ORIGINAL RESEARCH

The Development of PRIMA - A Belgian Prediction Model for Patient Encounters at Mass Gatherings

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Abbreviations:
ALS: Advanced Life Support
BLS: Basic Life Support
EMS: Emergency Medical Services
FPS: Federal Public Service
GP: general practitioner
HFCSE: Health, Food Chain Safety, and Environment
MDS: minimum data set
MedTRIS: Medical Triage and Registration Informatics System
MG: mass gathering
PDM: *Prehospital and Disaster Medicine*
PHC: Provincial Health Commission
PPR: patient presentation rate
PRIMA: Plan Risk Manifestation
TTHR: transport-to-hospital rate

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Abstract

Introduction: Mass gatherings (MGs) grow in frequency around the world. With the intrinsic potential for significant health risks for all involved, MGs pose a challenge for those responsible for the provision of on-site medical care. Belgian law obliges local governments to identify and analyze the risks involving a MG. Though medical risk factors are long known, all too often, resourcing for in-event health services is based on anecdotal and previous experiences.

Problem: Despite the fast-evolving science on MGs, the lack of reliable tools – based on empirical and analytical approaches – to predict patient presentation rates (PPRs) at MGs remains.

Methods: A two-step method was followed to develop, update, and support a Plan Risk Manifestation (PRIMA) program. First, a continuous systematic literature review was conducted. Once developed, the model was run using data obtained from Belgian Federal Public Service (FPS; Brussels, Belgium) Health, Food Chain Safety, and Environment (HFCSE); event organizers; and municipalities.

Results: In total, 231 studies and documents were included to form the program. With the data provided, three variables were computed to run the calculation model to predict the PPR. Three medical risk axes were defined for this model: (1) isolation risk; (2) population risk; and (3) risk at illness. A combined dataset was derived from the prediction of the PRIMA program combined with the actual data obtained after the MG. This proved a solid basis for the calculation model of the PRIMA program.

Conclusion: Despite that validation is needed, the PRIMA program and its prediction model for PPRs at MGs carries the promise of a general, applicable prediction and risk analysis tool for a multitude of events.

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Introduction

Mass gatherings (MGs) occur on a daily basis throughout the world and are a trait of modern Western European society. As defined by the World Health Organization (WHO; Geneva, Switzerland): "a gathering of persons at a specific location for a specific purpose for a defined period of time" with "the number of people attending to be sufficient to strain the planning and response resources of the community, state, or nation hosting the event."[1] Arbon adds to this that an MG is "a situation during which crowds gather and where there is the potential for a delayed response to emergencies because of the limited access to patients."[2] With these definitions in mind, it is clear that MG events intrinsically have the potential for significant health risks for all involved and pose a challenge for those involved in the provision of medical care.[3]

When approving an MG, the government guarantees that the medical support at this event meets national standards of quality of care and response time. Belgian law obliges municipal governments to identify and analyze the risks involving the MG event.[4] Though from a medical point of view, most risk factors and hazards are long known,[5-8] planners of MGs all too often rely on anecdotal and historical evidence.[9] Worse is when planners rely on the risk analysis by police or fire fighter services, because more than often, planners use police or fire fighter service safety measures to describe medical needs.

A decreased number of transfers to hospital is well-associated with the provision of on-site medical care by Emergency Medical Services (EMS) and personnel in the field.[10-12] And while the science of MG medicine is fast evolving, literature on models predicting patient encounters is scarce,[9] and except for Belgium's Red Cross Flanders' (Flanders, Belgium) Medical Triage and Registration Informatics System (MedTRIS),[13] minimum data sets (MDS) for research and evaluation of MGs are lacking. Models most cited in MG literature are the models of Arbon[5,14] and Hartman.[15] As a consequence of this scarcity, the lack of a comprehensive risk analysis tool to predict patient presentation rates (PPRs) may lead to inefficient use of medical resources.

A plan for risks and events (Plan Risk Manifestation [PRIMA]) model – a versatile predictive medical resource tool suitable for application across various types of MGs – has recently been developed.[16] The research reported in this paper describes the development of a prediction model for patient encounters at MGs. This PRIMA model could form a basis for modelling patient presentations at MGs, enabling governments and event planners to advice on the medical attendance at an MG event.

