BMC Medicine

RESEARCH

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Economic loss attributable to premature deaths and morbidity among adolescents in India and its states

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Abstract

Background India's large youth population presents a significant opportunity to harness the demographic dividend. The disease burden in adolescents could be a hindrance for the future economy if not appropriately addressed.

Methods We utilised the data on the number of adolescent deaths and attributable years lived with disability (morbidity) in every state of India as part of the Global Burden of Diseases, Injuries, and Risk Factors Study (GBD) 2021. We estimated the economic impact as the cost of lost output due to premature adolescent deaths and morbidity for every state of India in 2021, using an output-based method. The cost of lost output is reported in US Dollars (USD) and as a percentage of Gross Domestic Product (GDP) for all diseases/conditions together, and separately for communicable diseases (CDs), non-communicable diseases (NCDs), and injuries.

Results The lost output from premature deaths and morbidity attributable to adolescents was USD 9.87 (95% CI 9.04–10.71) and USD 28.13 (95% CI 20.53–37.71) billion respectively, in India in 2021. The total economic loss of USD 38.01 billion (95% CI 29.57–48.41) was 1.30% (1.01–1.65) of India's GDP. The total economic loss as a percentage of the state's GDP varied 3.42 times between the states in 2021, ranging from 2.43% in Bihar to 0.71% in Sikkim. The total economic loss due to CDs, NCDs, and injuries was estimated at 0.45%, 0.69% and 0.16% of India's GDP in 2021, with significant variations across the states.

Conclusions Strengthening the Indian Adolescent Health Strategy to address the diseases/ conditions contributing most to the total economic loss is needed to facilitate substantial avoidance of the high economic losses attributable to adolescent premature deaths and morbidity in India.

Keywords Adolescent, Disease burden, Death, Economic, Loss of output, Morbidity, India

Background

Adolescents (10–19 years) make up 16.4% of the world's population [1]. Adolescent health is increasingly receiving attention worldwide [2–9]. A recent World Health Organization (WHO) report has estimated the cost of inaction if improvements are not made in the health of adolescents at USD110 trillion between 2024 and 2050, amounting to 7.7% of the total GDP of the countries comprising around 80% of the world's population [10]. Though a case for investment to improve the well-being of adolescents is made across all five domains of adolescent well-being, the WHO report does not provide the

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cost of inaction at country-level, and costs are estimated for select areas including health (adolescent health services, HPV vaccination, tuberculosis prevention and treatment and treatment of myopia); education and training; child marriage; and road traffic injuries [10].

With adolescents estimated at 266.5 million, constituting about one-fifth of India's population in 2021 [1], the economic costs of premature deaths and illness among adolescents in India are likely to be significant. The India Adolescent Health Strategy (IAHS) was launched in 2014 and envisages that all adolescents in India are able to realise their full potential by making informed and responsible decisions related to their health and well-being and by accessing the services and support they need to do so [11, 12]. We have recently reported on the gaps in the IAHS thematic areas in comparison to the disease burden for fatal and non-fatal diseases and conditions among adolescents in India across injuries, communicable diseases (CDs), and non-communicable diseases (NCDs), which can pose substantial limitations for improving adolescent health in India [13]. Because investing in adolescents and their well-being strengthens the human capital of a country, and in turn a country's potential for further development and for creating more inclusive societies [10], we report on the economic loss attributable due to premature deaths and morbidity among adolescents in India and its states. The aim of this analysis is to provide an evidence base in terms of economic resources lost by CDs, NCDs, and injuries for policymakers, program planners, researchers, funders, and civil society organisations to invest in further improvements in adolescent wellbeing.

Methods

The analysis of the economic impact of adolescent-related premature deaths and morbidity for India and its states in 2021 was undertaken using data from the Global Burden of Diseases, Injuries and Risk Factors Study (GBD) 2021 accessed from the Institute of Health Metrics and Evaluation's Global Health Data Exchange [14]. We report the absolute number of deaths and years lived with disability (YLDs; morbidity) disaggregated by communicable diseases (CDs), non-communicable diseases (NCDs), and injuries for both sexes combined for India and its states in 2021 as a background to the economic cost calculations as estimated by the GBD study [14]. A comprehensive description of the GBD methods for estimating deaths, YLDs, statistical modelling for the cause of deaths and data sources used in GBD Study 2021 is reported elsewhere [15–17].

We used an output-based approach to estimate the economic cost of lost output from premature deaths and morbidity among adolescents in India and each state of India using the previously published method to estimate the economic cost of air pollution in India [18]. The output-based approach is used to estimate the indirect economic costs, which equates the economic cost of premature mortality to the present value of lost income and values morbidity by lost output [18–20]. The methods relevant for this paper are summarised. The economic cost of premature death was estimated as the present discounted value of output lost for a person in the age group 10–19 years who died in India in 2021 and the output lost when a person had morbidity during the adolescent age. Both of these require estimation of output per worker [18]. The output per worker in India in 2021 was calculated as the labour share of Gross Domestic Product (GDP) multiplied by the average GDP of 2020–2021 and 2021–2022 [21], divided by the number of people who were employed. The labour share of GDP for India for the year 2020–2021 was taken from the India-Capital, Labour, Energy, Materials and Services (KLEMS) 2023 database, which is published by the Reserve Bank of India [22]. This labour share of GDP available through KLEMS includes adjustments for labour force based on employment and earnings across five educational categories and 27 industry types, thereby capturing heterogeneity in the employment patterns [22]. It was assumed that labour's share of GDP was the same for all states and that it remained constant over time at its current value.

We assumed the workers of all ages to produce the same output per worker. Because not all people of a given age work, we adjusted the output per worker by the fraction of people in each age group who work, which is the worker-to-population ratio (WPR). We calculated WPR for each age group using individual-level data from the National Sample Survey Office-Periodic Labour Force Survey (NSSO-PLFS) 2021–2022 [23]. To predict the output in future years, output per worker was assumed to grow at the historical rate of growth of output per worker, estimated using data from the KLEMS 2023 database [22]. For people not working, the expected output per worker in each year was assumed to be equal to 53.1% of market output to allow for non-market production [24, 25]. The value of non-market output was calculated as the product of the average time spent on household unpaid activities, the average wage rate and the number of persons [26]. The estimates on average time spent on household activities per person per day were taken from the Time Use Survey Report 2019 [24], the average wage was calculated using estimates on earnings of the salaried, self-employed and casual labour available in the NSSO-PLFS 2018–2019 [25], and the estimated India population from GBD study 2021 [14].

