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High prevalence of bancroftian filariasis and comorbidities in the eastern coalfield regions of West Bengal, India following COVID-19 disruption

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Lymphatic filariasis (LF) is one of the most debilitating parasitic diseases worldwide, casting a shadow of socio-economic stigma over the affected underprivileged communities. The present study is a maiden investigation depicting LF prevalence in the previously unexplored remote eastern coalfield districts of West Bengal state, India during and after COVID-19 pandemic. A community-based cross-sectional survey (August 2021–March 2024) was conducted in four LF-endemic districts of West Bengal. Symptomatic cases were graded clinically, and asymptomatic infections confirmed by filaria-specific IgG/IgM and nocturnal microfilariae (mf) detection. Comorbidities were systematically recorded. Of 3705 individuals (50.7% females and 49.3% males) screened, the overall LF prevalence was 16.65% (95% CI:15.45% -17.85%, 617 individuals). Asymptomatic mf + ICT-positive cases accounted for 10.63% (95% CI, 9.64–11.62; *n* = 394), while 6.02% (95% CI, 5.30–6.82; *n* = 223) were symptomatic. Among the symptomatic cases, 144 had circulating mf, filaria-specific IgG/IgM (ICT positive) and clinical symptoms of lymphedema, most commonly Grade II (34.79%) and Grade III (43.48%). Chronic mf-negative lymphedema was observed in 2.13% (*n* = 79). Active LF prevalence, defined by mf and ICT positivity, was 14.52% (95% CI, 13.4–15.7; *n* = 538). Acute dermato-lymphangio-adenitis (ADLA) among the clinical categories was ranged between 8.71% and 39.79%. LF prevalence was higher in the rural areas, while hypertension, diabetes, and fungal infections as major comorbidities. The eastern coalfield region of West Bengal state presents heightened prevalence of severe chronic lymphedema and a marginal prevalence of new LF cases possibly due to interruption of mass drug administration in this neglected remote areas and poor morbidity management during COVID-19.

Keywords Lymphatic filariasis, Wuchereria bancrofti, Prevalence, Lymphedema, Co-morbidity, Post COVID-19

Lymphatic filariasis (LF) is a mosquito-borne chronic inflammatory parasitic disease caused by the filarial nematodes, *Wuchereria bancrofti*, *Brugia malayi* and *B. timori* remains as significant cause for huge socio-economic impact, currently affecting over 657 million people across 39 countries, disproportionately among underprivileged population in developing countries[1]. *W. bancrofti* is the primary causative parasite for LF cases in India and hence the LF form is termed as "bancroftian filariasis". Filarial infections are often asymptomatic in the initial stages but can progress to disfiguring clinical manifestations, including lymphedema, lymphangitis, hydrocoele, and other immunopathological complications. These conditions disrupt physiological homeostasis and increase susceptibility to opportunistic microbial infections[2, 3]. Globally, LF accounts for an estimated

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1.31 million Disability-Adjusted Life Years (DALYs) annually, ranking as the second leading cause of long-term disability while India contributes ~ 42% to the global LF burden, with 2.06 million DALYs equivalent to an annual economic loss of USD $811 million[4].

The World Health Organization (WHO) recognizes LF as one of the neglected tropical diseases (NTDs) and targets its elimination through the Global Program to Eliminate Lymphatic Filariasis (GPELF) by 2030[5]. Launched in 2000, the program relies on mass drug administration (MDA) to interrupt transmission and morbidity management to alleviate disability[8]. The COVID-19 pandemic has significantly disrupted the GPELF with MDA and related activities suspended in March 2020 and resuming only in February 2024[6, 7]. This four-year interruption slowed progress toward the 2030 elimination goal and highlighted the vulnerability of NTD programs during global health crises[7, 8]. In response to these challenges, WHO introduced a revised roadmap (2021–2030) targeting the control and elimination of LF and four other NTDs[5].

Assessing LF prevalence during and after public health emergencies is essential to sustain surveillance and elimination efforts. In India, intensified MDA campaigns are underway through the Department of Health & Family Welfare, Government of West Bengal, with the national goal of elimination by 2027[9, 10, 11]. Despite these efforts, reliable prevalence data from the Eastern Coalfield districts of West Bengal remain limited. Earlier surveys reported < 1% prevalence in Purulia and Birbhum and 1–6% in Paschim Bardhaman and Bankura in 1995, shifting by 2007 to > 5% in Purulia, ~ 0.5% in Paschim Bardhaman and Bankura, and 1–5% in Birbhum. More recent studies were localized, reporting prevalence from 0.97% in Paschim Bardhaman (2019–2020) to > 13% in selected urban and rural populations of Bankura[12, 13, 14, 15]. To address this gap, the present study was undertaken with an objective to estimate the prevalence of bancroftian filariasis in the aforementioned districts to investigate the current status of infected ones, emergence of new cases, association of various co-morbid conditions alongside enumerating the possible indirect impact of COVID-19 on the disease prevalence. We conducted a population-based survey of 3,705 individuals across all four districts (August 2021–March 2024), being the first comprehensive assessment of LF during the COVID-19 emergency.

Methods

Data sources and procedures

We conducted a community-based, cross-sectional household survey to assess the prevalence of LF among residents of the filaria-endemic remote Eastern Coalfield districts of West Bengal India. The sampling frame consisted of households located within the identified LF–endemic zones across the four districts of West Bengal, India namely Paschim Bardhaman (23.6902° N, 87.1822° E), Bankura (23.1645° N, 87.0624° E), Purulia (Puruliya) (23.2483° N, 86.4997° E), and Birbhum (23.8402° N, 87.6186° E) (Fig. 1).The workflow of participant recruitment, eligibility assessment, immunochromatographic (ICT) screening, and confirmatory nocturnal microfilariae examination are illustrated in Fig. 2.

The study was carried out from August 2021 to March 2024, a period spanning the COVID-19 pandemic and early recovery phase, to assess potential impacts of disrupted health services on LF transmission and morbidity.

