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Global, regional, and subregional classification of abortions by safety, 2010–14: estimates from a Bayesian hierarchical model

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Summary

Background Global estimates of unsafe abortions have been produced for 1995, 2003, and 2008. However, reconceptualisation of the framework and methods for estimating abortion safety is needed owing to the increased availability of simple methods for safe abortion (eg, medical abortion), the increasingly widespread use of misoprostol outside formal health systems in contexts where abortion is legally restricted, and the need to account for the multiple factors that affect abortion safety.

Methods We used all available empirical data on abortion methods, providers, and settings, and factors affecting safety as covariates within a Bayesian hierarchical model to estimate the global, regional, and subregional distributions of abortion by safety categories. We used a three-tiered categorisation based on the WHO definition of unsafe abortion and WHO guidelines on safe abortion to categorise abortions as safe or unsafe and to further divide unsafe abortions into two categories of less safe and least safe.

Findings Of the 55·7 million abortions that occurred worldwide each year between 2010–14, we estimated that 30·6 million (54·9%, 90% uncertainty interval 49·9–59·4) were safe, 17·1 million (30·7%, 25·5–35·6) were less safe, and 8·0 million (14·4%, 11·5–18·1) were least safe. Thus, 25·1 million (45·1%, 40·6–50·1) abortions each year between 2010 and 2014 were unsafe, with 24·3 million (97%) of these in developing countries. The proportion of unsafe abortions was significantly higher in developing countries than developed countries (49·5% *vs* 12·5%). When grouped by the legal status of abortion, the proportion of unsafe abortions was significantly higher in countries with highly restrictive abortion laws than in those with less restrictive laws.

Interpretation Increased efforts are needed, especially in developing countries, to ensure access to safe abortion. The paucity of empirical data is a limitation of these findings. Improved in-country data for health services and innovative research to address these gaps are needed to improve future estimates.

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Introduction

Despite scientific advances that enable the provision of safe abortion at the primary care level, unsafe abortions persist and result in a high burden of complications; maternal death; and substantial costs to women, families, and health systems.[1–3]

WHO defines unsafe abortion as a procedure for termination of a pregnancy done by an individual who does not have the necessary training or in an environment not conforming to minimal medical standards. However, abortions done in accordance with these standards are considered safe and the risk of severe complications or death is minimal.[4] The people, skills, and environment needed to meet medical standards are outlined in WHO guidelines, which are updated periodically.[5,6] In the 25 years since unsafe abortion was defined, evidence has evolved and simple technologies, such as manual vacuum aspiration and medical abortion (with mifepristone and misoprostol, or misoprostol alone if mifepristone is unavailable), have made the provision of safe abortions possible at the primary care level and by health workers other than doctors.[5,6] The conditions leading to a safe abortion are in turn affected by numerous factors, including the laws and policies on abortion (ie, legal context), the socioeconomic conditions, the availability of safe abortion services, and the stigma surrounding abortion. Stigma related to seeking or provision of abortion is increasingly being recognised as having an

Research in context

Evidence before this study

From 1990 to 2008, WHO used indirect estimation techniques to determine the incidence of abortion in countries with restrictive laws and in countries with more permissive laws but where a large number of abortions took place illegally. These abortions were labelled as unsafe, and these estimates were integrated with estimates of the incidence of legal abortion worldwide, developed by the Guttmacher Institute. Such global, regional, and subregional estimates of safe and unsafe abortions have been produced for 1995, 2003, and 2008. The most recent estimates were published in *The Lancet* in 2012 and concluded that 21·6 million (49%) of 43·8 million abortions in 2008 were unsafe. However, to date, categorisation of safety based on the actual characteristics of abortion has never been attempted.

Added value of this study

The new approach used in this study represents a significant advance compared with previously published estimates for several reasons. First, this study is the first to explicitly align the operational estimation of safety categories with the conceptual definition of unsafe abortion used by WHO and with the technical standards of care outlined in WHO guidelines. Second, use of a model-based approach allowed for consideration of multiple factors affecting abortion safety in a systematic way. Third, replacement of the dichotomous division of safety with a three-tiered classification (safe, less safe, and least safe) permitted a more nuanced description of the spectrum of varying situations that constitute unsafe abortion and the increasingly widespread substitution of dangerous, invasive methods with use of misoprostol outside formal health systems in some legally restricted contexts to be accounted for. Fourth, this study is the first to include uncertainty bounds around the estimates.

Implications of all the available evidence

The three-tiered categorisation of safety in this paper replaces the previous dichotomous classification of safety. Although simple and safe primary care interventions for safe abortion exist, about 25·1 million unsafe abortions took place worldwide each year between 2010 and 2014, of which 24·3 million (97%) were in developing countries. The findings call for the need to ensure access to safe abortion to the full extent of the law, particularly in low-income regions of the world. Efforts are also needed to replace the use of unsafe methods with safe methods. The study also highlighted the need for routine collection of monitoring data within health systems and development of innovative research methods to address data gaps to improve future estimates.

effect on how and where women access care and who provides care.[7]

Estimates of the magnitude of unsafe abortion have been periodically produced since 1995. Because of the paucity of data, previous estimates relied on the legality of abortion in a given setting and a qualitative assessment of the country context as the primary basis for distinguishing safe from unsafe abortions.[8,9] This approach to classification was a reasonable proxy for safety in an era when only facility-based surgical abortions met medical standards of safety and when unsafe abortions in legally restricted contexts were usually done with dangerous and invasive methods. However, the increasingly widespread substitution of such dangerous methods with misoprostol outside formal health systems necessitates reconceptualisation of how we categorise abortion safety to capture the spectrum of situations that constitute unsafe abortion and the continuum of risk they represent.[4,10]

About 55·7 million abortions took place worldwide every year during the period of 2010–14, the most recent period for which information about abortion incidence is available.[11] Here, we present a new theoretical framework within a Bayesian hierarchical model to generate cross-sectional estimates of the global, regional, and subregional distributions of these abortions by safety categories. In doing so, we replace the dichotomous classification of abortion safety that has been used since 1990 with a three-tiered classification underpinned by WHO recommendations for safe abortion.