To quantify the output losses in future years if a person of a given age between 10 and 19 years dies in the current year requires estimating the present discounted

value of their future output. An individual's output at each age is the product of output per worker and the probability that a person is working at each age, measured as the ratio of the working population to the total population at that age. This estimate of lost output must be adjusted to reflect the probability a person survives to each future age. The life table for India and the states was constructed using GBD 2021 data and survival probabilities were computed. Expected future output at each age was discounted to the present at a rate of interest of 6.5%, taken to be the yield on 10-year Indian Government bonds in December 2021 [27]. The total output lost due to premature deaths among adolescents was estimated as the present discounted value of lost market and non-market output for a person who dies in 2021 at each age between 10 and 19 years multiplied by the number of deaths among adolescents in 2021 for that age, with the result summed over all these ages. The present value of lost output per adolescent over the remainder of their working life is a conservative estimate of the loss in output that is a consequence of premature death. The details of economic loss estimation are described in Additional file 1: S1 [14, 21–23, 27, 28]. It was assumed that India and state-specific life tables remained constant over the period of the analysis.

The total economic losses in monetary terms (US Dollars) and as a percentage of GDP for adolescent deaths and morbidity (YLDs) irrespective of disease/condition and for CDs, NCDs, and injuries are reported for India and 30 geographical units in India in 2021. We also report on the distribution of economic loss due to major diseases/conditions under CDs, NCDs and injuries. A sensitivity analysis was undertaken on the overall economic loss by varying the discounting of the expected future output at each age to the present at a rate of interest ranging between 3% and 9%. For the estimation of economic loss, labour share of GDP, discount rate which is used to estimate the present value of future earnings, and the rate of growth in output per worker were assumed to be the same for all the states. We report all the estimates with 95% confidence intervals (CIs) where relevant. For the 95% CIs calculation for total economic loss estimates, CIs of disease burden measures from GBD 2021 were considered, which was based on 1000 runs of the models for each quantity of measures, with the mean regarded as the point estimate and the 2.5th and 97.5th percentiles considered as the 95% CIs.

The 30 geographical units include 28 states, the union territory of Delhi, and the union territories of Jammu & Kashmir and Ladakh (combined). The other small union territories (Andaman and Nicobar Islands, Chandigarh, Dadra and Nagar Haveli, Daman and Diu, Lakshadweep, and Puducherry), were excluded due to small numbers. The states were categorised as the Empowered Action Group (EAG: Bihar, Chhattisgarh, Jharkhand, Madhya Pradesh, Odisha, Rajasthan, Uttar Pradesh and Uttarakhand), north-east (NE) states, and the rest of the states were categorised as other states [29, 30]. The exchange rate for USD to Indian Rupees (INR) at the time of this analysis was 73.93 [31]. The accessed data from the Global Health Data Exchange and other sources were copied into MS Excel for this analysis. QGIS was used to plot economic burden estimates across the states of India.

Results

The number of adolescent deaths in India was 167,078 in 2021, and ranged from 51 in Sikkim to 41,286 in Uttar Pradesh at the state level (Additional file 2: Table S1). The adolescent burden of YLDs was 18,174,979 in India, 54.2% of it in EAG states, 4% in NE states, and 41.6% in the other states; these groups of states account for 48%, 3.8%, and 47.9% of the country's population, respectively. The CDs, NCDs and injuries accounted for 37.0%, 23.2% and 38.0% of total deaths, and 34.4%, 62.7%, and 2.9% of total YLDs in the adolescent age group in India in 2021.

The economic loss due to adolescent disease burden was estimated at USD 38.01 billion (95% CI 29.57–48.41) in India in 2021, including USD 9.87 (95% CI 9.04–10.71) billion due to deaths and USD 28.14 (95% CI 20.53–37.71) billion due to morbidity, as shown in Table 1. Extrapolating the total economic loss in terms of GDP, the total loss was estimated at 1.30% (95% CI 1.01–1.65) of India's GDP in 2021 (Table 2). This included an economic loss from premature deaths at 0.34% (95% CI 0.31–0.37) and from morbidity at 0.96% (95% CI 0.70–1.29) of India's GDP in 2021 (Table 2). A sensitivity analysis showed that, with a discount rate ranging between 3% and 9%, the estimated total economic loss for India would range between USD 51.22 (95% CI 41.68–62.75) billion and USD 34.46 (95% CI 26.32–44.56) billion accounting for 1.75% (95% CI 1.42–2.14) and 1.18% (95% CI 0.90–1.52) of India's GDP, respectively (Additional file 1: Fig. S1 and Fig. S2). The total economic loss due to adolescent disease burden in the EAG states ranged from USD 4.40 billion in Uttar Pradesh to USD 462 million in Uttarakhand; in the NE states ranged from USD 755 million in Assam to USD 34 million in Sikkim, and in the other states ranged from USD 3.78 billion in Maharashtra to USD 93 million in Goa. The total economic loss as a percentage of the state's GDP varied 3.42 times between the states, with ten states (33.3%) having an economic loss of 1.30–1.49% of the state's GDP and three states (10%) of > 1.5% of state's GDP (Table 2; Fig. 1). The economic loss due to premature deaths among adolescents ranged from 0.12% of the state's GDP in Kerala to 0.58% in Bihar, with a 4.71-fold

Table 1 Economic loss due to adolescent deaths and morbidity in India and its states in 2021 in USD (million). YLDs is years lived with disability and EAG is Empowered Action Group

	Economic loss due to adolescent deaths and morbidity in USD (million) (95% confidence interval)		
	Due to deaths	Due to morbidity (YLDs)	Total
India	**9868 (9039–10,708)**	**28,139 (20,533–37,706)**	**38,006 (29,572–48,413)**
EAG states			
Bihar	479 (422–543)	1520 (1090–2049)	1999 (1512–2591)
Chhattisgarh	209 (187–235)	420 (304–568)	628 (491–803)
Jharkhand	145 (131–160)	470 (342–629)	615 (473–789)
Madhya Pradesh	643 (569–715)	1265 (918–1718)	1907 (1487–2433)
Odisha	310 (276–343)	778 (559–1046)	1088 (835–1389)
Rajasthan	532 (475–590)	1540 (1115–2093)	2072 (1590–2683)
Uttar Pradesh	1257 (1123–1395)	3144 (2256–4235)	4401 (3379–5629)
Uttarakhand	130 (115–147)	332 (240–448)	462 (354–595)
North-east states			
Arunachal Pradesh	15 (12–17)	51 (37–68)	65 (49–85)
Assam	206 (184–226)	549 (398–740)	755 (582–967)
Manipur	16 (13–18)	51 (37–69)	67 (50–87)
Meghalaya	19 (16–22)	58 (41–79)	77 (58–101)
Mizoram	10 (9–12)	33 (24–44)	43 (32–56)
Nagaland	13 (11–16)	41 (30–55)	54 (41–71)
Sikkim	8 (6–9)	26 (19–35)	34 (25–44)
Tripura	19 (16–22)	57 (41–77)	76 (57–99)
Other states			
Andhra Pradesh	259 (217–308)	988 (715–1317)	1247 (932–1625)
Delhi	257 (232–283)	1130 (810–1549)	1388 (1042–1832)
Goa	15 (12–18)	78 (56–105)	93 (69–123)
Gujarat	658 (599–724)	2016 (1455–2702)	2674 (2054–3426)
Haryana	358 (321–396)	1121 (812–1492)	1479 (1133–1888)
Himachal Pradesh	36 (32–40)	127 (91–171)	163 (123–211)
Jammu & Kashmir and Ladakh	71 (63–79)	228 (165–306)	299 (228–385)
Karnataka	569 (503–641)	1860 (1346–2495)	2430 (1850–3135)
Kerala	142 (125–160)	726 (521–983)	868 (646–1143)
Maharashtra	810 (712–904)	2967 (2153–3968)	3777 (2865–4871)
Punjab	193 (172–217)	625 (456–832)	818 (628–1049)
Tamil Nadu	601 (522–672)	1696 (1230–2264)	2297 (1752–2936)
Telangana	310 (254–369)	958 (697–1285)	1268 (951–1654)
West Bengal	410 (365–456)	1371 (995–1849)	1781 (1361–2305)

