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SYSTEMATIC REVIEW OF SCIENTIFIC PUBLICATIONS ON DISEASE BURDEN DUE TO EARTHQUAKES

Gülay EKİNCİ[1], Özgül ÖZKOÇ[2], Aysun DANAYİYEN[3], Mustafa Hakan YILMAZTÜRK[4]

[1] Dr. Öğr. Üyesi, İstanbul Sabahattin Zaim University, Faculty of Health Sciences, Department of Health Management,34000, İstanbul/Türkiye, gulay.ekinci@izu.edu.tr.
(https://orcid.org/ 0000-0003-4773-4821)

[2] Dr. Öğr. Üyesi, Altınbaş University, Faculty of Health Sciences, Department of Health Management,34000, İstanbul/ Türkiye, ozgul.ozkoc@altinbas.edu.tr
(https://orcid.org/ 4349-0617-0002-0000),

[3] Dr. Öğr. Üyesi, İstanbul Sabahattin Zaim University, Faculty of Health Sciences, Department of Health Management,34000, İstanbul/Türkiye, aysun.danayiyeyen@izu.edu.tr,
(https://orcid.org/ 0000-0002-4782-5697)

[4] Yeni Yüzyıl University Faculty of Health Sciences/Health and Hygiene Manager Istanbul Metropolitan Municipality,34000, İstanbul/ Türkiye, hakan.yilmazturk@ibb.gov.tr,
(https://orcid.org/ 0000-0003-2976-1818)

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*Corresponding author

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Abstract

The purpose of this study is to analyse studies related to health impacts caused by earthquakes. This study is a retrospective study planned as a systematic review. The systematic review was conducted by examining three databases: Google Scholar, Web of Science, and Scopus. No date range was specified in the research, and the search was conducted using keywords related to earthquakes and health impacts. The PRISMA guidelines and SPSS-20 program were used to collect, analyse, interpret the research data, and present the findings.

In this study, Google Scholar was selected to access research articles written in Turkish, while the Web of Science and Scopus databases were targeted for research articles written in English. A total of 896 publications were identified during the data collection phase of the systematic review study. Based on the inclusion and exclusion criteria determined within the framework of content, title, abstract evaluation, and quality evaluation, 6 articles were selected for review.

The methodological quality assessments of the study were independently evaluated by two researchers using 12 questions. Each item was scored with '1 point' if fully met, and '0 points' if not. The highest score given to the articles was 12, and the lowest score was 10. Additionally, the reliability of the scorers was calculated using the 'goodness of fit value of 0.75 kappa value' in the SPSS-20 program. According to the result, the inter-rater reliability was interpreted as good.

As a result of the methodological evaluation, 6 publications were included in the study, indicating recent discussions in the literature regarding earthquakes and their health impacts.

The evaluation of the content of the articles revealed that studies on earthquakes and health impacts have recently emerged in the literature. It was determined that the publications examined within the scope of the research were made after 2010. Three of the six publications were made in 2015, 2016, and 2017, and the remaining three were made in 2018. Numerical methods were used in the evaluated publications. Considering the frequency of earthquakes and their regional situation, research on health impacts and disasters worldwide needs to be further developed.

Keywords: Earthquake, Year Lost Disability, Year Lost Life, Disease Burdens, Health Economics

1. Introduction

Disaster is defined as the outcome of natural, technological, or human-induced hazards that adversely affect normal life processes, causing a society or a segment thereof to suffer physical, economic, and social losses beyond its own capabilities to mitigate (Eryılmaz, 2007:10). Disasters are categorized into two types: natural and human-induced. Human-induced disasters include events like industrial accidents, nuclear incidents, terrorist attacks, and wars,

stemming from human interaction. Such disasters, often under human control, lead to substantial economic impacts. Santos (2006) assessed the September 11 attacks as one of the largest economic losses in recent times, estimating losses at approximately $108 billion. Park et al. (2014) indicated in their study that an attack resulting in the destruction of bridges over the Mississippi River or reaching Denver could lead to $17.8 billion in economic losses for the US economy. Anderson et al. (2007), in their examination of the economic effects of the 2003 Northeast Power Outage, noted that the outage, lasting only 3 days, cost the United States $6.5 billion, with $2 billion attributed to energy loss and $4.41 billion to absenteeism.

