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ORIGINAL RESEARCH

Health Hazard Among Shrimp Cultivators in India: A Quantitative Burden of Disease Study

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Background: The lack of focus on the health status of shrimp cultivators by previous studies while the production of shrimp has been rising over the years after the introduction of the blue revolution in India. The present study estimated the burden of diseases among shrimp cultivators in India.

Methods: Primary data were collected by using simple random sampling. The sample size was 357. The classification of diseases were made by using the international classification of diseases, tenth revision (ICD-10), version 2019. Disability-adjusted life years (DALY) were used to measure the health status of shrimp cultivators. DALY is the summation of the burden of disease from mortality and morbidity. Sensitive and uncertainty analysis was used by changing the value of the parameter and method, respectively.

Results: The burden of disease among shrimp cultivators in 2020 ranges from 101.03 DALY based on equal age weightage, without discount rate, and potential life expectancy ($DALY_{0,0,PLE}$) to 84.02 DALY based on unequal age weightage, discount rate, and standardized life expectancy ($DALY_{1,0.03,SLE}$). The burden of disease per 100,000 shrimp cultivators was 28,477.74 DALY and 23,600.84 DALY when calculated by using $DALY_{0,0,PLE}$ and $DALY_{1,0.03,SLE}$ method, respectively. The higher burden of diseases from non-communicable diseases was followed by injury and communicable diseases for both methods. The disease burden from mortality was more than two-thirds of the total burden of disease and the rest from morbidity. The burden of disease among shrimp cultivators was sensitive to parameter changes because it changes between 92.10 DALY and 63.03 DALY with the change in the parameter. Uncertainty in the burden of disease among them was due to method variation, which ranges from 120.03 DALY to 74.06 DALY.

Conclusion: The higher burden of non-communicable diseases, and the lower burden of communicable, and injuries per 100,000 shrimp cultivators compared to the national level in India.

Keywords: shrimp cultivators, DALY, occupational hazard, epidemiology, India

Introduction

Fish cultivation led to the pollution of water bodies because fishermen did not have adequate knowledge about the quantity of chemicals to be used per acre.[1,2] Consumption of fish produced from contaminated water bodies has led to health complications due to the transfer of chemicals from the fish to the human body.[3–5] In addition, other environmental factors were responsible for illness among the fishermen, such as exposure to sunlight, light reflection at the sea surface, and air pollution. For example, sunlight exposure caused skin cancer in fishermen,[6,7] while sunlight reflection at the sea surface caused eye problems.[8] Other illnesses resulting from environmental pollution were respiratory problems among fishermen.[8–11]

Besides environmental degradation, a hazardous working environment also created health issues among fishermen.[12,13] Loud noise during fishing caused hearing problems among fishermen.[6,8,14] Another consequence of the continuous noise at the workplace was the fishermen being deprived of sound sleep. Moreover, long working hours left the fishermen with fewer sleeping hours. Consequently, fishermen who had worked more than eight hours with disturbed sleep were more susceptible to illness than the other fishermen. As a result of long work hours, fishermen were affected by musculoskeletal diseases and stress.[8,15]

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The lifestyle factors of fishermen were also responsible for illnesses among them. The consumption of alcohol, and tobacco[16] by fishermen to overcome body pain resulting from long hours of work.[17–19] However, their lack of knowledge regarding the safe amount of consumption of alcohol,[20] smoking, and tobacco led to illness among them.[18] Also, poor oral health status among fishermen was due to the consumption of alcohol and tobacco.[21,22] Moreover, the higher rate of hernias among fishermen aged 20–35 years was because of the high prevalence of smoking among this age group compared to other age groups.[23] The consumption of alcohol and tobacco was also the cause of the increased risk of cancer among fishermen.[24] Another cause of fishermen suffering from cancer was higher consumption of fish compared to vegetables and fruits due to lack of storage facilities when they went to sea for fishing. Fishermen's consumption patterns were also linked to the prevalence of diabetes[25] and digestive diseases.[26]

The main causes of mental health problems among fishermen were risk and uncertainty in fishing. The reasons for risk and uncertainty were working conditions, market variation, amount of fishing, and risk of unemployment.[25] Furthermore, self-employed people were significantly associated with higher mental health problems than paid workers.[7] Hence, the prevalence of high blood pressure among fishermen was due to stress at work resulting from being self-employed.[6]

16 million people depend on fisheries in India. Fisheries are divided into two parts. One is marine fishery and another one is inland fisheries. The marine fishery spread along the large coastal area which includes 2.02 million square km of exclusive economic zone and 0.53 million sq. km of continental shelf area.[27] Shrimp cultivation comes under inland fisheries. Those who cultivate shrimp are known as shrimp cultivators. Therefore, they are coming under a sub-category of fishermen. During the time of the growth of the shrimp firm, it was banned by the Supreme Court in India to avoid problems related to disease, and environmental problems.[28] Currently, shrimp cultivation is regulated by the Coastal Aquaculture Authority (CAA) of India by issuing of license to shrimp cultivator.[29] Shrimp cultivation is mostly affected by viruses such as white spot syndrome (WSS)[30] and hepatopancreatic microsporidiosis disease.[31] One study in Bangladesh found that WSS virus transmission from shrimp to shrimp cultivators creates a health hazard among them.[32] However, there is no study on the health status of the shrimp cultivator in India. Hence, estimating the burden of diseases among shrimp cultivators is the novelty of our study.

Existing literature exhibits three limitations. (i) Many studies have been conducted on the health status of fishermen in India and the world. In addition, most of the studies have been conducted on sea fishermen and very few studies have also been done on the health status of inland fisheries in India and the world. (ii) Further, there is a lack of focus on the health status of shrimp cultivators in India while the production of shrimp culture has been rising over the years after the introduction of the blue revolution in India. (iii) Previous studies have used traditional methodologies to measure health status, including morbidity and mortality rates, standardized incident rates, standardized mortality rates, and relative risk to measure health status. In this regard and with the shortcomings of the existing literature,[33] we attempted to perform a concise analysis of the burden of diseases among shrimp cultivators in India using a new methodology, disability-adjusted life years (DALY).

Materials and Methods
Materials

The present study was based on primary data. Primary data were collected through simple random sampling employing the lottery method, using a structured schedule. Data were collected for 2020 by using a one-year recall period. Therefore, a survey was conducted between 3 January and 24 February 2021. Odisha was selected randomly out of the top five shrimp-producing states in India.[34] Shrimp was cultivated in the seven districts of Odisha such as Ganjam, Bhadrak, Balasore, Puri, Kendrapara, Jagatsinghpur, and Khorda. Jagatsinghpur district was randomly selected out of seven shrimp-cultivated districts of Odisha.[29] There were eight blocks in Jagatsinghpur district, and shrimps were cultivated in three blocks, namely Balikuda, Erasama, and Kujanga.[35] Erasama block was selected randomly by lottery method out of three shrimp cultivated blocks in Jagatsinghpur district.