difference between states, and that due to adolescent morbidity from 0.55% of the state's GDP in Sikkim to 1.85% in Bihar, with a 3.38-fold difference between the states (Table 2).

Of the total deaths among adolescents in 2021, the proportion of deaths due to CDs ranged from 22.7% in Kerala to 52.9% in Mizoram—a 2.3 times difference across the states, whereas the proportion of YLDs due to CDs ranged from 25.6% in Manipur to 37.7% in Bihar—a 1.75 times variation (Additional file 2: Table S1). The total economic loss due to CDs among adolescents was estimated at USD 13.25 (95% CI 10.10–17.17) billion in 2021 accounting for 0.45% (95% CI 0.34–0.59) of India's GDP (Table 3; Additional file 2: Table S2). This included an economic loss of USD 3.65 (3.18–4.18) billion due to deaths and USD 9.60 (95% CI 6.92–12.99) billion due to morbidity (YLDs) as shown in Additional file 2: Table S3. The economic loss due to CDs accounted for 35.2% of the total economic loss among adolescents in India, ranging from 25.5% to 38.9% across the states in 2021 (Fig. 2). The

Table 2 Economic loss due to adolescent deaths and morbidity as a percentage of Gross Domestic Product (GDP) in India and its states in 2021. YLDs is years lived with disability and EAG is Empowered Action Group

	GDP 2021–2022[a] (USD, in million)	GDP per capita 2021–122 (USD)	Economic loss due to adolescent deaths and morbidity as % of GDP 2021–2022 (95% confidence interval)		
			Due to deaths	Due to morbidity (YLDs)	Total
India	**2,928,355**	**2070**	**0.34 (0.31–0.37)**	**0.96 (0.70–1.29)**	**1.30 (1.01–1.65)**
EAG states					
Bihar	82,341	655	0.58 (0.51–0.66)	1.85 (1.32–2.49)	2.43 (1.84–3.15)
Chhattisgarh	51,003	1682	0.41 (0.37–0.46)	0.82 (0.60–1.11)	1.23 (0.96–1.57)
Jharkhand	44,332	1135	0.33 (0.30–0.36)	1.06 (0.77–1.42)	1.39 (1.07–1.78)
Madhya Pradesh	141,869	1573	0.45 (0.40–0.50)	0.89 (0.65–1.21)	1.34 (1.05–1.71)
Odisha	81,900	1733	0.38 (0.34–0.42)	0.95 (0.68–1.28)	1.33 (1.02–1.70)
Rajasthan	151,327	1845	0.35 (0.31–0.39)	1.02 (0.74–1.38)	1.37 (1.05–1.77)
Uttar Pradesh	244,803	977	0.51 (0.46–0.57)	1.28 (0.92–1.73)	1.80 (1.38–2.30)
Uttarakhand	34,424	2839	0.38 (0.33–0.43)	0.97 (0.70–1.30)	1.34 (1.03–1.73)
North-east states					
Arunachal Pradesh	4441	2552	0.33 (0.28–0.39)	1.14 (0.83–1.53)	1.47 (1.11–1.91)
Assam	51,818	1415	0.40 (0.35–0.44)	1.06 (0.77–1.43)	1.46 (1.12–1.87)
Manipur	4489	1222	0.35 (0.29–0.40)	1.14 (0.83–1.54)	1.49 (1.12–1.94)
Meghalaya	4907	1351	0.38 (0.33–0.44)	1.19 (0.85–1.61)	1.57 (1.17–2.06)
Mizoram	3500	2724	0.29 (0.24–0.34)	0.94 (0.67–1.27)	1.23 (0.92–1.61)
Nagaland	4176	2237	0.32 (0.27–0.37)	0.98 (0.71–1.32)	1.30 (0.98–1.69)
Sikkim	4773	6951	0.16 (0.14–0.19)	0.55 (0.40–0.73)	0.71 (0.53–0.92)
Tripura	7849	1897	0.24 (0.20–0.28)	0.73 (0.53–0.98)	0.97 (0.73–1.26)
Other states					
Andhra Pradesh	141,385	2605	0.18 (0.15–0.22)	0.70 (0.51–0.93)	0.88 (0.66–1.15)
Delhi	112,809	5786	0.23 (0.21–0.25)	1.00 (0.72–1.37)	1.23 (0.92–1.62)
Goa	10,706	6953	0.14 (0.12–0.17)	0.73 (0.52–0.98)	0.87 (0.64–1.15)
Gujarat	240,294	3410	0.27 (0.25–0.30)	0.84 (0.61–1.12)	1.11 (0.85–1.43)
Haryana	109,051	3745	0.33 (0.29–0.36)	1.03 (0.75–1.37)	1.36 (1.04–1.73)
Himachal Pradesh	22,420	2934	0.16 (0.14–0.18)	0.57 (0.41–0.76)	0.73 (0.55–0.94)
Jammu & Kashmir and Ladakh	24,858	1756	0.29 (0.25–0.32)	0.92 (0.66–1.23)	1.20 (0.92–1.55)
Karnataka	242,636	3461	0.23 (0.21–0.26)	0.77 (0.55–1.03)	1.00 (0.76–1.29)
Kerala	115,251	3280	0.12 (0.11–0.14)	0.63 (0.45–0.85)	0.75 (0.56–0.99)
Maharashtra	387,885	3104	0.21 (0.18–0.23)	0.76 (0.56–1.02)	0.97 (0.74–1.26)
Punjab	78,116	2500	0.25 (0.22–0.28)	0.80 (0.58–1.07)	1.05 (0.80–1.34)
Tamil Nadu	261,001	3254	0.23 (0.20–0.26)	0.65 (0.47–0.87)	0.88 (0.67–1.12)
Telangana	140,106	3562	0.22 (0.18–0.26)	0.68 (0.50–0.92)	0.90 (0.68–1.18)
West Bengal	170,405	1703	0.24 (0.21–0.27)	0.80 (0.58–1.09)	1.04 (0.80–1.35)