Natural disasters, on the other hand, are events caused by natural processes such as earthquakes, floods, storms, and hurricanes, resulting in physical, economic, and social losses to all living and non-living entities. Abbas Khan et al. (2019) studied the effects of natural disasters such as storms and floods on external migration, price levels, poverty rates, health expenditures, energy and environmental resources, water demand, financial development, and economic growth in Asian countries over the period 2005-2017. They found that natural disasters significantly increase external migration, price levels, and poverty rates, thereby negatively impacting economies by increasing health expenditures, energy demand, and reducing economic growth. Richardson et al. (2014) estimated the economic repercussions of the 2011 Joplin tornado, with total losses amounting to $6 billion in the first year, emphasizing that the business sector incurred the majority of this loss, totaling $4 billion. In 2018, 133.6 billion labor hours were lost due to extreme temperatures, marking a $45 billion increase compared to 2000 (WHO, 2021).

Among natural disasters, earthquakes are unpredictable, destructive events that occur suddenly, causing property damage, injuries, and mass fatalities (CRED, 2020). They lead to building collapses, people trapped under rubble, injuries, and fatalities. Furthermore, access to emergency healthcare services becomes challenging due to infrastructure deterioration (road closures, hospital damage, etc.). Moreover, deteriorated hygiene conditions such as water resource contamination and sewage system damage may increase the risk of spreading infectious diseases like cholera, typhoid, and diarrhea. Earthquakes also result in economic losses such as collapsed buildings, damaged infrastructure and businesses, halted economic activities, and job losses (Mavrouli et al., 2023).

In a study on the Wenchuan earthquake, it was determined that it caused significant losses in material, human, financial, and physical capital in the disaster areas, and its impact was widely felt. Findings from the study include: i) Earthquakes with different characteristics had varying effects on the population. Wealthy households had lower disaster mortality rates than average and poor households. Regarding different gender and age structures, women were more affected by disasters than men, and the elderly more than the young. ii) Regarding the impact of the earthquake on housing collapse, the proportion of collapsed houses was higher among poor households than average and wealthy households. Among houses needing repair, wealthy households had the highest proportion, while poor households had the smallest. iii) Post-disaster household incomes showed an increase among wealthy households but significant decreases among middle-income and poor households. While expenditures increased among wealthy households post-disaster, they tended to decrease among average and poor households. iv) The proportion of damaged cultivated land was higher for average and wealthy households compared to poor households. In terms of residential occupied agricultural land, poor and average households had larger areas than wealthy households (Jia et al., 2018).

MacKenzie et al. (2012) stated that the two-month production loss due to the 2011 earthquake and tsunami in Japan was $84 billion, with $17 billion in losses outside Japan during those two months. Rose and Liao (2005) estimated that an earthquake disabling the Portland Metropolitan Water System in Oregon could lead to regional production losses between $418 million and $516 million. Brookshire and McKee (1992) estimated that a hypothetical earthquake in the United States causing a 10% loss scenario would result in approximately $29 billion in direct losses and $16 billion in indirect losses nationwide. Zandian et al. (2016) evaluated the economic and human capital consequences of the earthquake in Iran's Tabas district, noting a reduced increase in years of schooling for those born 10 years after the earthquake compared to those born 10 years before, amounting to about a third of a school year less than in control areas. The Tabas earthquake negatively impacted educational time, literacy rates, and socio-economic status indices, resulting in reduced educational and economic progress post-earthquake.

The literature reports that there were 7,348 disasters worldwide in the last two decades, resulting in approximately 1.23 million deaths, affecting over 4 billion people, and causing $2.97 trillion in global losses (CRED, UNDRR, 2020). The United Nations stresses that the effects of disasters on households, communities, and countries—through death, disease, damaged or destroyed housing and infrastructure, and disruptions in agricultural production—are multi-dimensional. Measuring only deaths and economic losses may not fully reflect the true effects of disasters, as health problems or psychosocial effects post-disaster can have long-term impacts beyond economic losses. Hence, adopting a multidisciplinary approach to understand disaster effects and develop appropriate plans and policies can effectively manage disaster risks and enhance societal resilience (UNISDR, 2015).