This study considered only shrimp cultivators of licensed shrimp-cultivated ponds. The list of licensed shrimp-cultivated ponds was collected from the Fishery Office, Jagatsinghpur. There were twenty-five panchayats in the Erasama block. Shrimps have been cultivated in seventeen panchayats of the Erasama block. Out of seventeen shrimp-cultivated panchayats in the Erasama block, Padmapur and Gadaharispur panchayats were selected through random sampling by the

lottery method. All licensed shrimp-cultivated ponds of the two panchayats were taken for the present study. All shrimp cultivators of licensed shrimp-cultivated ponds in the two panchayats were included in this survey. Criteria for cultivators included in this study were at least two years actively employed in shrimp cultivation to know its impact on their health status effectively. The sample unit was the shrimp cultivator and the sample size was 357.

Methods

Disability-adjusted life years (DALY) have been used to estimate the burden of diseases and injuries among shrimp cultivators. Time is the unit of measure of DALY, and it is measured by year. One DALY shows the loss of one healthy life year.[36–38] Years of life lost from morbidity (YLD) and life lost from mortality (YLL) are two components of DALY. YLL is always based on incidence. YLD is either calculated by the incidence approach or the prevalence approach.[39] To calculate YLD, the present study used the prevalence approach employed in the Global Burden of Diseases Study (GBD) 2019.[40] The classification of diseases in this study is based on the international classification of diseases, tenth revision (ICD-10), version 2019.[41]

Two methods are used to estimate the burden of diseases and injuries among shrimp cultivators to compare the results. One method is based on equal age weightage, without the discount rate and potential life expectancy (DALY$_{0, 0, PLE}$) shown in equations 1.1, 1.2, and 1.3.[40,42] Potential years of life expectancy (PLE) are the years of life expectancy at birth. The second method is based on the assignment of unequal age weightage, use of the discount rate, and standard expected years of life lost (DALY$_{1, 0.03, SLE}$) given in equations 2.1, 2.2, and 2.5.[43–46] For both methods, the assignment of disability weight varies from zero to one. It represents the severity of the disease. Disability weightage zero shows perfect health while one shows death. The WHO assigns disability weightage to different diseases according to the severity of diseases.[40]

$$YLD = \sum_{x=0}^{x=l}(P_x \times DW \times L_x) \tag{1.1}$$

Where x = age groups, x = 0 and x = l are the first and last age groups respectively, P_x is the number of prevalence cases among the age group x, DW is the disability weightage, and L_x is the average duration of illness among age group x in a year in equation 1.1.

$$YLL = \sum_{x=0}^{x=l} d_x (L - x) \tag{1.2}$$

Where d_x is the number of people dead among age group x, L is PLE, and x is the average age at death among x age group people if dead before the years of PLE in equation 1.2. For example, PLE in Odisha is 69.8 years.[47]

Equations 1.1 and 1.2 calculate YLD and YLL for all shrimp cultivators. Therefore, DALY among all shrimp cultivators is the summation of YLD and YLL given in equation 1.3 by using DALY$_{0, 0, PLE}$ method.

$$DALY = YLD + YLL \tag{1.3}$$

$$YLD = \int_{x=a}^{x=a+L} DKCxe^{-\beta x}e^{-r(x-a)}dx \tag{2.1}$$

where a = age of onset of disability, L = disease duration, D = Disability weightage, K = age weightage modulation factor (K = 1 for assignment of unequal age weightage and K = 0 for equal age weightage), C = age weightage constant (0.1658), β = parameter from age weightage function (0.04), and r = discount rate (0.03).

$$YLL = \int_{x=a}^{x=a+L} KCxe^{-\beta x}e^{-r(x-a)}dx \tag{2.2}$$

Where a = age at death, L = standard expectation of life expectancy at age a, and other parameters in equation 2.2 are the same as in equation 2.1. The only difference between equations 2.1 and 2.2 is disability weightage. When one person dies from disease, disability weightage is equal to one. Therefore, disability weightage is not taken in equation 2.2 for YLL. Standardized life expectancy at different ages in Odisha was obtained from Sample Registration System-Abridged Life Tables 2015–2019.[47]

When solving the integration in equations 2.1 and 2.2, the formula for calculating YLD and YLL is given in equations 2.3 and 2.4, respectively.

$$\text{YLD} = D\left\{\frac{KCe^{ra}}{(r+\beta)^2}\right\}\left\{e^{-(r+\beta)(L+a)}[-(r+\beta)(L+a)-1]-e^{-(r+\beta)a}[-(r+\beta)a-1]+\frac{1-K}{r}\left(1-e^{-rL}\right)\right\} \quad (2.3)$$

$$\text{YLL} = \frac{KCe^{ra}}{(r+\beta)^2}\left\{e^{-(r+\beta)(L+a)}[-(r+\beta)(L+a)-1]-e^{-(r+\beta)a}[-(r+\beta)a-1]+\frac{1-K}{r}\left(1-e^{-rL}\right)\right\} \quad (2.4)$$

Equations 2.3 and 2.4 are used to calculate YLD and YLL for an individual. Therefore, DALY among all the shrimp cultivators in the second method ($\text{DALY}_{1,0.03,\text{SLE}}$) is the summation of all individuals YLD and YLL, which is given in equation 2.5.

$$DALY = \sum_{x=0}^{x=l} YLD + \sum_{x=0}^{x=l} YLL \quad (2.5)$$

The discount rate is used to determine the present value of the future loss of healthy life years because people prefer to live healthy at present rather than in the future. The reason is that the future is uncertain and the value of life decreases with age. The discount rate is low when calculating the return on investment in the long term.[48] The return to society from health in the long term rather than the short term. Therefore, a low discount rate is used for health outcomes.[37] Economists have preferred a 5% discount rate for health and social perspectives. At the same time, modern environmentalists and renewable energy experts say that a low discount rate is used from a social perspective.[49] The present study used a 3% discount rate.[37,43–46,49]

The assignment of age weightage to different age groups is justifiable based on the contribution of each age group to national income. Therefore, the higher age weightage has been given to the working age group than to children and elderly people. The age weightage function estimates the age weightage given in equation 3.[37]

$$Cxe^{-\beta x} \quad (3)$$

All parameters in equation 3 are the same as in equation 2.1. Here, x is age. C is constant, used for no significant variation of health outcome when the use of age weightage is compared to no use of age weightage. According to Murray (1994),[37] the age weightage function (β) is used between 0.03 and 0.05. The GBD has used 0.04 for β. So, the present study used 0.04 for β. There is no logical reason to use 0.04 for β. When changing the value of β, we need to change the value of C to keep the total area under all age groups remain constant.

