Quantitative Metrics in Mass-Gathering Studies: A Comprehensive Systematic Review

Cüneyt Çalışkan, MSc, MEds, PhD;[1,2] Ahmet Doğan Kuday, MSc, PhDc;[1] Tuğba Özcan, MSc, PhDc;[1] Nihal Dağ, MSc, PhDc;[1,2] Kerem Kınık, MD, PhD[1,2]

1. Department of Disaster Medicine, Hamidiye Institute of Health Sciences, University of Health Sciences, Istanbul, Türkiye
2. Department of Emergency Aid and Disaster Management, Hamidiye Faculty of Health Sciences, University of Health Sciences, Istanbul, Türkiye

Correspondence:
Ahmet Doğan Kuday
Department of Disaster Medicine
Hamidiye Institute of Health Sciences
University of Health Sciences
Istanbul, Türkiye
E-mail: dogankuday@gmail.com

Conflicts of interest: None declared.

Keywords: mass gathering; metrics; rate; ratio; standardization

Abbreviations:
ATR: ambulance transfer rate
EHP: event-to-host-population ratio
FAR: first aid rate
MARR: mutual aid request rate
MERGE: Metrics and Essential Ratios for Gathering Events
METH: medical service to hospital
MMAT: Mixed Methods Appraisal Tool
MTR: medical transfer rate
MUR: medical usage rate
OHCA: out-of-hospital cardiac arrest
PDR: pre-diagnosis rate
PPR: patient presentation rate
PPTT: patient-per-ten-thousand
PRISMA: Preferred Reporting Items for Systematic Reviews and Meta-Analyses
RTHR: referral-to-hospital rate
TTHR: transfer-to-hospital rate
SFMF: Start-Finish Medical Post
USFMP: using Start-Finish Medical Post
VAR: venue accommodation rate

Received: January 6, 2024
Revised: February 14, 2024
Accepted: March 14, 2024

Abstract

Introduction: Mass gatherings are events where many people come together at a specific location for a specific purpose, such as concerts, sports events, or religious gatherings, within a certain period of time. In mass-gathering studies, many rates and ratios are used to assess the demand for medical resources. Understanding such metrics is crucial for effective planning and intervention efforts. Therefore, this systematic review aims to investigate the usage of rates and ratios reported in mass-gathering studies.

Methods: In this systematic review, the PRISMA guidelines were followed. Articles published through December 2023 were searched on Web of Science, Scopus, Cochrane, and PubMed using the specified keywords. Subsequently, articles were screened based on titles, abstracts, and full texts to determine their eligibility for inclusion in the study. Finally, the articles that were related to the study's aim were evaluated.

Results: Out of 745 articles screened, 55 were deemed relevant for inclusion in the study. These included 45 original research articles, three special reports, three case presentations, two brief reports, one short paper, and one field report. A total of 15 metrics were identified, which were subsequently classified into three categories: assessment of population density, assessment of in-event health services, and assessment of out-of-event health services.

Conclusion: The findings of this study revealed notable inconsistencies in the reporting of rates and ratios in mass-gathering studies. To address these inconsistencies and to standardize the information reported in mass-gathering studies, a Metrics and Essential Ratios for Gathering Events (MERGE) table was proposed. Future research should promote consistency in terminology and adopt standardized methods for presenting rates and ratios. This would not only enhance comparability but would also contribute to a more nuanced understanding of the dynamics associated with mass gatherings.

Çalışkan C, Kuday AD, Özcan T, Dağ N, Kınık K. Quantitative metrics in mass-gathering studies: a comprehensive systematic review. *Prehosp Disaster Med.* 2024;39(2):195–205.

Introduction

Perhaps there is no universally accepted definition of a mass gathering in the literature, but a mass gathering typically refers to the coming together of many people at a specific location for a common purpose or event.[1] Although this definition does not specify the number of attendees, a mass gathering typically involves many attendees, ranging from several thousand to several million. These events can take various forms such as concerts, festivals, sporting events, political rallies, religious meetings, and more. Mass gatherings often play a substantial role in uniting attendees, fostering a sense of community, enriching social interaction, promoting artistic and cultural engagement, and providing valuable contributions to the local economy. However, these spontaneous or planned (recurring or one-time) events can also strain the planning and intervention resources of the host community, city, or country.[2]

Mass gatherings may present various challenges, including crowd management, security concerns, public health issues, and logistical matters.[3] Organizers and authorities often need to plan and implement measures to ensure the safety and well-being of attendees, address

doi:10.1017/S1049023X2400027X

potential security risks, and manage the overall logistics of the event. Especially due to the potential spread of infectious diseases in crowded environments, mass gatherings can pose significant public health risks.[4] To overcome these challenges, organizers and authorities need to take proactive measures for public health surveillance and monitoring to prevent, detect, and control infectious diseases.

Effectively managing risks in mass gatherings is a complex and multifaceted undertaking that requires a comprehensive strategy.[5] At the core of this comprehensive approach lies the creation of a robust risk assessment tool that serves as a fundamental mechanism for identifying potential health hazards.[6] This tool facilitates the systematic evaluation of various factors contributing to the overall risk environment. Moreover, estimating medical resource utilization within this framework is crucial. This estimation process is complex and greatly influenced by factors such as the nature and duration of the event, attendance levels, prevailing weather conditions, venue factors, crowd mood and density, as well as alcohol and drug consumption.[7] Event organizers and authorities can enhance their capacity to anticipate, mitigate, and effectively respond to potential health and safety issues during mass gatherings by considering these various factors.

In mass-gathering studies, the use of rates and ratios is crucial for assessing the demand on medical resources and providing a quantitative perspective on the health aspects of mass gatherings. Such metrics play an important role in developing targeted interventions and resource allocation strategies. As the risk environment evolves, a nuanced understanding of these metrics contributes to enhancing the overall resilience and preparedness of stakeholders involved in organizing and managing mass gatherings. Despite significant variations depending on the nature, scale, and purpose of mass gatherings, there are several metrics and formulas in the literature. However, significant differences were observed in the results of studies in the literature.[8] Recent literature has highlighted a notable risk of inaccuracies in calculating medical usage rates (MURs) using different models in various contexts.[9] Therefore, a systematic analysis of rates and ratios related to mass gatherings was conducted in this study, to lay the groundwork for the development and implementation of more effective strategies for future mass-gathering events.

Methods

Definitional Concepts

This study conducted a systematic review of articles that presented rates and ratios related to mass-gathering events. An integrative review approach was used in this study because of its ability to bring together different perspectives on the topic.[10] The review process included stages such as defining the problem, conducting a literature review, selecting and collecting data, analyzing the quality of evidence, and presenting the data. Although no specific protocol or record outlining inclusion criteria and methods of analysis has been established for this study, the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines have been followed.

The research question has been determined as follows: "*What are the rates and ratios derived for mass-gatherings events?*" Within the scope of the defined question, the "participants" of this study consisted of all types of mass gatherings, such as sports events, music concerts, and festivals (*Participation*). The rates and ratios derived for mass gatherings were examined (*Intervention*). A comparative analysis was performed on the derived rates and ratios (*Comparison*). Rates and ratios obtained from different articles constituted the outcomes of the research (*Outcomes*). All studies published in English with accessible full texts were included in the research (*Study Design*).

Databases and Search Strategies

Database searching was conducted with the combination of the relevant keywords as follows: (mass gathering*) AND (rate* OR ratio*). For the selection of key terms, experts in the disaster medicine field were consulted and the consensus of four researchers was taken into consideration. A comprehensive search was conducted on PubMed (National Center for Biotechnology Information, National Institutes of Health; Bethesda, Maryland USA); Scopus (Elsevier; Amsterdam, Netherlands); Web of Science (Clarivate Analytics; London, United Kingdom); and Cochrane (Wiley; Hoboken, New Jersey USA) databases, and articles published through December 1, 2023 were obtained for relevant studies.

