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For numbered affiliations see end of article.

Correspondence to

Dr Spencer L James, Institute for Health Metrics and Evaluation, University of Washington, Seattle, WA 98121, USA; spencj@uw.edu

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Global injury morbidity and mortality from 1990 to 2017: results from the Global Burden of Disease Study 2017

Spencer L James,¹ Chris D Castle,¹ Zachary V Dingels,¹ Jack T Fox,¹ Erin B Hamilton,¹ Zichen Liu,¹ Nicholas L S Roberts,¹ Dillon O Sylte,¹ Nathaniel J Henry,¹ Kate E LeGrand,¹ Ahmed Abdelalim,² Amir Abdoli,³ Ibrahim Abdollahpour,⁴ Rizwan Suliankatchi Abdulkader,⁵ Aidin Abedi,⁶ Akine Eshete Abosetugn,⁷ Abdelrahman I Abushouk,⁸ Oladimeji M Adebayo,⁹ Marcela Agudelo-Botero,¹⁰ Tauseef Ahmad,^{11,12} Rushdia Ahmed,^{13,14} Muktar Beshir Ahmed,¹⁵ Miloud Taki Eddine Aichour,¹⁶ Fares Alahdab,¹⁷ Genet Melak Alamene,¹⁸ Fahad Mashhour Alanezi,¹⁹ Animut Alebel,²⁰ Niguse Meles Alema,²¹ Suliman A Alghnam,²² Samar Al-Hajj,^{23,24} Beriwan Abdulqadir Ali,^{25,26} Saqib Ali,²⁷ Mahtab Alikhani,²⁸ Cyrus Alinia,²⁹ Vahid Alipour,^{30,31} Syed Mohamed Aljunid,^{32,33} Amir Almasi-Hashiani,³⁴ Nihad A Almasri,³⁵ Khalid Altirkawi,³⁶ Yasser Sami Abdeldayem Amer,^{37,38} Saeed Amini,³⁹ Arianna Maefer Loreche Amit,^{40,41} Catalina Liliana Andrei,⁴² Alireza Ansari-Moghaddam,⁴³ Carl Abelardo T Antonio,^{44,45} Seth Christopher Yaw Appiah,^{46,47} Jalal Arabloo,³⁰ Morteza Arab-Zozani,⁴⁸ Zohreh Arefi,⁴⁹ Olatunde Aremu,⁵⁰ Filippo Ariani,⁵¹ Amit Arora,^{52,53} Malke Asaad,⁵⁴ Babak Asghari,⁵⁵ Nefsu Awoke,⁵⁶ Beatriz Paulina Ayala Quintanilla,^{57,58} Getinet Ayano,⁵⁹ Martin Amogre Ayanore,⁶⁰ Samad Azari,³⁰ Ghasem Azarian,⁶¹ Alaa Badawi,^{62,63} Ashish D Badiye,⁶⁴ Eleni Bagli,^{65,66} Atif Amin Baig,^{67,68} Mohan Bairwa,^{69,70} Ahad Bakhtiari,⁷¹ Arun Balachandran,^{72,73} Maciej Banach,^{74,75} Srikanta K Banerjee,⁷⁶ Palash Chandra Banik,⁷⁷ Amrit Banstola,⁷⁸ Suzanne Lyn Barker-Collo,⁷⁹ Till Winfried Bärnighausen,^{80,81} Lope H Barrero,⁸² Akbar Barzegar,⁸³ Mohsen Bayati,⁸⁴ Bayisa Abdissa Baye,⁸⁵ Neeraj Bedi,^{86,87} Masoud Behzadifar,⁸⁸ Tariku Tesfaye Bekuma,⁸⁹ Habte Belete,⁹⁰ Corina Benjet,⁹¹ Derrick A Bennett,⁹² Isabela M Bensenor,⁹³ Kidanemaryam Berhe,⁹⁴ Pankaj Bhardwaj,^{95,96} Anusha Ganapati Bhat,⁹⁷ Krittika Bhattacharyya,^{98,99} Sadia Bibi,¹⁰⁰ Ali Bijani,¹⁰¹ Muhammad Shahdaat Bin Sayeed,^{102,103} Guilherme Borges,⁹¹ Antonio Maria Borzi,¹⁰⁴ Soufiane Boufous,¹⁰⁵ Alexandra Brazinova,¹⁰⁶ Nikolay Ivanovich Briko,¹⁰⁷ Shyam S Budhathoki,¹⁰⁸ Josip Car,^{109,110} Rosario Cárdenas,¹¹¹ Félix Carvalho,¹¹² João Mauricio Castaldelli-Maia,¹¹³ Carlos A Castañeda-Orjuela,^{114,115} Giulio Castelpietra,^{116,117} Ferrán Catalá-López,^{118,119} Ester Cerin,^{120,121} Joht S Chandan,¹²² Wagaye Fentahun Chanie,¹²³ Soosanna Kumary Chattu,¹²⁴ Vijay Kumar Chattu,¹²⁵ Irini Chatziralli,^{126,127} Neha Chaudhary,^{128,129} Daniel Youngwhan Cho,¹³⁰ Mohiuddin Ahsanul Kabir Chowdhury,^{131,132} Dinh-Toi Chu,¹³³ Samantha M Colquhoun,¹³⁴ Maria-Magdalena Constantin,^{135,136} Vera M Costa,¹¹² Giovanni Damiani,^{137,138} Ahmad Daryani,¹³⁹ Claudio Alberto Dávila-Cervantes,¹⁴⁰ Feleke Mekonnen Demeke,¹⁴¹ Asmamaw Bizuneh Demis,^{142,143} Gebre Teklemariam Demoz,^{144,145} Desalegn Getnet Demsie,²¹ Afshin Derakhshani,¹⁴⁶ Kebede Deribe,^{147,148} Rupak Desai,¹⁴⁹ Mostafa Dianati Nasab,¹⁵⁰ Diana Dias da Silva,¹⁵¹ Zahra Sadat Dibaji Forooshani,¹⁵² Kerrie E Doyle,¹⁵³ Tim Robert Driscoll,¹⁵⁴



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Eleonora Dubljanin,¹⁵⁵ Bereket Duko Adema,^{156,157} Arielle Wilder Eagan,^{158,159} Aziz Eftekhari,^{160,161} Elham Ehsani-Chimeh,¹⁶² Maysaa El Sayed Zaki,¹⁶³ Demelash Abewa Elemineh,¹⁶⁴ Shaimaa I El-Jaafary,² Ziad El-Khatib,^{165,166} Christian Lycke Ellingsen,^{167,168} Mohammad Hassan Emamian,¹⁶⁹ Daniel Adane Endalew,¹⁷⁰ Sharareh Eskandarieh,¹⁷¹ Pawan Sirwan Faris,^{172,173} Andre Faro,¹⁷⁴ Farshad Farzadfar,¹⁷⁵ Yousef Fatahi,¹⁷⁶ Wubalem Fekadu,^{90,177} Tomas Y Ferede,¹⁷⁸ Seyed-Mohammad Fereshtehnejad,^{179,180} Eduarda Fernandes,¹⁸¹ Pietro Ferrara,¹⁸² Garumma Tolu Feyissa,¹⁸³ Irina Filip,^{184,185} Florian Fischer,¹⁸⁶ Morenike Oluwatoyin Folayan,¹⁸⁷ Masoud Foroutan,¹⁸⁸ Joel Msafiri Francis,¹⁸⁹ Richard Charles Franklin,^{190,191} Takeshi Fukumoto,^{192,193} Biniyam Sahiledengle Geberemariam,¹⁹⁴ Abadi Kahsu Gebre,¹⁹⁵ Ketema Bizuwork Gebremedhin,¹⁹⁶ Gebreamlak Gebremedhn Gebremeskel,^{197,198} Berhe Gebremichael,¹⁹⁹ Getnet Azeze Gedefaw,^{200,201} Birhanu Geta,²⁰² Mansour Ghafourifard,²⁰³ Farhad Ghamari,²⁰⁴ Ahmad Ghashghae,²⁰⁵ Asadollah Gholamian,^{206,207} Tiffany K Gill,²⁰⁸ Alessandra C Goulart,^{93,209} Ayman Grada,²¹⁰ Michal Grivna,²¹¹ Mohammed Ibrahim Mohialdeen Gubari,²¹² Rafael Alves Guimarães,²¹³ Yuming Guo,^{214,215} Gaurav Gupta,²¹⁶ Juanita A Haagsma,²¹⁷ Nima Hafezi-Nejad,^{218,219} Hassan Haghparast Bidgoli,²²⁰ Brian James Hall,²²¹ Randah R Hamadeh,²²² Samer Hamidi,²²³ Josep Maria Haro,^{224,225} Md Mehedi Hasan,²²⁶ Amir Hasanzadeh,^{227,228} Soheil Hassanipour,²²⁹ Hadi Hassankhani,^{230,231} Hamid Yimam Hassen,^{232,233} Rasmus Havmoeller,²³⁴ Khezar Hayat,^{235,236} Delia Hendrie,⁵⁹ Fatemeh Heydarpour,²³⁷ Martha Hajar,^{238,239} Hung Chak Ho,²⁴⁰ Chi Linh Hoang,²⁴¹ Michael K Hole,²⁴² Ramesh Holla,²⁴³ Naznin Hossain,^{244,245} Mehdi Hosseinzadeh,^{246,247} Sorin Hostiuc,^{248,249} Guoqing Hu,²⁵⁰ Segun Emmanuel Ibitoye,²⁵¹ Olayinka Stephen Ilesanmi,²⁵² Irena Ilic,¹⁵⁵ Milena D Ilic,²⁵³ Leebek Raja Inbaraj,²⁵⁴ Endang Indriasih,²⁵⁵ Seyed Sina Naghibi Irvani,²⁵⁶ Sheikh Mohammed Shariful Islam,^{257,258} M Mofizul Islam,²⁵⁹ Rebecca Q Ivers,²⁶⁰ Kathryn H Jacobsen,²⁶¹ Mohammad Ali Jahani,²⁶² Nader Jahanmehr,^{263,264} Mihajlo Jakovljevic,²⁶⁵ Farzad Jalilian,²⁶⁶ Sudha Jayaraman,²⁶⁷ Achala Upendra Jayatilleke,^{268,269} Ravi Prakash Jha,²⁷⁰ Yetunde O John-Akinola,²⁵¹ Jost B Jonas,^{271,272} Nitin Joseph,²⁷³ Farahnaz Joukar,²²⁹ Jacek Jerzy Jozwiak,²⁷⁴ Suresh Banayya Jungari,²⁷⁵ Mikk Jürisson,²⁷⁶ Ali Kabir,²⁷⁷ Rajendra Kadel,²⁷⁸ Amaha Kahsay,⁹⁴ Leila R Kalankesh,²⁷⁹ Rohollah Kalhor,^{280,281} Teshome Abegaz Kamil,²⁸² Tanuj Kanchan,²⁸³ Neeti Kapoor,⁶⁴ Manoochehr Karami,²⁸⁴ Amir Kasaeian,^{285,286} Hagazi Gebremedhin Kassaye,²¹ Taras Kavetsky,^{287,288} Hafte Kahsay Kebede,²⁸⁹ Peter Njenga Keiyoro,²⁹⁰ Abraham Getachew Kelbore,²⁹¹ Bayew Kelkay,²⁹² Yousef Saleh Khader,²⁹³ Morteza Abdullatif Khafaie,²⁹⁴ Nauman Khalid,²⁹⁵ Ibrahim A Khalil,²⁹⁶ Rovshan Khalilov,²⁹⁷ Mohammad Khammarnia,²⁹⁸ Ejaz Ahmad Khan,²⁹⁹ Maseer Khan,³⁰⁰ Tripti Khanna,^{301,302} Habibolah Khazaie,³⁰³ Fatemeh Khosravi Shadmani,³⁰⁴ Roba Khundkar,³⁰⁵ Daniel N Kiirithio,³⁰⁶ Young-Eun Kim,³⁰⁷ Daniel Kim,³⁰⁸ Yun Jin Kim,³⁰⁹ Adnan Kisa,³¹⁰ Sezer Kisa,³¹¹ Hamidreza Komaki,^{312,313} Shivakumar K M Kondlahalli,³¹⁴ Vladimir Andreevich Korshunov,¹⁰⁷ Ai Koyanagi,^{315,316} Moritz U G Kraemer,^{317,318} Kewal Krishan,³¹⁹ Burcu Kucuk Bicer,^{320,321} Nuworza Kugbey,^{322,323} Vivek Kumar,³²⁴ Nithin Kumar,²⁷³ G Anil Kumar,³²⁵ Manasi Kumar,^{326,327} Girikumar Kumaresh,³²⁸ Om P Kurmi,^{327,329} Oluwatosin Kuti,³³⁰ Carlo La Vecchia,³³¹ Faris Hasan Lami,³³² Prabhat Lamichhane,³³³ Justin J Lang,³³⁴ Van C Lansingh,^{335,336} Dennis Odai Laryea,³³⁷ Savita Lasrado,³³⁸ Arman Latifi,³³⁹ Paolo Lauriola,³⁴⁰ Janet L Leasher,³⁴¹ Shaun Wen Huey Lee,^{342,343} Tsegaye Lolaso Lenjebo,³⁴⁴ Miriam Levi,^{51,345} Shanshan Li,²¹⁴ Shai Linn,³⁴⁶ Xuefeng Liu,³⁴⁷ Alan D Lopez,^{1,348,349} Paulo A Lotufo,³⁵⁰ Raimundas Lunevicius,^{351,352} Ronan A Lyons,³⁵³ Mohammed Madadin,³⁵⁴ Muhammed Magdy Abd El Razek,³⁵⁵ Narayan Bahadur Mahotra,³⁵⁶ Marek Majdan,³⁵⁷ Azeem Majeed,³⁵⁸ Jeadran N Malagon-Rojas,^{359,360} Venkatesh Maled,^{361,362} Reza Malekzadeh,^{363,364} Deborah Carvalho Malta,³⁶⁵ Navid Manafi,^{366,367} Amir Manafi,³⁶⁸ Ana-Laura Manda,³⁶⁹ Narayana Manjunatha,³⁷⁰ Fariborz Mansour-Ghanaei,²²⁹ Borhan Mansouri,³⁷¹ Mohammad Ali Mansournia,³⁷² Joemer C Maravilla,³⁷³ Lyn M March,³⁷⁴ Amanda J Mason-Jones,³⁷⁵ Seyedeh Zahra Masoumi,³⁷⁶ Benjamin Ballard Massenburg,¹³⁰ Pallab K Maulik,^{377,378} Gebrekiros Gebremichael Meles,³⁷⁹ Addisu Melese,¹⁴¹ Zeleke Aschalew Melketsedik,³⁸⁰ Peter T N Memiah,³⁸¹ Walter Mendoza,³⁸²

