific hazards leading to cooking-related injuries. And while this prohibits the development of safety protocols based on a quantitative evaluation of risk, the hazards can be identified and limited such that they are within acceptable safety margins. The hazard-based approach used by Johnson (177) identified cookstove hazards, introduced protocols to address the hazards, and provided procedures to measure cookstove performance against each protocol. Ten safety protocols were given to address hazards related to burns (including scalds), cuts and property loss (Box 1.1). Five protocols were adapted from ANSI standards related to indoor and outdoor gas cooking appliances (178, 179); five additional protocols were created to address additional concerns for hand-crafted solid fuel cookstoves. Additional cookstove safety standards from around the world were also consulted, and are provided in Annex 1 with updated editions and new protocols.

An example measurement is given in Box 1.2 for protocol 2, cookstove tipping. The metric of interest is the angle at which the cookstove begins to tip, as discussed by American National Standards Institute ANSI (178) and expanded to a tiered rating by Johnson (177). This procedure is easier for field implementation than horizontal force calculations using force gauges in other standards (180).

Box 1.1. Solid fuel cookstove safety protocols.

1. Sharp edges and points: Exterior surfaces of a cookstove should not catch or tear any article of clothing or cut hands during normal use.
2. Cookstove tipping: Cookstoves should come back to rest upright after being slightly tipped from their original position.
3. Containment of fuel: Burning fuel should rarely fall from stove if overturned; embers/burning fuel should have little chance of being expelled from the combustion chamber.
4. Obstructions near the cooking surface: The area surrounding the cooking area should be flat.
5. Cookstove surface temperature: Burns should not occur if the cookstove surface is touched for a short duration of time.
6. Environment surface temperatures: A cookstove should not cause dangerously elevated temperatures on surrounding surfaces in the environment.
7. Temperature of operational construction: Cookstove operational construction should not reach a temperature where use can cause harm either directly or indirectly.
8. Chimney shielding: Chimneys with elevated temperatures should have shielding to prevent contact from children and users.
9. Flames surrounding cooking vessel: Flames touching the cooking vessel should be concealed and not able to come into contact with hands or clothing.
10. Flames/fuel exiting the fuel chamber: Flames or fuel should not protrude from the fuel chamber.

Each protocol specifies a one- to four-point rating system (1-Poor, 2-Fair, 3-Good, 4-Best). This is a departure from product standards in developed countries that commonly use a compulsory

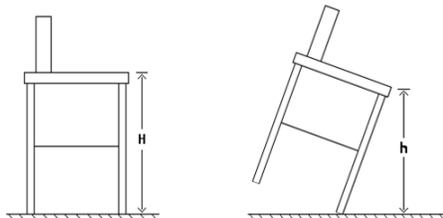
all-or-none judgment. The tiered safety rating system was preferred in that the protocols are voluntary, provide a mechanism to track safety improvements for each protocol, facilitate consideration of safety alongside other cookstove performance criteria, and capture trends in the highly heterogeneous market of hand-crafted solid fuel cookstoves. Each protocol is assigned a multiplier based on a qualitative understanding that some hazards (for example open flames) have a higher risk than others hazards (for example sharp edges), thereby equating the 40-point scale to a 100-point scale.

Box 1.2. Cookstove tipping protocol. Reproduced with permission

Equipment: Fuel, cooking vessel, tape measure, calculator

Procedure:

1. Load stove with fuel but do not ignite;
2. Pick one side to tip the stove, measure the standing height of that side, H , place the value in Table A;
3. Slowly tip the cookstove in that direction until the cookstove begins to fall without added force, measure the new height of the point, h , place in Table A;
4. Using a calculator, divide the tipped height by the standing height to find the tipping ratio, R ;
5. Repeat four times for each direction;
6. Repeat process as many times as there are legs on the cookstove, or no less than four times for a circular base;
7. Use the largest tipping ratio, R , from tests completed in all directions with the metric in Table B to find the safety rating;
8. Repeat with the cooking vessel.