Methods

Study design

We analysed data from 182 countries and regions listed by the UN Department of Economic and Social Affairs (UN DESA), Population Division.[12] We excluded small countries with populations of fewer than 100 000 inhabitants because of insufficient information about covariates. Figure 1 is a schematic representation of the analysis framework.

We systematically searched PubMed, POPLINE, and Embase without language filters; LILACS and SciELO for Spanish-language and Portuguese-language articles; BDSP and INEDOC for French-language studies; Panteleimon for Russian-language studies; and SINOMED, China National Knowledge Infrastructure, and Wanfang for Chinese-language articles. The search terms used for each database are shown in the appendix. We also searched the OpenThesis dissertation database, did snowball searches of websites of non-governmental organisations, canvassed relevant online discussion groups and experts in the field, and hand searched references cited in identified studies. We searched for data from Jan 1, 1990, to Dec 31, 2015. For the purpose of this analysis, we used the subset of the search results for 2010–14. We first included national data for 2010–14; for countries without such data, we included national data for 2008–09 if available and, in the absence of both, we considered subnational data on a case-by-case

See Online for appendix

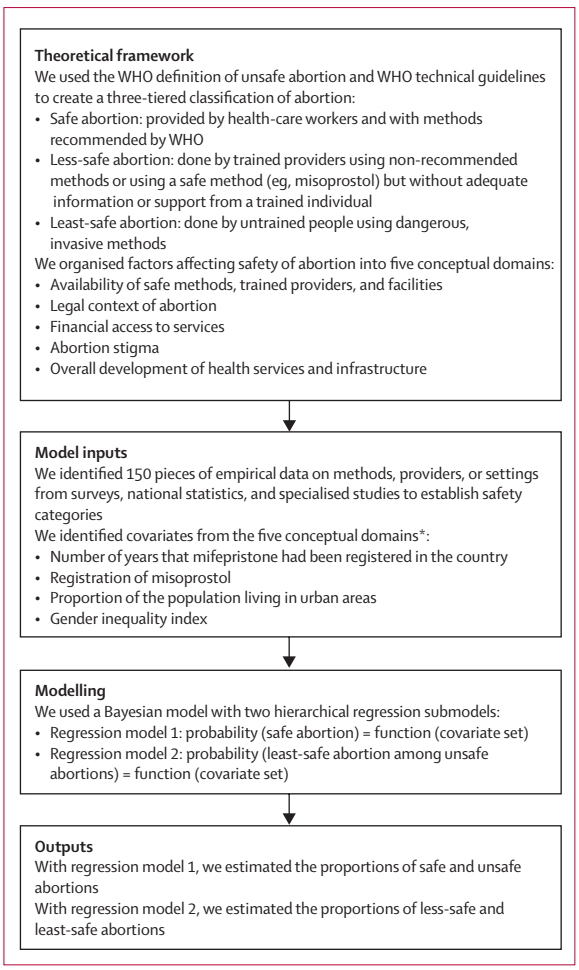

Figure 1: **Schematic representation of the framework for estimating the distribution of abortion by safety categories**
*Other covariates considered for the model but not used for conceptual, data, or statistical reasons are shown in the appendix.

basis. We excluded clinical trials and data limited to specific age subgroups (eg, adolescents) or occupation-related subgroups (eg, sex workers). We assessed the remaining sources for quality of reporting with five criteria adapted from items within the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) statement: eligibility criteria for study sample clearly defined, methods of measurement of each variable of interest defined, characteristics of study participants provided, clear numerator and denominator information included, and inclusion of a discussion of sources of bias in the results. Reports and papers not meeting at least three of the five criteria were excluded. The included studies used different designs and included population-based surveys with reports from women on abortion care-seeking, indirect data based on surveys of health professionals, and nationally or subnationally representative data on abortion management at the facility level.

Theoretical framework

We used the WHO definition of unsafe abortion and recommendations within WHO guidelines on safe abortion[4–6] to conceptualise abortion safety as falling into three categories: safe, less safe, and least safe. The less-safe and least-safe categories together reflect the spectrum of unsafe abortions. We classified abortions as safe if they were done with a method recommended by WHO (medical abortion, vacuum aspiration, or dilatation and evacuation) that was appropriate to the pregnancy duration and if the person providing the abortion was trained. We classified abortions as less safe if only one of the two criteria were met—ie, either the abortion was done by a trained provider but with an outdated method (eg, sharp curettage) or a safe method of abortion (eg, misoprostol) was used but without adequate information or support from a trained individual. We classified abortions as least safe if they were provided by untrained individuals using dangerous methods, such as ingestion of caustic substances, insertion of foreign bodies, or use of traditional concoctions.

From a review of the literature and expert group discussions, we identified factors affecting abortion safety at the country level. We organised these factors into five conceptual domains: (1) the abortion service-delivery environment, which encompasses the availability of safe methods, trained providers, and facilities equipped to provide safe abortion; (2) financial access to services, which refers to a woman's ability to pay for safe abortion services within or outside her country of residence; (3) abortion stigma, which reflects attitudes toward abortion and is associated with gender inequality regarding women's empowerment, autonomy, and agency;[7] (4) legal context, which accounts for the legal grounds for abortion, associated laws and policies, and their interpretation and implementation; and (5) development, which includes the overall development level of health services and health infrastructure.

Model inputs

We used our theoretical framework to categorise the available empirical data into three catergories of safety. Sources did not typically include data on all three characteristics (methods, providers, and settings); thus we mainly relied on data related to methods used to induce abortion (available in 132 [88%] of the included sources) to categorise abortions as safe, less safe, or least safe. Given the absence of standardised reporting among the data sources, this characteristic was also the simplest to interpret in relation to WHO recommendations. For 14 (9%) sources, for which information about methods was not available, we relied on data describing the types of providers from whom services were obtained, and, for four (3%) sources, for which neither of these characteristics were available, we used data on the setting where abortion took place.

Data were used as point estimates if they were representative of a cross-section of women nationally or

subnationally. When not representative of a cross-section of women, data were used to represent a maximum upper limit of the proportion of safe abortions or a minimum lower limit for the proportion of least-safe abortions (appendix). For 18 countries for which data on the distribution of abortions by methods were available from official statistics for multiple years in the study period, we averaged the data across the available years. Further detail for the data sources is available in the appendix.