[a] Reserve Bank of India. Handbook of Statistics on Indian Economy, 2022–2023. 2023. https://www.rbi.org.in/scripts/AnnualPublications.aspx?head=Handbook+of+Statistics+on+Indian+Economy

total economic loss due to CDs varied widely between the states, ranging from USD 10.8 million in Sikkim to USD 1.63 billion in Uttar Pradesh (Table 3). The total economic loss due to CDs among adolescents accounted for > 0.5% of the state's GDP in three (37.5%) of the eight EAG states, two (26%) in eight NE states, and none of the other states (Additional file 2: Table S2). Among the major CDs, diarrheal diseases had the highest contribution to the economic loss due to deaths followed by tuberculosis and lower respiratory infections with some variations by the state group, whereas nutritional deficiencies accounted for most of the economic loss due to morbidity in India and its states in 2021 (Table 4).

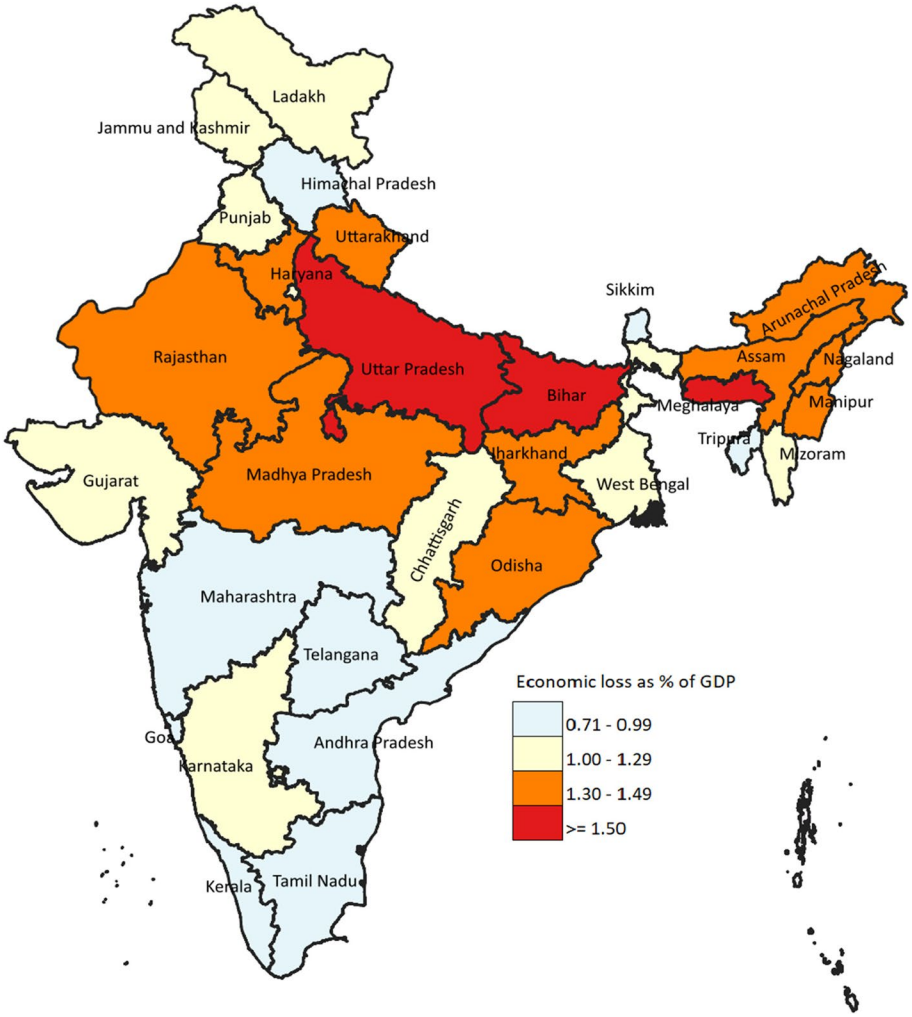

Fig. 1 Distribution of economic loss due to adolescent deaths and morbidity as a percentage of Gross Domestic Product (GDP) in the states of India in 2021

Of the total deaths among adolescents in India in 2021, the proportion of deaths due to NCDs varied 1.6 times between the states, ranging from 20.9% in Uttar Pradesh to 32.4% in Punjab, and the proportion of YLDs due to NCDs out of the total YLDs varied 1.2 times between the states, ranging from 59.7% in Bihar to 71.5% in Manipur (Additional file 2: Table S1). The total economic loss due to NCDs among adolescents was estimated at USD 20.01 (95% CI 14.60–26.74) billion (Table 3), which was 0.69% of GDP (95% CI 0.50–0.91) as shown in Additional file 2: Table S2. This included USD 2.29 (95% CI 2.03–2.56) billion due to premature deaths and USD 17.72 (95% CI 12.57–24.18) billion due to morbidity (YLDs) (Additional file 2: Table S3). The economic loss due to NCDs accounted for 53.1% of the total economic loss among adolescents in India, ranging from 49.1% to 64.6% across the states in 2021 (Fig. 2). The economic loss due to NCDs ranged from USD 19.6 million in Sikkim to USD 2.20 billion in Uttar Pradesh (Table 3). The economic loss due to NCDs accounted for > 0.5% of the state's GDP in all of the eight EAG states, in seven (97.5%) of the eight North-east states, and in 10 (71.4%) of the other states (Additional file 2: Table S2). Among the major NCDs, neoplasms had the highest contribution to economic loss due to deaths followed by cardiovascular diseases, and digestive diseases; and neurological disorders accounted for the most economic loss due to morbidity in India and its states in 2021 (Table 4).