While sociological and psychological effects of natural disasters, particularly earthquakes, on society and their relationship with GDP are frequently studied, research specifically examining the economic impacts of health impact remains limited in the literature (Demirchyan et al., 2022; Zandian et al., 2016; Fujimaki et al., 2023). When health impact are assessed from a health economics perspective, they are evaluated within the context of disease burden—measured as the number of healthy life years lost due to disease, disability, or premature death.

Within the scope of disease burdens, these losses are defined by indicators such as years of life lost due to premature death (YLL), years of life lost due to the development of disability (YLD), and disability-adjusted life years (DALY). Disease burdens can cause damage to the general economy by increasing health expenditures and negatively affecting the human capital structure. Moreover, the health and social supports to be provided for long-term care will also have long-term effects on the general economy. Therefore, health impact occurring in earthquakes and the socio-economic effects of these losses are considered as an important problem for countries.

The literature indicates that there are no studies that systematically evaluate temporal changes in health and long-term care expenditures in the pre- and post-disaster periods (Hasegawa et al. 2019). It is also stated that detailed studies evaluating health care and long-term care in case of a disaster have not been conducted in the literature (Ebner et al. 2016; Nomura et al. 2016; Ohira et al. 2017; Murakami et al. 2017). The number of studies relating disaster losses to health expenditures is also limited.

Hasegawa et al. (2019) analyzed the health status, care needs, access to healthcare, health expenditures, and long-term care expenditures among evacuees and non-evacuees in the region following the 2011 Fukushima disaster.

Fukushima Prefecture was categorized into four regions based on evacuation status: non-EOA (municipalities without evacuation orders), EOAs/non-EOAs, short-term EOAs (areas where evacuation orders were mostly lifted by fiscal year 2011), and long-term EOAs (areas where evacuation orders remained in effect through fiscal year 2015). Per capita health and long-term care expenditures in short-term and long-term EOAs were higher in fiscal year 2015 compared to average values from fiscal years 2008-2010. These spending increases were more pronounced in short-term and long-term EOAs than in non-EOAs and EOAs/non-EOAs. Increased spending on dental healthcare was associated with improved access to dental facilities. Additionally, evacuations contributed to higher health and long-term care expenditures, improving access to healthcare facilities regardless of aging.

Benali (2022) empirically analyzed the relationship between natural disasters, health expenditures, urban population, gross fixed capital formation, and GDP per capita for low-middle-income countries from 2000 to 2019. The research findings revealed a positive relationship between per capita GDP and health expenditures with urban population. It also showed a unidirectional link from natural disasters to GDP per capita and health expenditures in both short and long terms, and a reciprocal relationship between health expenditures and urban population in the short term. In the long term, there was a two-way relationship between GDP per capita and health expenditures.

Shahpari et al. (2020), in their study on the earthquake's impact on the Iranian economy, modeled the decrease in capital stock resulting from the earthquake and outlined its effects on GDP, the health sector, and household welfare. Simulation results indicated that household welfare decreased after the earthquake, and urban populations became more vulnerable. They also noted that the earthquake disproportionately affected the supply side of the health sector due to damage to healthcare facilities more than the demand side.

Getachew et al. (2023) evaluated the incidence and factors associated with catastrophic health expenditures among households in non-community-based health insurance areas of Ethiopia. The study found statistically significant associations with family size, average daily income, out-of-pocket payments, chronic diseases, and disaster-related health expenditures. To mitigate financial risks, it was suggested that the Federal Ministry of Health develop guidelines considering household income per capita to increase participation in community-based health insurance. The study also recommended that regional health bureaus increase their budget allocation by 10% to enhance coverage for low-income households.

Health economics research related to disasters, particularly on health expenditures, has begun to emerge in the literature. However, economic evaluations of health impact due to earthquakes in terms of YLL and YLD are crucial. This study aims to systematically review current academic research evaluating disease burdens as YLL-YLD resulting from earthquakes. Within this systematic review, four research questions were identified:

1- What is the current state of research on earthquakes and health impact in terms of YLL-YLD?

2- What methodologies have been utilized in studies on earthquakes and health impact as YLL-YLD?