Within the five conceptual domains, we listed potential plausible covariates and shortlisted those for which systematic information for the reference period was available for at least 85% of the countries. We assessed potential covariates for availability of data and ease of interpretation and chose those that were conceptually the strongest. Details of the covariates used or considered can be found in the appendix.

Our final set of covariates for estimating the proportion of safe abortions included the number of years that mifepristone had been registered in the country; the proportion of the population that lived in urban areas; and the gender inequality index (GII), which is a composite measure that includes indicators of reproductive health (measured as the maternal mortality ratio and adolescent birth rates), empowerment (measured as proportion of parliamentary seats occupied by women and proportion of adult women and men aged 25 years or older with at least some secondary education), and economic status (measured as labour force participation of women and men aged 15 years or older).[13] Additionally, the registration status of misoprostol (for any indication) was used as a covariate to distinguish abortions using misoprostol outside of health systems from the least-safe abortions. Although considered, the legal grounds for abortion and the gross national income (GNI) were not used in the final model because these covariates did not improve model fit. Additionally, not using these covariates in the model allowed presentation of results for countries grouped by legal status and by economic levels.

We used time-matched covariates to fit the model; however, we used 2012 values for covariates to calculate estimates for 2010–14. Country point estimates for the three safety categories were based on rescaled median posterior estimates for each country. Rescaled median values were used as point estimates to ensure that the sum of the estimated proportions was equal to one. Country-level proportions of abortions in each safety category, estimated with the model, were weighted on the basis of available, modelled estimates of abortion incidence in each country and aggregated to the subregional, regional, and global levels with the UN DESA classification of countries. We calculated 90% uncertainty intervals (UIs) for the aggregate outcomes using the highest posterior density intervals for the respective posterior samples for these outcomes. We limited the presentation of results to the subregional level as the lowest level of disaggregation given the paucity of data at the country level.

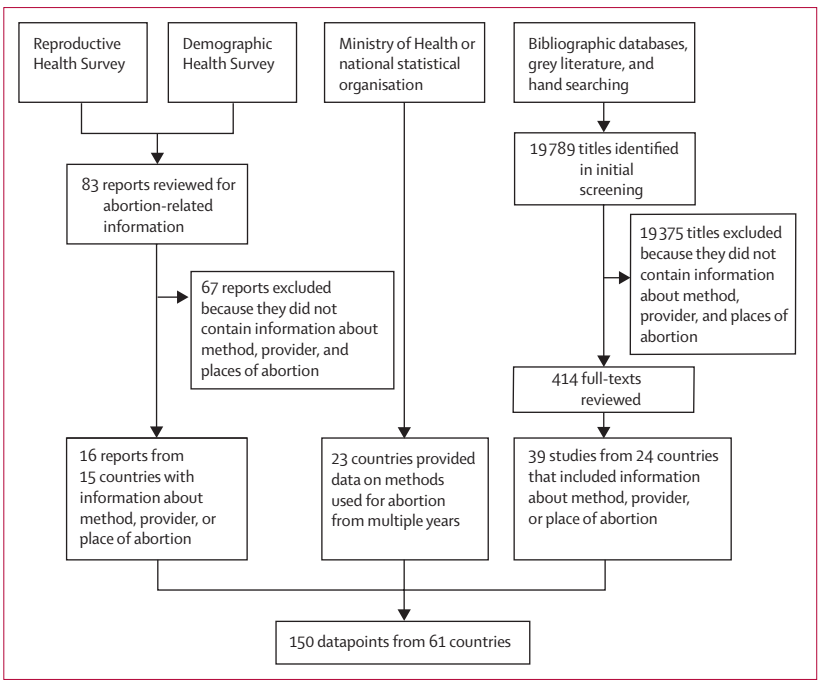

Figure 2: **Sources of empirical data**

We examined the distribution of safety categories for countries grouped together on the basis of the legal grounds on which abortion was allowed. We used the existing UN DESA classification of countries according to abortion law[14] to group countries into three broad categories: countries where abortion on request was allowed, countries where abortion on request was not allowed but where the legal grounds included preservation of a woman's mental health or socioeconomic reasons, and countries that did not allow abortion or only allowed it to save the life or physical health of a woman. We also examined the distribution of safety categories when countries were grouped on the basis of their per-head income with the standard World Bank classification.[15]

We did not directly estimate abortion-related deaths in our analysis. However, to examine the association between abortion safety and abortion-related mortality, we did a secondary analysis to calculate subregional case fatality rates. We computed case fatality rates using available information about the proportion of maternal deaths that were due to abortion for the period of 2003–09, the latest period for which such data were available; 2012 estimates of the number of maternal deaths; and estimates of abortion incidence for the period of 2010–14.[2,11,16] We examined the subregional distribution of unsafe abortion and case fatality.

Model

We used a Bayesian hierarchical model to estimate the proportion of abortions in each of the three safety