Methods

Development of the Model

Since the Belgian royal decree of February 16, 2006, all governmental levels in Belgium are obliged to develop contingency and intervention plans.[4] One of these plans is a mono-disciplinary intervention plan for medical emergency services. This mono-disciplinary plan contains four separate plans: (1) the Medical Intervention Plan (MIP); (2) the Psychosocial Intervention Plan (PSIP); (3) the Sanitary Intervention Plan (SIP); and (4) the Plan for Risks and Events (PRIMA).[16]

The federal government delegates the development of PRIMA to the Provincial Health Commission (PHC; Brussels, Belgium), who advices municipal governments and event organizers on the on-site medical care during an MG. In the province of Antwerp, Belgium, a draft model was made comparable to the model of Hartman.[15] One of the authors of this article (WH), being head of the PHC for EMS, further developed the paper fill-in document into a Microsoft 97-2003 file (Microsoft Corporation; Redmond, Washington USA).

To develop, update, and support the model, a two-step method was followed. A continuous systematic literature search was conducted first. The design of the literature review was based on the Preferred Reporting Items of Systematic Reviews and Meta-Analysis (PRISMA) guidelines.[17] The model was then run using the data provided by the Belgian Federal Public Service (FPS; Brussels, Belgium) Health, Food Chain Safety, and Environment (HFCSE); event organizers; and municipalities.

Search Strategy and Data Collection Literature Search

Databases that were used for this review included PubMed (National Center for Biotechnology Information, National Institutes of Health; Bethesda, Maryland USA); ScienceDirect (Elsevier; Amsterdam, Netherlands); CINAHL (EBSCO Information Services; Ipswich, Massachusetts USA); and Wiley Online Library (John Wiley & Sons, Inc.; Hoboken, New Jersey USA). Different combinations of Medical Subject Headings (MeSH) terms and keywords that were thought to be relevant to the risk analysis of MGs were used.

Besides the search strategy described above, "grey literature" was searched by using Google Scholar (Google Inc.; Mountain View, California USA) with a search strategy of at least 10 pages deep. Within the chosen articles, citations were also searched to identify additional references useful to the review. Furthermore, literature was obtained directly from the journal *Prehospital and Disaster Medicine* (PDM; Madison, Wisconsin USA). This journal is known to have the most numerous publications relating to MG medicine.[18] The table of contents of PDM was screened for articles related to MGs. The inclusion and exclusion criteria used to determine whether to include or exclude an article of PDM were those used by Ranse, et al,[19] except for the date limitation. Studies and documents that were published from 1980 were included.

Data Analysis Literature Search

For the literature search, appropriate articles were entered into a Microsoft Excel 2016 table. This information consisted of: author(s), title, year of publication, journal in which the article was published, keywords, type of MG, and for which component of PRIMA the article could be useful.

Data Collection PRIMA Advice

Since 2012, the PHC of the province of Antwerp asked municipalities and event organizers to fill in the PRIMA Excel program. Those who filled in the program received an output of the file containing advice whether or not on-site medical staff was needed. And if needed, what level of clinical capacity should be present during the MG (first aid level only versus a higher level of care). Post-event, the event organizers, EMS, or municipal government were asked to hand in data regarding the use of medical means. These data allowed the authors to calculate standard metrics within MG medicine and use these data to adjust the advice for next editions. The standard metrics within MG medicine were:

1. Patient Presentation Rate (PPR): number of patients seen by the on-site health services per 1,000 attendees;[20] and
2. Transfer-To-Hospital-Rate (TTHR): number of attendees requiring transfer-to-hospital from the MG (either by ambulance or non-ambulance means) per 1,000 attendees.[20]

Development of PRIMA's Calculation Model

The starting point for PRIMA's calculation model was developing a basic population model as described by Lund.[21] The numbers used for this population model came from the emergency dispatch centers and were provided by the Belgian FPS HFCSE. It provided for the opportunity to compute the incidence of medical emergencies in the baseline population (not during an MG).

Ethical Considerations

The research was deemed to be exempt from review because: (1) the development of the model exclusively involved secondary use of anonymous data that did not generate identifiable information; and (2) the use of reported literature.