3- What issues have been addressed in studies on earthquakes and health impact as YLL-YLD?

4- What are the findings of studies on earthquakes and health impact as YLL-YLD?

Methods

This study employed a systematic review methodology to examine health impact resulting from earthquakes as disaster situations. A systematic review involves comprehensively scanning all studies published in a specific field, using predefined inclusion and exclusion criteria, and evaluating study quality to address a particular question or problem, synthesizing findings from the included studies (Burns and Grove, 2007; Centre for Reviews and Dissemination [CRD], 2008; Higgins and Green, 2011). This research is retrospective in nature and was designed to be conducted as a systematic review.

Screening Process: The aim of this research was to evaluate publications concerning health-related losses caused by earthquakes. Deaths resulting from earthquakes were assessed in terms of "years of life lost due to premature death," while years lived with disabilities due to earthquakes were considered as "years of life lost due to disability.

The keywords “earthquake AND years of life lost due to premature death” and “earthquake AND years of life lost due to disability” were employed to conduct searches across the Web of Science, Scopus, and Google Scholar databases. Studies were selected based on a comprehensive evaluation of the pertinent literature identified through these keyword searches. The literature review was completed on March 13, 2024.

Research Inclusion Criteria: The study included articles focusing on health-related losses due to earthquakes in terms of YLL and YLD, without any date restrictions, and encompassed original qualitative or quantitative research.

Criteria for Exclusion in the Research: Excluded from the study were compilations, review articles, letters to the editor, opinion pieces, internet news articles, research reports, book reviews, editorials, conference papers, and oral or poster presentations presented at conferences.

Limitations: Limitations of this research included the evaluation of studies available only in English and Turkish, focusing on health impact due to earthquakes in terms of YLL and YLD, and the inclusion of data up to March 13, 2024, from three databases.

Evaluation of Methodological Quality: The methodological quality of the included publications was assessed independently by two evaluators using criteria proposed by Polit and Beck (2006). These criteria provided a comprehensive evaluation based on the research's purpose, sample characteristics, findings, discussion, and conclusion. Each article was scored independently, with '1 point' awarded for fully meeting each criterion and '0 point' otherwise. Articles scoring 8 or higher were included in the analysis.

Inter-Rater Reliability: Cohen's Kappa statistic was employed to assess the consistency of methodological evaluations between the independent evaluators. Cohen's Kappa values range from -1 to +1, where 0 indicates agreement expected by random chance and 1 indicates perfect agreement. Interpretation of kappa values follows Cohen's guidelines: ≤ 0 indicates no agreement, 0.01-0.20 indicates slight agreement, 0.21-0.40 indicates fair

agreement, 0.41-0.60 indicates moderate agreement, 0.61-0.80 indicates substantial agreement, and 0.81-1.00 indicates almost perfect agreement (McHugh, 2012).

2. Results

This research utilized the PRISMA research flow chart, commonly employed in systematic reviews in the literature. The process depicted in Figure 1 was followed, encompassing scanning, screening, selecting, and including articles in four distinct steps.

A total of 896 publications were identified through searches conducted in the designated databases for this research. Following the initial screening based on keywords, 882 publications were excluded, leaving 14 publications for further evaluation. Subsequently, after reviewing titles and abstracts, 3 publications were further excluded. The remaining 11 publications underwent full-text content evaluation. During this phase, 5 publications were excluded: 4 duplicates and 1 inaccessible full text. The remaining 6 publications proceeded to undergo quality assessment.

The methodological quality of the study was independently assessed by two researchers using a set of 12 questions. Each question received a score of '1' if fully met or '0' if not. The articles received scores ranging from 10 to 12. Since publications with a quality score of 8 or higher were included in the research, all articles evaluated had scores of 10 or above.