Eligibility Criteria

Inclusion Criteria—The inclusion criteria consisted of the following:

1. Articles that address rates or ratios derived from mass-gathering events;
2. Articles that are accessible and free of charge; and
3. Articles written in English.

Exclusion Criteria—The exclusion criteria consisted of the following:

1. Articles that do not address rates or ratios derived from mass-gathering events;
2. Articles that are not accessible and free of charge;
3. Articles not written in English;
4. Articles that report the incidence and prevalence of infectious diseases, such as COVID-19; and
5. Articles that include only simple percentages.

Study Selection and Data Extraction

Two researchers (ADK and TÖ) independently screened the titles and abstracts of all references obtained in the search results. Subsequently, the full text of each article potentially meeting the eligibility criteria was obtained. After the full-text assessment, studies that did not meet the selection criteria were excluded. Disagreements between researchers were resolved through consensus or consultation with a third referee (CC). For each included study, reference lists were scanned for relevant additional records. The Mendeley Reference Manager (Mendeley Ltd.; London, UK) app was used to manage scanned references and eliminate duplicate entries. Data obtained from the reviewed studies were extracted using a form created by the authors. All extracted data were reviewed by members of the research team to confirm accuracy and completeness. The following information was recorded to describe the findings: author(s), country, study type, event type, event duration, number of attendees, and outcome metrics.

Quality Appraisal

In this study, the Mixed Methods Appraisal Tool (MMAT) 2018 version was used to assess the quality of the included articles. The MMAT is a comprehensive appraisal tool that allows the evaluation of various research designs, including quantitative, qualitative, and mixed methods studies. It consists of five

https://doi.org/10.1017/S1049023X2400027X Published online by Cambridge University Press

categories, each with five specific criteria: the qualitative set, randomized controlled trials set, non-randomized studies set, observational descriptive studies set, and mixed methods set.[11] In the process of quality assessment, two researchers (ADK & TÖ) scrutinized each article for potential biases according to MMAT categories. Any disparities were addressed through discussion or consultation with a third author. The outcomes of the quality assessment using MMAT 2018 in this systematic review encompass articles meeting three to five criteria (out of five).[12]

Results

Included Studies Characteristics

Following the search, a total of 745 publications were identified from the Web of Science, Scopus, Cochrane, and PubMed databases. After eliminating duplicate articles, 567 publications remained. Among these, the abstracts of 440 studies did not meet the inclusion criteria, and the full texts were not reviewed. The full texts of the remaining 127 studies were read, and 72 of them were excluded. Of these, 61 of them were not relevant, eight were of low quality, the full text of two could not be accessed, and one was not in English. As a result, 55 articles were included in the study findings (Figure 1). The publication dates of the 55 studies included in the research findings ranged from 1990 through 2023. Among them, 45 were original research, three were special reports, three were case reports, two were brief reports, one was a short paper, and one was a report from the field (Table 1[13–67]).

Descriptive Analysis of Documents

As a result of the systematic review, a total of 15 metrics were obtained, including event-to-host-population ratio (EHP), venue accommodation rate (VAR), injury/season injury rate, rates of out-of-hospital cardiac arrest (OHCA), pre-diagnosis rate (PDR), attack rate, patient presentation rate (PPR), rate of using Start-Finish Medical Post (USFMP), MUR, ambulance transfer rate (ATR), medical service to hospital (METH), mutual aid request rate (MARR), transfer-to-hospital rate (TTHR), referral-to-hospital rate (RTHR), and medical transfer rate (MTR). These 15 metrics have been categorized into three groups: assessment of population density, in-event health services, and out-of-event health services. The formulas for the rate and ratios used in mass gatherings are presented in Table 2, and detailed information regarding these metrics is elaborated below.

Assessment of Population Density

Event-to-Host-Population Ratio (EHP)—The EHP ratio refers to the ratio of the number of attendees in a mass-gathering event to the host population during the event.[54] Derived by dividing attendees by the host population, it guides resource planning, aiding organizers in ensuring event success without overwhelming infrastructure. Additionally, the EHP ratio anticipates health care demand, serving as a proactive tool for preparedness.

Venue Accommodation Rate (VAR)—The crowd density affects the volume of patients treated at an event, and the VAR serves as an indicator of this density.[7] It is defined as the rate of the actual number of spectators per event to the maximum capacity for attendees, expressed as a percentage.[47] A high rate suggests that the actual number of attendees per event is approaching or exceeding the maximum capacity, indicating a densely populated venue. On the other hand, a low rate suggests that there is still considerable capacity available in the venue, indicating a lower crowd density.

Assessment of In-Event Health Services

Injury Rate/Season Injury Rate—The injury rate is a metric that measures the frequency of injuries in a specific population or context and is commonly reported in mass-gathering events. The calculation of the injury rate involves dividing the total number of injuries by the overall number of attendees, typically presenting the result as a percentage. In addition, the season injury rate illustrates the cumulative injury rate occurring over one year, obtained by dividing the total injury rates within a year by 12 months.[51] A higher injury rate indicates a greater frequency of injuries relative to the population or exposure, while a lower rate suggests a lower incidence of injuries.

Rate of Out-of-Hospital Cardiac Arrest (OHCA)—While OHCA is not a metric specific to mass gatherings, it signifies the unexpected cessation of an individual's heart activity, typically occurring outside the hospital. The OHCA rate is calculated by dividing the number of OHCA cases during the event by the total number of attendees and then multiplying the result by a factor, often expressed per 100,000 attendees.[29] Even though not explicitly stated as OHCA in the literature, there are also studies providing the incidence rate of cardiopulmonary arrest per 10,000 attendees.[18,59] A high OHCA rate or incidence rate of cardiopulmonary arrest in mass-gathering events suggests a high demand for emergency medical interventions and services such as responding to heart attacks. On the other hand, a low rate suggests a lower demand for emergency health care services during the event, and organizers may require fewer emergency resources.

Pre-Diagnosis Rate (PDR)—Injuries and illnesses like trauma, acute gastroenteritis, headache, myalgia, and sunburn are usually presented by frequency or percentage in mass-gathering events. In the literature, a few studies have provided PDR or the incidence rates of patient diagnosis/symptoms.[58] The PDR or rates of patient diagnosis/symptoms are employed to evaluate the incidence of specific diagnoses among patients or injured individuals. It is calculated by dividing the count of diagnoses by the total number of attendees and then multiplying the result by a factor, often expressed per 1,000 attendees.[37] A high diagnosis rate suggests an increased incidence of specific conditions among attendees in mass gatherings, indicating potential health issues before a formal diagnosis. This information assists event planners, health care professionals, and public health authorities in customizing their services. On the flip side, a lower rate of diagnosis might suggest an attendee population that is generally healthier; however, factors such as the type of event, demographics, and pre-existing conditions observed should be taken into account.

Attack Rate—Attack rate is a term typically used to measure the speed of the spread of an outbreak or disease. It is calculated by dividing the total number of cases that occur during a specific period or in a specific situation by the total population, often expressed as a percentage. While not exclusive to mass gatherings, it is a crucial metric for understanding the dynamics of the spread of outbreaks and diseases, informing preventive measures, and guiding the implementation of public health strategies in mass gatherings.[52] It plays a significant role, particularly in the control of infectious diseases and the management of outbreak situations.