Results

Age Weightage

Equal and unequal age weightage given to different age groups is listed in Figure 1. The horizontal straight line shows equal age weightage for all age groups. Using equation 3, weightage is assigned to different age groups. Age weight rises with age up to the age group of 25–30 years, then falls continuously. The lowest age weightage (0.08) is given to the age group of 0–1 years.

The change in the values of β and C to know the variation in the economic importance of each age group is presented in Table 1. The different combinations of β and C have been taken from the previous study.[38] The value of β increases with increasing C to keep the total area the same under all age groups, as reflected in Figure 2. The maximum and the minimum age weightage has increased with the rise in the values of β and C. There is an inverse relationship between the values of β and C and the highest age-weighted age group.

Years of Life Lost Based on Different Methods

The DALY from mortality at different ages has been calculated by using two methods; (a) YLL based on equal age weightage, without discount rate, and potential life expectancy ($\text{YLL}_{0,0,\text{PLE}}$) and YLL based on unequal age weightage, discount rate, and standardized life expectancy ($\text{YLL}_{1,0.03,\text{SLE}}$) shown in Figure 3. The PLE and SLE at the different ages
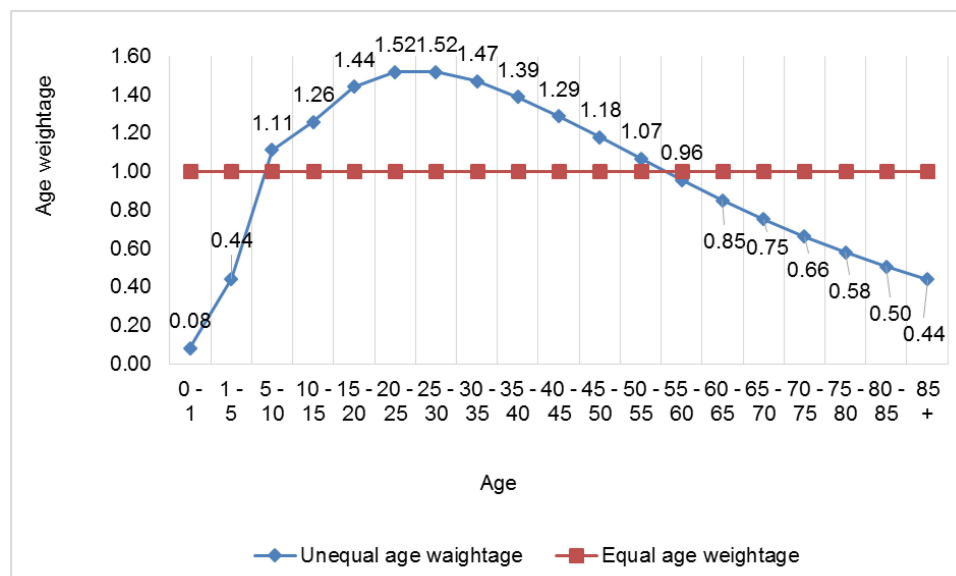
Figure 1 Age weightage to different age groups.
Note: Authors' estimated by using equation 3.

are given in [Appendix Table 1]. The loss of healthy life years in the $YLL_{1,0.03,SLE}$ method is lower than in the $YLL_{0,0,PLE}$ method up to the age of 60 years, while life expectancy is higher based on the SLE than PLE method. The reason is the rise in life expectancy in the SLE method is less than the fall in life expectancy[50] due to a discount at 3% in $YLL_{1,0.03,SLE}$ compared to $YLL_{0,0,PLE}$ method. The highest loss of healthy life years occurred among the age group of 0–1 year in the $YLL_{0,0,PLE}$ method, and 5–10 years in the $YLL_{1,3,SLE}$ method. The reason is the age weightage and discount rate used in the $YLL_{1,0.03,SLE}$ methods. In the $YLL_{1,0.03,SLE}$ method, the highest age weightage is assigned to the age group of 25–30 years, while the highest loss of healthy life years occurred among the age group of 5–10 years. This is because the increase in loss of healthy life years caused by assigning unequal age weightage is less than the fall in loss of healthy life years caused by the use of a 3% discount rate for the age between 10 and 30 years.

Disability-Adjusted Life Years

The total loss of healthy life years is 101.38 years among 357 shrimp cultivators in 2020 due to disability and mortality based on $DALY_{0,0,PLE}$. However, the loss of healthy life years has been reduced by 17.36 years as the total DALY is 84.02 years based on $DALY_{1,0.03,SLE}$, presented in Figure 4. The reason for the change in DALY due to the change in method is explained in Figures 5 and 6.

Table 1 Impact of Change in β and C on the Maximum and Minimum Age Weightage

| β	C	Maximum Age Weightage	Age of Maximum Age Weightage	Minimum Age Weightage	Age of Minimum Age Weightage
0.02	0.0634	1.16	50–55	0.03	0–1
0.03	0.1051	1.29	30–35	0.05	0–1
0.04	0.1658	1.52	25–30	0.08	0–1
0.05	0.2487	1.82	20–25	0.12	0–1
0.06	0.3560	2.18	15–20	0.16	80–85