	Total abortions per year*	Safe abortions		Less-safe abortions		Least-safe abortions		Unsafe abortions (sum of less-safe and least-safe abortions)	
		n	% (90% UI)	n	% (90% UI)	n	% (90% UI)	n	% (90% UI)
Worldwide	55 700 000	30 600 000	54·9% (49·9–59·4)	17 100 000	30·7 (25·5–35·6)	8 010 000	14·4 (11·5–18·1)	25 100 000	45·1 (40·6–50·1)
Developed countries	6 580 000	5 760 000	87·5% (81·9–89·6)	818 000	12·4 (10·2–17·9)	5180	0·08 (0·0–1·36)	823 000	12·5 (10·4–18·1)
Developing countries	49 100 000	24 800 000	50·5% (45·2–55·9)	16 300 000	33·2 (27–38·3)	8 010 000	16·3 (13·1–20·7)	24 300 000	49·5 (44·1–54·9)
Northern America	1 190 000	1 180 000	99·0% (97·7–99·8)	11 200	0·9 (0·2–2·3)	†	0·0 (0·0–0·03)	11 200	0·9 (0·2–2·3)
Europe	4 290 000	3 800 000	88·8% (80·3–91·7)	480 000	11·2 (7·8–19·3)	3770	0·0 (0·0–0·02)	483 000	11·2 (8·3–19·7)
Southern	750 000	684 000	91·2% (85·6–92·9)	65 400	8·7 (6–13·9)	820	0·11 (0·0–2·9)	66 200	8·8 (7·0–14·5)
Western	562 000	525 000	93·5% (90·6–96·1)	36 500	6·5 (3·9–9·4)	†	0·0 (0·0–0·03)	36 500	6·5 (3·9–9·4)
Northern	349 000	341 000	97·9% (92·8–99·6)	7370	2·1 (0·4–6·8)	†	0·03 (0·0–0·9)	7370	2·1 (0·4–7·2)
Eastern	2 630 000	2 250 000	85·8% (73·3–91·1)	370 000	14·1 (8·4–26·5)	2950	0·11 (0–2·4)	373 000	14·2 (8·8–26·7)
Asia	34 500 000	21 000 000	62·1% (54·8–67·2)	10 500 000	29·7 (23·5–36·6)	2 950 000	8·3 (4·9–13·3)	13 500 000	37·8 (32·8–45·2)
Eastern	12 800 000	11 300 000	88·9% (78·3–95·7)	1 410 000	11·1 (4·1–21·3)	5730	0·04 (0·0–0·6)	1 420 000	11·1 (4·3–21·7)
South-eastern	5 140 000	3 070 000	59·6% (38·4–77·7)	1 380 000	26·9 (10·8–45·9)	694 000	13·5 (2·3–30)	2 080 000	40·4 (12·3–61·6)
South-central	15 700 000	6 620 000	42·2% (34·1–49·6)	7 040 000	44·9 (35·1–53·3)	2 020 000	12·9 (7–19·2)	9 060 000	57·8 (50·3–65·9)
Western	1 870 000	962 000	51·5% (40·9–66·4)	678 000	36·3 (19·2–48·5)	229 000	12·3 (1·2–23·4)	907 000	48·5 (33·7–59·1)
Latin America	6 420 000	1 510 000	23·6% (8·8–47·0)	3 830 000	59·7 (32·7–72·2)	1 070 000	16·7 (8·8–33·4)	4 900 000	76·4 (53·0–91·3)
Caribbean	519 000	132 000	25·4% (6·7–47·6)	258 000	49·6 (23·8–64·9)	129 000	24·9 (15·1–40·8)	387 000	74·6 (52·4–93·3)
Central America	1 310 000	241 000	18·4% (10·6–28·9)	684 000	52·1 (37·7–63·5)	388 000	29·6 (16·9–40·3)	1 070 000	81·6 (71·1–89·5)
South America	4 590 000	1 140 000	24·9% (4·7–53·7)	2 890 000	63 (28·9–79·3)	555 000	12·1 (3–31·9)	3 440 000	75·1 (46·3–95·4)
Africa	6 860 000	2 010 000	24·4% (18·6–33·6)	2 280 000	27·6 (21·2–37·0)	3 950 000	48·0 (36·5–52·9)	6 230 000	75·6 (66·4–81·4)
Eastern	2 650 000	634 000	23·9% (17·0–33·0)	774 000	29·2 (19·9–37·6)	1 240 000	46·9 (36·5–54·9)	2 020 000	76·1 (66·9–83·0)
Middle	1 020 000	120 000	11·8% (5·5–30·4)	195 000	19·2 (6·7–40·7)	702 000	69·0 (38·0–81·2)	897 000	88·2 (69·6–94·6)
Northern	1 920 000	557 000	29·0% (11·0–49·9)	510 000	26·6 (10–46·3)	852 000	44·4 (19·5–58·9)	1 360 000	71·0 (50·1–89·0)
Western	2 140 000	327 000	15·3% (10·4–24·1)	698 000	32·6 (24·1–42·8)	1 120 000	52·1 (40–59·8)	1 820 000	84·7 (75·9–89·6)
Southern	510 000	375 000	73·5% (27·7–93·2)	98 800	19·4 (1·5–62·1)	36 400	7·1 (2·6–11·1)	135 000	26·5 (6·7–72·3)
Oceania	144 000	95 700	66·3% (61·4–77·7)	11 200	7·8 (3·5–17·9)	37 400	25·9 (11·5–31·1)	48 600	33·7 (22·3–38·6)

Numbers greater than 10 million are rounded to the nearest 100 000, greater than 1 million to the nearest 10 000, greater than 100 000 to the nearest 1000, greater than 10 000 to the nearest 100, greater than 1000 to the nearest 10, and numbers less than 1000 to the nearest 1. UI=uncertainty interval. UN DESA=UN Department of Economic and Social Affairs. *Data are median. †Estimated numbers were fewer than 200 abortions.

Table 1: **Distribution of the annual number of safe, less-safe, and least-safe abortions by UN DESA, Population Division region for the period 2010–14**

categories (further details of the model are provided in the appendix). The statistical model included two hierarchical regression submodels: one for estimation of the proportion of safe abortions and one for division of the remaining unsafe abortions into two categories of less safe and least safe. The two submodels combined provided estimates for the three safety categories.

In the first regression submodel, the logit-transformed probability of a safe abortion was estimated with a country-specific intercept and the (regression-coefficient) weighted sum of the predictors of abortion safety. The model was fitted to the country-specific data on the proportion of abortions that was considered safe. Country intercepts were estimated with a hierarchical model based on regional groupings (ie, to represent geographical regions), such that intercepts for countries with no or uncertain data were informed by estimates for other countries in the region. Similarly, in the second regression submodel, we used a model with country-specific intercepts and covariates to estimate the proportion of unsafe abortions that were less safe and those that were least safe.

We created progressively increasing uncertainty levels on the basis of our confidence in the different data sources (from most confident to least confident): national data with categorisation based on methods of abortion, national data with categorisation based on providers, national data with categorisation based on setting, and subnational data with categorisation based on any of these factors.

Based on the theoretical framework, we included four covariates (registration of mifepristone, registration of misoprostol, proportion of the population living in urban areas, and the GII) in the model. We explored whether covariates referring to the legal grounds for abortion and the GNI improved model fit. We used an initial in-sample measure of goodness of fit to assess model performance and out-of-sample validation exercises to select the final model from among the models of best fit that fulfilled both conceptual and statistical criteria (appendix). Given the similar validation results across models, we selected the most parsimonious model for use in this study.