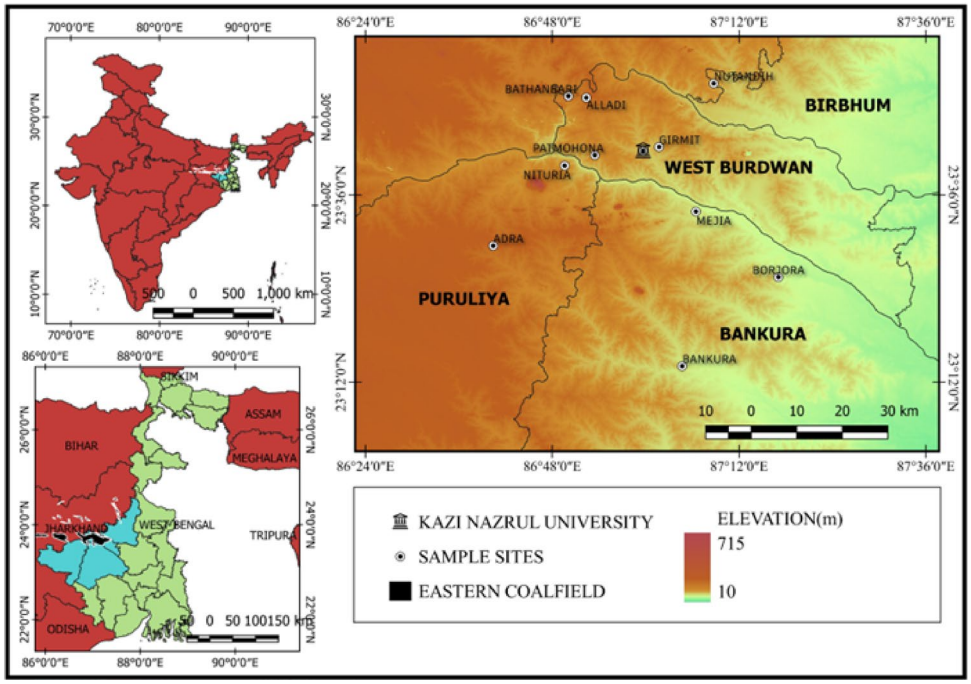

Fig. 1. Geographic representation of the sampling areas in the Eastern Coalfield districts of West Bengal, India. Epidemiological survey zones in the Paschim Bardhaman, Purulia, Bankura and Birbhum districts. This figure is created using the Q-GIS platform (version 3.18).

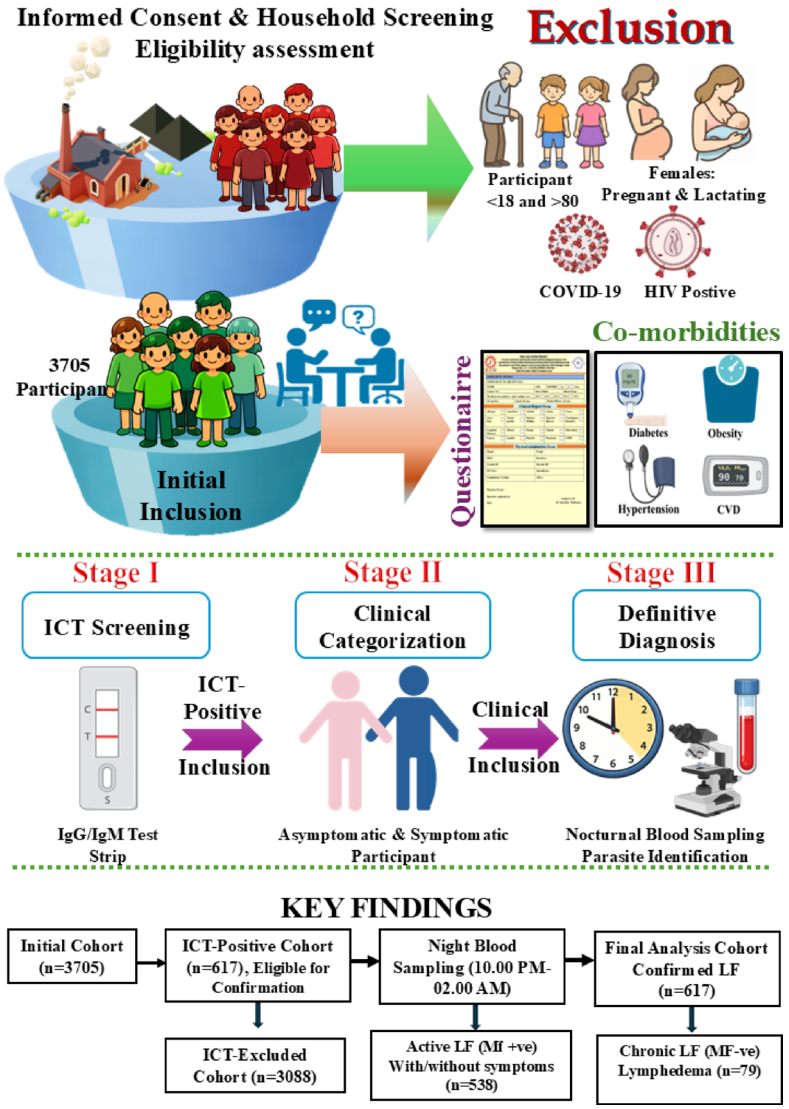

Fig. 2. Participant flow and diagnostic classification of lymphatic filariasis. Flow diagram showing household recruitment, eligibility assessment, ICT screening, and confirmatory nocturnal microfilariae (mf) testing in eastern coalfield districts of West Bengal. Of 3,705 individuals screened, 617 were ICT-positive and underwent nocturnal blood examination, of whom 538 were mf-positive (active LF) and 79 were mf-negative (chronic LF). ICT-negative individuals ($n = 3,088$) were excluded from parasitological confirmation. This figure is created using Biorender.com.

Permissions were obtained from the office of the Chief Medical Officer of Health and local health authorities prior to study initiation (Fig. 2).

The study utilized a community-based sampling (CBS) strategy, implementing as a non-probabilistic purposive multistage field approach. In the initial stage, households within each selected locality were approached using systematic door-to-door recruitment. Field teams (comprising of trained interviewers, phlebotomist, supervisor and volunteers) obtained informed consent from the households within each locality and approached through systematic door-to-door recruitment. They selected a random starting household in each locality and subsequently visited adjacent households sequentially until the target sample size for that locality was achieved. All eligible adult residents present at the time of the visit were invited to participate after obtaining written informed consent. Households that declined participation or were unavailable after repeat visits were recorded as non-responders. Although formal statistical cluster sampling was not used, each endemic locality was treated as a practical field cluster for operational purposes. The number of households surveyed within each locality varied depending on population size and accessibility. This approach allowed wide coverage of high-risk communities while ensuring that the survey remained feasible under field conditions. Clinical assessment was performed following WHO-recommended grading criteria for lymphedema[27]. Blood samples were collected under standardized procedures previously published by us[3] with appropriate quality assurance and adherence to COVID-19 safety protocols of WHO (https://www.who.int/emergencies/diseases/novel-coronavirus-2019/advice-for-public) and ICMR, Govt of India (https://www.icmr.gov.in/icmrobject/custom_data/pdf/resource-gu

idelines/ethical_guidelines_0.pdf) Demographic and clinical information were documented using a structured Clinical Report Form/Questionnaire (Supplementary Fig. 1), and data were recorded in real time face-to-face interview during the household visits[16]. Each participant enlisted in this study was provided with a Patient card (Supplementary Fig. 2).

Epidemiological Investigation

After confirming the sampling zones and defining the target population, three categories of parameters were included in the epidemiological investigation: (I) Socio-demographic data (II) Physical profiling and, (III) Detection of the infection. The minimum required sample size/cohort for the study was calculated using standard epidemiological formula:

$$n = \frac{Z^2 p(1-p)}{d^2} \quad (1)$$

(Eq. 1: n represents sample size, Z corresponds to the desired confidence level, p is the expected prevalence derived from prior regional studies or pilot observations, and d denotes the desired precision).