Notes: Authors' calculation. Different combinations of β and C followed from the previous study.[38]
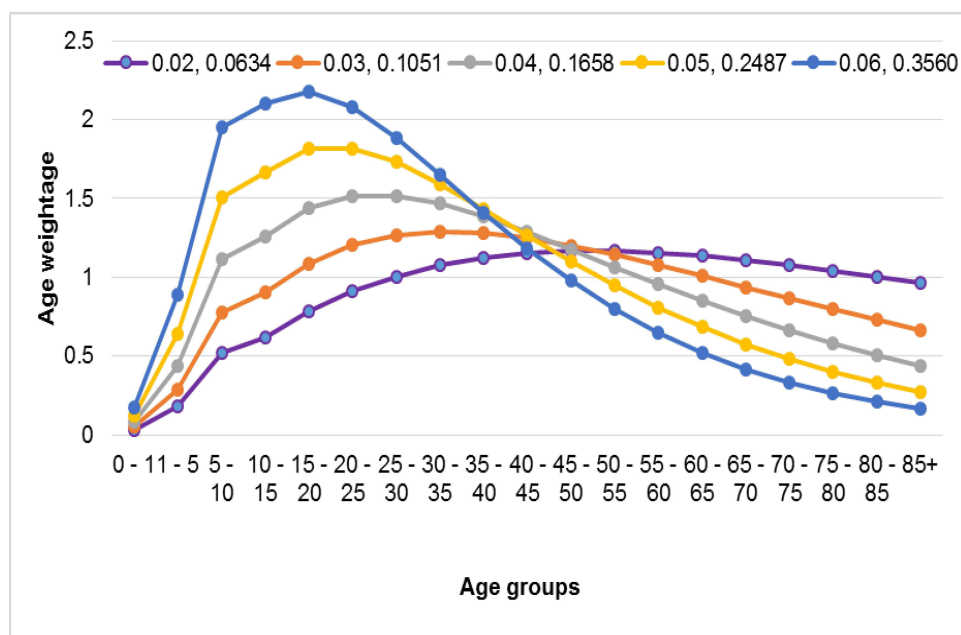
Figure 2 Impact of change in the value of β and C on age weightage to different age groups.
**Note**: Authors' estimated by using equation 3.
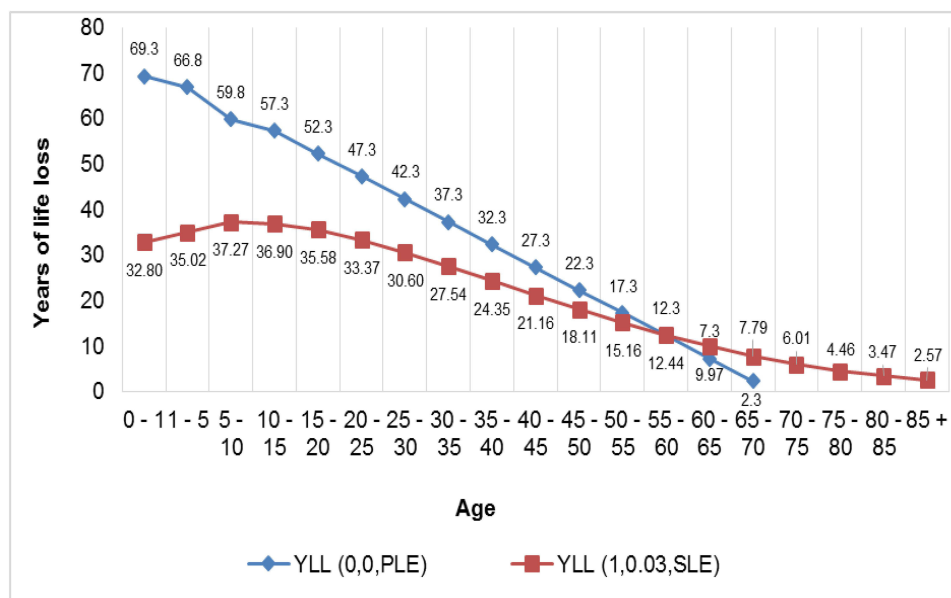
Figure 3 Years of life lost from mortality at different age.
**Note**: Authors' calculated from SRS-abridged life tables.

Based on $DALY_{0,0,PLE}$, the loss of healthy life years from YLL and YLD are 74.7 (73.68%) and 26.68 (26.32%) years, respectively, as shown in Figure 5. YLL has reduced to 56.72 (67.51%), while YLD has increased to 27.3 (32.49%) when estimated by the $DALY_{1,0.03,SLE}$ method, as presented in Figure 6. The rise in YLD is offset more by the fall in YLL-based $DALY_{1,0.03,SLE}$, which leads to a DALY reduction of 16.84%, based on the $DALY_{1,0.03,SLE}$ compared to $DALY_{0,0,PLE}$.

The reason for the fall in YLL and rise in YLD when changing the method from $DALY_{0,0,PLE}$ to $DALY_{1,0.03,SLE}$ is presented in Figure 7. The rise in the loss of healthy life years from 0.28 to 0.36 for communicable diseases and 0.73 to 0.76 for injuries when the method is changed from $DALY_{0,0,PLE}$ to $DALY_{1,0.03,SLE}$ while the loss of healthy life years
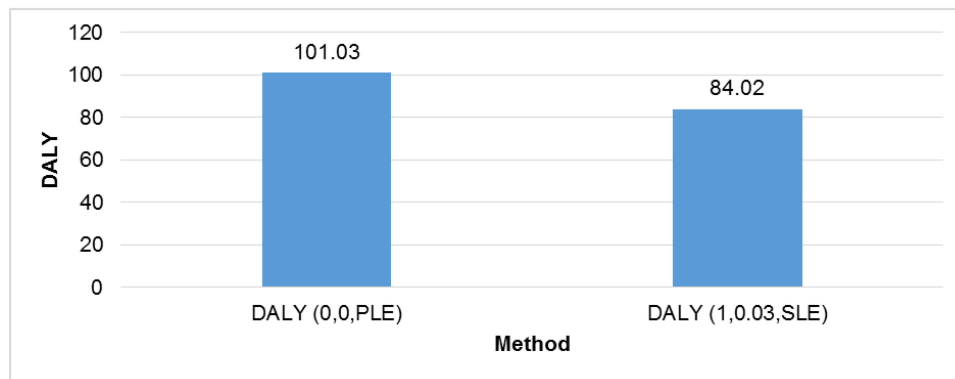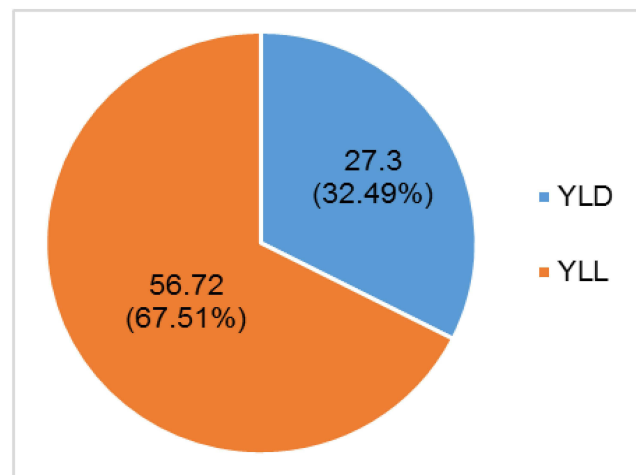
Figure 4 Change in disability-adjusted life years from change in method.
Note: Authors' calculation from primary data.
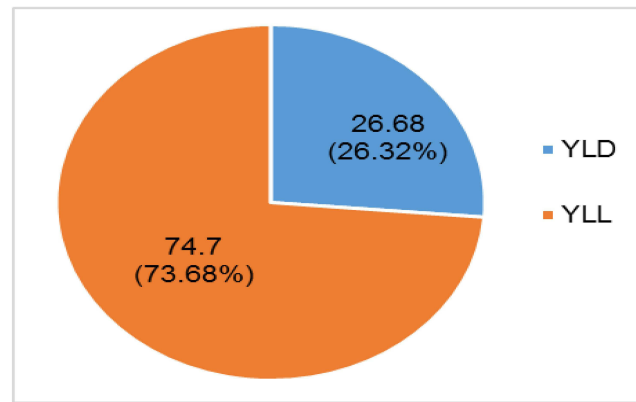
Figure 5 DALY (0,0,PLE).
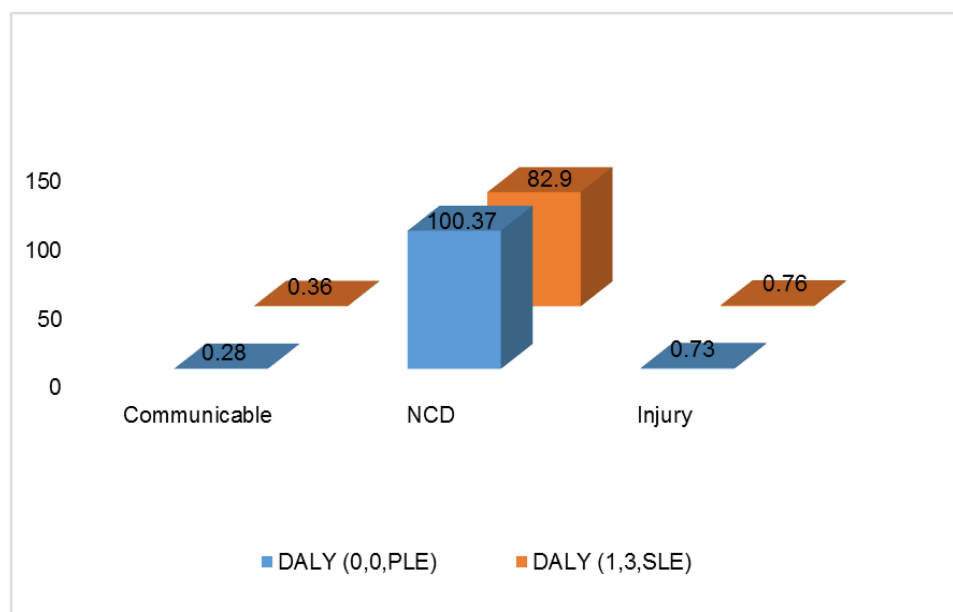**Note**: Authors' calculation from primary data.

