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Bibliometric analysis in motorcycle accident research: a global overview

Holman Ospina-Mateus[1,2] · Leonardo Augusto Quintana Jiménez[2] · Francisco J. Lopez-Valdes[3] · Katherinne Salas-Navarro[4]

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Abstract
770 million motorcycles are estimated on the roads. Motorcyclists represent more than 380,000 annual deaths worldwide. 28% of the global fatalities in the roads in 2016. With the increase of the accident rate, studies have been developed within the scientific literature. Bibliometric analysis is applied in the field of motorcycle safety in order to identify relevant publications on risk factors of road crashes and their implications. The information in this research was extracted from Web of Science and Scopus databases between 1947 and May 31, 2018. The study identified the key bibliometric indicators such as publications, authors, journals, countries, institutions, citation and co-citation analysis, subject categories, and co-occurrence of terms. EndNote, Microsoft Excel, Statgraphics Centurion and VOS-viewer software were used for the analysis. In total, 1813 articles were considered. The publications from 2000 to 2017 exhibits an average growth of 9%. The journal "Accident Analysis and Prevention" was the key issue in the publication and citation. The top institutions were the University of California, Universiti Putra Malaysia, and Monash University. The average citation of the top 10 articles was 134. A network visualization map showed that 'vehicle', 'model', 'system', 'road', 'safety', and 'behavior' were the most commons key terms. Bibliometric analysis demonstrates a high collaboration between authors and institutions. Two growing trends were identified. First, studies on the protection of the motorcyclist and the safe design considering the performance. Second, studies in analysis, characterization, and prevention of accidents. These studies are more related to the generation of strategies for the protection of road safety for motorcyclists.

Keywords Bibliometric analysis · Motorcycle · Accident · Crash · Injury

✉ Holman Ospina-Mateus
hospina@utb.edu.co

[1] Department of Industrial Engineering, Universidad Tecnológica de Bolívar, Cartagena, Colombia

[2] Department of Industrial Engineering, Pontificia Universidad Javeriana, Bogotá, Colombia

[3] ICAI Engineering School, Instituto de Investigacion Tecnológica (IIT), Universidad Pontificia de Comillas, Madrid, Spain

[4] Department of Industrial Management, Agroindustry and Operations, Universidad de la Costa, Barranquilla, Colombia

Introduction

Bibliometrics allows for the analysis of a significant amount of scientific literature within a research area. A detailed assessment can be considered as an extensive task, which can generate a vision in a field of research (Rodrigues et al. 2014; Zhou et al. 2015). The quantitative study of information (authors, years) allows for characterizing the scientific development of a specific field (Jia et al. 2014; Li and Hale 2016). Bibliometrics include cooperation analysis, citation, and journals that make research visible. The analysis of institutions and authors enables identification of the knowledge frontier. The bibliometric analysis helps in identifying future works, novel applications, research priorities and references within a topic, according to their geographical location and research network (Wang et al. 2014).

Motorcycles are used in utilitarian tasks related to mobility, transport, sport, and economic activities (Balasubramanian and Jagannath 2014). Motorcycles are a means of unsafe transport (Shahar et al. 2010). Motorcycles are compact, agile, fuel efficient, easy to maneuver in congested areas (Ospina-Mateus and Jiménez 2019). Between the driving of cars and motorcycles, motorcyclists are at greater risk owing to the level of exposure to the environment, noise, and vibrations (Walker et al. 2006). Motorcycle riding attracts a higher risk of accidents than car driving (Horswill and Helman 2003). Approximately 1.4 million people died in traffic accidents in 2016, and it is estimated that over 50 million people suffered serious injuries (WHO 2018). Injuries in road crashes are the main cause of death in people aged 15–29 years and affect pedestrians, cyclists, and motorcyclists. Half of all road deaths occur among motorcyclists (28%), pedestrians (23%), and cyclists (3%). Motorcyclists represent more than 380,000 annual deaths worldwide. The fatalities of motorcyclists have increased worldwide by 22% from 2013 to 2016.

There are several common areas that have emerged as dominant themes within motorcycle safety research. Within different researches are studies that examine the use of the helmet, the impact of legislation, related injuries and deaths in crashes. Other studies have involved specific aspects related to the frequency and risk of factors of motorcycle crashes. These studies have used models, causal analyses and forecasts. There is also empirical research has examined a variety of factors including environmental conditions, aspects of motorcycles, socioeconomic factors, road design, the characteristics of motorcyclists, driving behavior, alcohol consumption, and clinical and medical studies in traumas, fractures, and injuries.

The present study aims to provide a bibliometric overview of research in the field of motorcycle safety. This bibliometric analysis will help to identify relevant publications on causes and risk of factors of road crashes and their implications. The bibliometric study will recognize the most influential authors, journals, institutes, articles, countries in the development of motorcyclist accident researches. At the end of the document, relevant aspects of the research are discussed, as well as findings that direct future research and support the development of countermeasures to improve road safety for motorcyclists.

Table 1 List of terms used for literature search, grouped into four different types

Group	Search Terms
Vehicle	Moped, Motorbike, Motorcycle, Motorcyclist, Rider, Scooter
Event, condition or incident	Accident, Collision, Crash, Death, Factor, Fatality, Hazard, Helmet, Incident, Injury, Risk, "Risk Factor", Road, Safety, Severity, Speed, Traffic, Wound

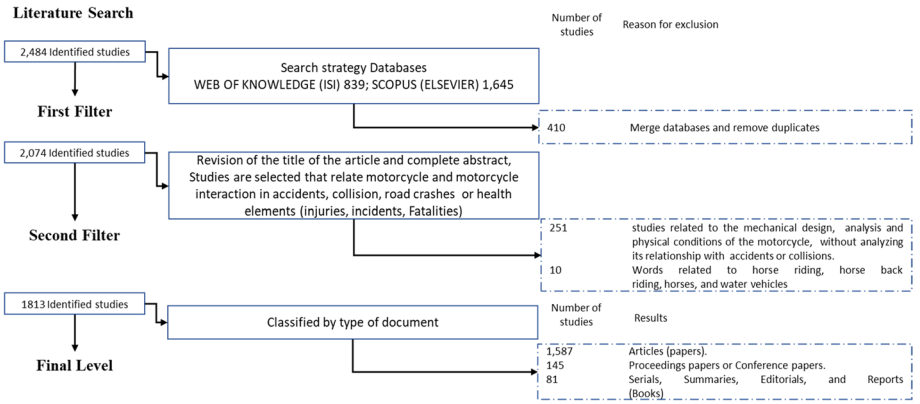

Fig. 1 Process of selection of studies for inclusion in the review

Data and methods

The Web of Science (WoS) and Scopus databases were selected as a search engine owing to their extensive acceptance in the analysis of scientific publications (Yang et al. 2013). The term motorcyclist accidents refer to a set of keywords related to the motorcyclist, vehicle, and event. The terms searched by title were divided into two groups, as follows. The vehicle and driver identify the vehicle types and their drivers. The event: the incident points out certain driving conditions, injuries, and risks to the exposed motorcyclist. Table 1 displays the defined key terms.