Ritesh G Menezes,³⁸³ Meresa Berwo Mengesha,³⁸⁴ Melkamu Merid Mengesha,³⁸⁵ Tuomo J Meretoja,^{386,387} Atte Meretoja,^{388,389} Hayimro Edemealem Merie,¹⁶⁴ Tomislav Mestrovic,^{390,391} Bartosz Miazgowski,³⁹² Tomasz Miazgowski,³⁹³ Ted R Miller,^{59,394} GK Mini,^{395,396} Andreea Mirica,^{397,398} Erkin M Mirrakhimov,^{399,400} Mehdi Mirzaei-Alavijeh,²⁶⁶ Prasanna Mithra,²⁷³ Babak Moazen,^{401,402} Masoud Moghadaszadeh,^{403,404} Efat Mohamadi,⁴⁰⁵ Yousef Mohammad,⁴⁰⁶ Karzan Abdulmuhsin Mohammad,^{407,408} Aso Mohammad Darwesh,⁴⁰⁹ Naser Mohammad Gholi Mezerji,⁴¹⁰ Abdollah Mohammadian-Hafshejani,⁴¹¹ Milad Mohammadoo-Khorasani,⁴¹² Reza Mohammadpourhodki,⁴¹³ Shafiu Mohammed,^{80,414} Jemal Abdu Mohammed,⁴¹⁵ Farnam Mohebi,^{175,416} Mariam Molokhia,⁴¹⁷ Lorenzo Monasta,⁴¹⁸ Yoshan Moodley,⁴¹⁹ Mahmood Moosazadeh,⁴²⁰ Masoud Moradi,⁴²¹ Ghobad Moradi,^{422,423} Maziar Moradi-Lakeh,⁴²⁴ Farhad Moradpour,⁴²² Lidia Morawska,⁴²⁵ Ilais Moreno Velásquez,⁴²⁶ Naho Morisaki,⁴²⁷ Shane Douglas Morrison,¹³⁰ Tilahun Belete Mossie,⁹⁰ Atalay Goshu Muluneh,⁴²⁸ Srinivas Murthy,⁴²⁹ Kamarul Imran Musa,⁴³⁰ Ghulam Mustafa,^{431,432} Ashraf F Nabhan,^{433,434} Ahamarshan Jayaraman Nagarajan,^{435,436} Gurudatta Naik,⁴³⁷ Mukhammad David Naimzada,^{438,439} Farid Najafi,⁴⁴⁰ Vinay Nangia,⁴⁴¹ Bruno Ramos Nascimento,⁴⁴² Morteza Naserbakht,^{424,443} Vinod Nayak,⁴⁴⁴ Duduzile Edith Ndwandwe,⁴⁴⁵ Ionut Negoii,^{446,447} Josephine W Ngunjiri,⁴⁴⁸ Cuong Tat Nguyen,⁴⁴⁹ Huong Lan Thi Nguyen,⁴⁴⁹ Rajan Nikbakhsh,^{450,451} Dina Nur Anggraini Ningrum,^{452,453} Chukwudi A Nnaji,^{445,454} Peter S Nyasulu,⁴⁵⁵ Felix Akpojene Ogbo,¹¹² Onome Bright Oghenetega,⁴⁵⁶ In-Hwan Oh,⁴⁵⁷ Emmanuel Wandera Okunga,⁴⁵⁸ Andrew T Olagunju,^{459,460} Tinuke O Olagunju,⁴⁶¹ Ahmed Omar Bali,⁴⁶² Obinna E Onwujekwe,⁴⁶³ Kwaku Oppong Asante,^{464,465} Heather M Orpana,^{466,467} Erika Ota,⁴⁶⁸ Nikita Otstavnov,^{438,469} Stanislav S Otstavnov,^{438,470} Mahesh P A,⁴⁷¹ Jagadish Rao Padubidri,⁴⁷² Smita Pakhale,⁴⁷³ Keyvan Pakshir,⁴⁷⁴ Songhomitra Panda-Jonas,⁴⁷⁵ Eun-Kee Park,⁴⁷⁶ Sangram Kishor Patel,^{477,478} Ashish Pathak,^{165,479} Sanghamitra Pati,⁴⁸⁰ George C Patton,^{481,482} Kebreab Paulos,⁴⁸³ Amy E Peden,^{191,484} Veincent Christian Filipino Pepito,⁴⁸⁵ Jeevan Pereira,⁴⁸⁶ Hai Quang Pham,⁴⁴⁹ Michael R Phillips,^{487,488} Marina Pinheiro,⁴⁸⁹ Roman V Polibin,⁴⁹⁰ Suzanne Polinder,²¹⁷ Hossein Poustchi,³⁶³ Swayam Prakash,⁴⁹¹ Dimas Ria Angga Pribadi,⁴⁹² Parul Puri,⁴⁹³ Zahiruddin Quazi Syed,⁹⁶ Mohammad Rabiee,⁴⁹⁴ Navid Rabiee,⁴⁹⁵ Amir Radfar,^{496,497} Anwar Rafay,⁴⁹⁸ Ata Rafiee,⁴⁹⁹ Alireza Rafiei,^{500,501} Fakher Rahim,^{502,503} Siavash Rahimi,⁵⁰⁴ Vafa Rahimi-Movaghar,⁵⁰⁵ Muhammad Aziz Rahman,^{506,507} Ali Rajabpour-Sanati,⁵⁰⁸ Fatemeh Rajati,⁴²¹ Ivo Rakovac,⁵⁰⁹ Kavitha Ranganathan,⁵¹⁰ Sowmya J Rao,⁵¹¹ Vahid Rashedi,⁵¹² Prateek Rastogi,⁵¹³ Priya Rathi,⁵¹⁴ Salman Rawaf,^{358,515} Lal Rawal,⁵¹⁶ Reza Rawassizadeh,⁵¹⁷ Vishnu Renjith,⁵¹⁸ Andre M N Renzaho,^{519,520} Serge Resnikoff,⁵²¹ Aziz Rezapour,⁵²² Ana Isabel Ribeiro,⁵²³ Jennifer Rickard,^{524,525} Carlos Miguel Rios González,^{526,527} Luca Ronfani,⁴¹⁸ Gholamreza Roshandel,^{363,528} Anas M Saad,⁵²⁹ Yogesh Damodar Sabde,⁵³⁰ Siamak Sabour,⁵³¹ Basema Saddik,⁵³² Saeed Safari,⁵³³ Roya Safari-Faramani,⁵³⁴ Hamid Safarpour,⁵³⁵ Mahdi Safdarian,^{505,536} S Mohammad Sajadi,⁵³⁷ Payman Salamati,⁵⁰⁵ Farkhonde Salehi,⁵³⁸ Saleh Salehi Zahabi,^{539,540} Marwa R Rashad Salem,⁵⁴¹ Hosni Salem,⁵⁴² Omar Salman,^{543,544} Inbal Salz,⁵⁴⁵ Abdallah M Samy,⁵⁴⁶ Juan Sanabria,^{547,548} Lidia Sanchez Riera,^{549,550} Milena M Santric Milicevic,^{551,552} Abdur Razzaque Sarker,⁵⁵³ Arash Sarveazad,⁵⁵⁴ Brijesh Sathian,^{555,556} Monika Sawhney,⁵⁵⁷ Susan M Sawyer,^{558,559} Sonia Saxena,⁵⁶⁰ Mehdi Sayyah,⁵⁶¹ David C Schwebel,⁵⁶² Soraya Seedat,⁵⁶³ Subramanian Senthilkumaran,⁵⁶⁴ Sadaf G Sepanlou,^{363,364} Seyedmojtaba Seyedmousavi,⁵⁶⁵ Feng Sha,⁵⁶⁶ Faramarz Shaahmadi,⁵⁶⁷ Saeed Shahabi,⁵⁶⁸ Masood Ali Shaikh,⁵⁶⁹ Mehran Shams-Beyranvand,⁵⁷⁰ Morteza Shamsizadeh,⁵⁷¹ Mahdi Sharif-Alhoseini,⁵⁰⁵ Hamid Sharifi,⁵⁷² Aziz Sheikh,^{573,574} Mika Shigematsu,⁵⁷⁵ Jae Il Shin,^{576,577} Rahman Shiri,⁵⁷⁸ Soraya Siabani,^{579,580} Inga Dora Sigfusdottir,^{581,582} Pankaj Kumar Singh,⁵⁸³ Jasvinder A Singh,^{584,585} Dharendra Narain Sinha,^{586,587} Catalin-Gabriel Smarandache,^{588,589} Emma U R Smith,^{590,591} Amin Soheili,^{592,593} Bija Soleymani,²³⁷ Ali Reza Soltanian,⁵⁹⁴ Joan B Soriano,^{595,596} Muluken Bekele Sorrie,⁵⁹⁷ Ireneous N Soyiri,^{598,599} Dan J Stein,^{600,601} Mark A Stokes,⁶⁰² Mu'awiyah Babale Sufiyan,⁶⁰³ Hafiz Ansar Rasul Suleria,⁶⁰⁴ Bryan L Sykes,⁶⁰⁵ Rafael Tabarés-Seisdedos,^{606,607} Karen M Tabb,⁶⁰⁸ Biruk Wogayehu Taddele,⁶⁰⁹

Degen Bahrey Tadesse,^{197,610} Anmut Tagele Tamiru,⁶¹¹ Ingan Ukur Tarigan,²⁵⁵ Yonatal Mesfin Tefera,^{612,613} Arash Tehrani-Banihashemi,^{424,614} Merhawi Gebremedhin Tekle,¹⁹⁹ Gebretsadkan Hints Tekulu,⁶¹⁵ Ayenew Kassie Tesema,⁶¹⁶ Berhe Etsay Tesfay,⁶¹⁷ Rekha Thapar,²⁷³ Asres Bedaso Tilahun,⁶¹⁸ Kenean Getaneh Tlaye,¹⁴² Hamid Reza Tohidinik,^{372,572} Roman Topor-Madry,^{619,620} Bach Xuan Tran,⁶²¹ Khanh Bao Tran,^{622,623} Jaya Prasad Tripathy,⁶²⁴ Alexander C Tsai,^{625,626} Lorainne Tudor Car,⁶²⁷ Saif Ullah,⁶²⁸ Irfan Ullah,^{629,630} Maida Umar,⁶³¹ Bhaskaran Unnikrishnan,²⁷³ Era Upadhyay,⁶³² Olalekan A Uthman,⁶³³ Pascual R Valdez,^{634,635} Tommi Juhani Vasankari,⁶³⁶ Narayanaswamy Venketasubramanian,^{637,638} Francesco S Violante,^{639,640} Vasily Vlassov,⁶⁴¹ Yasir Waheed,⁶⁴² Girmay Teklay Weldesamuel,¹⁹⁷ Andrea Werdecker,^{643,644} Taweewat Wiangkham,⁶⁴⁵ Haileab Fekadu Wolde,⁴²⁸ Dawit Habte Woldeyes,⁶⁴⁶ Dawit Zewdu Wondafrash,^{647,648} Temesgen Gebeyehu Wondmeneh,⁴¹⁵ Adam Belay Wondmieneh,^{196,649} Ai-Min Wu,⁶⁵⁰ Rajaram Yadav,⁴⁹³ Ali Yadollahpour,⁶⁵¹ Yuichiro Yano,⁶⁵² Sanni Yaya,⁶⁵³ Vahid Yazdi-Feyzabadi,^{654,655} Paul Yip,^{656,657} Engida Yisma,⁶⁵⁸ Naohiro Yonemoto,⁶⁵⁹ Seok-Jun Yoon,³⁰⁷ Yoosik Youm,⁶⁶⁰ Mustafa Z Younis,^{661,662} Zabihollah Yousefi,^{663,664} Yong Yu,⁶⁶⁵ Chuanhua Yu,^{666,667} Hasan Yusefzadeh,²⁹ Telma Zahirian Moghadam,^{30,668} Zoubida Zaidi,⁶⁶⁹ Sojib Bin Zaman,^{131,670} Mohammad Zamani,⁶⁷¹ Maryam Zamanian,³⁴ Hamed Zandian,^{668,672} Ahmad Zarei,⁶⁷³ Fatemeh Zare,⁶⁷⁴ Zhi-Jiang Zhang,⁶⁷⁵ Yunquan Zhang,^{676,677} Sanjay Zodpey,⁶⁷⁸ Lalit Dandona,^{1,325,349} Rakhi Dandona,^{1,325} Louisa Degenhardt,^{1,679} Samath Dhamminda Dharmaratne,^{1,349,680} Simon I Hay,^{1,349} Ali H Mokdad,^{1,349} Robert C Reiner Jr,^{1,349} Benn Sartorius,^{349,681} Theo Vos^{1,349}

SUMMARY

Background Past research in population health trends has shown that injuries form a substantial burden of population health loss. Regular updates to injury burden assessments are critical. We report Global Burden of Disease (GBD) 2017 Study estimates on morbidity and mortality for all injuries.

Methods We reviewed results for injuries from the GBD 2017 study. GBD 2017 measured injury-specific mortality and years of life lost (YLLs) using the Cause of Death Ensemble model. To measure non-fatal injuries, GBD 2017 modelled injury-specific incidence and converted this to prevalence and years lived with disability (YLDs). YLLs and YLDs were summed to calculate disability-adjusted life years (DALYs).

Findings In 1990, there were 4 260 493 (4 085 700 to 4 396 138) injury deaths, which increased to 4 484 722 (4 332 010 to 4 585 554) deaths in 2017, while age-standardised mortality decreased from 1079 (1073 to 1086) to 738 (730 to 745) per 100 000. In 1990, there were 354 064 302 (95% uncertainty interval: 338 174 876 to 371 610 802) new cases of injury globally, which increased to 520 710 288 (493 430 247 to 547 988 635) new cases in 2017. During this time, age-standardised incidence decreased non-significantly from 6824 (6534 to 7147) to 6763 (6412 to 7118) per 100 000. Between 1990 and 2017, age-standardised DALYs decreased from 4947 (4655 to 5233) per 100 000 to 3267 (3058 to 3505).

Interpretation Injuries are an important cause of health loss globally, though mortality has declined between 1990 and 2017. Future research in injury burden should focus on prevention in high-burden populations, improving data collection and ensuring access to medical care.

INTRODUCTION

Injury burden assessments are a critical component of population health measurement. Across the global landscape of population health research, injuries are unique in that they are almost universally avertable yet can cause death or disability at any age. Even common injuries such as concussion resulting from falls,

violence or road injuries may cause longer term sequelae, and injuries such as spinal cord injuries or limb amputations can cause long-term disability.¹ As a result, injuries are recognised as being a source of lost health and human capital that could be averted with improved safety and prevention programmes as well as ensuring access to care resources.² Across geographies, certain injuries such as envenomation may be relevant in specific locations where venomous creatures live, while injuries such as those occurring from adverse medical events are an increasing area of research in higher income areas of the world.^{3–5} Bolstering such programmes, however, requires detailed measurement of when, where and to whom injuries are occurring, necessitating focused research studies to add insight and context to broader geographical trends. Across all domains of injury prevention research, it is important to measure the causes of injury, such as road injuries, and the resulting disability, such as fractures, burns or traumatic brain injury, that can occur as a result. Such detailed measurement lends perspective for understanding burden and anticipating resources needed to care for and hopefully prevent future injury burden. Detailed measurements and assessments of this nature are critical for empowering policy makers and health system planners to appropriately plan and invest for mitigating future health loss from injuries. Reducing injury burden is an important component in global efforts such as the Sustainable Development Goal 3 to ‘ensure healthy lives and promote well-being for all at all ages’.⁶

While some research has focused on a certain type of injury or outcome from injury or specific area of the world,^{7–10} it has become important in an era of more sophisticated population health measurement to measure health loss from injuries comprehensively with detailed fatal and non-fatal estimates for different ages, sexes, across time periods and accounting for multiple different types of morbidity that can occur in an injury. Previously published literature on global injury burden through 2015 has provided comprehensive measurements of health loss due to injuries but still require regular updates to help inform research and policy, as new years of estimates are

added and as new injuries and injury outcomes are incorporated.¹¹ Comprehensive research of this nature shows how injury burden varies dynamically by age, sex, year, area of the world and type of injury, and hence, it is important to maintain close monitoring of injury burden every year in all parts of the world. In addition, as new datasets and statistical modelling methods become available, producing regular updates to burden estimation also ensures that results are as accurate as possible.

While the burden of injuries is widely studied and monitored through various methods of research, the Global Burden of Diseases, Injuries, and Risk Factors (GBD) Study is the only study framework that routinely provides estimates of morbidity and mortality from an exhaustive list of injuries in all areas of the world across ages and sexes. The most recent update to GBD was published in 2018 and provided morbidity and mortality estimates for 30 mutually exclusive causes of injury for 195 countries from 1990 to 2017.^{12–17} As part of this regular update, new datasets on cause of death and incidence are incorporated into the study, and additional geographical detail is added to better measure heterogeneity in burden estimates at a subnational level. In addition, updates such as reporting both nature of injury and cause of injury (described in more detail below) are incorporated. In this study, we describe key components in the GBD injury methodology and provide results from key trends in injury burden in terms of incidence, prevalence, years lived with disability (YLDs), cause-specific mortality, years of life lost (YLLs) and disability-adjusted life years (DALYs) by country, age groups, sex, year and injury type.

METHODS

The methods and results in this study are the same as are provided in GBD capstone publications, and a detailed description of GBD data and methods used for all processes related to GBD 2017 is provided in associated studies.^{12–17} Overall, GBD methods are also summarised in online supplementary appendix 1. Below, we summarise the specific methods used for measurement of injuries morbidity and mortality in GBD 2017.

Key components of GBD study design

The GBD study incorporates several key components to allow for internally consistent estimates across all burden measures and metrics. First, population is measured to ensure consistent denominators for all population-level measurement. Second, all-cause mortality is measured using demographic methods. Third, cause-specific mortality for a mutually exclusive, collectively exhaustive hierarchy of diseases and injuries is measured, such that every death has one underlying cause of death and such that estimates for every possible cause of death are included, which requires the use of residual causes like ‘other transport injuries’. This results in the sum of cause-specific mortality equalling total all-cause mortality. Fourth, non-fatal health loss is measured for individuals living with a disease or injury that detracts from their full health status. Fifth, a composite measure of mortality and morbidity is computed. These steps are conducted within an age, sex and location hierarchy constructed such that demographic detail is available but where all estimates are internally consistent with all other estimates. GBD produces estimates for all causes, ages, sexes, years and locations. Risk factors and attributable burden for different are also measured, but those results are not included in this study.

Case definition and cause hierarchy

The GBD case definition for an injury death is a death where the injury was the underlying cause of death. For example, if an individual falls on ice and sustains an epidural haematoma and dies after a seizure, the fall is the underlying cause. If an individual sustains a myocardial infarction and then falls and sustains the same epidural haematoma, then the myocardial infarction is the underlying cause of death. For non-fatal injuries, we define a case as an injury that warranted medical care. For example, if an individual slips and falls but does not sustain any bodily injury, it is not considered an injury. Online supplementary appendix table 1 provides the International Classification of Disease (ICD) codes used to identify causes of injury.

Cause-specific mortality estimation

Cause-specific mortality from injuries is measured using the Cause of Death Ensemble model (CODEm). CODEm is described in more detail elsewhere; a summary of its use for injuries is as follows.¹⁸ First, all available data that can be used for cause of death estimation are identified. For injuries, this includes vital registration, verbal autopsy, police records, mortuary data and census data. These data are processed for use in the GBD cause and demographic hierarchy via a series of data processing steps including a process whereby ill-defined causes of death are re-assigned to true underlying causes of death, which is described in more detail elsewhere but essentially is the process by which ill-defined causes of death are reclassified to causes of death in the GBD cause hierarchy.^{19 20} Next, a cause-specific mortality model is developed for each one of the 30 different causes of injury. For example, falls are modelled differently than road injuries, though both use the same CODEm modelling architecture. For each cause of injury, covariates that may be associated with the cause are identified and added as candidate covariates. CODEm runs different combinations of models using different covariates and outcome variables, specifically cause fraction models and cause-specific mortality rate models. Ensembles of models are also conducted to test performance of overall models formed from submodels. Once all models have been run, the top-performing models are selected based on out-of-sample predictive validity, wherein the model makes predictions on data that were not included in developing the model. The top-performing models are then weighted according to performance, and the final estimates form the penultimate estimate for cause-specific mortality from that injury. Those estimates are then adjusted to fit within the all-cause mortality estimate, so that cause-specific deaths sum up to the overall mortality estimate for each population and demographic. YLLs are computed as the cause-specific mortality rate at a given age multiplied by the residual life expectancy at that age, which is based on the observed maximum global life expectancy.