Figure 6 DALY (1,0.03,SLE).
Note: Authors' calculation from primary data.

falls from 100.37 to 82.9 for NCDs. The main reason for the falling DALY based on $DALY_{1,0.03,SLE}$ compared to $DALY_{0,0,PLE}$ is that the rise in the DALY from communicable diseases and injury has been offset by the fall in the DALY from NCDs in the former method. The reason for the rise in DALY from communicable diseases based on the

Figure 7 Burden of a broad category of diseases and injuries.
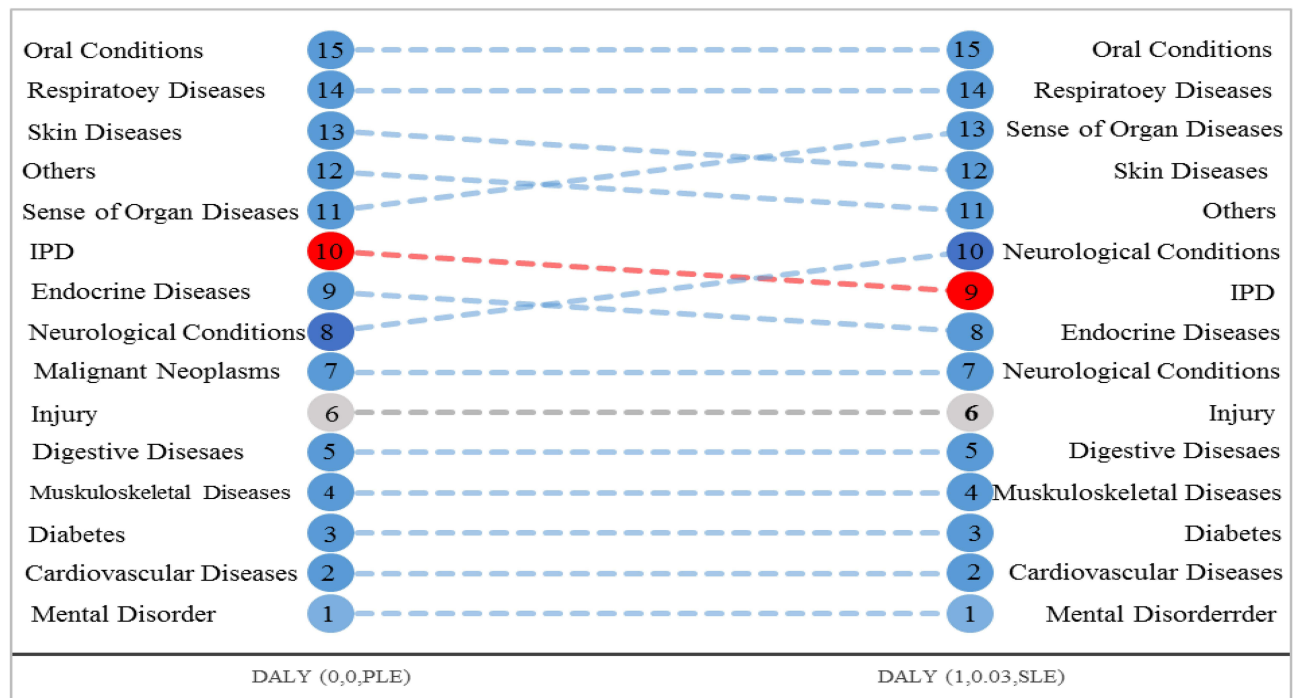**Note**: Authors' calculation from primary data.

$DALY_{1,0.03,SLE}$ is the rise in DALY from tuberculosis, malaria, dengue, and typhoid, because higher age weightage is given to younger shrimp cultivators who have suffered from these diseases. On the other hand, the rise in DALY from injury has resulted in a rise in YLD from all types of injuries except traumatic brain injury long-term consequences (TBILTC) and fracture of the patella. The main reason for the fall in DALY from NCDs is the fall in YLL from 74.47 to 56.72 years when changing methods from the $DALY_{0,0,PLE}$ to $DALY_{1,0.03,SLE}$ because of the fall in YLL from diabetics, heart attack, and depressive disorder (Appendix Table 2). The reason for falling YLL from these three diseases is discounted at 3% in $DALY_{1,0.03,SLE}$ method.

Figure 8 reflects the rank of diseases in descending order. The highest disease burden among shrimp cultivators is from mental disorders, followed by cardiovascular diseases, diabetes, musculoskeletal diseases, and digestive diseases. Six subcategories of diseases change their rank when the method of estimation of DALY changes from $DALY_{0,0,PLE}$ to $DALY_{1,0.03,SLE}$. Skin diseases, endocrine diseases, infectious and parasitic disease (IPD), and other diseases have improved their rank by one each. In contrast, the rank of sense of organ diseases and neurological conditions has deteriorated by two each due to the change in methodology. The main causes of the deterioration in the rank of neurological conditions from 8 to 10 are that DALY from parkinson's disease and dementia have fallen by 41% and 47%, respectively, due to the fall in age weightage in $DALY_{1,0.03,SLE}$ method. The reason for the fall in age weightage is that one person from each of the two diseases suffered between the age of 75 and 80 years. The reason for the improvement of the rank of IPD and endocrine diseases by one each is the deterioration in the rank of sense organ diseases. The fall in the DALY from 0.25 to 0.168 for hearing problems is responsible for the deterioration in the rank of sense organ diseases from 11 to 13.