We estimated the posterior distributions of the outcomes of interest with a Markov chain Monte Carlo

algorithm in JAGS open source software (version 4.2).[17] The statistical analysis was done in R 3.2.0.[18]

Role of the funding source

The funders had no role in the study design, data collection, data analysis, data interpretation, or writing of the report. The corresponding author (BG) had full access to all the data in the study and had final responsibility for the decision to submit for publication.

Results

We included 150 pieces of empirical data from 61 countries (figure 2), including 131 (87%) pieces of national-level data. Empirical data were available for 23 (54%) of 43 developed countries and for 38 (27%) of 139 developing countries (appendix). Data came from routinely collected national statistics on reported abortions (23 countries), from Demographic and Health Surveys and Reproductive Health Surveys (including data on women's reports of abortion care-seeking; 15 countries), and from national and subnational studies (24 countries).

During 2010–14, 55·7 million abortions occurred annually worldwide, of which 30·6 million (54·9%, 90% UI 49·9–59·4) were safe. Almost all abortions in developed countries (87·5%, 81·9–89·6), and roughly half of those in developing countries (50·5%, 45·2–55·9), were safe (table 1).

We estimated that 17·1 million (30·7%, 90% UI 25·5–35·6) abortions worldwide for 2010–14 were less safe and that 8·0 million (14·4%, 11·5–18·1) abortions were least safe. Thus, combining the less-safe and least-safe categories, 25·1 million (45·1%, 40·6–50·1) abortions were done in unsafe circumstances each year (table 1, figure 3).

The distribution of abortions across safety categories was similar across developed subregions, with the exception of eastern Europe, where the proportion of safe abortions was marginally lower than for other subregions in Europe (figure 4). Among developing regions, eastern Asia (including China) had a safety distribution similar to that of developed countries. Only in three other developing subregions (southeastern Asia, western Asia, and southern Africa) did the proportion of safe abortions exceed 50%. Other than for southern Africa, the proportion of safe abortions was 25% or less in all of Africa and throughout Latin America. However, in Latin America, most unsafe abortions were categorised as less safe, whereas, in Africa, almost all unsafe abortions were categorised as least safe. The highest proportion of least-safe abortions occurred in middle Africa, followed by western Africa and eastern Africa.

Given that the number of abortions in the subregions of Micronesia, Polynesia, and Melanesia were small, we did not separate Oceania into its subregions. Thus, the results for Oceania reflected a mix of safety scenarios. When the Australia–New Zealand subregion was considered on its own, 92·3% (90% UI 89·3–95·4; data not shown) of abortions were safe, similar to the pattern in other developed regions.

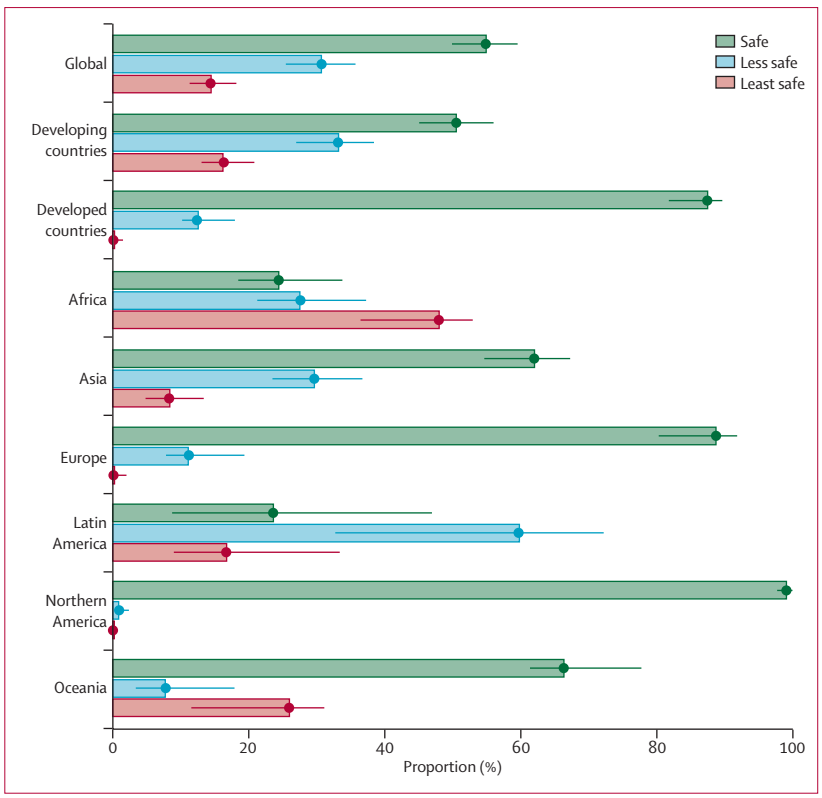

Figure 3: **Distribution of abortion safety categories worldwide and by region**
Bars and dots show the point estimates of the proportion of abortions in each category and horizontal lines are 90% uncertainty intervals.

When the distribution of abortion safety was considered by the legal status of abortion, 87·4% (90% UI 79·2–92·0) of all abortions in the 57 countries in which abortion was available on request were safe compared with 25·2% (14·5–41·0) in the 62 countries where abortion was completely banned or allowed only to save the woman's life or to preserve her physical health (table 2, figure 5). In such legally restrictive settings, nearly a third of abortions (31·3%, 90% UI 21·0–41·9) were categorised as least safe. A direct association was also seen between abortion safety and country income level; most abortions in upper-middle-income countries (67·1%, 58·7–75·7) and high-income countries (82·2%, 75·8–85·7) were safe compared with about one in five abortions (21·8%, 17·4–30·7) in low-income countries (table 2, figure 6). The proportion of abortions that were least safe was also significantly higher in developing countries with the most restrictive laws than in developed countries with similarly restrictive laws (31·3% *vs* 0·3%; data not shown).