Results

Literature

The literature search resulted in 58,903 references in the aforementioned databases, Google Scholar, and the PDM journal. After duplicates were removed, 3,450 articles were screened. Of those, 3,219 were excluded after title and abstract review. Of the remaining 231 studies, 28 were ultimately excluded because of not meeting the inclusion criteria, resulting in 203 articles being included in this study (Figure 1). Of these 203 studies, 176 (86.7%) were retrospective/observational, 18 (8.9%) were cross-sectional, five (2.5%) were case series, and four (1.9%) were qualitative studies.

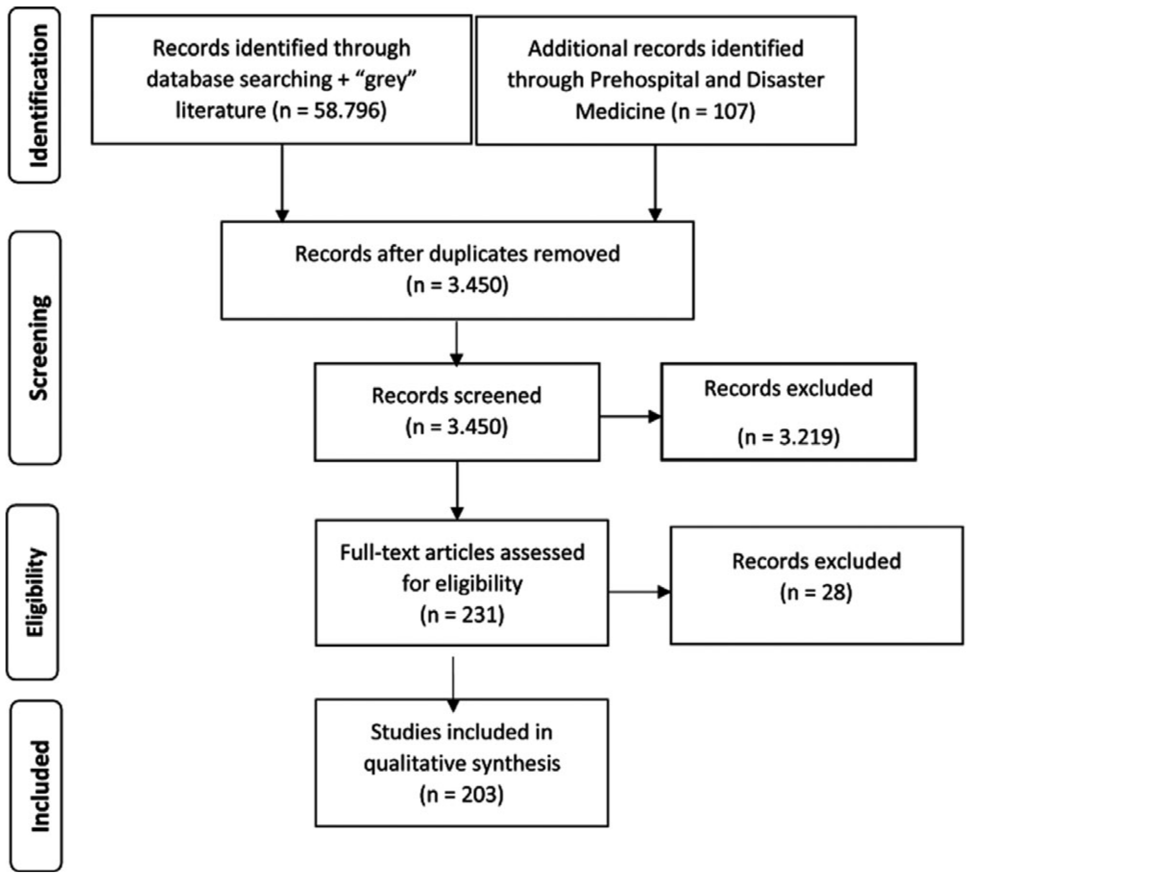

Figure 1. PRISMA Flow Diagram.
Abbreviation: PRISMA, Preferred Reporting Items of Systematic Reviews and Meta-Analysis.

Calculation Model

With the data provided by the FPS, three variables were computed to run the calculation model. First, the number of life-threatening emergencies in the Belgian population at baseline (not during an MG) was calculated. This was done by taking the number of life-threatening emergencies regulated and dispatched by the Belgian emergency dispatch centers (0.019/10,000/5hours). Then, the number of non-life-threatening emergencies regulated and dispatched by the Belgian emergency dispatch center (0.19/10,000/5hours) was calculated. Finally, the number of minor ailments and injuries, for which an ambulance was dispatched and regulated, occurring in the baseline population (2/10,000/5 hours) was computed.