The percentage change in DALY is due to the change in method from $DALY_{0,0,PLE}$ to $DALY_{1,0.03,SLE}$ as presented in Figure 9. $DALY_{0,0,PLE}$ has been taken as the base to determine the percentage change. The percentage change in DALY negatively shows a fall in DALY in the $DALY_{1,0.03,SLE}$ compared to the $DALY_{0,0,PLE,}$ and vice-versa. The percentage of change in DALY is highest for oral health conditions, followed by sense organ diseases, and lowest for musculoskeletal diseases.

Table 2 shows the DALY per lakh shrimp cultivators because most of the studies on the burden of diseases are estimated per one lakh people. $DALY_{0,0,SLE}$ method is based on equal age weightage, without discount rate, and standardized life expectancy. DALY is estimated in $DALY_{0,0,SLE}$ method to compare the burden of disease between shrimp cultivators and the national level in India estimated by the GBD 2019. The DALY per 100,000 shrimp cultivators is 28,477.74, 33,837.50, and
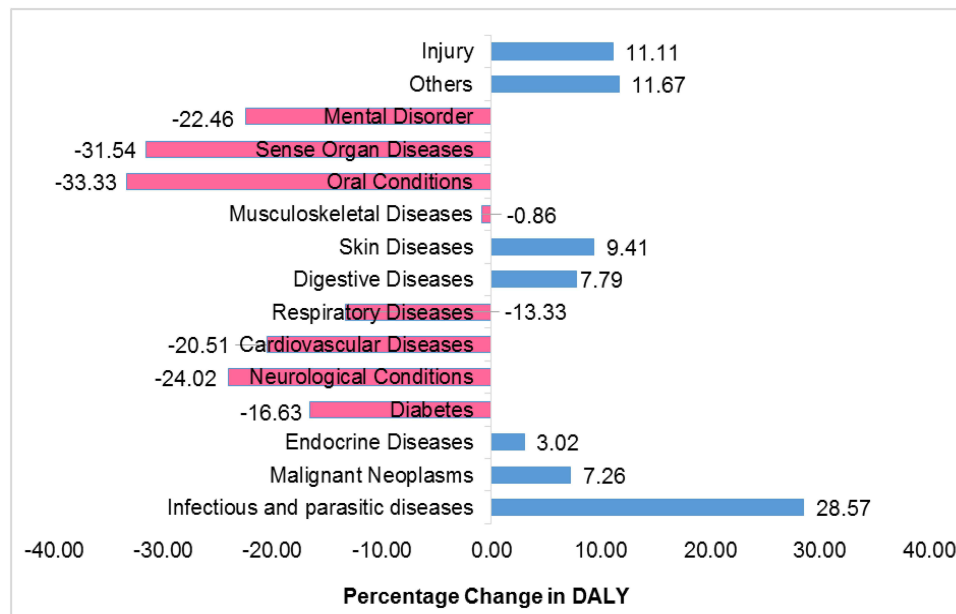
Figure 8 Impact of change in methodology on the rank of diseases (in descending order).
Note: Authors' calculation from primary data.

Figure 9 Percentage change in DALY (1,0.03,SLE) compared to DALY (0,0,PLE).
Note: Authors' calculation from primary data.

23,600.84 using $DALY_{0,0,PLE}$, $DALY_{0,0,SLE}$, and $DALY_{1,0.03,SLE}$ methods, respectively. The lowest DALY in the $DALY_{1,0.03,SLE}$ methods is because of the use of 3% discounting rate. The highest DALY based on $DALY_{0,0,SLE}$ is due to the higher life expectancy at each age when using the SLE method. The difference in DALY between $DALY_{0,0,SLE}$ and $DALY_{0,0,PLE}$ methods is the increase in YLL caused by the increase in life expectancy based on SLE compared to PLE

Table 2 Disability-Adjusted Life Years per 100,000 Shrimp Cultivator

Sl. No	Diseases	DALY (0,0,PLE)	DALY (0,0,SLE)	DALY (1,0.03,SLE)
I	Communicable diseases	78.65169	78.65	101.1236
1.1	IPD	78.65169	78.65	101.1236
2	NCDs	28,193.96	33,553.79	23,285.37
2.1	Malignant neoplasms	185.6742	174.16	199.1573
2.2	Endocrine diseases	120.7865	120.79	124.4382
2.3	Diabetes	5213.483	7095.51	4346.629
2.4	Neurological conditions	128.6517	129.21	97.75281
2.5	Cardiovascular diseases	6146.067	8137.64	4885.646
2.6	Respiratory diseases	16.85393	16.85	14.60674
2.7	Digestive diseases	1520.787	1519.66	1639.326
2.8	Skin diseases	47.75281	47.75	52.24719
2.9	Musculoskeletal diseases	1984.831	1994.38	1967.697
2.1	Oral conditions	0.421348	0.42	0.280899
2.11	Sense of organ diseases	73.03371	73.03	50
2.12	Mental disorder	12,705.06	14,193.82	9851.124
2.13	Others	50.5618	50.56	56.46067
3	Injury	205.132	205.06	214.3539
4	Total	28,477.74	33,837.50	23,600.84

Note: Primary data.
**Abbreviations**: IPD, Infectious and parasitic disease; NCDs, Non-communicable diseases.

Sensitive Analysis of Disability-Adjusted Life Years

The sensitivity of DALY to the change in the parameter's value is presented in Table 3. Sensitivity analysis shows the impact of parameters on the DALY. We used the DALY $_{1.0.03,\text{SLE}}$ method and only changed the values of C and β for sensitive analysis. The highest DALY is obtained when using β = 0.02 and C = 0.0634. DALY continuously falls with the rise in the value of C and β because the age weightage for people aged between 15 and 45 years is continuously falling, then rising. In the present study, 59% of people are between the age of 15 and 45 years. Therefore, the DALY continuously falls with the rise in C and β.

