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Knowledge, attitudes and practices related to health and well-being in a forest fringe community in southern India

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Abstract

Background Variations in healthcare perceptions, knowledge and behaviors across different socioeconomic strata and regions underscore disparities in healthcare access and satisfaction levels. The Covid-19 pandemic exposed the vulnerability of forest-dependent communities to increased disease risks and the need to involve local communities in pandemic preparedness through education and awareness regarding disease and ill-health. This article synthesizes the challenges with respect to health and disease, healthcare services, and access to the same among forest-fringe communities.

Methods We undertook a Knowledge, Attitudes and Practices (KAP) survey of 35 villages in and around the Mudumalai Tiger Reserve in southern India. Semi-structured interviews using open-ended questions were used to collect information from households on these broad themes: self-reported health issues, healthcare-seeking behaviors, opinion on the healthcare options available to them, risky-behaviors related to disease and ill-health, and self-perceived risk factors for disease or ill-health. Data was also collected on socioeconomic status. Reponses were converted to nominal categories and analyzed using mixed methods.

Results Our respondents self-reported a mix of acute (31%) and chronic (62%) health issues, with undiagnosed fever being the most reported acute ailment (57%). Access to healthcare services showed a preference for government facilities for primary care (63%) but private facilities for surgical procedures (30%, $p < 0.05$). A substantial portion (15%) reported paying more than a month's income for healthcare services. Education levels seemed to influence perceptions, with higher education correlating to a broader understanding of disease causation ($p < 0.05$). Lack of basic amenities such as clean drinking water, proper methods of garbage and sewage disposal, and access to nutritious food seem to be important risk factors for disease and illness. Overall, majority of the respondents (76%) expressed satisfaction with government healthcare services, reporting dignified treatment (64%) and regular visits by healthcare workers (74%, $p < 0.05$).

Conclusion Our study highlights the need to incorporate socioeconomic inequities and barriers while devising healthcare outreach, awareness and service program. We suggest interventions aimed at enhancing healthcare access and promoting healthier practices that mirror the specific needs and socioeconomic dynamics of the local communities for improved community health and well-being.

Keywords Public health, Community health, Healthcare access, Indigenous communities, KAP, India

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Background

Loss of biodiversity and the fragmentation of forests and natural habitats have been linked with increased risks of diseases, especially infectious and zoonotic diseases, in humans [1–5]. These risks are compounded by the challenges of underreporting, misdiagnosis, lack of surveillance and awareness which increase the burden of such diseases in most developing countries [6, 7].

Post-Covid-19 pandemic, healthcare systems globally have had to change the way they perceive preparedness and prevention. Now more than ever, it is clear that complete preparedness will only be successful and effective if all members of the community are informed, involved and included equally in their healthcare and outcomes [7–9]. The most effective and feasible approach is to educate local communities about disease risks and create awareness on how they can be prevented or mitigated [7]. In rural and remote areas, knowledge about disease, health conditions, risk factors and safe behaviors is limited due to the limited reach of health education and outreach programs.

Nowhere is this more important than in the forest fringe communities that live in and around the various protected areas in India. These areas are already challenged by their remoteness and difficult terrain. The people who live in and around these reserves are impacted, both directly and indirectly, by the forests and the wildlife within them [10–14]. The relationship and impacts are reciprocal [13–16]. Many of the people who live in these areas are non-natives and non-tribal who settled in the region 60–70 years ago. Unlike the indigenous/tribal populations, their connection to the forest and its wildlife is likely based more on the benefits they can get from the forests than any spiritual or cultural value that the forest and its inhabitants provide [17–20]. They are, therefore, more likely to engage in activities such as deforestation, encroachment on forest land, and habitat destruction [17–19, 21]. They are also more likely to tend livestock which graze in the nearby forests and interact closely with the wildlife living there [17, 19, 21]. This in turn might result in increased interface for disease interactions between these groups [22–27] and opportunity for disease spillover and emergence [6, 28–32].

According to the One Health High-Level Expert Panel's (OHHLEP) Theory of Change [33] one of the main anthropogenic influences on health are societal challenges. The pathway to change for better human and animal health includes data, evidence, education, and knowledge exchange. Knowledge and awareness on how diseases and ill-health occur, practices to avoid ill-health and ensure well-being, and even access to various healthcare options, however, are not the same across various communities. They may depend on various factors such as education, gender, type of livelihood activity, economic status, whether indigenous or non-indigenous to the area, among others [7–9]. It is important, therefore, to take these differences into consideration when designing education and awareness programs on healthcare and planning for accessible healthcare schemes and services[34–37]. One of the actions suggested include strengthening the scientific evidence base and using this evidence to inform best practices.

We, therefore, undertook a study among the communities living in and around the Mudumalai Tiger Reserve (MTR) in southern India, to understand how socioeconomic factors impact knowledge, attitudes and practices (KAP) to disease and health issues, healthcare services and access to the same. This study was part of a larger project to ensure better community health in the landscape with the aim of demonstrating the link between biodiversity conservation and human health and well-being. The goal was to enlist local support and participation in conservation activities [38] in the region under a One Health framework. By working with communities to identify and evaluate the status of their health and well-being, as well as that of animals in the region, we aim to develop more positive attitudes and invested participation by such communities towards biodiversity conservation [8, 9, 20, 39–41].

We hypothesized that people living close to the forests (in the core areas), and/or those practicing livelihoods that involve working in the forests or outdoors would be more likely to be affected by acute illnesses, due to increased risk of exposure to vector-borne, infectious and/or zoonotic diseases of wildlife origin. People living further away from the forests (buffer areas or on the boundaries) or working indoors would be more likely to be affected by chronic conditions, such as those impacted by stress and lifestyles. We also hypothesized that communities that have traditionally been forest dwellers (like the indigenous tribes) and those that have at least a high school education are more likely to be aware of risk factors for common diseases and conditions that affect well-being compared to non-indigenous tribes and people with lower education levels. Communities living close to the forests would also be less likely to have access to good healthcare services and schemes due to poor access to these areas as summarized by Ramesh et al., 2019 [19].

Methods

Study area

The Mudumalai Tiger Reserve (11°32'- 11°43'N, 76°22'-76°45'E) lies in the Nilgiri District of the southern Indian state of Tamil Nadu (Fig. 1) and is bound by the state of Karnataka in the north and the state of Kerala in the west. It is one of nine other protected areas that form

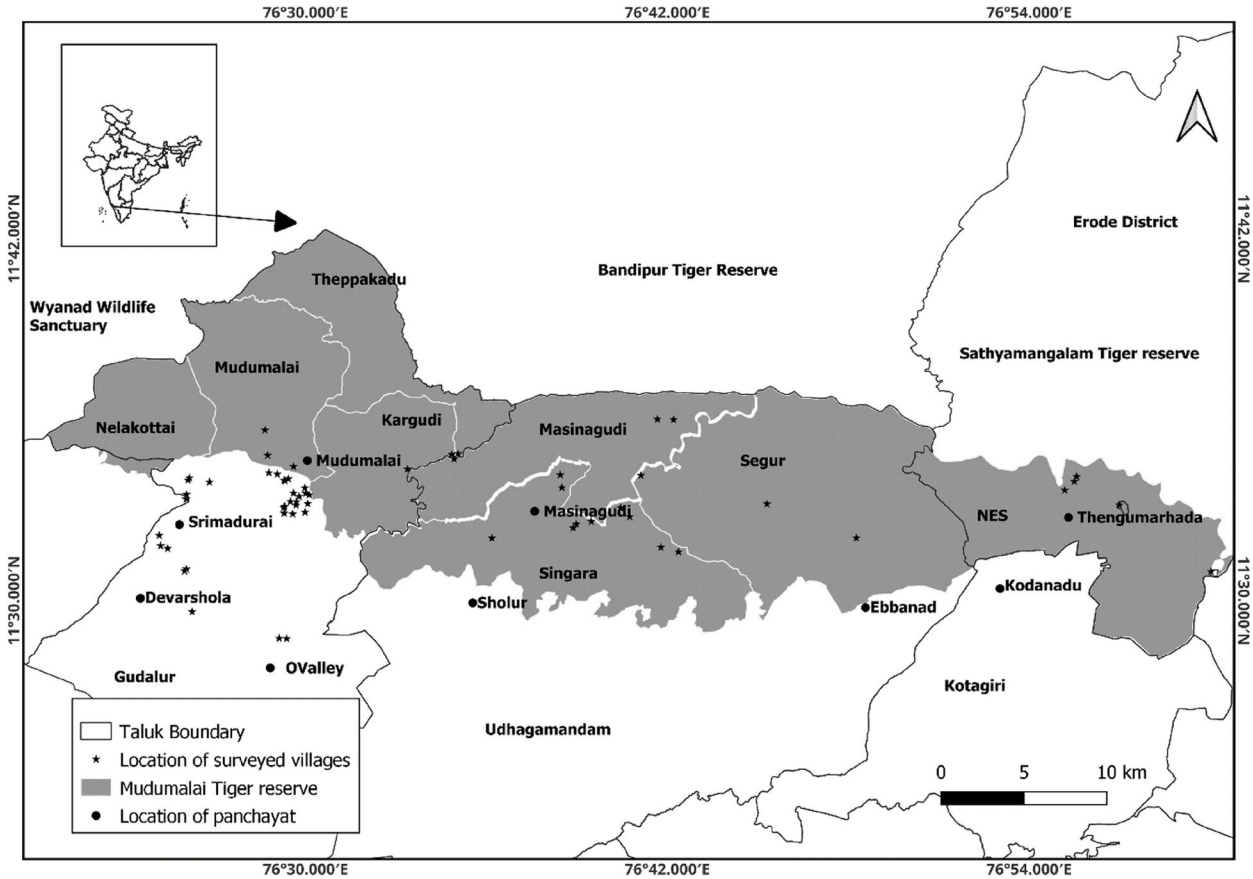

Fig. 1 Map showing the study area, Mudumalai Tiger Reserve, within India (inset)

The figure shows the location of the various ranges within the Mudumalai Tiger Reserve, located in southern India, and the villages and panchayats covered under the study

the Nilgiri Biosphere Reserve, an area identified as such by the United Nations Educational, Scientific & Cultural Organization (UNESCO) under its Man and Biosphere Program, for its unique value for biodiversity and humans. The elevation ranges from 850–1,250 m (2,790–4,100 ft) and the vegetation is predominantly tropical and subtropical moist broadleaf forests, with scattered scrub thorn forests, especially in the southeast. The Moyar river and its tributaries drains the Reserve.

The MTR consists of a National Park and Wildlife Sanctuary covering approximately 321 sq. km of core area, with about 367 sq. km of buffer zone. The core zone (an area where no human activity is permitted) comprises of the Mudumalai, Kargudi, Theppakadu and Nelakottai forest ranges. The buffer zone (a belt around the core zone where certain human activities, such as collecting firewood and other forest produce, are permitted) comprises of the Masinagudi, Segur, Singara, MTR boundary and North-eastern slopes (NES) forest ranges. A range is an administrative unit of the Reserve. The State Forest Department governs all forests and protected areas and is responsible for monitoring and managing human use and activity within these areas, as prescribed under the Wildlife Protection Act (1972) of India.