Non-fatal injury estimation

Non-fatal injury estimation is also described in more detail in GBD literature. Key components in this process are as follows. First, data on incidence of non-fatal injury causes (eg, road injuries) is obtained from the GBD collaborator network and other injury research groups and researchers around the world. Data are cleaned and organised according to GBD study guidelines. Next, incidence of each cause of injury is modelled in DisMod-MR 2.1, which is a Bayesian meta-analysis tool used extensively in GBD research. Incidence estimates of injuries requiring medical care for each cause of injury then stream through an analytical pipeline. During this process, injury incidence is split into

inpatient and outpatient to account for the different severity that is expected to occur. The coefficient that determines this split is derived from locations where both inpatient and outpatient data are available. After this, we measure the proportion of each cause of injury that leads to one of 47 different natures of injury using clinical data where both cause and nature are coded as well as a Dirichlet statistical modelling process. Based on these steps, the incidence of each cause is also split into incidence of each cause-nature, which is the proportion of a given cause's incidence leading to some specific nature of injury being the most severe injury sustained as estimated by the Dirichlet regression. These estimates are then converted to short-term and long-term injuries based on probability of each injury becoming long term, as determined by long-term follow-up injury surveys.^{21–27} For short-term injuries, incidence is converted to prevalence based on multiplying incidence by an expected duration of injury as determined by physicians and injury experts involved in the GBD study. For long-term injuries, incidence is converted to prevalence using differential equations that take into account the increased mortality for certain types of injury, for example, traumatic brain injury.¹ Disability weights as derived elsewhere in the GBD study are then used to measure disability based on nature of injury.²⁸ These measures are then summed across natures of injury for each cause to calculate YLDs. Each of these steps is conducted for every cause, age, sex, year and location in the GBD study design. Associated literature provides more detail on each of these steps.^{12–17}

DALY measurement

DALYs are calculated by summing YLLs and YLDs for each cause, age, sex, year and location.

Uncertainty measurement

Uncertainty is measured at each step of the analytical process based on the sample size, SE or original uncertainty interval (UI) from each input to the study. Uncertainty is propagated through each step of the analysis by maintaining distributions of 1000 draws on which each analytical step is conducted. Final 95% UIs are determined based on the 25th and 975th values of the ordered values across draws.

Code and results

Steps of the analytical process were conducted in Python version 2.7, Stata V.13.1 or R version 3.3. All steps of the analytical process are available online at ghdx.healthdata.org. This study reports a subset of measures and metrics for every cause of injury. All results and results with additional detail by age, sex, year and location can be downloaded at ghdx.healthdata.org.

Guidelines for Accurate and Transparent Health Estimates Reporting (GATHER) statement

This study is adherent with guidelines from the GATHER (described in more detail in online supplementary appendix 2).²⁹

RESULTS

Online supplementary appendix table 2 shows age-standardised incidence, prevalence, YLDs, deaths, YLLs and DALYs in 2017 by country as well as percentage change and UI from 1990 for each metric. Online supplementary appendix table 3 shows all-age numbers (ie, not divided by population) of incidence, prevalence, YLDs, deaths, YLLs and DALYs in 2017 by country as well as percentage change from 1990 and UI for each metric. In some instances, the UI for the per cent change crosses zero,

meaning that statistically there was no significant difference. Online supplementary appendix figures 1–6, show the incidence and mortality from transport injuries, unintentional injuries, and interpersonal violence and self-harm by country for 2017 as well as the percentage change for both incidence and mortality between 1990 and 2017. All other results including age-specific and sex-specific results can be viewed and downloaded via freely and publicly available tools at ghdx.healthdata.org.

Global trends in overall injury burden

In terms of fatal outcomes, deaths due to all injuries increased from 4 260 493 (4 085 700 to 4 396 138) in 1990 to 4 484 722 (4 332 010 to 4 585 554) in 2017, while YLLs decreased from 232 104 206 (219 920 058 to 241 973 733) to 195 231 148 (188 807 653 to 199 825 464) and age-standardised mortality rates decreased from 1079 (1073 to 1086) to 738 (730 to 745) per 100 000. In terms of non-fatal outcomes, all-injury incidence (new cases) increased from 354 064 302 (338 174 876 to 371 610 802) in 1990 to 520 710 288 (493 430 247 to 547 988 635) in 2017, and YLDs increased from 37 452 031 (27 805 854 to 49 010 103) to 57 174 469 (42 073 855 to 75 427 036), while age-standardised incidence rates decreased non-significantly from 6824 (6534 to 7147) to 6763 (6412 to 7118) per 100 000. In terms of DALYs, age-standardised DALY rates decreased from 4947 (4655 to 5233) per 100 000 in 1990 to 3267 (3058 to 3505) in 2017.

Figure 1 shows age-standardised DALY rates by country for 2017. While certain countries—specifically, Syria, Central African Republic and Iraq—have much higher DALY rates than most other countries, there still exists considerable heterogeneity across countries that are not among these countries with the highest burden. South Sudan, Somalia and Yemen have much higher injury burden than much of the rest of the world, for example, with age-standardised DALY rates of 7391.51 per 100 000 (6536.44 to 8440.14), 7364.66 per 100 000 (6143.11 to 8960.58) and 7297.88 per 100 000 (6525.7 to 8438.15), respectively. Papua New Guinea also demonstrates high all-injury burden with 6803.33 DALYs per 100 000 (5652.2 to 8040.89) in 2017.

Figure 2 presents deaths as a stacked graph for overall injury groups and population from 1990 to 2017 with labelled fatal discontinuities, defined as changes in deaths due to sudden, unexpected spikes in mortality that depart from the underlying mortality trend.¹³ Although population has steadily increased in the 28 years of the study, deaths per year due to injuries have remained relatively consistent over time. Natural disasters, such as earthquakes, have caused pronounced spikes in unintentional injuries deaths, while conflict and genocide have caused spikes in deaths in the interpersonal violence injury category.

All-injury YLDs and YLLs by country in 2017

Figure 3 shows the percentage of total all-age, combined-sex YLDs by country in 2017. This figure shows several geographical patterns that help depict the non-fatal burden of injuries globally in terms of their relative contribution to overall disability. First, the percentage of total disability caused by injuries varies widely by country. Mauritius experiences only 3.04% (2.79% to 3.29%) of non-fatal burden from injuries, while Slovenia experiences 19.11% (17.11% to 21.27%) of non-fatal burden from injuries. In other words, if all disability in these two populations is combined in 2017, there is over sixfold variation in how much of this disability was caused by injuries. These patterns also reflect burden from non-injury conditions, since locations with higher burden from communicable disease may have correspondingly lower proportion due to injuries. As an extension of

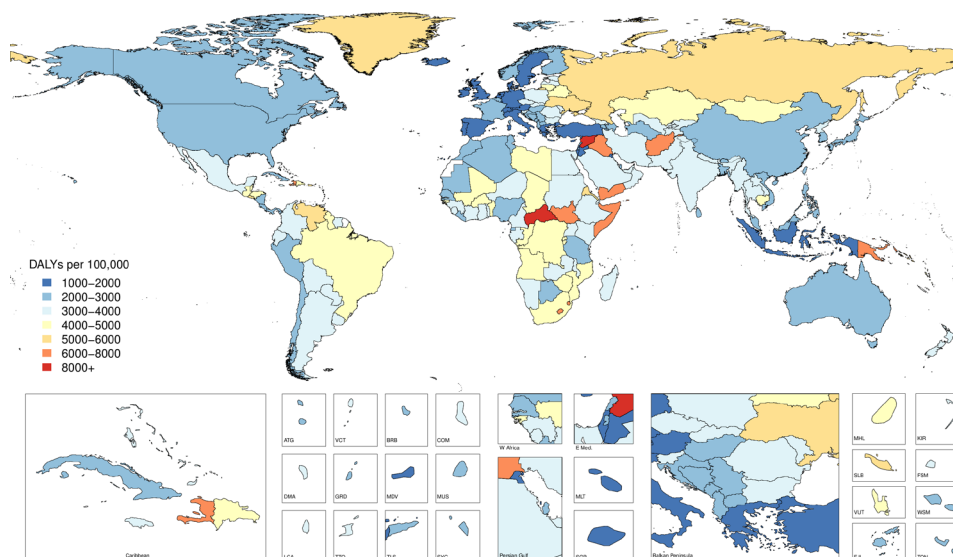


Figure 1 Age-standardised DALY rates by country, 2017. DALYs, disability-adjusted life years.

these geographical trends, this map makes it evident that there are striking regional patterns in non-fatal injury burden. Eastern and Central Europe and Central Asia as well as Australasia have a notably higher percentage of total non-fatal burden from injuries than countries in other regions, while these percentages are relatively lower in most areas of Africa, the Americas and areas of South, East and Southeast Asia. To some extent, this map also reflects the underlying burden from non-injury causes, too, since areas of the world with high non-fatal disability from conditions such as anaemia, communicable diseases and other types of health loss could have correspondingly higher percentages of disability from these conditions instead of injuries. This map also shows examples of positive deviations from global trends; Indonesia,

for example, has a relatively low percentage of non-fatal health loss due to injuries compared with many other countries.

Figure 4 similarly shows the percentage of total all-age, combined-sex YLLs by country in 2017. This figure interestingly shows how mortality patterns demonstrate different geographical trends than the non-fatal burden, as depicted in figure 2, though it should be noted that YLLs will also be disproportionately higher in younger populations, all else being equal. In particular, the locations with the highest percentage of YLLs due to injuries are in certain countries in North Africa and the Middle East, including Syria, where 59.51% (56.59% to 62.35%) of YLLs were due to injuries in 2017, and Iraq, where 41.34% of YLLs were due to injuries in 2017. Areas of

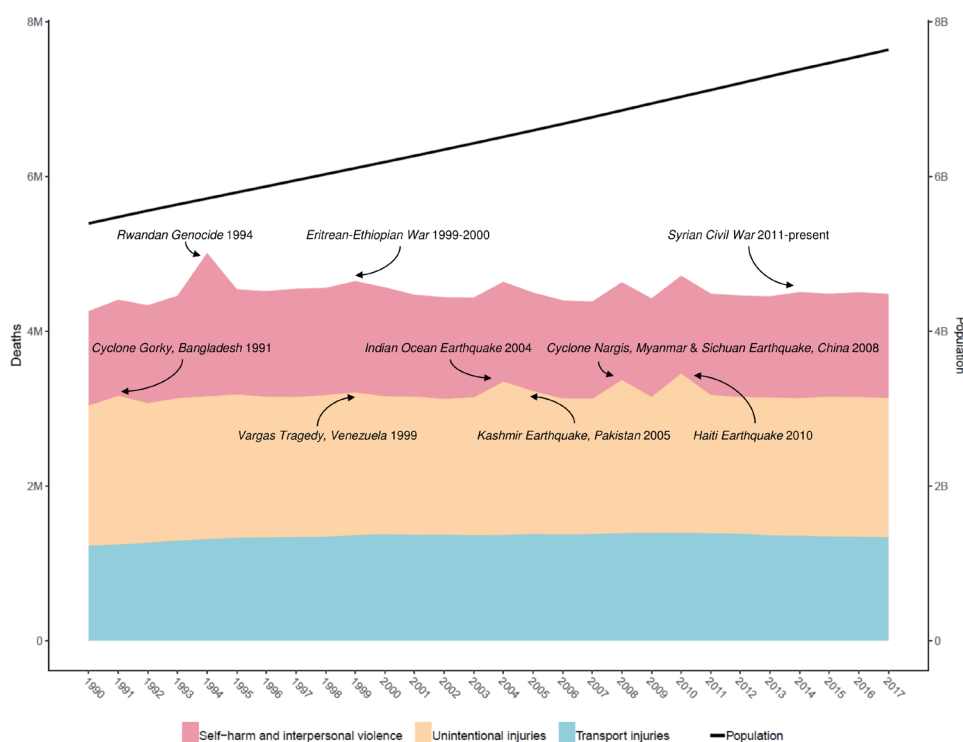


Figure 2 Global deaths for level 2 injuries and population from 1990 to 2017 with labelled fatal discontinuities.

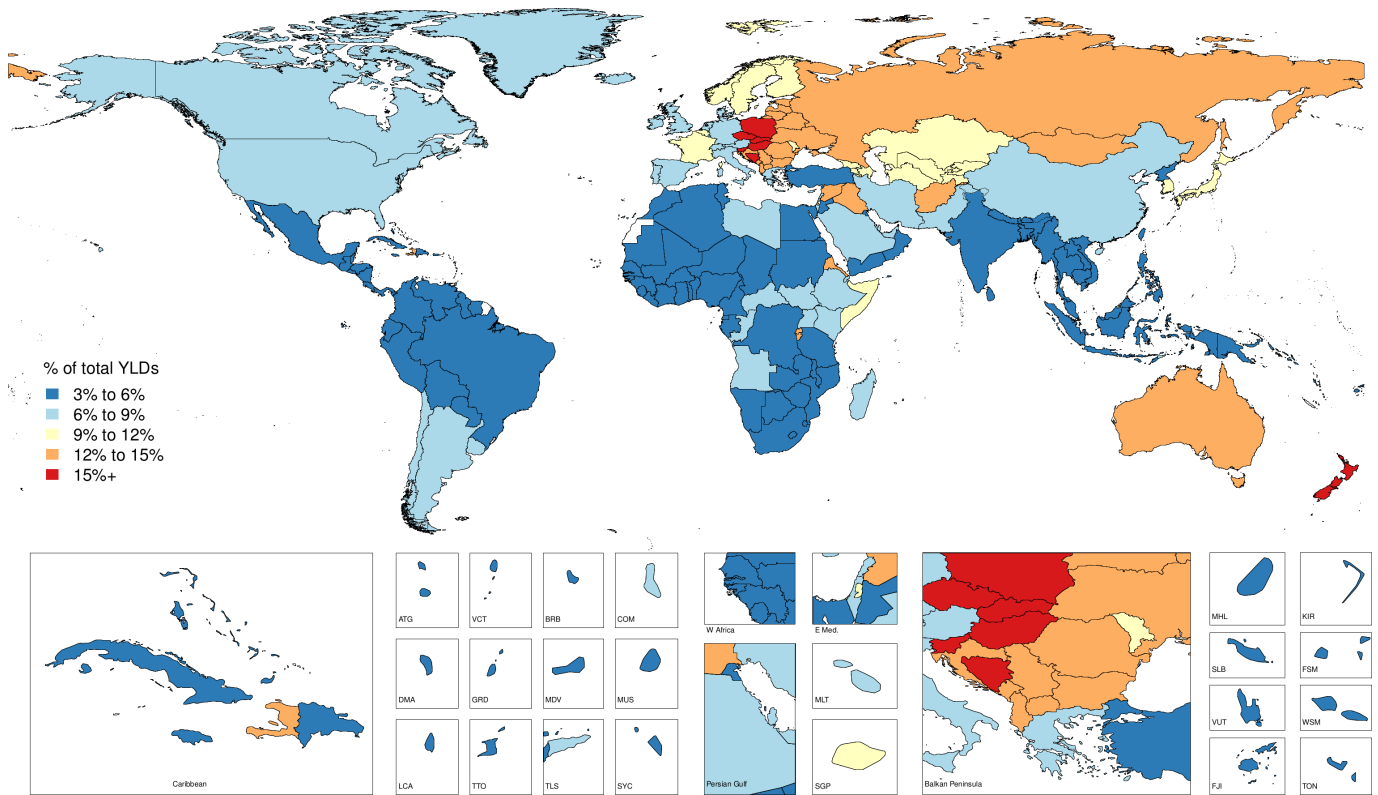


Figure 3 Percentage of YLDs in all ages due to injuries in 2017. YLDs, years lived with disability.

Latin America including Venezuela, Honduras and Belize also have a relatively high percentage of total YLLs due to injuries. Conversely, certain areas of the world also demonstrate a relatively low percentage of total YLLs due to injuries, specifically,

certain countries in Africa such as Nigeria and Madagascar have relatively lower percentages, though this also reflects relatively higher mortality from other non-injury causes in these countries.