No clear association was observed between the incidence of abortion in UN DESA subregions and the distribution of safe abortions. However, the three regions with incidences of fewer than 30 per 1000 women (northern America, northern Europe, and western

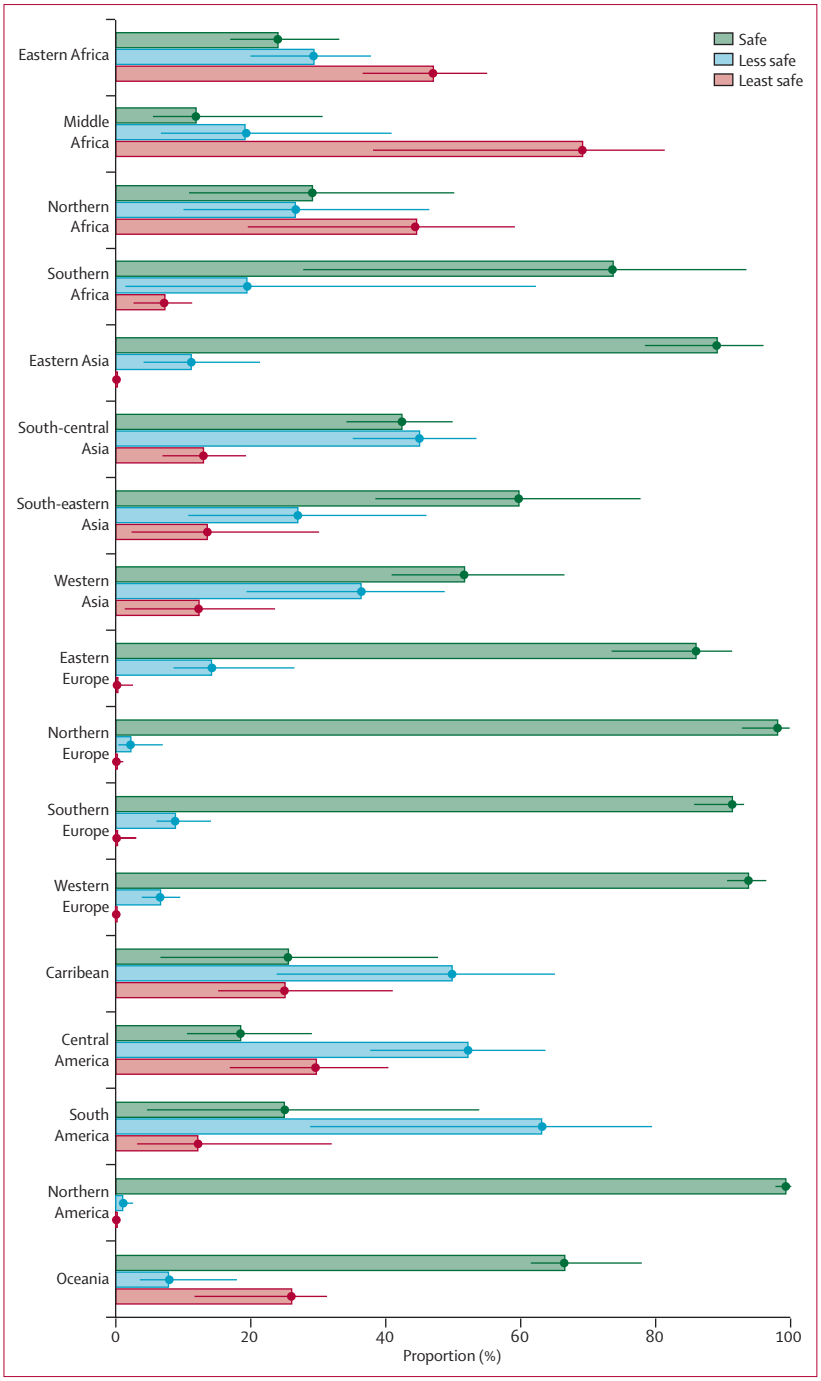

Figure 4: **Distribution of abortion safety categories by subregion**
Bars and dots show the point estimates of the proportion of abortions in each category and horizontal lines are 90% uncertainty intervals.

Europe) also had the highest proportions of safe abortions (figure 7). Similarly, no clear association was observed between the proportions of unsafe abortions by subregion and case fatality rates (data not shown). However, an association was seen between the proportions of least-safe abortions by subregion and the case fatality rates; most subregions with a high proportion of least-safe abortions had high case fatality rates (figure 8).

Discussion

The results showed a disparity in abortion safety between developed and developing regions. In 2010–14, almost all abortions in developed countries were safe, although a small proportion of less-safe abortions was also seen—notably in eastern Europe—probably due to the persistence of outdated medical practices such as sharp curettage. In eastern Europe, as in many parts of Asia, development of evidence-based national standards and guidelines and training of providers could result in substantial improvements in the safety and quality of abortion care.

The subregions with the highest proportions of safe abortions (northern Europe and northern America) also showed the lowest incidence of abortion. Most countries in these two subregions have less restrictive laws on abortion, high contraceptive use, high economic development, high levels of gender equality, and well developed health infrastructures, suggesting that achievement of both low incidence of abortion and high safety in such contexts is possible.

Although eastern Asia was similar to developed regions, fewer than one in two abortions in south-central Asia and about one in four abortions in Africa were safe. Most abortions in Africa were characterised as least safe, suggesting that use of dangerous invasive methods by untrained individuals is common. Although the estimates of case fatality rates should be interpreted with caution because they were calculated with information from several different estimates and various time periods, our results suggested that the subregions with the highest proportions of least-safe abortions also had the highest case fatality rates. This finding might be due to the more serious complications arising from least-safe abortions and the poor health infrastructure to treat complications when they occur. Multifaceted interventions addressing legal, policy, and health system barriers; health-worker shortages; provider attitudes; gender inequality; and abortion stigma are needed.