The search was developed with the combination of Vehicle and Event, using the Boolean operator "AND" and between categories, with "OR". The bibliographic search criteria are detailed in Appendix 1. The period of the search was from 2001 to 2018 in Web of Science, while in Scopus it was from 1947 until May 31, 2018. The last update of the database was May 31, 2018. If the same search strategy is performed on a different date, the results may differ slightly. These differences are owing to the fact that the databases are continuously updated (Liu et al. 2013). A total of 839 and 1645 publications related to motorcyclist traffic accidents were identified in WoS and Scopus, respectively. The total number of publications without duplicates was 2074. After eliminating duplicates, all the titles and abstracts were read to select the relevant publications. Publications associated with the physical and mechanical design of motorcycles (without considering the road crashes or accidents), as well as those related to horse riding were excluded. Only publications related to motorcyclist accidents, road safety, vehicle safety, prevention and protection of the motorcyclist were considered. The Process of

selection of studies for inclusion is detailed in Fig. 1. In total, 1813 scientific publications were considered.

The publications found in the databases contain information including the date of publication, authors, affiliation, title, abstract, journal, and keywords, among other key aspects that were managed in Excel and Statgraphics Centurion XVI (StatPoint Technologies, Inc. 2009). The VOS-viewer software (www.vosviewer.com) (Van Eck and Waltman 2010) application was used to identify the relationships among authors, countries, co-citations, and terms included in the network analysis (van Eck et al. 2010). The analysis identified information based on a map concurrency and distance relationship. The interpretation of the network maps was simple owing to classification by colors (cluster), sizes, and distances of the evaluated terms. This analysis followed the methodology of van Nunen et al. (2018). With the information, the following aspects were analyzed: (1) publication output and growth trend, (2) authors and their cooperation, (3) journal publishing, (4) geographical and institutional distribution and cooperation, (5) Citation analysis, (6) citing and co-citation analysis, (7) subject categories, and (8) terms.

Results

Publication output and growth trend

The scientific documents were analyzed by periods (see Fig. 2). Publications began to increase in 1980. In the last three decades there was a constant growth in the average of publications (1990–1999: 17; 2000–2010: 50; 2011–2017: 100). The highest peak of publications was in 2016 ($n = 142$). The average variation of publications from 2000 to 2017 exhibits an average growth of 9%.

The volume of publications was predicted using the statistical model of best fit for the mean error and the mean square error. The ARIMA model (2.0.2) was found to be the best fit. The forecast for the next 4 years (including 2018) is 146, 150, 169, and

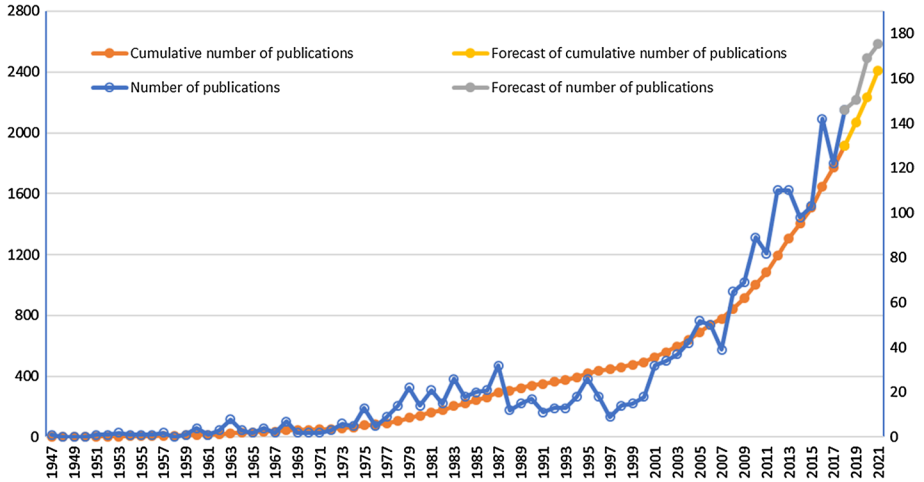

Fig. 2 Number and accumulation of publications per year in motorcycle accident research

175 publications. Cumulative growth indicates the importance and exponentially increased over the years of the subject.

Authors and their cooperation

The 1813 publications were written by 4572 different authors. The largest proportion of authors (84.3%; $n=3852/4572$) are related to only one publication. 10.6% ($n=486/4572$) is credited in two publications. 5.1% ($n=234/4572$) is credited in three or more publications. Table 2 displays the top ten most productive authors. The classification is based on the total number of publications. J.F. Kraus is the most productive and the most cited author. His research area is related to Injury Prevention.

The average number of publications per author is 1.27. 33 publications do not have specific authorship. 18.1% ($n=328/1813$) of the publications had singled authorship. 21.1% ($n=383/1813$) of the publications has two authors. 20.9% ($n=379/1813$) had three authors. 15.7% ($n=285/1813$) had four authors. 10.3% ($n=187/1813$) had five authors. 12% ($n=217/1813$) had six or more authors (with a maximum of 14 authors). The cooperation pattern of the authors publishing was examined with VOS-viewer (see Fig. 3). The circle sizes illustrate the volume of publications. The curved connections represent cooperation. The color scales indicate the collaboration clusters. In the cooperation network, 16 author clusters are distinguished.