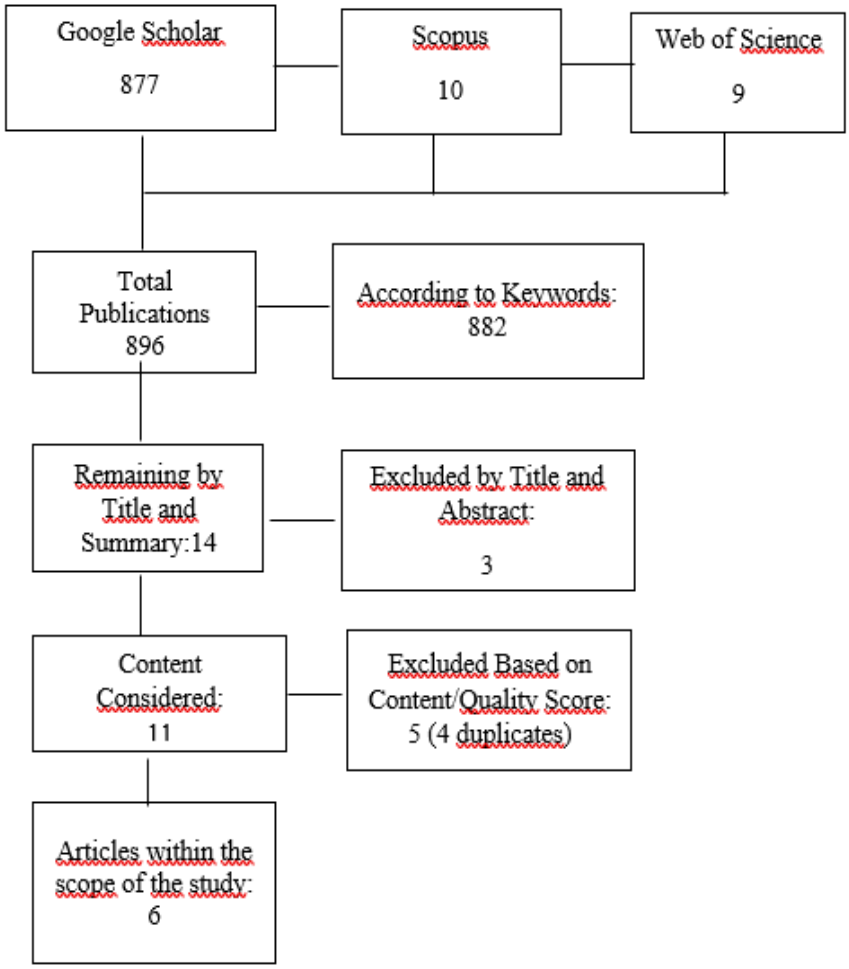

Figure 1: Research Flow Chart PRISMA (Moher at al., 2009).

Additionally, the inter-rater reliability was assessed using the goodness of fit value, specifically the kappa statistic, which yielded a value of 0.75 ($p = 0.07$). This indicates a significant and good level of agreement between the scorers. Subsequently, the remaining 6 publications were evaluated. Summary information regarding the included publications in the research is presented in Table 1.