Medical Risk Axes

Bearing in mind the definitions, the literature, and the empirical data, three main medical risk axes for the PRIMA model were defined: (1) isolation risk, (2) population risk, and (3) risk at illness.

First, there was the problem of an isolated event or the event causing increased response times to EMS. As mentioned in the definition, the event gathers an amount of people into a specific location with sufficient numbers to strain responding resources, and there is a potential delay for response to emergencies. This was called the isolation risk. Survival in cardiac arrest was taken as the benchmark for the need of short response times for EMS. Knowing that in most communities, there was a median response interval (the median time between the emergency call and the arrival of EMS) of five to eight minutes,[22] the delayed response for EMS due to the MG justified the presence of EMS or Basic Life Support (BLS) crews on-site.

Due to the lack of legal standards in response times for Belgian ambulances, it was decided that in 95% of the calls, the start of BLS should not exceed the limit of eight minutes. If exceeded, the presence of at least one BLS crew at the event was advised. Advanced Life Support (ALS) crews in Belgian EMS (mobile medical teams staffed by an emergency physician and nurse), however, do have a maximum response time of 15 minutes. Therefore, the threshold for the arrival of an ALS crew on-site should not exceed 15 minutes. If exceeded, the presence of at least one ALS crew at the event was advised. For the host population living within the perimeter of the event, these time limits were in place as well. If response times for those living in the perimeter of the event were not met, it was advised that the on-site medical means for the MG also provided emergency medical aid to the host population in the event perimeter.

A second problem from a medical perspective was the increased population. With "the number of people attending to be sufficient to strain the planning and response resources of the community, state, or nation hosting the event,"[1] it was clear this posed a potentially serious threat. Who should be taken into account for the population risk is well-described in Lund's "Mass-Gathering Health Population Model."[21]

To predict the number of ambulances needed, the comparison with regular EMS for the Belgium population (not during an MG)

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was drawn. In Belgium, there are approximately 540 ambulances and 100 mobile medical teams for a population of 11.3 million. This results in one ambulance per 21,000 inhabitants and one mobile medical team per 110,000 inhabitants. With this in mind, it was advised to have an extra ambulance when the number of people attending an MG exceeded 10,000. A mobile medical team should be on-site when the number of people attending the MG exceeded 55,000.

The third and last medical axis for the model was the risk at illness. People attending an MG share a common interest. This specific composition of the people attending an MG allowed for the prediction of types of behavior. As Hutton described, event planners can develop event safety messages and health promotion for a particular type of event.[23] By using literature data on prevalence and incidence, one can calculate the possibility of illness, but also by using medical literature regarding comparable events. When this calculation pointed towards a possible excess of illness compared to the baseline population, precautionary measures must be taken. Whereas the first two axis considered the quantity of medical requirements, the risk at illness considered the quality of the medical means.

Structure of the PRIMA Microsoft Excel Program

The PRIMA program in a Microsoft Excel file consisted of 21 spreadsheets (Supplementary Material; available online only). The first five of these sheets contained 160 questions, of which 128 were multidisciplinary and 32 were medical. Seventy-seven questions were closed-ended questions and seventy-eight were open-ended questions. The five remaining questions were filled in automatically when answering the questions. Filling in the PRIMA program forms a flow (Figure 2). The calculation model within the PRIMA program used the answers to the questions and generated advice to the event organizer and the government (Figure 3).

Both the event organizer and municipal emergency manager filled in questions in the PRIMA program. Each had their own restricted spreadsheets. Upon completion of the PRIMA program, advice was generated by the Federal Health Inspector.

The first spreadsheet consisted of general information on the event (date and location of the event, type of event, hours during which the event takes place, and general information of the organizer) and the population at risk (expected attendance, crew, and host population within event perimeter). Questions in the second spreadsheet formed the assessment of the need for medical attendance at the event (Table 1).

The third spreadsheet was the actual risk-analysis of the event. It was comprised of questions on the three medical axes (Table 2), and also of multidisciplinary questions (means of communication, familiarity with the organizer, utilities, and international attendance; as well as fireworks, security, and VIP attendance). A final component of this spreadsheet was the disaster preparedness (adequate plans available, shelter for extreme weather conditions, communication with emergency dispatch center, and the existence of a contingency plan compliant with the royal decree of February 16, 2006).