Patient Presentation Rate (PPR)—The PPR is a metric used to assess the number of patient presentations to a health care facility or service during a specific period within a mass-gathering event. In the literature, it is also observed that the PPR is analyzed in two

https://doi.org/10.1017/S1049023X2400027X Published online by Cambridge University Press

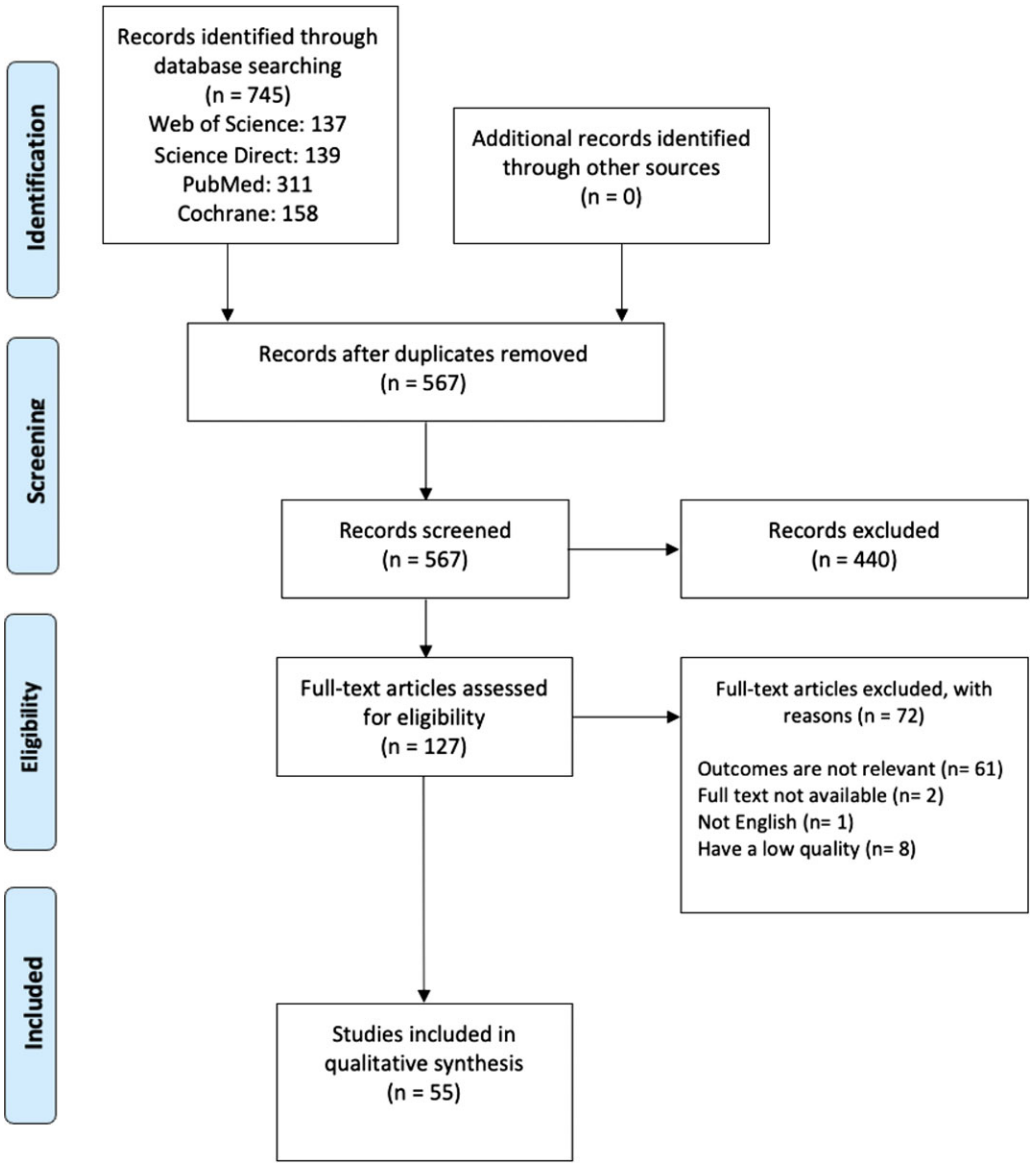

Figure 1. Flow Diagram of Study Identification and Selection Process.

separate categories for mass-gathering events: "Intra-venue PPR (In-PPR)" and "Out-of-venue PPR (Out-PPR)." In-PPR refers to presentations within the event venue, while Out-PPR pertains to presentations outside the venue.[47] However, it is often reported as PPR in the literature. The PPR is calculated by dividing the total number of patient presentations during the event by the overall number of attendees, and the result is often multiplied by a coefficient such as 10,000 for standardized reporting.[17] A heightened PPR typically indicates a heightened demand for health care services, suggesting an escalation in health-related concerns during mass gatherings and signaling a potential necessity for emergency interventions. Conversely, a lower PPR generally signifies reduced demand for health care services, indicating that anticipated health issues during mass gatherings are limited, thereby reducing the need for emergency interventions.

Rate of Using Start-Finish Medical Post (USFMP)—Start-Finish Medical Post (SFMP) is a facility located at the start and finish lines of mass gatherings like marathons or cycling races. Its purpose is to provide prompt medical assistance to attendees facing emergencies, serving as a central hub with personnel and resources. The rate of USFMP is a metric that indicates the frequency or ratio of attendees seeking medical assistance or services at the SFMP during an event. It is calculated by dividing the number of individuals who utilize the SFMP services by the total number of attendees, often expressed per 10,000 attendees.[62] Although it yields the same output as PPR, USFMP is commonly used in sports events.

Medical Usage Rate (MUR)—The MUR, as also known overall usage rate, refers to the rate of utilization or demand for medical services or resources during a mass-gathering event.[7,20] The MUR is calculated by dividing the number of individuals seeking medical care by the total attendance for that event and is typically reported as a rate in patients per 10,000 (PPTT).[34,53,60] The PPR also is referred to as the MUR, but PPR may be limited in some studies to presentations to medical services and exclude first aid and other

https://doi.org/10.1017/S1049023X2400027X Published online by Cambridge University Press

No	Author(s)	Country	Study Type	Event Type	Event Duration	Attendees	Outcome Metrics
1	Alassaf WI – 2017[13]	Saudi Arabia	Case Report	10KSA - a charity event held for breast cancer awareness	1 Day	10,000	• PPR • TTHR
2	Allen, et al – 2006[14]	USA	Original Research	2002 Winter Olympic Games	19 Days	414,121	• MUR
3	Allgaier, et al – 2019[15]	South Africa	Original Research	9 MG Events	1 Months	1,916,116	• PPR • TTHR
4	Anikeeva, et al – 2018[16]	Australia	Original Research	15 MG Events	1 Year	303,500	• PPR
5	Arbon, et al – 2001[17]	Australia	Special Report	201 MG Events	1 Year	12,046,436	• PPR • TTHR
6	Bock, et al – 1992[18]	USA	Original Research	Indianapolis 500 Mile Race	8 Years (1983-1990)	3,200,000	• Cardiac Arrests Incidence
7	Bortolin, et al – 2013[19]	Italy	Original Research	Holy Shroud Exhibition	42 Days	2,113,128	• PPR • TTHR • METH
8	Burton, et al – 2012[20]	UK	Original Research	Rugby Matches and Horse Races	1 Year	286,383	• MUR
9	Ceyhan, et al – 2018[21]	Turkey	Original Research	Political Public Meetings	69 Days	5,265,450	• PPR • TTHR
10	Ceyhan, et al – 2020[22]	Turkey	Original Research	Shopping Centers	1 Year	53,277,239	• PPR • TTHR
11	Chang, et al – 2010[23]	Taiwan	Original Research	Festival of Sun-Moon Lake - a long-distance swimming mass gathering	1 Day	15,189	• PPR • MUR • TTHR
12	Crabtree, et al – 2017[24]	Australia	Original Research	Royal Easter Show	3 Years (2012-2014)	> 2,500,000	• PPR • TTHR • RTHR
13	Dutch, et al – 2008[25]	Australia	Original Research	Melbourne 2006 Commonwealth Games	12 Days	4,098,390	• PPR • TTHR
14	Friedman, et al – 2016[26]	USA	Special Report	Electronic Dance Music Festival	3 Days	58,000	• PPR • TTHR
15	Friedman, et al – 2018[27]	USA	Original Research	Music Festival	4 Years (2014-2017)	8,000	• PPR • TTHR • MARR
16	Golberg, et al – 2018[28]	USA	Original Research	Gillette Stadium	6 Years (2010-2015)	8,260,349	• PPR • TTHR
17	Goldberg, et al – 2023[29]	USA	Short Paper	Gillette Stadium	10 Years (2010-2019)	7,767,345	• OHCA
18	Grant, et al – 2010[30]	USA	Case Report	New York State Fair	5 Years (2004-2008)	950,973	• PPR • TTHR
19	Gutman, et al – 2011[31]	Canada	Original Research	2009 World Police and Fire Games	10 Days	13,363	• PPR • ATR • MTR
20	Hardcastle, et al – 2012[32]	South Africa	Original Research	2010 Soccer World Cup	25 Days	> 455,000	• PPR • TTHR
21	Hoe Ho, et al – 2014[33]	Singapore	Original Research	Formula One Night Race	4 Years (2009-2012)	327,968	• PPR • TTHR
22	Hostettler-Blunier, et al – 2017[34]	Switzerland	Original Research	Swiss Wrestling and Alpine Games	3 Days	300,000	• MUR