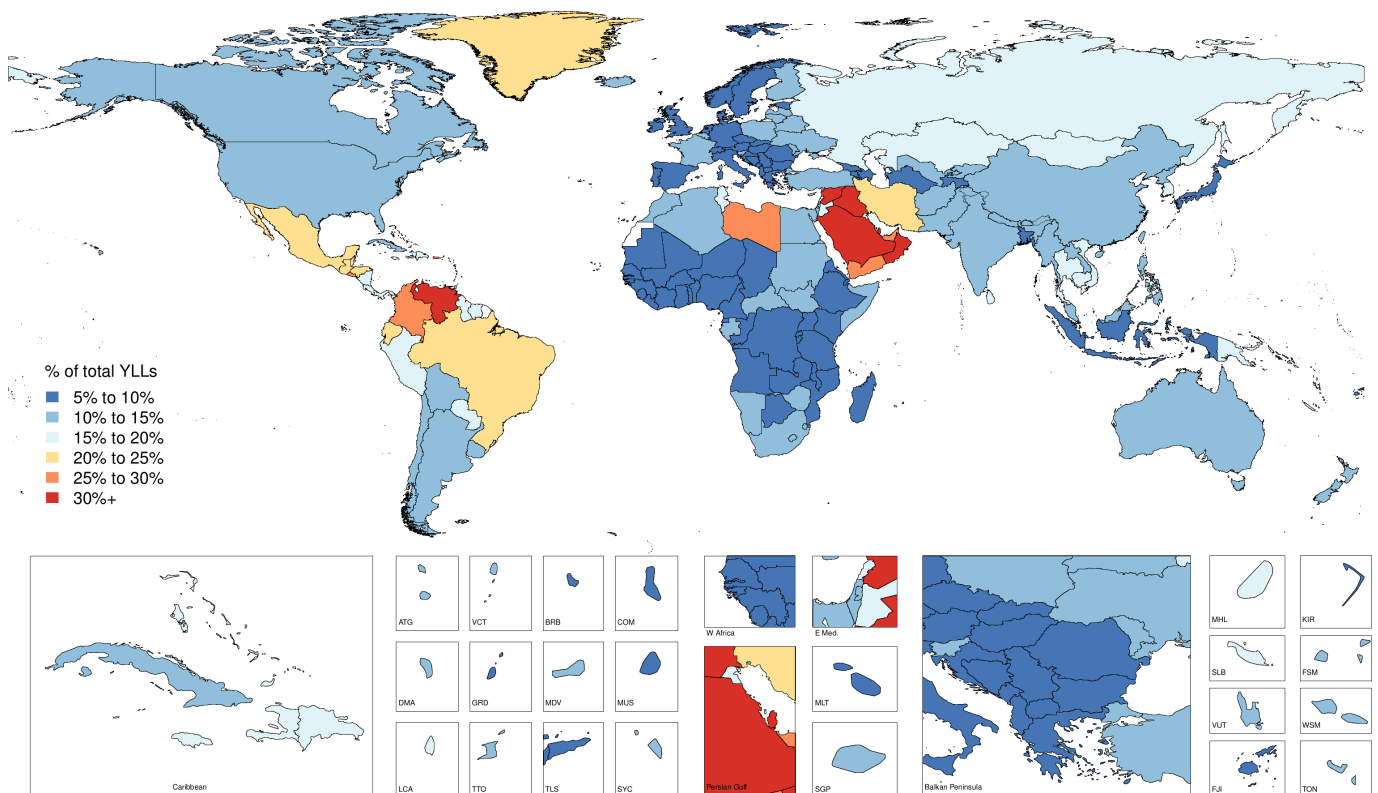


Figure 4 Percentage of YLLs in all ages due to injuries in 2017. YLLs, years of life lost.

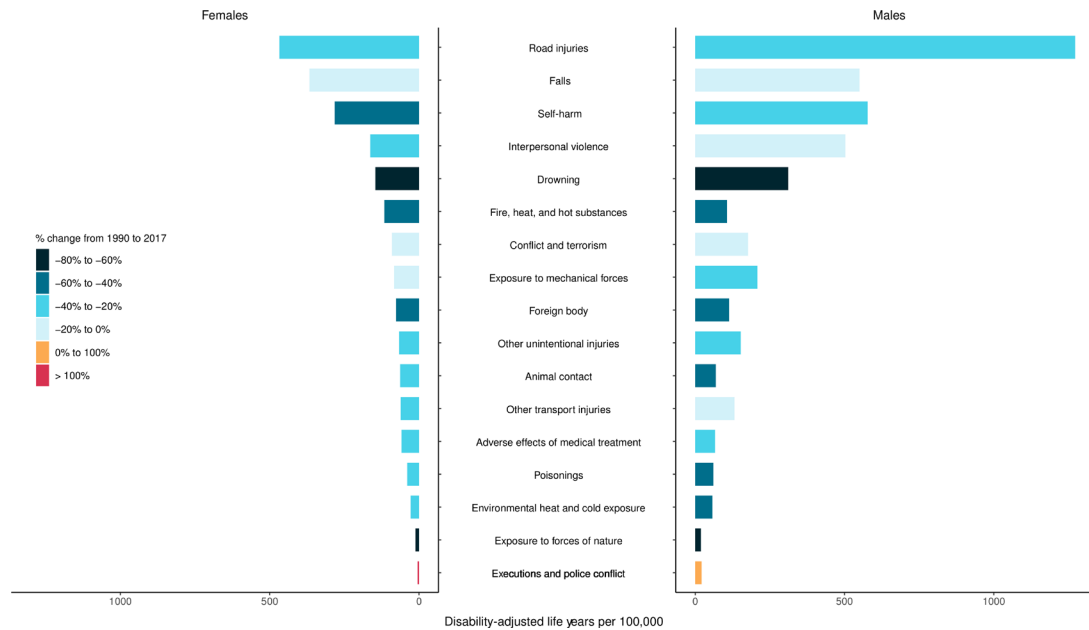


Figure 5 Age-standardised DALY rates by sex for injuries in level 3 of the GBD cause hierarchy in 2017 and percentage change from 1990 to 2017. DALY, disability-adjusted life year; GBD, Global Burden of Disease.

Cause-specific DALY rates by sex

Figure 5 shows cause-specific DALY rates by sex for 17 injuries in 2017 as well as percentage change from 1990 to 2017 by cause and sex. The black and dark blue bars show causes with greater relative improvement over the time period of this study, while lighter blue, orange and red show injuries that have had lesser improvements, no improvements or increasing burden over time.

In 2017, men experienced higher age-standardised DALY rates than women for all injuries except fire, heat and hot substances. The most marked differences, where DALY rates for men are more than double those of women, can be seen in self-harm, interpersonal violence, road injuries, other transport injuries, exposure to mechanical forces, environmental heat and cold exposure, and executions and police violence. Road injuries (1272 (1209 to 1331) per 100 000), self-harm (577 (525 to 604)) and falls (550 (462 to 653)) were the causes with the highest DALY rates for men in 2017. Women had the highest DALY rates due to the same injuries, but at a lesser magnitude, with rates of 467 (432 to 502) per 100 000 for road injuries, 367 (304 to 442) for falls and 282 (268 to 293) for self-harm.

The causes with the largest decreases in DALY rates for men from 1990 to 2017 were exposure to forces of nature (72.4% (63.8% to 79.1%)), drowning (62.7% (58.8% to 65.4%)) and fire, heat and hot substances (43.6% (26.4% to 49.9%)). For women, exposure to forces of nature (72.8% (63.8% to 79.6%)), drowning (65.8% (58.6% to 69.2%)) and self-harm (50.8% (48.2% to 55.9%)) had the largest decreases in DALY rates. The only increases in DALY rates were seen in executions and police conflict for both women (298.0% (257.1% to 389.0%)) and men (46.4% (31.2% to 173.0%)).

Comparative regional DALY rates in 2017

Figure 6 shows a heatmap of the number of standard deviations (SD) above or below the mean of a row (ie, a Z-score) of age-standardised DALY rates for select injuries by GBD region in 2017. For example, the figure shows that the rate of age-standardised DALYs in Eastern Europe is approximately three SD higher than the across mean age-standardised DALY rates of environmental heat and cold exposure across all regions.

Poisonings is also a cause with an age-standardised DALY rate that is approximately three SD higher than in other regions. Positive deviance is seen in high-income Asia Pacific for road injuries, where age-standardised DALYs are one SD lower than the mean across regions. Conversely, Central sub-Saharan Africa has age-standardised DALY rates that are two SD higher than the mean across regions. This figure also demonstrates how certain causes have relatively less variation across regions, for example, most regions do not deviate from the mean age-standardised DALY rates across regions for exposure to forces of nature, with the exception of the Caribbean, which had an age-standardised DALY rate that was approximately four SD above the mean across regions in 2017. Oceania and Eastern Europe stand out as having higher DALY rates for select injuries than other regions, while East Asia, high-income Asia Pacific, high-income North America, Western Europe and Southern Latin America experienced less than average burden of injuries in 2017.

DISCUSSION

Measuring, understanding and acting on the global burden of injuries should be considered a foundational component of population health research. While this study has reviewed injury burden trends from GBD 2017, it is also evident that these trends are sufficiently different by injury type and geography that it becomes difficult to succinctly generalise the findings in this study. Nevertheless, this study reveals themes and principles germane to the state of global injury burden in 2017 that are relevant to injury burden and prevention research.

First, it should be recognised that despite global population growth with increases in injury cases and deaths, age-standardised death rates from injuries declined from 1990 to 2017. More research into successful improvements for specific injuries in specific countries should be more investigated to help guide efforts towards future improvements. In general terms, the reduction in injury mortality likely represent the combined effects of improvements in healthcare systems, investments in injury prevention programmes and, in certain circumstances, safety improvement such as vehicle safety testing, helmet, seatbelt

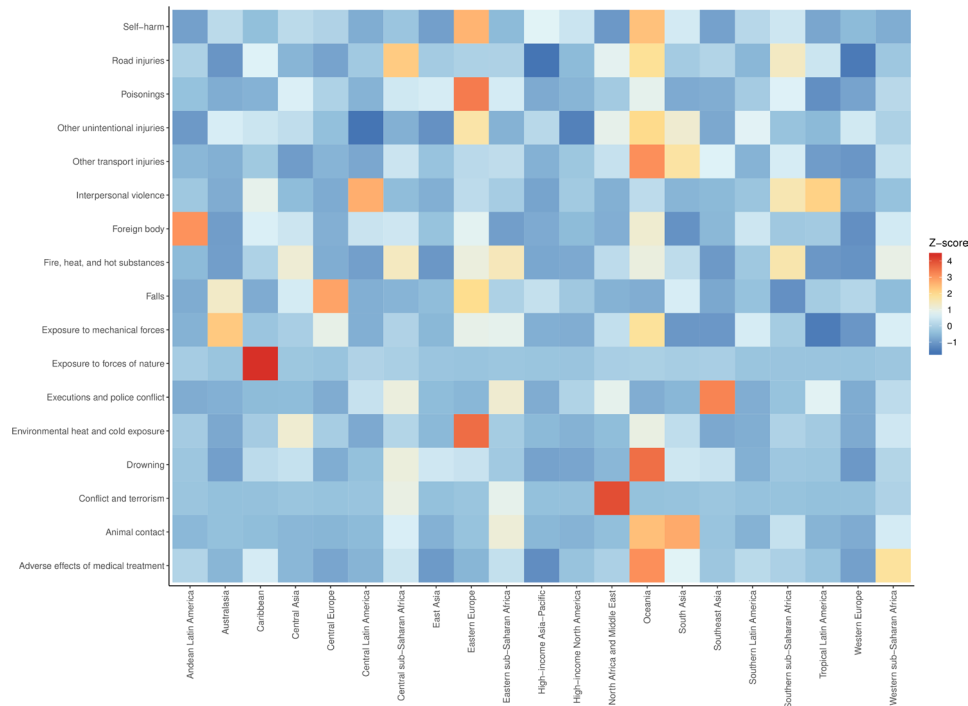


Figure 6 Heatmap showing the Z-score of age-standardised mean DALY rates for select injuries by GBD region in 2017. GBD, Global Burden of Disease.

and drinking and driving laws. While burden trends across all diseases and injuries vary by geography and time, these improvements in injury burden are generally consistent with reporting of communicable and non-communicable disease trends reported in GBD 2017.

Despite improvements in terms of rates, however, it is important to consider the impact of absolute injury burden in younger and adult ages on the social capital and workforce in

a country. Second, in reviewing temporal trends in figure 2, it becomes evident that war and conflict and environmental disasters can cause profound increases in deaths over a short period of time. This unfortunate and tragic reality should be made more broadly visible as issues such as war, conflict and climate change continue to threaten the populations of the 21st century. Third, sex differentials in the burden of different injury types are large, with men experiencing significantly higher burden from the four leading causes of injury DALYs in 2017. Preventive research and focused interventions into why this is occurring in road injuries, falls, self-harm, interpersonal violence and drowning is critical. It is also critical to address injuries such as fire, heat and hot substance and sexual violence where females experience greater burden and to better understand the factors that drive sex differences. As a fourth theme, we observed that there are cases of both positive and negative deviance from cross-region trends for each injury, as shown in figure 6, which appear to occur even outside of expected differences by income group. For example, understanding why high-income Asia Pacific and Western Europe are performing better than high-income North America in road injury burden could help improve road injury burden even in this higher income setting.

Beyond these four themes, there are evidently a great deal of nuances and specific outcomes to measure and understand in future injury research. While every cause of health loss in a population is important to measure and understand, injuries are unique in that understanding burden requires investigation of an array of circumstances such as infrastructure, the built environment, rates of interpersonal violence in a population and individual behaviours such as alcohol intoxication or drug use. The findings in this paper also demonstrate how it is critical to measure and understand the spectrum of health loss due to injuries ranging from relatively silent injuries to injuries that profoundly affect functional status. An incident as elemental as a trip and fall can lead to profoundly disabling health consequences

What is already known on the subject

- ▶ Injury burden globally varies across many dimensions but remains as an important component of global health loss. Regular updates in injury burden measurement are critical.
- ▶ Injuries can be largely preventable, but prevention efforts must be guided by up-to-date estimates of injury burden that can be used on an age-specific, sex-specific, year-specific, location-specific and injury-specific basis.

What this study adds

- ▶ This study incorporates updated data and methods that were used in Global Burden of Disease 2017 with updated burden estimates for the year 2017, as well as newly available results in terms of nature of injury.
- ▶ Global age-standardised mortality and disability-adjusted life years decreased between 1990 and 2017. Decreases in age-standardised incidence were not statistically significant.
- ▶ Trends over time vary depending on the specific injury, sex and location.
- ▶ Injury burden in a population can be radically affected by war, civil conflict and natural disasters.

such as spinal cord injury, which can have lifelong disability. The disability caused by shorter term injuries, such as an arm fracture, in addition to causing suffering and disability, can cause loss of human capital.³⁰ While this study focused more on the causes of injury as defined in the GBD cause hierarchy, future GBD studies should focus also on depicting the distribution of nature of injury results to better understand how these types of disability affect an individual's functional status. Such analyses become increasingly meaningful as research emerges on, for example, the increased risk of dementia that traumatic brain injury patients may experience.³¹ The findings in this paper also demonstrate how measuring injury burden necessitates review of the population factors that affect injury risk. For example, an event as disastrous as an earthquake may have radically different impacts on a population depending on infrastructure and access to care resources. Understanding how populations can protect themselves against future, unanticipated catastrophe could lead to averted death and disability in the future. As was shown in figure 2, catastrophic events both in terms of natural disasters and war and conflict can significantly add to the death and disability experienced by a population in a short period of time.

The geographical trends shown in this paper are also critical to review and understand by the broader global health community. As shown in figure 6, considerable heterogeneity exists across regions for certain causes. While vehicles were driven in nearly every populated area of earth in 2017, this study shows that different regions of the world have markedly different rates of death and disability resulting from road injuries, underscoring the importance of measuring and understanding the effects of specific factors on injury burden.³² It is not necessarily surprising to observe that countries or regions with relatively lower health-care access and quality, less road safety infrastructure and lower utilisation of vehicles with modern safety standards would have higher rates of road injuries DALYs. The question that extends from this observation, however, is the extent to which burden from this type of injury cause could be avoided were every country to have the safety and prevention factors available in higher income settings. The injury and safety research communities should consider future investigation of counterfactual analyses to better measure and understand the impact that road safety legislation, modernisation of roads and vehicles and improving first response medical care could have on road injury burden, as an example, though parallel examples can be developed for other injury causes as well. This research could help cost-effectiveness analyses and guide investment in safer infrastructure.

These observations converge on a common theme: much of the injury burden may be largely preventable and understanding the success or failure of different prevention efforts should be a prioritised area of health research. Moreover, it is critical for there to be continued engagement across different areas of the world for the purposes of discussing effective and ineffective injury prevention strategies. Dialogue focused on findings across injury prevention efforts via forums such as global safety conferences as well as studies published in research journals should continue to help policy makers and public health planners make strategic investments for preventing future injury burden.³³ In addition, more research into the cause of injury and resulting bodily injury and environmental and contextual features where injuries occur such type of road in a road injury or fires in factories versus in residences may provide further insight into preventing future injury burden.

Known limitations of injury burden estimation in the GBD framework have been reported previously in peer-reviewed

literature.^{1 11 13 16} Generally, identified limitations include data sparsity and correspondingly greater uncertainty in certain geographies, limited geographical coverage of data informing long-term disability estimates and cause–nature relationships, and potential reporting biases for injuries such as self-harm and interpersonal violence. These limitations have been discussed in the aforementioned literature, and this overview study was additionally limited in scope due to the extensive size of the GBD cause hierarchy and location hierarchy. Indeed, over 1400 different cause–nature combinations are available for reporting in the GBD cause hierarchy, and future research would benefit from examining results in the detailed cause hierarchy and across the detailed location, age and sex hierarchy. The GBD Study platform and collaborator network provide a constructive collaborative platform on which future assessments can be conducted and published.

CONCLUSION

Injury burden is complex but foundational in formulating global health loss. We have identified four broad trends in global injury burden that converge on the principle that injuries should be considered largely preventable but that detailed burden estimates through recent years are a critical global resource to inform meaningful policy. It will be important accurate measurement to continue into the future to guide injury prevention policy.