The Reserve experiences significant anthropogenic pressures from a large population that lives in and around it, as well as through the movement of people, animals, and vehicles through a national highway that runs through the Reserve [42]. The native or indigenous inhabitants (considered Scheduled Tribes, or STs, under the Constitution of India) have been living in proximity to the wildlife of the region for centuries. They include the Jenu Kurubas, Betta Kurubas, Soligas, Irulas, Kattu Nayakans and Phaniyas [19, 21, 43]. They are traditionally forest-dependent communities that have a cultural and spiritual connection with the forests and wildlife, and have lived sustainably off the natural resources. However, they (especially the Irulas) have slowly been transitioning to the more 'conventional' lifestyle of settler farmers and agriculturists, with much less 'economic' dependence

on the forest and its produce [21, 42, 44]. This has also resulted in a shift in lifestyles, healthcare practices, as well as exposure to diseases and health issues. The non-indigenous communities living in and around the Reserve, on the other hand, include people from various castes and religions who moved into the area from other parts of Tamil Nadu, Karnataka and Kerala [17, 18, 21, 43]. They depend on MTR solely for economic benefit, including through extraction of Non-timber Forest Produce (NTFP), grazing their livestock in the forests and tourism-related activities. They also practice settled agriculture and tend livestock [18, 21, 43] bringing them into closer interaction with other humans, animals and therefore, sources of disease and ill-health. In 2010, it was estimated that 1773 families lived inside the MTR in 54 different hamlets [18, 43]. However, 7 of these villages were relocated between 2010 and 2019 from the core areas of MTR [18, 43].

The main towns in the study area include Masinagudi and Gudalur. Most people in the target villages depend on forest produce, agriculture or livestock farming for livelihoods [21]. However, people in bigger towns have other sources of livelihoods including tourism, local plantations, and industries. As the main center for tourism in the reserve area, Masinagudi also has a significant impact and dependence on the MTR [19, 21, 43].

Administrative units

The entire study area falls within one district- The Nilgiris, which is subdivided into four blocks. Each block has several local governance subunits known as 'panchayats', each of which encompasses a group of villages in the area. The panchayat office is responsible for village level administrative and financial governance and management, including providing and maintaining basic services and amenities such as clean drinking water and sanitation.

Healthcare system

Healthcare and services is governed at the state level (which itself is monitored by a centralized federal system), with the State Health Department governing various District level hospitals. These in turn, are responsible for panchayat level Public Health Clinics (PHCs) and in some cases, Community Health Clinics (CHCs) which usually provide basic and intermediary level healthcare services at the panchayat level. Apart from regular healthcare workers, PHCs also employ a large number of semi-voluntary groups of basic, community level healthcare workers known as Accredited Social Health Activists (ASHA), and Village Health Nurses (VHN). These frontline workers form the backbone of the village level healthcare system and usually come from the communities they serve, hence, enhancing community level care and compassion. They are complemented by frontline child healthcare centres known as Anganwadi centres, developed by the Indian government under a program to combat child hunger and malnutrition. In addition, in Tamil Nadu, the state where this study was conducted, each district government hospital has a tribal health counsellor to help tribal communities access healthcare.

Sample size and data collection

A total of 35 villages (representing ~ 16,500 people) falling inside or within a zone of influence of 5 km distance from the Reserve boundaries were surveyed between April and October 2022 (Fig. 1). All villages fall under four blocks (Gudalur, Panthalur, Udhagamandalam and Kotagiri) and 9 panchayats (Mudumalai, Masinagudi, Thengumarhada, Srimadurai, Sholur, Ebbanad, Kadanadu, Devarshola, Ovalley) within the Nilgiris district. Mudumalai panchayat falls within the core zone of the Reserve. Masinagudi, Sholur, Ebbanad, Kadanad, Thengumarahada panchayats fall within the buffer zone while Srimadurai, Ovalley, and Devarshola panchayats fall within the boundary region (outside of the formal Reserve area) of the Reserve. Villages close to or within the boundary of MTR were sampled first, followed by villages within the identified zone of influence (Fig. 1). Sample size for the survey was calculated using the formula:

$$\left[z^2xp(1-p)/e^2\right]/\left[1+(z^2xp(1-p)/e^2N)\right]$$

where,

N = population size, e = margin of error (percentage in decimals), z = z-score (number of standard deviations a proportion is away from the mean; for 95% confidence interval (CI), it is 1.96).

Sample size for our study population of approximately 17,000 with a CI of 95% and a margin of error of 5% was about 375 households. As our populations varied greatly in socio-economic status, they were stratified based on caste and religion for each panchayat, and attempts made to sample each stratum proportionately (at least 5% of the total local population in each strata) in a random manner.

Data was collected using household surveys for family health and well-being. Three researchers were dropped at the center of target villages and they moved together in the same direction in every village, choosing random houses for sampling. All respondents and participants were informed about the study and its purpose, the privacy of their data, how it was going to be used, and how all of this required their voluntary participation as recorded in a verbal (recorded as audio message) or written (taken on pre-printed consent forms) consent. Only

those consenting to be interviewed and to the use of the data provided for our research purposes were interviewed. When other members of the family were present, they were encouraged to provide additional information, although the respondent was the primary source of all information. All interviews were conducted in the local languages (Tamil, Kannada and Malayalam) and data was later translated to English.

Interviews and analysis

Semi-structured interviews using open-ended questions were used to collect information from households, with each interview ranging from 2–3 h in length. Due to restrictions on accessing villages within the Tiger Reserve, and large distances from basecamp for those outside, interviews could not be conducted in the early morning and/ or late evening hours when most male members of the households would be available. Thus, there is likely to be a female bias in the results. The implications are discussed in the Discussion section. Interviews focused on these broad themes: self-reported health issues, healthcare-seeking behaviors, opinion on the healthcare options available to them, risky-behaviors related to disease and ill-health, and self-perceived risk factors for disease or ill-health (Supplementary File 1). Table 1 lists the broad themes and questions used to steer the conversation and obtain required information. The survey was standardized using pilot surveys, which were then discarded from the analysis. Specific themes and sub-themes emerging from the surveys, not covered under our pre-planned themes or questions were identified based on thematic analysis and responses to these were recorded as frequencies and then categorized under the respective theme. If respondents did not know the name of their specific disease or condition, they were encouraged to describe the symptoms they suffered. For descriptive statistics, all information was converted to 'yes' and 'no' responses, except for information on risky behaviours and opinion on healthcare services, which were converted to a 3–5-point Likert scale depending on the variable, with those not responding recorded as 'NR'. For some categories, such as socioeconomic status, 'don't know' responses were also classified as 'NR' since it was unlikely respondents were unaware of their caste, income or assets owned.

Information was also collected on demographic structure of families and their socioeconomic status. Specifically, information was collected on respondent's age, sex, livelihood (if any), educational and marital status, how long they had been living in the study area (generational; to establish residency), information on the family's caste category, age and sex composition, number of members in family group, educational status of other family members, main and alternative sources of livelihood, average monthly family income, movable and immovable assets owned if any (house or vehicle), whether have patta (legal document recording right of ownership) for land or house, access to electricity, water and sewage/sanitation systems, and the type of sewage systems available (open or closed). Ownership of immovable assets was used as an indicator of the living standard and economic status of the respondents. We also obtained information on whether the families possessed an Aadhar card (government-issued identity card), an Arogya card (government-issued health card) and/ or a Ration card (government-issued food subsidy program card) in order to assess if they were covered under any of the existing government health and welfare schemes. Since living inside Reserve boundaries comes with certain restrictions as well as benefits not applicable to those living in the boundary, we also categorized each village based on the panchayat (local administrative unit), range, and Reserve zone.

All interview data were analyzed using descriptive statistics. Chi-square, multinomial exact test and Pearson's coefficient were used to test the effect of individual socioeconomic factors on the respondents' knowledge, attitude and practices relating to health. Effect sizes were measured using Cramer's V. Where observed frequencies were too small for meaningful analysis, categories were clubbed and have been reported as such. Only results that were significant ($p < 0.05$), or significantly different from other category members ($p < 0.05$) with medium to high effect sizes (0.3 to 1) have been reported here.

The relationship between various independent variables (socioeconomic factors) and the response variables (KAP, health conditions) were analyzed using Multiple Correspondence Analysis (MCA). The MCA is similar to Principal Component Analysis (PCA) but for categorical data, that is converted into a numerical space, with binary indicators. Each row represents individual observations and each column represents a category. The rows and columns are then plotted on a factor map, with similar categories or observations appearing close together. This identifies the principal axes (dimensions) that explain the most variance in the dataset. The first few dimensions usually explain the most variance in the dataset. Interviews with NR responses for any of the independent variables (socioeconomic factors) were dropped from the MCA. Significance of associations were tested by testing the inertia explained by the first two dimensions in the MCA results against a reference value derived from the 0.95-quantile of the inertia percentage distributions from MCAs performed on 5000

Table 1 Broad themes and respective guiding questions for semi-structured household interviews

Self-reported health issues (self and family)	Risk factors for disease or ill-health	Risky-behaviours related to disease and ill-health	Health-seeking behaviours	Opinion on available healthcare options
Acute illnesses	How or why do you (or family) fall sick or get diseases?	Do you use the toilet or do you defecate in the open?	What do you do when you are sick?	Do you receive free/ subsidized healthcare service?
Chronic illnesses		Do you throw household waste in the open, or do you collect and cover it?	Where do you get your health services from?	Is the ambulance service available at all times?
Disability/ies		Do you wash your hands with soap? When?	Do you consult a doctor if you get any disease or illness?	How much money have you spent on healthcare (hospital) in last 3 years?
Unusual symptoms, if any (and possible cause)		Do you filter water for drinking purposes?	What facilities have you used at a government hospital?	How happy are you with government health services?
Surgery(ies)		Where do you get meat and milk from? How do you use it (uncooked meat and raw milk)?	Where do you go for surgeries and treatments?	Do you receive dignified healthcare?
Ongoing treatments/medications		Do you feel the necessity to wear a mask?	Have you attended health camps organized by the government?	Do Village Health Nurses (VHNs) and Accredited Social Health Activists (ASHAs) visit regularly?
Mental health issues/ suicides		Do you get timely vaccinations as prescribed by the government?	Where do you go for child birth?	What services do they provide?
Any child birth complications		Do you visit the doctor when acute illnesses persist for over a day?	What steps or measures do you take to prevent disease?	What facilities does your child receive at the Anganwadi center?
Abortions		Do you attend health camps regularly?	Do your children go to Anganwadi center?	How happy are you with the Anganwadi center services?
Covid-19 cases		Did you get the Covid-19 vaccine? If yes, how many doses?		Do you get free vaccines?
Hereditary health issues				Did you get free Covid-19 vaccines?
Death in family due to illness				
Most common health issue/ disease among people in village				

iterations of a simulated dataset [45–47]. If the variation explained by the MCA was greater than this reference value, then it was considered significant. The reports for the MCAs presented in this manuscript are provided in Supplemental files 3 and 4.