The fourth spreadsheet consisted of questions on public health (prevention of sunburn, heatwave, mobile toilets, waste management, and catering). Although it is well-known that these issues can lead to the demand for medical resources, the answers to these questions did not count in the advice for medical attendance or resources at the MG. They were intended to serve as a reminder for the organizer to potential public health problems. The fifth and final spreadsheet contained the calculation fields with data provided by the FPS.

The remaining spreadsheets of the PRIMA program generated export-files with advice and recommendations for the event organizer, local government (mayor), emergency dispatch center, surrounding hospitals, Federal Agency for the Security of the Food Chain (FASFC; Brussels, Belgium), and local association of general practitioners (GPs). The time that was required to complete the 160 questions was no more than 30 minutes.

Advices Produced

Since the development of the PRIMA program in 2012 and December 31, 2018, 1,439 files for events ranging from multiday electronic dance festivals, to pageants, to the Special Olympics, Prides, and public screenings of World Cup games have been generated. Within the advices, the standard metrics in MG medicine (PPR and TTHR) were predicted. After the MG, the event organizers and medical team leaders provided feedback by registering the actual PPR and TTHR. The combined dataset (prediction and actual data) proved a solid basis for development of the PRIMA program and the medical risk analysis of new and recurring events.

Discussion

The science of MG medicine is fast evolving, though literature on models predicting patient encounters remains scarce.[9] The lack of a comprehensive risk analysis tool to predict PPRs leads to inefficient use of medical means. By combining MG literature and developing a calculation model, the PRIMA program was elaborated.

The continuous literature search lead to an excess of articles. Most of the articles were anecdotal and descriptive of particular MG (eg, religious gatherings like Hajj). Few of these articles were relevant to Belgian MGs. To allow for data analysis, data sets are essential. Whereas Ranse first proposed the MDS for MG health research and evaluation in 2012,[24] no published MDS so far was found. However, together with another Belgian tool, MedTRIS,[13] the PRIMA program paves the way for MG data analysis suggesting better delivery of medical resources at MGs.

Not only does the PRIMA model allow for data analysis, the development of the calculation model in the PRIMA program makes it possible to predict PPRs for MGs and to advise on the allocation of medical resources on-site of the MG. And although the program is fed with most recent data, the advice on the number of ambulances and mobile medical teams still is consistent with the guidelines published by Sanders in 1986.[25]

Because this model is the first to focus on three medical risk axes, it provides general applicability and holds multidisciplinary focuses for all sorts of MGs. Contrary to existing literature,[26] every MG in Belgium is the subject of preparatory meetings and risk analyses in a municipal security council. This collaborative approach is enhanced by having both the event organizer and municipal emergency manager filling in questions in the PRIMA program. Despite the program having 160 questions, there is a natural flow in filling in the document and it is not as time consuming as it seems.

Future Research and Limitations

While there is on-going development and validation of the tool in a Microsoft Excel program, the aim for the future should point towards the creation of an online tool.