Table 1. Characteristics of the Included Articles (*continued*)

https://doi.org/10.1017/S1049023X2400027X Published online by Cambridge University Press

No	Author(s)	Country	Study Type	Event Type	Event Duration	Attendees	Outcome Metrics
23	Imbriaco, et al – 2020[35]	Italy	Field Report	U21 Football Championship	18 Days	72,655	• PPR • TTHR
24	Johnsson, et al – 2006[36]	Sweden	Brief Report	European Union Summit	2 Days	50,000	• PPR
25	Koçak, et al – 2018[37]	Turkey	Original Research	Commemoration Ceremonies for the 100th Anniversary of the Battle of Gallipoli	2 Days	50,000	• PPR • TTHR • PDR
26	Koçak, et al – 2022[38]	Turkey	Original Research	4 MG Events	4 Years (2015-2018)	351,000	• PPR • TTHR
27	Locoh-Donou, et al – 2016[39]	USA	Original Research	79 MG Events	3 Years (2009-2011)	917,307	• PPR
28	Lønnee, et al – 2021[40]	Denmark	Original Research	Roskilde Festival	9 Days	130,000	• PPR • TTHR
29	Lund, et al – 2015[41]	Canada	Original Research	Electronic Dance Music Event	2 Days	20,301	• PPR • ATR
30	Maleczek, et al – 2021[42]	Austria	Original Research	Music Festival	7 Years (2011-2017)	1,003,500	• PPR • TTHR
31	Milsten, et al – 2003[43]	USA	Original Research	Professional American Football, Baseball, and Rock Concerts	3 Years (1997-1999)	9,708,567	• MUR • PPTT
32	Milsten, et al – 2017[44]	USA	Original Research	Moshing	4 Years (2011-2014)	63,200	• TTHR
33	Milsten, et al – 2022[45]	USA	Original Research	Major League Baseball Games	11 Years (2005-2016)	26,066,862	• PPTT • TTHR
34	Milsten, et al – 2022[46]	USA	Original Research	National Hockey League Games	6 Years (2013-2018)	4,370,671	• PPTT • TTHR
35	Morimura, et al – 2004[47]	Korea/ Japan	Original Research	2002 FIFA World Cup	1 Year	2,416,080	• PPR • In-PPR • Out-PPR • TTHR • VAR
36	Munn, et al – 2016[48]	Canada	Case Report	Shambhala Music Festival	7 Days	67,120	• PPR • ATR
37	Pakravan, et al – 2013[49]	UK	Brief Report	Suffolk Show (Agricultural Fairs)	2 Days	90,000	• PPR • TTHR
38	Piat, et al – 2010[50]	Italy	Original Research	Torino 2006 Winter Olympic Games	34 Days	2,607	• MUR
39	Rabb, et al – 2018[51]	Canada	Original Research	Obstacle Course Racing	3 Years (2015-2017)	73,366	• Injury Rate • Season Injury Rate
40	Rajakrishnan, et al – 2022[52]	Malaysia	Original Research	MG Event in Petaling District	1 Day	20,000	• Attack Rate
41	Sabra, et al – 2014[53]	USA	Original Research	Formula One	3 Days	265,500	• PPTT • MUR
42	Spaepen, et al – 2020[54]	Belgium	Original Research	Music Mass Gatherings	5 Years (2012-2016)	4,126,435	• PPR • EHP
43	Spaepen, et al – 2021[55]	Belgium	Original Research	Public Cultural Mass Gathering	7 Years (2013-2019)	8,673,000	• PPR
44	Spaepen, et al – 2021[56]	Belgium	Original Research	Football Mass Gatherings	10 Years (2010-2019)	1,630,549	• PPR • TTHR

Table 1. Characteristics of the Included Articles (*continued*)

https://doi.org/10.1017/S1049023X2400027X Published online by Cambridge University Press

No	Author(s)	Country	Study Type	Event Type	Event Duration	Attendees	Outcome Metrics
45	Spaepen, et al – 2023[57]	Belgium	Original Research	Electronic Dance Music Festivals	10 Days	400,000	• PPR • TTHR • EHP
46	Spaite, et al – 1990[58]	USA	Original Research	Football Stadium	4 Years (1983-1986)	1,264,341	• Injury Rates
47	Tajima, et al – 2020[59]	Japan	Original Research	Rugby World Cup	44 Days	1,704,443	• PPR • Incidence Rate of Cardiopulmonary Arrest
48	Thierbach, et al – 2003[60]	Germany	Original Research	Fun Fair	10 Days	100,000	• Usage Rate
49	Turris, et al – 2018[61]	Canada	Original Research	Music Festivals	34 Days	632,365	• PPR • ATR • TTHR
50	Ussahgij, et al 2022[62]	Thailand	Original Research	International Marathon Race	1 Day	16,489	• USFMP
51	Westrol, et al – 2017[63]	USA	Original Research	Outdoor Music Concerts	10 Years (2005-2014)	2,399,864	• MUR
52	Yazawa, et al – 2007[64]	Japan	Special Report	Suwa Onbashira Festival	12 Days	1,800,000	• PPTT
53	Zeitz, et al – 2002[65]	Australia	Original Research	Royal Adelaide Show	7 Years (1995-2001)	4,316,404	• PPR • TTHR
54	Zeitz, et al – 2005[66]	Australia	Original Research	Royal Adelaide Show	7 Years (1995-2001)	622,234	• PPR • TTHR
55	Zeitz, et al – 2013[67]	Australian	Original Research	Australian Football League	2 Years	11,000,000	• PPR

Table 1. *(continued).* Characteristics of the Included Articles
Abbreviations: ATR, ambulance transfer rate; EHP, event-to-host-population ratio; In-PPR, intra-venue PPR; MARR, mutual aid request rate; METH, medical center to hospital; MG, mass gathering; MTR, medical transfer rate; MUR, medical usage rate; OHCA, out-of-hospital cardiac arrest; Out-PPR, out-of-venue PPR; PDR, pre-diagnosis rate; PPR, patient presentation rate; RTHR, referrals-to-hospital rate; TTHR, transport-to-hospital rate; USFMP, using start-finish medical post; VAR, venue accommodation rate.

prehospital care presentations.[68] Therefore, it can be said that MUR encompasses the total patient presentations, including all presentations delivered by first aid providers and professional health care workers.