Journal publishing on motorcycle accident research

A total of 1813 articles were published in 820 different journals. Of the 820 journals, 599 (73%) published only one article. 120 (14.6%) published two articles. 83 (10.1%) published three and 10 articles. 18 (2.2%) published 10 or more articles (ranging from 11 to 127 publications). Table 3 provides information on the top 10 most active journals. These 10 journals published 26% of all publications ($n=468/1813$). The categories of sub-areas in the most recurrent journals according to the Scimago Journal Ranking (SJR) are "Medicine:

Table 2 Top ten most productive authors publishing in motorcycle accident research

No.[a]	Name of author	Country of author	Number of publications	Total citations	Average citation per publication	Number of publications as first author
1	J. F. Kraus	United States	25	870	34.8	12
2	R. S. Radin Umar	Malaysia	20	160	8.0	3
3	J. D. Langley	New Zealand	15	323	21.5	7
4	S. V. Wong	Malaysia	14	67	4.8	0
5	J. Brown	New Zealand	14	34	2.4	2
6	R. Ivers	Australia	12	351	29.3	2
7	J. V. Ouellet	United States	12	160	13.3	7
8	M. R. Lin	Taiwan	10	384	38.4	6
9	C. W. Pai	Taiwan	10	239	23.9	10
10	L. De Rome	Australia	10	64	6.4	5

[a]Ordered by number of publications, then number of citations

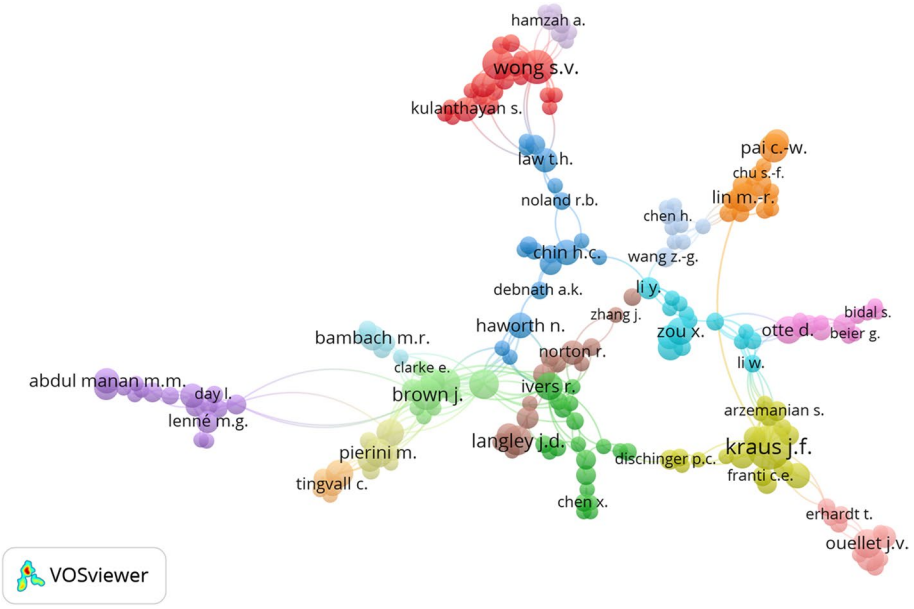

Fig. 3 Author cooperation network in motorcycle accident research

Public Health, Environmental and Occupational Health", followed by "Engineering: Safety, Risk, Reliability, and Quality". Appendix 2 illustrates the publication frequency by years of the top five of the most influential journals. There was an increase in publications in the last decade. The high volume of publications in the "SAE Technical Papers" and "Transportation Research Record" is due to the compilation of conference proceedings and, editorials.

Geographical, institutional distribution and cooperation

Each publication was assigned to a country, according to the information available in the author affiliations and addresses listed in WoS and Scopus. There were 411 publications without information. 77% of the publications were related to a region or country. A publication may be related to different countries or institutions are given a multiple affiliation or authorship. All affiliations of authors by country or institution were considered.

Countries and territories

The publications in Motorcyclist traffic accidents originated from 69 different regions. Of all countries, 25 of these are in Europe, 22 in Asia, 11 in Africa, 9 in America, and 2 in Oceania. Figure 4 illustrates the global distribution of the contribution of these countries and territories. A total of 32 countries or territories (50.7%) produced less than 10 publications. 21 countries or territories (30.4%) have produced between 11 and 50 publications. 10 countries or territories (14.5%) have produced between 51 and 150 publications. Finally, 5.8% of countries or territories have produced more than 151 publications. The USA produced the most publications. Appendix 3 illustrates the top 10 most productive countries

Table 3 Top 10 most active journals publishing in motorcycle accident research

No.	Title (journal)	Num of publications	SJR-2017	Impact factor-2016	Subject category (SJR)
1	Accident Analysis and Prevention	127	1.462	2.685	Social Sciences: Law Engineering: Safety, Risk, Reliability and Quality Medicine: Public Health, Environmental and Occupational Health Social Sciences: Human Factors and Ergonomics
2	SAE Technical Papers	81	0.36	NA	Engineering: Industrial and Manufacturing Engineering Engineering: Safety, Risk, Reliability and Quality Engineering: Automotive Engineering Environmental Science: Pollution
3	Traffic Injury Prevention	60	0.773	1.29	Medicine: Public Health, Environmental and Occupational Health Social Sciences: Safety Research
4	Transportation Research Record	41	0.589	0.598	Engineering: Civil and Structural Engineering Engineering: Mechanical Engineering
5	Injury Prevention	37	1.03	1.482	Medicine: Public Health, Environmental and Occupational Health
6	Injury	30	0.99	NA	Medicine: Emergency Medicine Medicine: Orthopedics and Sports Medicine Medicine: Surgery
7	Annals of Emergency Medicine	26	1.632	4.728	Medicine: Emergency Medicine
8	JAMA—Journal of the American Medical Association	23	8.876	44.405	Medicine: Medicine (miscellaneous)
9	Journal of Trauma—Injury, Infection and Critical Care	22	NA	NA	Medicine: Critical Care and Intensive Care Medicine Medicine: Surgery
10	International Journal of Injury Control and Safety Promotion	21	0.378	0.875	Medicine: Public Health, Environmental and Occupational Health Social Sciences: Safety Research

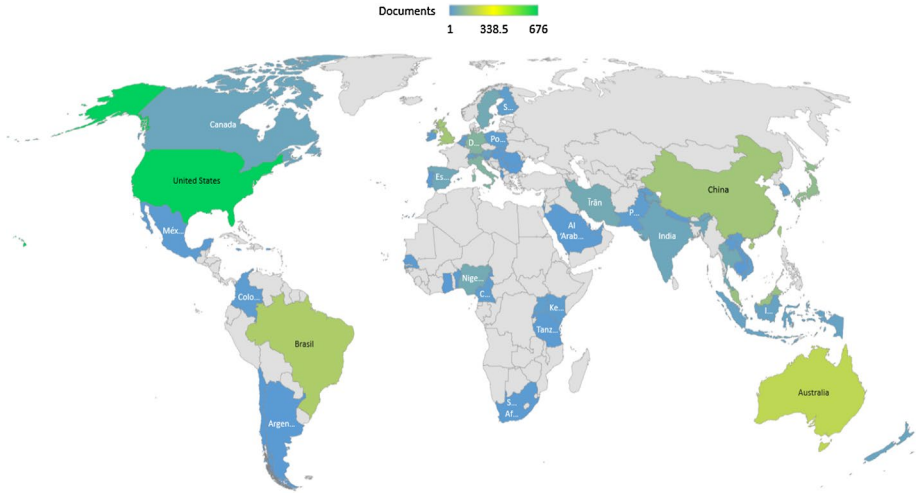

Fig. 4 Number of publications distributed by country or territory in motorcycle accident research

and territories in publications. Countries with economic development are those that contribute and provide scientifically and academically. The seven most industrialized countries (G7: USA, Japan, Italy, Germany, United Kingdom, Canada, and France) are ranked among the top 20 of most productive countries in motorcycle accident publications.

