Original Article

Understanding Drowning Fatalities in Odisha, India: A Data-Driven Approach

Saumyasree Pradhan[1], Barsharani Mohapatra[2], Rabindra Nath Hota[3], Shreerup Goswami[4], Amarendra Mohapatra[5]

[1]Ph.D in Public Health, Department of Public Health, Utkal University, Bhubaneswar, Odisha, India, Faculty in Department of Public Health, Orcid ID: 0000_0002_4289_4749, [2]MPH, Student in Master in Public health, in the Department of Public health Utkal University, Bhubaneswar, Odisha, India, [3]Adjunct Professor, Department of Geology, Fakir Mohan University, Vyasa Vihar, Balasore, Odisha, India, [4]Professor and Head, Department of Geology, Utkal University, Vani Vihar, Bhubaneswar, Odisha, India, [5]Ph.D in Anthropology, Retd. Scientist G, Regional Medical Research Centre(ICMR), Bhubaneswar Odisha, India.

How to cite this article: Saumyasree Pradhan, Barsharani Mohapatra, Rabindra Nath Hota et. al. Understanding Drowning Fatalities in Odisha, India: A Data-Driven Approach. Indian Journal of Public Health Research and Development / Vol. 16 No. 2, April-June 2025.

Abstract

Background: Death, morbidity, or mortality are the three possible consequences of drowning, which is defined as the process of experiencing respiratory impairment from submersion or immersion in liquid. Drowning is the third most common unintentional injury-related death cause worldwide, accounting for around 320,000 deaths annually, or 7% of all injury-related deaths. Children 1-4 years old have the highest rate of drowning, followed by those 5-9 years old. Males are particularly at risk, with a drowning mortality rate twice that of females.

Methods: Case information was extracted from secondary data collected from the Revenue & Disaster Management Department for the period from January 1, 2016, to December 30, 2022, in Odisha, with projections extended to 2044. Statistical analyses were conducted using SPSS between 2016 and 2023.

Conclusion: There were 7,721 identified drowning deaths in Odisha. Death rates due to drowning have risen each year. The number of deaths in 2017-18 nearly doubled compared to the previous year and then slowed until 2020-21, with an average annual increase of 172 deaths. In 2021-22, the number decreased to 1,209, before jumping to 1,738 in 2022-23. The findings highlight the urgent need for comprehensive public health interventions to address this critical issue. The results suggest a need for effective drowning prevention strategies.

Key words: Drowning, Burden of disease, Mortality, Disability adjusted life year

Introduction

Millions of lives are lost to drowning every year, making it a major global public health concern. Approximately 500,000 drowning deaths are reported each year, though actual numbers may be higher due to underreporting of many cases

Corresponding Author: Saumyasree Pradhan, Ph.D in Public Health, Department of Public Health, Utkal University, Bhubaneswar, Odisha, India.

E-mail: saumyasreep@gmail.com

Submission date: September 23, 2024 **Acceptance date**: October 24, 2024 **Published date: March 11, 2025**

[1]. In India, drowning accounts for a considerable proportion of unintentional injury and deaths, particularly in states with extensive river systems and coastal areas [2]. However, drowning may be made intentionally and might be a case of suicide. According to WHO estimates, there were 449,000 drowning deaths globally in 2000 (7.4 per 100,000 persons), with low- and middle-income countries accounting for 97.0 percent of these deaths [3]. 3,442,895 disability-adjusted life years (DALYs) were lost in India in 2016 as a result of both fatal and non-fatal drowning, according to data from the Global Burden of Disease (GBD) research. This represents 0.7% of the DALYs lost that year from all causes [4]. According to a nationally representative study, the ratio of male drowning deaths to female drowning deaths was 2:1[5]. A further study using the same data set discovered that males drowned at a rate of 97/100,000 compared to 69/100,000 for girls between the ages of 0 and 5 years[6]. Retrospective assessments of medical records revealed that men accounted for 85% and 78% of drowning deaths [7][8]. According to data from the national police, men were involved in 77% of fatal drowning occurrences.