Assessment of Out-of-Event Health Services

Ambulance Transfer Rate (ATR)—The ATR typically refers to the rate of individuals at a mass-gathering event who require transportation to a health care facility via ambulance. This rate is calculated by dividing the number of individuals transferred by ambulance to a medical facility by the total number of attendees in the mass gathering, often expressed as per 1,000 attendees.[31,41] The ATR is an important metric in assessing the need for Emergency Medical Services and the overall health and safety considerations during large events. It provides insights into the demand for ambulance services, the severity of incidents, and the effectiveness of medical response strategies in the context of mass gatherings.

Medical Center to Hospital (METH)—The METH metric refers to individuals who, after receiving on-site medical services at a medical center or medical station located at an event, are transferred to a hospital for further medical treatment. The rate of METH is calculated by dividing the number of individuals evacuated to the hospital by the total number of cases or individuals.[19] Similar to ATR, METH provides the rate of patients transported by ambulance; however, METH is usually presented as a percentage.

Mutual Aid Request Rate (MARR)—In general terms, mutual aid refers to cooperation and assistance provided by one organization or group to another, often in emergency or challenging situations. The MARR represents the rate of mutual aid requests made during a mass gathering, and it is defined as the ratio of patients transported to the hospital by ambulance, excluding ambulances stationed on campus for the event, to every 1,000 attendees.[27]

Transport-to-Hospital Rate (TTHR)—The TTHR is a metric that measures the rate at which individuals are transported to a hospital after seeking emergency services or another health care unit in mass-gathering events. It is calculated by dividing the total number of patients transported to the hospital during the event by the overall number of attendees, and the result is often multiplied by a coefficient such as 10,000 for standardized reporting.[17] Similar to METH and ATR, TTHR typically presents the rate of patients

https://doi.org/10.1017/S1049023X2400027X Published online by Cambridge University Press

No	Metrics	Formulas
1	ATR	$\frac{\text{Number of ambulance transfers}}{\text{Total number of attendees}} \times 1,000$
2	Attack Rate	$\frac{\text{Number of cases}}{\text{Total number of attendees}} \times 100$
3	EHP	$\frac{\text{Number of attendees}}{\text{Number of people in the host community}}$
4	Injury Rate	$\frac{\text{Number of injuries}}{\text{Total number of attendees}} \times 100$
5	MARR	$\frac{\text{Number of mutual aid requests}}{\text{Total number of attendees}} \times 1,000$
6	METH	$\frac{\text{Number of patients evacuated from medical center to hospital}}{\text{Total number of attendees}} \times 100$
7	MTR	$\frac{\text{Number of all external referral and transport}}{\text{Total number of attendees}} \times 1,000$
8	MUR	$\frac{\text{Number of total patient presentations}}{\text{Total number of attendees}} \times 10,000$
9	OHCA	$\frac{\text{Number of OHCA cases}}{\text{Total number of attendees}} \times 100,000$
10	PDR	$\frac{\text{Number of prediagnoses}}{\text{Total number of attendees}} \times 1,000$
11	PPR	$\frac{\text{Number of patient presentation}}{\text{Total number of attendees}} \times 10,000$
12	RTHR	$\frac{\text{Attendees who are referred to hospital}}{\text{Total number of attendees}} \times 10,000$
13	TTHR	$\frac{\text{Attendees who are transported to hospital via ambulance}}{\text{Total number of attendees}} \times 10,000$
14	USFMP	$\frac{\text{Attendees who are using to the USFMP}}{\text{Total number of attendees}} \times 10,000$
15	VAR	$\frac{\text{Number of attendees}}{\text{Maximum capacity for spectators}} \times 100$

Table 2. Formulas for the Metrics Used in Mass-Gathering Events

Abbreviations: ATR, ambulance transfer rate; EHP, event-to-host-population ratio; In-PPR, intra-venue PPR; MARR, mutual aid request rate; METH, medical center to hospital; MTR, medical transfer rate; MUR, medical usage rate; OHCA, out-of-hospital cardiac arrest; Out-PPR, out-of-venue PPR; PDR, pre-diagnosis rate; PPR, patient presentation rate; RTHR, referral-to-hospital rate; TTHR, transport-to-hospital rate; USFMP, using start-finish medical post; VAR, venue accommodation rate.

transported by ambulance and may not include patients who were transferred to the hospital using their own means. This rate, typically provided alongside PPR, is used to assess the severity of out-of-event health care services during mass-gathering events, to ensure patients' access to appropriate treatment, and to allocate health resources effectively.[69] A high TTHR may indicate increased out-of-event health care services needs and more serious patient conditions in mass gatherings, implying a higher demand for emergency medical intervention. Conversely, a low TTHR suggests milder health issues and lower demand for out-of-event health care services.

Referral-to-Hospital Rate (RTHR)—Transport generally refers to the conveyance of an individual to a health care facility, typically facilitated by an ambulance. The TTHR specifically encompasses referrals to the hospital through ambulances, and it indicates how many individuals were transported to the hospital via ambulances during a mass-gathering event. Referral, on the other hand, signifies directing an individual to a more specialized health care unit or a specialized doctor, and it encompasses all methods. This includes individuals referred to the hospital by health care professionals, ambulance, or different methods.[70] In this context, RTHR measures the frequency of individuals being referred to specialized health care services during mass gatherings, indicating the likelihood of referral based on incident severity. The calculation involves dividing the total hospital-referred patients by the overall attendee count during the event, and the outcome is frequently scaled by a coefficient like 10,000 for standardized reporting.[24]

Medical Transfer Rate (MTR)—The ATR specifically pertains to the frequency of emergency ambulance responses and transfers, specifically related to emergency calls, throughout the event. On the other hand, MTR comprises all external referrals, encompassing ambulance transfers and other forms of medical transportation.[31] To elaborate, the ATR is narrowly focused on the occurrence of emergency ambulance responses and subsequent transfers, whereas the MTR encompasses a broader spectrum of medical transfers, accounting for various modes of transportation that may not necessarily involve public ambulance services. In short, it can be said that it produces the same output as RTHR and encompasses all total referrals.

Discussion

Most articles on mass gatherings are inherently descriptive, and these studies often include rates related to venue-specific disease, injuries, and patient transfers. In this study, the rates and ratios reported in mass-gathering studies were examined and tried to be gathered in a framework. The 15 metrics obtained in this study help to evaluate the effectiveness of health care services, to understand the demand for emergency services, and to monitor the number of individuals seeking medical assistance during mass gatherings within a specific time frame.[16] However, it is important to note that the interpretation of these metrics depends on the characteristics of the mass-gathering event, the organization of health care services, and other relevant factors.