Table 3 Sensitiveness of DALY to Changes in the Value of Parameters (β, C)

Diseases	Parameter (*β*, C)				
	DALY (0.02, 0.0634)	DALYs (0.03, 0.1051)	DALYs (0.04, 0.1658)	DALYs (0.05, 0.2487)	DALYs (0.06, 0.3560)
Communicable	0.37	0.37	0.36	0.33	0.29
NCDs	90.72	87.07	82.9	69.96	62.03
Injury	1.00	0.87	0.76	0.80	0.72
Total	92.10	88.32	84.02	71.09	63.03

Notes: Primary data. Different combinations of β and C followed from the previous study.[38]
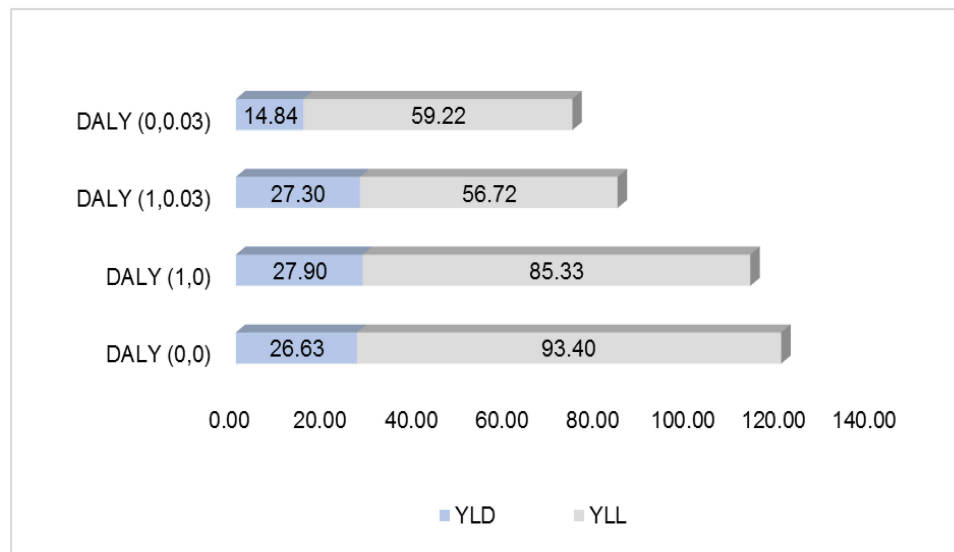
Figure 10 Scenario Analysis of DALY (k,r).
Note: Authors' calculation from primary data. For the calculation of DALY (1, 0) and DALY (0, 0.03), see reference numbers, respectively.[43,49]

Uncertainty Analysis of Disability-Adjusted Life Years

Scenario analysis of DALY is reflected in Figure 10. Scenario analysis explains the uncertainty in DALY due to changes in methods of estimation of DALY, such as applying equal age weightage (K = 0) or unequal age weightage (K = 1) and discount rate (r = 3%) or without discount rate (r = 0%). For this analysis, we use SLE for all methods, and C = 0.1658 and β = 0.04 when K = 1. The highest DALY in the DALY(0,0) method is then followed by DALY(1,0), DALY(1,0.03), and DALY(0,0.03).

Discussion

The literature review of the health status of fishermen in the present study is based on traditional health status measures like mortality rate, morbidity rate, standardized incident ratio, and relative risk of suffering from a given disease. However, this study used the DALY to measure health status. As a result, challenges arise when comparing the current study's findings with other studies due to methodological variation.[51] Besides these challenges, the present study's findings compare with other studies based on the number of people suffering from diseases.

The justification for the lowest age weightage given to the age group of 0–1 years (0.08) is that there is less economic loss when one person dies or suffers from illness at this age compared to other age groups because, at this age, there is less investment in a person compared to other age groups. The highest age weightage (1.518) is given to the age group of 25–30 years because of the peak stage of investment in a person at this age.[37] The greatest societal loss occurs when a person dies or suffers from illness at this age. Age weightage continuously falls after the age of 30 years because there is less loss to society when a death after this age.[52] There is zero or negligible return from investment in human capital between the ages of 20 and 30 years while receiving some return after the age of 30 years by participating in economic activity. Returns to human capital increase with age after the age of 30 years.[53]

Only one person has suffered from malaria. This finding contradicted the findings of the previous study which found that malaria was the main health problem among the fishermen.[54] The very negligible burden of malaria in the present study is due to shrimp cultivators being aware of malaria. There is zero prevalence of HIV among shrimp cultivators, while a previous study[55] found 19.7% prevalence of HIV among fishermen. This disparity is because of differences in occupational environments and countries.[56] Furthermore, typhoid is the main communicable disease among shrimp cultivators, but its prevalence is low (0.84%).

The present study used the DALY$_{0,0,SLE}$ method to compare the burden of diseases among shrimp cultivators with the national level burden of disease in India.[57,58] The burden of communicable diseases is lower among shrimp cultivators

(0.23%) than at the national level in India (30.45%).[58] The reason is the higher burden of communicable diseases among the elderly and children in India. In this study, children are not included. In addition, No one died from communicable diseases among the shrimp cultivators. It leads to a lower burden of diseases from communicable diseases. Another reason is that the sample size is limited to 357 shrimp cultivators. Further study is needed to compare the burden of diseases among shrimp cultivators with the burden of diseases at the national level in India.

The percentage of fishermen who have diabetes varies between 2.1 and 11, as found in previous studies.[6,19] In the present study, 5.6% of shrimp cultivators have diabetes, which is consistent with one study.[6] The percentage of shrimp cultivators who have suffered from digestive diseases is 9.8, supported by a previous study.[59] The reason is 64.6% of the shrimp cultivators do not have a timetable for eating meals due to heavy workload, as higher emphasis has been given to shrimp cultivation due to a mean expenditure of Rs. 291,679 per acre within three months for one-time cultivation of Vannamei shrimp. A lower percentage of shrimp cultivators has been affected by cancer compared to the previous studies.[7,24,26,60,61] The reason is the consumption of alcohol by shrimp cultivators (12.4%) is lower than in the previous study.[17–19,62] Also, 60.9% of shrimp cultivators coming under the ideal body mass index (BMI) is responsible for a lower burden of cancer in this study, which is consistent with the previous studies.[60,63] The long hours of physical work have led to more than 60% of shrimp cultivators having an ideal BMI.[64]

Cardiovascular diseases account for 33.33% of deaths among shrimp cultivators, while a previous study[60] discovered that it varies between 45% and 55%. The low mortality rate from cardiovascular disease in this study is because 87.1% of the shrimp cultivators belong to the working age.[65] The percentage of shrimp cultivators who have suffered from musculoskeletal diseases is 26.40. This finding is close to the previous study.[60] The reason for the second highest prevalence of musculoskeletal diseases among all types of diseases is the long work hours.[25] 49.2% of shrimp cultivators worked more than 10 hours per day. The prevalence of respiratory diseases varied from 0.3% to 13% in previous studies.[8,9] Its prevalence is 1.12% among shrimp cultivators, similar to one previous study.[10] The lower rate of prevalence of respiratory diseases in this study compared to the existing study[8] is due to the shrimp cultivators being more aware of respiratory problems because 86.8% of them have used masks during the process of administering medicine and bleaching in the pond.