A 95% confidence level (Z = 1.96) was used, consistent with the standard epidemiological practices for prevalence estimation[17]. We have expected prevalence to be 10% based on prior regional reports, and a precision of 2%, thus the initial calculated sample size was 865. Because the study employed community-based sampling across the geographically defined endemic localities rather than simple random sampling, a design effect of 2 was applied to account for potential clustering of responses within the target communities, which can reduce statistical independence. This value was selected as a conservative and widely accepted standard for field epidemiological surveys, especially for conducting filarial prevalence study[18]. The adjusted sample size was therefore 1,730. To compensate for possible nonresponse due to refusals, absentees, or incomplete participation during the field visits, a 10% nonresponse rate was incorporated, resulting in a final required sample size of approximately 1,922. The achieved sample size of 3,705 individuals substantially exceeded this requirement, ensuring adequate statistical precision and robustness of prevalence estimates[18].

The study incorporated the following criteria under each category.

Inclusion Criteria: All the individuals, residing in a particular filarial endemic area.

Exclusion Criteria: Exclusion criteria included participants younger than 18 years or older than 80 years, along with pregnant or lactating women, to ensure safety. Female participants of reproductive age were screened through a brief interview on menstrual history, contraceptive use, and prior gynaecologic procedures (e.g., tubal ligation, hysterectomy) to rule out early pregnancy. Individuals with confirmed COVID-19 or AIDS were also excluded to avoid confounding and maintain safety during the pandemic. These criteria ensured recruitment of representative community cohorts while protecting vulnerable groups and preserving methodological rigor.

Socio-demographic data collection

Using a pre-designed, structured questionnaire, developed in alignment with previously published epidemiological tools and World Health Organization (WHO) guidelines for LF assessment. Prior to large-scale implementation, the instrument was pilot-tested within the eastern coalfield region to evaluate clarity, feasibility, and contextual relevance. Based on pilot observations, minor refinements were incorporated to improve wording and response categorization. Content validity was ensured through expert review by investigators experienced in filarial epidemiology and public health research. Field investigators underwent standardized training in questionnaire administration, WHO-recommended lymphedema grading, blood collection procedures, and real-time data recording to minimize inter-observer variability and information bias. Finally, face-to-face interviews were conducted during household visits from August 2021 to March 2024 collected included socio-economic status, comorbidity history, treatment history, and demographic data (age, sex, residence, family income, and duration of infection), summarized in Supplementary Table 1 and Table 1.

Clinical manifestations were documented through physical examination and graded according to WHO criteria. Presentations ranged from asymptomatic infection to acute inflammatory episodes and chronic lymphedema. Because the precise time of infection cannot be determined, "duration of infection" was defined as the interval since first reported symptoms or, for asymptomatic individuals, since initial diagnosis as illustrated in Supplementary Fig. 2.

Estimation of disease prevalence

Prevalence was used as the primary epidemiological indicator to assess *W. bancrofti* infection. Eligible participants included males and females aged 18–80 were subjected to written informed consent prior to the survey and/or blood sample collection. Additionally, with appropriate consent, physical examinations were conducted in the presence of study physician for individuals reporting a family or community history of LF.

Filarial infection was initially screened using a 50 µL finger-prick blood sample applied to an immunochromatographic test (ICT) strip (TRUSTline Filariasis IgG/IgM Rapid Test, Athenese-Dx Pvt. Ltd., Chennai, India) (Supplementary Fig. 2B (i)[19, 20]. This antibody-based assay detects both IgG and IgM against filarial antigens, providing evidence of exposure in acute and chronic infections. Unlike the WHO-recommended Alere Filariasis Test Strip (FTS), which is antigen-based, the TRUSTline IgG/IgM rapid test is widely used in India for prevalence surveys[19, 21]. Because IgG/IgM positivity reflects prior exposure rather than definitive evidence of patent infection[22, 23, 24, 26], ICT was employed as a screening tool for exposure mapping and transmission dynamics, particularly in post-MDA settings.

Variables		Frequency	Percentage	Cumulative Percentage
Gender	Female	1878	50.7	50.7
	Male	1827	49.3	100
Age of Respondent (years)	18–30	713	19.2	19.2
	31–45	1238	33.4	52.7
	46–60	1065	28.7	81.4
	60+	689	18.7	100.0
Residence	Rural	2732	73.7	73.7
	Urban	973	26.3	100.0
Income of the Respondents (Indian Rupees)	10,000–50,000	640	17.3	17.3
	50,001–100,000	64	1.7	19.0
	100,001–500,000	927	25.0	44.0
	500,000+	2074	56.0	100.0

Table 1. Demographic details of the total study population residing in the filaria endemic areas.

Therefore, for the definitive diagnosis of LF, all individuals who initially tested positive by ICT were resampled at night (between 10:00 PM and 2:00 AM) to prepare 20mm^3 peripheral blood smears for the detection of mf in circulation[3]. Briefly, blood sample was spread onto a glass slide, air-dried, dehemoglobinized, fixed in methanol, and stained using Jaswant Singh–Bhattacharji (JSB) Stain Solution No. 1 (Stanbio Reagents Pvt. Ltd., Kolkata, India). The presence of *W. bancrofti* mf was confirmed by microscopic examination of the stained smear, as shown in Supplementary Fig. 2B (ii)[26]. Mf prevalence was calculated following the methodology described by Gayen et al. Accordingly, all asymptomatic LF-positive cases in our study were confirmed by both ICT and mf positivity, ensuring parasitological confirmation of infection.

Strategies for assessing new and old LF cases

"New cases" were defined as previously undiagnosed individuals identified during cross-sectional household surveys. Potential cases were screened through structured interviews recording self-reported LF symptoms (e.g., limb swelling, acute dermato-lymphangio-adenitis [ADLA]) and behavioral risk factors (e.g., mosquito net use, exposure to vector habitats). Individuals with suggestive symptoms or no prior LF diagnosis underwent nocturnal blood sampling, and thick smears were examined microscopically for microfilariae (mf) to confirm active infection.

Clinical examinations were performed by trained personnel using WHO-recommended criteria to document both acute and chronic LF manifestations. Parameters included lymphadenopathy, lymphangitis, cellulitis, limb circumference, and edema assessment. Lymphedema was staged according to the Dreyer four-grade classification (WHO, 1992)[27]. This combined diagnostic and clinical assessment approach enabled detection of active infections while capturing the broader morbidity burden in the study population.

Profiling of co-morbidities in the endemic population

Comorbidities including diabetes, hypertension, obesity, cardiovascular disease (CVD), and fungal infections were recorded across the study population to evaluate their association with LF and to characterize the broader health burden in endemic communities. Body Mass Index (BMI) of the participants was calculated following the guidelines of the Endocrine Society of India to determine the incidence of obesity[28]. Blood pressure was measured using automated digital monitors, and hypertension was classified according to the Indian Hypertension Guidelines[29]. The presence of fungal infections, particularly in skin folds and fissures of participants with elephantiasis, was assessed by clinical examination as previously described[3]. For metabolic evaluation, participants observed a 12-hour fasting period before venous blood collection. Fasting plasma glucose was measured within two hours of collection using the hexokinase enzymatic method, and classification of glycemic status followed American Diabetes Association criteria[30]. This standardized approach enabled systematic profiling of comorbidities and their distribution among individuals with and without LF, providing insight into overlapping health risks within filaria-endemic populations.