Of the total deaths among adolescents in India in 2021, the proportion of deaths due to injuries ranged from 23.6% in Mizoram to 51.4% in Tamil Nadu—a 2.2 times variation between states, whereas the proportion of YLDs due to injuries of the total YLDs ranged from 2.4% in Jharkhand to 3.8% in Jammu & Kashmir and

Table 3 Total economic loss due to adolescent deaths and morbidity in USD (million) as a result of communicable diseases, non-communicable diseases, and injuries in India and its states in 2021. EAG is Empowered Action Group

	Economic loss for adolescent deaths and morbidity in USD (million) (95% confidence interval)		
	Communicable diseases	**Non-communicable diseases**	**Injuries**
India	**13,251 (10,102–17,166)**	**20,009 (14,597–26,739)**	**4572 (3865–5303)**
EAG states			
Bihar	774 (556–1,063)	1022 (734–1,383)	193 (153–240)
Chhattisgarh	232 (167–328)	307 (214–416)	86 (56–113)
Jharkhand	230 (163–313)	327 (233–446)	56 (40–73)
Madhya Pradesh	659 (488–896)	940 (683–1,265)	300 (241–364)
Odisha	389 (284–525)	564 (407–760)	132 (103–162)
Rajasthan	749 (549–1,025)	1081 (779–1459)	234 (190–285)
Uttar Pradesh	1628 (1211–2184)	2198 (1586–2977)	549 (444–665)
Uttarakhand	139 (105–189)	255 (184–343)	66 (54–79)
North-east states			
Arunachal Pradesh	21 (15–28)	37 (27–51)	7 (5–8)
Assam	278 (207–365)	391 (285–527)	83 (68–98)
Manipur	19 (14–25)	40 (29–54)	7 (6–9)
Meghalaya	27 (20–37)	43 (31–59)	6 (5–8)
Mizoram	14 (10–20)	25 (17–35)	3 (2–4)
Nagaland	16 (12–21)	32 (23–44)	5 (4–6)
Sikkim	11 (8–14)	20 (14–26)	3 (2–4)
Tripura	28 (20–39)	46 (33–63)	9 (6–12)
Other states			
Andhra Pradesh	438 (310–583)	675 (482–918)	129 (100–163)
Delhi	488 (336–704)	787 (566–1,065)	109 (88–135)
Goa	30 (22–41)	55 (39–74)	8 (6–10)
Gujarat	934 (684–1,235)	1395 (1012–1885)	336 (273–400)
Haryana	545 (397–726)	902 (658–1207)	170 (140–203)
Himachal Pradesh	47 (35–64)	96 (69–128)	20 (16–24)
Jammu & Kashmir and Ladakh	88 (65–118)	171 (125–229)	39 (32–46)
Karnataka	777 (567–1040)	1340 (968–1799)	302 (246–361)
Kerala	221 (163–294)	559 (400–760)	86 (70–104)
Maharashtra	1240 (907–1638)	2122 (1533–2842)	396 (319–481)
Punjab	257 (188–350)	469 (341–625)	89 (73–107)
Tamil Nadu	622 (456–842)	1243 (904–1683)	368 (293–441)
Telangana	380 (274–520)	718 (514–974)	167 (126–210)
West Bengal	567 (407–772)	983 (712–1320)	226 (175–270)

Ladakh—a 1.6 times variation between states (Additional file 2: Table S1). The total economic loss due to injuries among adolescents was estimated at USD 4.57 (95% CI 3.87–5.30) billion, accounting for 0.16% of India's GDP in 2021 (95% CI 0.13–0.18) as shown in Additional file 2: Table S2. This included USD 3.75 (95% CI 3.26–4.22) billion due to deaths and USD 818 million (95% CI 607–1080) due to morbidity (YLDs). The economic loss due to injuries accounted for 11.7% of the total economic loss among adolescents in India in 2021 (Fig. 2). The economic loss due to injuries ranged from USD 3.2 million in Sikkim to USD 548.9 million in Uttar Pradesh (Table 3). The economic loss due to injuries accounted for $\leq$ 0.25% of the state's GDP in all the EAG states, and $\leq$ 0.20% of the state's GDP in all the NE states and all other states (Additional file 2: Table S2). Among the major injuries, self-harm contributed the maximum economic loss due to deaths followed by road injuries and drowning, whereas falls contributed

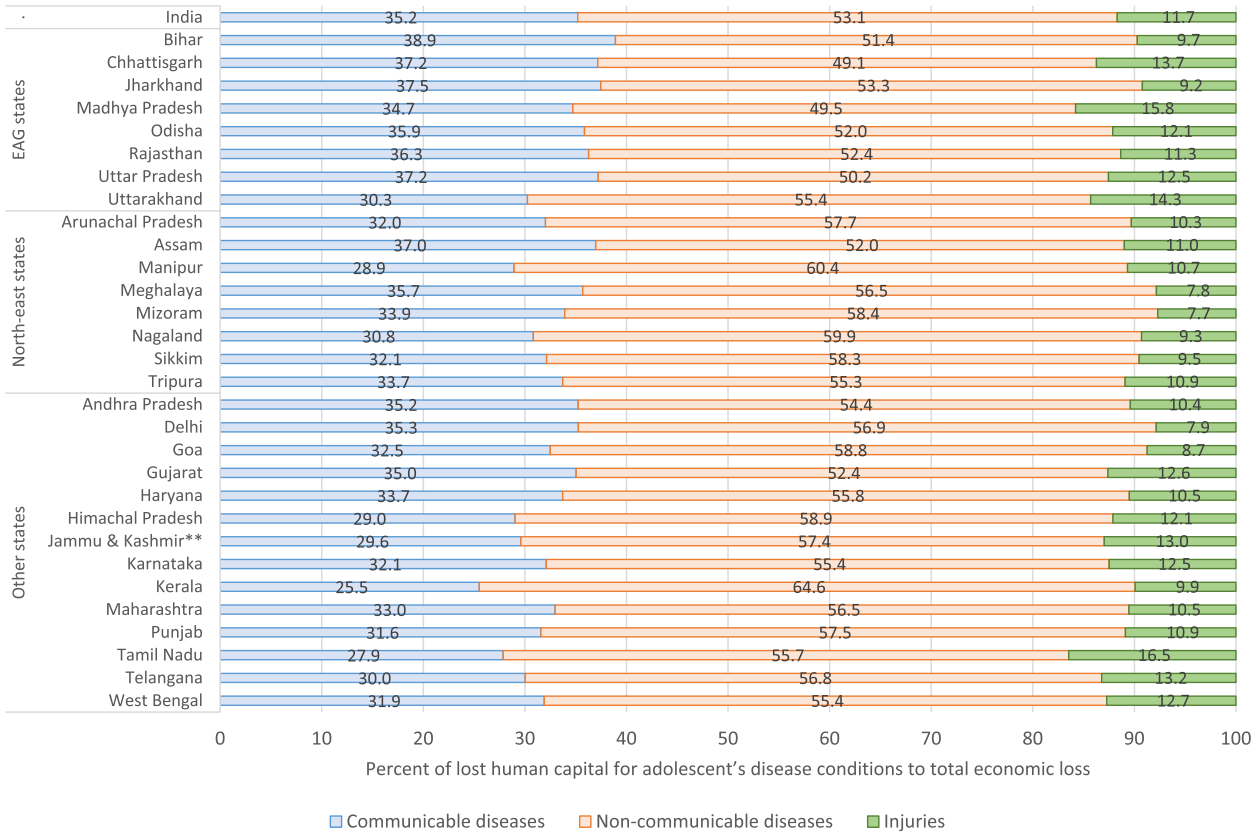

Fig. 2 Contribution to the total economic loss by type of diseases/condition for total adolescent deaths and morbidity in India and states in 2021. EAG is the Empowered Action Group

the maximum economic loss due to morbidity across the states in 2021 (Table 4).