1402 publications contain information from countries and territories affiliation of the authors. The publications related 2746 affiliations of the authors (one author can be affiliated to more than one country). According to the countries and territories, America

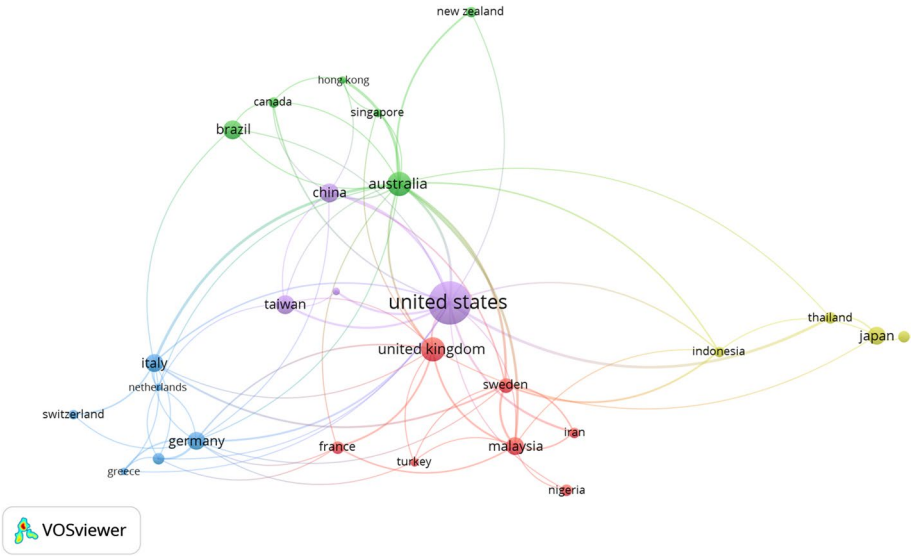

Fig. 5 Cooperation network between countries and territories in motorcycle accident research

produced 33% of publications ($n=906/2746$), Asia 31% ($n=850/2746$), and Europe 22.9% ($n=629/2746$). The continents with the lowest participation were Oceania (8.7%) and Africa (4.3%). Figure 5 illustrates the cooperation network between countries and territories.

The analysis was developed using VOS-viewer software. The network indicates countries with 10 or more publications. Those countries that are not connected with others are not included in the network. The circle sizes represent the publication volume. The connections represent the collaborations between countries. Five main groups were identified. The first cluster relates to the United States (central group). The second cluster relates to the United Kingdom (red group). The third cluster relates to Australia (green group). The fourth cluster relates to Germany and Italy (blue group). The fifth cluster relates to Japan (yellow group). When analyzing cooperation between countries in publications. The group from Germany is related to the countries of Western Europe. Nigeria is the only country represented of the African continent. Nigeria has a strong relationship between Malaysia and the United Kingdom. The United States has two other main contributors: China and Taiwan. Japan is related to other nearby Asian countries.

Institutions

A total of 1543 research institutions participated in 1402 publications with available affiliation data (a publication can be written by several authors or an author can be affiliated to more than one institution). The names reported in the databases were homologated, according to the different records in the Scopus and WoS. Of all institutions, 75.2% ($n=1161$) have participated in only one publication. 13.4% ($n=206$) have participated in two publications. 11% ($n=170$) have participated between three and 20 publications. Six institutions (0.45%) developed 20 or more publications. Table 4 provides information on the top 10 most productive institutions. The System of the University of California relates more than 53 publications. Most of the institutions are universities, but there is also evidence of the presence of private organizations, research centers, study centers and institutes.

Table 4 Top 10 most productive institutions publishing in motorcycle accident research

No.	Institution	Country	Number of publications
1	University of California (General)	USA	53
2	Universiti Putra Malaysia	Malaysia	45
3	Monash University	Australia	41
4	University of New South Wales	Australia	31
5	Taipei Medical University	Taiwan	29
6	Malaysia Institute of Road Safety Research (MIROS)	Malaysia	21
7	National Taiwan University	Taiwan	20
8	Universidade de Sao Paulo	Brazil	19
8	University of Otago	New Zealand	19
9	Centers for Disease Control and Prevention	USA	16
10	Università degli Studi di Firenze	Italy	15
10	University of Sydney	Australia	15
10	National Cheng Kung University	Taiwan	15

Citation analysis

In this section, we present how the documents are cited in other publications (knowledge output: cited analysis) (Li and Hale 2016). The analysis of citations allows for identifying the times that a publication has been referenced, considering the Scopus records. In total, 1813 publications were used 15,206 times as references in other publications (until data extraction). The average citation per publication is 8.03. 39.4% ($n=714/1813$) of the articles had not been cited. 13.5% ($n=245/1813$) were cited once. 2.98% ($n=54/1813$) of publications had more than 50 citations. Finally, 0.4% ($n=7/1813$) of the articles were cited more than 100 times. The average citation of the top 10 articles was 134. Table 5 lists the 10 most frequently cited publications.

The most cited is 23 years old. The USA is best represented as country of the first author with five publications, followed by Taiwan and the United Kingdom. J.F. Kraus is the only author with two appearances in the list. Accident Analysis and Prevention is the journal with the greatest representation, with three articles published. According to the central topic of the publications (Category SCimago Journal- SJR), five of the journals cover topics of "Public Health, Environmental and Occupational Health" and "Safety and Risk".

In the total citations of the 820 journals (493 journals with more than one citation), 39.9% ($n=327/820$) of the journals have no citations. 12.1% ($n=99/820$) have a single citation. 25.2% ($n=207/820$) have between two and 10 citations. 17.4% ($n=13/820$) have between 11 and 50 citations. 4.6% have between 51 and 200 citations, and 1.3% ($n=12/820$) have more than 200 citations. The journal with the highest citations is Accident Analysis and Prevention, with 23.2% ($n=3522/15,206$). The journals Traffic Injury Prevention, Journal of Safety Research, Journal of Trauma-Injury, Infection and Critical Care, and American Journal of Public Health obtained 14% ($n=2123/15,206$) of the total citations. The figures indicate a close relationship between the total number of publications and the most referenced journals. Appendix 4 illustrates the top five journals referenced by other articles.