Author affiliations

- ¹Institute for Health Metrics and Evaluation, University of Washington, Seattle, WA, USA
- ²Department of Neurology, Cairo University, Cairo, Egypt
- ³Department of Parasitology and Mycology, Jahrom University of Medical Sciences, Jahrom, Iran
- ⁴Neuroscience Research Center, Isfahan University of Medical Sciences, Isfahan, Iran
- ⁵Department of Public Health, Ministry of Health, Riyadh, Saudi Arabia
- ⁶Department of Orthopaedic Surgery, University of Southern California, Los Angeles, CA, USA
- ⁷Department of Public Health, Debre Berhan University, Debre Berhan, Ethiopia
- ⁸Cardiovascular Medicine, Ain Shams University, Abbasia, Egypt
- ⁹Department of Medicine, University College Hospital, Ibadan, Ibadan, Nigeria
- ¹⁰School of Medicine Center for Politics, Population and Health Research, National Autonomous University of Mexico, Mexico City, Mexico
- ¹¹Department of Epidemiology and Health Statistics, Southeast University Nanjing, Nanjing, China
- ¹²Department of Microbiology, Hazara University Mansehra, Mansehra, Pakistan
- ¹³James P Grant School of Public Health, BRAC University, Dhaka, Bangladesh
- ¹⁴Health Systems and Population Studies Division, International Centre for Diarrhoeal Disease Research, Bangladesh, Dhaka, Bangladesh
- ¹⁵Department of Epidemiology, Jimma University, Jimma, Ethiopia
- ¹⁶Higher National School of Veterinary Medicine, Algiers, Algeria
- ¹⁷Evidence Based Practice Center, Mayo Clinic Foundation for Medical Education and Research, Rochester, MN, USA
- ¹⁸School of Health Sciences, Madda Walabu University, Bale Goba, Ethiopia
- ¹⁹Department of Computer Sciences, Imam Abdulrehman Bin Faisal University, Dammam, Saudi Arabia
- ²⁰Department of Nursing, Debre Markos University, Debre Markos, Ethiopia
- ²¹Department of Pharmacy, Adigrat University, Adigrat, Ethiopia
- ²²Department of Population Health Research, King Abdullah International Medical Research Center, Riyadh, Saudi Arabia
- ²³Faculty of Health Sciences - Health Management and Policy, American University of Beirut, Beirut, Lebanon
- ²⁴British Columbia Injury Research Prevention Unit, British Columbia Children's Hospital Research Institute, Vancouver, BC, Canada
- ²⁵Medical Technical Institute, Erbil Polytechnic University, Erbil, Iraq
- ²⁶Faculty of Pharmacy, Ishik University, Erbil, Iraq
- ²⁷Department of Information Systems, College of Economics and Political Science, Sultan Qaboos University, Muscat, Oman
- ²⁸School of Health Management and Information Sciences, Department of Health Services Management, Iran University of Medical Sciences, Tehran, Iran
- ²⁹Department of Health Care Management and Economics, Urmia University of Medical Science, Urmia, Iran
- ³⁰Health Management and Economics Research Center, Iran University of Medical Sciences, Tehran, Iran

- ³¹Health Economics Department, Iran University of Medical Sciences, Tehran, Iran
- ³²Department of Health Policy and Management, Kuwait University, Safat, Kuwait
- ³³International Centre for Casemix and Clinical Coding, National University of Malaysia, Bandar Tun Razak, Malaysia
- ³⁴Department of Epidemiology, Arak University of Medical Sciences, Arak, Iran
- ³⁵Physiotherapy Department, The University of Jordan, Amman, Jordan
- ³⁶King Saud University, Riyadh, Saudi Arabia
- ³⁷Clinical Practice Guidelines Unit, King Saud University, Riyadh, Saudi Arabia
- ³⁸Alexandria Center for Evidence-Based Clinical Practice Guidelines, Alexandria University, Alexandria, Egypt
- ³⁹Health Services Management Department, Arak University of Medical Sciences, Arak, Iran
- ⁴⁰Department of Epidemiology and Biostatistics, University of the Philippines Manila, Manila, Philippines
- ⁴¹Online Programs for Applied Learning, Johns Hopkins University, Baltimore, MD, USA
- ⁴²Carol Davila University of Medicine and Pharmacy, Bucharest, Romania
- ⁴³Department of Epidemiology and Biostatistics, Health Promotion Research Center, Zahedan, Iran
- ⁴⁴Department of Health Policy and Administration, University of the Philippines Manila, Manila, Philippines
- ⁴⁵Department of Applied Social Sciences, Hong Kong Polytechnic University, Hong Kong, China
- ⁴⁶Department of Sociology and Social Work, Kwame Nkrumah University of Science and Technology, Kumasi, Ghana
- ⁴⁷Center for International Health, Ludwig Maximilians University, Munich, Germany
- ⁴⁸Social Determinants of Health Research Center, Birjand University of Medical Sciences, Birjand, Iran
- ⁴⁹Department of Health Promotion and Education, Tehran University of Medical Sciences, Tehran, Iran
- ⁵⁰School of Health Sciences, Birmingham City University, Birmingham, UK
- ⁵¹Regional Centre for the Analysis of Data on Occupational and Work-related Injuries and Diseases, Local Health Unit Tuscany Centre, Florence, Italy
- ⁵²School of Science and Health, Western Sydney University, Sydney, New South Wales, Australia
- ⁵³Oral Health Services, Sydney Local Health District, Sydney, New South Wales, Australia
- ⁵⁴Department of Plastic Surgery, University of Texas, Houston, TX, USA
- ⁵⁵Department of Microbiology, Hamedan University of Medical Sciences, Azad Tabriz University, Iran
- ⁵⁶Department of Nursing, Wolaita Sodo University, Wolaita Sodo, Ethiopia
- ⁵⁷The Judith Lumley Centre, La Trobe University, Melbourne, VIC, Australia
- ⁵⁸General Office for Research and Technological Transfer, Peruvian National Institute of Health, Lima, Peru
- ⁵⁹School of Public Health, Curtin University, Perth, WA, Australia
- ⁶⁰Department of Health Policy Planning and Management, University of Health and Allied Sciences, Ho, Ghana
- ⁶¹Department of Environmental Health Engineering, Hamadan University of Medical Sciences, Hamadan, Iran
- ⁶²Public Health Risk Sciences Division, Public Health Agency of Canada, Toronto, Ontario, Canada
- ⁶³Department of Nutritional Sciences, University of Toronto, Toronto, Ontario, Canada
- ⁶⁴Department of Forensic Science, Government Institute of Forensic Science, Nagpur, India
- ⁶⁵Department of Ophthalmology, University Hospital of Ioannina, Ioannina, Greece
- ⁶⁶Institute of Molecular Biology & Biotechnology, Foundation for Research & Technology, Ioannina, Greece
- ⁶⁷Biochemistry Unit, Universiti Sultan Zainal Abidin, Kuala Terengganu, Malaysia
- ⁶⁸School of Health Sciences, Univeristi Sultan Zainal Abidin, Kuala Terengganu, Malaysia
- ⁶⁹Institute of Health Management Research, Indian Institute of Health Management Research University, Jaipur, India
- ⁷⁰Department of Epidemiology, Johns Hopkins University, Baltimore, MD, USA
- ⁷¹Health Policy And Management Department, Tehran University of Medical Sciences, Tehran, Iran
- ⁷²Department of Demography, University of Groningen, Groningen, Netherlands
- ⁷³Population Research Centre, Institute for Social and Economic Change, Bengaluru, India
- ⁷⁴Department of Hypertension, Medical University of Lodz, Lodz, Poland
- ⁷⁵Polish Mothers' Memorial Hospital Research Institute, Lodz, Poland
- ⁷⁶School of Health Sciences, Walden University, Minneapolis, MN, USA
- ⁷⁷Department of Noncommunicable Diseases, Bangladesh University of Health Sciences (BUHS), Dhaka, Bangladesh
- ⁷⁸Department of Research, Public Health Perspective Nepal, Pokhara-Lekhath Metropolitan City, Nepal
- ⁷⁹School of Psychology, University of Auckland, Auckland, New Zealand
- ⁸⁰Heidelberg Institute of Global Health (HIGH), Heidelberg University, Heidelberg, Germany
- ⁸¹T H Chan School of Public Health, Harvard University, Boston, MA, USA
- ⁸²Department of Industrial Engineering, Pontifical Javeriana University, Bogota, Colombia
- ⁸³Occupational Health Department, Kermanshah University of Medical Sciences, Kermanshah, Iran
- ⁸⁴Health Human Resources Research Center, Shiraz University of Medical Sciences, Shiraz, Iran
- ⁸⁵Department of Public Health, Ambo University, Ambo, Ethiopia
- ⁸⁶Department of Community Medicine, Gandhi Medical College Bhopal, Bhopal, India
- ⁸⁷Jazan University, Jazan, Saudi Arabia
- ⁸⁸Social Determinants of Health Research Center, Lorestan University of Medical Sciences, Khorramabad, Iran
- ⁸⁹Institute of Health Sciences, School of Public Health, Wollega University, Nekemte, Ethiopia
- ⁹⁰Department of Psychiatry, Bahir Dar University, Bahir Dar, Ethiopia
- ⁹¹Department of Epidemiology and Psychosocial Reseach, Ramón de la Fuente Muñiz National Institute of Psychiatry, Mexico City, Mexico
- ⁹²Nuffield Department of Population Health, University of Oxford, Oxford, UK
- ⁹³Department of Internal Medicine, University of São Paulo, São Paulo, Brazil
- ⁹⁴Department of Nutrition and Dietetics, Mekelle University, Mekelle, Ethiopia
- ⁹⁵Department of Community Medicine and Family Medicine, All India Institute of Medical Sciences, Jodhpur, India
- ⁹⁶Department of Community Medicine, Datta Meghe Institute of Medical Sciences, Wardha, India
- ⁹⁷Department of Internal Medicine, University of Massachusetts Medical School, Springfield, MA, USA
- ⁹⁸Department of Statistical and Computational Genomics, National Institute of Biomedical Genomics, Kalyani, India
- ⁹⁹Department of Statistics, University of Calcutta, Kolkata, India
- ¹⁰⁰Institute of Soil and Environmental Sciences, University of Agriculture, Faisalabad, Faisalabad, Pakistan
- ¹⁰¹Social Determinants of Health Research Center, Babol University of Medical Sciences, Babol, Iran
- ¹⁰²National Centre for Epidemiology and Population Health, Australian National University, Canberra, ACT, Australia
- ¹⁰³Department of Clinical Pharmacy and Pharmacology, University of Dhaka, Dhaka, Bangladesh
- ¹⁰⁴Department of Clinical and Experimental Medicine, University of Catania, Catania, Italy
- ¹⁰⁵Transport and Road Safety (TARS) Research Department, University of New South Wales, Sydney, New South Wales, Australia
- ¹⁰⁶Institute of Epidemiology, Comenius University, Bratislava, Slovakia
- ¹⁰⁷Department of Epidemiology and Evidence Based Medicine, I M Sechenov First Moscow State Medical University, Moscow, Russia
- ¹⁰⁸Research Department, Golden Community, Kathmandu, Nepal
- ¹⁰⁹Centre for Population Health Sciences, Nanyang Technological University, Singapore
- ¹¹⁰Global eHealth Unit, Imperial College London, London, UK
- ¹¹¹Department of Population and Health, Metropolitan Autonomous University, Mexico City, Mexico
- ¹¹²Research Unit on Applied Molecular Biosciences (UCIBIO), University of Porto, Porto, Portugal
- ¹¹³Department of Psychiatry, University of São Paulo, São Paulo, Brazil
- ¹¹⁴Colombian National Health Observatory, National Institute of Health, Bogota, Colombia
- ¹¹⁵Epidemiology and Public Health Evaluation Group, National University of Colombia, Bogota, Colombia
- ¹¹⁶Primary Care Services Area, Central Health Directorate, Region Friuli Venezia Giulia, Trieste, Italy
- ¹¹⁷Department of Medicine (DAME), University of Udine, Udine, Italy
- ¹¹⁸National School of Public Health, Carlos III Health Institute, Madrid, Spain
- ¹¹⁹Clinical Epidemiology Program, Ottawa Hospital Research Institute, Ottawa, ON, Canada
- ¹²⁰Mary MacKillop Institute for Health Research, Australian Catholic University, Melbourne, VIC, Australia
- ¹²¹School of Public Health, University of Hong Kong, Hong Kong, China
- ¹²²Institute of Applied Health Research, University of Birmingham, Birmingham, UK
- ¹²³Department of Gynecology and Obstetrics, University of Gondar, Gondar, Ethiopia
- ¹²⁴Department of Public Health, Texila American University, Georgetown, Guyana
- ¹²⁵Department of Medicine, University of Toronto, Toronto, Canada
- ¹²⁶2nd Department of Ophthalmology, University of Athens, Haidari, Greece
- ¹²⁷Ophthalmology Private Practice Office, Independent Consultant, Athens, Greece
- ¹²⁸Department of Pediatrics, Harvard University, Boston, MA, USA
- ¹²⁹Department of Neonatology, Beth Israel Deaconess Medical center, Boston, MA, USA
- ¹³⁰Department of Surgery, Division of Plastic and Reconstructive Surgery, University of Washington, Seattle, WA, USA