Global drowning mortality is estimated to have declined by 44.5% between 1990 (531,956 deaths) and 2020 (295,210 deaths) [9], though the precision of health surveillance in capturing drowning mortality and morbidity is debated [10][11]. Studies using verbal autopsy in Bangladesh and India have highlighted a previously hidden burden among children in low- and middle-income countries, prompting increased interest from governments, multilateral organizations such as the World Health Organization (WHO) and United Nations Children's Fund (UNICEF), non-governmental organizations, and donors [12][13]. Significant advances include the development of a new drowning definition in 2005 (Van et al. 2005), followed by increased interest in the drowning burden in low- and middle-income countries, particularly in Asia, as evidenced in the WHO World Report on Child Injury Prevention [14].

By employing rigorous statistical techniques, including analysis of variance (ANOVA) and regression analyses, this research aims to identify significant trends and patterns in drowning fatalities. Furthermore, this study forecasts drowning deaths for the years 2023 to 2044 using a third-degree time-series model, providing crucial insights for policymakers and public health officials. Previous studies have highlighted the importance of temporal analysis in understanding drowning trends and implementing effective prevention strategies. For instance, Rahman et al. (2009) emphasized the need for region-specific drowning prevention measures based on local epidemiological data [15]. Similarly, a study by Franklin et al. (2010) demonstrated the effectiveness of predictive models in informing targeted interventions for drowning prevention [16]. In Odisha, various factors contribute to the high incidence of drowning, including geographical features, socio-economic conditions, and seasonal variations. The state's extensive network of rivers and proximity to the sea increase the risk of drowning, particularly during the monsoon season when water levels rise significantly [17]. Additionally, socio-economic factors such as limited access to swimming lessons and life-saving equipment further exacerbate the risk. This study employs a comprehensive statistical approach to analyze drowning data, incorporating both descriptive and inferential statistics. The analysis of variance (ANOVA) is used to determine the significance of trends in drowning cases across different years, while regression analyses provide insights into the relationship between time and drowning incidents. The goodness of fit of these models is evaluated to ensure the reliability of the predictions.

The findings of this research have important implications for public health planning and policy formulation in Odisha. By identifying high-risk districts and time periods, targeted interventions can be designed to reduce drowning fatalities. Furthermore, the predictive models developed in this study can aid in resource allocation and emergency preparedness, ultimately contributing to the prevention of drowning deaths in the state. By providing a detailed statistical analysis of drowning cases and projecting future trends, this study aims to contribute to the understanding and prevention of drowning fatalities in Odisha.

Material and Method

This study adopts a comprehensive statistical approach to analyze and forecast drowning fatalities in Odisha, India, from 2016 to 2022-23, with predictions extending to 2044. The methodology is divided into several key stages:

Data Collection

Data on drowning deaths were collected for all 30 districts of Odisha for the period 2016-2022 from various official sources, including the National Crime Records Bureau (NCRB) and state government reports[20]. The data were compiled into a comprehensive dataset for further analysis.

Descriptive Analysis

Initial descriptive statistics were calculated to understand the basic characteristics of the drowning data.

Trend analysis and regression models

To understand the temporal trends in drowning fatalities, various regression models were fitted to the data:

1. **First-Degree (Linear) Regression:** $y= \beta_0+ \beta_1 x$
2. **Second-Degree (Quadratic) Regression:** $y= \beta_0+ \beta_1 x+ \beta_2 x^2$
3. **Third-Degree (Cubic) Regression:** $y= \beta_0+ \beta_1 x+ \beta_2 x^2+ \beta_3 x^3$
4. **Fourth-Degree Regression:** $y= \beta_0+ \beta_1 x+ \beta_2 x^2+ \beta_3 x^3 + \beta_4 x^4$

The coefficients (β\betaβ) were estimated using the least squares method, and the goodness of fit for each model was evaluated using the coefficient of determination (R^2). Analysis of Variance (ANOVA) was performed to test the significance of the trend lines at each degree of regression and increase of the degree of the equation. The F-test was used to compare the explained variance by the model to the unexplained variance, determining the statistical significance of each model. Critical values for the F-test were obtained from statistical tables to evaluate the significance levels. Based on the regression analysis, the third-degree cubic model was selected as the best fit due to its higher goodness of fit (R^2) and statistical significance. This model was used to predict future drowning fatalities from 2023 to 2044. The prediction intervals were calculated to provide a range within which the actual future values are expected to fall. The statistical analyses were conducted using SPSS.