Data analysis

Collected data were tabulated in Microsoft Excel and analyzed using IBM SPSS Statistics (version 7),GraphPad Prism (version 8), Origin (Learning Edition 2025) and SRPlot (https://www.bioinformatics.com.cn/en). Prevalence was expressed as percentages with corresponding 95% confidence intervals (CIs). Comparative analyses were conducted using two-way ANOVA where applicable. Participants who completed the interview phase but either declined or were unavailable for night blood sampling were categorized as having incomplete data and excluded from analyses requiring parasitological confirmation. Inferential statistics were restricted to participants with complete clinical and diagnostic data.

Ethical clearance

The study adhered to the Declaration of Helsinki and STROBE guidelines[31,32] and was approved by the Human Research Ethics Committee of Kazi Nazrul University, India (Ref. No. KNU/HREC/CC/2/2021). Participation

was entirely voluntary, and strict measures were taken to ensure anonymity, confidentiality, and protection of patient rights and personal data.

The workflow of this epidemiological investigation aimed at assessing the prevalence and clinical burden of LF in the endemic coalfield regions of West Bengal is outlined in Supplementary Fig. 2. All study activities were conducted in accordance with the WHO COVID-19 safety guidelines as outlined in the checklist provided in Supplementary Table 2.

Results

Socio-demographic characteristics of the study population

A total of 3705 individuals from the coalfield districts (Paschim Bardhaman, Purulia, Bankura and Birbhum) of West Bengal state, India were selected for this study (Fig. 1). According to the 2011 Census, the combined population of these districts was 12,910,842. Although lymphedema and elephantiasis are frequently observed in this region, comprehensive prevalence data are scarce, with the last district-wide report published in 2007[12]. The affected communities primarily consist of coal mine labourers, residing in the endemic zones with limited knowledge of hygiene practices and minimal use of mosquito nets. Socioeconomic details of the participants were gathered through surveys and are presented in Table 1.

Estimation of disease prevalence

A total of 3,705 individuals were screened across the eastern coalfield districts of West Bengal comprising 50.7% females and 49.3% males LF prevalence was significantly higher in rural compared with urban areas (Table 2). The overall prevalence was 16.65%, (95% CI: 15.46–17.84; $n = 617$) including 10.63% (95% CI, 9.67–11.65; $n = 394$) asymptomatic individuals positive for both mf and filaria-specific IgG/IgM, and 6.02% (95% CI: 5.30–6.82; $n = 223$) presented with clinical manifestations including lymphadenopathy, lymphangitis, cellulitis, or limb edema. Notably, some patients exhibited red streaks along inflamed lymphatic vessels, indicative of lymphangitis.

Among symptomatic cases, 144 individuals showed active infection confirmed by circulating mf, ICT positivity, and clinical manifestations, whereas 79 individuals (2.13% of the cohort, 95% CI: 1.67–2.59) presented with chronic lymphedema (> 15 years) without detectable mf. Of the 617 individuals who tested positive by ICT, a further confirmatory nocturnal blood smear examination for the presence of *W. bancrofti* mf identified 538 mf-positive cases and 79 mf-negative cases. This yielded a positive predictive value (PPV) of 87.2% (95% CI: 84.6–89.8%) for ICT in detecting mf-confirmed infection. Since, nocturnal blood smears were only performed on ICT-positive participants, the number of false negatives and true negatives remains as 'Not-Determined' (ND). Consequently, the study design precludes the calculation of sensitivity, specificity, and negative predictive value (NPV). The overall prevalence of active LF, defined as mf and ICT positivity with or without symptoms, was 14.52% (95% CI, 13.39–15.66; $n = 538$) (Fig. 3A), indicating ongoing transmission.

Microscopic examination of thick smears prepared from nocturnal blood samples of ICT-positive individuals confirmed the presence of *W. bancrofti* mf, with molecular identity verified by PCR amplification of filaria 18 S rRNA[3](Fig. 3B). The mean mf density in 20 µL of nocturnal blood was 210 ± 1.78. Prevalence varied across districts (Fig. 3C), and mf density peaked between 23:00 and 03:00 h, with the highest counts observed at 01:00 h (Fig. 3D). All four WHO-defined stages of lymphedema were detected in the study population (Fig. 3E).

Disease profiling and dominancy of co-morbidities

Comorbidity profiling of the study population revealed hypertension as the most prevalent condition, affecting 58.81% **(95% CI: 57.23–60.38)** of individuals, followed by obesity (25.61%; 95% CI: **24.25–27.01**), CVD (21.05%; **95% CI: 19.77–22.40**), fungal co-infections (6.96%; **95% CI: 6.20–7.80**), and diabetes (4.85%; **95% CI: 4.21–5.58**) (Table 2; Fig. 4A). Gender-specific patterns were observed. LF-positive individuals ($n = 394$) were predominantly male (65.98%). Similarly, fungal infections (62.4% male), diabetes (60.0% male), and hypertension (62.82% male) were more frequent among men. In contrast, obesity was more common in women (62.59%), while CVD showed a near-equal distribution (51.15% male, 48.85% female) (Fig. 4B).

Geographic comparisons highlighted rural–urban disparities. LF prevalence (63.45% rural vs. 36.55% urban) and fungal co-infections (73.64% rural vs. 26.36% urban) were significantly higher in rural communities. These differences likely reflect unequal healthcare access, environmental exposures, and lifestyle factors between rural and urban populations. By contrast, lifestyle-related conditions, including diabetes (58.33% urban), obesity (65.23% urban), and CVD (57.82% urban), were more common in urban populations (Fig. 4C).

We detected all four stages of lymphedema in the study population and recorded stage distribution across different age groups (Fig. 4D). Among symptomatic LF cases ($n = 223$), Grade III lymphedema was most common (43.48%), followed by Grade II (34.79%), with fewer Grade IV cases (8.69%), consistent with the impact of mass drug administration (Fig. 4E). Episodes of ADLA were most frequent in Grade I lymphedema (39.79%) but remained clinically significant across all stages.

A disease state–dependent distribution of comorbidities was a key focus of this study, emphasizing the need for early diagnosis and integrated management of both filarial pathology and associated conditions (Fig. 5A). We conducted a comprehensive analysis of major co-morbidities including fungal co-infection, diabetes, hypertension, obesity, and CVD among individuals diagnosed with LF, stratified by clinical status which includes asymptomatic mf-positive individuals (Fig. 5B) as well as those exhibiting varying grades of lymphedema (Fig. 5C and D).