- ¹³¹Maternal and Child Health Division, International Centre for Diarrhoeal Disease Research, Bangladesh, Dhaka, Bangladesh
- ¹³²Department of Epidemiology and Biostatistics, University of South Carolina, Columbia, SC, USA
- ¹³³Faculty of Biology, Hanoi National University of Education, Hanoi, Vietnam
- ¹³⁴Research School of Population Health, Australian National University, Action, ACT, Australia
- ¹³⁵Department of Dermatology, Carol Davila University of Medicine and Pharmacy, Bucharest, Romania
- ¹³⁶2nd Department of Dermatology, Colentina Clinical Hospital, Bucharest, Romania
- ¹³⁷Department of Dermatology, Case Western Reserve University, Cleveland, OH, USA
- ¹³⁸Department of Dermatology, University of Milan, Milan, Italy
- ¹³⁹Toxoplasmosis Research Center, Mazandaran University of Medical Sciences, Sari, Iran
- ¹⁴⁰Population and Development, Facultad Latinoamericana de Ciencias Sociales Mexico, Mexico City, Mexico
- ¹⁴¹Department of Medical Laboratory Sciences, Bahir Dar University, Bahir Dar, Ethiopia
- ¹⁴²Department of Nursing, Woldia University, Woldia, Ethiopia
- ¹⁴³School of Nursing, Jimma University, Jimma, Ethiopia
- ¹⁴⁴School of Pharmacy, Aksum University, Aksum, Ethiopia
- ¹⁴⁵Addis Ababa University, Addis Ababa, Ethiopia
- ¹⁴⁶Immunology Research Center, Tabriz University of Medical Sciences, , Iran
- ¹⁴⁷Department of Global Health and Infection, Brighton and Sussex Medical School, Brighton, UK
- ¹⁴⁸School of Public Health, Addis Ababa University, Addis Ababa, Ethiopia
- ¹⁴⁹Division of Cardiology, Atlanta Veterans Affairs Medical Center, Decatur, GA, USA
- ¹⁵⁰Department of Epidemiology, Shiraz University of Medical Sciences, Shiraz, Iran
- ¹⁵¹Faculty of Pharmacy, University of Porto, Porto, Portugal
- ¹⁵²Tehran University of Medical Sciences, Tehran, Iran
- ¹⁵³School of Health and Biomedical Sciences, Royal Melbourne Institute of Technology University, Bundoora, VIC, Australia
- ¹⁵⁴Sydney School of Public Health, University of Sydney, Sydney, NSW, Australia
- ¹⁵⁵Faculty of Medicine, University of Belgrade, Belgrade, Serbia
- ¹⁵⁶Public Health Department, Hawassa University, Hawassa, Ethiopia
- ¹⁵⁷Curtin University, Perth, WA, Australia
- ¹⁵⁸Department of Global Health and Social Medicine, Harvard University, Boston, MA, USA
- ¹⁵⁹Department of Social Services, Tufts Medical Center, Boston, MA, USA
- ¹⁶⁰Department of Pharmacology and Toxicology, Maragheh University of Medical Sciences, Maragheh, Iran
- ¹⁶¹Department of Pharmacology and Toxicology, Tabriz University of Medical Sciences, Tabriz, Iran
- ¹⁶²National Institute for Health Researches, Tehran University of Medical Sciences, Tehran, Iran
- ¹⁶³Department of Clinical Pathology, Mansoura University, Mansoura, Egypt
- ¹⁶⁴Department of Statistics, Debre Markos University, Debre Markos, Ethiopia
- ¹⁶⁵Department of Public Health Sciences, Karolinska Institutet, Stockholm, Sweden
- ¹⁶⁶World Health Programme, Université du Québec en Abitibi-Témiscamingue, Rouyn-Noranda, QC, Canada
- ¹⁶⁷Department of Pathology, Stavanger University Hospital, Stavanger, Norway
- ¹⁶⁸Norwegian Institute of Public Health, Oslo, Norway
- ¹⁶⁹Ophthalmic Epidemiology Research Center, Shahroud University of Medical Sciences, Shahroud, Iran
- ¹⁷⁰Department of Midwifery, Wolkite University, Wolkite, Ethiopia
- ¹⁷¹Multiple Sclerosis Research Center, Tehran University of Medical Sciences, Tehran, Iran
- ¹⁷²Biology Department, Salahaddin University-Erbil, Erbil, Iraq
- ¹⁷³Biology and Biotechnolaniogy "L Spallanzani", University of Pavia, Pavia, Italy
- ¹⁷⁴Department of Psychology, Federal University of Sergipe, Sao Cristovao, Brazil
- ¹⁷⁵Non-communicable Diseases Research Center, Tehran University of Medical Sciences, Tehran, Iran
- ¹⁷⁶Pharmaceutical Nanotechnology, Tehran University of Medical Sciences, Tehran, Iran
- ¹⁷⁷Department of Psychiatry, Addis Ababa University, Addis Ababa, Ethiopia
- ¹⁷⁸Nursing Department, Hawassa University, Hawassa, Ethiopia
- ¹⁷⁹Department of Neurobiology, Karolinska Institutet, Stockholm, Sweden
- ¹⁸⁰Division of Neurology, University of Ottawa, Ottawa, ON, Canada
- ¹⁸¹REQUIMTE/LAQV, University of Porto, Porto, Portugal
- ¹⁸²Research Centre on Public Health (CESP), University of Milan Bicocca, Monza, Italy
- ¹⁸³Department of Health Education & Behavioral Sciences, Jimma University, Jimma, Ethiopia
- ¹⁸⁴Psychiatry Department, Kaiser Permanente, Fontana, CA, USA
- ¹⁸⁵School of Health Sciences, A T Still University, Mesa, AZ, USA
- ¹⁸⁶Department of Population Medicine and Health Services Research, Bielefeld University, Bielefeld, Germany
- ¹⁸⁷Department of Child Dental Health, Obafemi Awolowo University, Ile-Ife, Nigeria
- ¹⁸⁸Abadan School of Medical Sciences, Abadan University of Medical Sciences, Abadan, Iran
- ¹⁸⁹Department of Family Medicine and Primary Care, University of the Witwatersrand, Johannesburg, South Africa
- ¹⁹⁰College of Public Health, Medical and Veterinary Science, James Cook University, Douglas, QLD, Australia
- ¹⁹¹Royal Life Saving Society, Sydney, NSW, Australia
- ¹⁹²Department of Dermatology, Kobe University, Kobe, Japan
- ¹⁹³Gene Expression & Regulation Program, The Wistar Institute, Philadelphia, PA, USA
- ¹⁹⁴Public Health Department, Madda Walabu University, Bale-Robe, Ethiopia
- ¹⁹⁵School of Pharmacy, Mekelle University, Mekelle, Ethiopia
- ¹⁹⁶Department of Nursing and Midwifery, Addis Ababa University, Addis Ababa, Ethiopia
- ¹⁹⁷Department of Nursing, Aksum University, Aksum, Ethiopia
- ¹⁹⁸Department of Nursing, Mekelle University, Mekelle, Ethiopia
- ¹⁹⁹School of Public Health, Haramaya University, Harar, Ethiopia
- ²⁰⁰Bahir Dar University, Bahir Dar, Ethiopia
- ²⁰¹Haramaya University, Dire Dawa, Ethiopia
- ²⁰²Department of Pharmacy, Wollo University, Dessie, Ethiopia
- ²⁰³Department of Medical Surgery, Tabriz University of Medical Sciences, Tabriz, Iran
- ²⁰⁴Occupational Health Department, Arak University of Medical Sciences, Arak, Iran
- ²⁰⁵Department of Health Services Management, Iran University of Medical Sciences, Tehran, Iran
- ²⁰⁶Science and Research Branch, Islamic Azad University, Tehran, Iran
- ²⁰⁷Young Researchers and Elite Club, Rasht Branch, Islamic Azad University, Rasht, Iran
- ²⁰⁸Adelaide Medical School, University of Adelaide, Adelaide, SA, Australia
- ²⁰⁹Center for Clinical and Epidemiological Research, University of São Paulo, Sao Paulo, Brazil
- ²¹⁰Department of Dermatology, Boston University, Boston, MA, USA
- ²¹¹Institute of Public Health, United Arab Emirates University, Al Ain, United Arab Emirates
- ²¹²Technical College of Health, Sulaimani Polytechnic University, Sulaimani, Iraq
- ²¹³Instituto de Patologia Tropical e Saúde Pública, Federal University of Goias, Goiânia, Brazil
- ²¹⁴School of Public Health and Preventive Medicine, Monash University, Melbourne, VIC, Australia
- ²¹⁵Department of Epidemiology and Biostatistics, Zhengzhou University, Zhengzhou, China
- ²¹⁶Non-Communicable Diseases (NCD), World Health Organization (WHO), New Delhi, India
- ²¹⁷Department of Public Health, Erasmus University Medical Center, Rotterdam, Netherlands
- ²¹⁸Department of Radiology and Radiological Sciences, Johns Hopkins University, Baltimore, MD, USA
- ²¹⁹School of Medicine, Tehran University of Medical Sciences, Tehran, Iran
- ²²⁰Institute for Global Health, University College London, London, UK
- ²²¹Global and Community Mental Health Research Group, University of Macau, Macao, China
- ²²²Department of Family and Community Medicine, Arabian Gulf University, Manama, Bahrain
- ²²³School of Health and Environmental Studies, Hamdan Bin Mohammed Smart University, Dubai, United Arab Emirates
- ²²⁴Biomedical Research Networking Center for Mental Health Network (CiberSAM), Madrid, Spain
- ²²⁵Research and Development Unit, San Juan de Dios Sanitary Park, Sant Boi de Llobregat, Spain
- ²²⁶Institute for Social Science Research, The University of Queensland, Indooroopilly, QLD, Australia
- ²²⁷Department of Microbiology, Maragheh University of Medical Sciences, Maragheh, Iran
- ²²⁸Department of Microbiology, Tehran University of Medical Sciences, Tehran, Iran
- ²²⁹Gastrointestinal and Liver Disease Research Center, Guilan University of Medical Sciences, Rasht, Iran
- ²³⁰School of Nursing and Midwifery, Tabriz University of Medical Sciences, Tabriz, Iran
- ²³¹Independent Consultant, Tabriz, Iran
- ²³²Department of Public Health, Mizan-Tepi University, Tepi, Ethiopia
- ²³³Unit of Epidemiology and Social Medicine, University Hospital Antwerp, Wilrijk, Belgium
- ²³⁴Department of Clinical Sciences, Karolinska University Hospital, Stockholm, Sweden
- ²³⁵Institute of Pharmaceutical Sciences, University of Veterinary and Animal Sciences, Lahore, Pakistan
- ²³⁶Department of Pharmacy Administration and Clinical Pharmacy, Xian Jiaotong University, Xian, China
- ²³⁷Medical Biology Research Center, Kermanshah University of Medical Sciences, Kermanshah, Iran
- ²³⁸Research Coordination, AC Environments Foundation, Cuernavaca, Mexico

- ²³⁹CISS, National Institute of Public Health, Cuernavaca, Mexico
- ²⁴⁰Department of Urban Planning and Design, University of Hong Kong, Hong Kong, China
- ²⁴¹Center of Excellence in Behavioral Medicine, Nguyen Tat Thanh University, Ho Chi Minh City, Vietnam
- ²⁴²Department of Pediatrics, Dell Medical School, University of Texas Austin, Austin, TX, USA
- ²⁴³Kasturba Medical College, Manipal Academy of Higher Education, Manipal, India
- ²⁴⁴Department of Pharmacology and Therapeutics, Dhaka Medical College, Dhaka, Bangladesh
- ²⁴⁵Department of Pharmacology, Bangladesh Industrial Gases Limited, Tangail, Bangladesh
- ²⁴⁶Department of Computer Engineering, Islamic Azad University, Tehran, Iran
- ²⁴⁷Computer Science Department, University of Human Development, Sulaymaniyah, Iraq
- ²⁴⁸Department of Legal Medicine and Bioethics, Carol Davila University of Medicine and Pharmacy, Bucharest, Romania
- ²⁴⁹Clinical Legal Medicine Department, National Institute of Legal Medicine Mina Minovici, Bucharest, Romania
- ²⁵⁰Department of Epidemiology and Health Statistics, Central South University, Changsha, China
- ²⁵¹Department of Health Promotion and Education, University of Ibadan, Ibadan, Nigeria
- ²⁵²Department of Community Medicine, University of Ibadan, Ibadan, Nigeria
- ²⁵³Department of Epidemiology, University of Kragujevac, Kragujevac, Serbia
- ²⁵⁴Department of Family Medicine, Bangalore Baptist Hospital, Bangalore, India
- ²⁵⁵Center for Health Resource and Services Research and Development, National Institute of Health Research & Development, Jakarta, Indonesia
- ²⁵⁶Research Institute for Endocrine Sciences, Shahid Beheshti University of Medical Sciences, Tehran, Iran
- ²⁵⁷Institute for Physical Activity and Nutrition, Deakin University, Burwood, VIC, Australia
- ²⁵⁸Sydney Medical School, University of Sydney, Sydney, NSW, Australia
- ²⁵⁹School of Psychology and Public Health, La Trobe University, Bundoora, Melbourne, VIC, Australia
- ²⁶⁰School of Public Health and Community Medicine, University of New South Wales, Sydney, Australia
- ²⁶¹Department of Global and Community Health, George Mason University, Fairfax, VA, USA
- ²⁶²Faculty of Medicine, Babol University of Medical Sciences, Babol, Iran
- ²⁶³School of Management and Medical Education, Shahid Beheshti University of Medical Sciences, Tehran, Iran
- ²⁶⁴Safety Promotion and Injury Prevention Research Center, Shahid Beheshti University of Medical Sciences, Tehran, Iran
- ²⁶⁵Department of Health Care and Public Health, I M Sechenov First Moscow State Medical University, Moscow, Russia
- ²⁶⁶Social Development & Health Promotion Research Center, Kermanshah University of Medical Sciences, Kermanshah, Iran
- ²⁶⁷Department of Surgery, Virginia Commonwealth University, Richmond, VA, USA
- ²⁶⁸Institute of Medicine, University of Colombo, Colombo, Sri Lanka
- ²⁶⁹Faculty of Graduate Studies, University of Colombo, Colombo, Sri Lanka
- ²⁷⁰Department of Community Medicine, Banaras Hindu University, Varanasi, India
- ²⁷¹Department of Ophthalmology, Heidelberg University, Mannheim, Germany
- ²⁷²Beijing Ophthalmology & Visual Science Key Laboratory, Beijing Tongren Hospital, Beijing, China
- ²⁷³Department of Community Medicine, Kasturba Medical College, Manipal Academy of Higher Education, Mangalore, India
- ²⁷⁴Department of Family Medicine and Public Health, University of Opole, Opole, Poland
- ²⁷⁵School of Health Sciences, Savitribai Phule Pune University, Pune, India
- ²⁷⁶Institute of Family Medicine and Public Health, University of Tartu, Tartu, Estonia
- ²⁷⁷Minimally Invasive Surgery Research Center, Iran University of Medical Sciences, Tehran, Iran
- ²⁷⁸Personal Social Services Research Unit, London School of Economics and Political Science, London, UK
- ²⁷⁹Department of Medical Informatics, Tabriz University of Medical Sciences, Tabriz, Iran
- ²⁸⁰Social Determinants of Health Research Center, Research Institute for Prevention of Non-Communicable Diseases, Qazvin University of Medical Sciences, Qazvin, Iran
- ²⁸¹Health Services Management Department, Qazvin University of Medical Sciences, Qazvin, Iran
- ²⁸²School of Public Health, Department of Health Informatics and Health Innovation, A C S Medical College and Hospital, Mekelle, Ethiopia
- ²⁸³Department of Forensic Medicine and Toxicology, All India Institute of Medical Sciences, Jodhpur, India
- ²⁸⁴Department of Epidemiology, Hamadan University of Medical Sciences, Hamadan, Iran
- ²⁸⁵Hematology-Oncology and Stem Cell Transplantation Research Center, Tehran University of Medical Sciences, Tehran, Iran
- ²⁸⁶Pars Advanced and Minimally Invasive Medical Manners Research Center, Iran University of Medical Sciences, Tehran, Iran
- ²⁸⁷Department of Applied Physics, The John Paul II Catholic University of Lublin, Lublin Voivodeship, Poland
- ²⁸⁸Department of Biology and Chemistry, Drohobych Ivan Franko State Pedagogical University, Drohobych, Ukraine
- ²⁸⁹Department of Pharmacy, Jimma University, Jimma, Ethiopia
- ²⁹⁰Open, Distance and eLearning Campus, University of Nairobi, Nairobi, Kenya
- ²⁹¹Department of Dermatology, Wolaita Sodo University, Wolaita Sodo, Ethiopia
- ²⁹²Department of Midwifery, University of Gondar, Gondar, Ethiopia
- ²⁹³Department of Public Health, Jordan University of Science and Technology, Irbid, Jordan
- ²⁹⁴Social Determinants of Health Research Center, Ahvaz Jundishapur University of Medical Sciences, Ahvaz, Iran
- ²⁹⁵School of Food and Agricultural Sciences, University of Management and Technology, Lahore, Pakistan
- ²⁹⁶Department of Global Health, University of Washington, Seattle, WA, USA
- ²⁹⁷Department of Physiology, Baku State University, Baku, Azerbaijan
- ²⁹⁸Health Care Management, Zahedan University of Medical Sciences, zahedan, Iran
- ²⁹⁹Epidemiology and Biostatistics Department, Health Services Academy, Islamabad, Pakistan
- ³⁰⁰Faculty of Public Health and Tropical Medicine, Jazan University, Jazan, Saudi Arabia
- ³⁰¹Department of Health Research, Indian Council of Medical Research, New Delhi, India
- ³⁰²Centre for Ethics, Jawahar Lal Nehru University, New Delhi, India
- ³⁰³Department of Psychiatry, Kermanshah University of Medical Sciences, Kermanshah, Iran
- ³⁰⁴Department of Epidemiology, Kermanshah University of Medical Sciences, Kermanshah, Iran
- ³⁰⁵Nuffield Department of Surgical Sciences, Oxford University Global Surgery Group, University of Oxford, Oxford, UK
- ³⁰⁶Research and Data Solutions, Synotech Consultant, Nairobi, Kenya
- ³⁰⁷Department of Preventive Medicine, Korea University, Seoul, South Korea
- ³⁰⁸Department of Health Sciences, Northeastern University, Boston, MA, USA
- ³⁰⁹School of Medicine, Xiamen University Malaysia, Sepang, Malaysia
- ³¹⁰School of Health Sciences, Kristiania University College, Oslo, Norway
- ³¹¹Department of Nursing and Health Promotion, Oslo Metropolitan University, Oslo, Norway
- ³¹²Neurophysiology Research Center, Hamadan University of Medical Sciences, Hamadan, Iran
- ³¹³Brain Engineering Research Center, Institute for Research in Fundamental Sciences, Tehran, Iran
- ³¹⁴Department of Public Health Dentistry, Deemed University, Karad, India
- ³¹⁵CIBERSAM, San Juan de Dios Sanitary Park, Sant Boi de Llobregat, Spain
- ³¹⁶Catalan Institution for Research and Advanced Studies (ICREA), Barcelona, Spain
- ³¹⁷Department of Zoology, University of Oxford, Oxford, UK
- ³¹⁸Harvard Medical School, Harvard University, Boston, MA, USA
- ³¹⁹Department of Anthropology, Panjab University, Chandigarh, India
- ³²⁰Department of Public Health, Yuksek Ihtisas University, Ankara, Turkey
- ³²¹Department of Public Health, Hacettepe University, Ankara, Turkey
- ³²²Department of Family and Community Health, University of Health and Allied Sciences, Ho, Ghana
- ³²³Department of Psychology and Health Promotion, University of KwaZulu-Natal, Durban, South Africa
- ³²⁴Department of Medicine, Brigham and Women's Hospital, Harvard University, Boston, MA, USA
- ³²⁵Public Health Foundation of India, Gurugram, India
- ³²⁶Department of Psychiatry, University of Nairobi, Nairobi, Kenya
- ³²⁷Institute of Occupational and Environmental Medicine, University of Birmingham, Birmingham, UK
- ³²⁸Mechanical and Industrial Engineering, Indian Institute of Technology, Roorkee, Roorkee, India
- ³²⁹Department of Medicine, McMaster University, Hamilton, ON, Canada
- ³³⁰Health and Nutrition Section, United Nations Children's Fund (UNICEF), Accra, Ghana
- ³³¹Department of Clinical Medicine and Community Health, University of Milan, Milano, Italy
- ³³²Department of Community and Family Medicine, University of Baghdad, Baghdad, Iraq
- ³³³School of Medicine, Deakin University, Geelong, VIC, Australia
- ³³⁴Health Promotion and Chronic Disease Prevention Branch, Public Health Agency of Canada, Ottawa, ON, Canada
- ³³⁵HelpMeSee, New York, NY, USA
- ³³⁶International Relations, Mexican Institute of Ophthalmology, Queretaro, Mexico
- ³³⁷Disease Control Department, Ghana Health Service, Accra, Ghana