Inconsistencies Detected in the Literature

Unfortunately, a review of the literature revealed inconsistencies among the reported rates and ratios, missing values in some metrics, and rates were represented by different terminologies. Many studies included values such as the number of injuries, deaths, and hospitalizations; however, many studies were also found that did not provide these values.[34,60,71–73] In a study conducting a retrospective analysis of patient admissions over seven years, the number of attendees attending each year was provided, but the total number of attendees was not given. Moreover, PPR and TTHR values were provided on average, but they were not detailed for each specific year.[65] In addition, in a study conducted at six shopping malls in Ankara, Türkiye, it was reported that out of 4,634 treated patients, 189 were transported to the hospital by ambulance, and 299 patients were self-referred to hospitals. The fact that the TTHR value was provided while the RTHR value was not given is noteworthy.[22]

In the methods section of a study conducted at an outdoor music concert, the MUR was stated to be calculated per thousand attendees, but it was presented as PPTT in the results section. Moreover, it is noteworthy that while the total transport numbers were available, the calculation of TTHR was not conducted.[63] Even though Ussahgij's study was recent, it did not provide a value commonly found in the literature, such as MUR or PPR. Instead, the USFMP ratio was utilized for a study conducted at a sports event. Moreover, despite reporting that two individuals were admitted to the hospital, no ratios such as TTHR or MTR had been provided.[62] In the findings of another study conducted at a large university stadium, it was written that the injury/illness rate in

https://doi.org/10.1017/S1049023X2400027X Published online by Cambridge University Press

1983 was 29.5 per 10,000 attendees, but in the table, this rate was shown as 2.95.[58]

Recommendation for Standardization

Although various names were used for rates and ratios in the literature, they essentially calculated the same things. However, the use of different names for these rates and the lack of values for some metrics may hinder standardization and complicate the comparison of studies. For example, PPR and MUR have often been used interchangeably in the literature. At this point, it should be noted that PPR may be limited to medical service presentations, and may not encompass first aid presentations. Therefore, if the data are appropriate, PPR should be presented separately from the first aid rate (FAR), and their sum should constitute MUR (FAR + PPR = MUR). The same issue existed in the ratios used for the evaluation of out-of-event health services. While METH, ATR, and TTHR typically indicate the ratio of patients transported by ambulance, they may not include patients transported to the hospital by their own means. The MARR, on the other hand, also indicates the ratio of patients transported by ambulance, but it signifies collaboration and assistance provided from one organization or group to another. Both MTR and RTHR encompass a wider range of medical transfers by considering various modes of transportation, which may not necessarily include ambulance services. At this point, it would be more understandable to report separately the patients transported by ambulance, those directed to the hospital by their own means, and the total number of transfers. Therefore, patients transported by ambulance should be given as TTHR, patients directed to the hospital should be given as RTHR, and the total transfer should be given as MTR (TTHR + RTHR = MTR). The MARR is not widely used in the literature, however, if available, this ratio should also be added to the MTR.

Another crucial point for standardization is the necessity of expressing ratios per how many attendees. Essentially, this situation can vary based on the number of attendees. For instance, in an event with 10,000 attendees, the PPR may appear smaller when expressed as a percentage but larger when expressed per 10,000. Therefore, ratios can be multiplied by 100, 1,000, or 10,000 to make them more understandable and comparable, allowing for easier comparison of different events or situations. Upon examining studies in the literature, it was observed that PPR values were often given using a coefficient of 1,000,[13,21,66] but some researchers used 10,000 instead.[39,45,46] Similarly, from the perspective of TTHR, a coefficient of 1,000 was predominantly used,[17,23,35,65] but some researchers used 10,000 instead.[29,32,44] In addition, MUR was generally presented as PPR in the literature. However, some studies referred only to MUR without using PPR. Some studies reported MUR per 10,000 attendees[20,43,44,62–64] while others reported it per 1,000 attendees,[34] and yet others presented it as a percentage.[50] In light of this information, especially when documenting multiple studies conducted in the past, it is crucial to accurately report rates that vary based on the number of attendees. For example, if in one study the PPR value is five per 1,000 attendees, and in another study it is ten per 10,000 people, stating that the PPR value ranges from five to ten would be incorrect. It is necessary to specify that the PPR varies between one-to-five per 1,000 attendees or 10-50 per 10,000 attendees. As a result, taking the coefficient as 1,000 or 10,000 does not pose a problem; however, the coefficient value must be reported accurately, and caution should be exercised when making comparisons.

As a result, many studies lacked clear statements regarding the number of attendees, failed to provide rates for patient presentations and total transfers, and reported rates under different names. This situation makes it challenging to compare between studies, leads to incomplete or inconsistent data, and results in a lack of overall standardization. Therefore, to facilitate comparability between studies and ensure standardization, the use of the Metrics and Essential Ratios for Gathering Events (MERGE) table is recommended, which has been developed by including the minimum information that needs to be reported (Table 3). The MERGE table should minimally include VAR, FAR, PPR, MUR, TTHR, RTHR, MTR, and mortality rates. Although PDR is a value commonly reported in mass-gathering events, it is not included in the MERGE table. It would be more sensible to present a separate table containing PDR values related to injuries and illnesses.

The MERGE table developed in this study may not be universally applicable to every mass-gathering event, but it serves as a starting point to promote standardization in data reporting. It is essential to adapt this table to the specific characteristics of the mass-gathering events. For instance, consider a flash mob event organized in a public square, where attendees assemble suddenly and briefly perform a coordinated action before dispersing. In such spontaneous events, accurately estimating the total number of attendees can be challenging due to the rapid and unpredictable nature of the gathering. Therefore, some changes can be made to the table based on the number and type of incidents. In addition, presenting values related to personnel, materials, and equipment usage will also enrich the table. The number of attendees for each metric given in the table should be shown below it.

Limitations

This study is subject to certain limitations, as is common in most reviews. Firstly, there is no specific protocol or record outlining the inclusion criteria and analysis methods employed in this study. Additionally, the effectiveness of the selected keywords and the potential exclusion of relevant articles may have impacted the comprehensiveness of the review. Finally, the study is confined to open-access and English language literature, thereby not encompassing all potential articles published on the research topic.

Conclusion

The extensive analysis of 55 relevant studies spanning from 1990 through 2023 provides nuanced insights into the health dynamics associated with mass gatherings. Density metrics assist in proactive resource planning and crowd density management, while in-event health service metrics help assess health care demand and tailor services to prevalent health issues. Out-of-event health service metrics provide critical information regarding the severity of incidents and the demand for Emergency Medical Services. As the growth of mass-gathering events continues to be witnessed, these metrics serve as a foundation for future research and the development of effective health management strategies in mass-gathering settings. However, it has been observed in the literature that various terminologies and percentage expressions are used for similar ratios. To facilitate meaningful comparisons in future research, standardization is crucial. The MERGE table provided in this study serves as an example of a framework for standardizing reporting, emphasizing the need for a unified approach. This standardization would not only enhance the consistency of reporting, but it would also foster a more cohesive understanding of health metrics in mass gatherings across diverse studies.

https://doi.org/10.1017/S1049023X2400027X Published online by Cambridge University Press

Variables	*Event 1*	*Event 2*	*Event 3*	*Total*
Total Capacity	1,000,000	2,000,000	1,000,000	4,000,000
Number of Attendees	750,000	1,250,000	500,000	2,500,000
First Aid Response	20	10	30	60
Patient Presentation	80	50	100	230
Death	0	4	2	6
Total Patient	100	64	132	296
Transport via Ambulance	14	6	26	46
Referral to Hospital	4	4	24	32
Total Transport	18	10	50	78
ASSESSMENT OF POPULATION DENSITY				
VAR	75%	62.5%	50%	62.5%
ASSESSMENT OF IN-EVENT HEALTH SERVICES				
Total MUR[a]	1.33	0.51	2.64	1.18
FAR[a]	0.26	0.08	0.60	0.24
PPR[a]	1.07	0.40	2.00	0.92
Mortality Rate[b]	0	0.32	0.40	0.24
ASSESSMENT OF OUT-OF-EVENT HEALTH SERVICES				
Total MTR[a]	0.24	0.08	1.00	0.31
TTHR[a]	0.19	0.05	0.52	0.18
RTHR[a]	0.05	0.03	0.48	0.13

Table 3. Metrics and Essential Ratios for Gathering Events (MERGE) Table
Abbreviations: FAR, first aid rate; MTR, medical transport rate; MUR, medical usage rate; PPR, patient presentation rate; RTHR, referral-to-hospital rate; TTHR, transport-to-hospital rate; VAR, venue accommodation rate.