Only about one in four abortions in Latin America were safe, although most unsafe abortions were categorised as less safe, reflecting the transition of use of dangerous methods to use of misoprostol outside formal health systems in this region.[19] Such abortions might result in fewer complications than abortions done using dangerous methods, as shown by the lower case fatality rates in regions with a high proportion of less-safe abortions than in regions with a high proportion of least-safe abortions. However, these regions also have better functioning health systems and better access to care to treat complications when they occur. Self-management of medical abortion in early pregnancy is an evidence-based option in WHO guidelines,[6] however the use of misoprostol outside of the formal health system, often without access to appropriate information and a trained health-care worker if needed,

does not represent a standard of care, but rather an absence of safe options. Thus, despite lower case fatality rates, these abortions are considered less safe and structured health systems interventions that address access to information, medications, and support to women are needed.

The analysis showed a positive association between safe abortions and less restrictive laws. Such laws might promote an enabling environment for trained providers and improve access to safe methods. The highest proportions of safe abortion were seen in developed countries with less restrictive laws, suggesting that both the legal grounds and overall development of a country have a part in abortion safety.

Scarcity of data for the period before 2010–14 did not allow for a trend analysis with this model. Comparisons with previously published estimates of the proportions of safe and unsafe abortions cannot and should not be made because the theoretical framework, the data used, and the analytical approaches are different.

To the best of our knowledge, this study is the first to align the measurement of abortion safety with WHO's definition[4] of unsafe abortion and to link the categorisation of safety to current technical standards in WHO guidelines.[5,6] Furthermore, the three-tiered classification allowed for a more nuanced gradation of safety that distinguished the least-safe abortions from other types of unsafe abortion. The use of a model-based approach resulted in a systematic consideration of multiple factors that affect the conditions under which abortions take place and allowed, for the first time, the construction of uncertainty bounds around the estimates.

The analysis had several limitations due to the paucity of data. Empirical data in the model were scarce, particularly from countries where abortion was legally restricted and stigma was likely to be common. Data on abortion are likely to be under-reported or misclassified and, even in countries where abortion is legally available, the increasing privatisation of abortion care and a shift towards outpatient services with medication pose new challenges to the representativeness of data collected through health systems.[20–22] Variations in outcome definitions and reporting made it difficult to standardise data inputs.

We were also unable to fully represent all the conceptual domains in the statistical model because systematic, standardised data on covariates representing some domains did not exist. Information about the extent to which misoprostol was used in countries where abortion access was restricted was largely anecdotal, misoprostol-sales data collected by the pharmaceutical industry were not available for all countries, and misoprostol regulations within countries did not necessarily correlate with actual availability and sales in the formal and informal markets. Stigma related to both seeking and provision of abortion is increasingly recognised as having an effect on how and where women access care and who is willing to provide care.[7] Although the GII was used as a partial proxy of abortion stigma, more direct measures do not exist. The possibility of prosecution for seeking an

	Proportion of abortions that are safe	Proportion of abortions that are less safe	Proportion of abortions that are least safe
Legal grounds			
Restricted (not allowed or only allowed to save a woman's life or for physical health; n=62)	25·2% (14·5–41·0)	43·6% (27·6–54·2)	31·3% (21·0–41·9)
Allowed for mental health or socioeconomic reasons (n=62)	41·2% (35·9–46·7)	40·8% (34·6–47·1)	17·1% (13·3–22·0)*
Abortion without restriction to reason (n=57)	87·4% (79·2–92·0)*	11·9% (7·3–19·8)*	0·7% (0·5–1·8)*
Income level (World Bank)			
Low-income countries (n=31)	21·8% (17·4–30·7)	24·4% (18·6–34·6)	53·8% (40·4–58·3)
Lower-middle-income countries (n=51)	42·3% (35·1–47·9)†	37·9% (31·1–45·9)	19·7% (13·9–25·7)†
Upper-middle-income countries (n=52)	67·1% (58·7–75·7)†	27·8 (18·0–34·7)	5·1% (3·0–10·4)†
High-income countries (n=48)	82·2% (75·8–85·7)†	16·9 (12·5–22·2)	0·9% (0·3–3·7)†

Data are presented as % (90% uncertainty interval). *Significantly different from reference category (not allowed or only allowed to save a woman's life or physical health). †Significantly different from reference category (low-income countries).

Table 2: **Distribution of abortion safety categories for countries grouped by legal status and income level**

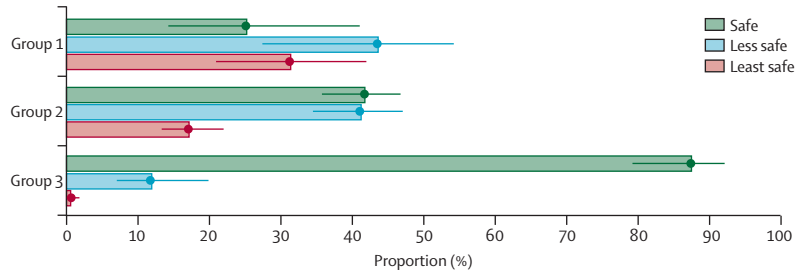

Figure 5: **Distribution of abortion safety categories for countries grouped by legal status**
Countries in group 1 did not allow abortion or only allowed it to save a woman's life or for physical health. Countries in group 2 allowed abortion on socioeconomic grounds or for mental health reasons. Countries in group 3 allowed abortion on request. Bars and dots show the point estimates of the proportion of abortions in each category and horizontal lines are 90% uncertainty intervals.

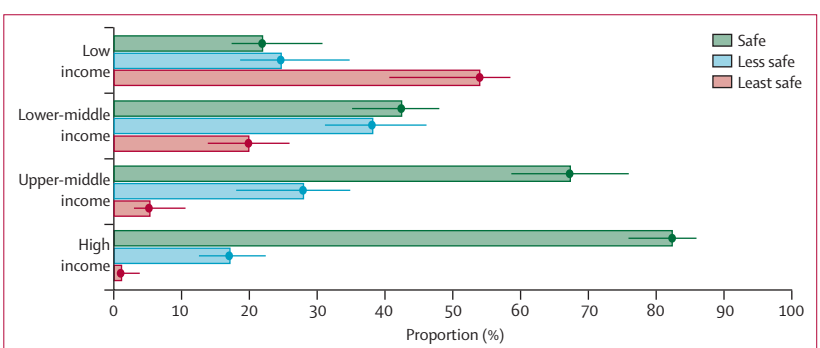

Figure 6: **Distribution of abortion safety categories for countries grouped by level of gross national income**
Bars and dots show the point estimates of the proportion of abortions in each category and horizontal lines are 90% uncertainty intervals.