Result and Discussion

The number of drowning deaths in Odisha is steadily increasing from 2016 onwards (Table 1 and Fig.1) with a total number of 7738 deaths till 2023 with an annual average of 1103. Attempt has been made to analyze the death numbers statistically and to predict the numbers likely to occur in future. The figure in 2017-18 almost doubled that of the preceding year and then slowed down till 2020-21 with an average increasing rate of 172 per year till 2020-21. In 2021-22 the figure decreased to 1209 and then jumped to 1738 in the year 2022-23. First- to fourth-degree time series lines were fitted to the data set. The equations with their goodness of fit (R^2 in percent) are presented in Table 2. The increase of goodness of fit from first- to second-degree is nominal (1.33%), but increase from second- to third-degree is substantial (5.98%) followed by 1.64% increase in case of fourth-degree line. This suggests possible best fit of the third-degree line, for which analysis of variance was performed. The results are given in Table 3. In case of first-, second- and third-degree lines, the calculated values of F are greater than the corresponding critical values suggesting the statistical significance of these three lines. The increases of the degrees of lines, however, are not significant as the computed values are less than the critical values. The fourth-degree line, which has goodness of fit of 97.45% is also statistically insignificant. Thus, it is concluded that the third-degree time-series line ($y = 399.1 + 584.1x - 160.4x^2 + 16.47x^3$ (Fig.2) is the most befitting line, in which y is the number of drowning death and x is the year number from 2016-17, which is the starting point of computation (x = 0). Substituting the value of years, prediction has been made for drowning deaths till 2043-44 (Table 4). It is a matter of grave concern that drowning fatalities in Odisha are projected to exceed 200,000 by 2044 if no significant interventions are made. This alarming trend highlights the urgent need for comprehensive preventive measures, including public awareness, safety regulations, and targeted intervention strategies. Without immediate and effective action, the current trajectory could lead to a substantial rise in preventable deaths.

CAGR (Compound Annual Growth Rate) of drowning death is calculated from the data provided in the Table 4.

$$\mathbf{CAGR} = \left[\frac{EV}{BV}\right]^{\frac{1}{n}} - 1$$

Where EV (End Value) = the drowning death value in the final year (2043-44); BV (Beginning Value)= the drowning death value in the starting year (2023-24); n = number of years between the start and end year.

The drowning death rate in Odisha is projected to grow at a CAGR of 25.77% from 2023-24 to 2043-44, which represents a dramatic rise in fatalities over the next two decades. This exponential growth highlights a critical need for the local administration to be prepared for the upcoming surge in drowning-related emergencies. Given this trend, the current infrastructure, including rescue services, healthcare systems, and public safety measures, may be insufficient to manage the expected load. Urgent steps are required to bolster community-based drowning prevention programs, improve emergency response readiness, and allocate resources effectively. Authorities should also consider investing in predictive analytics to anticipate high-risk periods and locations, and implement strategic interventions to mitigate the rising fatality rates.

Table 1. Number of drowning death in Odisha from 2016 – 2023

Year	Drowning death	Year	Drowning death
2016 – 17	418	2020 – 21	1337
2017 – 18	820	2021 – 22	1209
2018 – 19	999	2022 – 23	1738
2019 – 20	1200	Average	1103

Table 2. Regression equations and goodness of fit of year verses drowning cases in Odisha

Degree of equation	Trend line equation	Goodness of fit (%)
First	$y = 559.1 + 181.2x\ (\pm 256.003)^{\S}$	88.50
Second	$y = 497.9 + 254.7x - 12.23x^2\ (\pm 240.778)^{\S}$	89.83
Third	$y = 399.1 + 584.1x - 160.4x^2 + 16.47x^3\ (\pm 154.524)^{\S}$	95.81
Fourth	$y = 434.2 + 239.1x + 142.6x^2 - 65.39x^3 + 6.822x^4\ (120.668)^{\S}$	97.45

§95% confidential intervals are given in brackets

Table 3. Completed analysis of variance (ANOVA) for significance of trend lines of drowning cases in Odisha