Table 1: Imprint of Publications Included in the Research

Article Name	Year	Author	Aim	Methods	Results	Quality Score
Estimating the Lost Economic Production Caused by Internal Displacement Because of Disasters	2018	Mario A. Salgado-Ga'lvez	This article aims to determine the economic loss because of internal population displacement by using YLD and GDP in earthquakes.	Quantitative methods -The methodology is applied by using as a triggering event the April 2015 Gorkha, Nepal M7.8 earthquake.	The indirect cost resulting from the displacement of the population within the country due to the earthquake was estimated to be between 400 and 850 million USD in terms of economic production loss.	11
Probabilistic estimation of annual lost economic production due to premature deaths because of earthquakes	2016	Mario A. Salgado-Galvez et al.	This article proposes a methodology to probabilistically estimate the annual cost to society of premature deaths due to earthquakes.	Quantitative methods -The methodology draws on results obtained through prospective and probabilistic seismic risk assessments from which expected deaths due to building collapse are obtained.	The study, conducted in Medell, Colombia's second largest city, found that the cost of productivity loss due to premature deaths due to the earthquake was of a similar magnitude to the direct physical losses in public and private building stock calculated in the previous possible seismic risk calculation	12
Predictors of decline in IADL functioning among older survivors following the Great East Japan Earthquake: A Prospective study	2017	Toru Tsuboya et al.	It aimed to associations between the type of disaster experience and change in instrumental activities of daily living among older adult survivors before-after a terrible disaster.	Quantitative methods -Changes in the current activity of daily living (IADL) of elderly and survivors (N = 3,547) before and after the earthquake and tsunami injuries were evaluated.	Complete house loss and disruption of access to internal medicine after a disaster were associated with significant adverse impacts on the decline in physical and cognitive functions 2.5 years after the disaster, while loss of family/friends was not.	10
Comparing thedirecthumanimpactofnaturaldisastersfortwocases İn 2011: The Christchurch earthquake and the Bangkok flood	2015	Ilan Noy	The standard method of measuring damages from the Christchurch (NewZealand) earthquakes and the Greater Bangkok (Thailand) floods	Quantitative methods -The life year index and health burden of diseases in two events (Christchurch earthquake and Bangkok flood) was used.	It was concluded that New Zealand lost 180 thousand years of life and Thailand lost 2644 thousand years of life. Losses per capita are similar; Both countries lost approximately 15 days per capita due to catastrophic events in 2011.	10
Time to include burden of surgical injuries after disasters in the Global Surgery agenda? An assessment of DALYs and averted burden by surgery after the 2008 Wenchuan earthquake	2018	Jose Manuel Rodriguez-Llanes et al.	It evaluated the determination of the burden of surgical injuries after the Wenchuan earthquake and the extent to which surgery could prevent this burden.	Quantitative methods -This analysis used data from patients treated for earthquake-related injuries at the People's Hospital of Deyang City (PHDC) between 12 and 31 May 2008 to calculated the DALYs according to injury types	It was estimated 10 397 DALYs as the earthquake surgical-injury burden produced in 1861 hospitalised patients treated in a single hospital (on average, 5.6 DALYs per patient). The study also assessed that 4379 DALYs, or 2.4 DALYs per patient were averted by surgery (42%). In economic terms, DALY losses amounted to US$36.1 million, from which US$15.2 million were averted by surgery.	11

Determination of the Burden of Spinal Cord Injury and Limb Amputation as a Result of the Bam Earthquake in 2004	2018	Daneshi et al.	This study aimed at investigating the burden of injuries, including spinal cord injuries and limb amputation, caused by the Bam earthquake.	Quantitative methods - Calculation of disease burden (as YLL-YLD-DALY) due to spinal cord injuries and limb losses	The disability-adjusted life years (DALYs) caused by the spinal cord injury were 15,435 years. YLL due to premature mortality was 13,134 and YLD was 2301 years and the number of DALY caused by limb amputation was equal to 2184, all of which were due to YLD.	11,5

3. Discussion and Conclusion

The economic impacts of earthquakes extend beyond immediate physical damage to encompass a broader spectrum of indirect costs such as labor, income, production losses, and subsequent expenses like reconstruction, relief efforts, long-term care, and support services (Karagöz, 2007).

The aim of this study was to estimate the morbidity and mortality burden attributable to earthquakes. Conducted using a systematic compilation method, the research revealed a limited number of studies focused on health impact due to earthquakes. A total of 896 publications were identified through comprehensive literature review using predefined keywords, and following scope, content, and methodological evaluations, only 6 publications were included in the study. The analysis of these articles indicated that discussions on earthquakes and health impact have emerged relatively recently in the literature. Specifically, all examined publications were published after 2010, with three appearing in 2015, 2016, and 2017, and the remaining three in 2018. Given the frequency and global occurrence of earthquakes, there is a clear need for further research on health impacts and disaster response strategies. The evaluated publications predominantly employed quantitative methods, underscoring the significant economic repercussions of earthquakes on public health.

Noy (2015) examined the deaths, injuries, number of affected individuals, and financial damages resulting from the Christchurch earthquakes in New Zealand and the Great Bangkok flood in Thailand. In both cases, data on the years of life lost (YLL) and health burden of diseases were utilized. The YLL due to the Christchurch earthquake were calculated as 9,593 years for fatalities, 158 years for morbidity, 48,600 years for those affected, and 112,470 years due to financial losses. For the Great Bangkok flood, the YLL were calculated as 39,282 years for fatalities, 10,003 years for morbidity, 1,026,000 years for those affected, and 1,569,065 years due to financial damages. Based on these calculations, it was estimated that New Zealand experienced 180 thousand annual YLL and Thailand 2.6 million annual YLL.