Citation and co-citation analysis

In total, 44,235 references were used, with an average of 25 references per article. The co-citations analysis is illustrated to quantify the interaction between publications and helps analyze affinity. Of the 1813 articles, 9543 authors were identified. Considering only the references used more than 20 times. Of the 44,235 references, 98 achieved this threshold. In Fig. 6, the co-citation analysis developed using the VOS-viewer software is illustrated. The size of the circles evidences greater citation on the subject. The distance identifies the level of the relationship. Network evidence four groups. Based on the map, the red cluster is related to medical studies. The green group has an affinity with epidemiological analyzes of accidents. The yellow and blue groups are linked to the analysis of associated risk factors, statistical, and causal models. The presence of institutions such as the World Health Organization is indicated on the network map.

The most co-cited articles analyze the risk factors associated with the causality of accidents. Among the studies are Shankar and Mannering (1996), Savolainen and Mannering (2007) and Quddus et al. (2002). Also, the review of significant factors in motorcycle injuries developed by Lin and Kraus (2009) is highly co-cited. In addition, the global reports on road safety of the World Health Organization are highly co-cited due to the compilation of accident

Table 5 Top 10 most frequently cited publications in motorcycle accident research

No.	Title	References	Country (1st author)	Institution	Journal- IF (2016)-SJR (2017)	Times cited	Average citations per year	Main topic (category SJR)
1	An exploratory multinomial logit analysis of single-vehicle motorcycle accident severity	Shankar and Mannering (1996).	USA	University of Washington	Journal of Safety Research—(1.151–1.841)	185	8.64	Safety, Risk
2	Helmets for preventing injury in motorcycle riders	Liu et al. (2008)	UK	University of Oxford	Cochrane Database of Systematic Reviews—(6.124–2.347)	184	19.53	Medicine (miscellaneous)
3	Probabilistic models of motorcyclists' injury severities in single- and multi-vehicle crashes	Savolainen and Mannering (2007)	USA	Wayne State University, Purdue University	Accident Analysis and Prevention—(1.462–2.685)	177	16.99	Safety, Risk, Public Health, Environmental and Occupational Health
4	An analysis of motorcycle injury and vehicle damage severity using ordered probit models	Quddus et al. (2002)	U. K	Imperial College of Science, National University of Singapore	Journal of safety research—(1.113–2.246)	154	9.99	Safety, Risk
5	A review of risk factors and patterns of motorcycle injuries	Lin and Kraus (2009)	Taiwan	Taipei Medical University	Accident Analysis and Prevention—(1.462–2.685)	145	17.22	Safety, Risk, Public Health, Environmental and Occupational Health, Human Factors and Ergonomics
6	The effect of the Taiwan motorcycle helmet use law on head injuries	Chiu et al. (2000)	Taiwan	Taipei Medical University	American Journal of Public Health—(2.415–3.858)	103	5.91	Public Health, Environmental and Occupational Health

Table 5 (continued)

No.	Title	References	Country (1st author)	Institution	Journal- IF (2016)-SJR (2017)	Times cited	Average citations per year	Main topic (category SJR)
7	The effect of the 1992 California motorcycle helmet use law on motorcycle crash fatalities and injuries	Kraus et al. (1994)	USA	University of California	Journal of the American Medical Association—(8.876–44.405)	100	4.27	Medicine (miscellaneous)
8	Motorcycle helmet use and injury outcome and hospitalization costs from crashes in Washington State	Rowland et al. (1996)	USA	Washington State Department of Health	American Journal of Public Health—(2.415–3.858)	99	4.62	Public Health, Environmental and Occupational Health
9	Head Injury—Associated Deaths from Motorcycle Crashes: Relationship to Helmet-Use Laws	Sosin et al. (1990)	USA	Centers for Disease Control and Prevention	JAMA: The Journal of the American Medical Association—(8.876–44.405)	97	3.54	Medicine (miscellaneous)
10	Errors and violations in relation to motorcyclists' crash risk	Elliott et al. (2007)	UK	University of Strathclyde	Accident Analysis and Prevention—(1.462–2.685)	95	9.12	Safety, Risk, Public Health, Environmental and Occupational Health, Human Factors and Ergonomics

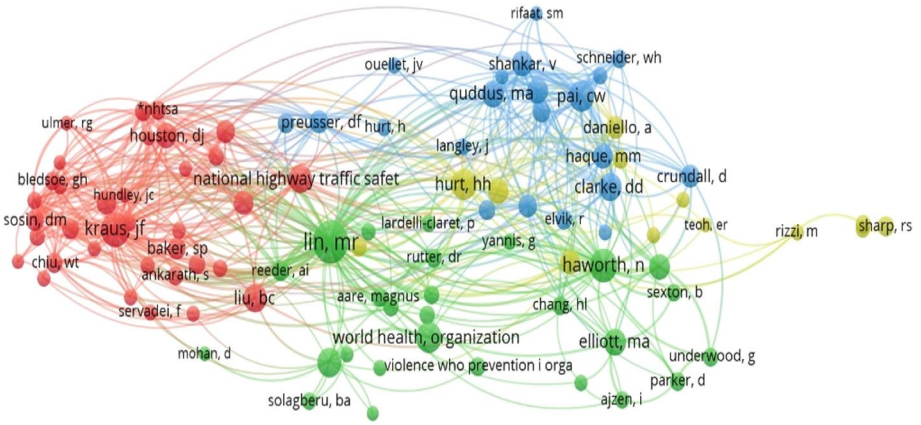

Fig. 6 Co-citation analysis of highly cited references used in publications in motorcycle accident research

figures (WHO 2009, 2013, 2015). These reports are used to justify road safety as a public health problem, where fatalities and injuries continue to increase.

Subject categories

An analysis of "Subject Categories" was carried out considering the classification by WoS and Scopus. In WoS, 75 different subjects were related, within 1391 assignments. In Scopus, 27 topics were categorized, within 2536 assignments. In Scopus, the "Medicine" category scores highest, with 61% of the publications, followed by "Engineering" with 35%, "Social Sciences" with 23% and finally "Science Environmental" with 7%. In WoS, "Public Environmental Occupational Health" scores highest with 38%, followed by "Transportation" with 34%, "Engineering" with 30%, and "Social Sciences" and other topics with 14%. An affinity between the subject of Public Environmental Occupational Health and Medicine was identified, with the highest percentages for each of the databases. An important classification regarding WoS is the area of transport. There are also areas such as engineering and social sciences in the two databases. In Appendix 5 the most representative subject categories and the division over time are shown.