The burden of comorbidities increased progressively with lymphedema severity. Fungal infections and diabetes were particularly elevated in advanced stages, consistent with worsening immunopathology (Fig. 5C and D). Cumulative analysis further demonstrated distinct patterns: most mf-positive individuals had no comorbidities, whereas those with lymphedema showed a marked shift toward single and multiple coexisting

Characteristics	Paschim Bardhaman			Bankura			Puruliya			Birbhum			Total	% Prevalence
Lymphatic Filariasis (Asymptomatic, microfilariae positive, ICT positive)														
		n = 94	%		*n* = 78	%		*n* = 139	%		*n* = 83	%		
Gender	Male	**62**	**65.96**	Male	**45**	**57.69**	Male	**95**	**68.35**	Male	**58**	**69.88**	**394 (95% CI:9.67–11.65)**	**10.63%**
	Female	**32**	**34.04**	Female	**33**	**42.31**	Female	**44**	**31.65**	Female	**25**	**30.12**		
Age of respondents	18–30	**8**	**8.51**	18–30	**5**	**6.41**	18–30	**17**	**12.23**	18–30	**7**	**8.43**		
	31–45	**13**	**13.83**	31–45	**8**	**10.26**	31–45	**19**	**13.67**	31–45	**12**	**14.46**		
	46–60	**56**	**59.57**	46–60	**46**	**58.97**	46–60	**81**	**58.27**	46–60	**49**	**59.04**		
	60+	**17**	**18.09**	60+	**19**	**24.36**	60+	**22**	**15.83**	60+	**15**	**18.07**		
Residence	Rural	**57**	**60.64**	Rural	**48**	**61.54**	Rural	**82**	**58.99**	Rural	**63**	**75.90**		
	Urban	**37**	**39.36**	Urban	**30**	**38.46**	Urban	**57**	**41.01**	Urban	**20**	**24.10**		
Lymphedema (Symptomatic)														
		n = 42	%		*n* = 21	%		***n* = 92**	%		*n* = 68	%		
Gender	Male	**23**	**54.76**	Male	**13**	**61.91**	Male	**54**	**58.69**	Male	**39**	**57.35**	**223 (95% CI: 5.30–6.82)**	**6.02%**
	Female	**19**	**45.24**	Female	**08**	**38.09**	Female	**38**	**41.31**	Female	**29**	**42.65**		
Age of respondents	18–30	**01**	**2.38**	18–30	**00**	**0**	18–30	**4**	**4.35**	18–30	**00**	**0**		
	31–45	**02**	**4.76**	31–45	**01**	**4.76**	31–45	**18**	**19.56**	31–45	7	**10.29**		
	46–60	**15**	**35.72**	46–60	**03**	**14.29**	46–60	**25**	**27.18**	46–60	**21**	**30.88**		
	60+	**24**	**57.14**	60+	**17**	**80.95**	60+	**45**	**48.91**	60+	**40**	**58.83**		
Residence	Rural	**29**	**69.05**	Rural	**17**	**80.95**	Rural	**61**	**66.31**	Rural	**47**	**69.12**		
	Urban	**13**	**30.95**	Urban	**04**	**19.05**	Urban	**31**	**33.69**	Urban	**21**	**30.88**		
Fungal Co-infection														
		n = 45	%		*n* = 60	%		*n* = 90	%		*n* = 63	%		
Gender	Male	**28**	**62.22**	Male	**36**	**60.00**	Male	**58**	**64.45**	Male	**39**	**61.90**	**258 (95% CI: 6.20–7.80)**	**6.96%**
	Female	**17**	**37.78**	Female	**24**	**40.00**	Female	**32**	**35.55**	Female	**24**	**38.10**		
Age of respondents	18–30	**00**	**0.00**	18–30	**02**	**3.33**	18–30	**09**	**10.00**	18–30	**06**	**9.52**		
	31–45	**07**	**15.55**	31–45	**13**	**21.67**	31–45	**20**	**22.22**	31–45	**14**	**22.23**		
	46–60	**17**	**37.78**	46–60	**21**	**35.00**	46–60	**28**	**31.11**	46–60	**18**	**28.57**		
	60+	**21**	**46.67**	60+	**24**	**40.00**	60+	**33**	**36.67**	60+	**25**	**39.68**		
Residence	Rural	**31**	**68.89**	Rural	**45**	**75**	Rural	**67**	**74.44**	Rural	**47**	**74.60**		
	Urban	**14**	**31.11**	Urban	**15**	**25**	Urban	**23**	**25.56**	Urban	**16**	**25.40**		
Diabetes														
		n = 46	%		*n* = 29	%		*n* = 73	%		*n* = 32	%		
Gender	Male	**37**	**80.43**	Male	**16**	**55.17**	Male	**38**	**52.05**	Male	**17**	**53.12**	**180 (95% CI: 4.21–5.58)**	**4.85%**
	Female	**9**	**19.57**	Female	**13**	**44.83**	Female	**35**	**47.95**	Female	**15**	**46.88**		
Age of respondents	18–30	**00**	**0**	18–30	**00**	**0**	18–30	**00**	**0**	18–30	**00**	**0**		
	31–45	**03**	**6.52**	31–45	**01**	**3.45**	31–45	**01**	**1.37**	31–45	**05**	**15.62**		
	46–60	**16**	**34.78**	46–60	**08**	**27.58**	46–60	**29**	**39.73**	46–60	**08**	**25**		
	60+	**27**	**58.70**	60+	**20**	**68.97**	60+	**43**	**58.90**	60+	**19**	**59.38**		
Residence	Rural	**20**	**43.48**	Rural	**10**	**34.48**	Rural	**24**	**32.88**	Rural	**21**	**65.62**		
	Urban	**26**	**56.52**	Urban	**19**	**65.52**	Urban	**49**	**67.12**	Urban	**11**	**34.38**		
Hypertension														
		n = 531	%		*n* = 384	%		*n* = 851	%		*n* = 413	%		
Gender	Male	**329**	**61.96**	Male	**269**	**70.05**	Male	**528**	**62.04**	Male	**243**	**58.84**	**2179 (95% CI: 57.23–60.38)**	**58.81%**
	Female	**202**	**38.04**	Female	**115**	**29.95**	Female	**323**	**37.96**	Female	**170**	**41.16**		
Age of respondents	18–30	**09**	**1.70**	18–30	**07**	**1.82**	18–30	**18**	**2.12**	18–30	**13**	**3.14**		
	31–45	**135**	**25.42**	31–45	**86**	**22.39**	31–45	**255**	**29.96**	31–45	**108**	**26.15**		
	46–60	**192**	**36.16**	46–60	**136**	**35.42**	46–60	**303**	**35.61**	46–60	**139**	**33.66**		
	60+	**195**	**36.72**	60+	**155**	**40.37**	60+	**275**	**32.31**	60+	**153**	**37.05**		
Residence	Rural	**253**	**47.65**	Rural	**223**	**58.07**	Rural	**452**	**53.11**	Rural	**224**	**54.24**		
	Urban	**278**	**52.35**	Urban	**161**	**41.93**	Urban	**399**	**46.89**	Urban	**189**	**45.76**		
Obesity														
		n = 332	%		*n* = 165	%		*n* = 196	%		*n* = 256	%		