Results

Socioeconomic profile of target population

A total of 317 households were surveyed during our study [48] of the 375 planned, due to non-cooperation by some households approached for the survey and/ or due to economic and logistic constraints of the study. On average, about 4 households were interviewed per day, with a total effort of about 1300 interview hours over approximately 90 working days.

The socioeconomic characterization of households surveyed is presented in Table 2. Most of the respondents were indigenous or tribal people, followed by people who had settled here less than 60 years ago, while 20% were non-tribal people who had settled here more than 60 years ago. Our respondents were predominantly female because they were more likely to be at home and willing to speak to us when we interviewed them. Due to the diurnal time constraints of our surveys, we were unable to include representative number of male household members as they were mostly away at work and unavailable during the interview periods.

Twenty-one percent of our respondents claimed they were illiterate and the rest had at least an elementary school education. However, when we looked at the highest level of education for the family, we found that at least 40% of the families interviewed had education up to high school and 16% had at least an undergrad degree for at least 1 member (data not shown). Daily wage labor was the single largest source of economic benefit for 55% of the respondents, followed by agriculture and government jobs. Livestock were the main source of income for only 2% respondents but formed a second income for 6.5% respondents (data not shown). Interestingly, half the respondents said they had at least one livestock or poultry.

When we looked at interactions and interdependence between various socioeconomic factors, we found that while there were no significant interactions between any of the factors, there were associations between some (Chi-square test, $p<0.005$; Supplementary Figure S1). Panchayat was significantly associated with forest division and range. Hence, among forest division, panchayat, and range, we considered forest division as representative of all three for the MCA analysis. Caste was significantly associated with residency and so we used caste as representative for MCA. Forest division, education of the respondent, religion, forest range, and panchayat were all significantly associated with livelihood (Supplementary Figures S2 and S3). Thus, in the final MCA model, we used forest division, caste and education of respondent as the main socioeconomic factors impacting our variables. Gender was not associated with any other factor. Hence, we have considered it separately for all further analysis. However, this could have been a result of our respondents being predominantly female.

Higher income levels were positively correlated with access to clean water ($r=0.45$, $p<0.001$) while higher education levels were correlated with better access to electricity ($r=0.35$, $p<0.005$), sewage systems ($r=0.40$, $p<0.01$) and possess health (Arogya) cards ($r=0.50$, $p<0.01$), indicating better health outcomes for such groups.

Self-reported health issues among target population

Self-reported health issues- Thirty-one percent of our respondents reported having acute illnesses, mainly fever (24%), while 4% did not respond to the question (Fig. 2 (a)). Sixty-two percent of our respondents reported suffering from chronic illnesses or ailments, while 7% did not respond to the question. The most common (37%) chronic ailment was blood pressure (BP)-related issues, mainly high BP, followed by low hemoglobin levels (17.7%), diabetes (17%) and joint-related issues (15.5%) (Fig. 2 (b)).

Deaths in family- More than half the reported deaths among families of the respondents were due to chronic conditions (Fig. 2 (c)) with heart-related problems being the main chronic cause (heart attacks-29%, stroke-11%, heart disease-4%), followed by cancer (20%). Infectious or acute illnesses led to 20% of the deaths reported and 13% of the deaths were attributed to unknown reasons.

Medical or surgical treatments- In terms of medical assistance sought (Fig. 3), various surgeries were the most sought after (39%), followed by treatment for various ailments (38%), and treatment for unusual symptoms (24%) which were mainly undiagnosed fevers. Eleven percent respondents sought medical assistance for pregnancy and childbirth-related complications, 9.5% for Covid-19 disease, and 8% for various disabilities. Less than 2% respondents reported seeking help for mental health issues. Birth control-related (9%) and C-section surgeries were the most common surgical procedures reported among the respondents and their families, while treatment was sought mainly for BP-related issues (16%). Among pregnancy and childbirth-related complications, abortion was the main complication (10%) followed by prolonged labor (3.5%).

Common health conditions in community- Overall, of the 236 (74%) respondents who responded (Fig. 4), 57%

Table 2 Socioeconomic characteristics (self-reported) of respondents from communities living in and around Mudumalai Tiger Reserve, India

Socioeconomic category		*n*	%	Socioeconomic category		*n*	%
Panchayat (N=317)	Devarshola	34	11	**Main Livelihood** (N=310)	Agriculture	34	11
	Ebbanad	7	2		Daily Wage	148	48
	Kadanadu	7	2		Daily Wage (FD)	9	3
	Masinagudi	107	34		Driver	19	6
	Mudumalai	30	9		Govt	8	3
	O'valley	6	2		Govt (FD)	7	2
	Sholur	16	5		Govt (TNEB)	9	3
	Srimadurai	68	21		IT	4	1
	Thengumarahada	42	13		Livestock	6	2
Forest Range (N=317)	Kargudi	14	4		MGNREGA	12	4
	Masinagudi	76	24		Other	19	6
	MTR bounbdary	108	34		Pension	12	4
	Mudumalai	4	1		Resort	7	2
	Nellaikottai	4	1		Trade	16	5
	NES	42	13		NR	7	2
	Segur	14	4	**Income** (N=279)	0-20k	252	90
	Singara	47	15		20-40k	16	6
	Thepakkadu	8	3		>40k	11	4
Forest Zone (N=317)	Boundary	30	9		NR	38	12
	Buffer	177	56	**Patta** (N=305)	Yes (House)	25	8
	Core	110	35		Yes (Land)	105	34
Gender (N=317)	Female	226	71		No	175	57
	Male	91	29		NR	12	4
Religion (N=314)	Christian	27	9	**Vehicle** (N=298)	2W	62	21
	Hindu	267	85		4W	23	8
	Muslim	20	6		2W+4W	13	4
	NR	3	1		Commercial	8	3
Caste (N=308)	BC	53	17		None	192	64
	BC (Chetti)	7	2		NR	19	6
	General	6	2	**Electric supply** (N=302)	Yes (Free)	236	78
	MBC	49	16		Yes (Paid)	28	9
	OBC	19	6		Awaited	7	2
	SC	39	13		No	31	10
	SC (Adi)	11	4		NR	15	5
	ST (Bettu Kuruba)	30	10	**Water supply** (N=300)	Yes (Piped)	227	76
	ST (Irula)	61	20		Yes (Not piped)	73	24
	ST (Kaatu Nayakar)	17	6		NR	17	5
	ST (Mallasar)	1	0	**Cooking Fuel** (N=303)	Firewood	159	52
	ST (Other Kurubas)	5	2		Gas	142	47
	ST (Phaniya)	10	3		Induction	2	1
	NR	9	3		NR	14	4
Residency (yrs) (N=304)	0-20	26	9	**Aadhar Card** (N=297)	Yes	291	98
	20-30	23	8		No	5	2
	30-60	70	23		Awaiting	1	0
	60-70	25	8		NR	20	6
	70-80	27	9	**Ration Card** (N=297)	Yes	293	98
	80-100	7	2		No	5	2
	>100	2	1		Awaiting	1	0
	Indigenous	124	41		NR	18	6
	NR	13	4	**Arogya Card** (N=288)	Yes	179	62
Education Respondent (N=275)	Illiterate	58	21		No	108	38
	Primary School	59	21		Awaiting	1	0
	Secondary School	47	17		NR	29	9
	High School	87	32	**Sewage System** (N=265)	Yes	103	39
	College	24	9		No	162	61
	NR	42	13		NR	52	16
				Type of Sewage System (N=265)	Open	14	78
					Closed	4	22
					NR	299	94

Table 2 (continued)

MTR Mudumalai Tiger Reserve, *NES* North-eastern slopes, *NR* No response, *BC* Backward class, *MBC* Most backward class, *OBC* Other backward class, *SC* Scheduled caste, *ST* Scheduled tribe, *FD* Forest department, *Govt* Government, *TNEB* Tamil Nadu Electricity Board, IT = Information technology, *MGNREGA* Mahatma Gandhi National Rural Employment Guarantee Act, k = 1000, Patta = legal claim to land or house, 2W = two-wheeled vehicle, 4W = four-wheeled vehicle, 2W + 4W = owns both two-wheeled as well as four-wheeled vehicle, Commercial = vehicle used for commercial purposes, Gas = liquified petroleum gas (LPG) used for cooking, Induction = induction stove that runs on electricity used for cooking, Aadhar card = national identity card, Ration card = national card for access to subsidized food including oil, pulses, grains and flour, Arogya card = national healthcare access card

felt that fever was the most common ailment seen in the study area, followed by cough (53%), and 10% felt there was no illness at all in the study area. Interestingly, only 16% felt that lifestyle-related conditions such as high blood pressure, cholesterol, heart ailments, and diabetes, were more common in the study area.

Socioeconomic status and self-reporting of health issues While there were some differences in health issues reported from various panchayats, based on education levels and gender, there were no clear patterns and effect sizes were too low (Cramer's $V < 0.25$) to indicate significant differences. While caste and forest division did not seem to have any significant impact on occurrence of acute and chronic illnesses, when we looked at the combined model for caste, forest division and education, we found that tribal people living in the core, with up to primary level education were more likely to be associated with acute illnesses compared to respondents from other castes living in the buffer or boundary zone and with higher education levels (($p < 0.05$; Fig. 5 (a)). Similarly, the former were less likely to report chronic illnesses compared to people living in buffer and boundary zones (($p < 0.05$; Fig. 5 (b)). People working as daily wagers reported greater health issues compared to those engaged in more stable and formal modes of livelihoods such as government services, resorts, agriculture ($r = -0.42$, $p < 0.01$).

Knowledge, Attitude and Practices (KAP) related to disease and health

Risk factors for disease or ill-health

We asked respondents to identify the risk factors or causes for disease or illness in their family and community (Fig. 6). Majority (39%) claimed that drinking contaminated water was the main reason people fell ill. Interestingly, only 9% respondents felt that lifestyle and lifestyle-related practices were responsible for ill-health and 5% believed tourists were to blame for the same. Lifestyle and lifestyle-related practices here were identified (by respondents) as sedentary versus active, outdoor-based versus indoor/ office-based, 'western' rather than 'traditional' lifestyle. Western lifestyles were associated more with eating non-traditional food, living in congested towns away from nature, and having stressful working conditions such as in an office environment. Traditional lifestyles were associated more with eating traditional, locally available food, living in villages or more traditional houses, and practicing agriculture, livestock or forest-related livelihoods. Since both western and traditional lifestyles include smoking, alcohol consumption and other addictions (chewing tobacco, smoking marijuana or other narcotics), they have been treated as separate factors not associated with lifestyle changes. 'Other' factors (2%) included after-effects of Covid-19 diseases, mental health issues, infections from spitting in public places. One percent of the respondents each felt that mosquito bites, bites from other insects, livestock, not wearing masks, burning plastic waste, and pre-existing or hereditary conditions could be the reason for disease or ill-health (not shown).