According to the analysis of subject categories, three thematic categories can be defined in the field of motorcycle accidents: (1) studies in Public Health, Environmental and Occupational Health and Medicine; (2) studies in the field of Engineering and Transport, and (3) studies in Social and Environmental Sciences. These categories are not mutually exclusive due to their multidisciplinary nature. These studies seek to analyze the conditions of the accident victims (fractures, injuries, fatalities), factors of associated risks (individual and environmental), safety conditions of the vehicle, causality, and consequences of the road crashes, behaviors in driving, road culture, as well as policy development and countermeasures.

Terms analysis

The analysis of terms of the publications can provide insight into main topics and research trends. The analysis was developed by the Software VOS-viewer considering the title,

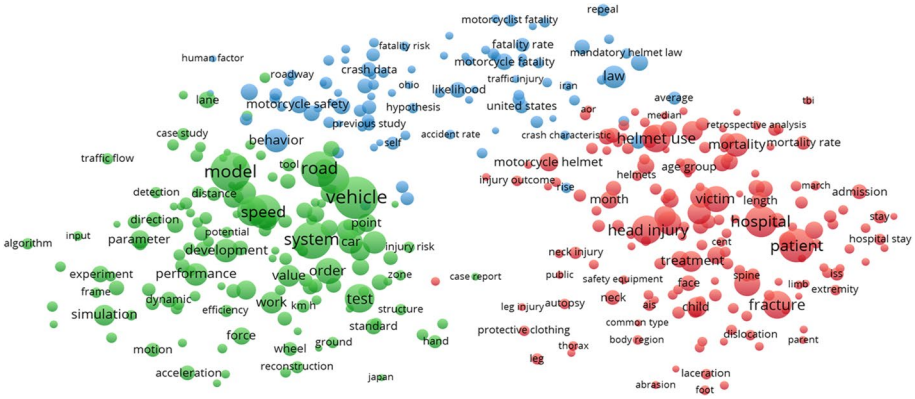

Fig. 7 Terms analysis in motorcycle accident research publications

keywords and abstract. The terms occurring in at least 10 publications were considered. 419 terms were selected for inclusion in the network. The results of the term analysis are presented in Fig. 7. The circles represent the occurrence of the terms. The distance between these indicates their relationship. The relationship between terms is provided by the number of times that terms occur together. Three clusters were distinguished. The red cluster (right) are related to medical aspects (head injury, hospital, patient, fracture, victim, trauma, autopsy). Body parts are also indicated (thorax, leg, neck, foot, head). The green cluster (left) is related to aspects of the motorcycle and conditions. The blue cluster (top) represents all the terms relating to motorcycle accidents, including accident, crash, death, fatality, traffic, and violation. The most frequent words are vehicle, road, model, system, speed, and safety.

In Fig. 8, the relationship between the terms in time is illustrated. The color of the terms indicates their publication period on average. This value is calculated by taking the average

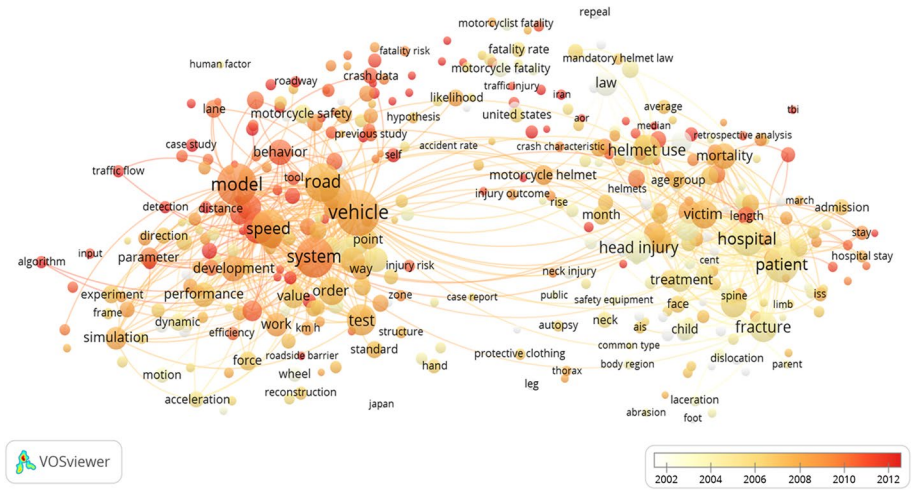

Fig. 8 Terms analysis in motorcycle accident research publications with time information

of the years of publication of all publications. The most used terms were identified in the range from 2002 to 2012. The yellow color is related to the oldest terms, while the red one with the most contemporary terms. According to the range of colors and sizes of the circle, the most recurrent terms appeared between 2006 and 2010. The clusters with more contemporary terms are those related to motorcycling and its conditions, as well as those related to accidents. The cluster relating to medical aspects refers to older terms.

The terms of medical aspects have reached maturity. This is identified in the decrease in the trend of terms before 2008. In investigations of medical aspects are predictable traumas and injuries of motorcyclists (Robbins et al. 2018; Roehler et al. 2015; Rahman et al. 2015; Grigorian and Rolfe 2015). The research developed by Lin and Kraus (2009), Sarkar et al. (1995), Peek et al. (1994) and Kraus et al. (1976) indicates that the traumas cranioencephalic are of high fatality, chest and abdominal injuries are the second most common cause of fatal motorcycle crashes, and the most common injuries occur in the lower extremities.

Discussion

In this study, we presented an overview of research in the field of motorcycle safety. The average annual publication in the last decade exceeds 100 manuscripts, and motorcyclist studies correspond to 5% of the studies of all the road users. Growth trends in the subject suggest maturity and consolidation of knowledge in the field. Likewise, the increase in publications recently may be due to technology, the overflow of information on the internet, online journals, and the rapidity of publication processes (Sharma et al. 2018). Since 2004, the World Health Organization prioritized its attention worldwide, in order to generate solutions in road safety (Peden et al. 2004). The accident rates show an impact on the injuries, mortality, and severity of vulnerable road users (Peden and Sminkey 2004).