Continued

Characteristics	Paschim Bardhaman			Bankura			Puruliya			Birbhum			Total	% Prevalence
Gender	Male	**119**	**35.84**	Male	**63**	**38.18**	Male	**76**	**38.78**	Male	**97**	**37.89**	**949 (95% CI: 24.25–27.01)**	**25.61%**
	Female	**213**	**64.16**	Female	**102**	**61.82**	Female	**120**	**61.22**	Female	**159**	**62.11**		
Age of respondents	18–30	**79**	**23.80**	18–30	**37**	**22.42**	18–30	**44**	**22.45**	18–30	**53**	**20.70**		
	31–45	**83**	**25**	31–45	**45**	**27.27**	31–45	**48**	**24.49**	31–45	**64**	**25**		
	46–60	**93**	**28.01**	46–60	**41**	**24.85**	46–60	**55**	**28.06**	46–60	**71**	**27.73**		
	60+	**77**	**23.19**	60+	**42**	**25.46**	60+	**49**	**25**	60+	**68**	**26.57**		
Residence	Rural	**113**	**34.04**	Rural	**92**	**55.76**	Rural	**67**	**34.18**	Rural	**58**	**22.66**		
	Urban	**219**	**65.96**	Urban	**73**	**44.24**	Urban	**129**	**65.82**	Urban	**198**	**77.34**		
Cardiovascular Diseases														
		n = 216	%		*n* = 186	%		*n* = 182	%		*n* = 196	%		
Gender	Male	**103**	**47.69**	Male	**105**	**56.45**	Male	**89**	**48.90**	Male	**102**	**52.04**	**780 (95% CI: 19.77–22.40)**	**21.05%**
	Female	**113**	**52.31**	Female	**81**	**43.55**	Female	**93**	**51.10**	Female	**94**	**47.96**		
Age of respondents	18–30	**00**	**0**	18–30	**00**	**0**	18–30	**00**	**0**	18–30	**00**	**0**		
	31–45	**02**	**0.93**	31–45	**03**	**1.62**	31–45	**00**	**0**	31–45	**00**	**0**		
	46–60	**97**	**44.90**	46–60	**87**	**46.77**	46–60	**55**	**30.22**	46–60	**95**	**48.47**		
	60+	**117**	**54.17**	60+	**96**	**51.61**	60+	**127**	**69.78**	60+	**101**	**51.53**		
Residence	Rural	**97**	**44.91**	Rural	**72**	**38.71**	Rural	**76**	**41.76**	Rural	**84**	**42.86**		
	Urban	**119**	**55.09**	Urban	**114**	**61.29**	Urban	**106**	**58.24**	Urban	**112**	**57.14**		

Table 2. Total sample distribution of LF, Fungal Co-infection, Diabetes, Hypertension, Obesity, and Cardiovascular diseases.

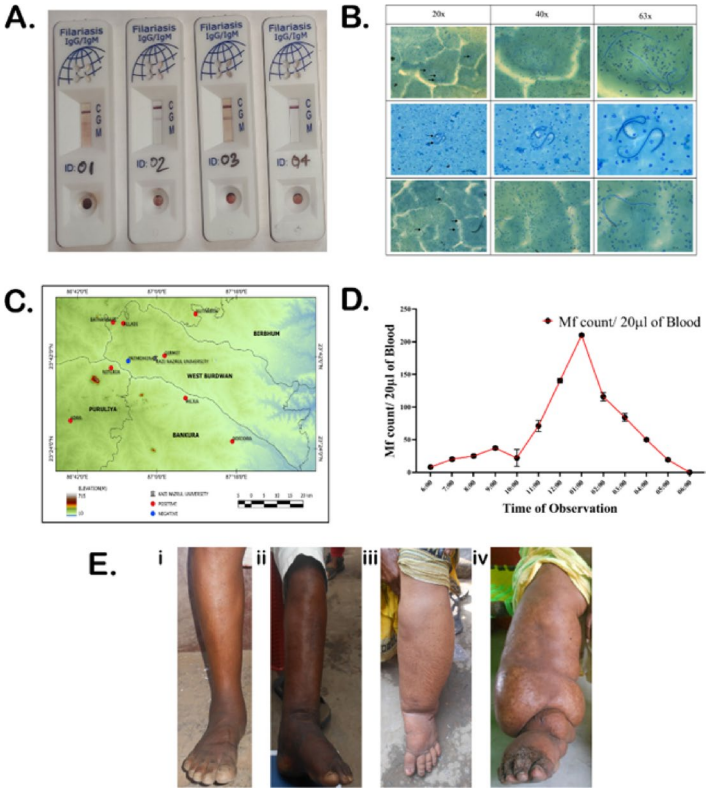

Fig. 3. Determination of *W. bancrofti* infection and its prevalence through a population-based cross-sectional survey-based study. **(A)** Selected results of TRUSTline Filariasis IgG/IgM Rapid detection of the filaria-positive cases among the study population. **(B)** JSB-1-stained thick blood smear showing the presence of *W. bancrofti* mf within the ICT-positive patients under penta-headed microscope. **(C)** Endemic zones identified with a higher prevalence of LF through the present cross-sectional study. **(D)** Graphical demonstration of the periodicity in terms of *W.bancrofti* mf density per 20 µL blood. The figure is a representation of the average mf density (mean ± SD). **(E)** Clinical classification of the chronic manifestations of LF like lymphedema into four grades as per the Dreyer system. (i) Grade I, (ii) Grade II, (iii) Grade III and (iv) Grade IV).

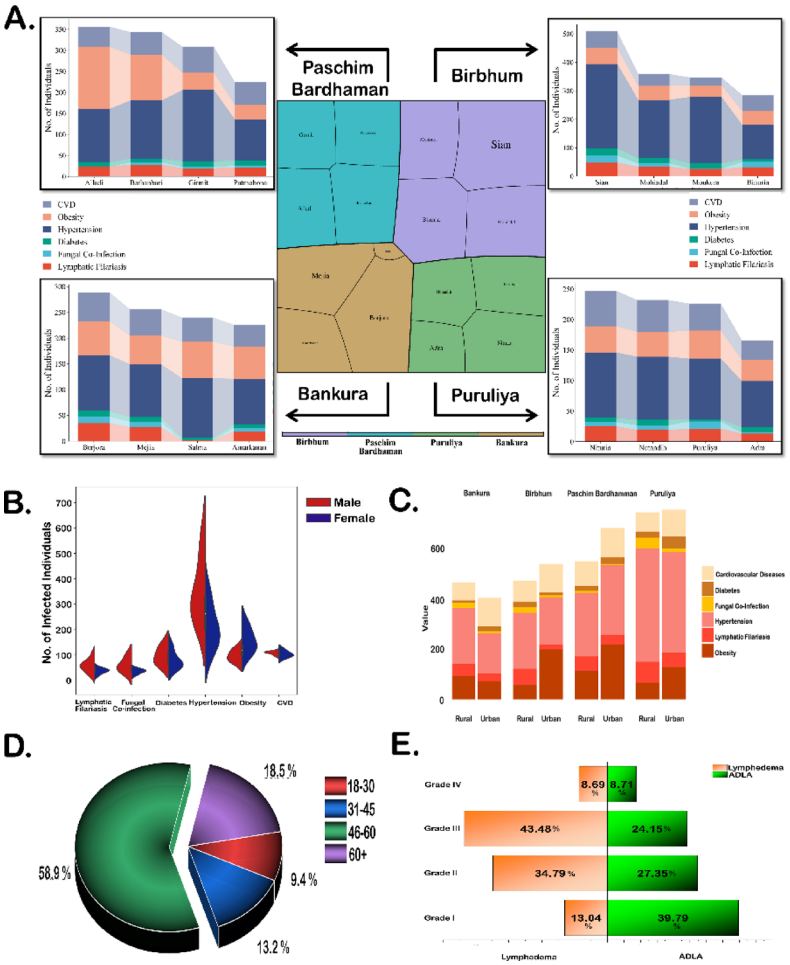

Fig. 4. A comprehensive analysis of the prevalence of LF, its consequences and associated co-morbidities in the Eastern Coalfield districts of West Bengal, India. **A**. An overview of survey data encompassing the sampling locations of four Eastern Coalfield districts, highlighting the prevalence rates of LF and related comorbid conditions. **B**. Gender-wise comparison of LF prevalence and comorbidities in the sampling areas. **C**. A comparative rural and urban geographic distribution of LF and comorbidities in the Eastern Coalfield districts of West Bengal. **D**. A pie chart depicting the age group-wise prevalence of lymphedema. **E**. A comparative representation of the prevalence and severity of lymphedema and Acute Dermatolymphangioadenitis (ADLA) across different lymphedema grades.

conditions (Fig. 5E). These observations underscore the high incidence of co-morbid conditions in the filaria-infected population and reinforce the need for comprehensive clinical assessment and integrated, multi-modal treatment strategies.