Source of Variation	Sum of squares	Degrees of freedom	Mean Squares	F-test result
First-degree regression (CSS_{R1})	919336.320	1	919336.320	$F_1 = 38.49$* ($F_{\upsilon1=1,\ \upsilon2=5,\ \alpha=0.05} = 6.61$)†
First-degree deviation (CSS_{D1})	119419.680	5	23883.936	
Second-degree regression (CSS_{R2})	933118.511	2	466559.256	$F_2 = 17.67$* ($F_{\upsilon1=2,\ \upsilon2=4,\ \alpha=0.05}=6.94$)†
Second-degree deviation (CSS_{D2})	105637.489	4	26409.372	
Added by second-degree (CSS_{R2-1})	13782.191	1	13782.191	$F_{2-1} = 0.52$ ($F_{\upsilon1=1,\ \upsilon2=4,\ \alpha=0.05}=7.71$)†
Third-degree regression (CSS_{R3})	995246.929	3	331748.976	$F_3 = 22.87$* ($F_{\upsilon1=3,\ \upsilon2=3,\ \alpha=0.05}=9.28$)†
Third-degree deviation (CSS_{D3})	43509.071	3	14503.024	
Added by third-degree (CSS_{R3-2})	62128.418	1	62128.418	$F_{3-2} = 4.28$ ($F_{\upsilon1=1,\ \upsilon2=3,\ \alpha=0.05}=10.13$)†
Fourth-degree regression (CSS_{R3})	1012224.524	4	253056.131	$F_4 = 19.08$ ($F_{\upsilon1=4,\ \upsilon2=2,\ \alpha=0.05}=19.25$)†
Fourth-degree deviation (CSS_{D4})	26531.476	2	13265.738	
Added by fourth-degree (CSS_{R4-3})	16977.595	1	16977.595	$F_{4-3} = 1.28$ ($F_{\upsilon1=1,\ \upsilon2=2,\ \alpha=0.05}=18.51$)†
Total variation (CSS_T)	1038756.000	6		

*Significant F value, †Critical values of F are given within brackets

Table 4. Prediction of drowning deaths on the basis of third-degree time-series line

Year	Drowning death	Year	Drowning death	Year	Drowning death
2023-24	2277	2030-31	22332	37-38	94457
24-25	3239	31-32	28657	38-39	110988
25-26	4670	32-33	36143	39-40	129372
26-27	6670	33-34	44890	40-41	149708
27-28	9337	34-35	54996	41-42	172095
28-29	12771	35-36	66560	42-43	196632
29-30	17069	36-37	79681	43-44	223417

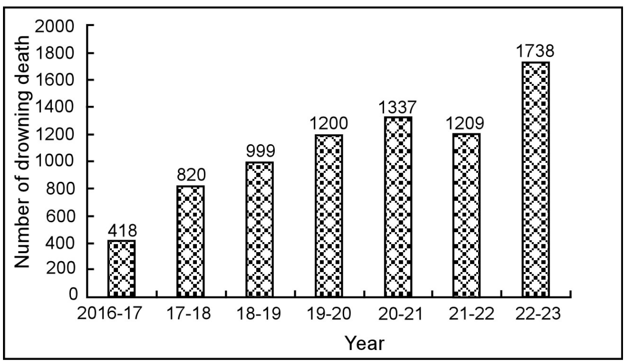

Figure 1. Third-degree trend line fitted to drowning deaths in Odisha

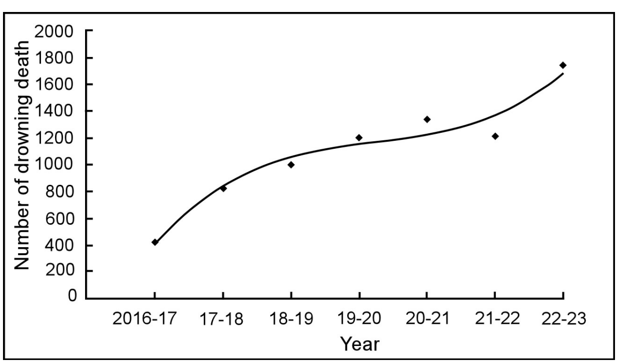

Figure 2. Third-degree trend line fitted to drowning deaths in Odisha

The analysis revealed that drowning deaths nearly doubled from 2016 to 2018, then slowed down till 2021 before a notable increase in 2022. These fluctuations could be attributed to several factors, including seasonal variations, socio-economic conditions, and possible changes in reporting accuracy. The marked increase in drowning deaths during 2022 could be related to extreme weather events or other environmental changes that warrant further investigation. The study shows a clear gender disparity in drowning fatalities, consistent with both national and international trends. In Australia, from 2002 to 2012, there were 303 drowning cases among boys and 165 among girls [9]. Similarly, in Mangalore, India from 1994 to 2005, there were 767 drowning cases among males and 217 among females [8]. This data highlights a male-to-female drowning mortality ratio of approximately 2:1 [6][8]. The higher mortality rate among males may be attributed to greater exposure to water-related activities and a propensity for risk-taking behaviors [6][9].