$$R = \frac{h}{H}$$

Table A

Run	Starting height H (cm)	Tipped height h (cm)	Tipping ratio R
1	85.2	80.8	0.948
2	85.2	81.1	0.952
3	85.2	80.7	0.947
4	85.2	80.9	0.950

Notes: no cooking vessel, direction towards fuel loading

Table B

Rating	Tipping ratio R
Best	$R < 0.940$
Good	$0.940 \leq R < 0.961$
Fair	$0.961 \leq R < 0.978$
Poor	$R \geq 0.978$

Hazards associated with solid fuel collection and storage were not considered in the analysis, yet can pose health risks. (181) To date these protocols have focused on improving cooking safety by advances in cookstove design and not through changing site-dependent fuel collection or storage practices.

6.3 Results from cookstove safety testing

Figure 5 displays the overall cookstove ratings for 42 different designs of solid fuel cookstoves. The ability of a cookstove design to reduce risk matches the trend in cookstove safety ratings

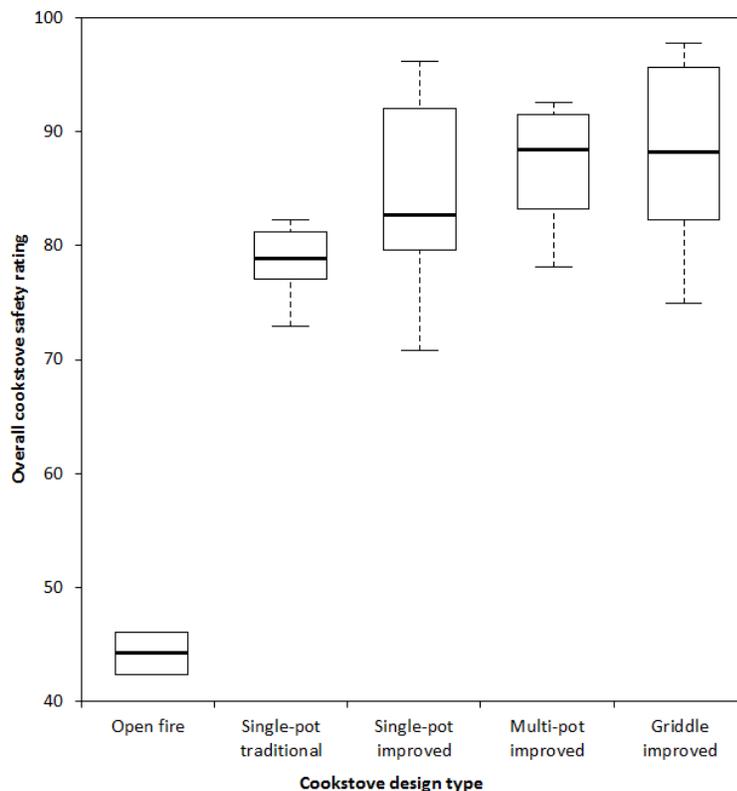
- Open fires score well below any type of enclosed fire in the other four design types. The lack of fire and ember enclosure (protocols 3, 5–7), flames surrounding the cooking vessel (protocol 9), and flames exiting the fuel chamber (protocol 10) produce an unsafe cooking environment for women and children.
- Single-pot traditional cookstoves include most charcoal stoves and many wood stoves that enclose the fire, yet lack an improved combustion chamber. These stove designs reduce the risk of skirt and hair fires by enclosing the fire and reduce the risk of burned hands or feet of children near the fire (protocols 3 and 10). However, many designs are hand-crafted with minimal tools that create sharp edges and points (protocol 1), small and prone to tipping (protocol 2), or have thin metal walls that reach excessive temperatures (protocols 5–7).
- Single-pot improved cookstoves include rocket stoves and gasifiers. Several designs are similar to single-pot traditional cookstoves in size and wall construction and therefore receive similar safety ratings. Several other designs have higher safety ratings. These improvements have commonly been achieved by adding insulation around the combustion chamber and increasing wall thickness. This in turn decreases exterior wall surface temperature—a hazard addressed by three of ten protocols (protocols 5–7).
- Multi-pot improved cookstoves are commonly fixed to the ground or have a broad base that prevents tipping. In general multi-pot cookstoves provide a reduced risk of burns due to low exterior surface temperatures, and a reduced risk of scalds due to the difficulty in cookstove tipping. Often including a chimney, the temperature of the chimney must also be within safe limits (protocol 5) or be shielded to prevent human contact (protocol 8).
- Griddle cookstoves often enclose the fire except for small space left open for fuel loading. The safest rated cookstoves are griddle designs with thick clay or earthen walls that yield low wall surface temperatures; the lower rated griddle designs generally have a metal wall construction with higher surface temperatures. As with many improved cookstoves, griddle cookstoves are typically manufactured with greater workmanship and therefore have reduced risk of cuts due to sharp edges (protocol 1). However, drop-in griddles commonly have handles that protrude from the cooking surface and create obstructions for pots moving from the griddle (protocol 4), thereby increasing the risk of scalding.