The prevalence of work-related stress among shrimp cultivators is 85.39%. According to the literature review,[6,8] it ranges between 0.5% and 10.7%. The reason for higher stress among shrimp cultivators in this study is that 4.2% of the workers are from outside the family, and the rest are from within the family. Therefore, 95.8% of shrimp cultivators are self-employed. The higher risk of stress among self-employed people compared to paid employees.[7] The higher uncertainty in shrimp cultivation is another important cause of stress among them. Another reason for the prevalence of higher stress found in this study compared to other studies is that shrimp production is affected by an uncontrollable factor like shrimp viruses, which communicate from one pond to another pond. A percentage of 3.92 of the shrimp cultivators are affected by injuries, which is lower than in the previous study.[17] Previous studies on marine fishermen showed a higher risk of accidents. This study only considers the risk of accidents when transporting fish for sale and input to a cultivated place. The other sources of injury are the pump set and the aerator at the workplace. Therefore, the low prevalence of injury in this study is due to the low risk of injury at the workplace compared to the previous studies.[27]

Uncertainty analysis shows that the highest burden of disease among shrimp cultivators based on DALY (0,0) because of the fall in YLD due to not assigning age weightage is less than the rise in YLL for using without the discount rate.[65] The highest loss of YLD in the DALY (1, 0) method is because of the assignment of unequal age weightage.[32] The higher age weightage has been given to the age group between 15 and 45 years in unequal age weightage than equal age weightage.[33] This age group has the highest number of participants in this study.[65]

The YLL falls in DALY (1,0) compared to the DALY (0,0) method because the rise in YLL for a person dying at the age of 32 years is less than the fall in YLL due to a person dying at the age of 51 years and a person dying at the age of 55 years in the former method. The rise in YLL for a person's death at the age of 32 years is that the assigned age weightage is 1.468, which is higher than the uniform weightage equal to 1. The fall in YLL due to a person's death at the age of 51 years and a person's death at the age of 55 years resulted in the fall in age weightage for both ages in unequal age weightage.[37,38,66]

DALY estimated based on DALY (1,0.03) is less than the DALY (1, 0) method because of the fall in both YLD and YLL due to the use of a 3% discount rate in the former method.[38] The lowest DALY in the DALY (0,0.03) method is due to a fall in YLD and YLL compared to other methods. There are two reasons for the fall in YLD. One is assigning equal

age weightage to all age groups; 59% of the people who are between the ages of 15 and 45 years[65] lead a fall in YLD due to age weightage for this age group being less in equal age weightage than unequal age weightage. The second is that using a discount rate reduces YLD. YLL is also reduced due to the use of a discount rate.[37,43,66] Furthermore, YLL has been reduced more in the DALY (0,0.03) compared to DALY (1,0) method because the fall in YLL due to discounting rate is higher than the fall in YLL due to the use of age weightage in the present data.[38]

Conclusions

The contribution of the present study to the existing literature is the first attempt to quantify the burden of diseases by using DALY for the shrimp cultivators in India. Government intervention helps reduce the burden of diseases caused by mental disorders, diabetes, cardiovascular diseases, and musculoskeletal diseases among shrimp cultivators. The government should provide training to shrimp cultivators to manage stress. The introduction of an insurance scheme for shrimp cultivation against loss by the government should help to reduce stress among shrimp cultivators. Shift-wise working hours can help to reduce musculoskeletal and other diseases. Shrimp cultivators should take meals at a given time each day to minimize the burden of digestive diseases.

The limitation of this study is the small sample size. The result may change when the study is conducted by taking a large sample. This study did not adjust for the prevailing co-morbidity. Future research should concentrate on the burden of diseases by age group and gender, the comparison of the health and economic burdens of diseases, and the factors influencing the burden of diseases among shrimp cultivators.

Abbreviations

DALY, Disability-adjusted life years; YLD, Years of life lost from morbidity or disability; YLL, Years of life lost from mortality; PLE, Potential life expectancy; SLE, Standardised life expectancy; $DALY_{0,0,PLE}$, Disability-adjusted life years based on equal age weights, without discount rate, and potential life expectancy; $DALY_{1,0.03,SLE}$, Disability-adjusted life years based on unequal age weights, discount rate (3%), and standardized life expectancy; $YLD_{0,0,PLE}$, Years of life lost from disability based on equal age weights, without discount rate, and potential life expectancy; $YLD_{1,0.03,SLE}$, Years of life lost from disability based on unequal age weights, discount rate (3%), and standardized life expectancy; $YLL_{0,0,PLE}$, Years of life lost from mortality based on equal age weights, without discount rate, and potential life expectancy; $YLL_{1,0.03,SLE}$, Years of life lost from mortality based on unequal age weights, discount rate (3%), and standardized life expectancy; GBD, Global burden of disease study; NCDs, Non-communicable diseases; IPD, Infectious and parasitic disease; TBILTC, Traumatic brain injury long-term consequences; DALY (0.02,0.0634), Disability-adjusted life years estimated by using parameter $\beta = 0.02$ and $C = 0.0634$; DALY (0.03,0.1051), Disability-adjusted life years estimated by using parameter $\beta = 0.03$ and $C = 0.1051$; DALY (0.04,0.1658), Disability-adjusted life years estimated by using parameter $\beta = 0.04$ and $C = 0.1658$; DALY (0.05,0.2487), Disability-adjusted life years estimated by using parameter $\beta = 0.05$ and $C = 0.2487$; DALY (0.06,0.3560), Disability-adjusted life years estimated by using parameter $\beta = 0.06$ and $C = 0.3560$; DALY (0,0.03), Disability-adjusted life years based on equal age weights and discount rate (3%); DALY (1,0.03), Disability-adjusted life years based on unequal age weights and discount rate (3%); DALY (1,0), Disability-adjusted life years based on unequal age weights and without discount rate; DALY (0,0), Disability-adjusted life years based on equal age weights and without discount rate; BMI, Body mass index; ICD-10, International classification of diseases 10.

Data Sharing Statement

The datasets used and/or analyzed during the current study are available from the corresponding author upon reasonable request.

Ethics Approval

The present study was based on primary data. The participants/respondents provided their informed consent to collect data and the study complied with the Declaration of Helsinki. The study was conducted after obtaining approval from the Departmental Research Committee (DRC) of the Department of Analytical & Applied Economics, Utkal University, Bhubaneswar, India (Approval no. ECO/85(A)/2020 and Date of approval: 21/03/2020).

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Author Contributions

All authors have made substantial contributions to the study whether that is in the conception or design of the work; the acquisition, analysis, or interpretation of data; took part in drafting, revising, or critically reviewing the article; gave final approval of the version to be published; have agreed on the journal to which the article has been submitted; and agree to be accountable for all aspects of the work.

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Disclosure

The authors declare that they have no competing interests in this work.

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