The information collected exhibits a large amount of collaborative research. The results indicate consistency with the findings of other investigations (Liu et al. 2012), where a select group of productive authors contribute significantly to a specific topic. A high number of co-authors indicates a closer relationship between authors and greater opportunity for future collaboration (Wang et al. 2014). The high number of journals indicates a wide variety of research with multidisciplinary characteristics. The Journals are related to accident analysis, medicine, engineering, social sciences, human factor and road safety. These topics find a place in the multidisciplinary theme of public health. Prevention, traffic accidents, and road safety are related to public health problems (Peden and Sminkey 2004; Liu et al. 2012). Of all institutions, over 60% are universities, and 40% are private organizations or research centers. This relationship evidences the participation among the stakeholders in road safety, for decision making, policies and countermeasures focused on the problems.

According to certain researchers, the number of citations is aligned to the relevance and quality of a publication. There are combined aspects relating to its visibility, impact, and scope. Recent research has determined that the citation is more related to its visibility, and open access publications exhibit a growing tendency to be cited (Whipple et al. 2013). In the top 10 analysis, the oldest article was published in 1990 and has been referenced 97 times. In contrast, the most recent article, published in 2009, has 145 citations. The time of publication of articles significantly influences citation in volume, in terms of greater possibilities (Qui and Chen 2009). However, this does not limit its scope, and the quality of this precedent can pass by in the background.

Two growing trends are identified. First, studies on the protection of the motorcyclist and the safe design of the motorcycle considering the performance and riding conditions. These terms are related to the area of engineering and transportation. Second, studies in analysis, characterization, and prevention of accidents. These investigations allow to identify the prevalence of risk factors, behaviors and predict unsafe conditions. These terms are related to the area of public health, engineering, transport, and social sciences. Research on causality and the severity of traffic accidents holds a dominant position in the new research trends. This category of studies is the most propitious for the development of policies, strategies, and countermeasures for road safety.

The pattern of domination of the G7 has occurred in most scientific fields, reflecting the high economic activity and academic level of these countries (Jia et al. 2014; Yang et al. 2013; Liu et al. 2012). As in other domains of scientific research, the collaborating countries tend to be geographically correlated and are centered around the most productive countries in terms of publication production (Zheng et al. 2016). The disproportion of publications between high and low-middle income countries is related to the accident rate worldwide. Mortality rates in low-income (27.5 fatalities per 100,000 population) countries are 3 times higher than in high-income (8.3 fatalities per 100,000 population) countries. 13% of deaths occur in these nations and only have 1% of the global automotive (WHO 2018). In high-income countries, motorcycles are usually used for recreation, while in low- and middle-income countries it is more common for commercial purposes (WHO 2017). The segment of motorcyclists worldwide is 770 million. The concentration of motorcycles estimates that 90% of motorcycles correspond to middle- and low-income countries. Approximately 85% of the global deaths of motorcyclists correspond to these countries. The most vulnerable victims in these countries are in the age range of 15 to 35 years (young generation).

The trend of publications by low-middle income countries is a manifestation of global road safety problems. Only 33% of publications correspond to authors with affiliation from low- and middle-income countries. Publications were identified with authors from 32 low-middle-income countries. 38% corresponds to East Asia, 34% to Africa, 16% to America and 13% to Eastern Europe. The regions with the greatest global difficulties in road safety are Africa, Eastern Europe, and East Asia. East Asia is the most dangerous region for motorcyclists worldwide. This region has an annual proportion of 43% deaths (8.9 fatalities per 100,000 population) (WHO 2018).

Low-income countries require solutions to a public health problem. Several studies indicate that these countries are affected by high motorcyclist traffic, bad road conditions, and road culture problems (Sharma et al. 2018; Suthanaya 2016). Researches should help identify the main problems. Among them, vulnerable users, environmental conditions, legislation, and road education. The solutions must be focused on the reduction of fatalities and injuries. It is important to promote studies in emerging countries and consider the proposals of WHO.

Among the policies, strategies and countermeasures to improve the road safety of the motorcyclist and the recommendations of WHO (2017), are: Promote culture and education in road safety for motorcyclists (Segui-Gomez and Lopez-Valdes 2007). Analysis and monitoring of accident reports on motorcycles to identify the associated risk factors (Schneider et al. 2012). Road safety campaigns on the most vulnerable users in the ages of 15–30 years (Ivers et al. 2016; Zambon and Hasselberg 2006). Promote the use of protective elements (helmet, gloves, shin guards, elbow-knee pads, airbags, lumbar protectors) (Li et al. 2008; Donate-López et al. 2010; Bourdet et al. 2012). Restrict and punish driving under the influence of drugs and alcohol (Albalate and Fernández-Villadangos 2010; Peek-Asa and Kraus 1996). Control the speed according to the road type (Clabaux et al. 2012).

Improve the quality of roads, or design exclusive lanes (Sager et al. 2014; Daniello and Gabler 2011). Improve mechanical conditions and maintenance (ABS brakes, quality tires, anti-shock system, and stabilization) (Langley et al. 2000; Rizzi et al. 2016; Fowler et al. 2016). Improve the visibility of the motorcyclist (vests, reflective, lighting system) (Clarke et al. 2007; Cercarelli et al. 1992). Improve road safety conditions such as signage, lighting, and infrastructure (Pai 2011; López-Valdés et al. 2005; Quddus et al. 2001; Haque et al. 2009; Schneider et al. 2010). Forbid the transport and exposition of children on motorcycles (Brown et al. 2018). Penalize violations and risky behaviors (overcapacity, maneuvers) (Elliott et al. 2007). Restrict the manipulation of electronic devices while riding (Truong et al. 2019). All these policies must be applied in a radical, intensive and constant way in low- and middle-income countries (emerging countries). It should be considered that the critical risk factors in the motorcyclist are related to speeding, riding inexperience, maneuvering and stunts (Shankar and Mannering 1996; Lin and Kraus 2009; Elliott et al. 2007; Pai 2011; Abdul Manan et al. 2018).

Limitations

- The information in this research was extracted from Web of Science (WoS) and Scopus databases only.
- Data analysis and homologation of the affiliation of the authors is a demanding task that many databases record information differently. Many name variations were identified by translation, simplification, or relationships with schools, departments or faculties. This analysis was conducted manually.
- In authorship, it is important to consider possible bias. Authors may present the same name or have two or more citation names in their publications. This limitation was sorted with a global examination. In authors with five or more publications, a detailed verification was made. Variations in citations names in the Scopus database were considered.

Conclusions

In general terms, within the bibliometric analysis, there is evidence of a high level of collaboration between authors and institutions worldwide in the development of investigations into motorcyclist accidents. A wide variety of journals published on the subject, related to different research fields, which indicates interdisciplinary studies. Two growing trends are identified. First, studies on the protection of the motorcyclist and the safe design of the motorcycle considering the performance and riding conditions. These terms are related to the area of engineering and transportation. Second, studies in analysis, characterization, and prevention of accidents. These investigations allow to identify the prevalence of risk factors, behaviors and predict unsafe conditions. These latest studies are more related to the generation of road safety strategies for motorcyclists. Research on causality and the severity of traffic accidents holds a dominant position in the new research trends.