[a] Patient per 10,000.

[b] Patient per 100,000.

Author Contributions

CC: Conceptualization, methodology, project administration, supervision. ADK: Resources, investigation, formal analysis, writing - review & editing, writing - original draft. TÖ: Resources, investigation, formal analysis, writing - review & editing, writing - original draft. ND: Resources, investigation, writing - review & editing, writing - original draft. KK: Conceptualization, methodology, project administration, supervision.

Supplementary Materials

To view supplementary material for this article, please visit https://doi.org/10.1017/S1049023X2400027X

References

1. Koçak H, Tuncay İ. Evaluation of trauma cases in different types of mass gathering events. *Ulus Travma Acil Cerrahi Derg.* 2022;28(6):781–789.
2. World Health Organization. Public health for mass gatherings: key considerations. 2015. https://www.who.int/publications-detail-redirect/public-health-for-mass-gatherings-key-considerations. Accessed November 22, 2023.
3. Yezli S, Alotaibi B. Mass gatherings and mass gatherings health. *Saudi Med J.* 2016;37(7):729–730.
4. Memish ZA, Steffen R, White P, et al. Mass gatherings medicine: public health issues arising from mass gathering religious and sporting events. *Lancet.* 2019; 393(10185):2073–2084.
5. Aitsi-Selmi A, Murray V, Heymann D, et al. Reducing risks to health and wellbeing at mass gatherings: the role of the Sendai Framework for Disaster Risk Reduction. *Int J Infect Dis.* 2016;47:101–104.
6. Sharma U, Desikachari BR, Sarma S. Protocol for development of a risk assessment tool for planning and management of religious mass-gathering events of India—a health system-strengthening initiative. *Pilot Feasibility Stud.* 2019;5(1):83.
7. Milsten AM, Maguire BJ, Bissell RA, et al. Mass-gathering medical care: a review of the literature. *Prehosp Disaster Med.* 2002;17(3):151–162.
8. De Lorenzo RA. Mass gathering medicine: a review. *Prehosp Disaster Med.* 1997; 12(1):68–72.
9. Van Remoortel H, Scheers H, De Buck E, et al. Prediction modelling studies for medical usage rates in mass gatherings: a systematic review. *PLoS One.* 2020;15(6): e0234977.
10. Whittemore R, Knafl K. The integrative review: updated methodology. *J Adv Nurs.* 2005;52(5):546–553.
11. Hong QN, Fàbregues S, Bartlett G, et al. The Mixed Methods Appraisal Tool (MMAT) version 2018 for information professionals and researchers. *Education for Information.* 2018;34(4):285–291.
12. Kuday AD, Özcan T, Çalışkan C, et al. Challenges faced by medical rescue teams during disaster response: a systematic review study. *Disaster Med Public Health Prep.* 2023;17:e548.
13. Alassaf WI. EMS Coverage of a female-only event with 10,000 attendees: preparation and implementation in one week. *Prehosp Disaster Med.* 2017;32(6):694–698.
14. Allen TL, Jolley SJ, Cooley VJ, et al. The epidemiology of illness and injury at the alpine venues during the Salt Lake City 2002 Winter Olympic Games. *J Emerg Med.* 2006;30(2):197–202.
15. Allgaier RL, Shaafi-Kabiri N, Romney CA, et al. Use of predictive modeling to plan for special event medical care during mass gathering events. *Disaster Med Public Health Prep.* 2019;13(5-6):874–879.
16. Anikeeva O, Arbon P, Zeitz K, et al. Patient presentation trends at 15 mass-gathering events in South Australia. *Prehosp Disaster Med.* 2018;33(4):368–374.
17. Arbon P, Bridgewater FH, Smith C. Mass gathering medicine: a predictive model for patient presentation and transport rates. *Prehosp Disaster Med.* 2001;16(3):150–158.
18. Bock HC, Cordell WH, Hawk AC, et al. Demographics of emergency medical care at the Indianapolis 500-mile race (1983-1990). *Ann Emerg Med.* 1992;21(10): 1204–1207.
19. Bortolin M, Ulla M, Bono A, et al. Holy shroud exhibition 2010: health services during a 40-day mass-gathering event. *Prehosp Disaster Med.* 2013;28(3):239–244.
20. Burton JO, Corry SJ, Lewis G, et al. Differences in medical care usage between two mass-gathering sporting events. *Prehosp Disaster Med.* 2012;27(5):458–462.