- ³³⁸Department of Otorhinolaryngology (ENT), Father Muller Medical College, Mangalore, India
- ³³⁹Department of Public Health, Maragheh University of Medical Sciences, Maragheh, Iran
- ³⁴⁰Institute of Clinical Physiology, Italian National Research Council, Pisa, Italy
- ³⁴¹College of Optometry, Nova Southeastern University, Fort Lauderdale, FL, USA
- ³⁴²School of Pharmacy, Monash University, Bandar Sunway, Malaysia
- ³⁴³School of Pharmacy, Taylor's University Lakeside Campus, Subang Jaya, Malaysia
- ³⁴⁴School of Public Health, Wolaïta Sodo University, Wolaïta Sodo, Ethiopia
- ³⁴⁵Department of Health Sciences, University of Florence, Florence, Italy
- ³⁴⁶School of Public Health, University of Haifa, Haifa, Israel
- ³⁴⁷Department of Systems, Populations and Leadership, University of Michigan, Ann Arbor, MI, USA
- ³⁴⁸School of Population and Global Health, University of Melbourne, Melbourne, VIC, Australia
- ³⁴⁹Department of Health Metrics Sciences, School of Medicine, University of Washington, Seattle, WA, USA
- ³⁵⁰Department of Medicine, University of São Paulo, Sao Paulo, Brazil
- ³⁵¹Department of General Surgery, Aintree University Hospital National Health Service (NHS) Foundation Trust, Liverpool, UK
- ³⁵²Department of Surgery, University of Liverpool, Liverpool, UK
- ³⁵³Health Data Research UK, Swansea University, Swansea, UK
- ³⁵⁴College of Medicine, Pathology Department, Imam Abdulrahman Bin Faisal University, Dammam, Saudi Arabia
- ³⁵⁵Ophthalmology Department, Aswan Faculty of Medicine, Aswan, Egypt
- ³⁵⁶Institute of Medicine, Tribhuvan University, Kathmandu, Nepal
- ³⁵⁷Department of Public Health, Trnava University, Trnava, Slovakia
- ³⁵⁸Department of Primary Care and Public Health, Imperial College London, London, UK
- ³⁵⁹Public Health Research Department, National Health Institute Colombia, Bogota, Colombia
- ³⁶⁰Faculty of Medicine, El Bosque University, Bogota, Colombia
- ³⁶¹Health Education and Research Department, SDM College of Medical Sciences & Hospital, Dharwad, India
- ³⁶²Rajiv Gandhi University of Health Sciences, Bangalore, India
- ³⁶³Digestive Diseases Research Institute, Tehran University of Medical Sciences, Tehran, Iran
- ³⁶⁴Non-communicable Diseases Research Center, Shiraz University of Medical Sciences, Shiraz, Iran
- ³⁶⁵Department of Maternal and Child Nursing and Public Health, Federal University of Minas Gerais, Belo Horizonte, Brazil
- ³⁶⁶Department of Ophthalmology, Iran University of Medical Sciences, Tehran, Iran
- ³⁶⁷Ophthalmology Department, University of Manitoba, Winnipeg, MB, Canada
- ³⁶⁸Department of Surgery, University of Virginia, Charlottesville, VA, USA
- ³⁶⁹Surgery Department, Emergency University Hospital Bucharest, Bucharest, Romania
- ³⁷⁰Department of Psychiatry, National Institute of Mental Health and Neurosciences, Bengaluru, India
- ³⁷¹Substance Abuse Prevention Research Center, Kermanshah University of Medical Sciences, Kermanshah, Iran
- ³⁷²Department of Epidemiology and Biostatistics, Tehran University of Medical Sciences, Tehran, Iran
- ³⁷³Institute for Social Science Research, The University of Queensland, Brisbane, QLD, Australia
- ³⁷⁴Institute of Bone and Joint Research, University of Sydney, St Leonards, NSW, Australia
- ³⁷⁵Department of Health Sciences, University of York, York, UK
- ³⁷⁶Department of Midwifery-Reproductive Health, Hamadan University of Medical Sciences, Hamadan, Iran
- ³⁷⁷Research Department, The George Institute for Global Health, New Delhi, India
- ³⁷⁸School of Medicine, University of New South Wales, Sydney, NSW, Australia
- ³⁷⁹Department of Public Health, Mekelle University, Mekelle, Ethiopia
- ³⁸⁰Department of Nursing, Arba Minch University, Arba Minch, Ethiopia
- ³⁸¹Division of Epidemiology and Prevention, Institute of Human Virology, University of Maryland, Baltimore, MD, USA
- ³⁸²Peru Country Office, United Nations Population Fund (UNFPA), Lima, Peru
- ³⁸³Forensic Medicine Division, Imam Abdulrahman Bin Faisal University, Dammam, Saudi Arabia
- ³⁸⁴College of Health Science, Department of Midwifery, Adigrat University, Adigrat, Ethiopia
- ³⁸⁵Department of Epidemiology and Biostatistics, Haramaya University, Harar, Ethiopia
- ³⁸⁶Breast Surgery Unit, Helsinki University Hospital, Helsinki, Finland
- ³⁸⁷University of Helsinki, Helsinki, Finland
- ³⁸⁸Neurocenter, Helsinki University Hospital, Helsinki, Finland
- ³⁸⁹School of Health Sciences, University of Melbourne, Parkville, VIC, Australia
- ³⁹⁰Clinical Microbiology and Parasitology Unit, ZoraProfociz Polyclinic, Zagreb, Croatia
- ³⁹¹University Centre Varazdin, University North, Varazdin, Croatia
- ³⁹²Center for Innovation in Medical Education, Pomeranian Medical University, Szczecin, Poland
- ³⁹³Department of Propedeutics of Internal Diseases & Arterial Hypertension, Pomeranian Medical University, Szczecin, Poland
- ³⁹⁴Pacific Institute for Research & Evaluation, Calverton, MD, USA
- ³⁹⁵Achutha Menon Centre for Health Science Studies, Sree Chitra Tirunal Institute for Medical Sciences and Technology, Trivandrum, India
- ³⁹⁶Global Institute of Public Health (GIPH), Ananthapuri Hospitals and Research Centre, Trivandrum, India
- ³⁹⁷Department of Statistics and Econometrics, Bucharest University of Economic Studies, Bucharest, Romania
- ³⁹⁸President's Office, National Institute of Statistics Romania, Bucharest, Romania
- ³⁹⁹Faculty of Internal Medicine, Kyrgyz State Medical Academy, Bishkek, Kyrgyzstan
- ⁴⁰⁰Department of Atherosclerosis and Coronary Heart Disease, National Center of Cardiology and Internal Disease, Bishkek, Kyrgyzstan
- ⁴⁰¹Heidelberg Institute of Global Health (HIGH), Faculty of Medicine and University Hospital, Heidelberg University, Heidelberg, Germany
- ⁴⁰²Institute of Addiction Research (ISFF), Frankfurt University of Applied Sciences, Frankfurt, Germany
- ⁴⁰³Biotechnology Research Center, Tabriz University of Medical Sciences, Tabriz, Iran
- ⁴⁰⁴Molecular Medicine Research Center, Tabriz University of Medical Sciences, Tabriz, Iran
- ⁴⁰⁵Health Equity Research Center, Tehran University of Medical Sciences, Tehran, Iran
- ⁴⁰⁶Internal Medicine Department, King Saud University, Riyadh, Saudi Arabia
- ⁴⁰⁷Research Center, Salahaddin University, Erbil, Iraq
- ⁴⁰⁸Shik University, Erbil, Iraq
- ⁴⁰⁹Department of Information Technology, University of Human Development, Sulaymaniyah, Iraq
- ⁴¹⁰Department of Biostatistics, Hamadan University of Medical Sciences, Hamadan, Iran
- ⁴¹¹Department of Epidemiology and Biostatistics, Shahrekord University of Medical Sciences, Shahrekord, Iran
- ⁴¹²Department of Clinical Biochemistry, Faculty of Medicine, Gonabad University of Medical Sciences, Gonabad, Iran
- ⁴¹³Department of Nursing, Shahroud University of Medical Sciences, Shahroud, Iran
- ⁴¹⁴Health Systems and Policy Research Unit, Ahmadu Bello University, Zaria, Nigeria
- ⁴¹⁵Department of Public Health, Samara University, Samara, Ethiopia
- ⁴¹⁶Iran National Institute of Health Research, Tehran University of Medical Sciences, Tehran, Iran
- ⁴¹⁷Faculty of Life Sciences and Medicine, King's College London, London, UK
- ⁴¹⁸Clinical Epidemiology and Public Health Research Unit, Burlo Garofolo Institute for Maternal and Child Health, Trieste, Italy
- ⁴¹⁹Department of Public Health Medicine, University of KwaZulu-Natal, Durban, South Africa
- ⁴²⁰Health Sciences Research Center, Mazandaran University of Medical Sciences, Sari, Iran
- ⁴²¹Research Center for Environmental Determinants of Health, Kermanshah University of Medical Sciences, Kermanshah, Iran
- ⁴²²Social Determinants of Health Research Center, Kurdistan University of Medical Sciences, Sanandaj, Iran
- ⁴²³Department of Epidemiology and Biostatistics, Kurdistan University of Medical Sciences, Sanandaj, Iran
- ⁴²⁴Preventive Medicine and Public Health Research Center, Iran University of Medical Sciences, Tehran, Iran
- ⁴²⁵International Laboratory for Air Quality and Health, Queensland University of Technology, Brisbane, QLD, Australia
- ⁴²⁶Gorgas Memorial Institute for Health Studies, Panama City, Panama
- ⁴²⁷Department of Social Medicine, National Center for Child Health and Development, Setagaya, Japan
- ⁴²⁸Department of Epidemiology and Biostatistics, University of Gondar, Gondar, Ethiopia
- ⁴²⁹Department of Pediatrics, University of British Columbia, Vancouver, BC, Canada
- ⁴³⁰School of Medical Sciences, Science University of Malaysia, Kubang Kerian, Malaysia
- ⁴³¹Department of Pediatric Medicine, Nishtar Medical University, Multan, Pakistan
- ⁴³²Department of Pediatrics & Pediatric Pulmonology, Institute of Mother & Child Care, Multan, Pakistan
- ⁴³³Department of Obstetrics and Gynecology, Ain Shams University, Cairo, Egypt
- ⁴³⁴Knowledge Translation and Utilization, Egyptian Center for Evidence Based Medicine, Egypt
- ⁴³⁵Research and Analytics, Initiative for Financing Health and Human Development, Chennai, India
- ⁴³⁶Research and Analytics, Bioinsilico Technologies, Chennai, India
- ⁴³⁷Department of Epidemiology, University of Alabama at Birmingham, Birmingham, AL, USA
- ⁴³⁸Laboratory of Public Health Indicators Analysis and Health Digitalization, Moscow Institute of Physics and Technology, Dolgoprudny, Russia

- ⁴³⁹Experimental Surgery and Oncology Laboratory, Kursk State Medical University of the Ministry of Health of the Russian Federation, Kursk, Russia
- ⁴⁴⁰Department of Epidemiology & Biostatistics, Kermanshah University of Medical Sciences, Kermanshah, Iran
- ⁴⁴¹Suraj Eye Institute, Nagpur, India
- ⁴⁴²Hospital of the Federal University of Minas Gerais, Federal University of Minas Gerais, Belo Horizonte, Brazil
- ⁴⁴³Mental Health Research Center, Iran University of Medical Sciences, Tehran, Iran
- ⁴⁴⁴Department of Forensic Medicine and Toxicology, Manipal Academy of Higher Education, Manipal, India
- ⁴⁴⁵Cochrane Unit, South African Medical Research Council, Cape Town, South Africa
- ⁴⁴⁶Department of General Surgery, Carol Davila University of Medicine and Pharmacy, Bucharest, Romania
- ⁴⁴⁷Department of General Surgery, Emergency Hospital of Bucharest, Bucharest, Romania
- ⁴⁴⁸Department of Biological Sciences, University of Embu, Embu, Kenya
- ⁴⁴⁹Institute for Global Health Innovations, Duy Tan University, Hanoi, Vietnam
- ⁴⁵⁰Department of Pharmacology, Shahid Beheshti University of Medical Sciences, Tehran, Iran
- ⁴⁵¹Heidelberg University Hospital, Heidelberg, Germany
- ⁴⁵²Public Health Department, Universitas Negeri Semarang, Kota Semarang, Indonesia
- ⁴⁵³Graduate Institute of Biomedical Informatics, Taipei Medical University, Taipei City, Taiwan
- ⁴⁵⁴School of Public Health and Family Medicine, University of Cape Town, Cape Town, South Africa
- ⁴⁵⁵Faculty of Medicine & Health Sciences, Stellenbosch University, Cape Town, South Africa
- ⁴⁵⁶Reproductive Health Sciences, Department Obstetrics and Gynecology, University of Ibadan, Ibadan, Nigeria
- ⁴⁵⁷Department of Preventive Medicine, Kyung Hee University, Dongdaemun-gu, South Korea
- ⁴⁵⁸Disease Surveillance and Epidemic Response, Ministry of Health, Nairobi, Kenya
- ⁴⁵⁹Department of Psychiatry and Behavioural Neurosciences, McMaster University, Hamilton, ON, Canada
- ⁴⁶⁰Department of Psychiatry, University of Lagos, Lagos, Nigeria
- ⁴⁶¹Department of Pathology and Molecular Medicine, McMaster University, Hamilton, ON, Canada
- ⁴⁶²Diplomacy and Public Relations Department, University of Human Development, Sulaimaniyah, Iraq
- ⁴⁶³Department of Pharmacology and Therapeutics, University of Nigeria Nsukka, Enugu, Nigeria
- ⁴⁶⁴Department of Psychology, University of Ghana, Accra, Ghana
- ⁴⁶⁵Discipline of Psychology, University of KwaZulu-Natal, Durban, South Africa
- ⁴⁶⁶Applied Research Division, Public Health Agency of Canada, Ottawa, ON, Canada
- ⁴⁶⁷School of Psychology, University of Ottawa, Ottawa, ON, Canada
- ⁴⁶⁸Department of Global Health Nursing, St Luke's International University, Chuo-ku, Japan
- ⁴⁶⁹Academic department, Unium Ltd, Moscow, Russia
- ⁴⁷⁰Department of Project Management, National Research University Higher School of Economics, Moscow, Russia
- ⁴⁷¹Department of Respiratory Medicine, Jagadguru Sri Shivarathreeswara Academy of Health Education and Research, Mysore, India
- ⁴⁷²Department of Forensic Medicine, Manipal Academy of Higher Education, Manipal, India
- ⁴⁷³Department of Medicine, Ottawa Hospital Research Institute, Ottawa, ON, Canada
- ⁴⁷⁴Parasitology and Mycology, Shiraz University of Medical Sciences, Shiraz, Iran
- ⁴⁷⁵Augenpraxis Jonas, Heidelberg University, Heidelberg, Germany
- ⁴⁷⁶Department of Medical Humanities and Social Medicine, Kosin University, Busan, South Korea
- ⁴⁷⁷Research and Evaluation, Population Council, New Delhi, India
- ⁴⁷⁸Indian Institute of Health Management Research University Delhi, Jaipur, India
- ⁴⁷⁹Department of Pediatrics, RD Gardi Medical College, Ujjain, India
- ⁴⁸⁰Regional Medical Research Centre, Indian Council of Medical Research, Bhubaneswar, India
- ⁴⁸¹Department of Paediatrics, University of Melbourne, Melbourne, VIC, Australia
- ⁴⁸²Population Health Theme, Murdoch Childrens Research Institute, Melbourne, VIC, Australia
- ⁴⁸³Department of Midwifery, Wolaita Sodo University, Wolaita Sodo, Ethiopia
- ⁴⁸⁴School of Public Health and Community Medicine, Faculty of Medicine, University of New South Wales, Sydney, NSW, Australia
- ⁴⁸⁵Center for Research and Innovation, Ateneo De Manila University, Pasig City, Philippines
- ⁴⁸⁶Department of Orthopedics, Yenepoya Medical College, Mangalore, India
- ⁴⁸⁷Shanghai Mental Health Center, Shanghai Jiao Tong University, Shanghai, China
- ⁴⁸⁸Department of Psychiatry, Department of Epidemiology, Columbia University, New York City, NY, USA
- ⁴⁸⁹Department of Chemistry, Faculty of Pharmacy, University of Porto, Porto, Portugal
- ⁴⁹⁰Department of Epidemiology and Evidence-Based Medicine, Sechenov University, Moscow, Russia
- ⁴⁹¹Department of Nephrology, Sanjay Gandhi Postgraduate Institute of Medical Sciences, Lucknow, India
- ⁴⁹²Health Sciences Department, Muhammadiyah University of Surakarta, Sukoharjo, Indonesia
- ⁴⁹³Department of Population Studies, International Institute for Population Sciences, Mumbai, India
- ⁴⁹⁴Biomedical Engineering Department, Amirkabir University of Technology, Tehran, Iran
- ⁴⁹⁵Department of Chemistry, Sharif University of Technology, Tehran, Iran
- ⁴⁹⁶College of Medicine, University of Central Florida, Orlando, FL, USA
- ⁴⁹⁷College of Graduate Health Sciences, A T Still University, Mesa, AZ, USA
- ⁴⁹⁸Department of Epidemiology & Biostatistics, Contech School of Public Health, Lahore, Pakistan
- ⁴⁹⁹Department of Medicine, University of Alberta, Edmonton, AB, Canada
- ⁵⁰⁰Department of Immunology, Mazandaran University of Medical Sciences, Sari, Iran
- ⁵⁰¹Molecular and Cell Biology Research Center, Mazandaran University of Medical Sciences, Sari, Iran
- ⁵⁰²Thalassemia and Hemoglobinopathy Research Center, Ahvaz Jundishapur University of Medical Sciences, Ahvaz, Iran
- ⁵⁰³Metabolomics and Genomics Research Center, Tehran University of Medical Sciences, Tehran, Iran
- ⁵⁰⁴Faculty of Medicine, Mazandaran University of Medical Sciences, Sari, Iran
- ⁵⁰⁵Sina Trauma and Surgery Research Center, Tehran University of Medical Sciences, Tehran, Iran
- ⁵⁰⁶School of Nursing and Healthcare Professions, Federation University Australia, Berwick, VIC, Australia
- ⁵⁰⁷School of Nursing and Midwifery, La Trobe University, Melbourne, VIC, Australia
- ⁵⁰⁸Faculty of Medicine, Birjand University of Medical Sciences, Birjand, Iran
- ⁵⁰⁹European Office for the Prevention and Control of Noncommunicable Diseases, World Health Organization (WHO), Moscow, Russia
- ⁵¹⁰Department of Surgery, University of Michigan, Ann Arbor, MI, USA
- ⁵¹¹Department of Oral Pathology, Srinivas Institute of Dental Sciences, Mangalore, India
- ⁵¹²School of Behavioral Sciences and Mental Health, Tehran Institute of Psychiatry, Tehran, Iran
- ⁵¹³Forensic Medicine, Manipal Academy of Higher Education, Mangalore, India
- ⁵¹⁴Kasturba Medical College, Manipal Academy of Higher Education, Mangalore, India
- ⁵¹⁵Academic Public Health Department, Public Health England, London, UK
- ⁵¹⁶School of Health, Medical and Applied Sciences, CQ University, Sydney, NSW, Australia
- ⁵¹⁷Department of Computer Science, Metropolitan College, Boston University, Boston, USA
- ⁵¹⁸Neurology Department, Sree Chitra Tirunal Institute for Medical Sciences and Technology, Thiruvananthapuram, India
- ⁵¹⁹School of Social Sciences and Psychology, Western Sydney University, Penrith, NSW, Australia
- ⁵²⁰Translational Health Research Institute, Western Sydney University, Penrith, NSW, Australia
- ⁵²¹Brien Holden Vision Institute, Sydney, NSW, Australia
- ⁵²²Organization for the Prevention of Blindness, Paris, France
- ⁵²³EPIUnit - Public Health Institute University Porto (ISPUP), University of Porto, Porto, Portugal
- ⁵²⁴Surgery Department, University of Minnesota, Minneapolis, MN, USA
- ⁵²⁵Surgery Department, University Teaching Hospital of Kigali, Kigali, Rwanda
- ⁵²⁶Research Directorate, Nihon Gakko University, Fernando de la Mora, Paraguay
- ⁵²⁷Research Direction, Universidad Nacional de Caaguazú, Coronel Oviedo, Paraguay
- ⁵²⁸Golestan Research Center of Gastroenterology and Hepatology, Golestan University of Medical Sciences, Gorgan, Iran
- ⁵²⁹Faculty of Medicine, Ain Shams University, Cairo, Egypt
- ⁵³⁰National Institute for Research in Environmental Health, Indian Council of Medical Research, Bhopal, India
- ⁵³¹Department of Epidemiology, Shahid Beheshti University of Medical Sciences, Tehran, Iran
- ⁵³²College of Medicine, University of Sharjah, Sharjah, United Arab Emirates
- ⁵³³Emergency Department, Shahid Beheshti University of Medical Sciences, Tehran, Iran
- ⁵³⁴Faculty of Public Health, Kermanshah University of Medical Sciences, Kermanshah, Iran
- ⁵³⁵Department of Health in Disasters and Emergencies, Shahid Beheshti University of Medical Sciences, Tehran, Iran
- ⁵³⁶Department of Neuroscience, Iran University of Medical Sciences, Tehran, Iran
- ⁵³⁷Nanobiotechnology Center, Soran University, Soran, Iraq
- ⁵³⁸Taleghani Hospital, Kermanshah University of Medical Sciences, Kermanshah, Iran
- ⁵³⁹Radiology and Nuclear Medicine Department, Kermanshah University of Medical Sciences, Kermanshah, Iran