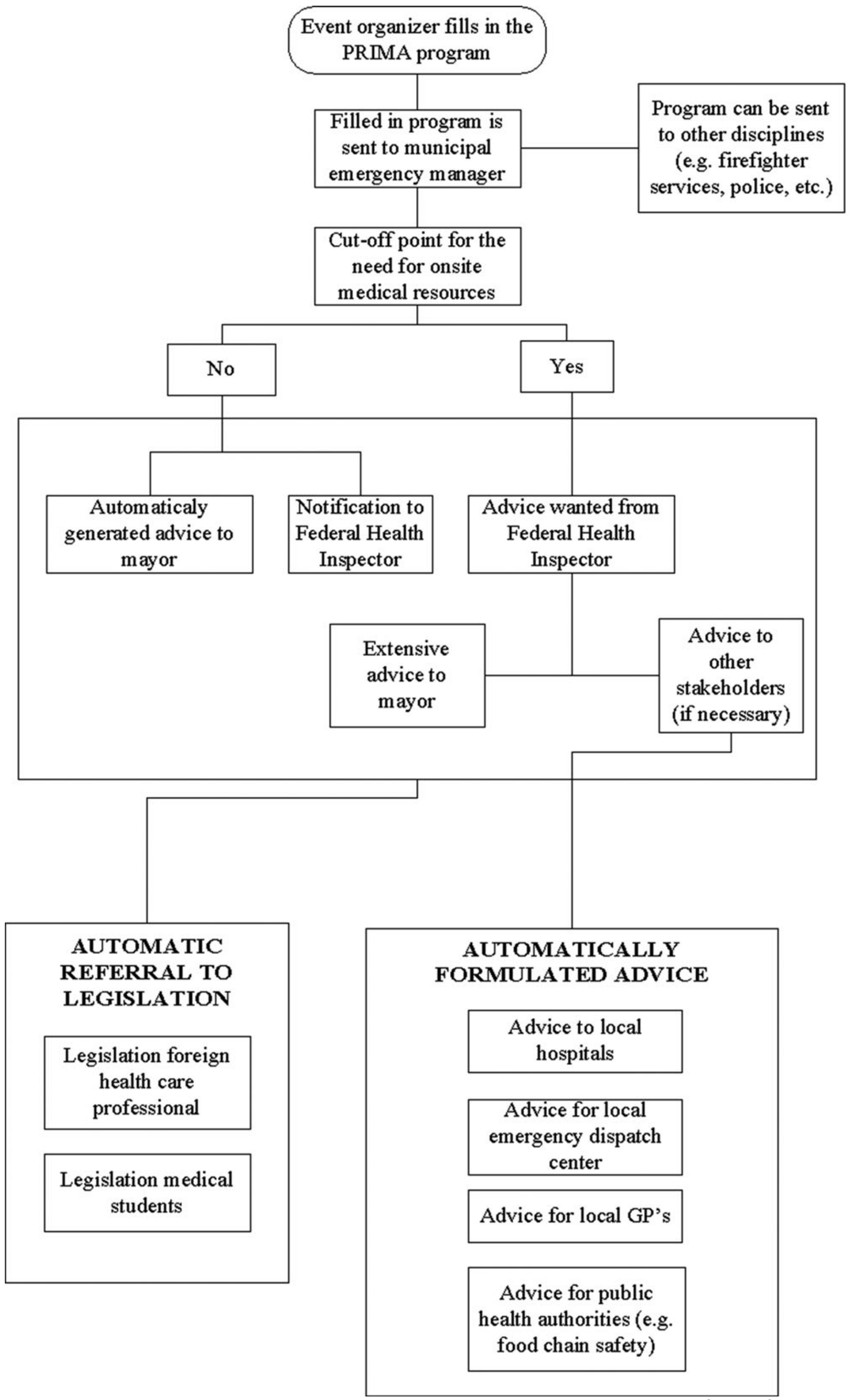

Figure 2. Flow Through the PRIMA Program.
Abbreviations: GP, general practitioner; PRIMA, Plan Risk Manifestation.

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Assessment for the Need for Medical Attendance at the Event
Distance between ambulance and MG (during non-event conditions)?
Distance between mobile medical team and MG (during non-event conditions)?
Are visitors of the event different to the baseline population (age, illness)?
Is there a risk according to the fire services?
Is there a risk according to the police?

Table 1. Questions to Assess the Need for Medical Attendance at the Event
Abbreviation: MG, mass gathering.