Both high- and low-income environments have different drowning risk variables. Participation in water-based recreational activities, like swimming, boating, and fishing, is linked to an increased risk of drowning among people in high-income countries (HICs) [16]. In contrast, in low-income countries (LMICs), children under five often drown in nearby natural bodies of water, despite not usually participating in recreational activities [17]. Risk factors for drowning in children in LMICs include lack of adult supervision, unsafe water access near homes, and limited swimming skills. Environmental factors such as open water bodies, floods, and inadequate barriers around water sources also increase the risk. No discernible gender variations in drowning rates were seen in the 5 to 9 age group, which is in contrast to other research conducted in LMIC rural situations [14][18]. The high incidence of drowning in Odisha is influenced by a combination of geographical, socio-economic, and seasonal factors [15]. Additionally, retrospective reviews and police data corroborate the predominance of male victims, underscoring the need for gender-specific prevention strategies [6][9]. The state's extensive network of rivers, lakes, and proximity to the Bay of Bengal increases the risk of drowning, particularly during the monsoon season when water levels rise significantly [20][21][22][23][24].

Socio-economic constraints, such as limited access to swimming lessons and life-saving equipment, further exacerbate the risk, especially for children and marginalized communities.

Conclusion

This study provides a comprehensive analysis of drowning fatalities in Odisha, India, over the period 2016-2023, with predictions extending to 2044. The key findings and implications of this research are as follows:

The number of drowning deaths in Odisha has shown a steady increase from 2016 onwards, with significant variations across different years. The application of various regression models revealed that the third-degree cubic model provides the best fit for the data, with a high coefficient of determination (95.81%). ANOVA results indicate that the first-, second-, and third-degree models are statistically significant, while the fourth-degree model, despite its higher goodness of fit (R^2), is not statistically significant. Predictions based on the third-degree model suggest a concerning upward trend in drowning fatalities, with the number of deaths likely to exceed 2,00,000 by 2044.

Implications for Public Health and Policy

The identification of high-risk districts and time periods can inform targeted interventions to prevent drowning deaths. The identification of high-risk districts and time periods can inform targeted interventions to prevent drowning deaths. Public health strategies should focus on improving water safety education, increasing access to life-saving equipment, and implementing community-based drowning prevention programs. Examples of evidence-based interventions include supervised daycare for children under five, swimming lessons with water survival skills, installation of barriers such as fencing around water bodies, and training in resuscitation techniques for community members. Additionally, providing life jackets and creating designated safe swimming zones have been shown to reduce drowning incidents. The predictive models developed in this study can aid in resource allocation and emergency preparedness, enabling authorities to take proactive measures to reduce drowning fatalities.

Future Research Directions

Further research is needed to explore the socio-economic and environmental factors contributing to the high incidence of drowning in Odisha. Longitudinal studies and real-time data collection can enhance the accuracy of future predictions and inform dynamic intervention strategies. Collaboration with local communities and stakeholders is essential to develop culturally appropriate and effective drowning prevention programs.

By providing a detailed statistical analysis and forecasting of drowning fatalities, this study aims to contribute to the understanding and prevention of drowning deaths in Odisha. The findings highlight the urgent need for comprehensive public health interventions to address this critical issue.