Discussion

Our prevalence data on LF collected over three consecutive surveillance periods across the endemic eastern coalfield districts revealed temporal variation, likely influenced by programmatic disruptions during the COVID-19 pandemic. This represents the first comprehensive estimate of LF burden, including chronic lymphedema and concurrent comorbidities, in these mining regions of West Bengal. Based on mf detection and ICT positivity among both asymptomatic and symptomatic individuals the prevalence of active LF was **14.52%**, which is substantially higher than previously documented comprehensive survey from 2007 which reported much lower prevalence, often < 1% in districts such as Purulia and Birbhum[12]. The ecological setting of the study zones bordered by the River Damodar and its tributaries, combined with unplanned urbanization likely provides extensive larval habitats for mosquito vectors[33, 34]. It is important to note that this investigation was a cross-sectional study and did not include longitudinal follow-up. As such, it captures undiagnosed prevalence rather than incident cases and cannot be used to determine the true incidence of LF. Potential selection bias could have arisen from the community-based door-to-door recruitment strategy, as participation depended on availability and willingness during household visits. Although non-responding households were documented, replacement sampling was not performed, which might have led to underrepresentation of individuals absent due to occupational migration or other socioeconomic factors. Information bias may also have occurred due to reliance on self-reported demographic and clinical histories, including duration of symptoms and prior

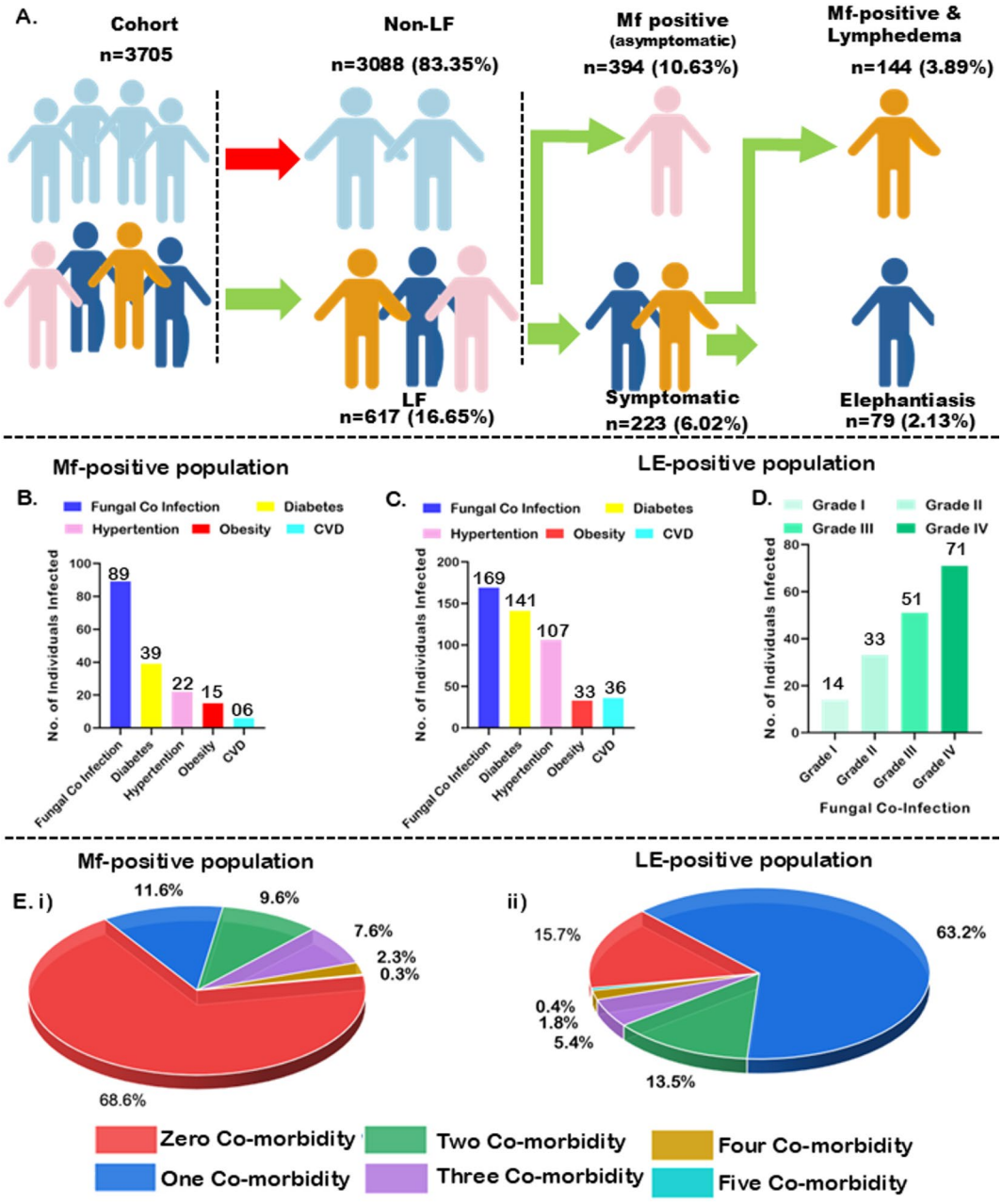

Fig. 5. Distribution of LF and Associated Comorbidities. **(A)** Schematic representation of the cohort distribution ($n = 3705$), with individuals categorized into LF cases ($n = 617$) and non-LF ($n = 3088$; 83.35%). Among the total LF cases, 394 (10.63%) were asymptomatic mf-positive individuals, while symptomatic cases were 223 (6.02%). The symptomatic group included 144 individuals (3.89% of LF population) with circulating mf, filaria-specific IgG + IgM (ICT positive) and clinical symptoms, while 79 individuals (2.13% of LF population) were with elephantiasis. **(B)** The number of individuals with different comorbidities among mf-positive individuals. **(C)** The distribution of comorbidities among lymphedema (LE)-positive cases. (**D**) Distribution of fungal co-infection across lymphedema grades in LE-positive individuals **(E)** Pie charts depicting the extent of multi-directional morbidity in (i) MF-positive and (ii) LE-positive individuals. Most MF-positive individuals (68.6%) had no comorbidities, whereas a majority of LE-positive individuals (63.2) have at least one co-morbidity, highlighting increased disease complexity in LE group.

treatment. Recall inaccuracies could have affected classification of chronic versus recent disease manifestations. To mitigate these, trained field investigators used standardized Clinical Report Forms and WHO-recommended grading criteria to ensure consistent clinical assessment and data recording, as well as minimizing biasness in the sampling.