Discussion

The economic loss due to lost output from premature deaths and morbidity attributable to adolescents at USD 38.01 billion is significantly high in India, equivalent to 1.30% of India's GDP in 2021. Premature deaths accounted for nearly one-fourth and NCDs accounted for nearly 70% of the total economic loss in India.

India, home to 1.4 billion people, is the world's most populous country [32], giving it potential advantages, especially at a time when countries around the world are facing declining birth rates and tight labour markets [33]. The government of India has taken several measures to harness the demographic dividend including investing in skills development efforts and the establishment of a vocational and technical training framework, a comprehensive framework to transform the education system, and policies seeking to mitigate gender discrimination and address structural imbalances [34–36]. The economic loss due to premature mortality and morbidity is a disinvestment in human capital stock [37]. Human capital is a broad concept, defined as the stock of knowledge and skills possessed by a population and the health status of that population, which is an important component of the inclusive wealth of a nation [38, 39]. With the total health expenditure in India at 3.27% of GDP in 2019 [40], and the economic loss due to the adolescent disease burden estimated at 1.30% of GDP, investing in adolescent wellbeing is needed to facilitate India's projected GDP of USD 10.0 trillion by 2030 [41]. Importantly, the economic loss due to adolescent disease burden is comparable with the 1.36% GDP loss reported previously for air pollution, another major public health concern in India [18]. It is important to note that we have estimated the indirect costs of lost output due to premature deaths and morbidity among adolescents in this paper using the output-based approach, which is more suited for financial analysis and accounting when calculating the cost of deaths and morbidity. There are alternative approaches to measuring the indirect costs such as the willingness-to-pay approach which evaluates the broader societal and economic benefits or costs [20], and the friction cost method which takes an employer's perspective and

Table 4 Contribution to the economic loss by the diseases/conditions under the communicable diseases, non-communicable diseases, and injuries among the adolescents in India, and in less developed and more developed states in 2021. YLDs is years lived with disability and EAG is Empowered Action Group

	Percent of economic loss due to major disease/conditions to total economic loss due to adolescent deaths and morbidity											
	India			EAG states			North-east states			Other states		
	Due to deaths	Due to morbidity (YLDs)	Total	Due to deaths	Due to morbidity (YLDs)	Total	Due to deaths	Due to morbidity (YLDs)	Total	Due to deaths	Due to morbidity (YLDs)	Total
Communicable diseases	**38.4%**	**34.1%**	**35.2%**	**42.2%**	**35.3%**	**37.2%**	**41.5%**	**34.0%**	**36.0%**	**31.3%**	**32.6%**	**32.3%**
Diarrheal diseases	5.9%	4.8%	5.1%	7.1%	5.1%	5.6%	6.6%	5.0%	5.5%	3.8%	4.4%	4.2%
Tuberculosis	4.3%	0.5%	1.5%	4.8%	0.6%	1.8%	4.6%	0.5%	1.6%	3.3%	0.4%	1.0%
Lower respiratory infections	3.5%	0.1%	0.9%	4.0%	0.1%	1.0%	3.5%	0.1%	1.0%	2.7%	0.1%	0.7%
Encephalitis	1.9%	0.2%	0.6%	1.7%	0.3%	0.7%	3.6%	0.2%	1.1%	1.9%	0.2%	0.6%
Maternal disorders	1.8%	0.03%	0.5%	2.2%	0.03%	0.6%	1.9%	0.04%	0.5%	1.0%	0.03%	0.2%
Malaria	1.4%	0.1%	0.4%	1.6%	0.1%	0.5%	1.1%	0.1%	0.3%	1.2%	0.1%	0.3%
Neglected tropical diseases	1.1%	2.2%	1.9%	1.2%	2.3%	2.0%	0.7%	1.9%	1.6%	1.0%	2.0%	1.8%
Nutritional deficiencies	0.3%	12.0%	9.0%	0.3%	12.5%	9.2%	0.2%	12.5%	9.4%	0.2%	11.3%	8.9%
Upper respiratory infections	0.02%	0.7%	0.5%	0.02%	0.7%	0.5%	0.02%	0.7%	0.5%	0.01%	0.7%	0.6%
Otitis media	0%	0.9%	0.6%	0%	1.0%	0.7%	0%	0.8%	0.6%	0%	0.7%	0.5%
Other communicable diseases	18.2%	12.7%	14.1%	19.3%	12.7%	14.5%	19.2%	12.1%	13.9%	16.2%	12.8%	13.5%
Non-communicable diseases	**24.1%**	**63.0%**	**53.1%**	**22.7%**	**61.8%**	**51.1%**	**26.7%**	**63.2%**	**53.7%**	**26.1%**	**64.4%**	**55.9%**
Neoplasms	5.8%	0.1%	1.5%	5.6%	0.1%	1.6%	5.2%	0.05%	1.4%	6.4%	0.1%	1.5%
Cardiovascular diseases	5.0%	0.8%	1.9%	4.3%	0.8%	1.8%	4.5%	0.8%	1.8%	6.2%	0.9%	2.1%
Digestive diseases	4.5%	1.0%	1.9%	4.6%	1.1%	2.0%	8.6%	1.1%	3.1%	4.0%	1.0%	1.7%
Neurological disorders[a]	2.6%	10.6%	8.6%	2.5%	10.4%	8.3%	2.7%	10.6%	8.5%	2.8%	10.7%	9.0%
Congenital birth defects	2.2%	1.7%	1.8%	1.9%	1.7%	1.8%	1.9%	1.7%	1.8%	2.8%	1.7%	1.9%
Chronic respiratory diseases	0.8%	1.6%	1.4%	0.9%	1.6%	1.4%	0.7%	1.7%	1.4%	0.6%	1.6%	1.4%
Diabetes mellitus	0.5%	0.4%	0.4%	0.4%	0.4%	0.4%	0.6%	0.4%	0.4%	0.6%	0.4%	0.5%
Hemoglobinopathies and hemolytic anemias	0.3%	2.0%	1.6%	0.3%	2.2%	1.6%	0.1%	1.9%	1.4%	0.3%	1.9%	1.5%
Substance use disorders	0.3%	0.6%	0.5%	0.3%	0.6%	0.5%	0.3%	0.6%	0.5%	0.2%	0.6%	0.5%
Skin and subcutaneous diseases	0.3%	9.2%	6.9%	0.3%	9.0%	6.6%	0.3%	9.3%	6.9%	0.2%	9.4%	7.3%
Musculoskeletal disorders	0.1%	6.0%	4.5%	0.1%	6.0%	4.4%	0.1%	5.6%	4.1%	0.1%	6.1%	4.8%
Gynaecological diseases	0.1%	1.9%	1.5%	0.1%	1.9%	1.4%	0.05%	1.9%	1.4%	0.05%	1.9%	1.5%
Depressive disorders	0%	5.4%	4.1%	0%	4.7%	3.4%	0%	5.4%	4.0%	0%	6.4%	4.9%
Hearing loss	0%	2.2%	1.6%	0%	2.1%	1.5%	0%	2.2%	1.6%	0%	2.3%	1.8%
Oral disorders	0%	1.1%	0.8%	0%	1.1%	0.8%	0%	1.1%	0.8%	0%	1.1%	0.9%
Blindness and vision impairment	0%	0.8%	0.6%	0%	0.8%	0.6%	0%	0.8%	0.6%	0%	0.8%	0.6%
Other mental health issues	0%	16.5%	12.3%	0%	16.4%	11.9%	0%	17.2%	12.7%	0%	16.5%	12.8%