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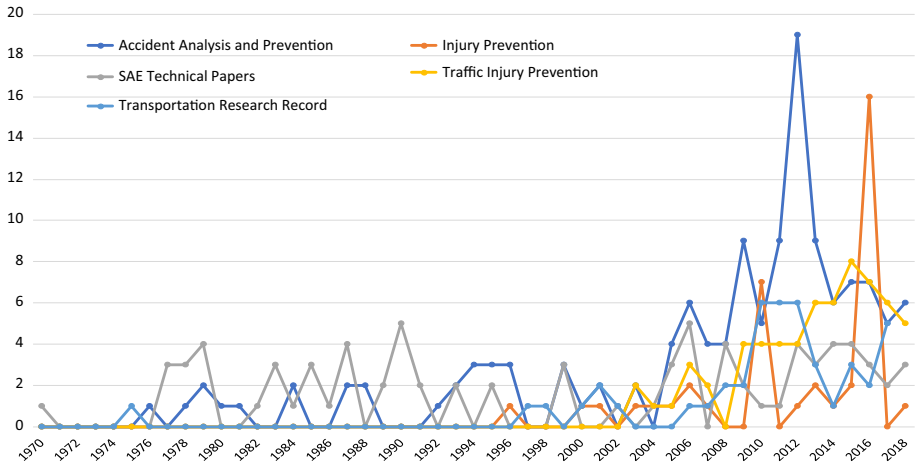
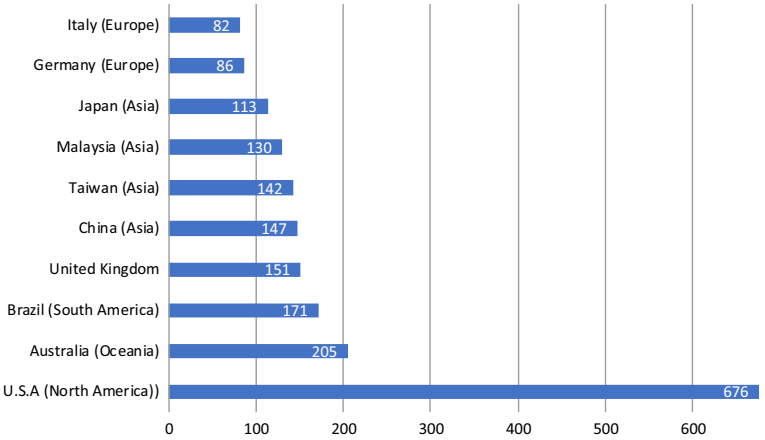
Appendix 1: Search strategy databases

Database	Search
ISI WEB OF KNOWLEDGE (Title)	Title: (Moped* or Motorbike* or Motorcycle* or Motorcyclist* or Scooter*) AND Title: (Accident* or Collision* or Crash* or Death* or Factor or Fatal* or Hazard* or Helmet* or Incident* or Injur* or Risk* or "Risk Factor" or Road* or Safe* or Safety or Severit* or Speed* or Traffic* or Wound*) Period: all years. Indices: SCI-EXPANDED, SSCI, A&HCI, ESCI
SCOPUS (TITLE)	(TITLE (moped OR motorbike OR motorcycle OR motorcyclist OR scooter) AND TITLE (accident OR collision OR crash OR death OR factor OR fatal OR hazard OR Helmet OR incident OR injur OR risk OR "Risk Factor" OR road OR Safe OR safety OR severit OR speed OR traffic OR wound))

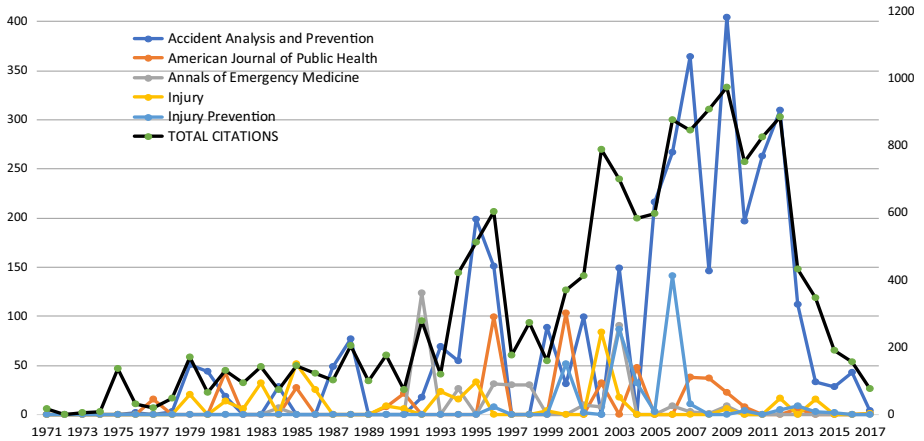
Appendix 2: Top 5 most active journals publishing by year in motorcycle accident research



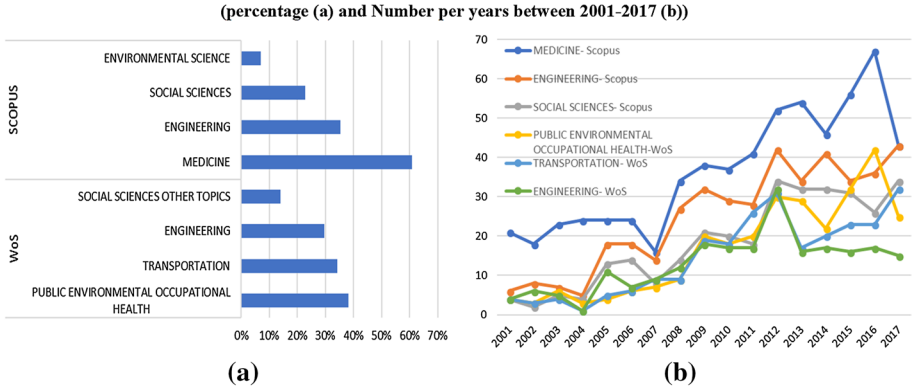
Appendix 3: Top 10 of most productive countries or territories publishing in motorcycle accident research



Appendix 4: Top five most active journals in citation per year in motorcycle accident research



Appendix 5: Most frequently assigned WoS and Scopus subject categories in motorcycle accident research



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