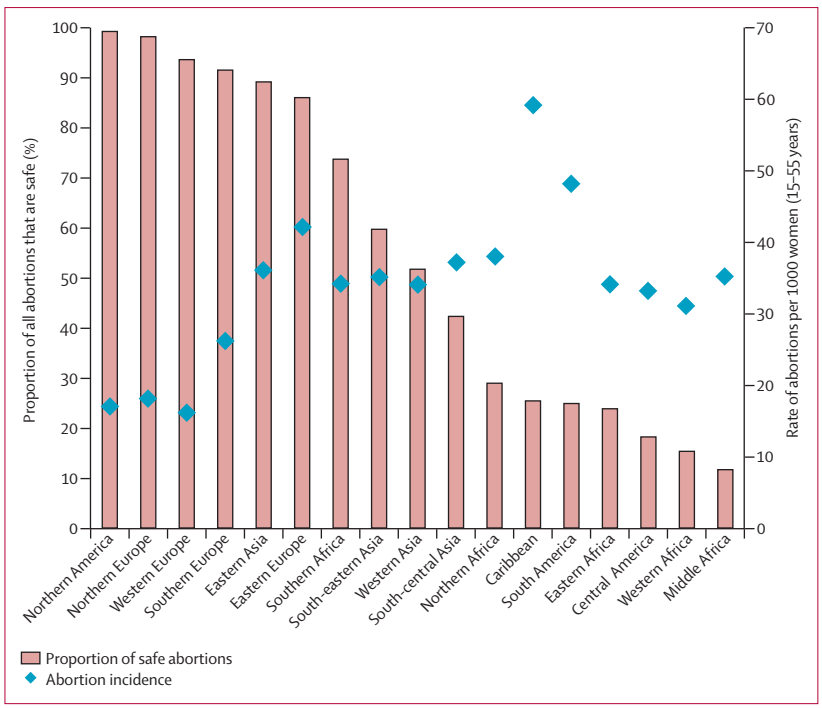

***Figure 7*: Distribution of the proportion of safe abortions and the incidence of abortion by UN DESA, Population Division subregion**
Abortion incidence was the number of abortions occurring each year per 1000 women aged 15–55 years. Data for abortion incidence came from reference 11. UN DESA=UN Department of Economic and Social Affairs.

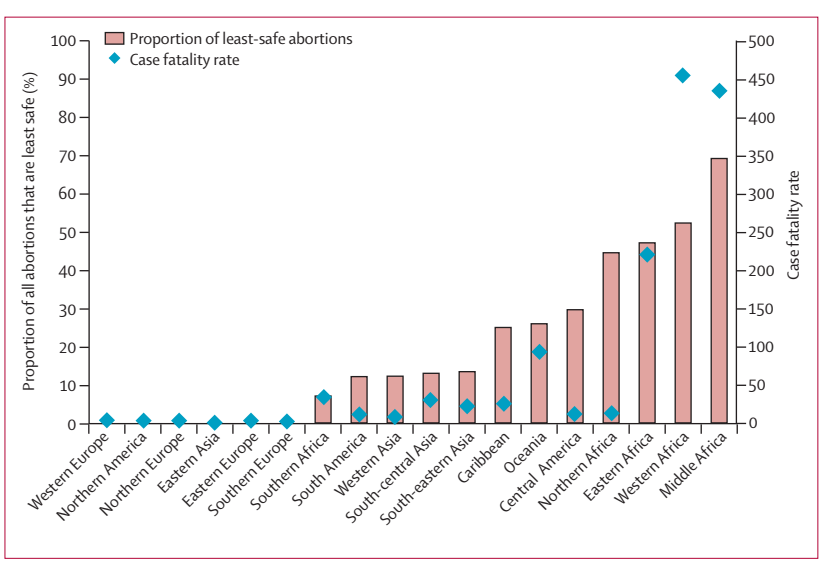

***Figure 8*: Distribution of the proportion of least-safe abortions and case fatality rate by UN DESA, Population Division subregion**
Case fatality rate was defined as the number of abortion-related deaths per 100 000 abortions. UN DESA=UN Department of Economic and Social Affairs.

abortion might also lead women to unsafe options; however, we were unable to quantify this risk for use as a covariate. Additionally, although abortions in both the first trimester and later are safe if done according to WHO standards, the risk of complications does increase with increasing duration of pregnancy.[23] However, we were unable to account for this in the model because of data constraints.

Innovative research to address these gaps is urgently needed, especially in contexts where many abortions occur outside formal health systems.[23–25] Where legal grounds for provision of an abortion exist, increased commitment to collection and standardised reporting of routine data with monitoring indicators recommended by WHO are needed.[5] Improvements in data would also allow future estimates to be disaggregated to the country level; for inequalities related to age, marital status, and economic conditions to be examined; and for national-level progress in increasing access to safe abortion to become visible.

In conclusion, this analysis suggested that unsafe abortion is still a major problem in developing countries and that progress towards safer abortion is needed, even in some developed countries. Although efforts to increase the availability, accessibility, and affordability of contraception can reduce the incidence of unintended pregnancies and, therefore, abortions,[11] it is essential to combine this strategy with interventions to ensure access to safe abortion. Both strategies are needed to eliminate unsafe abortion and to fulfil the global commitment to the Sustainable Development Goal of universal access to sexual and reproductive health.[26]

Contributors

BG conceptualised and led the work. BG, CG, BRJ Jr, CR, and ÖT developed the analysis plan. CG and ÖT developed the data screening tool and the quality assessment criteria. CR, AA, CG, AP, and BG collected and collated data. BG did the preliminary categorisation of empirical data with input from CG and CR. CG, BRJ Jr, BG, and CR developed the covariate domains. CG and BG did the preliminary exploratory analysis. LA developed the statistical model and wrote the technical appendix. BG, ZK, and AA developed the tables. BG wrote the first draft of the paper and subsequent versions with input from all authors. All authors reviewed the paper and provided input into development of the estimates via periodic meetings and teleconferences. All authors read and approved the final version.

Declaration of interests

We declare no competing interests.

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