Table 4 (continued)

	Percent of economic loss due to major disease/conditions to total economic loss due to adolescent deaths and morbidity											
	India			EAG states			North-east states			Other states		
	Due to deaths	Due to morbidity (YLDs)	Total	Due to deaths	Due to morbidity (YLDs)	Total	Due to deaths	Due to morbidity (YLDs)	Total	Due to deaths	Due to morbidity (YLDs)	Total
Other non-communicable diseases	1.7%	0.9%	1.1%	1.6%	0.9%	1.1%	1.5%	0.9%	1.1%	1.9%	1.0%	1.2%
Injuries	**37.5%**	**2.9%**	**11.7%**	**35.1%**	**2.9%**	**11.7%**	**31.8%**	**2.8%**	**10.3%**	**42.5%**	**2.9%**	**11.8%**
Self-harm	12.1%	0.1%	3.1%	9.5%	0.1%	2.6%	10.5%	0.1%	2.8%	16.9%	0.1%	3.8%
Road injuries	8.7%	0.2%	2.3%	8.3%	0.2%	2.4%	7.0%	0.2%	1.9%	9.6%	0.2%	2.3%
Drowning	4.6%	0.01%	1.2%	4.4%	0.01%	1.2%	5.9%	0.02%	1.5%	4.9%	0.01%	1.1%
Animal contact	3.4%	0.1%	1.0%	4.0%	0.1%	1.2%	1.6%	0.1%	0.5%	2.7%	0.1%	0.7%
Falls	2.4%	1.2%	1.5%	2.4%	1.2%	1.5%	1.8%	1.0%	1.2%	2.5%	1.2%	1.5%
Physical violence	1.9%	0.2%	0.6%	2.2%	0.2%	0.7%	2.0%	0.2%	0.7%	1.6%	0.2%	0.5%
Sexual violence	0%	0.3%	0.2%	0%	0.3%	0.2%	0%	0.3%	0.2%	0%	0.3%	0.2%
Other unintentional injuries	4.3%	0.9%	1.7%	4.4%	0.8%	1.8%	3.0%	1.0%	1.5%	4.4%	0.9%	1.6%

[a] Includes stroke, headache disorders, epilepsy, cerebral palsy, Alzheimer's disease and other dementias, brain and CNS cancer, Parkinson's disease, multiple sclerosis, motor neuron diseases, and a few others

measures only the production losses during the time it takes to replace a worker [42, 43].

The loss of output in monetary terms attributable to adolescent disease burden at the state level is associated with the number and the age distribution of deaths and morbidity in each state and state GDP per worker. This economic loss as a percentage of state GDP was the highest for the state of Bihar at 2.43% followed by the state of Uttar Pradesh at 1.80%. The burden of economic loss was relatively higher in the EAG states, which are considered less developed as compared with the other states, with a much higher variation between the states in the former than in the latter group. The vast disparities in the Sustainable Development Goal (SDG) 3 across the states with the health index in the EAG states lower compared with the other states has been highlighted as a challenge towards improving population health in India [44]. We have previously also reported considerable state heterogeneity in the disease burden of the leading causes among adolescents highlighting the response to improve adolescent wellbeing to be specific to the needs of each state [13]. The state governments are essential stakeholders in India's achievement of SDGs as they play a pivotal role in implementing programmes to improve health. In this background, the finding that the EAG states with lower per-capita GDP are most vulnerable to the adverse economic impacts of adolescent premature deaths and morbidity is significant. The economic loss due to lost output from adolescent disease burden disaggregated by the type of disease/condition is an important value-add of this analysis towards specific actions needed at the state level to improve adolescent health. The estimates by disease/condition are particularly relevant as significant gaps are documented in the IAHS in comparison to the disease burden across CDs, NCDs, and injuries which can have serious implications for improving adolescent health in India and its states [13].

The CDs accounted for 35.2% of the total economic loss in India in 2021 estimated at 0.45% of GDP with the majority of this burden in the EAG states. The contribution to economic loss due to deaths was the most by diarrheal diseases and TB. We have previously reported that neither of these diseases is currently a focus in the IAHS and that the former is in the top 10 causes of years of lives lost for both 10–14 years and 15–19 years whereas the latter is only in 15–19 years [13]. A number of studies that had estimated the cost per TB death averted since the introduction of the WHO End TB Strategy in 2014 were summarised in the Lancet Commission on TB [45], and the significant economic and social benefits of addressing TB in adolescents have been estimated in the recent WHO report [10]. Nutritional deficiencies accounted for the most economic loss due to morbidity across all states. Currently, dietary iron deficiency is among the focus conditions being addressed for adolescents under IAHS [12, 13]. The Government of India has expanded its school meal scheme from classes 1 to V up to class VIII children in government schools to include 11–13-year-old adolescents [46]. As malnutrition continues to be the leading risk factor for disease burden in India for all age groups, and substantially higher rates of improvement are needed in most states to achieve the Indian 2022 and the global 2030 targets [47], implementation of recommended interventions and policies that cut across sectors such as education, health, food systems, social protection, and digital media are needed to improve upon adolescent nutrition, health, growth and development [48].