21. Ceyhan MA, Demir GG, Güler GB. Evaluation of health care services provided in political public meetings in Turkey: a forgotten detail in politics. *Prehosp Disaster Med.* 2018;33(6):607–613.
22. Ceyhan MA, Demir GG. Health care services in shopping centers: a routine mass-gathering event. *Prehosp Disaster Med.* 2020;35(6):669–675.
23. Chang WH, Chang KS, Huang CS, et al. Mass gathering emergency medicine: a review of the Taiwan experience of long-distance swimming across Sun-Moon Lake. *Int J Gerontol.* 2010;4(2):53–68.
24. Crabtree N, Mo S, Ong L, et al. Retrospective analysis of patient presentations at the Sydney (Australia) Royal Easter Show from 2012 to 2014. *Prehosp Disaster Med.* 2017;32(2):187–194.
25. Dutch MJ, Senini LM, Taylor DJ. Mass gathering medicine: the Melbourne 2006 Commonwealth Games experience. *Emerg Med Australas.* 2008;20(3):228–233.
26. Friedman MS, Plocki A, Likourezos A, et al. A prospective analysis of patients presenting for medical attention at a large electronic dance music festival. *Prehosp Disaster Med.* 2017;32(1):78–82.
27. Friedman NMG, O'Connor EK, Munro T, et al. Mass-gathering medical care provided by a collegiate-based first response service at an annual college music festival and campus-wide celebration. *Prehosp Disaster Med.* 2019;34(1):25–29.
28. Goldberg SA, Maggin J, Molloy MS, et al. The Gillette Stadium experience: a retrospective review of mass gathering events from 2010 to 2015. *Disaster Med Public Health Prep.* 2018;12(6):752–758.
29. Goldberg SA, Battistini V, Cash RE, et al. A retrospective review of out of hospital cardiac arrest at Gillette Stadium: 10 years of experience at a large sports venue. *Resusc Plus.* 2023;14.
30. Grant WD, Nacca NE, Prince LA, et al. Mass-gathering medical care: retrospective analysis of patient presentations over five years at a multi-day mass gathering. *Prehosp Disaster Med.* 2010;25(2):183–187.
31. Gutman SJ, Lund A, Turris SA. Medical support for the 2009 world police and fire games: a descriptive analysis of a large-scale participation event and its impact. *Prehosp Disaster Med.* 2011;26(1):33–39.
32. Hardcastle TC, Samlal S, Naidoo R, et al. A redundant resource: a pre-planned casualty clearing station for a FIFA 2010 stadium in Durban. *Prehosp Disaster Med.* 2012;27(5):409–415.
33. Ho WH, Koenig KL, Quek LS. Formula one night race in Singapore: a 4-year analysis of a planned mass gathering. *Prehosp Disaster Med.* 2014;29(5):489–493.
34. Hostettler-Blunier S, Müller N, Haltmeier T, et al. Public medical preparedness at the "Swiss Wrestling and Alpine Games 2013": descriptive analysis of 1,533 patients treated at the largest 3-day sporting event in Switzerland. *Emerg Med Int.* 2017;2017:9162095.
35. Imbriaco G, Flauto A, Bussolari T, et al. Mass gathering emergency medicine organization for the Union of European Football Associations' under-21 championship 2019 in Bologna, Italy. *Disaster Med Public Health Prep.* 2022;16(1):405–408.
36. Johnsson KMC, Örtenwall PA, Kivi ALH, et al. Medical support during the European Union Summit in Gothenburg, Sweden, June 2001. *Prehosp Disaster Med.* 2006;21(4):282–285.
37. Koçak H, Çalışkan C, Sönmezler MŞ, et al. Analysis of medical responses in mass gatherings: the commemoration ceremonies for the 100th anniversary of the Battle of Gallipoli. *Prehosp Disaster Med.* 2018;33(3):288–292.
38. Kocak H, Tuncay I. Comparison of emergency medical services cases in different types of mass gathering events held between 2015-2018 in Turkey. *Eurasian J Emerg Med.* 2022;21(2):93–99.
39. Locoh-Donou S, Yan G, Berry T, et al. Mass gathering medicine: event factors predicting patient presentation rates. *Intern Emerg Med.* 2016;11(5):745–752.
40. Lonnee M, Andersen KG, Stagelund S, et al. Use of medical supplies at the Roskilde Festival 2016: a prospective observational study. *Prehosp Disaster Med.* 2021; 36(3):306–312.
41. Lund A, Turris SA. Mass-gathering medicine: risks and patient presentations at a 2-day electronic dance music event. *Prehosp Disaster Med.* 2015;30(3):271–278.
42. Maleczek M, Rubi S, Fohringer C, et al. Medical care at a mass gathering music festival: retrospective study over 7 years (2011-2017). *Wien Klin Wochenschr.* 2022;134(7-8):324–331.
43. Milsten AM, Seaman KG, Liu P, et al. Variables influencing medical usage rates, injury patterns, and levels of care for mass gatherings. *Prehosp Disaster Med.* 2003;18(4):334–346.
44. Milsten AM, Tennyson J, Weisberg S. Retrospective analysis of mosh-pit-related injuries. *Prehosp Disaster Med.* 2017;32(6):636–641.
45. Milsten A, Bradley WF, Hill M, et al. Foul ball rates and injuries at Major League Baseball games: a retrospective analysis of data from three stadiums. *Prehosp Disaster Med.* 2022;37(2):277–283.
46. Milsten A, Ness J. Hockey puck strike rates and injuries at National Hockey League games: a retrospective analysis of data from six seasons. *Prehosp Disaster Med.* 2022;37(3):397–400.
47. Morimura N, Katsumi A, Koido Y, et al. Analysis of patient load data from the 2002 FIFA World Cup Korea/Japan. *Prehosp Disaster Med.* 2004;19(3):278–284.
48. Munn MB, Lund A, Golby R, et al. Observed benefits to on-site medical services during an annual 5-day electronic dance music event with harm reduction services. *Prehosp Disaster Med.* 2016;31(2):228–234.
49. Pakravan AH, West RJ, Hodgkinson DW. Suffolk Show 2011: prehospital medical coverage in a mass-gathering event. *Prehosp Disaster Med.* 2013;28(5):529–532.
50. Piat SC, Minniti D, Traversi D, et al. Torino 2006 Winter Olympic Games: highlight on health services organization. *J Emerg Med.* 2010;39(4):454–461.
51. Rabb H, Coleby J. Hurt on the hill: a longitudinal analysis of obstacle course racing injuries. *Orthop J Sports Med.* 2018;6(6):2325967118779854.
52. Rajakrishnan S, Hafiz Ismail MZ, Jamalulail SH, et al. Investigation of a foodborne outbreak at a mass gathering in Petaling District, Selangor, Malaysia. *Western Pac Surveill Response J.* 2022;13(1):1–5.
53. Sabra JP, Cabañas JG, Bedolla J, et al. Medical support at a large-scale motorsports mass-gathering event: the inaugural formula one united states grand prix in Austin, Texas. *Prehosp Disaster Med.* 2014;29(4):392–398.
54. Spaepen K, Haenen WAP, Kaufman L, et al. Validation of a Belgian prediction model for patient encounters at music mass gatherings. *Prehosp Disaster Med.* 2020;35(5): 561–566.
55. Spaepen K, Arno G, Kaufman L, et al. Validation of a Belgian prediction model for patient encounters at Belgium's largest public cultural mass gathering. *Disaster Med Public Health Prep.* 2022;16(3):1128–1133.
56. Spaepen K, Lauwaert D, Kaufman L, et al. Validation of a Belgian prediction model for patient encounters at football mass gatherings. *Prehosp Disaster Med.* 2021;36(6): 724–729.
57. Spaepen K, Cardinas R, Haenen WAP, et al. The impact of in-event health services at Europe's largest electronic dance music festival on EMS and ED in the host community. *Int J Environ Res Public Health.* 2023;20(4):3207.
58. Spaite DW, Meislin HW, Valenzuela TD, et al. Banning alcohol in a major college stadium: impact on the incidence and patterns of injury and illness. *J Am Coll Health Assoc.* 1990;39(3):125–128.
59. Tajima T, Takazawa Y, Yamada M, et al. Spectator medicine at an international mega sports event: Rugby World Cup 2019 in Japan. *Environ Health Prev Med.* 2020;25(1):72.
60. Thierbach AR, Wolcke BB, Piepho T, et al. Medical support for children's mass gatherings. *Prehosp Disaster Med.* 2003;18(1):14–19.
61. Turris SA, Callaghan CW, Rabb H, et al. On the way out: an analysis of patient transfers from four large-scale north American music festivals over two years. *Prehosp Disaster Med.* 2019;34(1):38–45.
62. Ussahgij W, Kotruchin P, Osotthanakorn P, et al. Analysis of medical interventions at the Start-Finish Medical Post of an international running event in rural Thailand. *Prehosp Disaster Med.* 2022;37(1):84–89.
63. Westrol MS, Koneru S, Mcintyre N, et al. Music genre as a predictor of resource utilization at outdoor music concerts. *Prehosp Disaster Med.* 2017;32(3): 289–296.
64. Yazawa K, Kamijo Y, Sakai R, et al. Medical care for a mass gathering: the Suwa Onbashira festival. *Prehosp Disaster Med.* 2007;22(5):431–435.
65. Zeitz KM, Schneider DPA, Jarrett D, et al. Mass gathering events: retrospective analysis of patient presentations over seven years. *Prehosp Disaster Med.* 2002; 17(3):147–150.
66. Zeitz KM, Zeitz CJ, Arbon P. Forecasting medical work at mass-gathering events: predictive model versus retrospective review. *Prehosp Disaster Med.* 2005;20(3): 164–168.
67. Zeitz K, Haghighi PD, Burstein F, et al. Understanding the drivers on medical workloads: an analysis of spectators at the Australian Football League. *Australian Health Review.* 2013;37(3):402–406.
68. Arbon P. The development of conceptual models for mass-gathering health. *Prehosp Disaster Med.* 2004;19(3):208–212.
69. Scheers H, Van Remoortel H, Lauwers K, et al. Predicting medical usage rate at mass gathering events in Belgium: development and validation of a nonlinear multivariable regression model. *BMC Public Health.* 2022;22(1):173.
70. Ranse J, Hutton A. Minimum data set for mass-gathering health research and evaluation: a discussion paper. *Prehosp Disaster Med.* 2012;27(6):543–550.
71. Agar C, Pickard L, Bhangu A. The tough guy prehospital experience: patterns of injury at a major UK endurance event. *Emerg Med J.* 2009;26(11):826–830.
72. Wetterhall SF, Coulombier DM, Herndon JM, et al. Medical care delivery at the 1996 Olympic games. *JAMA.* 1998;279(18):1463–1468.
73. Chan SB, Quinn JE. Outcomes in EMS-transported attendees from events at a large indoor arena. *Prehosp Emerg Care.* 2003;7(3):332–335.