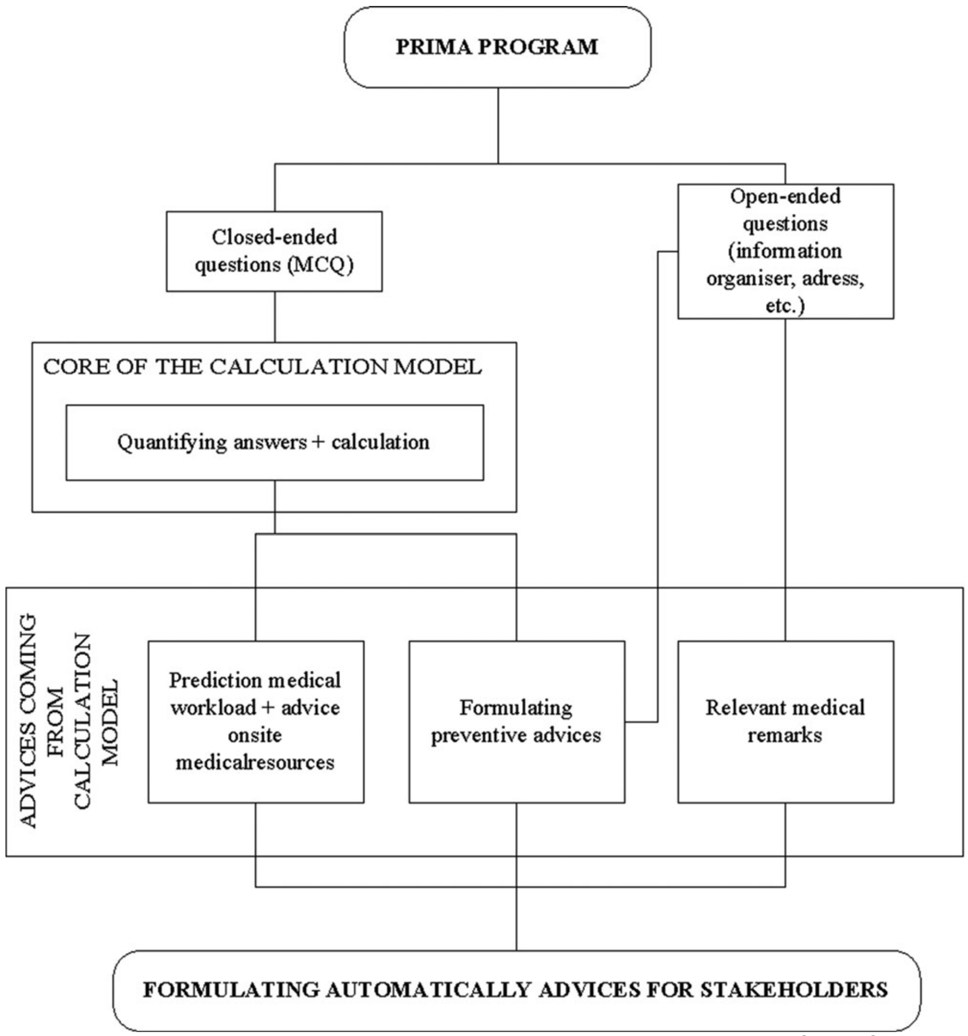

Figure 3. What Happens with the Answers to the Questions in the Program.
Abbreviation: MCQ, multiple-choice question.

Although this study adds to the science of MG medicine, it holds limitations. First, there is a risk for data bias. Some of the data (eg, attendance) comes from the event organizer or secondary sources (eg, popular press). Second, obtaining data post-event is often ignored or refused by the medical team that provided care. Except for the Belgian Red Cross-Flanders,[13] there is still a lack in uniform patient registration in Belgium. And even the Belgian Red Cross-Flanders is apprehensive to share their MedTRIS data. Third, the program is currently only applicable with local (Belgian) data, and adjustments to the calculation model need to be done in order to generalize the program for MGs outside Belgium. Fourth and final is the need for extensive validation for a multitude of MGs that still needs to be done.

Conclusion

The research reported here focused on the development of a prediction model for the prediction of PPRs at MG events. The PRIMA program is applicable across a multitude of events, although validation is needed. The medical means, as proposed in this advice, serve not only to provide medical first aid to those who fall ill

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Medical Risk Analysis of the Event
Isolation Risk
Distance between ambulance and MG (during non-event conditions)?[a]
Distance between mobile medical team and MG (during non-event conditions)?[a]
Accessibility of the MG for medical means?
Terrain variables (bounded/unbounded, surface, seats, indoor/outdoor, temporary structures like tents)?
Population at Risk
Generated automatically from first spreadsheet.
Risk at Illness
Age of participants (children/elderly)?
Availability of alcohol?
Risk on illicit drug use?
Known illnesses to participants?
Humidity (%) and temperature (minimum – maximum) expected for the day of the event?
Does the event take place during office hours?

Table 2. Medical Risk Analysis of the Event
Abbreviation: MG, mass gathering.
[a] Generated automatically from second spreadsheet.

or get injured during an MG, but are often regarded as an extra service to the visiting attendees. Should a mass-casualty situation occur, the on-site medical resources will start a medical response.

Supplementary Material

To view supplementary material for this article, please visit https://doi.org/10.1017/S1049023X20000989

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