6.4 Next steps and research and development needs

These protocols were proposed for voluntary use as interim measures to move the discussion forward towards improved cookstove safety. As such, the procedures were designed for use by decentralized small-scale producers that have little, if any, mechanism to measure cookstove safety. Cookstoves machined to strict tolerances and mass-produced for global distribution can implement a different strategy based on internationally recognized standards that can be more rigorous than field-based protocols. Future work for both low- and high-volume production includes

- Durability (static loads and thermal cycling),
- Additional protocols to prevent hazards unsuitable for field testing,
- Laboratory-based procedures and equipment with controlled operating conditions for improved repeatability,
- Protocols and procedures applicable to all cookstove designs and fuel types (for example solar ,liquid fuels, gaseous fuels),
- Consideration given to fuel collection and storage.

Figure 5: Safety ratings for solid fuel cookstoves (minimum of 25, maximum of 100 points).



Results from tests completed at Iowa State University, the Engines and Energy Conversion Laboratory at Colorado State University, and Aprovecho Research Center.

7. Conclusions

We reviewed the quality and strength of the evidence in low and middle-income countries for burns, including scalds, associated with the combustion of household fuels used for cooking, heating, and lighting. We also applied this process to poisonings resulting from the ingestion of liquid fuels such as kerosene.

The published literature is sparse when examining the burden, risk factors, and prevention efforts associated with these issues. For example, except for one unpublished randomized

controlled trial (1) and one quasi-experimental study from Madagascar (2) there are no experimental studies focused on burn injuries.

Evidence informing the epidemiology of burns comes primarily from studies including national and regional public health registries, hospital and/or burn center registries, and community surveys. There is a probable bias with HICs and regions of higher income in LMICs having better hospital facilities, surveillance systems, and the capacity to generate data and publish findings.

In the combustion of fuels at home (that is, cooking, heating, and lighting), most burn injuries are caused by a hot liquid (scalds), a hot solid (contact burns), or a flame (flame burns) (6). The most severe burns (in terms of depth of burn and size of area burned) are caused by flames. Cookstove explosions, although sparsely documented in the scientific literature, can be devastating and cause mass casualties.