Financial Support and Sponsorship: No funding is available

Conflicts of Interest: The authors do not have conflict of interest

Ethical Approval: There is no human or animal subject involved in this study

References

1. Schilling UM, Bortolin M. Drowning. Minerva Anestesiol. Jan;78(1):69-77. Epub 2011 May 30. PMID: 21623341.
2. World Health Organization. (2014). Global report on drowning: Preventing a leading killer. World Health Organization.
3. Peden, M.M.; McGee, K. The epidemiology of drowning worldwide. Inj. Control Saf. Promot. 2003, 10, 195–199.
4. Lukaszyk C, Ivers RQ, Jagnoor J. Systematic review of drowning in India: assessment of burden and risk. Inj Prev. 2018 Dec;24(6):451-458.
5. Jagnoor J, Suraweera W, Keay L, et al. Unintentional injury mortality in India, 2005: nationally representative mortality survey of 1.1 million homes. BMC Public Health 2012; 12:1.
6. Jagnoor J, Bassani DG, Keay L, et al. Unintentional injury deaths among children younger than 5 years of age in India: a nationally representative study. Inj Prev 2011; 17:151–5.
7. Kanchan T, Rastogi P, Mohanty MK. Profile of near drowning victims in a coastal region of Karnataka. J Indian Acad Forensic Med 2007; 29:52–4.

8. Suresh Kumar Shetty B, Shetty M. Epidemiology of drowning in Mangalore, a coastal Taluk of South India. J Forensic Leg Med 2007; 14:410–5.

9. Franklin, R. C., Pearn, J. H., Peden, A. E., & Mahony, A. J. Drowning fatalities in childhood: The role of pre-existing medical conditions. Archives of Disease in Childhood 2010, 95(11), 869-873.

10. Lu, T.H.; Lunetta, P.; Walker, S. Quality of cause-of-death reporting using ICD-10 drowning codes: A descriptive study of 69 countries. BMC Med. Res. Methodol. 2010, 10.

11. Passmore, J.W.; Smith, J.O.; Clapperton, A. True burden of drowning: Compiling data to meet the new definition. Int. J. Inj. Control. Saf. Promot. 2007, 14, 1–3.

12. Baqui, A.H.; Black, R.E.; Arifeen, S.E.; Hill, K.; Mitra, S.N.; Al Sabir, A. Causes of childhood deaths in Bangladesh: Results of a nationwide verbal autopsy study. Bull. World Health Organ. 1998, 76, 161–171.

13. Van Beeck, E.F.; Branche, C.M.; Szpilman, D.; Modell, J.H.; Bierens, J.J.L.M. A new definition of drowning: Towards documentation and prevention of a global public health problem. Bull. World Health Organ. 2005, 83, 853–856.

14. Rahman, F., Bose, S., Linnan, M., Rahman, A., Mashreky, S. R., Haaland, B., & Rahman, F. Cost-effectiveness of an injury and drowning prevention program in Bangladesh. Pediatrics 2009, 124(4), e705-e713.

15. National Crime Records Bureau. (2022). Accidental deaths and suicides in India. Ministry of Home Affairs, Government of India.

16. Leavy JE, Crawford G, Portsmouth L, et al. Recreational drowning prevention interventions for adults, 1990–2012: a Review. J Community Health 2015; 40:725–35

17. Tyler MD, Richards DB, Riske-Nielsen C, et al. The epidemiology of drowning in lowand middle-income countries: a systematic review. BMC Public Health 2017; 17:413.

18. Dandona R, Kumar GA, George S, et al. Risk profile for drowning deaths in children in the Indian state of Bihar: results from a population-based study. Inj Prev 2019; 25:364–71.

19. Global Health Data Exchange. GBD Results Tool, 2017. http://ghdx.healthdata.org/gbd-results-tool (accessed 17 Feb 2017).

20. National Crime Records Bureau. Accidental deaths and suicides in India. New Delhi :Ministry of Home Affairs, 2015.

21. Franklin, R.C.; Peden, A.E.; Hamilton, E.B.; Bisignano, C.; Castle, C.D.; Dingels, Z.V.; Hay, S.I.; Liu, Z.; Mokdad, A.H.; Roberts, N.L.S.; et al. The burden of unintentional drowning: Global, regional and national estimates of mortality from the Global Burden of Disease 2017 Study. Inj. Prev..

22. Jagnoor, J.; Suraweera, W.; Keay, L.; Ivers, R.Q.; Thakur, J.S.; Jha, P. Unintentional injury mortality in India, Nationally representative mortality survey of 1.1 million homes. BMC Public Health 2012, 12.

23. World Health Organization. World Report on Child Injury Prevention; World Health Organization: Geneva, Switzerland, 2008

24. Rahman A, Alonge O, Bhuiyan A-A, et al. Epidemiology of drowning in Bangladesh: an update. Int J Environ Res Public Health 2017; 14:488.