Socioeconomic status and knowledge of risk factors for disease and health Most socioeconomic factors did not seem to have much of an impact on respondents' knowledge of the risk factors associated with disease or ill-health. The significant ones included correlation of panchayat (Chi sq = 102.281, df = 24, $p = < 0.001$, $V = 0.328$) and forest division (Chi sq = 100.338, df = 24, $p = < 0.001$, $V = 0.325$) with seasonal changes leading to ill-health. People living in villages outside or on boundary of the Reserve (Devarshola, Srimadurai, Sholur, Thengumarhada) were more likely to consider seasonal changes, especially rains, as a cause of sickness, compared to those living inside the Reserve (Masinagudi, Mudumalai).

(See figure on next page.)

Fig. 2 Acute (**a**) and chronic (**b**) health conditions and causes of deaths (**c**) self-reported by communities

HiCholest = high cholesterol levels, Low Hb = low hemoglobin levels, TB = tuberculosis, CNS = central nervous system related conditions, joints = joint-related issues, Low BP = low blood pressure, High BP = high blood pressure, Infec/ Acute causes = infectious or acute causes, condns = conditions, NR = no response

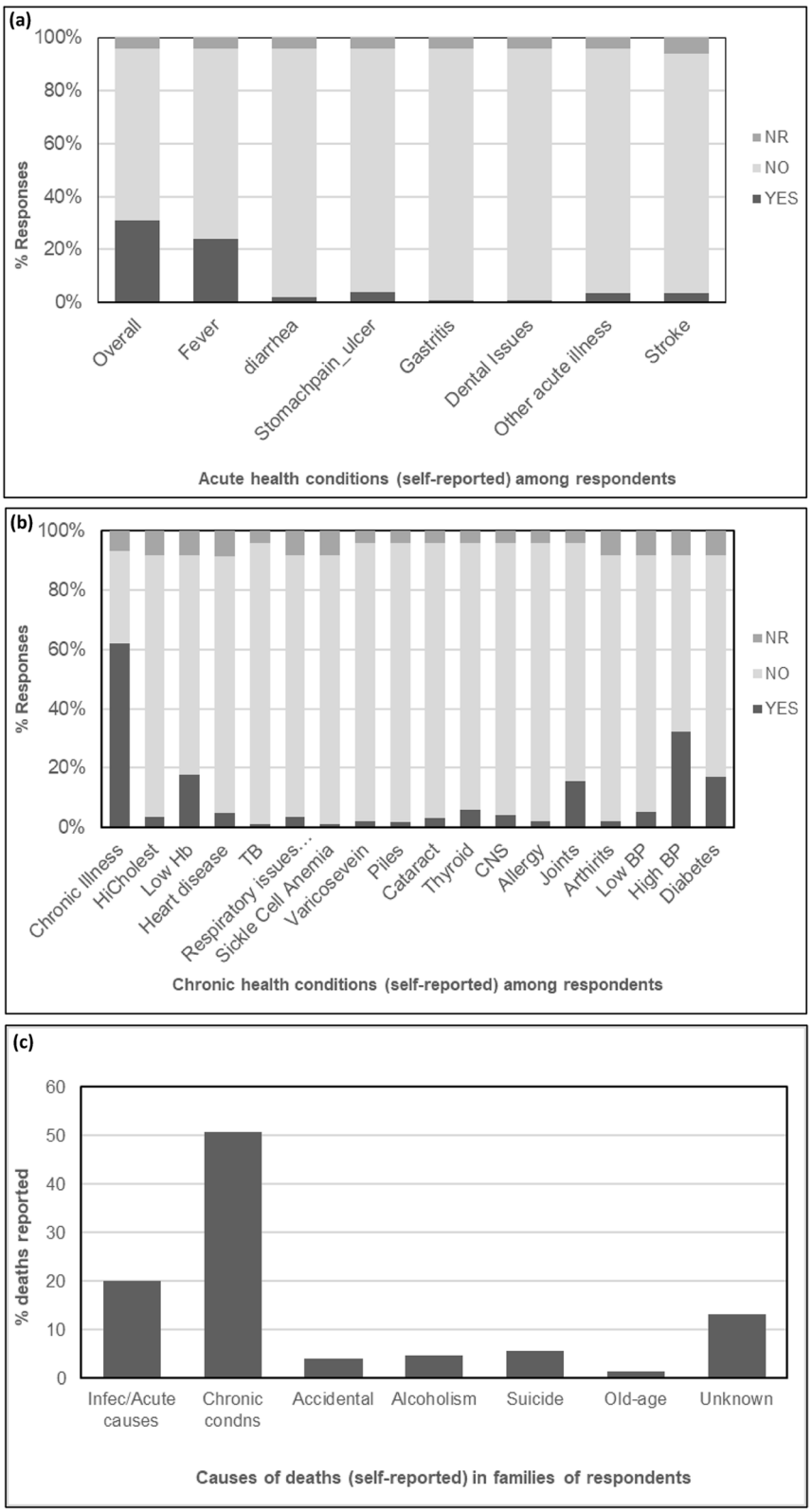

Fig. 2 (See legend on previous page.)

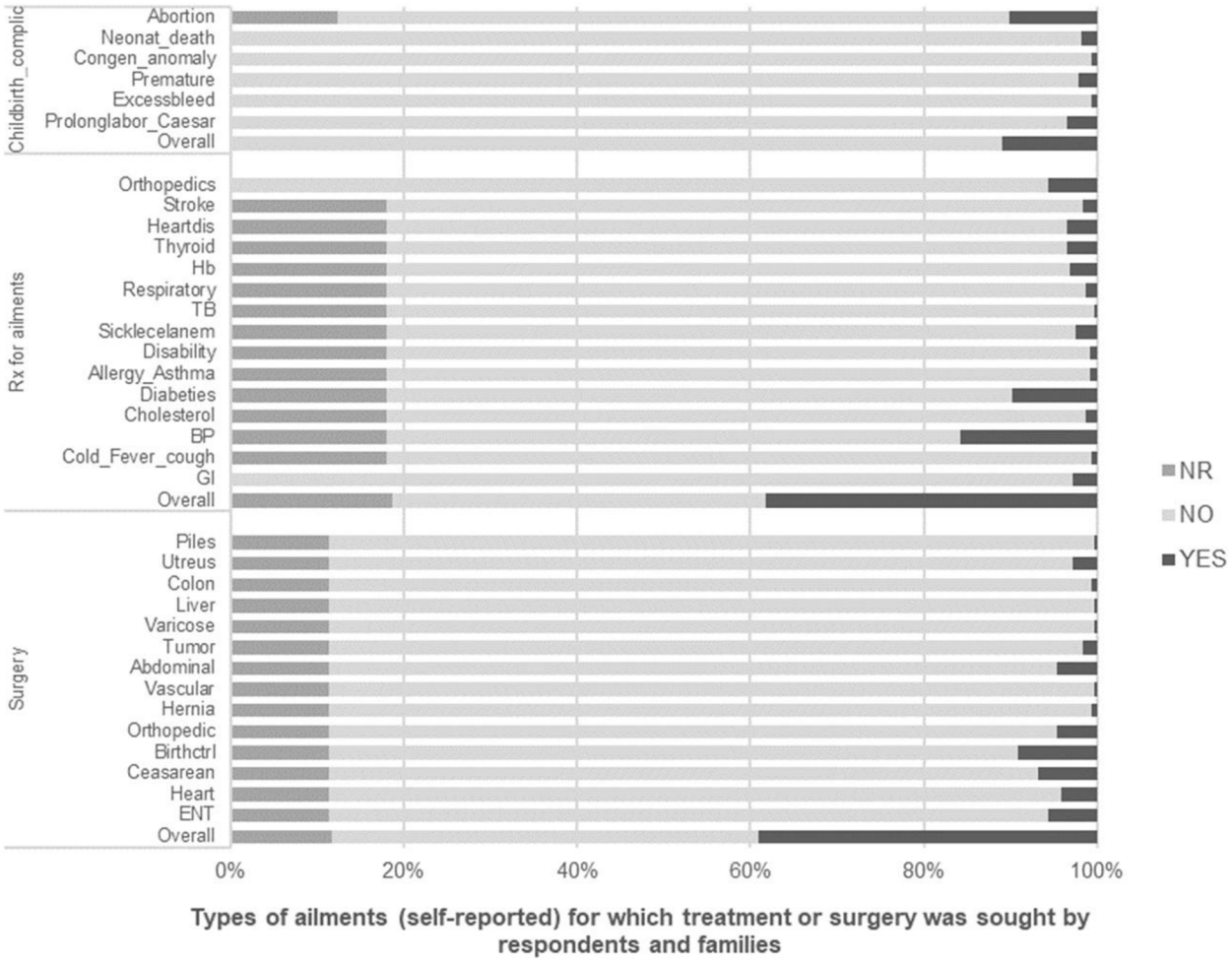

Fig. 3 Ailments or conditions (self-reported) for which treatment and/ surgery was sought in the study area

The figure shows the most common (self-reported) ailments and conditions for which treatments or surgery was sought by respondents & their families in the study area. Childbirth_complic = complications at or during childbirth, Neonat_death = neonatal death, Congen_anomaly = congenital anomalies, Premature = neonate born prematurely, Excessbleed = excessive bleeding (mother), Prolonglabor_Caesar = prolonged labour or caesarean section, Rx = treatment, dis = disease, Hb = low hemoglobin levels, TB = tuberculosis, Sicklecelanem = Sickle cell anemia, BP = high or low blood pressure, GI = gastro-intestinal ailments, Varicose = varicose veins, Birthctrl = birth control, ENT = ear, nose and throat, NR = no response

Most tribal people also (except Irulas) thought that lifestyle and related changes cause disease and ill-health, compared to non-tribal people. The former did not consider mosquito bites as a source of illness. People involved in agriculture and daily wages were also more likely to think that seasonal changes and getting wet in the rain would lead to illness and disease. People earning > INR 20,000 monthly were more likely to think that pollution can lead to disease and ill-health compared to those earning less. Education seemed to play an important role in knowledge regarding causes of disease and illness. Those with at least a secondary school education were more likely to think that poor hygiene causes illness compared to people who only had primary education or were illiterate. The latter were more likely to associate getting wet in rains with illness. Only graduates thought infectious agents and contagion from other sick people or animals could spread disease and ill-health. They were also more likely to think that tourists can spread disease in their area. However, all these factors had weaker effects ($V < 0.3$) even though they were significantly different ($p < 0.05$).