Adolescent NCDs accounted for half or more of the total economic loss in India and its states in 2021, with the total lost capital due to adolescent NCDs in India at 0.69% of GDP. Nine of the 10 USD lost due to NCDs were due to morbidity in India; the burden of total loss was higher in the EAG states which is a reflection of the epidemiological transition in India [16]. Recent reports on the trends and heterogeneity of the burden of neoplasms and cardiovascular diseases have highlighted the systemic, access and prevention issues that have to be addressed in India to address mortality due to these diseases [49, 50]. Ischaemic heart disease is among the focus conditions in the IAHS for deaths but not neoplasms [13]. Leukaemia accounts for most deaths in this age group [49]; measures to reduce potentially harmful exposures [51], and improving prevention and access to treatment can decrease the risk of disease in adolescents [49]. Neurological disorders accounted for the most economic loss due to NCDs in adolescents, and these disorders are not currently addressed in the IAHS [13]. The burden of neurological disorders has increased over the last decades in India, and the need for state-specific health system responses to address the gaps in neurology services related to awareness, early identification, treatment, and rehabilitation has been previously highlighted [52].

At 0.16% of GDP, injuries accounted for 11.7% of the total economic loss in India in 2021 with 80% of this loss as a result of premature deaths. Injuries, sexual abuse, domestic violence and gender-based violence are considered a theme in the IAHS [12]. The injuries resulting in most economic loss due to premature deaths, self-harm and road injuries, are listed as a focus area with the latter under injuries and screening for suicidal tendencies is indicated as a strategy under the mental health theme in IAHS [12]. The generic injury strategies proposed in the IAHS cannot address these injuries in adolescents effectively as previously noted [13, 53–57]. More specificity is also needed in the National Suicide Prevention Strategy

to target suicide prevention among adolescents in India [57], including an understanding of risks, protective factors, and effectiveness of interventions [58]. Lessons can be learnt from cost-effective interventions such as the Youth Aware of Mental Health programme in preventing both a suicide attempt and severe suicidal ideation among young in Europe [59]. Deaths and serious injuries from road traffic injuries can be addressed by known effective interventions, which have also been shown to be good economic and social investments [10]. Falls, leading the economic loss for adolescent morbidity in injuries, are not currently addressed in the IAHS [13]. Limited data are available on fall-related injuries predominately from emergency departments of large hospitals indicating at least one-third of fall-related injuries in children and adolescents [60, 61].

There are limitations to this analysis. The general limitations of GBD methods are published elsewhere [16, 17, 62–64]. Importantly, the estimates for output loss from adolescent premature deaths and morbidity depend on several assumptions, which, if changed, would alter the results. A specific limitation for India is an incomplete medically certified cause of death system that covers only a small proportion of the deaths in India and has variable coverage across the states [65]. The economic estimation assumed that the workers irrespective of age in a state would produce the same output per worker, the ratio of worker to population would remain constant over time, and the labour's share of GDP, rate of growth in output per worker and the discount rate were same for all states. Additionally, for simplicity, the labour's share of GDP was assumed to remain constant over time at its current value. The estimates of economic loss are dependent on the rate at which future output is discounted. We have done a sensitivity analysis for this using varying discount rates. In addition, India and state-specific life tables were assumed to remain constant over the lifetimes of people currently alive, which may have understated the economic losses in less developed states where survival probabilities are likely to increase in the future. We have not quantified the direct health-care costs and other potentially negative economic impacts such as that due to the COVID-19 pandemic on adolescents which are beyond the scope of this analysis [66]. Despite these limitations, this study provides useful estimates of economic loss attributable to adolescent premature deaths and morbidity in every state of India using the most recent burden data in this population.

Conclusions

In light of the findings presented in this paper, appropriate actions are urgently needed at the national and state levels to improve adolescent wellbeing as an investment in India's future economic growth. Strengthening the current initiative to improve adolescent wellbeing needs to be expanded to address the specific diseases/conditions contributing most to the total economic loss to facilitate substantial avoidance of economic losses attributable to due to adolescent premature deaths and morbidity in India.

Abbreviations

CDs	Communicable diseases
CIs	Confidence intervals
EAG	Empowered Action Group
GBD	Global Burden of Diseases, Injuries and Risk Factors Study
GDP	Gross Domestic Product
IAHS	India Adolescent Health Strategy
NCDs	Non-communicable diseases
NE	North Eastern
NSSO	National Sample Survey Organization
PLFS	Periodic Labour Force Survey
WPR	Worker-to-population ratio
WHO	World Health Organization
YLDs	Years lived with disability

Supplementary Information

The online version contains supplementary material available at https://doi.org/10.1186/s12916-025-03895-5.

Additional file 1: Fig S1. Total economic loss due to adolescent deaths and morbidity in USDin India, 2021. Fig S2. Economic loss due to premature deaths and morbidity among adolescents as a percentage of India's GDP, 2021

Additional file 2: Table S1. Distribution of number of deaths and years lived with disabilityfor adolescents overall and disaggregated by communicable diseases, non-communicable diseases, and injuries in India and its states in 2021 as per the Global Burden of Disease Study 2021. EAG is Empowered Action Group. Table S2: Total economic loss due to adolescent deaths and morbidity as percent of Gross Domestic Productfor communicable diseases, non-communicable diseases and injuries in India and its states in 2021. YLDs is years lived with disability and EAG is Empowered Action Group. Table S3: Total economic loss due to adolescent deaths and morbidity in USDby communicable diseases, non-communicable diseases and injuries in India and its states in 2021. YLDs is years lived with disability and EAG is Empowered Action Group

Authors' contributions

RD and GAK conceptualised the study and drafted the manuscript. GAK performed the data analysis with contributions from AP and RD. All authors contributed to the interpretation and agreed with the final version of the paper. GAK and AP verified the data underlying this study. All authors had full access to all the data in the study and had the final responsibility for the decision to submit for publication. All authors read and approved the final manuscript.

Funding

Bill & Melinda Gates Foundation; the funder had no role in the interpretation of the data and findings, or decision to publish.

Data availability

The data used for estimating disease burden in this paper are available at VizHub - GBD Results (healthdata.org), and from the authors on request. All other data used for this analysis are publicly available and the references are shown in the methods section of paper.

Declarations

Ethics approval and consent to participate

Not applicable, as this research is based on secondary data available in the public domain with no individual identifiers.

Consent for publication

Not applicable.

Competing interests

The authors declare no competing interests.

Received: 10 August 2024 Accepted: 23 January 2025
Published online: 29 January 2025

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