Cookstoves may represent the single most important modifiable risk factor for burn injuries. Interventions that have been proposed to reduce exposure to fires and flames seem intuitively correct but have largely not yet been formally tested for effectiveness in reducing burn injuries. RESPIRE, which assessed the impact of an improved wood stove with a chimney (compared to the continued use of an open stove), is the only intervention study demonstrating reductions in cookstove-related burn injuries. The Sri Lanka Safe Bottle Lamp Program reduces kerosene spills from toppled lamps, and should reduce the risk of burn injuries, although reduction in burns has not yet been documented. Research on cookstove burn safety should focus on improving cookstove designs and implementation, and increasing quality data collection and reporting. There are four main practices that can increase the public health benefits in a growing movement to develop and disseminate cookstoves in low and middle-income countries: targeting high risk populations, increasing health education and promotion efforts (e.g., in tandem with the rollout of cookstove programs),, informing policy efforts, and collaborating with international partners.

Kerosene poisoning remains an important public health problem, especially among children in developing countries where kerosene is used regularly for cooking, heating, and lighting. The development and implementation of prevention efforts will be enhanced when there is more systematic data at the country and community level to fully understand the burden and risk.

Annex 9.1. Summary of international stove safety standards

Fuel Type	Institution	Year	Standard No.	Standard Title
Solid	CEN	2003	EN 1860-1	Appliances, solid fuels and firelighters for barbecuing - Barbecues burning solid fuels
	CEN	2004	EN 1860-4	Appliances, solid fuels and firelighters for barbecuing - Single use barbecues burning solid fuels
	CEN	2001	EN 12815	Residential cookers fired by solid fuel
	CEN	2001	EN 13229	Inset appliances including open fires fired by solid fuels
	BIS	1991	IS 1315Z	Solid biomass chulha
	SABS	2008	SANS 1111	Coal-burning appliances (reduced smoke emission type)
	SABS	1982	VC 8034	Coal-burning stoves and heaters for use in a dwelling
	UL	2007	ANSI/UL 737	Fireplace stoves
	UL	1999	UL 1101	Standard for solidified fuel cooking appliances for marine use
Liquid	ISO	2000	ISO 14895	Small craft - Liquid-fueled galley stoves
	SABS	2007	SANS 1243	Pressurized paraffin-fuelled appliances
	SABS	2009	SANS 1906	Non-pressure paraffin stoves and heaters
	UL	1999	UL 1100	Standard for alcohol and kerosene cooking appliances for marine use
Oil	JSA	2009	JIS S 2016	Oil burning cooking stoves
	JSA	2009	JIS S 2019	Open type natural ventilating oil burning space heaters
	JSA	2007	JIS S 2038	Wicks for oil burning appliances
	UL	1993	ANSI/UL 896	Standard for oil-burning stoves
Gel	SABS	2010	SANS 448	Ethanol gel for cooking and other gel burning appliances
	SABS	2008	SANS 666	Ethanol-gel fuelled appliances
Gas	ANSI	2005	ANSI Z21.1	Household cooking gas appliances
	ANSI	2007	ANSI Z21.58	Outdoor cooking gas appliances
	ANSI	2000	ANSI Z21.72	Portable type gas camp stove
	CEN	2008	EN 30-1-1	Domestic cooking appliances burning gas
Electric	CEN	2002	EN 60335-2-6	Household and similar electrical appliances. Particular requirements for stationary cooking ranges, hobs, ovens and similar appliances
	CEN	2002	EN 60335-2-36	Household and similar electrical appliances. Particular requirements for commercial electric cooking ranges, ovens, hobs and hob elements
	CEN	2002	EN 60335-2-37	Household and similar electrical appliances. Particular requirements for commercial electric deep fat fryers
	IEC	2010	IEC 61558-1	Safety of power transformers, power supplies, reactors and similar products
	SABS	2006	SANS 153	Electric stoves, cooking tops, ovens, grills and similar appliances
	UL	2010	ANSI/UL 197	Standard for commercial electric cooking appliances
	UL	2005	ANSI/UL 858	Standard for household electric ranges

Abbreviations

ISO International Standards Organization
ANSI American National Standards Institute
UL Underwriters Laboratory
CEN European Standard Commission

JSA Japanese Standards Association
BIS Bureau of Indian Standards
SABS South African Bureau of Standards

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