Risky behaviors related to disease and ill-health

When we looked at lifestyle and other practices followed by our study population (Fig. 7), we found that not getting vaccinations against infectious diseases (45%), not

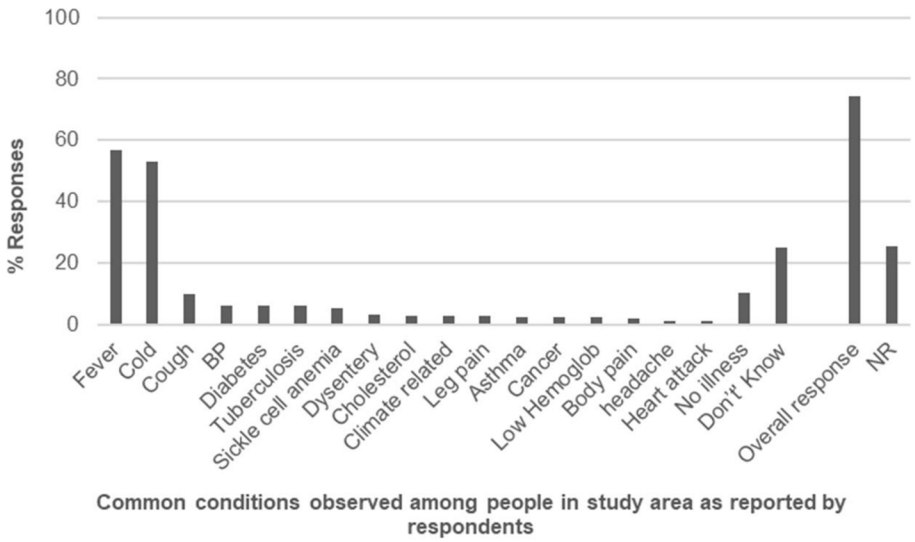

Fig. 4 Common conditions and health issues (self-reported) encountered among communities in the study area

The figure shows the most common health conditions or issues that have been observed in the larger community (apart from the respondent's family) by the respondents. BP = blood pressure, NR = no response

filtering or boiling water used for cooking or drinking (31%), and not attending health camps or seeking medical assistance for illness (29%) were the main risk factors associated with disease or ill-health.

Socioeconomic profile and risky behaviors related to disease and ill-health People belonging to STs (Chi sq = 95.407, df = 26, $p = < 0.001$, V = 0.388) and Indigenous people (Chi sq = 68.476, df = 16, $p = < 0.001$, V = 0.329), were more likely to practice open defecation even though they claim to have been provided toilets by the government (Chi sq = 31.053, df = 16, $p = < 0.013$, V = 0.330). All other caste, residency and education groups were more likely to use a toilet (Table 3).

Most STs and Indigenous people were more likely to throw waste in the open, or near forests, except ST (Irular) who preferred to use panchayat dustbins (Chi sq = 194.75, df = 91, $p = < 0.001$, V = 0.311) like the SC, BC and MBC. OBC and MBC groups were more likely to bury waste while people belonging to General caste reported burning them. In general, people living in the core of the Reserve reported burning or burying their waste while those in the buffer throw them in dustbins and those in the boundary bury or throw them near forests (Chi sq = 130.371, df = 14, $p = < 0.001$, V = 0.453).

Respondents from villages in the boundary zones were more likely to not wear a mask (Chi sq = 87.650a, df = 6, $p = < 0.001$, V = 0.372) and not wash hands (Chi sq = 59.412, df = 6, $p = < 0.001$, V = 0.306) after using the toilet or before cooking or eating. Villages in the boundary (Chi sq = 95.682, df = 16, $p = < 0.001$, V = 0.388) and people belonging to MBC or ST (Kattu Nayakan) (Chi sq = 222.025, df = 104, $p = < 0.001$, V = 0.311) were more likely to not consult a doctor for illness that persists for more than a day.

Overall, education of the respondent and caste seemed to be associated significantly with knowledge, attitudes and practices related to disease and ill-health (Fig. 8). People who were illiterate or studied up to primary school and belonging to ST caste (except Irulas and Kurumbas) had good knowledge of risk factors for, and more likely to practice safe behaviours against, disease and ill-health. They were more likely to use home remedies or traditional medicine for healthcare. These people were also likely to live in the core zone of the Reserve. ST Irulas had good knowledge of risk factors but were more likely to practice risky behaviours compared to other tribes. They were concentrated more toward the buffer zone of the Reserve. People who had at least a secondary school education, belonging to SC and BC caste had poor knowledge of risk factors for, and were more likely to practice risky behaviours leading to disease and ill-health. They were more likely to use a mixture of healthcare options including home remedies, traditional remedies and going to a hospital. They were mostly associated with the buffer zone of the Reserve. High school or college educated people, mostly belonging to BC, OBC and General caste categories and living more towards the boundary of the Reserve had poor to fair knowledge of risk factors and practiced some safe and some risky behaviours with respect to disease and ill-health.

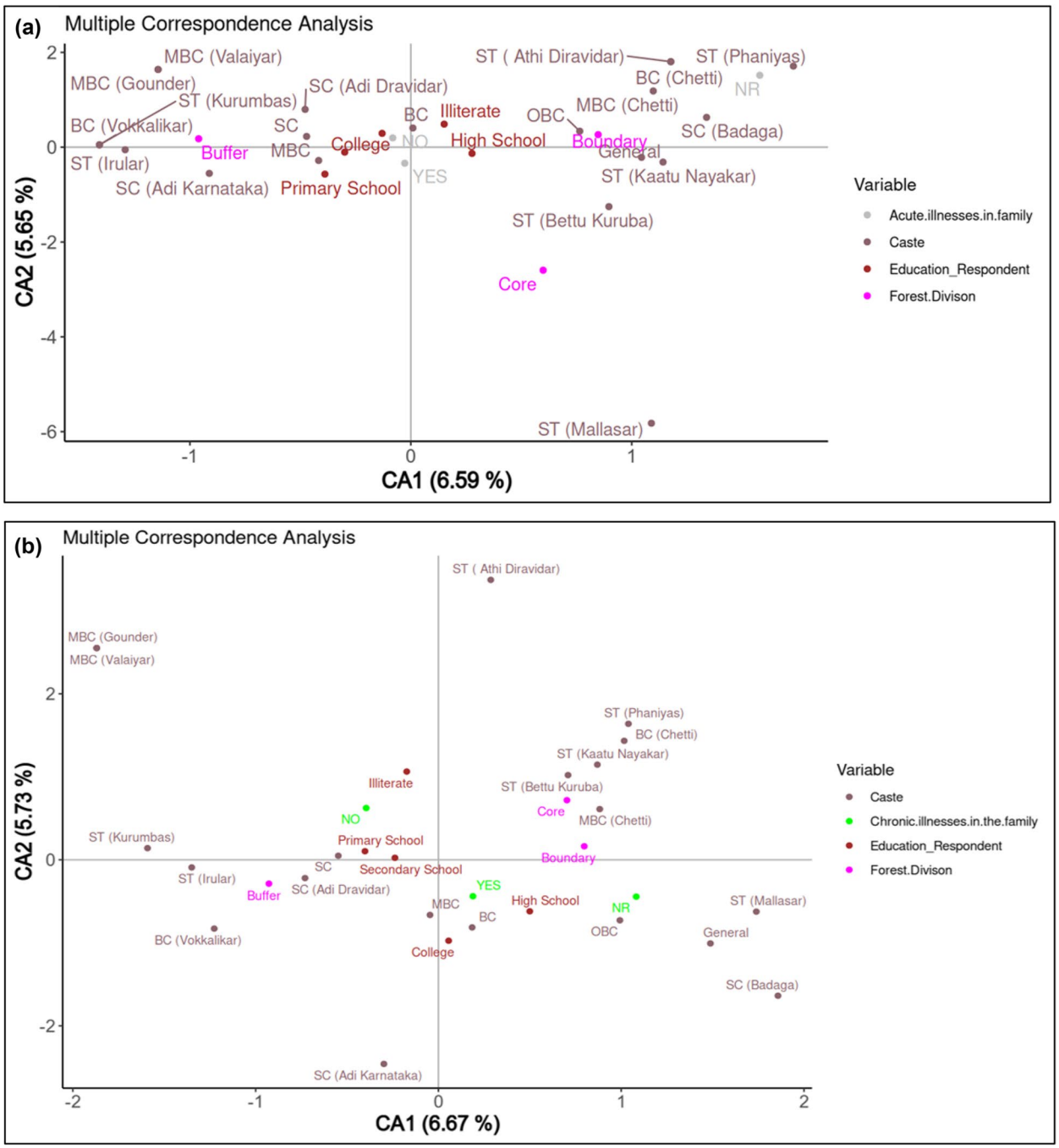

Fig. 5 Socioeconomic factors and acute (**a**) and chronic (**b**) illnesses in the study area ($p < 0.05$)

The figure shows the relationship between socioeconomic factors (cast, education level of the respondent and the forest division that their village belongs to) with the acute and chronic illnesses (self-reported) in their family. Abbreviations are explained in the text and in the legend for Table 1. **a**) The first two dimensions of the analyses express 12.24% of the total dataset inertia. This value is greater than the reference value that equals 11.52%, the variability explained by this plane is thus significant (the reference value is the 0.95-quantile of the inertia percentages distribution obtained by simulating 5000 data tables of equivalent size based on a uniform distribution). **b** The first two dimensions of analyses express 12.04% of the total dataset inertia. This value is greater than the reference value that equals 11.51%, the variability explained by this plane is thus significant (the reference value is the 0.95-quantile of the inertia percentages distribution obtained by simulating 5000 data tables of equivalent size on the basis of a uniform distribution). The MCA shows that tribals living in the core areas of the Reserve, with up to primary level education (if any) were more likely to report acute illnesses compared to respondents from other castes living in the buffer or boundary zones. Conversely, tribals living in the core areas were less likely to report chronic illnesses compared to the other castes living in the buffer and boundary zones

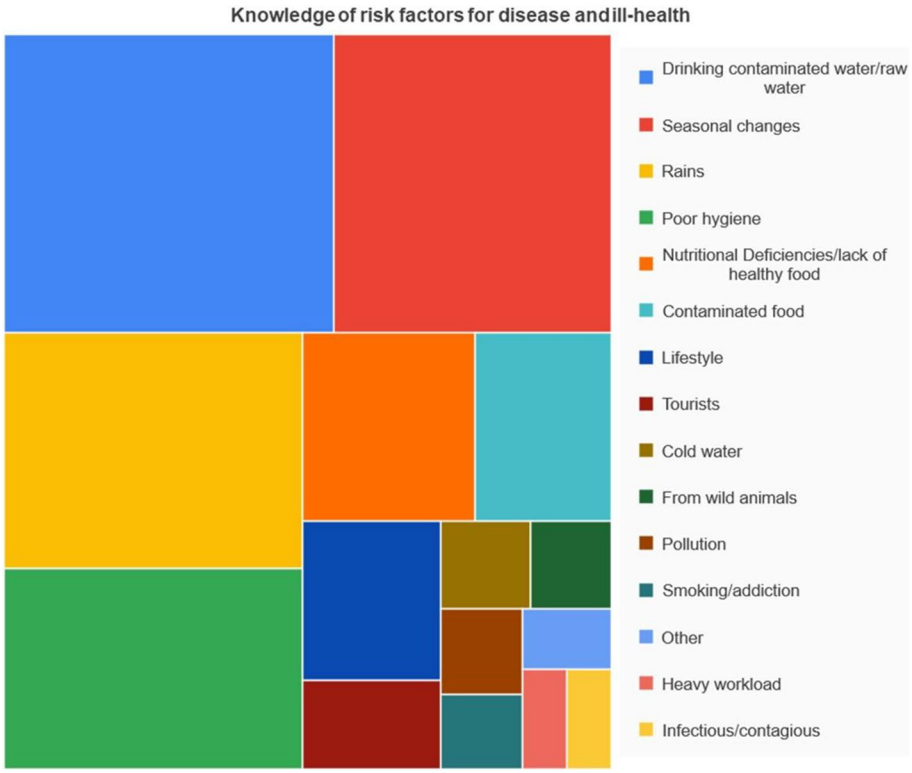

Fig. 6 Risk factors (self-reported) for disease and ill-health among communities in the study area