- ⁵⁴⁰Research Deputy, Taleghani Hospital, Kermanshah, Iran
- ⁵⁴¹Public Health and Community Medicine Department, Cairo University, Giza, Egypt
- ⁵⁴²Department of Urology, Cairo University, Cairo, Egypt
- ⁵⁴³Public Health and Policy, London School of Hygiene & Tropical Medicine, London, UK
- ⁵⁴⁴Global Health Institute, American University of Beirut, Beirut, Lebanon
- ⁵⁴⁵Health and Disability Intelligence Group, Ministry of Health, Wellington, New Zealand
- ⁵⁴⁶Department of Entomology, Ain Shams University, Cairo, Egypt
- ⁵⁴⁷Department of Surgery, Marshall University, Huntington, WV, USA
- ⁵⁴⁸Department of Nutrition and Preventive Medicine, Case Western Reserve University, Cleveland, OH, USA
- ⁵⁴⁹Rheumatology Department, University Hospitals Bristol NHS Foundation Trust, Bristol, UK
- ⁵⁵⁰Institute of Bone and Joint Research, University of Sydney, Sydney, NSW, Australia
- ⁵⁵¹Institute of Social Medicine, University of Belgrade, Belgrade, Serbia
- ⁵⁵²Centre-School of Public Health and Health Management, University of Belgrade, Belgrade, Serbia
- ⁵⁵³Health Economics, Bangladesh Institute of Development Studies (BIDS), Dhaka, Bangladesh
- ⁵⁵⁴Colorectal Research Center, Iran University of Medical Sciences, Tehran, Iran
- ⁵⁵⁵Surgery Department, Hamad Medical Corporation, Doha, Qatar
- ⁵⁵⁶Faculty of Health & Social Sciences, Bournemouth University, Bournemouth, UK
- ⁵⁵⁷Department of Public Health Sciences, University of North Carolina at Charlotte, Charlotte, NC, USA
- ⁵⁵⁸Department of Paediatrics, University of Melbourne, Parkville, VIC, Australia
- ⁵⁵⁹Centre for Adolescent Health, Murdoch Childrens Research Institute, Parkville, VIC, Australia
- ⁵⁶⁰School of Public Health, Imperial College London, London, UK
- ⁵⁶¹Faculty member of Education Development Center, Ahvaz Jundishapur University of Medical Sciences, Ahvaz, Iran
- ⁵⁶²Department of Psychology, University of Alabama at Birmingham, Birmingham, AL, USA
- ⁵⁶³Department of Psychiatry, Stellenbosch University, Cape Town, South Africa
- ⁵⁶⁴Emergency Department, Manian Medical Centre, Erode, India
- ⁵⁶⁵Microbiology Service, National Institutes of Health, Bethesda, MD, USA
- ⁵⁶⁶Center for Biomedical Information Technology, Shenzhen Institutes of Advanced Technology, Chinese Academy of Sciences, Shenzhen, China
- ⁵⁶⁷Department of Health Promotion and Education, Alborz University of Medical Sciences, Karaj, Iran
- ⁵⁶⁸Health Policy Research Center, Shiraz University of Medical Sciences, Shiraz, Iran
- ⁵⁶⁹Independent Consultant, Karachi, Pakistan
- ⁵⁷⁰School of Medicine, Alborz University of Medical Sciences, Karaj, Iran
- ⁵⁷¹Chronic Diseases (Home Care) Research Center, Hamadan University of Medical Sciences, Hamadan, Iran
- ⁵⁷²HIV/STI Surveillance Research Center, and WHO Collaborating Center for HIV Surveillance, Institute for Futures Studies in Health, Kerman University of Medical Sciences, Kerman, Iran
- ⁵⁷³Centre for Medical Informatics, University of Edinburgh, Edinburgh, UK
- ⁵⁷⁴Division of General Internal Medicine, Harvard University, Boston, MA, USA
- ⁵⁷⁵National Institute of Infectious Diseases, Tokyo, Japan
- ⁵⁷⁶College of Medicine, Yonsei University, Seodaemun-gu, South Korea
- ⁵⁷⁷Division of Cardiology, Emory University, Atlanta, GA, USA
- ⁵⁷⁸Finnish Institute of Occupational Health, Helsinki, Finland
- ⁵⁷⁹Department of Health Education & Promotion, Kermanshah University of Medical Sciences, Kermanshah, Iran
- ⁵⁸⁰School of Health, University of Technology Sydney, Sydney, NSW, Australia
- ⁵⁸¹Department of Psychology, Reykjavik University, Reykjavik, Iceland
- ⁵⁸²Department of Health and Behavior Studies, Columbia University, New York, NY, USA
- ⁵⁸³Department of Forensic Medicine, Kathmandu University, Dhulikhel, Nepal
- ⁵⁸⁴Department of Medicine, University of Alabama at Birmingham, Birmingham, AL, USA
- ⁵⁸⁵Medicine Service, US Department of Veterans Affairs (VA), Birmingham, AL, USA
- ⁵⁸⁶Department of Epidemiology, School of Preventive Oncology, Patna, India
- ⁵⁸⁷Department of Epidemiology, Healis Sekhsaria Institute for Public Health, Mumbai, India
- ⁵⁸⁸2nd Department of Surgery-SUUB, Carol Davila University of Medicine and Pharmacy, Bucharest, Romania
- ⁵⁸⁹2nd Surgery Department, Bucharest Emergency Hospital, Bucharest, Romania
- ⁵⁹⁰Pain Management Research Institute (PMRI), Northern Clinical School, University of Sydney, St Leonards, NSW, Australia
- ⁵⁹¹Michael J Cousins Pain Management & Research Centre, Northern Sydney Local Health District, St Leonards, NSW, Australia
- ⁵⁹²Department of Medical Surgical Nursing, Urmia University of Medical Science, Urmia, Iran
- ⁵⁹³Emergency Nursing Department, Semnan University of Medical Sciences, Semnan, Iran
- ⁵⁹⁴Department of Biostatistics, Hamedan University of Medical Sciences, Hamadan, Iran
- ⁵⁹⁵Hospital Universitario de la Princesa, Autonomous University of Madrid, Madrid, Spain
- ⁵⁹⁶Centro de Investigación Biomédica en Red Enfermedades Respiratorias (CIBERES), Madrid, Spain
- ⁵⁹⁷Department of Public Health, Arba Minch University, Arba Minch, Ethiopia
- ⁵⁹⁸Hull York Medical School, University of Hull, Hull City, UK
- ⁵⁹⁹Usher Institute of Population Health Sciences and Informatics, University of Edinburgh, Edinburgh, UK
- ⁶⁰⁰Department of Psychiatry and Mental Health, University of Cape Town, Cape Town, South Africa
- ⁶⁰¹South African Medical Research Council, Cape Town, South Africa
- ⁶⁰²Department of Psychology, Deakin University, Burwood, VIC, Australia
- ⁶⁰³Department of Community Medicine, Ahmadu Bello University, Zaria, Nigeria
- ⁶⁰⁴Department of Agriculture and Food Systems, University of Melbourne, Melbourne, VIC, Australia
- ⁶⁰⁵Department of Criminology, Law and Society, University of California Irvine, Irvine, CA, USA
- ⁶⁰⁶Department of Medicine, University of Valencia, Valencia, Spain
- ⁶⁰⁷Carlos III Health Institute, Biomedical Research Networking Center for Mental Health Network (CiberSAM), Madrid, Spain
- ⁶⁰⁸School of Social Work, University of Illinois, Urbana, IL, USA
- ⁶⁰⁹Department of Public Health, Arba Minch College of Health Sciences, Arba Minch town sikela, Ethiopia
- ⁶¹⁰Axum College of Health Science, mekelle, Ethiopia
- ⁶¹¹School of Midwifery, University of Gondar, Gondar, Ethiopia
- ⁶¹²School of Public Health, University of Adelaide, Adelaide, SA, Australia
- ⁶¹³Department of Environmental Health, Wollo University, Dessie, Ethiopia
- ⁶¹⁴Department of Community and Family Medicine, Iran University of Medical Sciences, Tehran, Iran
- ⁶¹⁵Department of Pharmacognosy, Mekelle University, Mekelle, Ethiopia
- ⁶¹⁶Institute of Public Health, University of Gondar, Gondar, Ethiopia
- ⁶¹⁷Department of Public Health, Adigrat University, Adigrat, Ethiopia
- ⁶¹⁸Psychiatry Department, Hawassa University, Hawassa, Ethiopia
- ⁶¹⁹Institute of Public Health, Jagiellonian University Medical College, Krakow, Poland
- ⁶²⁰The Agency for Health Technology Assessment and Tariff System, Warszawa, Poland
- ⁶²¹Department of Health Economics, Hanoi Medical University, Hanoi, Vietnam
- ⁶²²Department of Molecular Medicine and Pathology, University of Auckland, Auckland, New Zealand
- ⁶²³Clinical Hematology and Toxicology, Military Medical University, Hanoi, Vietnam
- ⁶²⁴Department of Community Medicine, All India Institute of Medical Sciences, Nagpur, India
- ⁶²⁵Department of Psychiatry, Massachusetts General Hospital, Boston, MA, USA
- ⁶²⁶Mbarara University of Science and Technology, Mbarara, Uganda
- ⁶²⁷Lee Kong Chian School of Medicine, Nanyang Technological University, Singapore
- ⁶²⁸Institute of Soil and Environmental Sciences, A T Still University, Faisalabad, Pakistan
- ⁶²⁹Gomal Center of Biochemistry and Biotechnology, Gomal University, Dera Ismail Khan, Pakistan
- ⁶³⁰TB Culture Laboratory, Mufti Mehmood Memorial Teaching Hospital, Dera Ismail Khan, Pakistan
- ⁶³¹Research Department, National Institute of Population Studies (NIPS), Islamabad, Pakistan
- ⁶³²Amity Institute of Biotechnology, Amity University Rajasthan, Jaipur, India
- ⁶³³Division of Health Sciences, University of Warwick, Coventry, UK
- ⁶³⁴Argentine Society of Medicine, Buenos Aires, Argentina
- ⁶³⁵Velez Sarsfield Hospital, Buenos Aires, Argentina
- ⁶³⁶JKK Institute, Tampere, Finland
- ⁶³⁷Raffles Neuroscience Centre, Raffles Hospital, Singapore
- ⁶³⁸Yong Loo Lin School of Medicine, National University of Singapore, Singapore
- ⁶³⁹Department of Medical and Surgical Sciences, University of Bologna, Bologna, Italy
- ⁶⁴⁰Occupational Health Unit, Sant'Orsola Malpighi Hospital, Bologna, Italy
- ⁶⁴¹Department of Health Care Administration and Economics, National Research University Higher School of Economics, Moscow, Russia
- ⁶⁴²Foundation University Medical College, Foundation University, Islamabad, Pakistan
- ⁶⁴³Demographic Change and Ageing Research Area, Federal Institute for Population Research, Wiesbaden, Germany
- ⁶⁴⁴Center of Population and Health, Wiesbaden, Germany
- ⁶⁴⁵Department of Physical Therapy, Naresuan University, Meung District, Thailand
- ⁶⁴⁶Department of Human Anatomy, Histology, Embryology, Bahir Dar University, Bahir Dar, Ethiopia
- ⁶⁴⁷Department of Pharmacology and Toxicology, Mekelle University, Mekelle, Ethiopia
- ⁶⁴⁸Department of Pharmacology, Addis Ababa University, Addis ababa, Ethiopia
- ⁶⁴⁹Department of Nursing, Wollo University, Dessie, Ethiopia
- ⁶⁵⁰Department of Orthopaedics, Wenzhou Medical University, Wenzhou, China

⁶⁵¹Medical Physics Department, Ahvaz Jundishapur University of Medical Sciences, Ahvaz, Iran
⁶⁵²Department of Preventive Medicine, Northwestern University, Chicago, IL, USA
⁶⁵³School of International Development and Global Studies, University of Ottawa, OttawaON, Canada
⁶⁵⁴Health Services Management Research Center, Kerman University of Medical Sciences, Kerman, Iran
⁶⁵⁵Department of Health Management, Policy and Economics, Kerman University of Medical Sciences, Kerman, Iran
⁶⁵⁶Centre for Suicide Research and Prevention, University of Hong Kong, Hong Kong, China
⁶⁵⁷Department of Social Work and Social Administration, University of Hong Kong, Hong Kong, China
⁶⁵⁸School of Allied Health Sciences, Addis Ababa University, Addis Ababa, Ethiopia
⁶⁵⁹Department of Psychopharmacology, National Center of Neurology and Psychiatry, Tokyo, Japan
⁶⁶⁰Department of Sociology, Yonsei University, Seoul, South Korea
⁶⁶¹Department of Health Policy & Management, Jackson State University, Jackson, MS, USA
⁶⁶²School of Medicine, Tsinghua University, Beijing, China
⁶⁶³Department of Environmental Health, Mazandaran University of Medical Sciences, Sari, Iran
⁶⁶⁴Department of Environmental Health, Academy of Medical Science, Sari, Iran
⁶⁶⁵School of Public Health and Management, Hubei University of Medicine, Shiyan, China
⁶⁶⁶Department of Epidemiology and Biostatistics, Wuhan University, Wuhan, China
⁶⁶⁷Global Health Institute, Wuhan University, Wuhan, China
⁶⁶⁸Social Determinants of Health Research Center, Ardabil University of Medical Science, Ardabil, Iran
⁶⁶⁹Department of Epidemiology, University Hospital of Setif, Setif, Algeria
⁶⁷⁰Department of Medicine, School of Clinical Sciences at Monash Health, Monash University, Melbourne, VIC, Australia
⁶⁷¹Student Research Committee, Babol University of Medical Sciences, Babol, Iran
⁶⁷²Department of Community Medicine, Ardabil University of Medical Science, Ardabil, Iran
⁶⁷³Department of Environment Health Engineering, Gonabad University of Medical Sciences, Gonabad, Iran
⁶⁷⁴Faculty of Medical Sciences, Department of Health Education, Tarbiat Modares University, Tehran, Iran
⁶⁷⁵Department of Preventive Medicine, Wuhan University, Wuhan, China
⁶⁷⁶School of Public Health, Wuhan University of Science and Technology, Wuhan, China
⁶⁷⁷Hubei Province Key Laboratory of Occupational Hazard Identification and Control, Wuhan University of Science and Technology, Wuhan, China
⁶⁷⁸Indian Institute of Public Health, Public Health Foundation of India, Gurugram, India
⁶⁷⁹National Drug and Alcohol Research Centre, University of New South Wales, Sydney, NSW, Australia
⁶⁸⁰Department of Community Medicine, University of Peradeniya, Peradeniya, Sri Lanka
⁶⁸¹Faculty of Infectious and Tropical Diseases, London School of Hygiene & Tropical Medicine, London, UK

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Correction: *Global injury morbidity and mortality from 1990 to 2017: results from the Global Burden of Disease Study 2017*

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This article was previously published with errors in affiliations for authors Serge Resnikof and Aziz Rezapour. The updated affiliations are below

Serge Resnikoff^{521, 522}

⁵²¹Brien Holden Vision Institute, Sydney, NSW, Australia

⁵²²Organization for the Prevention of Blindness, Paris, France

Aziz Rezapour³⁰

³⁰Health Management and Economics Research Center, Iran University of Medical Sciences, Tehran, Iran



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