Salgado-Galvez (2016) proposed a probabilistic methodology to estimate the annual costs of premature deaths caused by earthquakes on society. The methodology relies on prospective and probabilistic seismic risk assessments to determine expected deaths resulting from building collapses. The study focused specifically on Medellin, Colombia's second-largest city, dividing it into 16 regions and categorizing earthquake-related deaths, YLL, and life expectancy at birth by age groups. YLL for the working-age population (15-64 years old) were multiplied by Medellin's per capita income to estimate earthquake-related losses, totaling 672 million USD.

Tsuboya et al. (2017) aimed to assess the associations between disaster experiences and changes in instrumental activities of daily living (IADL) among older adult survivors before and after a major disaster. Changes in IADL among elderly survivors (N = 3547) before and after the earthquake and tsunami were evaluated. Complete loss of housing and disruption of access to medical care post-disaster were significantly associated with declines in physical and cognitive functions 2.5 years after the disaster. However, loss of family or friends did not show such significant impacts.

Salgado-Ga´lvez (2018) aimed to determine the economic loss because of internal population displacement by using YLD and GDP in earthquakes. The methodology is applied by using as a triggering event the 2015 Gorkha, Nepal M 7.8 earthquake. The indirect cost resulting from the displacement of the population within the country due to the earthquake was estimated to be between 400 and 850 million USD in terms of economic production loss.

Rodriguez-Llanes et al. (2018) analyzed the relationship between DALYs and surgical procedures for injuries sustained in the Wenchuan earthquakes. The analyzes used information on DALYs and surgical procedures for earthquake-related injuries, gender, and age. DALYs and DALYs prevented were calculated by injury type and per patient using disability weights and expert opinion available in the literature. They also suggested how DALYs could be further translated into economic measures using approaches from published literature. They estimated the earthquake surgical-injury burden on 1861 hospitalized patients treated in a single hospital to be 10,397 DALYs (average of 5.6 DALYs per patient). They also evaluated that 4379 DALYs, or 2.4 DALYs per patient, could be prevented by surgery (42%). In economic terms, DALY losses were calculated as 36.1 million US dollars, and 15.2 million US dollars of this amount could be effectively prevented by surgical procedures.

Daneshi et al. (2018) calculated the burden of injuries caused by the Bam earthquake, including spinal cord injuries and limb amputation, based on age and gender. Data on the morbidity of spinal cord injuries were obtained from records provided by the State Welfare Organization of Iran. Next, morbidity and mortality data for amputation and mortality for spinal cord injuries were obtained from previous studies using the network scaling method. Years of life lost (YLL) and years of life lost due to disability (YLD) were then calculated. YLL caused by spinal cord injury was calculated as 13134 years, YLD as 2301 years, and total disability-adjusted life years (DALYs) were calculated as 15,435 years. Death data due to limb amputation could not be evaluated, therefore the calculated YLD was 2184 years and DALY was accepted as 2184 years.

4. Recommendations

Earthquakes cause significant losses for countries in both the short and long terms. Apart from the immediate physical damage caused by building collapses, earthquakes severely impact a country's human capital structure through fatalities and injuries resulting from people being trapped under rubble. In this context, taking preventive measures against earthquakes and ensuring swift responses to damage can effectively mitigate potential losses.

This research evaluates health impact due to earthquakes and their impact on the human capital structure. It was found that six studies have been conducted in this field over the past decade. Health impact resulting from earthquakes lead to short-term increases in healthcare expenditures and contribute to long-term healthcare costs due to the development of permanent disabilities and illnesses. Moreover, the loss of productivity and economic growth negatively affects the economy by reducing contributions. Additionally, this situation imposes a long-term economic burden through increased social and support expenditures.

Conducting economic evaluations of these losses and quantifying them in terms of Years of Life Lost (YLL), Years Lived with Disability (YLD), Disability-Adjusted Life Years (DALYs), etc., will facilitate a thorough examination of the health impact and economic impacts of earthquakes. Therefore, conducting further research on health impact, not only specific to earthquakes but also encompassing all disaster situations, will enrich the existing literature.

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