'Other' factors included after-effects of Covid-19 diseases, mental health issues, infections from spitting in public places. One percent of the respondents each felt that mosquito bites, bites from other insects, livestock, not wearing masks, burning plastic waste, and pre-existing or hereditary conditions could be the reason for disease or ill-health (not shown)

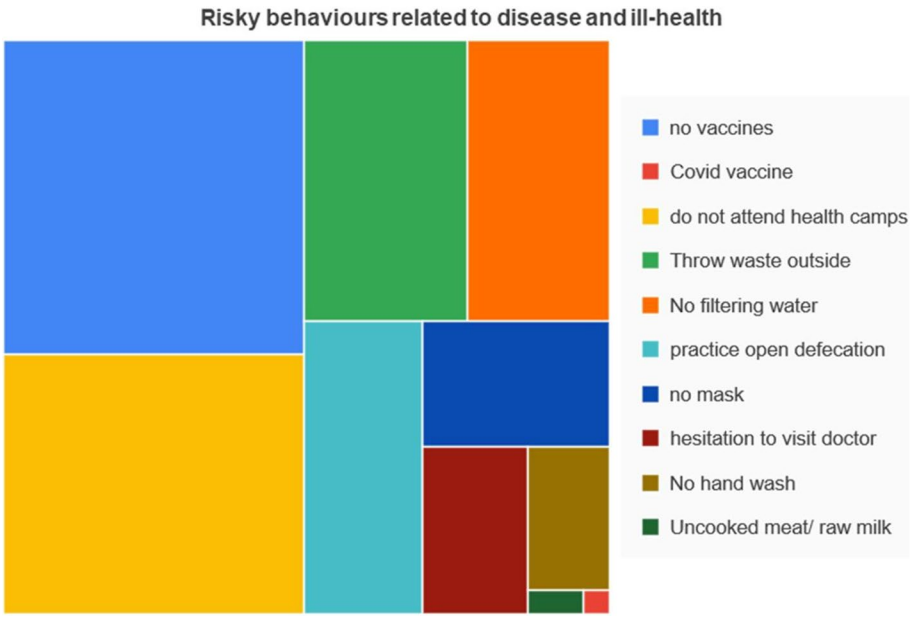

Fig. 7 Risky behaviours (self-reported) related to disease/ ill-health among communities in the study area

no vaccine = do not get themselves vaccinated against infectious diseases, Covid vaccine = did not get vaccinated against Covid-19, uncooked meat/ raw milk = do not cook meat before eating or boil milk before drinking

Table 3 Socioeconomic status and risky behaviours (self-reported) related to disease/ ill-health in the study area ($p < 0.05, V > 0.3$)

			Socioeconomic factors				
			Panchayat	**Forest Range**	**Forest Division**	**Caste**	**Residency (yrs)**
Risky behaviours for health reported by respondents	Toilet use and practice	Toilet	Masinagudi, Srimadurai, Thengumarhada			All Others	All except Indigenous
		Open defecation	Devarshola, Mudumalai, Sholur			All STs	Indigenous
	Toilet provided by Government	Yes				ST(Irular)	All except Indigenous
		no				Others mostly	Indigenous
	Sanitation & waste management	Bury	Devarshola	MTR boundary	Core, Boundary	General	
		Burn	Mudumalai	Kargudi	Core	MBC, OBC, ST(KNayakar)	
		Dustbin	Masinagudi, Sholur	Masinagudi, Singara	Buffer	BC, MBC, SC, ST (Irular)	
		Near forest			Boundary	ST(Bkuruba)	
		Throw out	Srimadurai, Thengumarhada	MTR boundary, NES	Boundary	BC(chetti), SC(A), ST(Okuruba),	
	Necessary to wear a mask	Yes	Masinagudi, Mudumalai, Thengumarhada	NES, Theppakadu			
		no	Devarshola, Srimadurai	MTR Boundary	Boundary		
	Hand wash after toilet use & before eating/ cooking	Yes	Thengumarhada	NES		General, BC, MBC, OBC	
		no	Devarshola, Srimadurai	MTR Boundary	Boundary	All others	
	consult doctor for illnesses > 1 day	Yes				All others	
		no			Boundary	MBC, ST(KNayakar)	
	filter water for drinking	Yes	Ebbanad, Masinagudi, Srimadurai, Ovalley				
		no	Devarshola, Sholur, Mudumalai, Thengumarhada				
	Timely vaccinations	Yes	Thengumarhada	NES			
		No	Devarshola, Sholur, Mudumalai	MTR Boundary	Boundary		
	Covid-19 vaccination & doses	2 doses	Ebbanad, Kadanadu, Masinagudi, Mudumalai, Sholur, Srimadurai, Ovalley,	Kargudi, Masinagudi, Segur, Singara, Theppakadu			
		3 doses	Devarshola, Thengumarhada	MTR boundary, NES			

Healthcare-seeking behaviors

Fifty-two percent of respondents reported that they visit a doctor or clinic when they fall ill (Fig. 9), while 25% preferred to take care of it themselves, through home remedies (19%) or self-medication (6%). Most people (42%) approached government health facilities, 17% used private health facilities, 39% used both government and private facilities. Among those who used government healthcare facilities, 63% used primary healthcare centers, 24% used secondary healthcare centers while 13% used tertiary healthcare centers. However, for surgical procedures, the majority (42%) reported using private

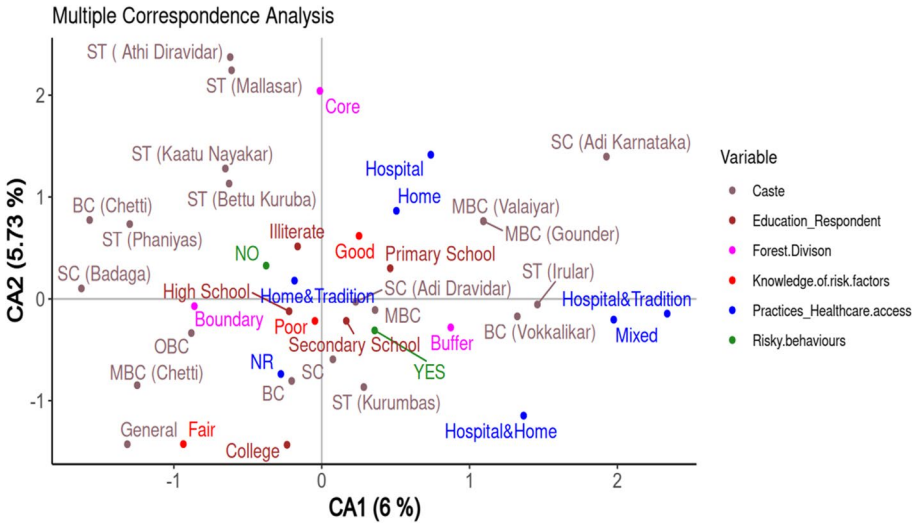

Fig. 8 Socioeconomic factors and KAP related to disease/ health among communities in the study area ($p < 0.05$)

The table shows the relationship between socioeconomic factors (caste, education level of the respondent, and the forest division their village belongs to) with knowledge of risk factors (Good, Fair, Poor), risky behaviours (Yes, No) practiced by the respondents with respect to disease and health, and their practices with respect to seeking healthcare or accessing the same (Hospital = go to the hospital, Home = use home remedies, Hospital&Tradition = visit hospitals and use traditional medicines or healers, Home& Tradition = use home remedies and traditional medicine or healers, Mixed = use home remedies, traditional medicine and also visit hospitals, NR = no response). Other abbreviations are explained in the text and in the legend for Table 1. The first two dimensions of the analyses express 11.72% of the total dataset inertia. This value is greater than the reference value that equals 10.07%. The variability explained by this plane is thus significant (the reference value is the 0.95-quantile of the inertia percentages distribution obtained by simulating 5000 data tables of equivalent size based on a uniform distribution). The MCA shows that respondents belonging to the scheduled tribes (ST) living in the core region of the Reserve and were either illiterate or had primary level of education were more likely to be aware of risk factors and practice safe behaviours against disease and ill-health. They were also more likely to use home remedies or traditional medicine for healthcare. As we move away from the core, the knowledge and safe behaviours about disease and health decreased, being fair to poor among the general public living in the boundary areas away from the forests, even though they had better education (at least secondary level). They were more likely to use hospitals for healthcare

healthcare facilities, with only 30% using government centers only and 9% using either. Sixty-fiver percent respondents went to hospitals for childbirth while 25% said they opt for home births. Of the 47% who responded, 20% said they received free healthcare services while 15.5% said they paid more than INR 20,000 per year for the same. About 53% respondents attended health camps organized by the government, while about 5% attended them sometimes or rarely. About 25% did not attend any health camps.

Socioeconomic profile and healthcare seeking behaviors There was no major effect of education on type of healthcare sought. All respondents were equally likely to opt for self-medication, traditional medicine, home remedies or herbal medicine and going to the hospital.

Those with at least an elementary education were more likely to opt for government healthcare service providers than private compared to those who self-identified as illiterate. Respondents who were illiterate or studied up to primary school were more likely to opt for home births than hospital deliveries. Those who had some level of college education were more likely to opt for giving birth in a government or private hospital.

While there was no clear difference, those who had high school or greater level of education reported spending more on healthcare (> INR 20,000 per year) compared to those who were illiterate or studied only up till secondary school.

Opinion on available healthcare options

Seventy-seven percent respondents felt that they had good access to ambulance services, and only 7% felt otherwise. 64% respondents felt they received dignified access to healthcare (they were treated with respect and same consideration irrespective of caste, religion, sex, or socioeconomic status). Majority of the respondents claimed that they were visited by ASHAs/VHNs regularly (74%) or occasionally (5%), while only about 11% claimed not to have been visited by either. About 23% respondents availed Anganwadi services and of these about 43% were happy and 4% were satisfied with these services.