Community-based studies assessing quality of life (QOL) among individuals with lymphedema in endemic zones have consistently documented progressive clinical worsening[35]. However, a limitation of such studies is

the timing of data collection, which often underrepresents men who are absent due to work, therefore, the sample typically included a smaller proportion of male participants. As a result, these studies may not accurately represent the entire endemic population. Our findings complement this literature by highlighting the combined social, clinical, and QOL concerns among individuals infected with or at risk for LF. We observed a notable increase in interdigital and dermal lesions, which contributed to a higher risk of falls and recurrent ADLA episodes, leading to significant physical discomfort and reduced social functioning. Social stigmatization, closely associated with visible disease severity, was a key factor discouraging individuals from seeking medical care[36, 37].

Our study identified a higher prevalence of LF among individuals ≥ 60 years, who accounted for nearly one-third of all cases and frequently presented with chronic manifestations such as Grade III–IV lymphedema. A clinic-based study from Pondicherry similarly reported increased LF incidence in older adults (60–80 years)[38], though differences in design may explain variation; clinic-based cohorts are more likely to include advanced cases due to delayed care-seeking, while regional epidemiology may also contribute. Importantly, detection of LF among younger adults (18–30 years), born after MDA implementation, indicates ongoing transmission in coalfield districts. Persistent ADLA episodes in older individuals with advanced lymphedema, despite doxycycline treatment, further highlight the potential role of chronic cases as reservoirs of infection and the limited impact of drug therapy alone. As ADLA is often precipitated by secondary bacterial infections, it remains a key driver of lymphedema progression[39, 40]. These findings align with recent surveillance reports from the Government of West Bengal documenting continued LF transmission in the region[41].

Studies suggest that combining hygiene practices with local antibiotic or antifungal treatments is more effective than antibiotics alone in reducing ADLA episodes[4]. WHO emphasizes that elimination of LF requires both transmission interruption and morbidity management/disability prevention (MMDP)[42]. COVID-19 disrupted MMDP services, restricted access to care, and paused hygiene education, likely exacerbating ADLA risk. Our findings highlight these gaps and reinforce the need for structured, resilient MMDP programs targeted to high-burden zones and re-energize stalled programs toward achieving LF elimination by 2030.

Filarial infection is associated with several comorbidities, notably secondary fungal infections and metabolic syndrome such as central obesity, hypertension, hyperglycemia, and dyslipidemia[4, 43]. In this study, 41.82% of LF patients (both asymptomatic and symptomatic) had secondary fungal infections, although overall prevalence in the total population was lower (6.96%). Fungal co-infections were particularly common in grade III/IV lymphedema, warranting further molecular investigation. LF cohort also showed high co-occurrence with venous hypertension (20.91%), morbid obesity (7.78%), and CVD (6.81%), while diabetes was less prevalent (29.17%) than fungal co-infection. Swollen extremities, a hallmark of LF, contribute to elevated venous pressure, and in obese individuals, tissue accumulation exacerbates lymphatic dysfunction, promoting inflammation and fibrosis[44].

The lower prevalence of diabetes among individuals with mf-positive asymptomatic subjects suggests a potential inverse relationship, possibly mediated by immunomodulatory effects of filarial parasites or their secreted molecules. This bidirectional relationship is under active investigation[43, 45, 46] as diabetes, a meta-inflammatory condition, may increase susceptibility to LF and worsen lymphatic damage, while chronic helminth infections may modulate immune responses and influence glucose metabolism[47]. Notably, in our cohort, individuals with advanced stages of lymphedema exhibit a higher prevalence of diabetes. Unlike earlier studies focusing on LF prevalence in diabetic populations, our findings highlight diabetes occurrence within LF-affected cohorts, particularly during and after the COVID-19 pandemic.

In the four surveyed districts, the National Programme to Eliminate Lymphatic Filariasis (NPELF) has regained momentum after COVID-19-related disruptions[48, 49]. Recent efforts have focused on revitalizing MDA through door-to-door campaigns led by ASHA workers and frontline personnel, while MMDP services have been expanded to include free lymphedema care kits and hydrocele surgeries[50, 51]. However, continued reliance on private or informal healthcare highlights gaps in public outreach and the need for stronger community engagement. Despite these advances, reliance on private and informal healthcare persists, reflecting gaps in public sector outreach and community engagement. Strengthening integration of LF surveillance and morbidity care into routine primary health services is therefore critical. Aligning local implementation with WHO's roadmap for neglected tropical diseases will be essential to ensure program resilience, address morbidity needs, and achieve sustained LF elimination.

Although this cross-sectional study estimates point prevalence rather than incidence and therefore cannot establish temporal or causal relationships, the findings provide critical public health insight into the current burden and transmission status of LF in the underserved coalfield communities. The detection of a substantial proportion of mf-positive individuals, including asymptomatic carriers, highlights the persistence of an active parasite reservoir capable of sustaining transmission to the healthy subjects and/or further clinical progression/worsening of pathological manifestations in the infected ones. Variations in prevalence and symptom severity across surveillance phases underscore the vulnerability of endemic communities during health crises while rising the need for resilient, integrated surveillance and care. These findings also identify geographic pockets where transmission may have persisted or resurged and reveal gaps in morbidity management. Sustained monitoring through community-based primary healthcare systems remains essential, in line with WHO's roadmap for neglected tropical diseases. Our results provide practical insights for refining GPELF strategies in post-emergency contexts and highlight the evolving epidemiology of LF under strained health systems. A key limitation of this study is the modest sample size ($n = 3,705$) across four districts, constrained by pandemic-related restrictions and safety protocols. This may affect precision and limit generalizability, while restricting subgroup analyses. Nonetheless, these data establish an important baseline for future surveillance and larger-scale studies.

Conclusion

While the elimination of LF remains a global public health priority, sustained emphasis on MMDP is critical to address the residual disease burden under the GPELF. Our study reveals a high prevalence of active LF in the remote Eastern Coalfield regions, likely attributable to disruptions in MDA during the COVID-19 pandemic, poor treatment compliance, and inadequate vector control measures in coal mining communities. This investigation offers a valuable framework for assessing LF prevalence and identifying patterns suggestive of ongoing transmission, as well as co-infections and comorbidities among affected individuals. So far, most the coal mining areas included in this study were neglected due to their remote characters, underprivileged demography and poor connectivity. The findings provide practical evidence for refining GPELF strategies to better address local needs in the post-pandemic context and reinforce the established link between socioeconomic conditions and LF burden. Thus, addressing the high LF prevalence could resist the future spillover from these infection pockets. Given that India accounts for a substantial proportion of the global LF burden, the success of the global elimination initiative is closely tied to progress achieved within the Indian subcontinent.

Data availability

The datasets used and/or analysed during the current study available from the corresponding author on reasonable request.

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Author contributions

PC, BKM, SD, and SM have curated the data. The investigation, methodology was conducted by PC and SM. Formal analysis was done by PC, AS, JB and SM. PC, JB and SM visualised and validated the data. Project administration, funding acquisition, resources, supervision was done by JB and SM. All the supervision was done by SM. The writing – original draft, and writing– review & editing was done by PC, JB and SM.

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Declarations

Competing interests
The authors declare no competing interests.

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