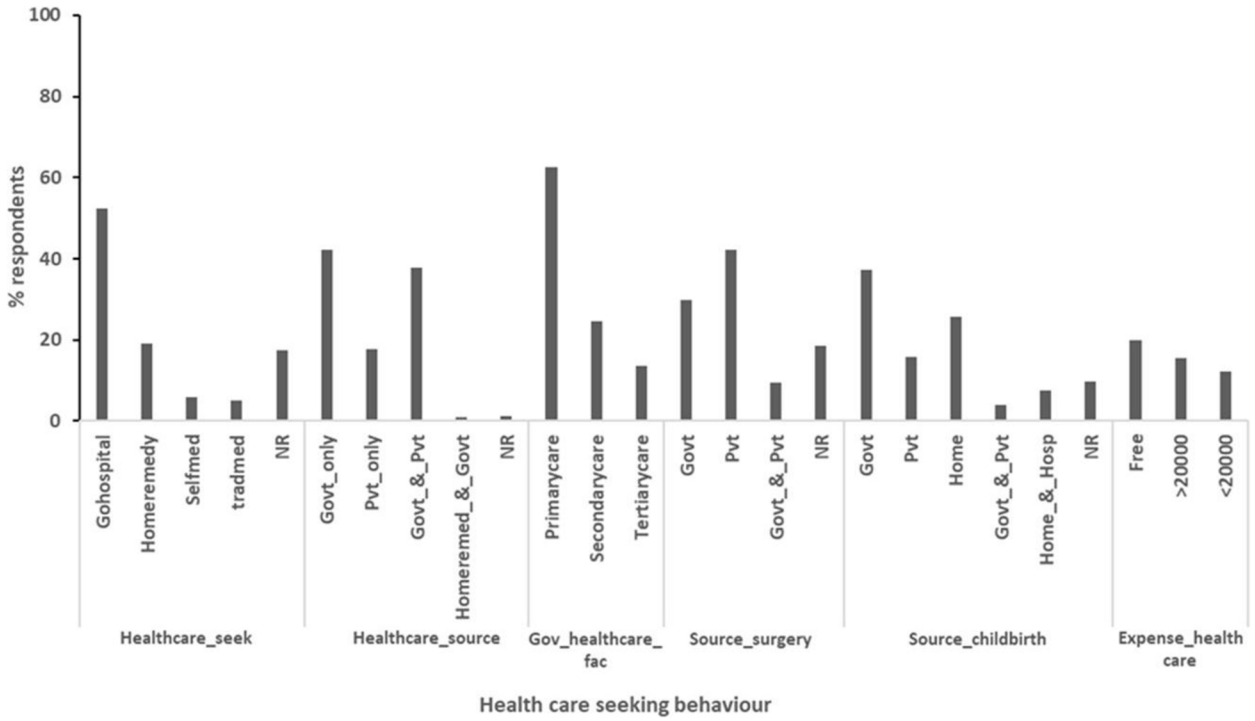

Fig. 9 Healthcare-seeking behaviours (self-reported) among communities in the study area

The figure shows the healthcare seeking behaviour (Healthcare_seek) of the respondents (Gohospital = visit the hospital; Homeremedy = use home remedies; Selfmed = self-medicate; tradmed = use traditional medicine; NR = No response), the source of healthcare (Healthcare_source; Govt_only = Government services only; Pvt_only = Private services only, Govt_&_Pvt = use both Government & Private services, Homeremed_&_Govt = use both home remedies and government services, NR), type of government provided healthcare facility used (Gov_healthcare_fac; Primarycare, Secondarycare, Tertiarycare), where they get surgeries done from (Source_surgery; Govt, Pvt, Govt_&_Pvt, NR), and where they go for childbirth (Source_childbirth; Govt, Pvt, Govt_&_Pvt, Home_&_Hosp = home and hospital, NR), and the Annual Expense for healthcare (Expense_healthcare; Free, < INR 20,000, > INR 20,000, where 1 INR = (approx.) 82 USD)

Overall, about 76% were happy with government healthcare services, while about 12% were somewhat satisfied. Another 12% were dissatisfied with government healthcare facilities and/or services.

Socioeconomic profile and opinion on available healthcare options People living in villages falling within MTR boundary zone, belonging to BC (Chetti), OBC, and ST (Irula) castes and with medium to high income, with access to electricity water and government-issued cards were likely to have better access to healthcare, more likely to be satisfied with government healthcare services and more likely to attend health camps.

People living in villages in MTR boundary zone, identifying as belonging to BC (Chetti), General, MBC, OBC, ST (Bettu Kuruba), ST (Phaniya) castes, working as daily wagers, with the Forest Department, or engaged in 'Other' livelihood activities, non-indigenous people, with lower monthly income (< INR 20,000) felt that healthcare workers treated them with dignity and respect.

Ambulance services- Respondents from boundary and some buffer zone villages of the Reserve expressed satisfaction with ambulance services as also those self-identifying as MBC, OBC, ST (Paniya), ST (Irula), residing in the area since less than 60 years, with income < INR 20,000.

People living in buffer zone, who had lived in the region for > 70 years or were Indigenous, were Hindus, with income < INR 20,000, who had a patta for house or land, received free electricity and/ or piped water, used gas to cook food, and/ or, who had an Aadhar and Arogya card, reported satisfaction with the services of the ASHA workers. However, people living in the boundary zones, or had settled here < 60 years, or did not have a patta, or collected firewood were not happy with services of the ASHA workers. People living in villages within the MTR boundary and core zones, or those who used gas for cooking, or possessed an Arogya card were satisfied with the Anganwadi workers and their services.

Discussion

In order to ensure community participation in healthcare outcomes, we need to ensure that the communities are aware of the problem, are involved in finding a solution, including incorporating into policies, and included in the final implementation of the same [7]. Our study provides comprehensive insights into the socioeconomic landscape, prevalent health issues, healthcare-seeking behaviors, and perceptions of healthcare services among the surveyed population.

We found that knowledge regarding risk factors for health and disease differed between community members depending on their socioeconomic status and demography. More than half of our respondents were either indigenous/ tribal people (more than one-third of total respondents) and people who had lived in the region for more than 60 years. Among tribal people, Irulas were the largest group in our study. The educational status of our respondents and their families (half the respondents were illiterate or had primary education) potentially also reflects on the main source of livelihood, which was daily wages (labor) for more than half the respondents, followed by agriculture. This is in concordance with results from Ramesh et al., 2019 [19]. Interestingly, livestock was the main livelihood for only 2% of the population. This is in contrast to previous studies from the region [19, 21, 49], which reported between 11 to 19% dependency on livestock for livelihood in the region. Per capita livestock ownership, too, seems to have decreased from 68% in 2001 [49] to about 50% in this study. This could be an outcome of the strict ban against grazing of livestock within the MTR imposed by the Tamil Nadu Forest Department. This in turn could potentially have an effect on the zoonotic illnesses reported from the community or risks from the same.

Majority of our respondents were women due to time constraints in access to many areas. Although we did ask respondents to talk about family practice when it came to attitude and practices, knowledge would have been influenced by the individual's education, perception and awareness. Women are typically marginalized in rural Indian societies and households. Thus, this gender bias could potentially be reflected in education levels of the respondent and knowledge of health issues, healthcare services and access to the same; knowledge of and access to government and other schemes for healthcare; attitudes and healthcare-seeking behaviour. However, women are typically the primary caregivers in Indian communities and responsible for family and children's health and hygiene. Therefore, information collected in our study would more accurately describe the knowledge, attitudes and practices related to health and healthcare in our target communities. Thus, this bias does not necessarily affect the goal of our study: improving community health and well-being through improved awareness, access, and equity.

In general, though there was limited ownership of land or vehicles among respondents most households possessed Aadhar and ration cards, indicating potential for access to government schemes and subsidized rations. However, about half the respondents did not have any health insurance or Arogya card. This could be a deterrent in terms of use of health services, as evidenced by only half the respondents participating in government-organized health camps, indicating limited engagement with healthcare outreach programs.

Our data clearly indicate a link between levels of education, income, source of livelihood and caste and hence, access to basic amenities such as clean drinking, piped water, electricity, subsidized food and health cards. People from non-marginalized castes (BC, OBC, General) tended to have higher education levels, better incomes and access to basic amenities compared to those from ST and SC backgrounds. Unfortunately, we could not find clear interactions between these factors and their impacts on each of the variables. Perhaps a larger sample size or more intensive sampling of different socioeconomic groups would help elucidate these complex interconnections and interactions.

At least a quarter of the respondents claimed to have no or limited access to clean drinking water. Sewage systems were lacking in more than half the households, posing a public health hazard. Cooking methods still primarily relied on firewood (52% respondents). This could lead to increased upper respiratory tract health conditions. The need to collect firewood would also bring the locals in direct conflict with wild animals as well as the forest department [17, 21, 49]. While LPG was used by almost 47% of the respondents, most of them also used firewood in addition to LPG when available. LPG was considered economically costlier, and dangerous, owing to the fear of house fire by LPG usage.

Our respondents self-reported a mix of acute (31%) and chronic (62%) health issues. Among acute illnesses, fever was the most reported ailment (57%). Villages inside the Reserve, especially in the core areas, reported more acute conditions like unexplained fever, body pain, inability to move well. These people are more likely to come into contact with wildlife and vectors of diseases, hence, these symptoms could be indicative of undiagnosed infectious and even zoonotic diseases [50–53]. However, households in the buffer zone were more likely to report pollution and insect-related illnesses as cause of ill-health. Chronic conditions such as high blood pressure, diabetes, and joint-related issues were reported at much lower levels overall, but lower in core zone compared to the

buffer or boundary zone. Surprisingly, less than 1% of the respondents reported having tuberculosis, which is much below the national average incidence of 36% per 100,000 population [54]. This could be due to their reluctance to admit the same because of the stigma still attached to the disease [55, 56]. We were unable to obtain panchayat level health data from the district public health office to confirm if these numbers reflect the true prevalence in the study population. Similar is the case with sickle cell anemia which was reported by less than 1% of the respondents, even though 39% of them were tribal people, a demographic known to be especially susceptible to the disease in the region [57–59].

In contrast to people's perception, chronic health issues accounted for a significant percentage of reported family deaths, primarily attributed to heart-related problems and cancer. This was surprising. We had expected people living close to natural areas to be affected more by acute illnesses, especially infectious diseases [50, 51] and less with chronic illnesses like high blood pressure which are more indicative of lifestyle-related ailments. The latter are expected to be more common in an urban rather than rural population. We did see a gradation with respect to chronic ailments in our study group, with people living in the core region, who were mostly Indigenous and presumably with large dependency on the forest for their livelihood, food and medicines, reporting fewer chronic ailments compared to people in the buffer and boundary zones. The former group reported more acute illnesses, especially fevers of unknown origins. This indicates that healthcare outreach must be targeted differently toward the two groups.

Mental health issues were also underreported, as evidenced by the discrepancy in number of cases self-reported (2.5%) vis-à-vis the number of deaths (5.6%) due to the same, possibly due to societal stigma, implying potential discrepancies between reported and actual figures. Studies have suggested that indigenous and tribal people suffer disproportionate levels of mental health-related issues due to a history of overexploitation, maltreatment and other atrocities committed against them [60]. Hence, it is important to study mental health issues among the people, especially indigenous people, in the region in more depth.

While more than half our respondents sought medical assistance from doctors or clinics when ill, a considerable proportion preferred home remedies or self-medication. This seemed more an outcome of persisting traditional healthcare practices in the region than any lack of faith in modern medicine [56, 61]. Most of the persons attending health camps seemed to be tribal people from within the core area, possibly due to the regular number of health camps organized by the Forest Department within the Reserve. Access to healthcare services showed a preference for government facilities for primary care but private facilities for surgical procedures (mainly childbirth and family planning). This could be due to the large number of target population living in the core areas having limited access to private hospitals (as also evidenced by the results of Ramesh et al., 2019 [19]. They do visit the Accord Hospital, a private hospital specializing in subsidized tribal healthcare, run by a local non-governmental trust in Gudalur town in the boundary of the Reserve. A substantial portion reported paying for healthcare services in excess of INR 20,000 annually. This is significant considering that about 80% of the respondents earn less than INR 20,000 per month [37, 62]. Therefore, apart from raising awareness on when and how to seek healthcare, it is important to make these healthcare services more easily available and accessible [63–66].

Knowledge, Attitude, and Practices (KAP) Related to Disease and Health:

The understanding of disease causation varied among respondents, with a predominant belief that contaminated water and seasonal changes were leading causes of illnesses. Education levels seemed to influence perceptions, with higher education correlating to a broader understanding of disease causation, including lifestyle-related factors and contagion from sick individuals, including Covid-19. This suggests better access to health information and services. Higher education correlated with better access to amenities, such as water, electricity, sanitation facilities, and lower incidences of health issues. There was also a significant difference based on religious identity, gender and caste with relation to attribution of causation of disease and ill-health. Risky behaviors such as not getting vaccinations, improper water treatment, and inadequate healthcare-seeking practices were prevalent. Socioeconomic factors, education levels, caste, and residency influenced these behaviors, highlighting disparities in health-related practices within the community. Similar results have been reported from other rural communities in India [50, 53, 56].

Interestingly, we found that Indigenous people (ST) living in the core regions were more likely to be aware of risk factors for ill health, especially chronic health conditions, and practice safe behaviours even though they were less educated than people living in the buffer and boundary zones. Smoking, drinking and other addictions were more prevalent in households with lower income and education levels. Higher reports of chronic illnesses from buffer and boundary regions could indicate greater lifestyle changes associated with tourism and agriculture-related activities causing pollution, affecting sanitation and nutritional quality of food. However, overall

awareness levels are low and there is a need to use innovative non-literary approaches to educate these groups about disease and health issues. Visual media, peer-peer networks and informal discussions within peer groups are proposed to likely be more effective [53].

Overall, a majority of respondents expressed satisfaction with government healthcare services, reporting dignified treatment and regular visits by healthcare workers. However, disparities in satisfaction were observed across different geographical regions, socioeconomic groups, and access to amenities. Greater responsiveness in healthcare systems would increase patient satisfaction and, in turn, use of healthcare services [65, 67–69].

Conclusion

Globally, variations in healthcare perceptions and behaviors across different socioeconomic strata and regions underscore disparities in healthcare access and satisfaction levels [35, 36, 65–68, 70]. Our findings highlight the complex interplay between socioeconomic factors and health outcomes, emphasizing the need for targeted interventions addressing specific health concerns while considering the socio-demographic nuances within a community.

Our study revealed that while tribal communities lack basic amenities such as education, stable sources of income, access to clean water, electricity and sanitation, they were more aware of risk factors and risky behaviours impacting disease and ill-health. This could be an outcome of the traditional wisdom and simpler lifestyles, closer to nature, that characterize indigenous communities. Other traditionally marginalized communities (MBCs and BCs), living in the buffer and boundary regions, not only lack access to clean water and sanitation but also knowledge of the risk factors, as well as risky and safe behaviors related to disease, health, and well-being. They also lacked knowledge of, and access to various government healthcare services and schemes. Future health awareness and outreach programs must ensure that these communities are included and should ideally be conducted in a participatory manner, preferably in their own language. Similarly, outreach and awareness programs need to be more visual and participatory in nature. Pamphlets, posters, and other written forms of awareness creation have lower chances of success. Peer-peer networks and informal discussions within peer groups are proposed to likely be more effective.

Only about 9% of our target population felt that lifestyle was a risk factor, but chronic conditions, especially cardiovascular conditions, which are typically related to lifestyles, were the main types of illness reported by them. The differences in knowledge of risk factors or perceptions of the risk factors based on religion, caste, education, and gender highlight the importance of targeted awareness programs for each of these different demographics and socioeconomic groups. People living in the core regions must be especially educated about zoonotic and vector-borne diseases and active surveillance for such diseases should be undertaken in these areas. Similarly, people living in the buffer and boundary zones must be made aware of risk factors for chronic ailments and provided information on nutrition and healthy lifestyles.

Separate awareness workshops need to be conducted for people who depend on daily wage work and belong to lower income groups (household income < Rs. 20,000 per month). They need to be especially informed about the various schemes of the government for free and/ or subsidized healthcare.

Globally studies have shown that access to clean drinking water and proper sanitation facilities are linked to better health outcomes [71–73]. At the administrative level, there is a need for improvement of access (physically and economically) to clean and safe drinking water in the region for all sections of society, but especially for those working as daily wagers and from lower income groups. Proper sewage disposal systems need to be developed along with improved waste disposal and collection systems as the existing practices will only lead to pollution of the environment and health issues among the communities.

There is a need to promote safe cooking energy such as LPG and create awareness and advocacy programs on LPG subsidies. These programs should focus on why LPG is a healthier option for users and the environment in the longer run, and a safer alternative to firewood in terms of health and welfare. It also reduces interaction with wildlife, which usually occurs during firewood collection, thus reducing the chances of wildlife attack injuries and loss of life, as well as transfer of diseases from wildlife, some of the negative consequences of human-wildlife interactions. This will also help the communities be less dependent on forest resources for fuel, aiding the conservation of these resources.

While there is a need to tally our results with data from the health departments, the respondents self-reported a high incidence of unexplained or undiagnosed fevers and body pain, which could be indicative of infectious diseases, including potential zoonotic diseases. Therefore, there is a need to conduct intensive disease surveillance for the same among the human population in the area.

There is also an increasing incidence or reporting of chronic health conditions, so it is important to understand lifestyle changes, including nutritional profile and stressors, in the community to understand the potential drivers for cardiovascular and other lifestyle-based diseases. Our study also highlighted the importance of more

detailed study on mental health problems, and access to mental health among the target populations, given the high suicide rates in the region.

Gaps in awareness of and access to vaccines against Covid-19 and their impacts indicate the need for further studies on reasons for vaccine hesitancy and barriers to accessing existing healthcare options, including the low adoption of health insurance and other government health schemes and services.

Most people had limited access to private hospital facilities within the Tiger Reserve. Yet, they seemed to prefer private facilities for treatment and healthcare services. This is similar to trends seen in other parts of the country and the world [37, 70, 74]. Therefore, government healthcare services could be improved in these regions and access to these services made easy, equal and equitable for all. Special schemes for specific socioeconomic and demographic groups should be developed to ensure everyone has equal access to these healthcare services and facilities. Health camps could be more inclusive and organized by the respective health department, not just by the forest department, to ensure maximum participation from all communities from all parts of the Reserve, both inside and in the boundary areas. Less than half of the people surveyed responded that they use government health services. The use of government health services for Primary Health services and private hospital services for tertiary health services suggests a gap in the availability of government-run advanced treatment and surgical facilities. This is an area that the health department and local administration could potentially focus on in the future [75].

Policy impact assessments are needed to evaluate the effectiveness of all the different interventions that have been undertaken by governmental and non-governmental agencies in the region aimed at improving health and socioeconomic conditions [34]. More longitudinal studies need to be conducted to track changes in socioeconomic and health indicators over time and to assess the impact of government policies and programs on improving living conditions, and therefore, health outcomes in marginalized communities. Information from such studies, locally and globally, should then be used to revise policies, develop new ones and strategize implementation pathways that are feasible, equitable and just.

The suggested interventions are aimed at enhancing healthcare access, promoting healthier practices, and developing sustainable conservation strategies that resonate with the specific needs and socioeconomic dynamics of the local communities. More such studies need to be undertaken in other parts of the Nilgiri Biosphere Reserve to formulate a landscape level One Health Plan for the region for fostering holistic well-being and conservation synergies within these ecologically sensitive regions.

Abbreviations

KAP	Knowledge, Attitudes & Practices
OHHLEP	One Health High-Level Expert Panel
MTR	Mudumalai Tiger Reserve
UNESCO	United Nations Educational, Scientific and Cultural Organization
NES	North-eastern Slopes
NTFP	Non-timber Forest Product
PHC	Public Health Centre
CHC	Community Health Clinics
ASHAs	Accredited Social Health Activists
VHNs	Village Health Nurses
CI	Confidence Interval
MCA	Multiple Correspondence Analysis
NR	No Response
MBC	Most Backward Classes
OBC	Other Backward Classes
BC	Backward Classes
SC	Scheduled Caste
ST	Scheduled Tribes
LPG	Liquefied Petroleum Gas
TB	Tuberculosis
C-section	Caesarean Sections
BP	Blood Pressure
INR	Indian Rupees

Supplementary Information

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Supplementary Material 1.

Supplementary Material 2.

Supplementary Material 3.

Supplementary Material 4.

Supplementary Material 5.

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Authors' contributions

BR conceptualized and designed the study, helped in acquisition of data, analysis, interpretation, preparation and writing of the manuscript. AW, SN and MS helped in acquisition of data, analysis and interpretation. KK acuired funding and helped with manuscript review.

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Data availability

The dataset(s) supporting the conclusions of this article are included within the article and in supplementary tables and figures in the Supplementary data file. All other dataset(s) supporting the conclusions of this article is available in the Dryad repository, with 10.5061/dryad.gmsbcc2w5, and can be accessed at: 10.5061/dryad.gmsbcc2w5.

Declarations

Ethics approval and consent to participate

All human subject research was conducted as per the guidelines set by the CWS Institutional Review Board following norms set by the Ethical Considerations and Approval for Research Involving Human Participants of the

University of Leicester, the Ethical Guidelines for Good Research Practice, Association of Social Anthropologists of the UK and Commonwealth, and the Ethical Guidelines for Social Science Research in Health, National Committee for Ethics in Social Science Research in Health, India (2000). All human subject research was approved by CWS IRB vide approval # CWS_IRB_2022_04 dated 16th April, 2024. Permission for working with tribal communities was granted by the District Adi Dravidar & Tribal Welfare Office, The Nilgiris, Government of Tamil Nadu, vide letter # H5/19610/2021 dated 7th April, 2022. Permission to work inside the MTR was granted by the Tamil Nadu Forest Department vide permission #13, dated 9th March, 2022.

Consent for publication

All respondents and participants were informed about the study and its purpose, the privacy of their data, how it was going to be used, and how all of this required their voluntary participation as recorded in a verbal (recorded as audio message) or written (taken on pre-printed consent forms) consent. Only those consenting to be interviewed and to the use of the data provided for our research purposes were interviewed. All participants (respondents) of the study consented to the use of their data for research and publication purposes on condition of anonymity. Each interview / respondent was identified by a number (anonymized) for the purpose of analysis and publication. All consent (oral and written) can be made available if/ where required.

Competing interests

The authors declare no competing interests.

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